OregonLive.com
Everything Oregon

Environmental news: Coos Bay in running for terminal to export coal to Asia; other port candidates

Published: Friday, July 22, 2011, 4:39 PM Updated: Friday, July 22, 2011, 4:53 PM

By Scott Learn, The Oregonian

There's another potential candidate in the running for a coal export terminal on the West Coast: Coos Bay.

Port of Coos Bay CEO Jeff Bishop told the Port's commissioners Thursday night that the port is in discussions with coal developers and has signed nondisclosure agreements with them, The World newspaper of Coos Bay reported.

Coos Bay joins Longview, Wash., Bellingham, Wash., and, perhaps, St. Helens as potential candidates for a coal export terminal. Coal companies are likely checking into other Northwest ports as well, environmental groups say.

Today, Vancouver, B.C., and Alaska host the West Coast's only export terminals. Coal companies want to export Powder River Basin coal from Montana and Wyoming to Asia.

The Sierra Club and other environmental groups are fighting coal exports, saying it would undermine efforts to reduce greenhouse gas generation and pollution in the United States.

Oregon and Washington both have plans to shutter their only coal-fired power plants.

-- Scott Learn

© OregonLive.com. All rights reserved.

OregonLive.com
Everything Oregon

Private negotiations, hurried vote on coal exports from Oregon's Port of St. Helens sidestepped public process, critics say

Published: Sunday, June 10, 2012, 7:48 PM Updated: Monday, June 11, 2012, 9:21 AM

By Scott Learn, The Oregonian

Scott Learn, The Oregonian

Ambre Energy would use this dock at the Port of St. Helens' Port Westward industrial park to transfer coal from Columbia River barges to ocean-going ships. Kinder Morgan plans a train-fed coal terminal and new dock at Port Westward to export coal to Asia.

When news first leaked last year that the Port of St. Helens might be working on deals to export coal, Gov. John Kitzhaber called for "an open, vigorous public debate" before any projects moved forward.

But the port's first major step on coal didn't follow that blueprint. By the time the port went public in January, option agreements with two coal exporters had already been hammered out, records show.

Earlier that month, port commissioners met with one exporter, Kinder Morgan, on separate days to avoid a quorum that could trigger state open meetings requirements.

And commissioners approved the option agreements, months in the making, the same night the companies first presented projects publicly. The public never saw the contracts before the vote.

Port officials say confidentiality agreements with the companies, Kinder Morgan and Ambre Energy, required private negotiations -- a common practice that gets little notice when the commodity isn't controversial.

The companies must still get state and federal permits, with public comment required along the way.

The option contract with Ambre locks in a long-term deal if the company gets its permits. But the commission can still reject Kinder Morgan's more controversial proposal, commission president Robert Keyser said.

"How else can you possibly do business?" he said. "You can't show up at a commission meeting with a nebulous agreement that has no specifics."

COAL CONTROVERSY

Critics say business as usual isn't appropriate for coal.

With no West Coast coal terminals outside Canada and Alaska, coal companies in Montana and Wyoming's Powder River Basin are pushing hard for a Northwest link to growing Asian markets.

Six potential export projects are afloat in Oregon and Washington, raising concerns ranging from global warming impacts to coal dust pollution to rail congestion.

Columbia Riverkeeper obtained the port's records after the January vote, having filed a lawsuit when the port rejected the environmental group's March 2011 request.

Riverkeeper's lawsuit noted 20 other Northwest ports responded to virtually identical requests, filed after the coal industry's interest in Asian export surfaced in 2010. The Port of St. Helens' refusal last year kept its coal plans hazy, said Brett VandenHeuvel, Riverkeeper's executive director.

"What's the point of a law requiring open meetings for these things if it's already a done deal before it happens?" he said. "It just seems to gut any public participation."

Keyser and other commissioners say there was no deliberation or nose-counting before the January vote -- steps that could violate open meetings law. Meetings with the companies were informational only, he said.

More

The Oregonian's continuing coverage of efforts to export coal through Oregon.

Some commissioners visited coal terminals with Kinder Morgan before the vote, at the port's expense, port officials said. The commission heard from Columbia Riverkeeper in September about general coal export concerns.

Critics also question whether the exporters knew the commission would approve the deal in advance.

An email from Kinder Morgan to port staff on the morning of the public meeting says, "It is our understanding that we have reached an agreement with you."

It adds that the company will bring copies of the option contract for commissioners to sign, and is "excited about embarking on our due diligence," a process that would start only if commissioners approved the deal.

Kinder Morgan spokesman Allen Fore said last week the email referred to an agreement with port staff, not the commission, which voted 4-1 for Kinder's lease option.

"I can say for certain we did not know how the commission was going to vote."

CONFIDENTIAL TALKS

Kinder Morgan proposes to bring in coal by rail -- the port expects up to 30 million tons a year -- shipping it out of a new $150 million to $200 million terminal at the Port Westward industrial park.

Ambre would export up to 8 million tons a year, transferring coal from trains to barges at the Port of Morrow, then from barges to ships at Port Westward's dock.

Brian Gard, local spokesman for Ambre's Morrow Pacific Project, said meetings before the vote were to seek questions and concerns. The company never asked commissioners, who unanimously endorsed the Ambre option contract, how they would vote, he said.

Confidentiality is important in competitive shipping and export, Gard and Fore said. "It's normal procedure anywhere," Fore said.

The port was aware of potential conflicts with Oregon's open meetings law. In early January, port staff consulted with their lawyer and suggested splitting meetings with Kinder Morgan over two days to avoid a quorum meeting on the same day.

Kinder Morgan also briefed local politicians -- including state Sen. Betsy Johnson, D-Scappoose, and Columbia County Commissioner Tony Hyde -- well before the vote, records indicate. Both said the briefings were informational only and they didn't pledge support.

Johnson's support was "a matter of 'make it or break it'" before the port could sign an option agreement, port staff emailed Kinder Morgan in March 2011.

But Johnson said last week she's undecided. "There are too many unanswered questions."

Hyde said his main concern is rail congestion from Kinder Morgan's project. Coal trains would run through five Columbia County cities.

"I told them, 'You come in my office with five smiling mayors and we'll talk,'" he said. "I don't think they can find five smiling mayors."

HURRIED VOTE

The commission met Jan. 25, after issuing an agenda and press release a week before spotlighting presentations from the coal exporters.

The meeting drew dozens of speakers, including union workers eager for jobs. Commissioners recessed into a closed executive session, then emerged and approved a lease option with Kinder Morgan and a terminal services option with Ambre.

The options set milestones the companies must meet in 12 to 18 months, with opportunities for extensions. During that period, the port can't pursue projects that interfere with Kinder Morgan's terminal or take up rail capacity.

The vote surprised many -- the agenda didn't say the commission might act. Keyser, board president, said that was a mistake. His impression was the companies wanted a vote that night.

The quick vote, allowed under open meetings law, left no opportunity for public review of the contracts.

Local opponents say they would have liked tighter terms on rail traffic and coal dust impacts. The option requires Kinder Morgan to work with Portland & Western Railroad "to address major concerns." Opponents also question why the port didn't leave wiggle room on the Ambre option.

Going forward, such concerns may be aired beforehand. The Port of St. Helens settled the Columbia Riverkeeper lawsuit, agreeing to no longer withhold records based on Oregon's confidential submissions exemption.

Ambre is pursuing state and federal permits now. Kinder Morgan plans to file for permits by year's end.

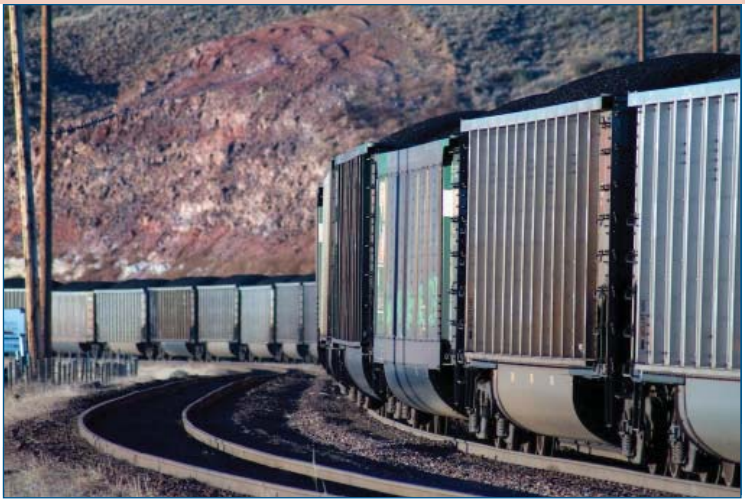
-- Scott Learn

© OregonLive.com. All rights reserved.

A Hidden

Cost of Coal

Exporting our coal to Asia



Northern Plains Resource Council's campaign to protect Montana communities and natural resources from the impacts of expanded coal strip mining and exports.

©Ian Maddaus photo

A coal train leaves Decker, Montana.

With domestic coal markets shrinking in the last few years, the U.S. coal industry has actively sought ways to keep customers of this 19th century fuel hooked well into the 21st century.[1]

Coal companies intend to move and expand their operations in the West, particularly in the Powder River Basin of Wyoming and Montana, in order to export the coal to Asian countries.[2]

The current level of U.S. coal exports is 13 million tons per year; the coal industry looks to expand this to 140 million tons.

The strip mines of the Powder River Basin produce more coal than anywhere else in the nation (mostly the portion in Wyoming because of geological differences).[3] Strip mining lays a huge price on the land, water, and air.

Over the years, coal mines in Montana have reclaimed a startlingly small portion of the land they have disturbed.

Coal companies increasing exports to Asia

In the past decade, coal's share of U.S. energy generation has declined.[4] According to the Energy Information Administration, "Coal-fired electric generation declined 11.6 percent between 2008 and 2009. With this decline, coal's share of electricity generation reached its lowest level since 1978: 44.5 percent of electricity generation in 2009, down from 48.2 percent in 2008." (Figure 1)

But growth in Asian coal demand is expected to lead to an increase in world coal consumption by 2030.[4] The U.S. Energy Information

Continued on next page

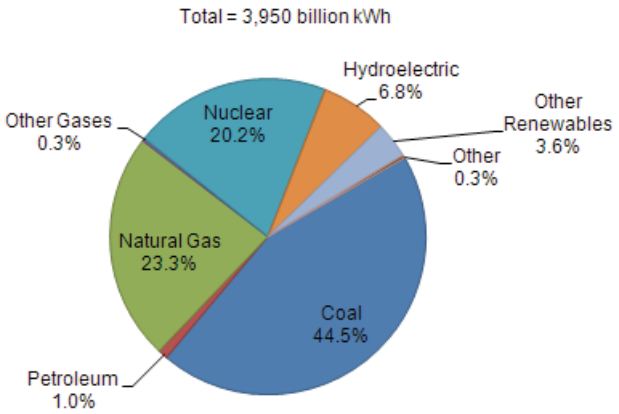


Figure 1:
U.S. Electric Power Industry Net Generation for 2009
http://www.eia.doe.gov/cneaf/electricity/epa/figes1.html

[1] U.S. Energy Information Administration, *International Energy Outlook 2010*, http://www.eia.doe.gov/oiaf/ieo/coal.html
[2] *Exporting Powder River Basin Coal: Risks and Costs*, Western Organization of Resource Councils (WORC) January 2011, page 1.
[3] U.S. Energy Information Administration, *Coal Transportation Issues, 2007*, http://www.eia.doe.gov/oiaf/aeo/otheranalysis/cti.html
[4] U.S. Energy Information Administration, *Electric Power Annual, 2009*, http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html#_ftnref11

4/11

Continued from previous page

Administration predicts that nearly 90% of that increased consumption will be attributed to China.[5]

Today, over 99% of the coal mined in the Powder River Basin is consumed in domestic coal markets. Between 2009 and 2010, however, US coal exports to Asia increased from 3.8 million tons to 13 million tons, a 240% increase.[6] If sufficient port and rail capacity can be built, numerous coal companies are looking to increase coal sales to Asian markets. Arch Coal expects half the global trade for coal will go to China and India by 2012.

Montana mines at center of export boom

A number of mines in Montana already do a small amount of coal exporting and have big plans to do more.

In November 2010, in a *Billings Gazette* article, Cloud Peak Energy (owner of the Spring Creek coal mine near the Montana-Wyoming border) announced an increase in coal exports. "Officials from the nation's third largest coal producer [Cloud Peak] say Montana coal exports to Asia are expected to top 3 million tons this year, nearly double last year's level. And millions of additional tons could cross the Pacific within a few years if developers succeed in expanding port facilities along the West Coast."[7]

Arch Coal CEO Steven Leer said, "With our superior operating position in the Powder River Basin and Western Bituminous Region, we have the capability to service growing coal demand in Asia, the world's largest and fastest-growing coal market."[8] The company has repeatedly stated the importance of Asian exports to its future plans.[9] Even more telling is Arch's recent purchase of a 38% share in Millennium Bulk Logistics, the company that has submitted a permit to build a coal export facility in Longview, Washington.[10]

Additionally, in a *Billings Gazette* article in March 2010, Nick Shakesby, Chief Operating Officer of Maple Carpenter Creek, a proposed coal mine 50 miles northeast of Billings, said a new mine could be running by 2014.

"We're not interested in sitting on it. We're interested in developing it and putting in a mine," he said. "We're marketing it offshore – Asia and India."[11]

The Port of Longview on the Columbia River.

Arch Coal buys into port expansion

According to an article in the January 12, 2011, *St. Louis Post-Dispatch,* Arch Coal paid $25 million for an interest with Millennium Bulk Terminals-Longview LLC, which owns a terminal near Longview, Washington, on the Columbia River. Millennium Bulk Terminals, a unit of Australia's Ambre Energy, is trying to get necessary approval and permits to complete dredging and other upgrades to handle coal shipments to Asia. Under the agreement, Arch will control 38 percent of the terminal's 5 million-ton annual capacity. "This transaction gives us a direct stake in participating in the growth of U.S. coal exports off the West Coast," said Arch CEO Steven Leer.

Almost all the major coal-producing companies at this point are investing in coal export mines, ports, and companies.

[5] Scott Learn , "Mining companies aim to export to China through Northwest ports," *The Oregonian*, September 8, 2010.

[6] U.S. Energy Information Administration, *U.S. Coal Exports, January 2011*, http://eia.doe.gov/cneaf/coal/quarterly/html/t7p01p1.html

[7] *Billings Business*, "Cloud Peak Energy Officials optimistic about boosting coal exports to Asia", November 2010, http://billingsgazette.com/business/article_23a03acc-53be-5ed3-a2fb-ff75909c3f34.html

[8] Dustin Bleizeffer, "Coal industry seeks exports to Asia while U.S. market falters, *WyoFile*, Jan. 18, 2011. http://wyofile.com/2011/01/coal-policy/

[9] Arch coal press release, "Arch Coal secures state-controlled Otter Creek coal reserves in Montana", March 18, 2010, http://investor.archcoal.com/phoenix.zhtml?c=107109&p=irol-newsArticle&ID=1403818&highlight=

[10] Arch coal press release, "Arch Coal acquires equity interest in West Coast terminal," January 12, 2011, http://news.archcoal.com/phoenix.zhtml?c=107109&p=irol-newsArticle&ID=1515428&highlight=

[11] *Billings Gazette*, "Coal mines pursued northeast of Billings," March 1, 2010, http://billingsgazette.com/news/state-and-regional/montana/article_627cd1ac-257e-11df-a999-001cc4c002e0.html

Coal strip mining damages air, water, land

Feeding these export plans will mean the expansion of coal strip mining, and that expansion will lead to greater damage to water quality and quantity, air quality, land use, wildlife, and the health of the surrounding communities.

Current existing Montana coal mines have disturbed 37,500 acres with strip mining, but only 50 acres have attained final reclamation.[12] Why is this final reclamation important? Montana requires reclamation of the groundwater in the area of the coal mine and, in many places in Montana, these coal companies cannot replace this vital resource. The coal seam is often itself the aquifer. Much of this land will never be returned to productive agricultural land if the area is not fully reclaimed.

Coal-fired power plants require water for cooling machinery and slurrying the coal. If a proposed coal-to-liquids facility ever becomes a reality, it will require vast amounts of water to operate, more than a typical power plant. This is water that eastern Montana doesn't have to spare.

Coal strip mining also affects the quality of water quality. At the Rosebud Mine in Colstrip, for example, there has been an incidence of water contamination by what is believed to be seepage from the mine. A rancher in the area has had cattle die from this contaminated water. Coal mining liberates heavy metals and other toxins from the coal beds, and that pollution often migrates to surface waters.

Coal strip mining also worsens air quality. By disturbing large quantities of dirt with heavy machinery, particulate levels and gases (nitrogen oxides, sulfur dioxides, and methane) can dramatically increase. These can lead to increased incidence of ailments such as asthma and bronchitis.[13]

Increased coal trains will snarl traffic

The new push to export coal will spread and intensify the impacts of coal mining to more communities along the proposed rail routes to the West Coast.

Communities along the route coal trains take to the West Coast will face up to 50 unit trains a day, which could significantly delay traffic and emergency responders.[14]

Coming to a railroad crossing near you: more long, traffic-stopping coal trains from the Powder River Basin of Wyoming and Montana headed for Asia via the West Coast.

In Billings, the train tracks cut off most of the south side of town; the airport and hospitals could be cut off from direct access to the Interstate highway.

In downtown Billings, there are virtually no areas where it is easy to cross the tracks, and very little room to build any overpasses or underpasses. This problem could be replayed in communities across Montana.

The big unanswered question is the impact of a five-fold increase in coal train traffic (from 10 coal trains per day to 50 coal trains) on the overall rail system.

Most of Montana's track is currently within capacity. However, the scale of traffic increase brought about by increasing coal exports could create disruptions for other rail traffic, as well as vehicular traffic.

Increasing capacity could involve strategies such as running trains faster, longer, or closer together. Track could be upgraded or curves straightened.

---

[12] U.S. Office of Surface Mining Reclamation and Enforcement, *Annual Evaluation Summary Report for the Montana Regulatory Program, Evaluation Year 2010*

[13] Sharma, Partha Das, "Coal Mining Pollution and its control measures" http://www.docstoc.com/docs/6608086/Coal-Mining-Pollution

[14] *Exporting Powder River Basin Coal: Risks and Costs*, Western Organization of Resource Councils (WORC) January 2011, page 9.

Coal infrastructure

Coal mining needs infrastructure, including railroads. Getting new coal to market will inevitably lead to the use of eminent domain to condemn Montana ranchland. Mining the Otter Creek coal could lead to construction of the Tongue River Railroad, a propposed project which has hung over the heads of Tongue River valley landowners since 1980. Just this one railroad would cut ranches in half for 130 miles, complicating day-to-day operations, reducing property values, bringing in weeds, and starting fires.

Coal dust and diesel

Each coal railcar loses roughly 500 pounds of coal dust during each trip to the coast – more than 30 tons per train on average. This coal dust goes into air, water, and land. It also accumulates on the tracks, increasing the risk of derailments.[15] In addition to coal dust, all of these trains are powered by diesel engines. In areas where the trains will be idling (e.g., Laurel, Montana), the unhealthy increase in diesel emissions could be substantial.[16]

Carbon impacts

Every ton of coal, when burned, puts roughly two tons of carbon dioxide into the atmosphere.[17] Shipping that coal by rail a thousand miles to a port, then thousands more miles by ship, will increase the proportion of greenhouse gases added to the atmosphere. Even when that coal is burned in China, the jet stream will carry it back across the ocean and across the Northern Hemisphere.

Wherever it is burned, the Otter Creek coal will add carbon dioxide totaling approximately 280 million tons per year to the atmosphere.[18]

[15] "Railroads, Utilities clash over dust from coal trains," *New York Times*, January 25, 2010, http://www.nytimes.com/gwire/2010/01/25/25greenwire-railroads-utilities-clash-over-dust-from-coal-55265.html

[16] *Exporting Powder River Basin Coal: Risks and Costs*, Western Organization of Resource Councils (WORC) January 2011, page 13.

[17] U.S. Energy Information Administration, *Carbon Dioxide Emission from the Generation of Electric Power in the United States*, July 2000, http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html

[18] *Exporting Powder River Basin Coal: Risks and Costs*, Western Organization of Resource Councils (WORC), January 2011, page 11.

Coal's long-term costs

Exporting this dirty, 19th century fuel is not an effective or sustainable path to prosperity or energy security in the 21st century. Coal exported overseas doesn't keep lights on or homes warm in Montana, Washington, or in the United States.

Exporting coal means we have to deal with the on-the-ground impacts here in Montana, including water and air pollution, damaged aquifers, condemnation of private property for coal infrastructure, large increases in rail traffic across Montana.

The increase in rail traffic that would be created by the additional trains to deliver coal to the facility at Longview could seriously disrupt vehicle traffic, slow emergency response vehicles, and cause more pollution and public safety problems in cities and towns along railroad lines across the Northwest.

Wherever the coal is burned, the skies above Montana will be polluted. We will be adding substantially to the load of carbon dioxide in the earth's atmosphere. In the process, we will be undermining all of our efforts to curb air pollution in America.

Every dollar America invests in new coal development is a dollar that can't be spent to develop clean energy jobs and true energy independence for our nation.

Keep informed! Join Northern Plains

Northern Plains Resource Council is a conservation and family agriculture group that organizes Montana citizens to protect our water quality, family farms and ranches, and unique quality of life.

220 S. 27th Street, Suite A
Billings, MT 59101
(406) 248-1154

www.northernplains.org

❑ I want to be a monthly donor: (Also for membership; credit/debit card withdrawal available)
❑$50/month ❑$25/month ❑$20/month ❑$15/month ❑$10/month ❑ Other___

❑ A one-time membership donation is better for me right now:
❑ Rider of the Big Sky $500+ ❑ Bottom Line Rider 200+ ❑ Rough Rider $100+
❑ Range Rider $50+ ❑ General $40 ❑ Living Lightly $15-39

I'm paying by: ❑ Check (payable to Northern Plains) ❑ Credit/Debit Card

Card Type_____ Card # _____ Code ____

Expires _____Name on Card_____Signature_____

❑ Withdraw from my Bank Account (please include VOIDED check and sign above)

NAME

ADDRESS

CITY, STATE, ZIP

PHONE EMAIL

Coal Export

A history of failure for western ports

August 2011

By Brett VandenHeuvel, Columbia Riverkeeper
and Eric de Place, Sightline Institute

Communities in Oregon and Washington are weighing the prospect of coal export facilities. Proponents of shipping American coal to Asia argue that coal will bring significant economic benefits to the region. In this research memo, we examine the risks of coal markets, review the history of coal exports on the West Coast, and evaluate the employment dimensions of coal terminals.

Contents:

1. Coal is "the most risky bulk mineral market"
2. Coal has a history of failure on the West Coast
3. Coal export is a poor strategy for jobs
4. Case studies: Clean redevelopments provide more jobs

1.) Coal is "the most risky bulk mineral market"

Coal companies are asking Pacific Northwest ports to dedicate large terminals to ship US coal to Asia. But coal is so unattractive that many ports have rejected coal, despite aggressively pursuing new business. Recently, the Port of Tacoma, located on Puget Sound, and the Columbia River Ports of Vancouver, Kalama, and Portland have all considered—and rejected—coal export proposals.

Port of Vancouver

The *Columbian* newspaper framed up the Port's choice, writing, "faced with a choice of helping to grow food or feed industry, the Port of Vancouver picked a fertilizer ingredient over the dirtiest fossil fuel on the planet." [1]

Larry Paulson, the Port of Vancouver's executive director, pointed out that "coal facilities have a tendency to come and go," and that was a big reason why Vancouver favored a terminal for potash, a more stable commodity. [2] The Port's operations manager, Mike Schiller, put it even more directly: "coal is the most risky bulk mineral market." [3]

Port of Tacoma

The headline of *Platts Coal Trader* said it all: "Tacoma Port torpedoes coal terminal plan." The Port of Tacoma stated that it rejected a large export proposal in 2010 because of a "multitude of business and community factors."[4] Local citizens have concerns about the health effects of coal dust and the impact of coal trains.

Port of Kalama

Kalama rejected a coal export proposal from Millennium Bulk Terminals in 2010. Kalama told Millennium that "after considerable deliberation on the issue, the Port will not be moving forward with plans for a coal export facility."[5] After the rejection, Millennium now seeks to site its project in Longview.

Port of Portland

The Port of Portland made clear that "a coal terminal is off the table for existing and future Port of Portland facilities." [6] A media statement explained, "The Port needs to be reflective of the community and its values. Coal doesn't seem to fit within those values."[7]

Perhaps heeding the Port of Vancouver's statement that "coal is the most risky bulk mineral market," no public port has voted to approve a coal export terminal. Coal is a notoriously unstable and risky commodity. That's why business reporter David Gambrel, writing for the industry publication *Coal Age*, recently questioned whether new export facilities on the West Coast really make sense:

> Will there be sufficient demand to justify a new coal supplier…? Let us not forget the same China that threatened to export coal 10 years ago is now viewed as a buyer with deep pockets and endless demand. How long will this last?[8]

It's an important question. Coal exports from Washington would rely on Asian markets that have historically been fickle. China, which has large domestic coal reserves, is both an importer and exporter of coal. It's enough to make some insiders, including Deutsche Bank commodities analysts, believe that the coal export market to China may be overhyped.[9]

2.) Coal has a history of failure on the West Coast

If Deutsche Bank is right that coal is currently overhyped, it wouldn't be the first time. West Coast port cities have already gambled and lost on coal export facilities. After

investing millions of dollars in infrastructure and setting aside sizeable harbor acreage to coal export facilities, both Portland and Los Angeles watched their promised revenue from coal exports evaporate.

Worse yet, local communities were stuck with the tab. The abandoned coal export facilities locked up millions of dollars in stranded investments and clean-up expenses, not to mention years-long missed opportunities for more durable economic development choices.[10]

What happened in Portland?

The early 1980s saw a rush of coal companies proposing export terminals in Washington and Oregon to satisfy a hungry Asian market. Longview, Kalama, Vancouver, and Astoria all entertained proposals, but the Port of Portland bought in.[11] Portland committed to a 25-year lease with Pacific Coal for 90 acres and 900 feet of prime riverfront for a coal export terminal.[12] Governor Atiyeh even broke ground at the site with a giant gold-painted power shovel in 1982.[13]

The Port and investors spent $25 million building a coal export terminal.[14] Two years later, the project imploded after Asian markets proved unstable, unreliable, and not-so-hungry. After a five-month investigation, the *Oregonian* reported, "Port and Pacific Coal officials heedlessly plunged ahead despite clear warnings that they might never move a solitary lump of coal."[15]

Contractors didn't get paid, borrowers defaulted, and lawsuits flourished.[16] By betting on coal, the Port wasted prime industrial land, money, and jobs. The *Oregonian* noted:

> Analysts later determined that coal export failed because the Asian demand was based on promises rather than actual long-term contracts. And international banks studying the issue found that the demand for coal had been 'vastly overstated.'[17]

Soon after the Port of Portland collapse, nearly all other West Coast coal plans were scrapped.

What happened in Los Angeles?

Despite Portland's dramatic failure in the 1980s, a decade later Los Angeles forged ahead with another "world-class" coal export facility. In the early 1990s, coal giant Peabody led a consortium of investors that promised jobs, tax revenue, and environmental protection with a new coal export terminal at the Port of Los Angeles (LAXT).[18] The enormously divisive project alarmed neighbors and nearby workers.[19]

A 1993 *Los Angeles Business Journal* article seems to prefigure today's debates in the Northwest:

> … although the terminal will create jobs and taxes throughout Southern California, the terminal will have a negligible impact on L.A. County because the product (coal) is sourced from other states and the automated terminal won't generate many direct jobs.[20]

And:

> The City of Long Beach filed a lawsuit July 14, alleging that the Port of L.A.'s environmental impact report doesn't adequately address the negative environmental impact of coal dust that will be spewed from the massive uncovered storage pile of coal and petroleum coke.[21]

Fears proved well-founded. The terminal experienced at least two fires after dangerous amounts of coal dust accumulated in the ship-loading machinery.[22] By that time, however, Peabody was no longer around; perhaps sensing market weakness, they dropped out of the consortium before the terminal was built.

The facility closed just six years after it opened owing to unfavorable market conditions.

When the facility shut down, the City of Los Angeles had to write off $19 million of capital investment, and forfeit $94 million in expected revenue.[23] Ultimately, the city was sued for improperly managing the site – and for failing to consider alternative uses of the site – and taxpayers shelled out $28 million to settle the suit.[24]

Today, it is not surprising that the Ports of Tacoma, Vancouver, Kalama, and Portland are leery of investing in coal after the history of failure.

3.) Coal is a poor strategy for jobs.

Each of the coal export facilities planned for Washington would occupy hundreds of acres of prime waterfront shipping property with storage for raw coal. There are far more job-intensive uses for port lands. For example, a marine construction company leasing just 3.5 acres of land and a new cold storage facility on 17 acres of land at the Port of Tacoma are each expected to generate 100 new jobs.[25] A Port of Seattle economic impact study found that shipping 1,000 metric tons of grain—a bulk commodity like coal—generated just 0.09 jobs, compared to 0.57 jobs for containerized cargo and 4.2 jobs for “break bulk” cargo, such as big machines or goods shipped on pallets, which requires more handling.[26] A study at the Port of Baltimore came to similar conclusions, finding that coal export supports just 0.11 jobs per 1,000 metric tons, as compared to 0.41 for other dry bulk commodities, 0.43 jobs for containerized cargo, and even 1.71 jobs for autos.[27]

Millennium Bulk Terminals in Longview estimates that it would employ 70 people to move about 5 million tons of coal. [28] Millennium's purchase of the property displaced 50 workers from the previous employer, however, so the net gain would be 20 jobs. [29] In Bellingham, project developers say that a 24-million-ton facility, which is planned to be operational in 2015, would employ 89 workers. Proponents estimate that in 2026, if the entire 54 million ton facility is completed, the coal terminal would directly employ about 280 people.[30]

It's important to understand the jobs numbers in context. The result is that coal exports at Longview, even if the entire 70 jobs are counted, can only be counted on to directly increase employment in Cowlitz County by less than two tenths of one percent. Meanwhile, coal exports at Cherry Point would directly increase employment in Whatcom County by less than one tenth of one percent by 2026. [31]

It is also important to weigh the promise of jobs against the economic threats of investing in the "most risky" coal market. Portland's gamble on coal was ridiculed for costing jobs: "By signing a 25-year lease with Pacific Coal, Port officials tied up 90.69 acres of riverfront land suitable for heavy industry at a time when the Portland area desperately needed jobs."[32]

4.) Case studies: Clean redevelopments provide more jobs

Millennium proposes to use a former mill site owned by Alcoa in Cowlitz County to export coal. The site, which features 416 acres of prime waterfront industrial land, is contaminated with pollution from the mill operation. Cowlitz County now faces a choice for the site: approve Millennium's proposed coal export terminal or force Alcoa to clean it up to attract other business. Alcoa has already signed an Agreed Order with the Department of Ecology, in 2007, that mandates Alcoa to clean up the site's pollution.[33]

Alcoa has a good track record cleaning up aluminum mills and selling the land for more productive uses. In the last 5 years, Alcoa has successfully completed cleanup of former aluminum mills in Troutdale, Oregon and Vancouver, Washington.[34] Alcoa even received a national award for its cleanup of the Troutdale site.[35] Both sites are now active industrial areas.

In Troutdale, the recently cleaned site is now the home of a FedEx Ground regional distribution center that employs over 750 people.[36] And in Vancouver, the Port purchased Alcoa's cleaned up 218-acre mill site and now expects up to 1,000 new jobs there. The Vancouver site, now called Terminal 5, will be put to immediate use to construct improved rail service and accommodate a surge in wind turbines and other cargos, while preparing for more development of the marine terminal in the near future.[37]

The employment numbers for coal exports don't stack up well. The proposed coal export terminal at Longview would occupy 416 acres of heavy industrial waterfront property and produce 70 jobs (with a net gain of 20 new jobs)—less than 0.2 jobs per acre. By contrast, the Troutdale facility occupies 700 acres of heavy industrial property, but supports 1.4 jobs per acre. The Port of Vancouver site, with 218 acres of heavy industrial waterfront, will generate 3.4 jobs per acre.[38]

Conclusion

West Coast coal terminals have a history of failure. The terminals locked in otherwise productive land use for years without delivering on promises of tax revenues and jobs. The cost of these failures is borne by the communities. When the facilities don't work out, the specialized equipment is difficult to remove or resell. Land and water pollution at coal export harbors is both inevitable and potentially irreversible. Millions must be spent to approximate clean-up and rededicate the land, often to lower-value uses.

Brett VandenHeuvel *is executive director of Columbia Riverkeeper, a nonprofit organization that works to protect the Columbia, reduce toxic pollution in river communities, and restore salmon runs.*

Eric de Place *is senior researcher at Sightline Institute, an independent, nonprofit research and communications center—a think tank—for the Pacific Northwest.*

---

[1] Aaron Corvin, "Port Dodges Coal, Embraces Potash," Vancouver *Columbian*, April 3, 2011, http://www.columbian.com/news/2011/apr/03/dodging-coal-embracing-potash-the-port-of-vancouve/

[2] Aaron Corvin, "Port Dodges Coal, Embraces Potash," Vancouver *Columbian*, April 3, 2011, http://www.columbian.com/news/2011/apr/03/dodging-coal-embracing-potash-the-port-of-vancouve/

[3] Email from Mike Schiller, operations manager, Port of Vancouver, Washington to Alastair Smith, November 20, 2008.

[4] Peter Gartrell, "Port of Tacoma Torpedoes Coal Export Terminal Plan," Platts Coal Trader, November 22, 2010.

[5] Email from Mark Wilson, development manager, Port of Kalama, to Mark Wilson, Ambre Energy, July 6, 2010.

[6] May 25, 2011 Port of Portland letter to Columbia Riverkeeper, Enclosure 1 ("talking points" dated March 22, 2011).

[7] May 25, 2011 Port of Portland letter to Columbia Riverkeeper, Enclosure 1 ("talking points" dated March 22, 2011).

[8] Dave Gambrel, "Building a Coal Terminal on the West Coast," *Coal Age*, November 18, 2010, http://www.coalage.com/index.php/features/763-building-a-coal-terminal-on-the-west-coast.html.

[9] "Improved Domestic Coal From China May Slow Imports," June 21, 2011, http://www.marketwatch.com/story/improved-domestic-coal-out-from-china-may-slow-imports-2011-07-21.

[10] In Los Angeles, for example, the city's projected losses were to include: writing off the city's $19 million investment; forfeiting nearly $94 million in projected revenue; losing access to 117 acres of harbor land; paying $1 million to clean up approximately 36 acres of that land. (See Patrick McGreevy, "L.A. Weighs Costly Exit From Coal Terminal," *Los Angeles Times*, June 14, 2003, http://articles.latimes.com/2003/jun/14/local/me-coal14.)

[11] Eric Goranson, “Coal’s once bright future goes up in smoke,” The *Oregonian*, February 14, 1983.

[12] James Long and Leslie L. Zaitz, “A terminal case: Demise of coal port more than just bad luck,” The *Oregonian*, March 14, 1984.

[13] Bob Olmos, “Pacific Coal terminal under way in Portland,” The *Oregonian*, March 2, 1982.

[14] James Long and Leslie L. Zaitz, “A terminal case: Demise of coal port more than just bad luck,” The *Oregonian*, March 14, 1984.

[15] James Long and Leslie L. Zaitz, “A terminal case: Demise of coal port more than just bad luck,” The *Oregonian*, March 14, 1984.

[16] James Long and Leslie L. Zaitz, “A terminal case: Demise of coal port more than just bad luck,” The *Oregonian*, March 14, 1984.

[17] James Long and Leslie L. Zaitz, “A terminal case: Demise of coal port more than just bad luck,” The *Oregonian*, March 14, 1984.

[18] “Planned coal-export terminal promises jobs, taxes,” *Los Angeles Business Journal*, August 23, 1993, http://www.entrepreneur.com/tradejournals/article/14361631.html.

[19] Deborah Belgum, “Huge Coal Storage Facility Fuels Fears,” *Los Angeles Times*, August 16, 1996, http://articles.latimes.com/1996-08-16/local/me-34702_1_coal-storage.

[20] “Planned coal-export terminal promises jobs, taxes,” *Los Angeles Business Journal*, August 23, 1993, http://www.entrepreneur.com/tradejournals/article/14361631.html.

[21] “Planned coal-export terminal promises jobs, taxes,” *Los Angeles Business Journal*, August 23, 1993, http://www.entrepreneur.com/tradejournals/article/14361631.html.

[22] Exponent, “Coke and Coal Shiploader Fire: Los Angeles Port,” http://www.exponent.com/Coke-and-Coal-Shiploader-Fire-Los-Angeles-Port/.

[23] Patrick McGreevy, “L.A. Weighs Costly Exit From Coal Terminal,” *Los Angeles Times*, June 14, 2003, http://articles.latimes.com/2003/jun/14/local/me-coal14.

[24] LAXT’s development and subsequent closure also sparked a firestorm of lobbying, backroom deals, and lawsuits. As one city councilmember at the time put it, "Every lobbyist I have ever heard of is in this chamber… I would like to know where, if [the terminal] is on the verge of bankruptcy, they got the money to hire all these lobbyists.” The *LA Times* reported that the terminal, “made 25 political contributions totaling more than $10,000 to city officials and candidates including Mayor James K. Hahn and his sister, Councilwoman Hahn.” (See Patrick McGreevy, “L.A. Weighs Costly Exit From Coal Terminal,” *Los Angeles Times*, June 14, 2003, http://articles.latimes.com/2003/jun/14/local/me-coal14; Patrick McGreevy, “L.A. To Pay $28 Million to Settle Port Suit,” *Los Angeles Times*, December 14, 2006, http://articles.latimes.com/2006/dec/14/local/me-settle14; and Patrick McGreevy, “City Is Hit With $4 Million in Claims Over Rejected Port Project,” *Los Angeles Times*, June 11, 2004, http://articles.latimes.com/2004/jun/11/local/me-laxt11).

[25] Port of Tacoma, “Construction starts on new cold storage facility at the Port of Tacoma,” January 12, 2010, http://www.portoftacoma.com/Page.aspx?cid=4229; and Port of Tacoma, “Port of Tacoma leases to marine contractor for new Northwest base,” March 24, 2010, http://www.portoftacoma.com/Page.aspx?cid=4365.

[26] Martin Associates, “The 2007 Economic Impact Study of the Port of Seattle,” February 10, 2009, http://www.portseattle.org/downloads/business/EconomicImpact_20091.pdf.

[27] Martin Associates, “The Economic Impacts of the Port of Baltimore,” January 28, 2009, http://mpa.maryland.gov/_media/client/planning/EconomicImpactReport-revisedJan'08.pdf.

[28] Erik Olson, “Westshore Provides Glimpse of Longview’s Potential Future With Coal,” Longview *Daily News*, February 12, 2011, http://tdn.com/news/local/article_35ad9c0c-3634-11e0-8eea-001cc4c03286.html.

[29] Andre Stepankowsky, “Millennium Buys Chinook Ventures Site, Pledges Cleanup of Contamination,” Longview *Daily News*, January 12, 2011, http://tdn.com/news/local/article_463012b6-1e7f-11e0-957c-001cc4c002e0.html.

[30] Gateway Pacific Terminal, http://www.gatewaypacificterminal.com/economic/localstate.shtml.

[31] All employment and labor force figures come from US Bureau of Labor Statistics, "Labor Force Data By County, 2010 Annual Averages," ftp://ftp.bls.gov/pub/special.requests/la/laucnty10.txt.

[32] James Long and Leslie L. Zaitz, "A terminal case: Demise of coal port more than just bad luck," The *Oregonian*, March 14, 1984.

[33] Washington State Department of Ecology, Agreed Order No. DE 4263, In the Matter of Remedial Action by Northwest Alloys Inc. and Chinook Ventures Inc. (2007).

[34]Oregon Department of Environmental Quality, "Environmental Cleanup Site Information (ECSI) Database Site Summary Report – Details for Site ID 154, Reynolds Metals Co," http://www.deq.state.or.us/lq/ECSI/ecsidetail.asp?seqnbr=154; Washington Department of Ecology, Port of Vancouver (Former Alcoa/Evergreen Smelter), http://www.ecy.wa.gov/programs/swfa/industrial/alum_alcoavan.htm.

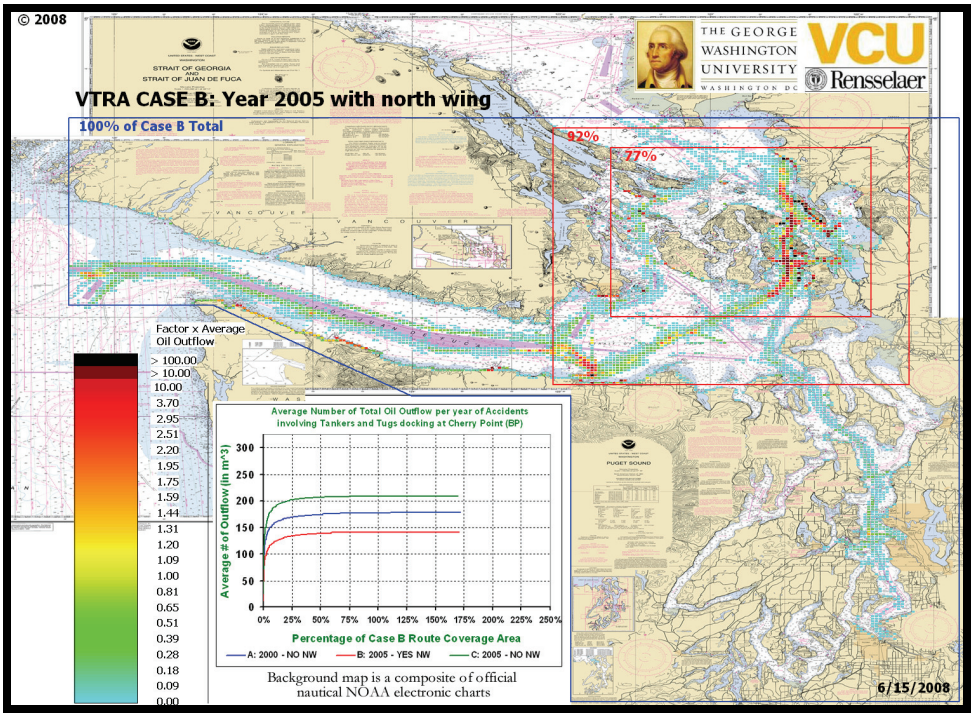
[35] Alcoa, "Alcoa Receives National Excellence in Brownfield Redevelopment Award," April 6, 2011, http://www.alcoa.com/global/en/news/news_detail.asp?pageID=20110406006385en&newsYear=2011.

[36] Alcoa, "Alcoa Receives National Excellence in Brownfield Redevelopment Award," April 6, 2011, http://www.alcoa.com/global/en/news/news_detail.asp?pageID=20110406006385en&newsYear=2011.

[37] Port of Vancouver, "Terminal 5 Brings New Jobs, Business and Rail to the Port of Vancouver," http://www.portvanusa.com/marine-terminals/new-marine-terminal.

[38] Port of Vancouver, "Cleanups," http://www.portvanusa.com/environmental-programs/cleanups.

MAIN REPORT



Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

Submitted by VTRA TEAM:

Johan Rene van Dorp (GWU), John R. Harrald (GWU),

Jason R.. W. Merrick (VCU) and Martha Grabowski (RPI)

August 31, 2008

PREFACE

This report is submitted by Johan Rene van Dorp, John R. Harrald, Jason R.W. Merrick and Martha Grabowski. Johan Rene van Dorp and John R. Harrald are professors at the George Washington University (GWU), Jason R. W Merrick is a professor at Virginia Commonwealth University (VCU) and Martha Grabowski is a professor at Rensselaer Polytechnic Institute (RPI). The content of the report describes a Vessel Traffic Risk Assessment (VTRA) and the team members above are referred to as the VTRA team.

The VTRA project commenced in June 2006 and spanned over a period of two years. Over the course of this project a comprehensive maritime risk management analysis tool has been developed for the VTRA study area that includes the approaches to and passages through the San Juan Islands, Puget Sound, Haro-Strait/Boundary Pass and the Strait of Juan de Fuca. However, we were tasked to only consider accident risk to vessel docking at the BP Cherry Point dock. The project was funded by BP.

From the outset of this project the support from the United States Coast Guard, Sector Seattle has been unwavering, in particular the support of Captain Stephen Metruck and Jason Tama, who was a lieutenant commander during the first year of this project in Seattle, proved instrumental. As of November 2006, the US Coast Guard introduced the VTRA team to the Puget Sound Harbor Safety committee. Since November 2006 and up to May 2008, we have been able to present our project progress during public meetings every two month held at the Army Corp of Engineers building, 4735 East Marginal Way South in Seattle, WA. During these meeting preliminary results were presented related to our base case analysis of the year 2005. Our last presentation to this community was held in May 2006 during the National Harbor Safety committee held in Seattle at that time.

The Puget Sound Harbor Safety committee, led by Bruce Reed, unselfishly extended their hospitality to allow us to present our progress over the course of this project. They provided us a public platform, missing at the outset of this project, to obtain feedback and access to

the maritime community within the VTRA study for data gathering purposes and expert judgment elicitations.

We are particularly indebted to efforts of Captain Stephen Metruck, LCDR Jason Tama, John Veentjer of the Marine Exchange and Craig Lee from BP Shipping for their efforts in soliciting experts from the maritime community. Experts were invited to and referred to the VTRA team through the United States Coast Guard and the Puget Sound Harbor Safety committee. Expert judgment elicitation sessions were scheduled predominantly at the US Coast Guard VTS, sector Seattle in December 2006, February 2007, June 2007, August 2007, September 2007 and December 2007. An elicitation session with ATC tanker captains was scheduled during an ATC conference in February 2007 in Portland, Oregon. In particular, the Puget Sound Pilots, led over the course of this project by Captains Richard McCurdy and Del Mackenzie, were an active participant during the elicitation sessions. None of the experts personally benefited from participating in the expert judgment elicitation. Each expert judgment elicitation session consisted of a morning and afternoon session. They donated their time for the enhancement of the safety levels in their maritime domain and they should be commended for it.

The approach for this VTRA risk assessment is builds on the methodology and the dynamic risk simulations developed for tanker operations in Prince William Sound, Alaska (1995-96), estimation of passenger risk for the Washington State Ferries (WSF) Risk Assessment (1998-1999) and the dynamic exposure simulation methodology for the San Francisco Bay Exposure Assessment (2002) also with a passenger safety focus. This methodology is described in a number of journal papers that have been reviewed by our academic peers:

- J.R.W. Merrick, J.R. van Dorp, J.P. Blackford, G.L. Shaw, T.A. Mazzuchi and J.R. Harrald (2003). "A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model", *Reliability Engineering and System Safety*, Vol. 81 (2): pp. 119-132.
- J.R.W. Merrick, J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn and M. Grabowski (2002). "The Prince William Sound Risk Assessment". *Interfaces*, Vol. 32 (6): pp.25-40.
- J.R. van Dorp, J.R.W. Merrick , J.R. Harrald, T.A. Mazzuchi, and M. Grabowski (2001). "A Risk Management procedure for the Washington State Ferries", *Journal of Risk Analysis*, Vol. 21 (1): pp. 127-142.

- P. Szwed, J. R. van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). "A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information", *European Journal of Operations Research*, Vol. 169 (1), pp. 157-177.

The off-prints of these papers are attached to this report as sub-appendices (not to be confused with the technical appendices below).

In this project, the VTRA team enhanced and improved their methodology described in the journal papers above in a variety of ways. Some of these improvements are: (1) the maritime system in the VTRA study area was modeled at unsurpassed levels of detail using both AIS and radar data to develop detailed traffic patterns of VTS reporting traffic, (2) small vessel event methodology now includes routes for sailing regattas, whale watching movements and routes from and to both tribal and commercial fishing grounds (3) the use of geographic profiles to display accident frequency and oil outflow across a geographic area using a color legend (this methodology was first used to display exposure in the San Francisco Bay Exposure Assessment), (4) enhanced collision and grounding model that take into account vessel speeds and shore-line interactions and (5) an oil outflow model that builds on those discussed in Special Report 259, *Environmental Performance of Tanker Designs in Collision and Grounding*, published by the National Research Council in 2001 with the ability to model vessel fuel losses in addition to crude oil or refined products cargo losses.

This report contains an executive summary, a main body containing several chapters and a conclusion section. Even though the report was developed to be predominantly self contained, it may refer at times to the following technical appendices A through G that describe the VTRA effort in more technical detail:

- Technical Appendix A: Database Construction and Analysis
- Technical Appendix B: System Description
- Technical Appendix C: Simulation Construction
- Technical Appendix D: Expert Judgment Elicitation
- Technical Appendix E: Oil Outflow Model
- Technical Appendix F: Future Scenarios
- Technical Appendix G: Geographic Exposure, Accident and Oil Outflow Profiles

Jason Merrick took the lead in the production and writing of the main report and Technical Appendix F, Martha Grabowski produced Technical Appendix A, Jack Harrald took the lead in developing Technical Appendix B, Jason Merrick and Johan Rene van Dorp co-authored Technical Appendix C, Johan Rene van Dorp wrote and developed Technical Appendices D, G and took the lead in the production and writing of Technical Appendix E. Finally, Johan Rene van Dorp managed the integration of these documents into a final product.

PROJECT TEAM MEMBERS

Various university members over the course of this project have contributed in a variety of ways to this report, the technical appendix and the analysis. The list below provides the affiliation of the respective university members that have contributed over the course of this two-year project and we would like to thank them for their efforts.

The George Washington University, School of Engineering and Applied Science, Engineering Management and Systems Engineering Department, 1776 G Street, NW, Washington D.C., 20052:

- Johan Rene van Dorp, Associate Professor
- John R. Harrald, Professor
- Greg Shaw, Managing Director of Institute of Crisis Disaster and Risk Management
- Adil Caner Sener, Graduate Research Assistant
- Christian Salmon, Graduate Research Assistant
- Giel van de Wiel, Exchange Visitor from the Delft University of Technology, The Netherlands

Virginia Commonwealth University, Statistical Sciences and Operations Research, P.O. Box 843083, 1001 West Main Street, Richmond, VA 23284-3083:

- Jason R. W. Merrick, Associate Professor
- Christina T. Werner, Research Associate

Rensselaer Polytechnic Institute, Department of Decision Sciences and Engineering Systems, CII 5015, 110 8th Street, Troy, New York, 12180-3590:

- Martha Grabowski, Professor
- Zhuyu You, Graduate Research Assistant
- Zhi Zhou, Graduate Research Assistant
- Huawei Song, Graduate Research Assistant
- Michael Steward, Graduate Research Assistant
- Brittany Steward, Graduate Research Assistant

EXECUTIVE SUMMARY

In June 2006, BP contracted with The George Washington University, Rensselaer Polytechnic University, and Virginia Commonwealth University to perform a vessel traffic risk assessment (VTRA) with the intent of incorporating its results into the Section 10 permit EIS for the addition of a north dock to the BP Cherry Point, Washington facility. The purpose of the VTRA study was to analyze the effects on oil spill risk of potential incremental vessel traffic projected to call at the Cherry Point dock through 2025 and to evaluate mitigation measures applicable to BP to address such impacts.

The maritime system in the VTRA study area was modeled at unsurpassed levels of detail, compared to our prior studies, and a comprehensive set of accident and incident data for all vessel types were collected and analyzed. However, the results and conclusions presented apply only to the interactions involving vessels carrying crude oil and petroleum products to and from the BP Cherry Point refinery. Tank vessels that dock at Cherry Point are articulated tug barges (ATB's), integrated tug barges (ITB's) and tankers, henceforth referred to as BP Cherry Point vessels (BPCHPT). BPCHPT vessels comprise a relatively small percentage of the total modeled vessel traffic in the study area; the time spent on the water by BPCHPT vessels accounts for 1.1% of all modeled traffic and 7 % of the modeled deep draft traffic. In contrast, the combined time on the water for all tankers, ATB's and ITB's, accounts for 3% of all traffic and 16% of deep draft traffic.

The specific scope of the study was as follows:

- The study evaluated the routes used by marine vessels to carry crude oil and petroleum products between the Cherry Point Refinery and:
    - the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J offshore of Cape Flattery, and
    - the Puget Sound.
- The study evaluated the incremental risk of (1) an accident (collision, grounding, or other scenario) involving a tank vessel, (2) resulting in a discharge of crude oil or

petroleum products, (3) associated with reasonably foreseeable increases in vessel traffic through calendar year 2025 to and from both wings of the Cherry Point Oil Spill Risk Assessment due to increased vessel traffic calling at Cherry Point Dock Refinery Pier, (4) as compared with the baseline traffic that the pre-North Wing pier could accommodate.

- In evaluating these risks the study modeled all vessel traffic (not just vessels carrying crude oil and petroleum products) and reasonably foreseeable increases and decreases in vessel traffic along the entire pathway followed by vessels between;
    - Cherry Point and the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J, and
    - Cherry Point and the Puget Sound,

  including but not limited to vessels calling in British Columbia, and vessels calling at the Cherry Point Refinery Pier, Conoco-Phillips, Intalco and reasonably foreseeable future marine terminal facilities in the Cherry Point area, including the proposed Gateway facility.
- The study accounted for non-VTS reporting vessels (fishing vessels and recreation traffic) using methods developed in the modeling of traffic in San Francisco Bay as far as data or expert judgment was available to model this traffic in a reasonable manner.
- The study evaluated low, medium and high traffic scenarios.
- The study considered the impact of human and organizational error on the likelihood of accidents and the effectiveness of risk reduction interventions.
- The study did not evaluate vessel traffic risks at locations other than those routes used by vessels traveling to and from Cherry Point.
- The study investigated risks associated with the Haro Strait and Huckleberry-Saddlebag approaches to and from Cherry Point.
- The study evaluated the following potential vessel traffic management protocols that potentially could reduce the risk of an accident and that can be instituted consistent with existing law: (1) use of Rosario Strait and Guemes Channel instead of the Huckleberry-Saddlebag traverse; (2) stationing a year-round prevention and response tug (of the kind currently stationed in Prince William Sound) in Neah Bay,

Washington; (3) a single tug escort requirement for the Western reaches of Juan de Fuca Strait with hand-off between prevention and response tugs stationed in Neah Bay and Port Angeles.

- The study included an impact analysis that described the outcomes of an accident as described by the location and size of oil outflows, but did not examine the fate and effects of an oil spill, a task to be performed by an independent EIS contractor based on the VTRA oil outflow analysis results.

The approach used for the VTRA extended the methodology developed by the VTRA team for the Prince William Sound Risk Assessment, the Washington State Ferries Risk Assessment, and the San Francisco Bay Water Transit Authority vessel traffic analysis. This approach recognizes that an accident is a culmination of a series of cascading events initiated by triggering mechanical failures and/or human errors. The creation of a comprehensive system simulation as the basic VTRA analysis tool ensures that the dynamic nature of system risk is captured. The system simulation provides a detailed representation of vessel traffic routes and transits for all traffic monitored by the US and Canadian Vessel Traffic Systems and an extensive capture of non VTS traffic such as fishing vessels, regattas and whale watching vessels. In addition, the system simulation represents the situational context of these transits by modeling wind conditions, visibility, and currents. The base year for the system simulation is 2005. In order for the simulation to be used as a risk management analysis tool, however, the absolute number of potential accidents and triggering incidents had to be estimated, and a method for calculating the likelihood that an incident, given a situational context, would result in an accident was required. As described in the basic report, these critical tasks were completed through extensive data analysis and the use of expert judgment where data was inadequate.

An analysis of maritime accidents and incidents in Puget Sound from 1995-2005 was completed to ensure that the maritime simulation was calibrated to historically accurate incident and accident frequencies. Accident and incident records for 1995-2005 for all vessel types and for the geographic scope of the project were solicited, and an accident-incident database was constructed. This data base consists of 2,705 events: 1462 accident events,

1159 incidents, 84 unusual events. Tank vessels accounted for 35 accidents, 111 incidents and 25 unusual events; tank barges accounted for 325 accidents, 87 incidents and 9 unusual events. The BP Cherry Point calling fleet accounted for 4 accidents and 59 incidents during the 1995-2005 time period; these events were used to calibrate the simulation for the base case year. 213 events were identified during the reporting period that were due to human error. Of the 213 human error events, 168 (79%) were unintended errors, rather than violations; of the 168 events, significantly more (52%) were due to perceptual errors, compared to skill-based errors (27%) or decision errors (21%). All of the accident and incident analyses, however, were limited by the availability of detailed information to support human and organizational error analysis.

The modeling of potential oil outflow following an accident extended work done previously by the National Research Council (NRC) and the International Maritime Organization (IMO). The oil outflow analysis estimates the probability of penetration, the number of compartments penetrated, and estimated outflow for each interaction scenario. Oil outflows were modeled for persistent oils (crude cargo and heavy fuel) and non-persistent oils (refined petroleum cargo products and diesel fuel) from vessels in the BP Cherry Point calling fleet and from other interacting vessels involved in a potential collision with the BP Cherry Point vessels.

The most likely base case accidents involving BP Cherry Point vessels were allisions followed by collisions and powered groundings. However, the average oil outflow potential was greatest from powered groundings, followed by collisions. The total potential average oil outflow from BP Cherry Point and interacting vessels in the 2005 base case was 141 cubic meters. In the base case simulation, BP Cherry Point vessels were the source of 97.5% of these oil outflows, interacting vessels accounted for 2.5%. Most (92%) of these oil outflows in the base case are concentrated in the area consisting of the approaches to and passages through the San Juan Islands and Anacortes.

Since shipping is a derived demand, projection of future vessel traffic is inherently uncertain. Actual future tanker and tank barge traffic will be dependent upon energy requirements and

distribution choices. Actual future container vessel traffic and bulk cargo traffic and vessel size are dependent upon demand for imports and exports. The vessel traffic described in the base case year (2005) was projected through 2025 using 15 years historical trend data analysis by vessel type. The opening of the Gateway bulk cargo terminal (that would effect this time series projection) and statistical techniques were used to construct upper and lower bounds for future traffic. The resulting high, medium and low forecasts were used as the basis for calculating future accident frequencies and oil outflows.

Detailed accident frequencies and oil outflow volumes were calculated for all locations in the study area for 15 VTRA cases. These 15 VTRA cases describe alternative systems in the years 2000, 2005 2025, considering the presence/absence of BP north wing, the presence or absence of the Gateway terminal, and presence or absence of mitigating measure—saddlebags, extended escort, Neah bay tug. The study's conclusions are based upon the analyses of the VTRA cases.

The following summary provides significant conclusions drawn from the analysis comparison of 2000-2005 VTRA cases, the comparison of 2000-2025 VTRA cases, and the analysis of specific potential risk reduction interventions[1]:

2000-2005 comparison conclusions derived from VTRA analysis results:

- If BP had restricted operations to the south wing in 2005, it could have served 96% of the BPCHPT vessels in 2005 actually served by both wings.
- In a 2005-2005 comparison, the addition of the north wing allowed the BP Cherry Point terminal to serve slightly more calling vessels, while reducing the potential for BPCHPT vessel accidents by 21% and decreasing oil outflows by 38%[2].
- With the north wing in operation in 2005 (but not in 2000), the potential for accidents involving BPCHPT vessels decreased by 10% between 2000 and 2005, and the oil outflow potential decreased by 21% between 2000 and 2005 in spite of the changes in vessel traffic during the same period.

[1] The main report and its technical appendices provide a more detailed explanation of these results.

[2] For consistency percentages are evaluated here as percentages of 2000 levels.

- With only the south wing in operation in both 2000 and 2005, the potential for accidents involving BPCHPT vessels would have increased by 12% between 2000 and 2005 and the potential outflows would have increased by 18% between 2000 and 2005.

2000-2025 analysis conclusions derived from VTRA analysis results:

- At each of the low, medium, and high traffic scenarios for 2025, having the north wing leads to lower average accident potential and oil outflow potential for BPCHPT vessels than not having it.
- Assuming the north wing being operational in a 2025 analysis with medium traffic increases, results in a total annual average oil outflow of 174.4 cubic meters, which is quite similar to the 177.7 cubic meters of the previous 2000 analysis when the dock was not operational (but a reduction of 1.8%).
- Assuming the north wing being operational in a 2025 analysis with high traffic increases, results in a total annual average oil outflow of 229.9 cubic meters, compared to the 177.7 cubic meters of the same 2000 analysis when the dock was not present (an increase of 29.4%).
- Hence, with additional traffic increases it remains possible that even with the addition of the north wing dock, oil transportation risk rises above a level previously experienced in 2000 when the north wing dock was not operational.

Risk intervention conclusions derived from VTRA analysis results:

- At the 2005 traffic levels, and not allowing the use of the Saddlebags route from BP Cherry Point to Anacortes in our maritime risk simulation model, leads to no appreciable change in either average accident potential or average oil outflow potential. In the high traffic scenario for 2025, not allowing the use of the Saddlebags route from BP Cherry Point to Anacortes in our maritime risk simulation leads to a 2% increase in average accident potential and a 0.1% increase in average oil outflow.
- At the 2005 traffic levels, extending the escorting of BP tankers and ITBs up to Buoy J in our maritime risk simulation model, leads to a decrease in both drift groundings

and collisions in the extended escorting area. The overall effect is a 1.5% decrease in total average accident potential and a 3% decrease in total average oil outflow potential. In the high traffic scenario for 2025, these decreases are 1% and 1.5%, respectively.

- A restricted analysis of the risk reduction potential of the Neah Bay Tug, considering only BP tankers (about 1.1% of the total modeled traffic and about 7% of the total modeled deep draft traffic) within the VTRA study area (i.e. up to 8 miles of Buoy J where traffic separation commences and, more importantly, including the area consisting of the approaches to and passages through the San Juan Islands and Anacortes typically beyond the Neah Bay tug's operating range) our maritime risk simulation model evaluated that the Neah Bay tug has no appreciable effect on total VTRA study area average accident potential and reduces its total average oil outflow potential by 0.1%.
- In the restricted analysis performed, and assuming the Neah Bay tug has the capability to save any disabled[3] BPCHPT vessel that it could get to in time, regardless of the situational context, it was shown that the Neah Bay tug could reduce total average VTRA study area accident potential by 0.03% and total average VTRA study area oil outflow potential by 0.75%.

Quantitative results in our study are presented as average point estimates commonly used for the evaluation of alternatives in a decision analysis context. These are derived from uncertain quantities as described in each step of the analysis as described in this report and its technical appendices. As with any risk assessment model, our model too represents an abstraction of reality and its results must be interpreted with care and with awareness of scoping, data limitations and modeling assumptions. In particular, the forecasts of maritime traffic, accident frequencies, and oil outflows in 2025 must be treated with care.

One primary limitation of the VTRA study is that, due to scoping constraints, the results reflect only on a small percentage of the vessel traffic described in the maritime simulation.

[3] Our definition of a disabled BPCHPT vessel here is one that experienced either a steering or propulsion failure.

If risk interventions have an appreciable effect beyond the BPCHPT vessels analyzed in this study, they should also be tested against this larger class of vessels to determine their effects on system wide accident frequencies and oil outflows. For example, a risk intervention that reduces accident frequency and or oil outflow of BP Cherry Point vessels, but results in a larger potential increase of accident frequency and/or oil outflows from the other traffic should not be implemented. Conversely, risk mitigation measures that have little or no impact on the BP Cherry Point vessels accident frequency or oil outflow may in fact significantly reduce risk to other vessels.

As such, a full evaluation of the risk reduction potential of the Neah Bay tug was not within the scope of the VTRA, as the analysis was restricted to BPCHPT vessels in the VTRA geographic scope. A full evaluation of the risk reduction potential of the Neah Bay tug requires (1) inclusion of all non-BP vessel traffic within the VTRA study area in its effectiveness analysis and (2) inclusion of all vessel traffic beyond the boundaries of our VTRA study area (i.e. beyond the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J offshore of Cape Flattery), but both limited to the tug's operating range. Neither was part of the scope of the VTRA study.

TABLE OF CONTENTS

PREFACE....2
PROJECT TEAM MEMBERS....6
EXECUTIVE SUMMARY....7
1. Introduction....19
2. Scope of the Study....21
3. Description of the System....23
3.1. Traffic to BP Cherry Point....23
3.2. Deep Draft Traffic....27
3.3. Ferry Traffic....31
3.4. Small Vessel Traffic....33
3.5. Traffic Rules....35
3.6. Overall Traffic Density....36
3.7. Environmental Factors – Wind, Visibility, and Current....38
4. Model Integration and Data Sources....42
4.1. Interactions....42
4.2. Incidents....44
4.3. Accidents....45
4.4. Oil Outflow....47
4.5. Organizations that Provided Experts....50
4.6. Data Sources Used....50
5. Analysis Results....52
5.1. Explanation of Cases Analyzed....52
5.2. Risk Changes from Adding North Wing....55
5.3. Future Changes in Risk....61
5.4. Evaluation of scope risk interventions....68
6. Conclusions....76
References....83

Sub-Appendix: J.R.W. Merrick, J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn and M. Grabowski (2002). "The Prince William Sound Risk Assessment". *Interfaces*, Vol. 32 (6): pp.25-40.

Sub-Appendix: J.R. van Dorp, J.R.W. Merrick , J.R. Harrald, T.A. Mazzuchi, and M. Grabowski (2001). "A Risk Management procedure for the Washington State Ferries", *Journal of Risk Analysis*, Vol. 21 (1): pp. 127-142.

Sub-Appendix: P. Szwed, J. R. van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). "A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information", *European Journal of Operations Research*, Vol. 169 (1), pp. 157-177.

Sub-Appendix: J.R.W. Merrick, J.R. van Dorp, J.P. Blackford, G.L. Shaw, T.A. Mazzuchi and J.R. Harrald (2003). "A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model", *Reliability Engineering and System Safety*, Vol. 81 (2): pp. 119-132.

TABLE OF FIGURES

Figure 1. A chart of the area discussed in the study. 19
Figure 2. A chart of the geographic scope of the study. 23
Figure 3. A satellite picture of the area around BP Cherry Point. 24
Figure 4. A satellite picture of the north and south wing of the dock at BP Cherry Point. ...24
Figure 5. Crude oil tankers calling at BP Cherry Point per month. 25
Figure 6. Petroleum product tankers calling at BP Cherry Point per month. 26
Figure 7. Representative Routes Used by Tankers Calling at BP Cherry Point. 26
Figure 8. The number of vessel transits per month since 1992. 28
Figure 9. The number of tug transits per month since 1996. 28
Figure 10. Representative Routes Used by Bulk Carriers. 29
Figure 11. Representative Routes Used by Chemical Carriers. 29
Figure 12. Representative Routes Used by Container Vessels. 30
Figure 13. Representative Routes Used by all Oil Tankers. 30
Figure 14. Representative Routes Used by Tug Tow Barges. 31
Figure 15. Representative Routes Used by Vehicle Carriers 31
Figure 16. The number of ferry transits per month since 1992. 32
Figure 17. Representative Routes Used by Ferries 32
Figure 18. Fishing areas and representative routes used by fishing vessels. 33
Figure 19. Representative Routes Used by USCG Registered Yacht Regattas. 34
Figure 20. Routes of whale watching movements record by Sound Watch. 34
Figure 21. The density of all traffic across the region. 37
Figure 22. The density of BP Cherry Point traffic across the region. 38
Figure 23. A map displaying the wind stations used the study. 40
Figure 24. A map defining the visibility locations used in the study. 40
Figure 25. The total number of days with poor visibility by month and location. 41
Figure 26. A map displaying the current stations used the study. 41
Figure 27. The chain of events that lead to an oil spill and the modeling techniques used for each step. 42
Figure 28. A geographic profile of the number of interactions 43

TABLE OF FIGURES (continued)

Figure 29. An example of a question used to assess the variation in accident probabilities between the different possible interaction scenarios. 45
Figure 30. A geographic profile of accident frequency results for a 2005 analysis with the north wing dock in operation. 47
Figure 31. A geographic profile of average oil outflow results for a 2005 analysis with the north wing dock in operation. 49
Figure 32. The accident potential by accident type for cases A, B, and C. 56
Figure 33. The oil outflow potential by accident type for cases A, B, and C. 56
Figure 34. Geographic profiles of accident potential for cases A, B, and C. 59
Figure 35. Geographic profiles of oil outflow potential for cases A, B, and C. 60
Figure 36. Accident potential in 2005 and 2025 with and without the north wing. 63
Figure 37. Oil Outflow potential in 2005 and 2025 with and without the north wing. 63
Figure 38. Geographic profiles of accident potential for the low, medium, and high traffic scenarios for 2025 both with (left) and without (right) the north wing. 65
Figure 39. Geographic profiles of oil outflow potential for the low, medium, and high traffic scenarios for 2025 both with (left) and without (right) the north wing. 66
Figure 40. The accident potential by accident type for each intervention in 2005. 69
Figure 41. The oil outflow potential by accident type for each intervention in 2005. 69
Figure 42. The accident potential by accident type for each intervention in 2025. 70
Figure 43. The oil outflow potential by accident type for each intervention in 2025. 70
Figure 44. Geographic profiles of accident potential with and without the Neah Bay tug and extended escorts. 74
Figure 45. Geographic profiles of oil outflow potential with and without the Neah Bay tug and extended escorts. 75

TABLE OF TABLES

Table 1. A list of all cases used in the analysis and the factors varied amongst them. 53
Table 2. The cases used to consider changes in risk from adding the north wing. 55
Table 3. The cases used to consider future changes in risk. 61
Table 4. The cases used to consider changes in risk from three risk interventions. 68

1. Introduction

The purpose of the VTRA study is to examine the changes in vessel traffic risk potentially resulting from the addition of the north-wing of the dock at BP's Cherry Point Refinery (see Figure 1). This risk is evaluated in terms of the risk of accidents involving tankers, articulated tug barges (ATBs) and integrated tug barges (ITBs) calling at BP Cherry Point and in terms of the potential for oil outflow from such accidents. The accidents included in the analysis are collisions with other vessels, groundings preceded by propulsion or steering failures (so the tanker drifts aground), groundings preceded by navigational failures or human errors (so the tanker goes aground under power), and allisions (collisions with the dock or other fixed objects). We will evaluate the changes in risk during our base case year (2005) were the dock to be used or not used. We will also evaluate the changes in risk since prior to the dock being constructed (specifically in the year 2000) and the changes in risk that could result because of future changes in traffic levels (evaluated in 2025). This will give an elaborate evaluation of the effect of the dock thus far and in to the future.

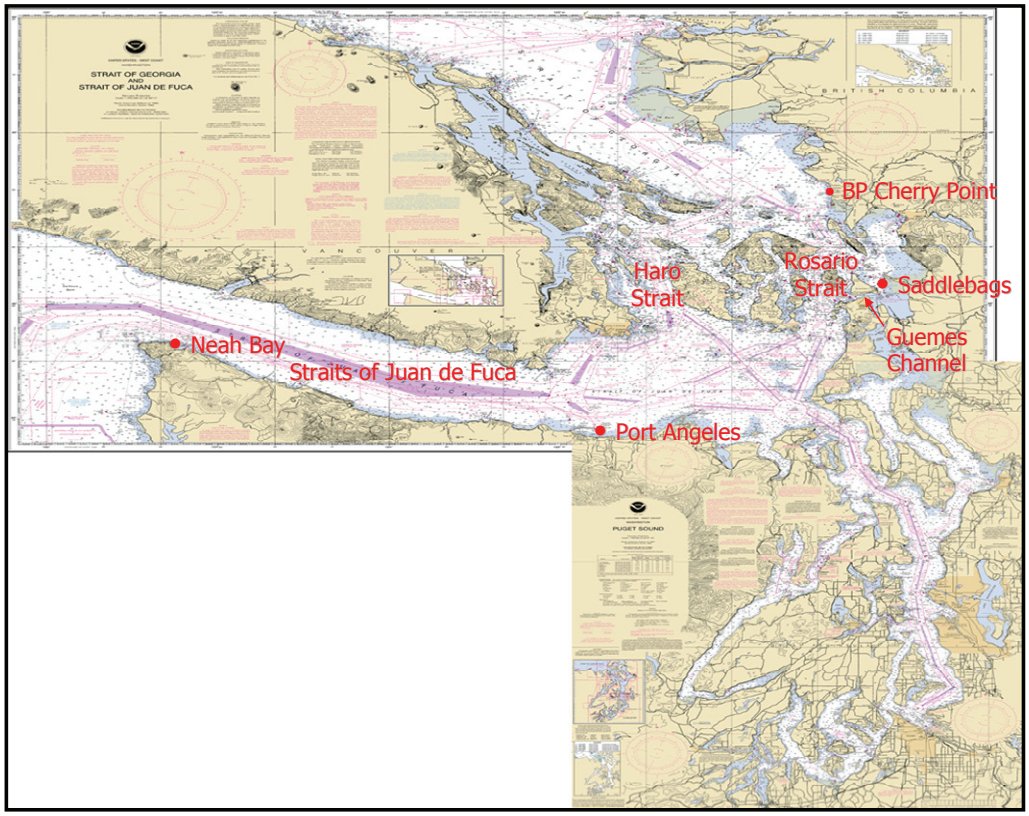


Figure 1. A chart of the area discussed in the study.

Three other changes to the risk of oil spills will be evaluated. Until 2005, tankers wanting to transit between BP Cherry Point or the Ferndale refinery and Anacortes would travel through an area known as the Saddlebags (Figure 1). We will evaluate the change in risk if the tanker were to not use Saddlebags, but instead to travel through Rosario Strait and then Guemes Channel. The other two changes involve alternatives to the current escorting system. Currently, tankers over 40,000 dead weight tons and carrying either crude oil or petroleum products must be escorted by a specialized tug from a point just after they pass by Port Angeles to the refinery or the anchorage they plan to use. They must then be escorted on any transits between anchorages and refineries until just before they reach Port Angeles on their way out through the Straits of Juan de Fuca. In addition, there is also an escort tug on 24 hour standby at Neah Bay near the entrance to the Straits of Juan de Fuca to assist any vessel within its range to assist. Two changes to this set up will be evaluated. Firstly, extending the escorts passed Port Angeles up to the end of the Straits of Juan de Fuca. Secondly, we will test the effect of removing the Neah Bay Tug to allow an evaluation of its effectiveness.

Each of the changes to be evaluated cause a change in the traffic patterns and these cause a change in the level of exposure to risk; the changes are dynamic, thus they must be evaluated using a dynamic simulation of the vessel traffic in the region. This simulation model is then integrated with models for the potential of incidents, such as propulsion failures, steering failures, navigational failures, and human errors, and with models for the potential for collisions, groundings, and allisions resulting from these incidents. A final layer of modeling takes the accident scenarios and assesses the potential for oil outflow. The form of results in this report include the aggregated potential for accidents, aggregated potential for oil outflow, and detailed maps showing the spread of each of these risk measures across the area, called geographic profiles.

In this report, we first provide the scope of the study that defines what is analyzed and what is not. We then provide a description of the system, the vessels that transit in it, the rules they follow, and the environmental factors that they encounter. The overall structure of the model used is then discussed and each of the individual pieces described, including the data

that was used and the organizations that provided experts. The results are then provided and the effect of changes to the system explained. We end with a summary of our findings.

2. Scope of the Study

The scope of the study is defined by the following items:

- The study will evaluate the routes used by marine vessels to carry crude oil and petroleum products between the Cherry Point Refinery and:
    - the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J offshore of Cape Flattery, and
    - the Puget Sound.
- The study will evaluate the incremental risk of (1) an accident (collision, grounding or other scenario) involving a tank vessel, (2) resulting in a discharge of crude oil or petroleum products, (3) associated with reasonably foreseeable increases in vessel traffic through calendar year 2025 to and from both wings of the Cherry Point Oil Spill Risk Assessment due to increased vessel traffic calling at Cherry Point Dock Refinery Pier, (4) as compared with the baseline traffic that the pre-North Wing pier could accommodate.
- In evaluating these risks the study will model all vessel traffic (not just vessels carrying crude oil and petroleum products) and reasonably foreseeable increases and decreases in vessel traffic along the entire pathway followed by vessels between;
    - Cherry Point and the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J, and
    - Cherry Point and the Puget Sound,

  including but not limited to vessels calling in British Columbia, and vessels calling at the Cherry Point Refinery Pier, Conoco-Phillips, Intalco and reasonably foreseeable future marine terminal facilities in the Cherry Point area, including the proposed Gateway facility.
- The study will account for non-VTS reporting vessels (fishing vessels and recreation traffic) using methods developed in the modeling of traffic in San Francisco Bay as far as data or expert judgment is available to model this traffic in a reasonable manner.

- The study will evaluate low, medium and high traffic scenarios.
- The study will consider the impact of human and organizational error on the likelihood of accidents and the effectiveness of risk reduction interventions.
- The study will not evaluate vessel traffic risks at locations other than those routes used by vessels traveling to and from Cherry Point.
- The study will cover risks associated with the Haro Strait and Huckleberry-Saddlebag approaches to and from Cherry Point.
- The study will include identification and evaluation of potential vessel traffic management protocols that would reduce the risk of an accident and that can be instituted consistent with existing law. At a minimum, the vessel traffic management protocols studied will include: (1) use of Rosario Strait and Guemes Channel instead of the Huckleberry-Saddlebag traverse; (2) stationing a year-round prevention and response tug (of the kind currently stationed in Prince William Sound) in Neah Bay, Washington; (3) a single tug escort requirement for the Western reaches of Juan de Fuca Strait with hand-off between prevention and response tugs stationed in Neah Bay and Port Angeles; and (4) any additional vessel traffic management protocols or other mitigation measures selected for analysis during the scoping stage of the EIS.
- The study will include an impact analysis that will describe the outcomes of an accident as described by the location and size of oil outflows, but will stop short of examining the fate and effects of an oil spill.
- The study will use, but not be constrained by, the results of prior studies that examined various aspects of maritime risk in Washington State waters. The study will be directed by Jack Harrald and Martha Grabowski.

Figure 2 shows the geographic area included in this scope. The study will only evaluate the risk of accidents involving crude oil or petroleum product carrying vessels that call at BP Cherry Point at some point in their transit in to this geographic area. Thus it will not include collisions between two vessels that do not call at BP Cherry Point and it will not include groundings or allisions of non-BP Cherry Point vessels. However, it will include collisions between BP Cherry Point vessels and any other vessel, thus the model must include as much

of the other traffic in the region as it is feasible to model, including small vessels for which transit data is more difficult to obtain.

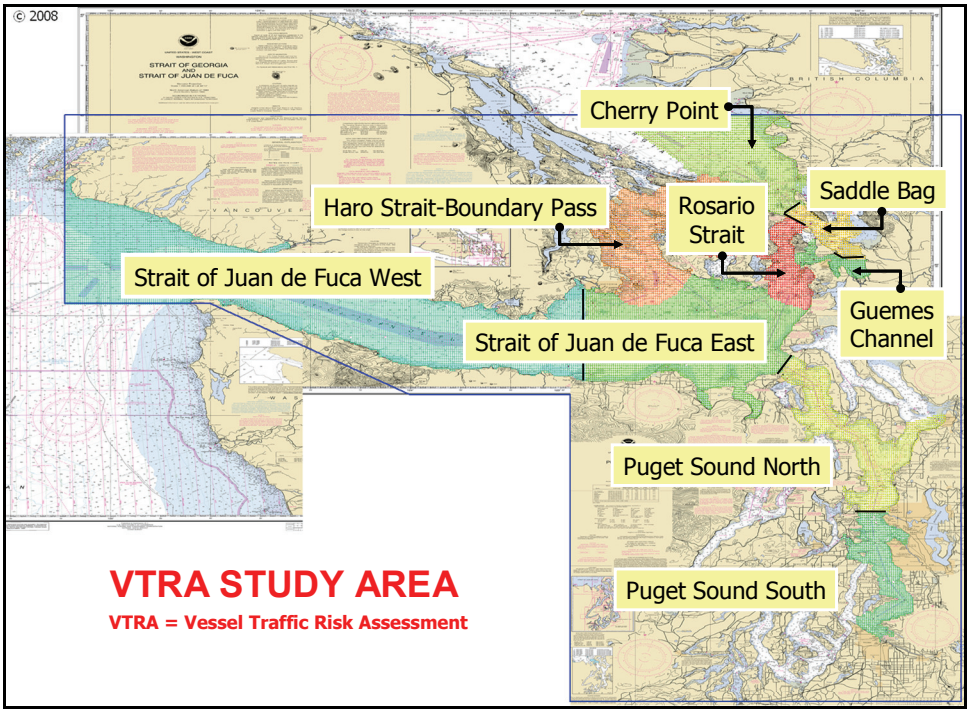


Figure 2. A chart of the geographic scope of the study.

3. Description of the System

3.1. Traffic to BP Cherry Point

Figure 3 shows a satellite map of the area around BP's Cherry Point Refinery. To the far left is Vancouver Island; the islands at the bottom are the San Juan Islands. Canada is at the top of the picture, specifically the city of Vancouver and the James River. To the lower right is Washington State. BP's Cherry Point Refinery is located at Cherry Point, which is near Bellingham.

Figure 3. A satellite picture of the area around BP Cherry Point.

Figure 4 shows a satellite image of the dock at BP's Cherry Point Refinery. The dock lower in the image is the south wing which is now used mostly for tankers carrying crude oil being delivered to the refinery, but can be used for petroleum product carrying vessels taking refined products away from the refinery. The south wing was constructed at the same time as the refinery, being finished in September 1971. The dock higher in the image is the north wing that was constructed by July of 2001 and went in to service in September of 2001. The north wing is used exclusively for vessels carrying refined petroleum product away from the refinery.

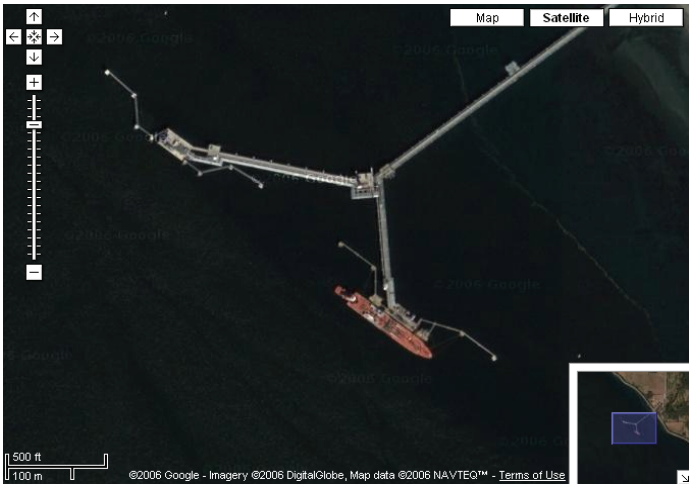


Figure 4. A satellite picture of the north and south wing of the dock at BP Cherry Point.

Figure 5 shows the number of crude oil tankers that called at BP Cherry Point each month from March 1997 to February 2008. The red line shows the point in time that BP merged with ARCO in April 2000. After that point there is a slow increase from an average of 9.2 transits per month to an average of 11.5 transits per month. It is noteworthy that this higher number of transits is actually reached before the north wing went in to operation.

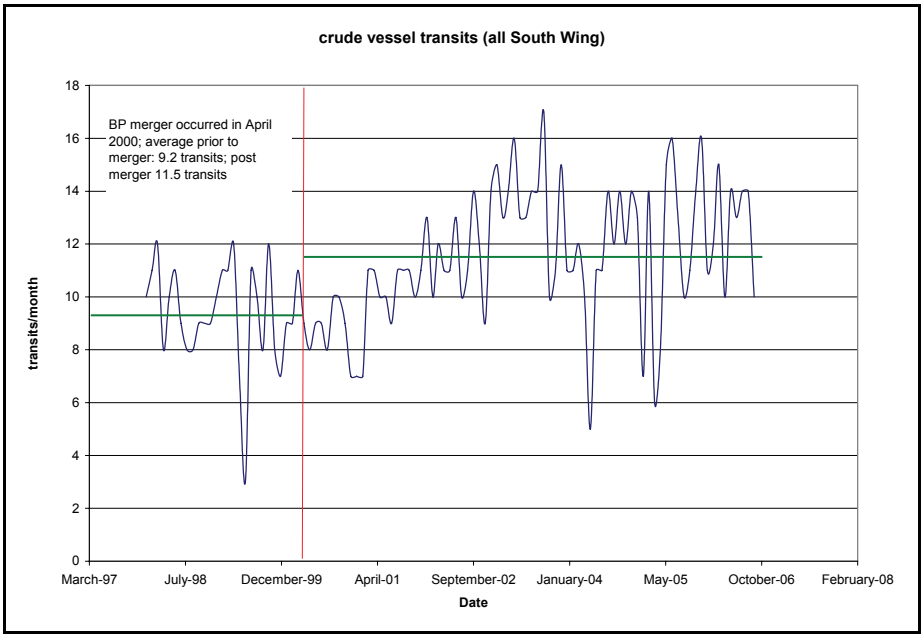


Figure 5. Crude oil tankers calling at BP Cherry Point per month.

Figure 6 shows the number of petroleum product carriers calling at BP Cherry Point from March 1997 to February 2008. Until September 2001, all product carriers had to use the south wing, but after that point they use the north wing if it is available and the south wing if the north wing is not available and no crude tanker is using the south wing. Prior to the use of the north wing, there was an average of 14 product carriers per month. With the north wing in place, an average of 12 product carriers per month used the north wing and 2 per month used the south wing. There appears to be a slight increase in 2006. This will not be reflected in our base case analysis (2005), but such trends will be considered in our analysis of future scenarios.

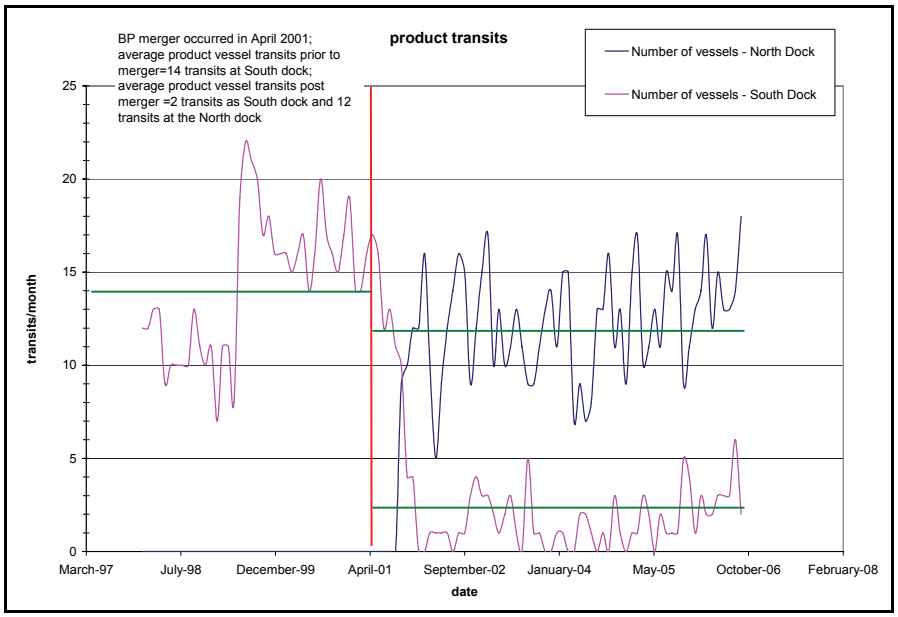


Figure 6. Petroleum product tankers calling at BP Cherry Point per month.

The routes used by tankers, ATBs, and ITBs that call at BP Cherry Point are shown in Figure 7. As can be seen, tankers transit in and out of the Straits of Juan de Fuca, south to the Puget Sound (specifically to Tacoma and Manchester), north to Vancouver, and locally to anchorages at Cherry Point, Vendovi Island, Anacortes, and Port Angeles and the refineries at Ferndale and Anacortes.

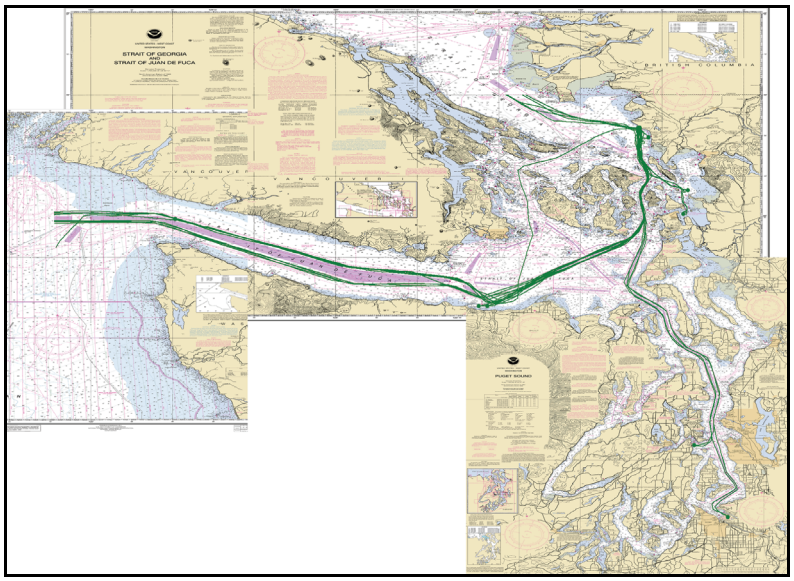


Figure 7. Representative Routes Used by Tankers Calling at BP Cherry Point.

3.2. Deep Draft Traffic

There are many other types of vessels that transit the waterways in this region. Larger vessels must report in to the Coast Guard Vessel Traffic Service (VTS). The specific requirements for a vessel to report in are:

(a) Every power-driven vessel of 40 meters (approximately 131 feet) or more in length, while navigating;

(b) Every commercial towing vessel of 8 meters (approximately 26 feet) or more in length, while navigating;

(c) Every vessel certificated to carry 50 or more passengers for hire, when engaged in trade.

The VTS records the transit and also monitors the movement of vessels on screens in their operating center. The USCG VTS in Seattle receives radar signals from 12 strategically located radar sites throughout the VTSPS area. Radar provides approximately 2,900 square miles of coverage including the Strait of Juan de Fuca, Rosario Strait, Admiralty Inlet, and Puget Sound south to Commencement Bay.

Additionally, close circuit TV provides coverage of various critical waterways. Since 1979, the U.S. Coast Guard has worked cooperatively with the Canadian Coast Guard in managing vessel traffic in adjacent waters through the Cooperative Vessel Traffic Service Puget Sound (CVTS). Two Canadian Vessel Traffic Centers work hand in hand with Puget Sound Vessel Traffic Service. The area west of the Strait of Juan De Fuca is managed by Tofino Vessel Traffic. North of the Strait of Juan De Fuca, through Haro Strait, to Vancouver Harbor, BC is managed by Victoria Vessel Traffic Service. The three Vessel Traffic Centers communicate via a computer link and dedicated telephone lines to advise each other of vessels passing between their respective zones.

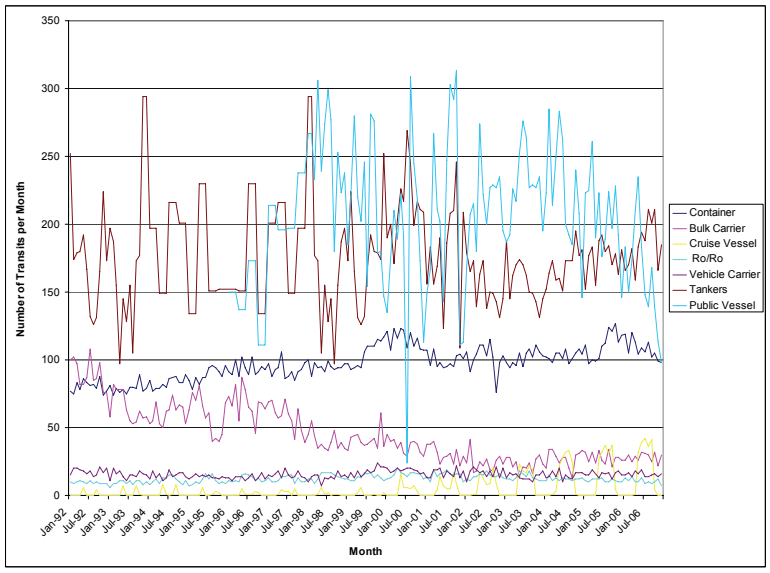


Figure 8. The number of vessel transits per month since 1992.

The number of transits per month for various types of vessels in the region are shown in Figures 8 and 9. Figure 8 shows bulk carriers, containers, cruise vessels, public vessels (navy and coast guard), roll-on/roll-off vessels, tankers, and vehicle carriers. Figure 9 shows tug tow barge transits separately as they are an order of magnitude higher than other vessels. Various trends are seen here, including a decrease in the number of bulk carriers, an increase in the number of container vessels, and a seasonal increase in the number of cruise vessels.

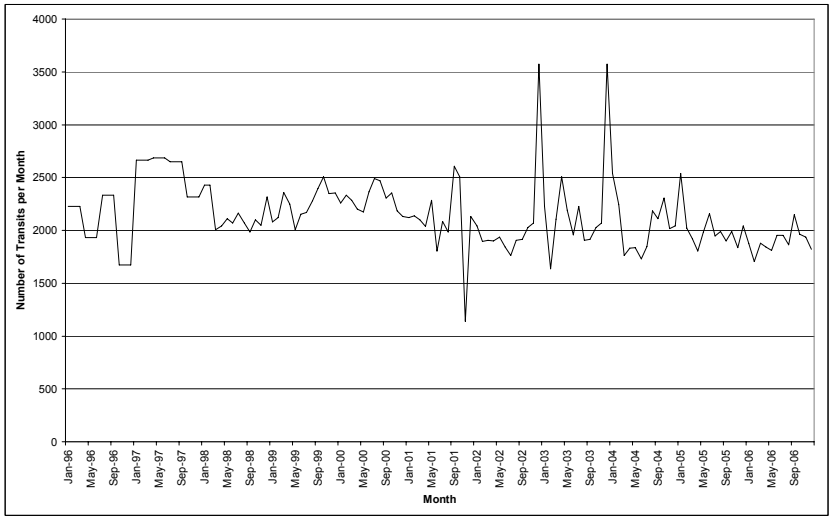


Figure 9. The number of tug transits per month since 1996.

The VTS centers also record the tracks of the vessels that report in. Figure 7, showing the routes of oil tankers, was generated by cleaning radar blips and other recording errors from these tracks for oil tanker transits and choosing representative tracks for each departure point and destination. Figure 10 through 15 show similarly generated routes for the other types of vessels that call in to the VTS.

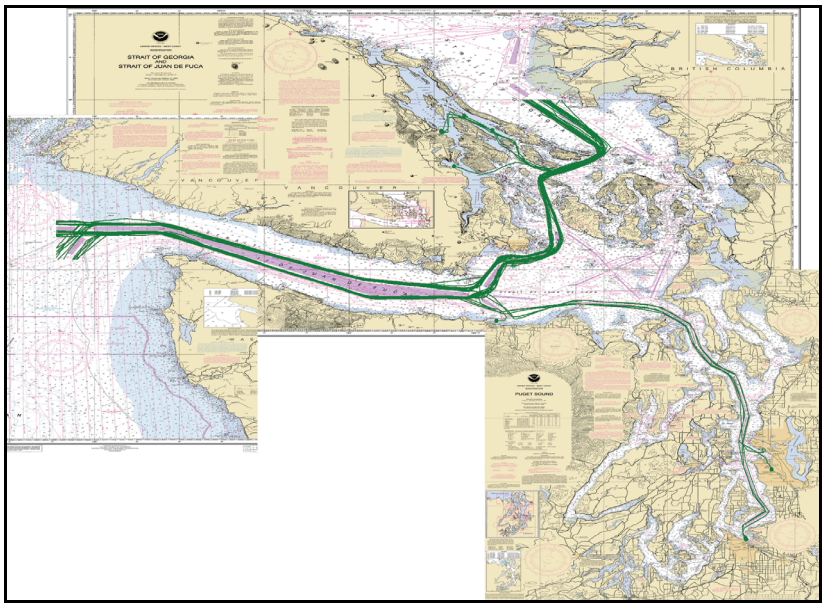


Figure 10. Representative Routes Used by Bulk Carriers.

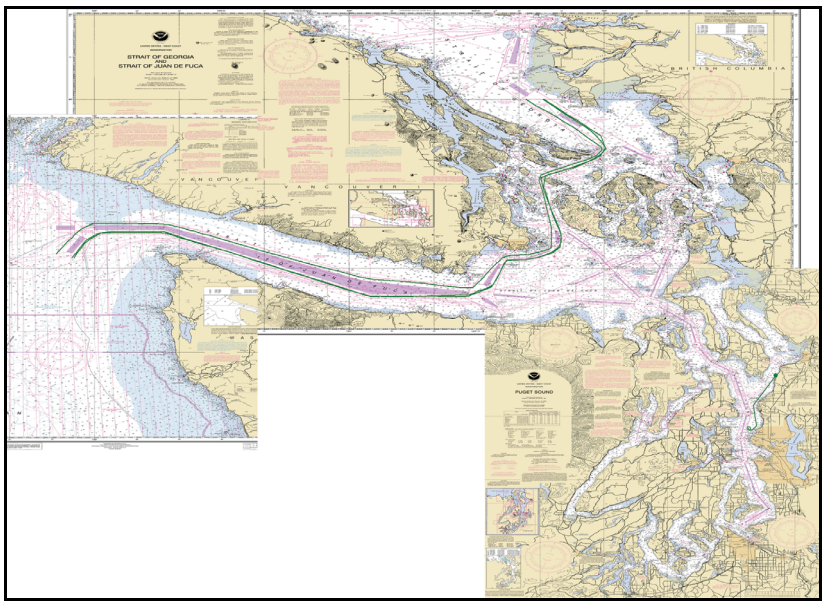


Figure 11. Representative Routes Used by Chemical Carriers.

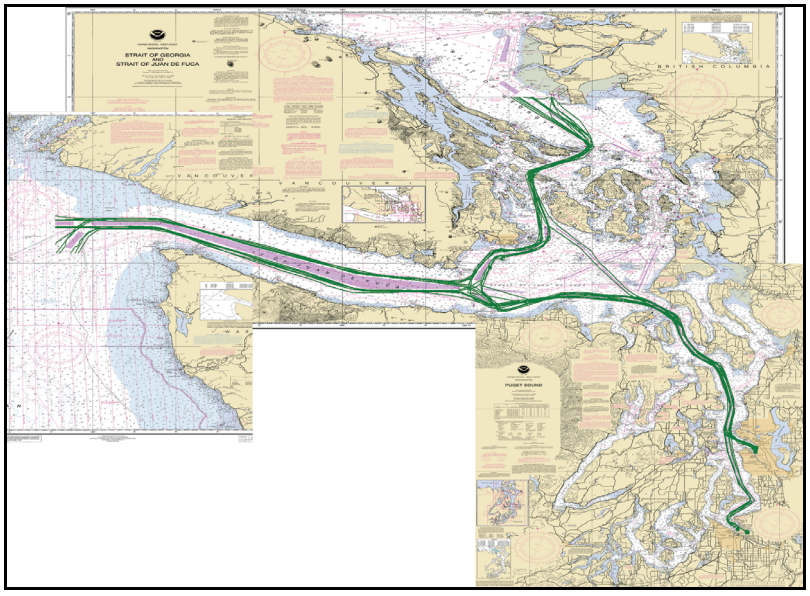


Figure 12. Representative Routes Used by Container Vessels.

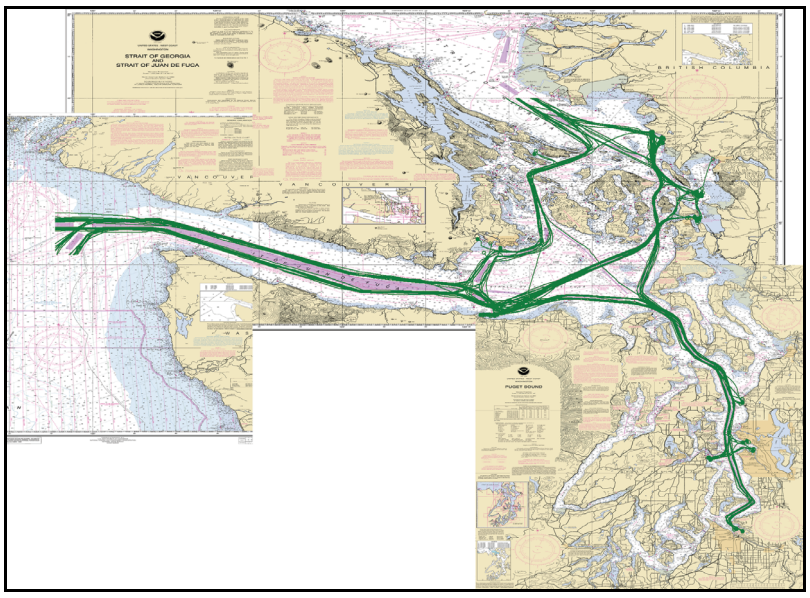


Figure 13. Representative Routes Used by all Oil Tankers.

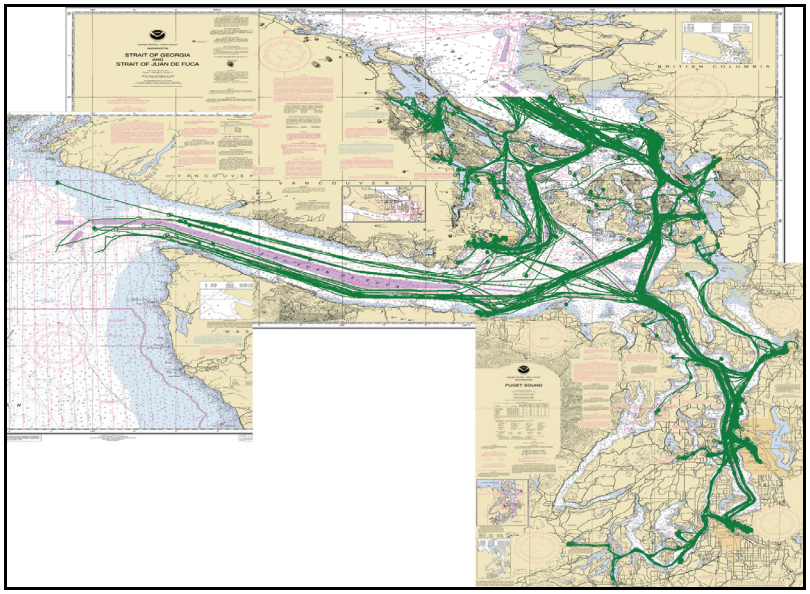


Figure 14. Representative Routes Used by Tug Tow Barges.

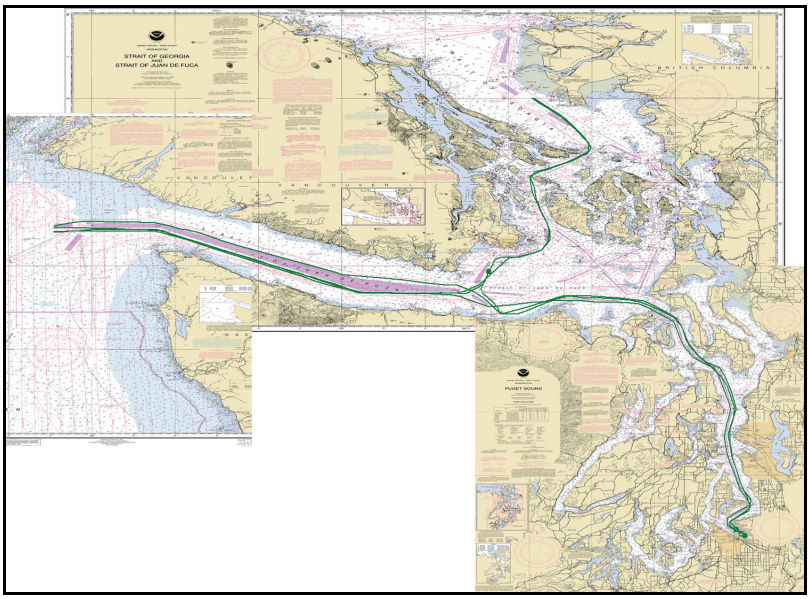


Figure 15. Representative Routes Used by Vehicle Carriers.

3.3. Ferry Traffic

The vessel type with the largest numbers of transits in this area is ferries. Ferries also call in to the VTS. The ferries in this area are operated by the Washington State Ferries (the largest

ferry service in the United States), the Victoria Clipper (between Victoria and Seattle), and various smaller Canadian operators. The total number of ferry transits per month since 1996 is shown in Figure 16, varying somewhere around 15000 transits per month. This is by far the highest number of transits per month of any VTS reporting traffic, but it should be realized that most of the routes in Figure 17 for ferries are much shorter than most of the routes for other VTS reporting traffic in Figures 10 through 15. Representative ferry routes are shown in Figure 17.

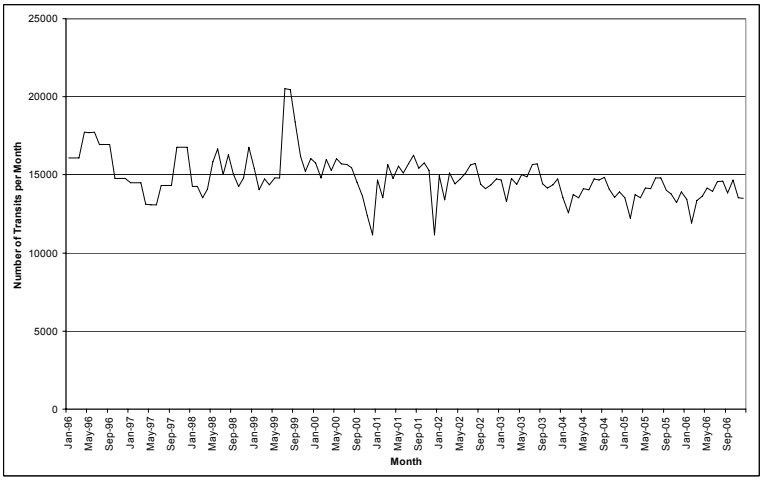


Figure 16. The number of ferry transits per month since 1992.

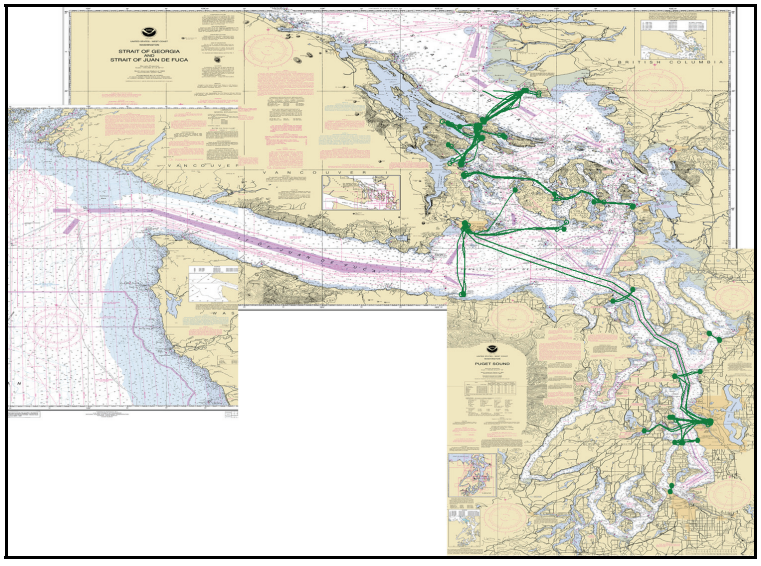


Figure 17. Representative Routes Used by Ferries.

3.4. Small Vessel Traffic

There are many other types of smaller vessels that use these waters. While data on these smaller vessels is harder to obtain, there are several groups that are recorded by various different entities.

Commercial and tribal fishing is regulated and recorded by various organizations. Canadian, US, and tribal fisheries managers provided information about the areas in which fishing occurs, the types of fishing and vessels, and the number of vessels that transit from each fishing port. Larger fishing vessels and fishing factory vessels also must report to the VTS. Figure 18 shows the sum of this information, with fishing areas shown in various colors depending on the type of fishing performed in each area and representative routes for transit to and from these areas and in and out of the region in green.

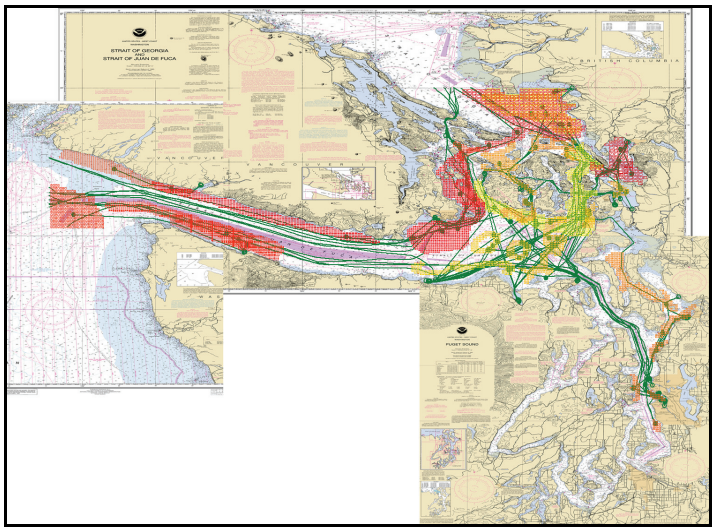


Figure 18. Fishing areas and representative routes used by fishing vessels.

Two other types of small vessel traffic for which data is recorded are regattas and whale watching. Regattas run by various yachting organizations in the area must be registered with the Coast Guard. This includes the time of the event, the route taken, and the expected number of vessels involved. Figure 19 shows the routes of regattas that took place during 2005.

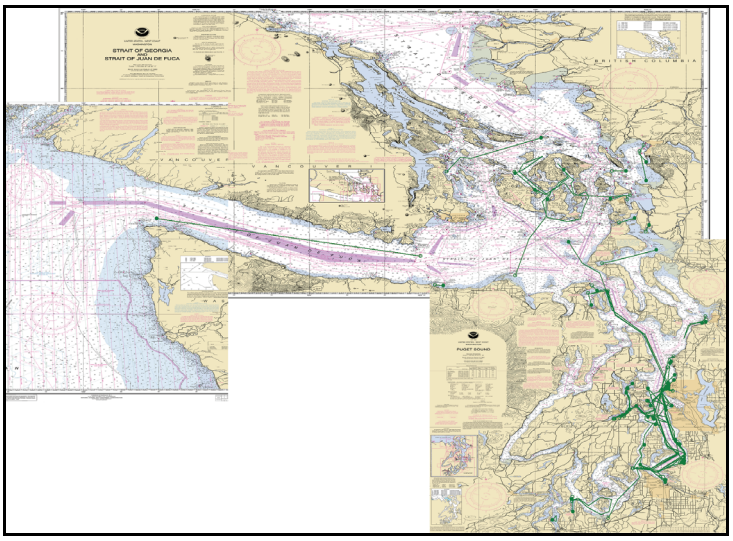


Figure 19. Representative Routes Used by USCG Registered Yacht Regattas.

Whale watching vessels follow the pods of killer whales that live in the region, allowing tourists and researchers to observe the whales. However, there are regulations that restrict these vessels from harassing the whales. Sound Watch is a non-profit organization that records the movements of whales, the number of vessels that are observing them, and any violations of the regulations. Figure 20 shows the movements of the whales and the whale watching vessels that followed them during 2005.

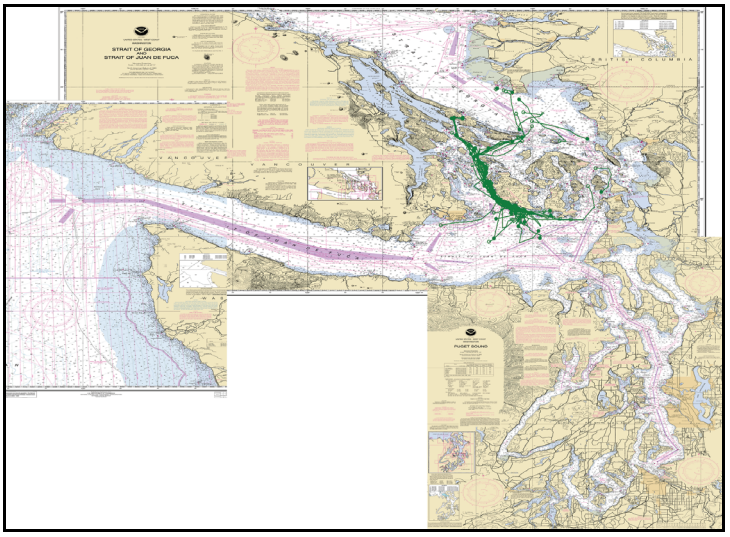


Figure 20. Routes of whale watching movements record by Sound Watch.

3.5. Traffic Rules

Reporting to the VTS is not the only requirement for vessels transiting the region. There are restrictions on where a vessel may transit, called traffic separation schemes, restrictions on speed, one-way zones, specified anchorage areas, escorting rules for oil tankers, and pilotage requirements.

Each of the charts showing representative routes also includes pink areas along certain waterways. These depict traffic separation schemes for vessels over 20 meters in length, or regions in which vessels should not travel, keep vessels transiting in opposite directions separated from each other. Areas of convergence of traffic are also depicted and caution is required in these areas. Vessels crossing the separation scheme must do so as close to a right angle as possible. No fishing or anchoring is allowed in the separation scheme area and vessels smaller than 20 meters and sailing vessels are not allowed to impede vessels in the scheme. Vessels not participating in the scheme or crossing the scheme must stay away from the areas depicted. There are also speed restrictions in various areas. In Elliot Bay, vessels are restricted to 5 knots; in Rosario Strait, deep draft vessels are restricted to 12 knots; and in the Saddlebags and Guemes Channel area, vessels are restricted to 6 knots.

The US Coast Guard has also designated a special navigation zone in Rosario Strait. This means that a vessel longer than 100 meters or more than 40,000 DWTs cannot meet, overtake, or cross within 2,000 yards of another vessel that meets these size limits within Rosario Strait. Also towing vessels cannot impede the passage of vessels more than 40,000 DWTs in this area. A similar designation is made in Haro Strait, but just applies to the smaller area at Turn Point, not the whole of Haro Strait. Guemes Channel and the area around Saddlebags and Vendovi Island are also areas where it is difficult for two vessels over 40,000 DWTs to maneuver around each other. While the area is not specifically designated as a special navigation zone, the Puget Sound VTS operates the area as if it were to avoid dangerous situations. Thus the Rosario Strait rules are essentially extended to include the waters east of Rosario Strait in practice.

Vessels requiring anchorage must get approval from the relevant VTS. There are many designated anchorage areas in the region, but four are specifically relevant to this study. Firstly, there is a large general anchorage area at Port Angeles for all deep draft vessels. There are then three anchorages with more limited capacity. Cherry Point anchorage is a short-term anchorage for tankers waiting to dock at Cherry Point or Ferndale. Anchorages around Vendovi Island can be used for longer; there are three designated anchorages for deep draft vessels and two for tugs. Finally, there are four anchorages at Anacortes, with one specifically designated for lightering operations.

The Puget Sound Pilots provide pilotage service for all U.S. ports and places East of 123 degrees 24' W longitude in the Strait of Juan de Fuca, including Puget Sound and adjacent inland waters. Pilotage is compulsory for all vessels except those under enrollment or engaged exclusively in the coasting trade on the west coast of the continental United States (including Alaska) and/or British Columbia. The pilot station is at Port Angeles, meaning that vessels picking up or dropping off a pilot will pass by Port Angeles at a slow speed, allowing a pilot boat to pull aside and the pilot to board or disembark on a pilot ladder. The pilots will navigate vessels to the dock and then back to the Port Angeles on their outbound trip.

Vessels transporting crude oil or petroleum products that are over 40,000 DWTs are required to have a tug escort beyond a point east of a line between Discovery Island and New Dungeness Light.

3.6. Overall Traffic Density

The transit counts and route maps give a general idea of traffic levels in the region, but as mentioned previously ferries have lots of transits on mostly short routes, while container vessels and bulk carriers have fewer transits, but usually on longer routes. Thus to get a true picture of the level of traffic on the water, we need to count the time that each vessel type spends on the water and where it goes. The following maps depict the time on the water with a colored legend and each colored cell is a quarter nautical mile by a quarter nautical miles. Figure 21 shows the generated density of all the traffic discussed thus far. The red

areas have higher traffic levels and they include the lanes within the traffic separation schemes, the ferry lanes, and the major fishing areas. There are also some gray and black cells that have the highest levels of traffic within Elliot Bay. However, it is not only important to understand the overall levels of traffic, but it is also of interest to understand what types of traffic make up this overall pattern.

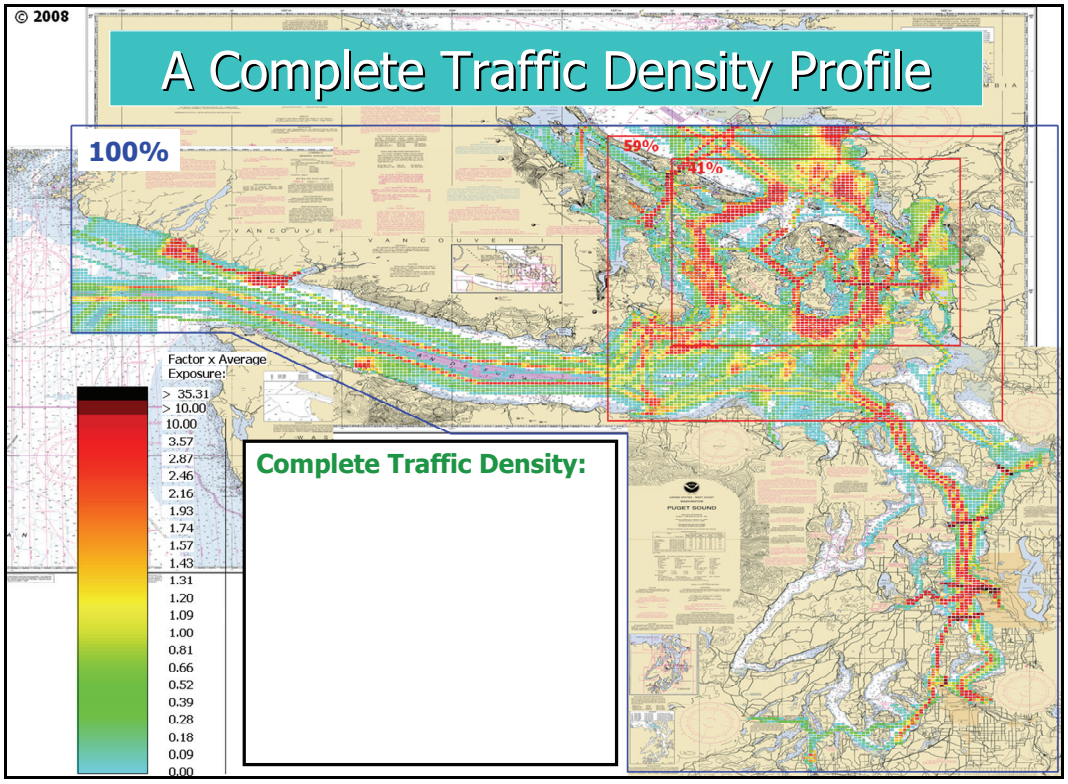


Figure 21. The density of all traffic across the region.

Let us concentrate first on the focus of this study, namely tankers, ATBs, and ITBs calling at BP Cherry Point at some point in their movements within the study area. Figure 22 shows the generated traffic density plot for BP Cherry Point traffic using the same legend as Figure 21 for all traffic. This allows us to see how much of the overall traffic picture is made up of BP Cherry Point traffic. Obviously there are specific areas that BP Cherry Point vessels transit and areas where they will not or cannot. However, of particular interest is that BP Cherry Point traffic only makes up 1.1% of the total time that vessels spend on the water in the study area.

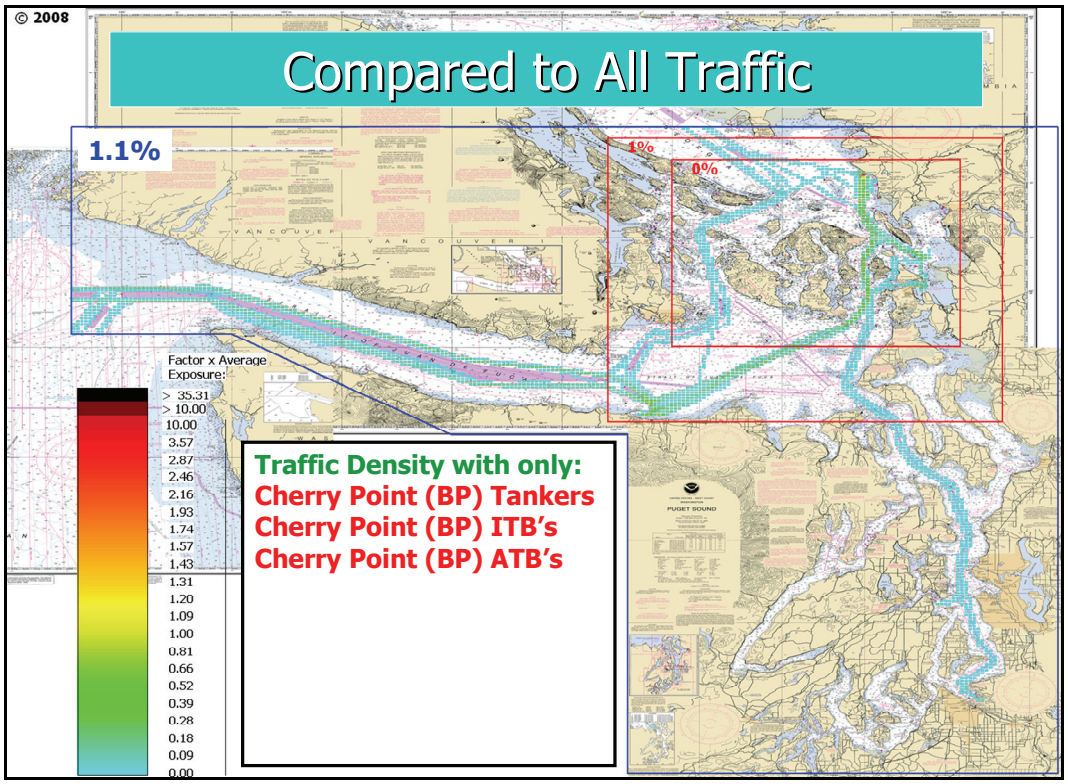


Figure 22. The density of BP Cherry Point traffic across the region.

We can generate similar statistics for other vessel types. Ferries account for 18% of the total transit time on the water even though they account for 50-75% of the transits recorded by the various VTS stations. Tug, towing vessels, and barges account for 17.1% of the total transit time on the water. Small vessel traffic, specifically commercial and tribal fishing, regattas, and whale watching vessels, make up 44.1% of the total transit time on the water. Naval, coast guard, service and supply vessels account for 4.7% of the total transit time on the water. And finally, all oil tankers, ATBs, and ITBs, not just those calling at BP Cherry Point, account for 2.6% of the total transit time on the water, thus BP Cherry Point traffic is 41% of the total for all oil tankers, ATBs, and ITBs.

3.7. Environmental Factors – Wind, Visibility, and Current

The National Climatic Data Center allows one to download hourly weather observations for the VTRA study area. Figure 23 displays seven weather stations for which we have obtained hourly wind speed and direction data based for the year 2005 on their availability and quality

as well being able to map them reasonable to the locations identified in Figure 2. The length of the "wind fans" in Figure 23 represents the different wind speeds across these weather stations. As can be observed also from the wind fans in Figure 23, winds tend to be at higher levels at the entrance of the West Strait of Juan de Fuca and further inward than the other locations.

Hourly land visibility data for 2005 was available from the various airports within the study area and has been obtained from the National Climatic Data Center as well. Unfortunately, no electronic data is available for a sea fog phenomenon. Sea fog occurs on the water even with good land visibility. Conditions that determine that are dew point temperature and water temperature as well as wind speeds being below a certain level. A sea fog visibility model using these parameters as input is described in Sanderson (1982). Using the land visibility data, the Sanderson (1982) model and combining it with hourly dew point, water temperature and wind data, information from the 2006 edition of the US Coast Pilot and expert judgment, we have been able to construct hourly visibility conditions for the visibility locations in Figure 24. Figure 25 summarizes the percentage of time bad visibility occurs for these locations by month. The higher levels in the Buoy J area, West Strait and East Strait of Juan de Fuca for the months June, July, August are primarily due to a sea/channel fog phenomenon. The higher levels for the other locations towards the end of the year are primarily representative of a land fog phenomenon.

Current tables were constructed for the year 2005 from the WXTIDE 32 software and cross-checked against those available from the National Oceanic and Atmospheric Administration tides and currents website. A harmonic behavior was modeled in between the max ebb, max flood and slack times of these current tables to evaluate current speeds for these current stations at every minute. Information regarding current directions from these two data sources was integrated and cross checked with those available in the MAPTECH software. Figure 26 displays the available max ebb and max flood directions for 130 current stations within the study area. Please observe from Figure 25 that current strengths vary from one area to the other over the different stations.

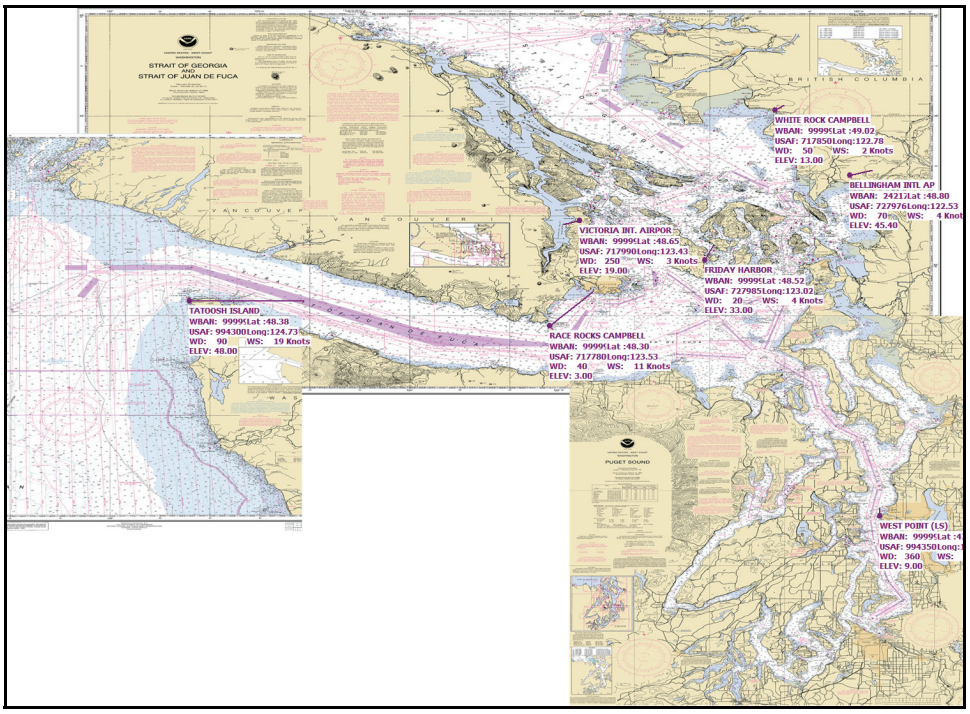


Figure 23. A map displaying the wind stations used the study.

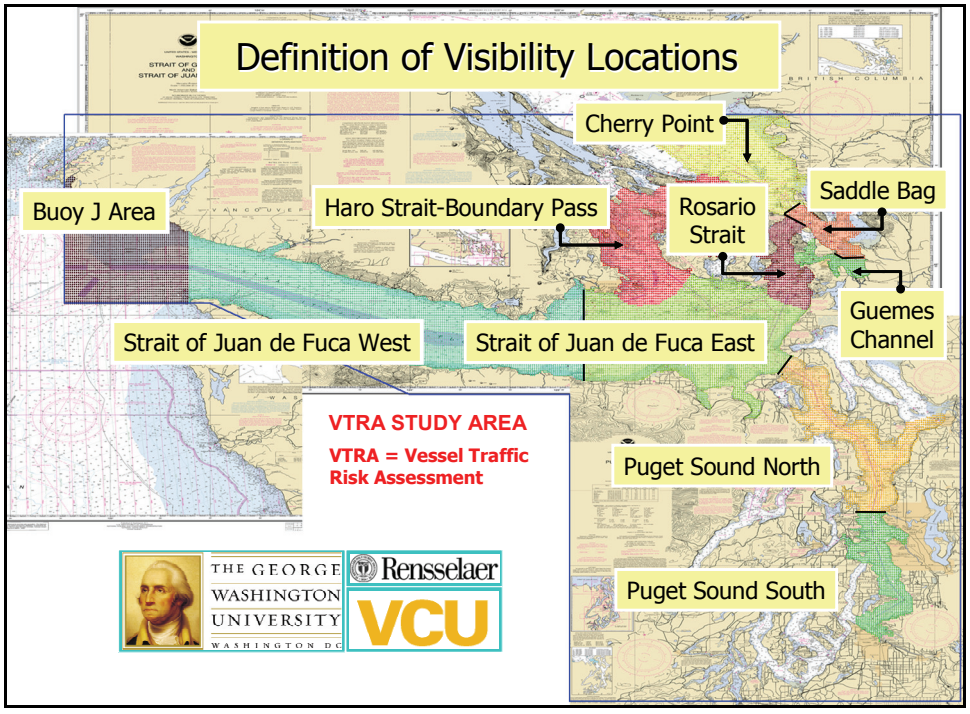


Figure 24. A map defining the visibility locations used in the study.

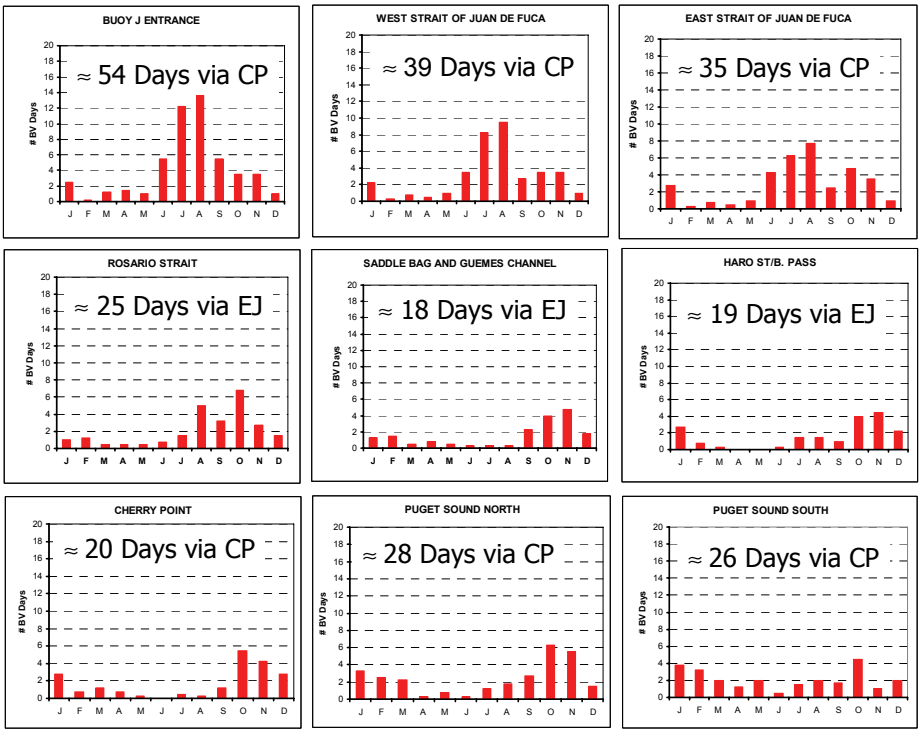


Figure 25. The total number of days with poor visibility by month and location.

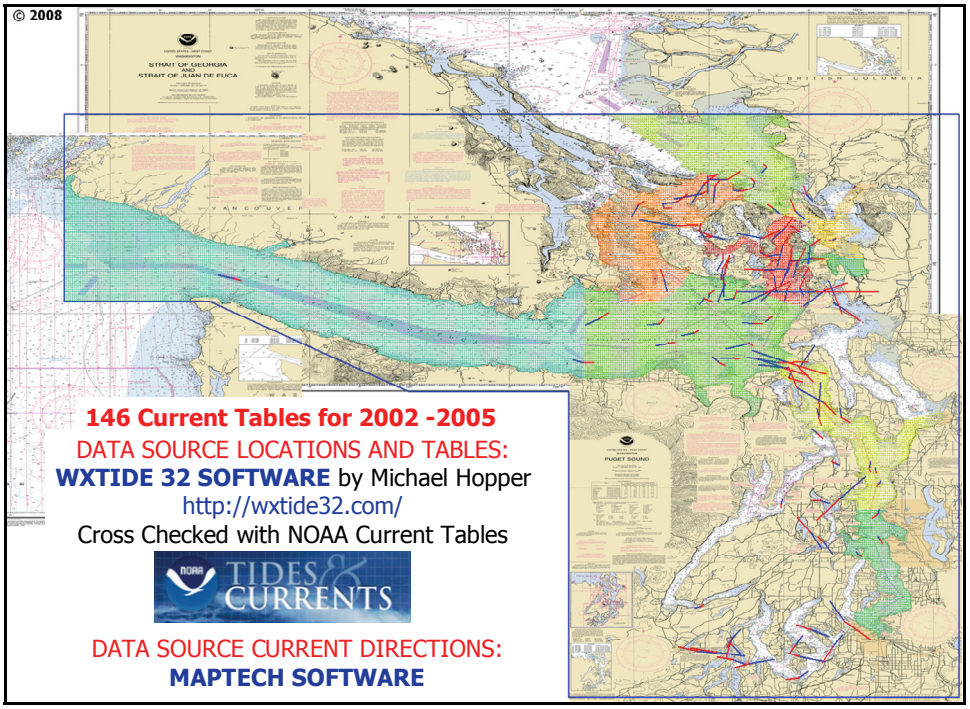


Figure 26. A map displaying the current stations used the study.

4. Model Integration and Data Sources

Our model represents the chain of events that could potentially lead to an oil spill. This model and approach has been used in the Prince William Sound Risk Assessment (Merrick et al, 2002), the Washington State Ferries Risk Assessment (van Dorp et al, 2001), and the Exposure Assessment of the San Francisco Bay ferries (Merrick et al, 2003).

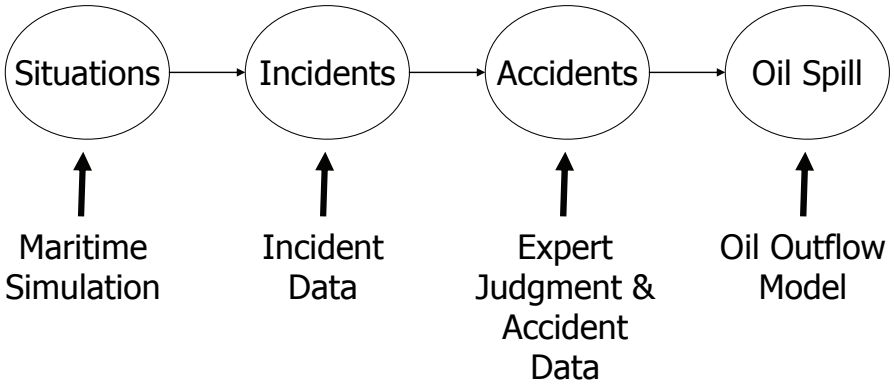


Figure 27. The chain of events that lead to an oil spill and the modeling techniques used for each step.

4.1. Interactions

Accidents can only occur when vessels are transiting through the system. Collisions can only occur when a vessel is in close proximity to another vessel. Grounding can only occur when a vessel is within close proximity (powered grounding) or drifting range (drift grounding) of shore or sufficiently shallow waters. When a BP Cherry Point tanker, ATB, or ITB is in one of these situations, we call this an interaction and the simulation is used to count these interactions. Our maritime simulation model attempts to re-create the operation of vessels and the environment within geographic scope of the study. The routes shown in Sections 3.1 to 3.3 are actually the routes used for vessel transits in the simulation model. The raw records used to obtain the transits counts in Sections 3.1 to 3.3 were used to model the transits and departure times in the simulation for the year 2005. The environmental factors modeled include wind, fog, and current. The underlying data discussed in Section 3.7 was fed in to provide dynamic environmental values in the simulation. Additional details about building maritime simulations can be found in Merrick et al (2002) and van Dorp et al (2001) and Technical Appendix C.

The interactions are counted over the course of a year of the simulation. Figure 27 shows a geographic profile of these counted interactions for the year 2005. Interactions along the shore indicate that a BP tanker, ATB, or ITB are within five hours of shore under power or within five hours of drifting ashore if they were to become disabled. Interactions on the water are with other vessels. There are also interactions with the dock. Informally, darker colors indicate more interactions and lighter colors indicate less. A black cell has one of the highest interactions of any cell in the study area; the light blue cells have the least. The light greenish-yellowish color to the left of the number 1.00 of the color legend's numerical scale represents the average number of interactions within a grid cell over the entire area.

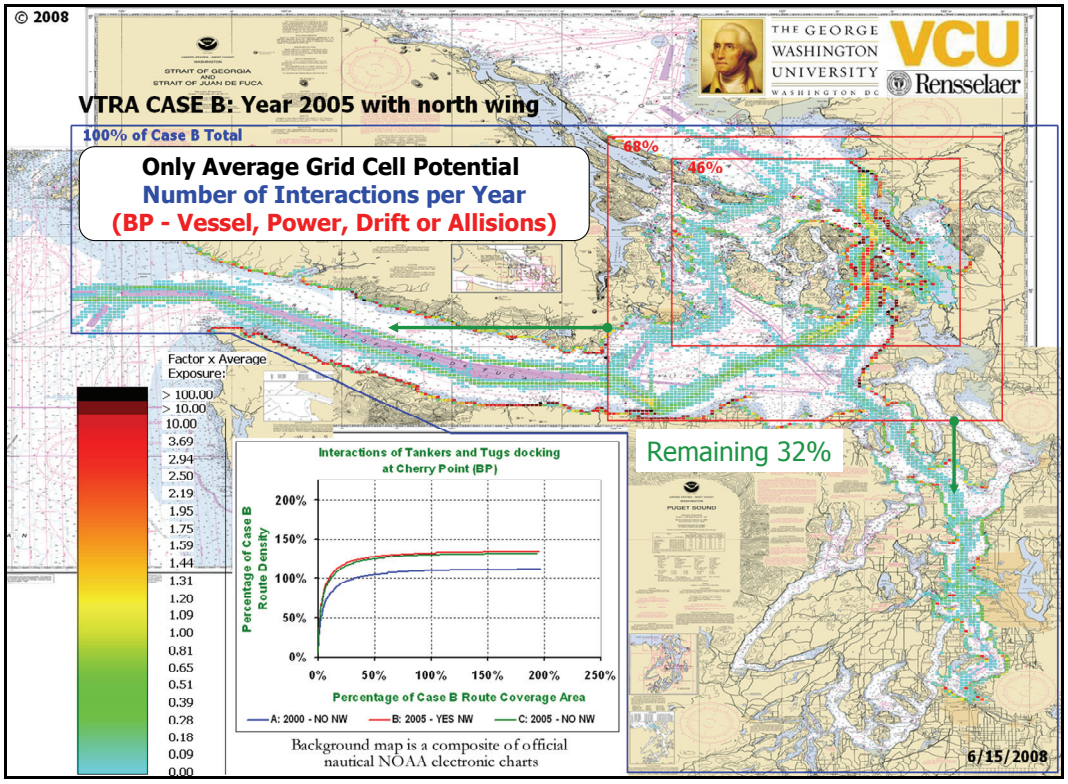


Figure 28. A geographic profile of the number of interactions counted in a simulation of 2005.

Hence, colors darker than this color (above 1.00) have more than an average number of interactions in a grid cell and colors below 1.00 have a lower than average number of interactions in a grid cell. The two red rectangles provide in the upper left corner the

percentage of interactions within that rectangle. Hence, 68% of all the interactions in Figure 27 occur within the largest red rectangle and 46% of all the interactions occur within the smallest red rectangle. The remaining 32% occur outside of the largest rectangle (but within the blue border area).

4.2. Incidents

Incidents are the events that immediately precede the accident. The types modeled include total propulsion losses, total steering losses, loss of navigational aids, and human errors. The impact of each of these types of triggering events on the occurrence of accidents is estimated by examining the records of each accident that occurs inside the study's geographic scope. An exhaustive analysis of all possible sources of relevant accident, near miss, incident, and unusual event data was performed. The tanker fleet calling at BP Cherry Point has experienced xx propulsion failures, xx steering failures, and xx navigational aid failures while within the study area over the 11 year period from 1995 to 2005. The ATB and ITB fleet that call at BP Cherry Point have not been operating for as long as the tankers, just 7.5 years. Over this period they have experienced 34 propulsion losses, 13 steering losses, and 12 navigational aid failures while within the study area. These counts are used to find the probability of a propulsion failure, steering loss, or navigational aid failure during each interaction that is counted in the simulation.

Human errors are not recorded as reliably as the mechanical failures discussed above. Thus we must find another method to estimate their frequency. If we perform an error analysis of accidents that have occurred in our data collection period (1995 to 2005), we find that 75% (3 of 4) of the accidents have been preceded by human errors, while 25% (1 of 4) have been caused by mechanical failures. This is in line with such percentages found in previous studies (Grabowksi et al 2000). Thus there are 3 times as many accidents preceded by human error than accidents preceded by mechanical failure. Thus we infer that there must be 3 times as many human errors as mechanical failures and we multiply the total number of propulsion losses, steering losses, and navigational failures by 3 to obtain the number of human errors. This number is then used to find the probability of a human error during each interaction that is counted in the simulation. Appendix A discusses in more detail the collection of incident and accident data for the VTRA study area.

4.3. Accidents

The accident types included in this study are collisions between two vessels, groundings (both powered and drift), and allisions. However, as the simulation counts the situations in which accidents could occur, it also records all the variables that could affect the chance that the accident will occur; these include the proximity of other vessels, the types of the vessels, the location of the situation, and the environmental variables from Section 3.7. We know how often accidents do occur from our analysis of incident and accident data, but there is not enough data to say how each of these variables affects the chances of an accident; accidents are rare! To determine this, we must turn to the experts. We ask experts to assess the differences in risk of two similar situations that they have extensive experience of. In each question we change only one factor and through a series of questions we build our accident probability model, incorporating the data where we can. The type of incident that has occurred to lead to the possibility of an accident is also specified for each question.

Q28

Situation 1	TANKER DESCRIPTION	Situation 2
Strait of Juan de Fuca East	**Location**	-
Outbound	**Direction**	-
1 Escort	**Escorts**	-
Untethered	**Tethering**	-
	INTERACTING VESSEL	
Passenger vessel	**Vessel Type**	-
Meeting	**Traffic Scenario**	-
Less than 1 mile	**Traffic Proximity**	-
	WATERWAY CONDITIONS	
More than 0.5 mile Visibility	**Visibility**	Less than 0.5 mile Visibility
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Opposite Direction	**Current Direction**	-
More? : ___	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**___ : More?**
Situation 1 is worse	**<==========X==========>**	**Situation 2 is worse**

Figure 29. An example of a question used to assess the variation in accident probabilities between the different possible interaction scenarios.

Figure 28 shows an example picture; here a total propulsion loss has occurred and an oil tanker with a tethered escort is meeting a ferry. The question asks how much difference

restricted visibility would make. This method has been developed over the course of over ten years of work in maritime risk assessment, has been peer reviewed by the National Research Council and our peers in the field of expert elicitation design and analysis, and has been improved thanks to funding from the National Science Foundation. The experts involved include tanker masters, tug masters, pilots, Coast Guard VTS operators, and ferry masters. Additional details about this method, how the responses are analyzed, and how the results are incorporated in to the over model can be found in Technical Appendix D and Szwed et. al (2006).

As these questions compare two scenarios, they can only be used to estimate the difference in the accident probability between two interaction scenarios. We still need to know the total number of accidents. Thus the accident probability model is calibrated to reflect the historical number of accidents that have occurred to the BP Cherry Point calling fleet within the study period over our data collection period. In all, there have been 4 accidents, 1 collision, 1 grounding, and 2 allisions.

Combining the information of geographic interaction profile in Figure 28 with the accident probability models per interaction allows one to develop a geographic profile of accident frequencies results. Figure 30 shows such a geographic profile for the year 2005. Please compare Figure 28 with Figure 30 and note that when going from interactions counts (exposure) to accident frequency the largest rectangle contains 88% of the total annual accident frequency, but contained 68% percent of the interactions. Going from interactions counts (exposure) to accident frequency the smallest rectangle contains 79% of the total annual accident frequency, but contained 46% percent of the interactions. Hence, we observe a higher concentration of accident frequency within these rectangles, compared to interaction counts. Even the though the color legends of Figures 28 and Figure 30 have different scales (since the yellow-greenish color to the left of 1.00 on the numerical scale of the color legend represents the average number of interactions over all grid cells in Figure 28 and the average accident frequency over all grid cells in Figure 30) this also follows from a lightening of colors along the coast lines in Figure 30 and a darkening of color within the smallest red rectangle in Figure 30.

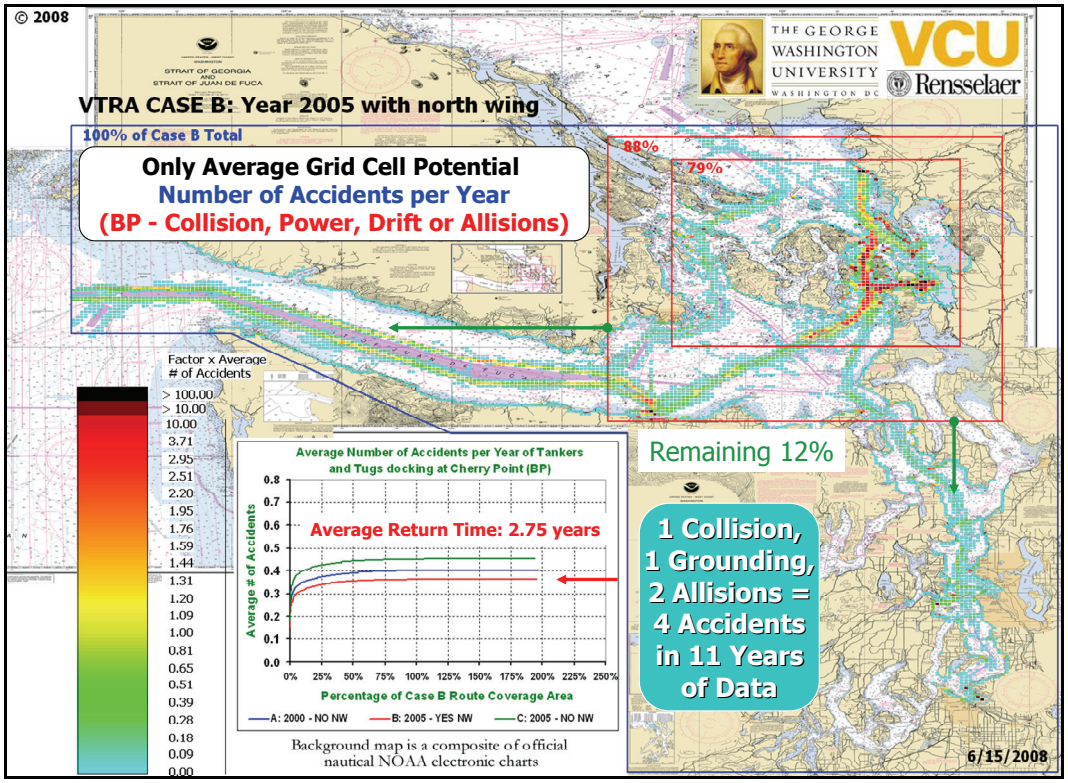


Figure 30. A geographic profile of accident frequency results for a 2005 analysis with the north wing dock in operation.

4.4. Oil Outflow

Our oil outflow methodology is derived from the one described in Special Report 259 published by the National Research Council (NRC) in 2001. For tankers, ATB's and ITB's we use the compartment configurations for single hull and double hull tankers provided in this NRC (2001) report. We make the worst case assumption that when a compartment is punctured that all its content is lost. Within the simulation, the speed and types of the vessels involved in each interaction are recorded along the angle of interaction for interactions between vessels. BP shipping provided the DWT, displacement, length, beam, and draft of each tanker, ATB, and ITB, along with the hull type. For each other type of vessels, DWT, length, beam, and draft were obtained and representative configurations of the fuel tanks developed. These were inputs to the oil outflow model.

BP could not provide specific details about how much crude or petroleum tankers carried on specific voyages. Instead, they provided the maximum capacity of each tanker and an average percentage of capacity carried based on the type of vessel and type of transit. Crude tankers are assumed to arrive in the study area full and leave empty. However, they can also make multiple calls at refinery docks during one visit to the study area. Thus they are assumed to unload an equal quantity of crude oil at each refinery. Product tankers are assumed to arrive in the study area empty and leave full. If they make multiple calls at refineries, then they are moving product between refineries in the study area. Thus they are assumed to be half full on each inter-refinery transit. All other vessels were assumed to carrying their full capacity of fuel as a worst-case assumption.

Once an accident has occurred, we must estimate the probability that the hull (or hulls in the case of double hulls) is punctured and then estimate how many compartments that are carrying crude cargo, product cargo, heavy fuel or diesel fuel have been penetrated. The speed and mass of the vessels are used to calculate the kinetic energy involved in the collision or grounding with the other vessel, the shore, or the dock, but is this kinetic energy enough to penetrate the hull of the tanker and, if so, how far in to the tanker will the penetration be? If we know this, then we can overlay this penetration on a picture of the vessel and determine which compartments are penetrated. The National Research Council 2001 study performed a large scale modeling study of oil spills for collisions and groundings using physical simulation models and described in NRC (2001). They studied both 40,000 DWT and 150,000 DWT tankers, with the smaller vessel configured like a product tanker and the larger like a crude tanker, and both single hull and double hull tankers of each size. 10,000 collision simulations and 10,000 grounding simulations of each of the four types of tankers were performed at multiple levels of each input factor. Rather than repeating these simulations, we fitted regression models to the data and then applied the fitted models to estimate the probability of penetration and the number of compartments penetrated in each interaction scenario. The regression models allow for an interpolation between the specific tankers sizes studied in the NRC (2001) report. Our oil outflow model is described in more detail in Appendix E.

Combining the information of geographic accident frequency profile in Figure 30 with the oil outflow models per accident allows one to develop a geographic profile of oil outflow results. Figure 31 shows such a geographic profile for the year 2005. Please compare Figure 30 with Figure 31 and note that when going from interactions counts (exposure) to accident frequency the largest rectangle contains 92% of the total annual average oil outflow, but contained 88% percent of the overall accident frequency. Going from accident frequency to oil outflow the smallest rectangle contains 77% of the total annual accident frequency, but contained 79% percent of the interactions.

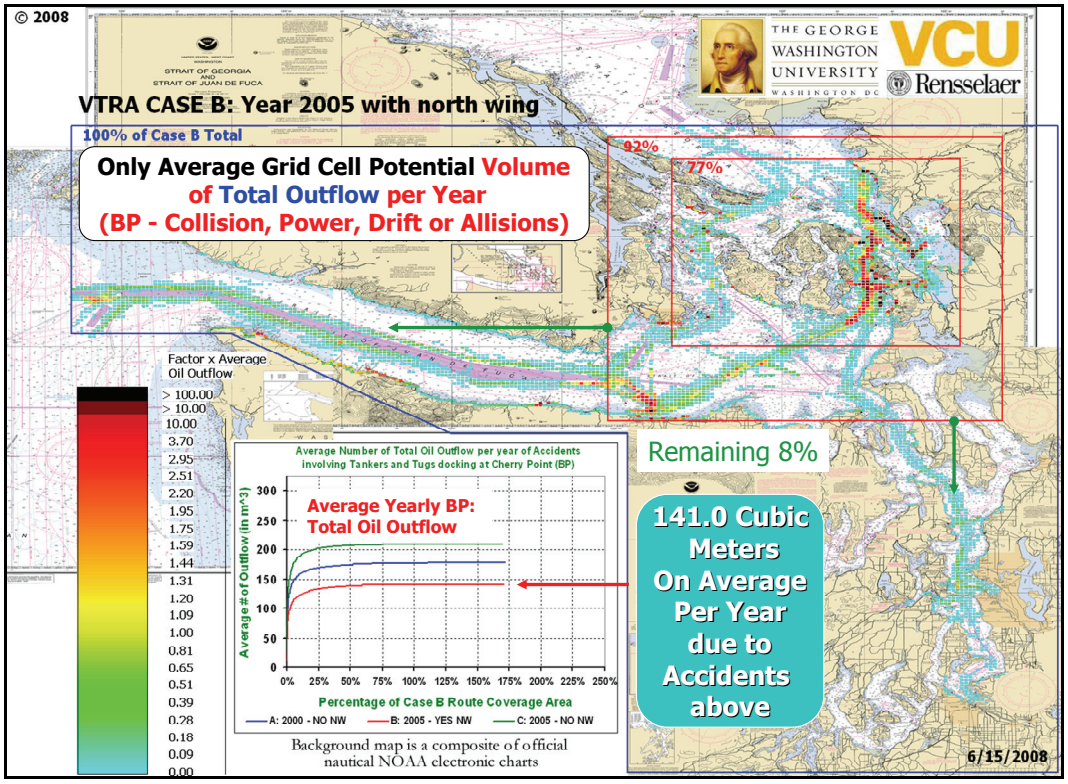


Figure 31. A geographic profile of average oil outflow results for a 2005 analysis with the north wing dock in operation.

Hence, we observe a higher concentration of oil outflow within the largest red rectangles, but a lower one in the smallest red rectangle compared to accident frequency. Even the though the color legends of Figures 28 and Figure 30 have different scales (since the yellow-

greenish color to the left of 1.00 on the numerical scale of the color legend represents the average accident frequency over all grid cells in Figure 30 and the average oil outflow over all grid cells in Figure 31) also follows by and a darkening of color within the smallest red rectangle in Figure 31 and a darkening of color within the largest red rectangle but outside of the smallest one.

4.5. Organizations that Provided Experts

The organization below provided experts for the expert judgment elicitation sessions. Experts were invited to and referred to the VTRA team through the United States Coast Guard and the Puget Sound Harbor Safety committee. Expert judgment elicitation sessions were scheduled predominantly at the US Coast Guard VTS, sector Seattle in December 2006, February 2007, June 2007, August 2007, September 2007 and December 2007. The elicitation session with the ATC tanker captains and master was scheduled during an ATC conference in February 2007 in Portland, Oregon. The combined numbers of years sailing experience of the experts who participated in the elicitation process of the VTRA study area exceeds 922 years.

1. Puget Sound Pilots
2. ATC
3. BP Shipping North America
4. US and Canadian Tug Companies operating in the VTRA study area:
   US-Based: Foss, Crowley, Olympic Tug and Barge (US),
   K-Sea, Sea Coast, Sause Bros.
   Canadian Based: Seaspan, Island Tug and Barge
5. The Washington State Ferries
6. Seattle sector US Coast guard VTS.

4.6. Data Sources Used

The organizations below have contributed to our data collections processes in various forms. Some provided data in electronic form, some sources were in hard copy and others assisted in a data assimilation process through personal communications. The data sources and their format are described in more detail in the technical appendices.

1. VTOS
2. The Washington Department of Fish and Wildlife
3. Washington State Fisheries
4. Canadian Fisheries
5. Native American Tribes
6. Sound Watch
7. National Climatic Data Center
8. NOAA Weather Buoys
9. NOAA Current Data
10. US Coast Pilot 7 - 2006 (38th) Edition.
11. USCG Accident/Incident Data
12. USCG Small Events Permitting Data
13. Washington State Department of Ecology Accident/Incident Data
14. Puget Sound Pilots Incident Data
15. National Research Council Report (2001).
16. Fuel vessel data from various vessel brokerage web-pages e.g.: www.yachts.com and www.ship-technology.com

5. Analysis Results

In this section, we examine the results obtained using the model discussed in Section 4. We start by describing the cases analyzed using this model and then proceed to understand the differences in the level of accident potential and oil outflow potential between these cases, including changes since before the north wing, changes that might be seen in the future, and changes caused by three alternatives.

5.1. Explanation of Cases Analyzed

The analysis is based on 15 cases that represent different configurations of the simulation. The first three cases A, B, and C allow us to examine the changes from before the north wing was constructed to the year 2005 after it was operational; we also examine a hypothetical scenario were the north wing to not have been operational in the year 2005.

We then have six scenarios which examine potential changes in risk in the year 2025. Since shipping is a derived demand, projection of future vessel traffic is inherently uncertain. Actual future tanker and tank barge traffic will be dependent upon energy requirements and distribution choices. Actual future container vessel traffic and bulk cargo traffic and vessel size are dependent upon demand for imports and exports. As traffic levels are uncertain that far in to the future, we use statistical forecasts of traffic levels. However, these forecasts provide a best guess estimate, but also an assessment of the level of uncertainty, which allows us to give high and low estimates too. The vessel traffic described in the base case year (2005) was projected through 2025 using 15 years historical trend data analysis by vessel type. The opening of the Gateway bulk cargo terminal (that would effect this time series projection) and statistical techniques were used to construct upper and lower bounds for future traffic. The resulting high, medium and low forecasts were used as the basis for calculating future accident frequencies and oil outflows. Appendix F discusses the development of these future scenarios at a higher level of technical detail.

Thus cases D through I represent high, medium, and low traffic scenarios both with and without the north wing being operational. This allows us to assess the risk affect of the north wing at different levels of forecasted traffic. The final six cases evaluate changes to the

operations of the BP Cherry Point tanker, ATB, and ITB traffic. Each of these changes are evaluated at the case B traffic levels and at the high forecasted level of 2025 to stress test the alternative. These changes represent risk interventions out of scope in this study if the north wing is operational, so the north wing is operational in all six cases J through O. The three risk interventions are not using Saddlebags for BP Cherry Point traffic, extending escorts to the whole area inside Buoy J, and taking out the Neah Bay tug (to assess the affect of it being included in the other cases).

The 15 cases are summarized in Table 1. We will break our discussion in to three parts, a discussion of cases A, B, and C to assess changes from 2000 to 2005 with the construction of the north wing, cases D through I to assess future changes in risk in 2025, and cases J through O to assess the affect of the three risk interventions relative to the entire VTRA study area.

Table 1. A list of all cases used in the analysis and the factors varied amongst them.

	Case	CP Traffic	Other Traffic	North Wing?	Saddlebags?	Extend Escorting?	Neah Bay?	Gate Way?
1	A	2000	2000	No	Yes	No	Yes	No
2	B	2005	2005	Yes	Yes	No	Yes	No
3	C	2005	2005	No	Yes	No	Yes	No
4	D	2025 Low	2025 Low	Yes	Yes	No	Yes	Yes
5	E	2025 Low	2025 Low	No	Yes	No	Yes	Yes
6	F	2025 Medium	2025 Medium	Yes	Yes	No	Yes	Yes
7	G	2025 Medium	2025 Medium	No	Yes	No	Yes	Yes
8	H	2025 High	2025 High	Yes	Yes	No	Yes	Yes
9	I	2025 High	2025 High	No	Yes	No	Yes	Yes
10	J	2005	2005	Yes	No	No	Yes	No
11	K	2025 High	2025 High	Yes	No	No	Yes	Yes
12	L	2005	2005	Yes	Yes	Yes	Yes	No
13	M	2025 High	2025 High	Yes	Yes	Yes	Yes	Yes
14	N	2005	2005	Yes	Yes	No	No	No
15	O	2025 High	2025 High	Yes	Yes	No	No	Yes

Let us first discuss cases A, B, and C in some detail. The base case is Case B which represents the operation of maritime traffic in the year 2005. The simulation replays VTS traffic, regattas, whale watching, and fishing traffic from the year 2005. The wind, visibility, and currents are also replayed from 2005. The north wing is operational, the BP Cherry Point tanker, ATB, and ITB traffic can use Saddlebags, and the Neah Bay tug is on standby; the tankers are escorted beyond a point east of a line between Discovery Island and New

Dungeness Light. Case A reflects the operation of the system before the north wing was constructed. The traffic levels reflect operations in the year 2000; much of the traffic has been consistent from 2000 to 2005, but product traffic at BP Cherry Point was 20% less in 2000 than 2005, while other tanker traffic was 23% higher in 2000. Bulk carriers were also 30% higher in 2000. The north wing was not constructed, so only one dock was available at BP Cherry Point. Case C is a fictional case that reflects the system in the year 2005 as in case B, but with the hypothetical scenario that the north wing was not operational.

The future scenario cases represent high, medium, and low forecasts of tanker traffic, container traffic, and bulk carrier traffic. Tanker traffic is broken in to BP crude tanker traffic, BP product traffic, and non BP traffic. For BP traffic, the low scenario represents the possibility that most crude is brought to the BP Cherry Point refinery by pipeline; the medium scenario is a moderate increase in both types of traffic; the high scenario represents the highest crude traffic level possible under currently permitted operations and a large increase in product traffic. For the low scenario, BP crude traffic is decreased to only 10% of the 2005 levels and BP product traffic is reduced by 2%. For the medium scenario, BP crude and product traffic are increased by 13%. For the high scenario, BP crude traffic is increased by 17%, but BP product traffic is increased by 90%. Other tanker traffic is forecasted to increase, but the uncertainty bounds are large due to the long forecast time horizon. Thus the low, medium, and high levels are a 52% decrease, a 55% increase, and a 162% increase. Container traffic is also forecasted to increase, but again with large uncertainty bounds. The low, medium, and high levels are a 54% decrease, a 20% increase, and a 93% increase. Bulk carrier traffic has decreased significantly over the past ten years, but for the past few years it has been consistent. However, with the renewed permit action associated with the Gateway facility, 241 additional bulk carrier transits are included from Buoy J to the Gateway facility and then back to Buoy J in the 2025 cases.

The risk interventions identified in the scope are run at case B traffic levels as well as the high future scenario. In cases J and K, BP tankers do not use the Saddlebags route to transit between BP Cherry Point and Anacortes, but instead use Rosario Strait and Guemes Channel. In cases L and M, tugs escort all tanker traffic from and to Buoy J. This is reflected

in the collision and grounding probabilities. In cases N and O, the effect of the Neah Bay tug on drift grounding probabilities is removed; in other cases the time that the Neah Bay tug would take to reach a drifting tanker is calculated and the effect of a tug on the probability of grounding is applied proportionally.

5.2. Risk Changes from Adding North Wing

In this section, we will examine cases A, B, and C. The specifics for these three cases are included in Table 2 as a reminder.

Table 2. The cases used to consider changes in risk from adding the north wing.

	Case	CP Traffic	Other Traffic	North Wing?	Saddlebags?	Extend Escorting?	Neah Bay?	Gate Way?
1	A	2000	2000	No	Yes	No	Yes	No
2	B	2005	2005	Yes	Yes	No	Yes	No
3	C	2005	2005	No	Yes	No	Yes	No

Comparison of cases A and B allow us to see the change in risk from 2000 to 2005; this is caused by both changes in traffic levels and the construction of the north wing. However, using case C we can separate these two effects. Comparing cases B and C allows us to assess the effect of just construction of the north wing, but with no changes in traffic. Comparison of cases A and C allows us to assess the effect of just changes in traffic from 2000 to 2005, but without the effect of the north wing. Figure 32 shows the accident potential results for cases A, B, and C. The total accident potential is the sum of the potential of the four accident types, allisions, drift groundings, powered groundings, and collisions. Thus Figure 29 shows the accident potential for each type of accident stacked one on top of the other. This means that the total height of the bar is the total accident potential for that case. Figure 30 shows the same stacked bars for oil outflow potential in these three cases.

Comparing case A to case C, we see the expected effect of an increase in traffic levels calling at BP Cherry Point with no other changes to the system (no north wing in either case): an increase in overall levels of risk. It can be noticed that the potential number of collisions, drift groundings, powered groundings, and allisions increases. There are 25% more BP crude tankers in case C than case A and the same number of BP product vessels, so with more BP vessels there are more accidents in case C. Overall, case C has 12% higher accident potential than case A.

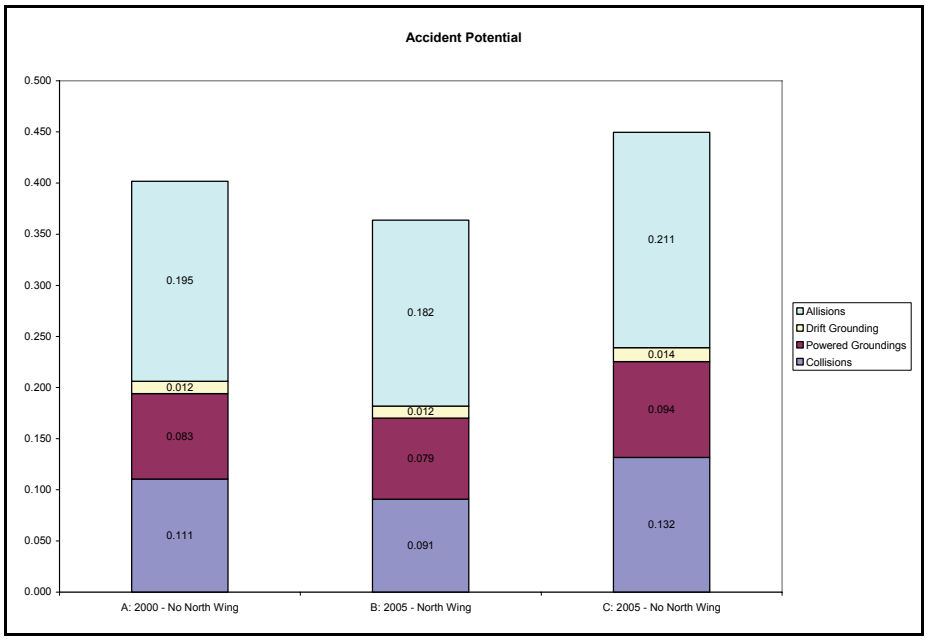


Figure 32. The accident potential by accident type for cases A, B, and C.

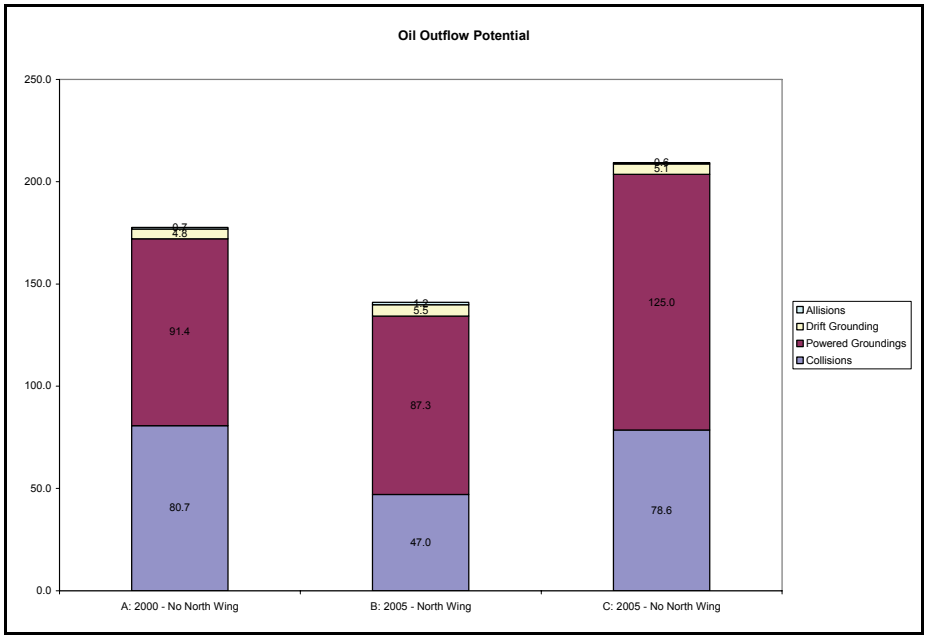


Figure 33. The oil outflow potential by accident type for cases A, B, and C.

We see some different effects in oil outflow as not all accidents cause the same level of potential oil outflow. Allisions have a much lower amount of oil outflow than the other three accident types. Oil outflow from potential powered groundings increases from case A to case C due to the increase in the number of BP crude tankers and the associated increase in the use of anchorages[4]. However, we can also see that the potential oil outflow from collisions is about the same though the potential number of collisions increases from A to C. Oil outflow from collisions depends on what the other vessel involved is. In case C, the BP vessels interact more with fishing vessels and less with ferries than case A. Increasing interactions with fishing vessels leads to more collision potential, but not a lot more oil outflow potential. Increased interactions with ferries leads to both collision and oil outflow potential. Thus case C has more collision potential because of the fishing vessels, but the oil outflow potential is a wash compared to case A because of the higher number of ferries interactions in Case A. Putting the effects on all types of accidents together though, there is a total increase of 18% from case A to case C in potential oil outflow.

Comparing case B to case C allows us to see the effect of the north wing with no other changes to the system[5]. We can see that the levels for each accident and the total level are lower in case B than in case C. The oil outflow potential is also higher without the north wing. This is because incoming tankers, ATBs, and ITBs do not have to transit at reduced speed or go to anchorage as often because the north wing is available. In fact the number of trips to anchorage for vessels inbound to BP Cherry Point is reduced by 40% if the north wing is available. This reduces the time that each tanker, ATB, and ITB spends in the study area on a given visit. However, taking a look at the other side of this same coin, in case C we use the same schedule for tankers as case B[6] but without the north wing, there is a 4% reduction in the number of BP tanker, ATB, and ITB visits in the one year of simulation as they can't pass through the study area as quickly. Despite handling slightly more BP vessels

[4] The trips to anchorage take vessels through waterways where the shore is closer.

[5] The traffic levels are the same

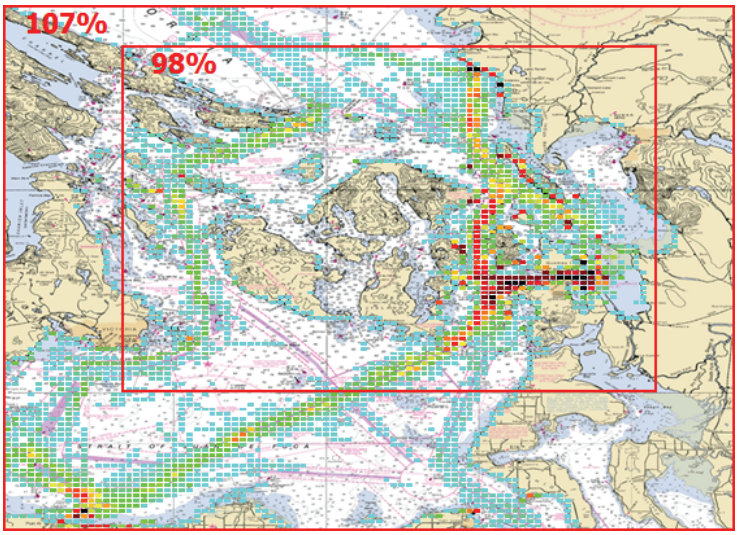
[6] Meaning each vessel spends the same amount of time out of the study area between calls and the same amount of time at each dock they visit

with the north wing than without it, having the north wing in 2005 reduces the accident potential by 21% and the oil outflow potential by 38%[7].

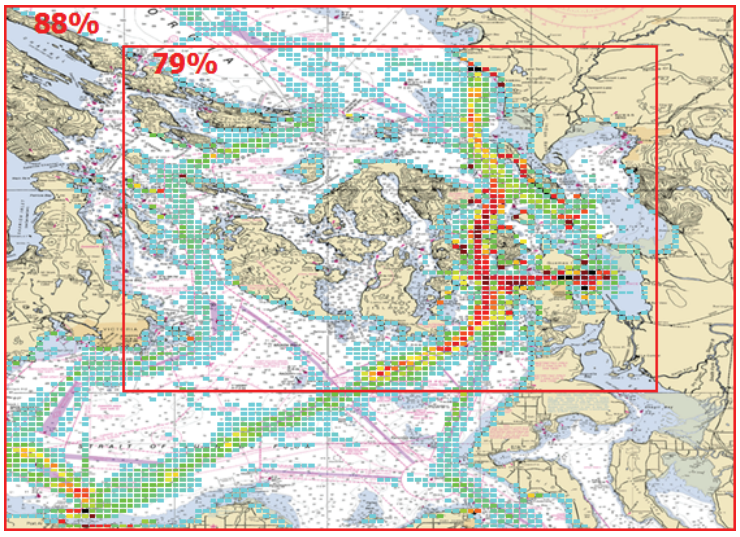
What then is the change from 2000 to 2005? The changes in traffic over this period increased accident and oil outflow potential in our case A and case C comparison. But at fixed traffic levels, having the north wing is better than not having it in our case B and case C comparison. What is the change in risk caused by both the changes in traffic levels and the addition of the north wing? Comparing case A to case B, we can see that the potential for all types of accidents decreases. The level of oil outflow potential is also lower. Overall, there is a 10% reduction in accident potential and a 21% reduction in oil outflow potential. Thus we can say that the addition of the north wing has reduced the risk to BP vessels in the study area despite the increase in crude tankers calling at BP Cherry Point from 2000 to 2005. Another way of saying this is that the addition of the north wing has mitigated the effect of traffic changes from 2000 to 2005.

It is useful to see the changes between these three cases on a geographical profile (Figures 34). A geographic profile is generated by counting the potential number of accidents or summing the potential volume of oil outflow in a grid of cells and then overlaying these amounts on a map of the study area. The cells are colored to indicate higher of lower amounts. The color scheme goes from blue for the lowest amounts, through green to yellow for average amounts, through orange, red and brown to black for the highest amounts. Figure 34 shows three such maps for the potential number of accidents, one each for cases A, B, and C. The maps show an area that includes BP Cherry Point to the top right and Port Angeles to the bottom left. In case B, this area includes 88% of the total potential number of accidents for the whole study area. In case A, this area has 7% more accidents than the whole study area does in case B. In case C, this area has 12% more accidents than the whole study area does in case B. These percentages are shown on the maps along with percentages for a smaller area shown as a red box.

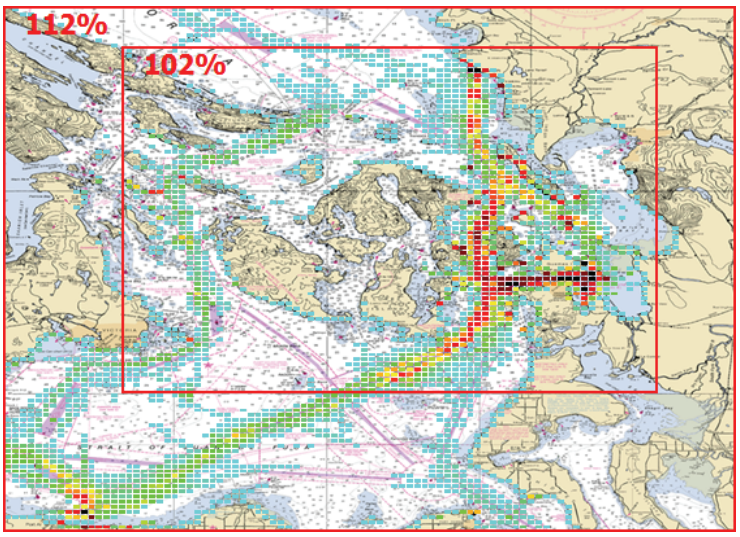
[7] For consistency percentages are evaluated here as percentages of 2000 levels as well.



Case A: Accident Potential

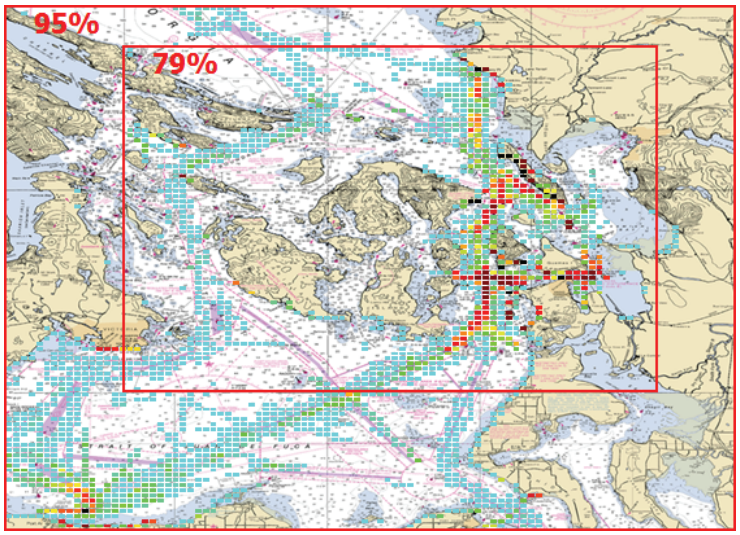


Case B: Accident Potential

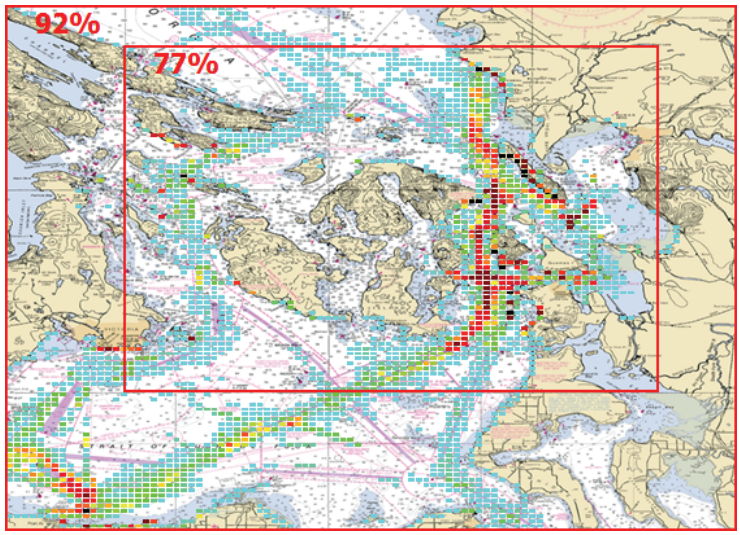


Case C: Accident Potential

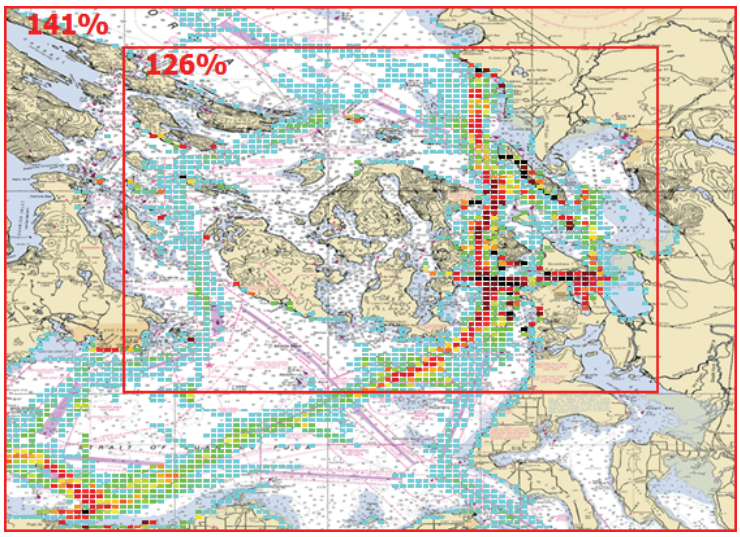
Figure 34. Geographic profiles of accident potential for cases A, B, and C.



Case A: Oil Outflow



Case B: Oil Outflow



Case C: Oil Outflow

Figure 35. Geographic profiles of oil outflow potential for cases A, B, and C.

Comparing the three maps in Figure 34 shows that cases A and C have more dark cells in Guemes channel, around Saddlebags and its approach from Rosario Strait. This is because tankers, ATBs and ITBs have to use the anchorages more often when there is no north wing. Cases B and C also have some brown cells higher up Rosario Strait where case A has red cells. There are also more red cells in case B and C than in case A on the approach to Rosario Strait at its south end. These effects are both because there are more BP tankers transits in cases B and C than in case A. Figure 35 shows similar maps to Figure 34 but showing a color scheme that depicts the potential volume of oil outflow. The interpretation of the color scheme is the same, but it is now showing higher and lower levels of potential oil outflow rather than potential numbers of accidents. Examination of these geographic profiles shows the same patterns of behavior in terms of oil outflow as the accident profiles.

5.3. Future Changes in Risk

In this section, we will examine cases D through I, the 2025 scenarios, and compare them to cases B and C for the year 2005. The specifics for these eight cases are included in Table 3 as a reminder.

Table 3. The cases used to consider future changes in risk.

	Case	CP Traffic	Other Traffic	North Wing?	Saddlebags?	Extend Escorting?	Neah Bay?	Gate Way?
2	B	2005	2005	Yes	Yes	No	Yes	No
3	C	2005	2005	No	Yes	No	Yes	No
4	D	2025 Low	2025 Low	Yes	Yes	No	Yes	Yes
5	E	2025 Low	2025 Low	No	Yes	No	Yes	Yes
6	F	2025 Medium	2025 Medium	Yes	Yes	No	Yes	Yes
7	G	2025 Medium	2025 Medium	No	Yes	No	Yes	Yes
8	H	2025 High	2025 High	Yes	Yes	No	Yes	Yes
9	I	2025 High	2025 High	No	Yes	No	Yes	Yes

Comparing case B to cases D, F, and H allow us to see the changes in risk from 2005 to 2025 if the north wing is operational, along with the range of uncertainty about the risk levels in the future with the north wing. Comparing case C to cases E, G, and I allow us to see the changes in risk from 2005 to 2025 if the north wing is *not* operational, along with the range of uncertainty about the risk levels in the future without the north wing. The uncertainty in future risk levels is derived from the level of uncertainty in the traffic levels

that may be seen in 2025, including BP tanker, ATB, and ITB traffic and other types of traffic.

We may also make another comparison; we have already compared cases B and C that have the same 2005 levels of traffic, one with the north wing operational and one without it. This showed that the level of accident potential and potential oil outflow is lower if north wing is operational. However, we may also assess the effect of the north wing being operational in each possible future traffic level by comparing cases D and E, cases F and G, or cases H and I. In each of these comparisons the traffic levels are kept the same and only the operation of the north wing differs. The results for each of the cases in terms of accident potential are shown in Figure 36. Cases B and C are shown as individual points as the traffic levels are not uncertain for 2005. However, cases D, F, and H are shown on a line as they all correspond to 2025 with the north wing, but for different possible traffic scenarios that are possible in that year. This shows the range of uncertainty in the level of accident potential in 2025 if the north wing is operational. Cases E, G, and I are shown in a similar fashion to show the range of uncertainty in 2025 if the north wing is not operational. The results for oil outflow potential are shown in the same fashion in Figure 37.

Comparing case B to cases D, F, and H, we see that the potential number of accidents is higher in cases F and H (the medium and high traffic cases) than in case B. However, the potential number of accidents is lower in case D (the low traffic case) than in case B. So there is no guarantee that the risk will increase from 2005 to 2025; it depends on what happens to the traffic levels and the number of vessels that call at the BP Cherrypoint dock.. Comparing case C to cases E, G, and I shows the same is true were the north wing to not be operational in 2005 and 2025.

It is tempting to now compare the range of cases D, F, and H to the range of cases E, G, and I in Figure 36. In a statistical sense, if these ranges overlap then we might conclude that we do not have enough evidence to say that the north wing will reduce risk levels in the future as it does in 2005[8]. However, this is not the correct approach.

[8] Case B has lower accident potential and oil outflow potential than case C

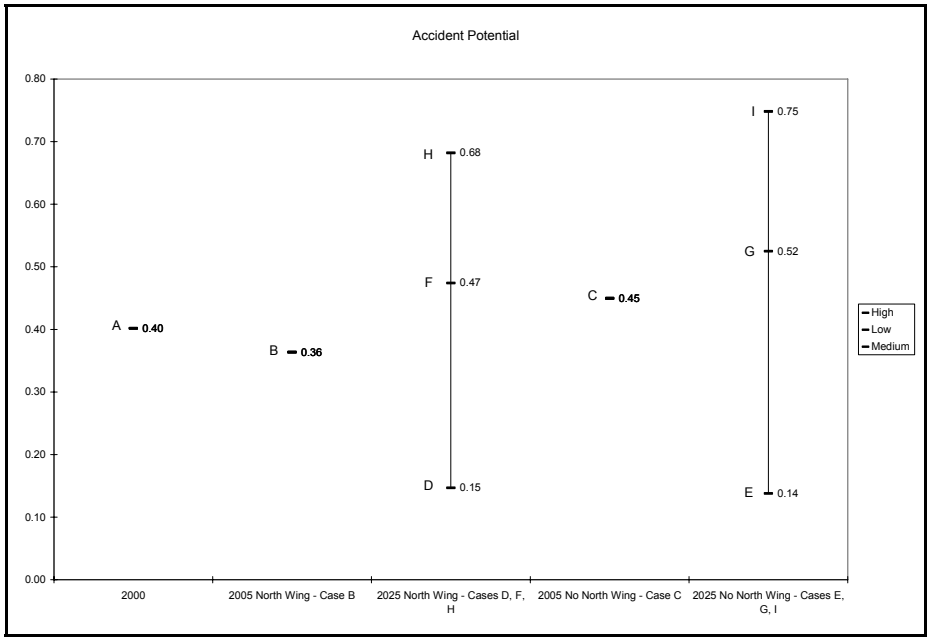


Figure 36. Accident potential in 2005 and 2025 with and without the north wing.

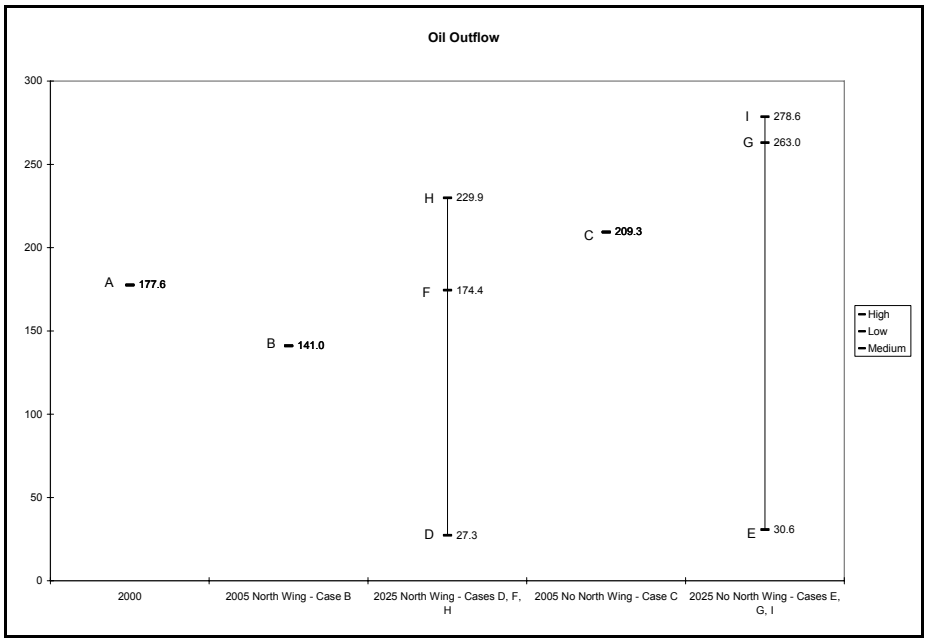


Figure 37. Oil Outflow potential in 2005 and 2025 with and without the north wing.

Instead we must consider each potential traffic level in 2025, low, medium, and high, and compare the case with the north wing operational to the case without it. Thus we must compare cases D and E for the low traffic scenario in 2025, cases F and G with the medium traffic scenario in 2025, and cases H and I with the high traffic scenario in 2025. Case F has a lower accident potential than case G, meaning that the north wing will reduce accident risk if the traffic levels are at the medium scenario in 2025. Case H has a lower accident potential than case I, meaning that the north wing will reduce accident risk if the traffic levels are at the high scenario in 2025. However, case D actually has a higher accident potential than case E, although the difference is much less than the other comparisons. Thus only if the traffic levels are at the low scenario in 2025 will the north wing lead to a slightly higher accident potential. This is because the number of BP tanker visits are slightly higher in case D than in case E, but as the total amount of traffic is low, there are no congestion problems in case E that lead to higher overall risk levels like it does in the medium and high traffic scenarios.

Figure 37 shows the same comparisons, but for oil outflow potential. We seem the same results, although there is one interesting result. The accident potential for case I was quite a bit higher than that for Case G, but there is little difference in oil outflow potential. Cases G and I each make the north wing not operational, but case G is for the medium traffic scenario in 2025 and case I is for the high traffic scenario. Recall that the increase for BP crude tankers from case B to Case G and I are 13% and 17% respectively and the increase for BP product tankers from case B to Case G and I are 13% and 90% respectively. Thus the large increase in BP product tankers leads to a large increase in accidents, but apparently not an associated large increase in oil outflow. Product tank vessels have a much lower carrying capacity than crude tankers. The small increase in BP crude tankers from case G to case I lead to a small increase in oil outflow potential.

Recall that the 17% increase in crude tankers calling at BP Cherry Point is the highest modeled future increase under when the north wing is not operational. Thus under these conditions there appears to be somewhat of an upper limit to the increase in oil outflow potential, but an increase in oil outflow of 97.5% as compared to case B levels.

Accident Potential

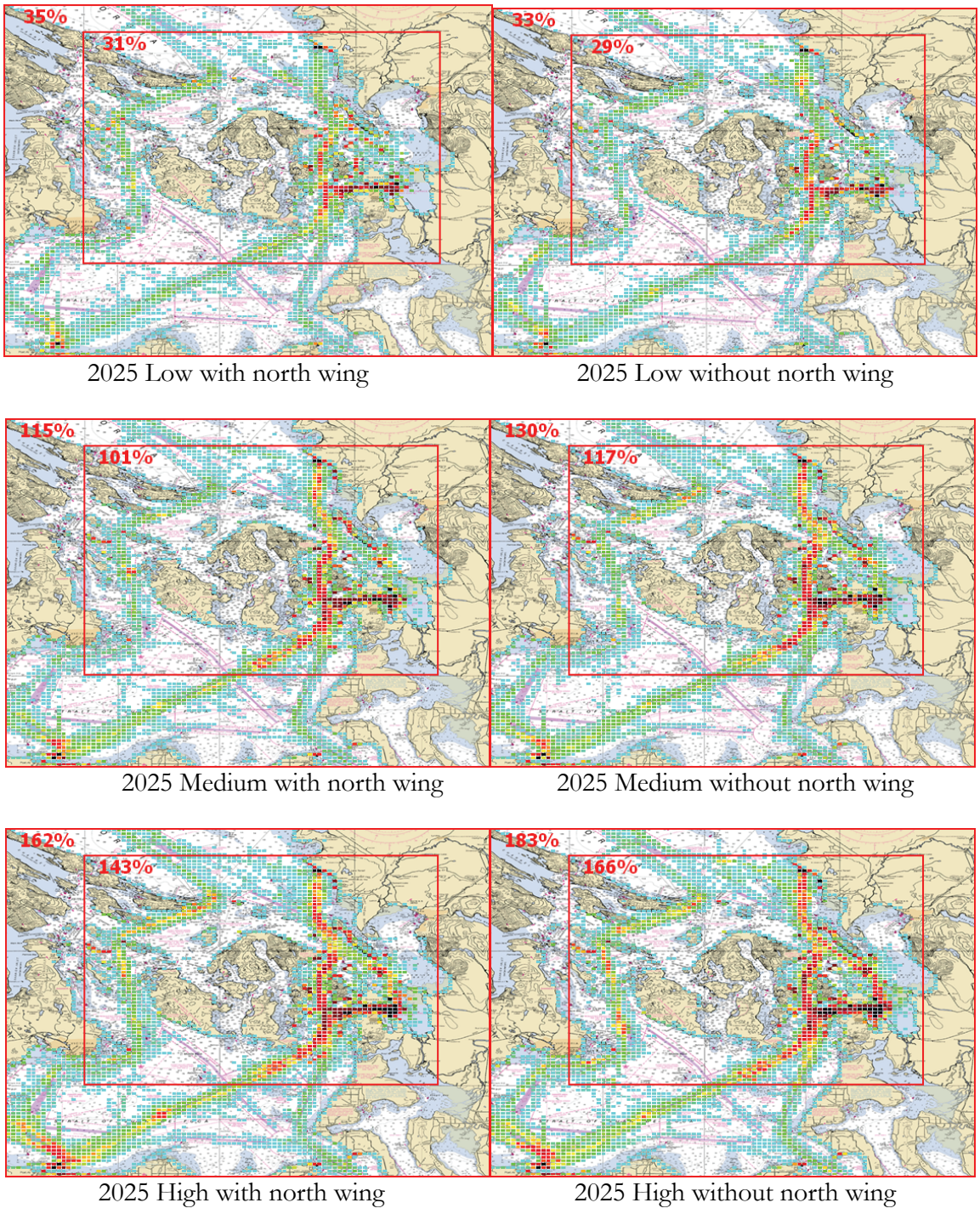
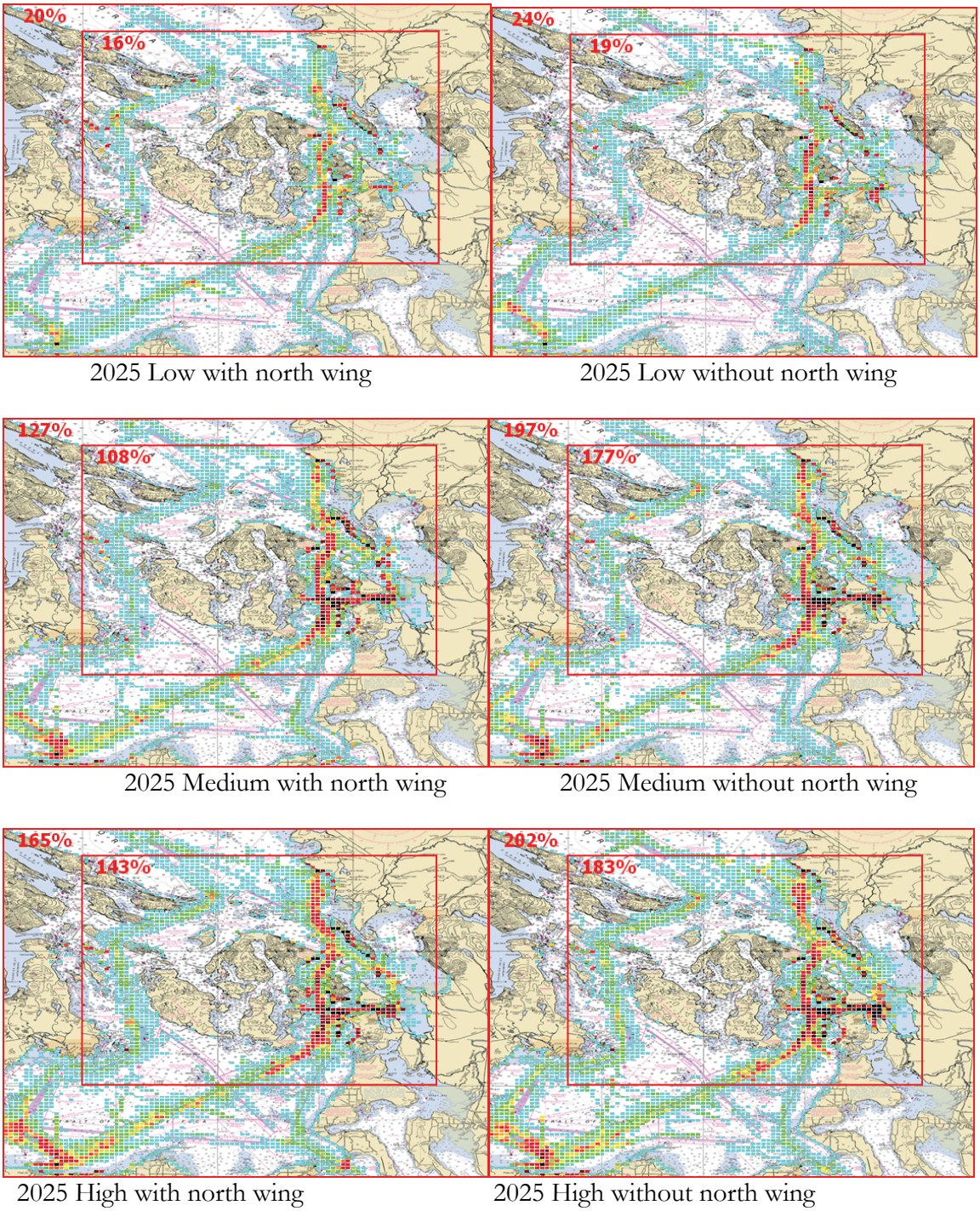


Figure 38. Geographic profiles of accident potential for the low, medium, and high traffic scenarios for 2025 both with (left) and without (right) the north wing.

Oil Outflow Potential



2025 Low with north wing | 2025 Low without north wing

2025 Medium with north wing | 2025 Medium without north wing

2025 High with north wing | 2025 High without north wing

Figure 39. Geographic profiles of oil outflow potential for the low, medium, and high traffic scenarios for 2025 both with (left) and without (right) the north wing.

The geographic profiles of accident potential and oil outflow potential for cases D through I are included in Figures 38 and 39 respectively using the color scale for the case B results. While we observe lower percentages of accident potential and oil outflow potential in the 2025 low scenarios as compared to case B in the largest red rectangular area (88% and 92% for accident potential and oil outflow potential, respectively, see Figures 34 and 35), one observes dramatic increases within these areas in the medium and high traffic scenarios.

In the medium 2025 scenario we observe 15% more accident potential within the largest red rectangular area alone as within the entire VTRA study area in case B when the north wing is operational. We have about the same (1% more) accident potential within the smallest red rectangle as compared to the total accident potential within case B. Hence, take the total accident potential in case B over the entire VTRA study area (see Figure 2), multiply it by a factor of 1.15 and this gives you the accident potential in the largest rectangular area alone under this 2025 medium scenario. In the case that the north wing is not operational the accident potential in the largest red rectangle increases to 30% more than the total accident potential in case B. In terms of oil outflow potential we observe from Figure 39 27% more oil outflow within this area alone as compared to the total oil outflow in case B when the north wing dock is operational and 97% more than the total oil outflow in case B when it is not.

In the high 2025 scenario we observe 62% more accident potential within the largest red rectangular area alone as the total accident potential in case B when the north wing is operational and 43% more in the smallest red rectangular area. Hence, take the total oil outflow potential in case B over the entire VTRA study area (see Figure 2), multiply it by a factor of 1.62 and this gives you the accident potential in the largest rectangular area alone under this 2025 high scenario. In the case that the north wing is not operational this even increases to 83% more than the total accident potential in case B. In terms of oil outflow potential we observe from Figure 39 65% more oil outflow within this area alone as compared to the total oil outflow in case B when the north wing dock is operational and 102% more when it is not.

5.4. Evaluation of scope risk interventions

In this section, we will examine cases J through O for the risk interventions identified in the scope. The specifics for these three cases are included in Table 4 as a reminder. Cases B, J, L, and N are set at the 2005 traffic levels. Case H, K, M, and O are set at the high scenario for 2025 to stress test the interventions. Each of these cases includes the north wing as these interventions were tested to see if they would mitigate risk if the north wing is operational.

Table 4. The cases used to consider changes in risk from three risk interventions.

	Case	CP Traffic	Other Traffic	North Wing?	Saddlebags?	Extend Escorting?	Neah Bay?	Gate Way?
2	B	2005	2005	Yes	Yes	No	Yes	No
10	J	2005	2005	Yes	No	No	Yes	No
12	L	2005	2005	Yes	Yes	Yes	Yes	No
14	N	2005	2005	Yes	Yes	No	No	No
8	H	2025 High	2025 High	Yes	Yes	No	Yes	Yes
11	K	2025 High	2025 High	Yes	No	No	Yes	Yes
13	M	2025 High	2025 High	Yes	Yes	Yes	Yes	Yes
15	O	2025 High	2025 High	Yes	Yes	No	No	Yes

Figures 40 shows the accident potential results for cases B, J, L, and N all with 2005 traffic levels. Each accident is shown separately, but the columns are stacked so the total can also be seen. Figure 41 shows the corresponding oil outflow results. Figure 42 shows the accident potential results for cases H, K, M, and O all with traffic levels from the high scenario for 2025. Figure 43 shows the corresponding oil outflow results.

Let us first consider the use or not of Saddlebags. In cases B and J, the traffic is set to 2005 levels. Case B has BP tankers using the Saddlebags route to transit between BP Cherry Point and Anacortes, while case J has BP tankers using the Rosario/Guemes route. The total potential number of accidents shown in Figure 40 is the same in these two cases, although there are slightly more allisions in case J and slightly less in case B. When we examine the potential oil outflow in Figure 41, it is again the same in total, but case J has slightly more oil outflow from powered groundings and slightly less from collisions. The accident potential and oil outflow geographic profiles look seemingly identical for these two cases and are thus not included.

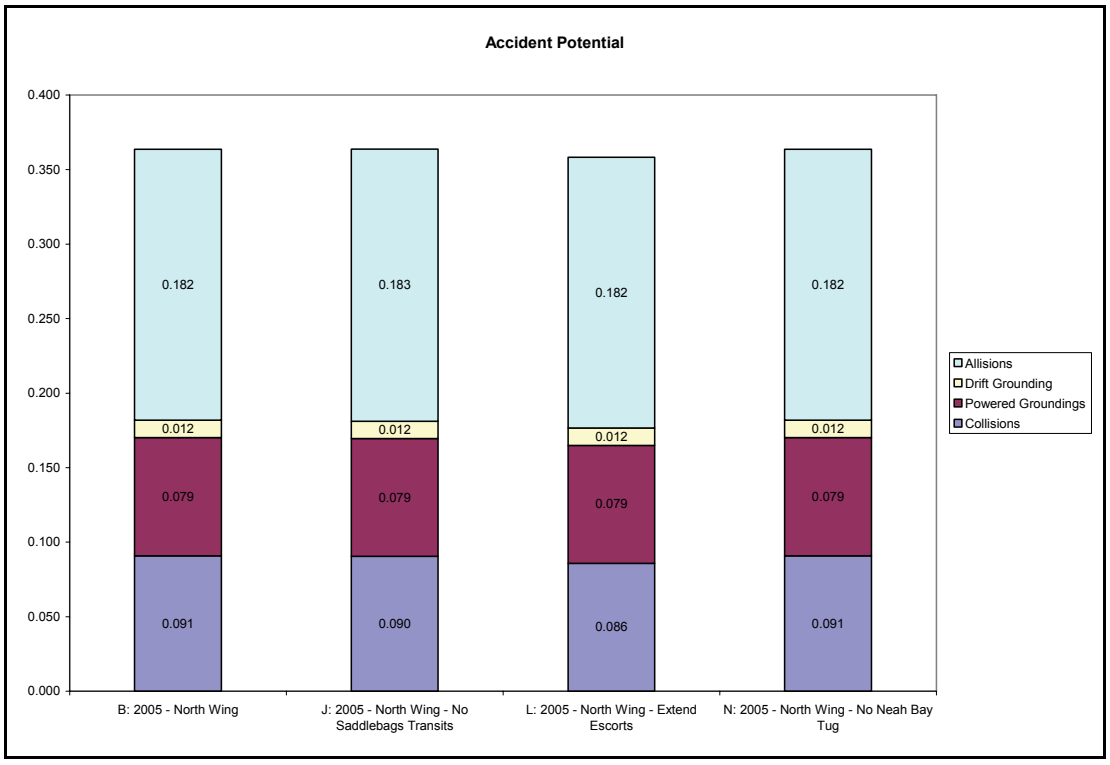


Figure 40. The accident potential by accident type for each intervention in 2005.

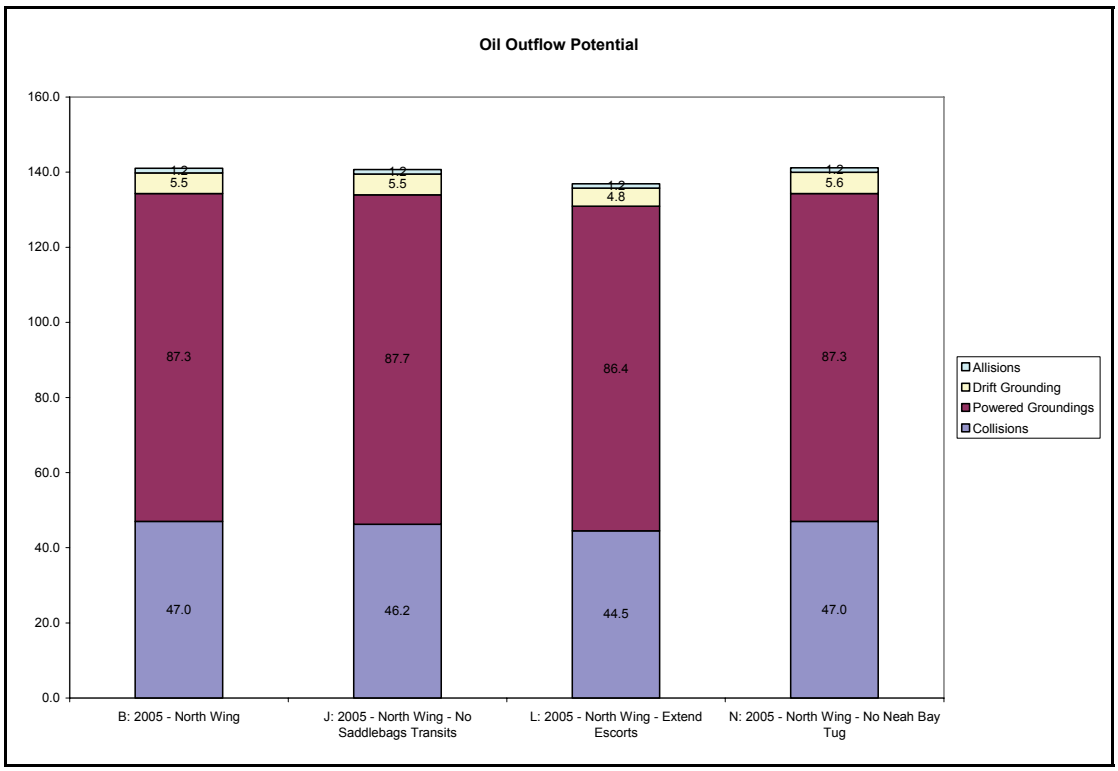


Figure 41. The oil outflow potential by accident type for each intervention in 2005.

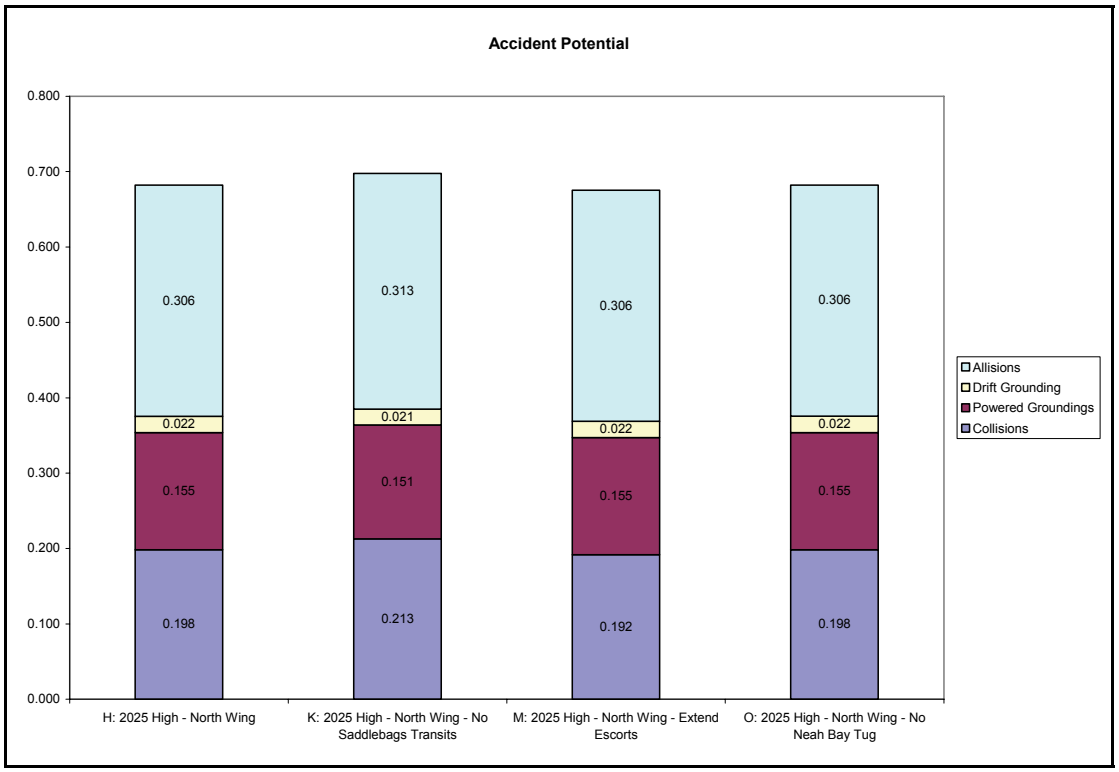


Figure 42. The accident potential by accident type for each intervention in 2025.

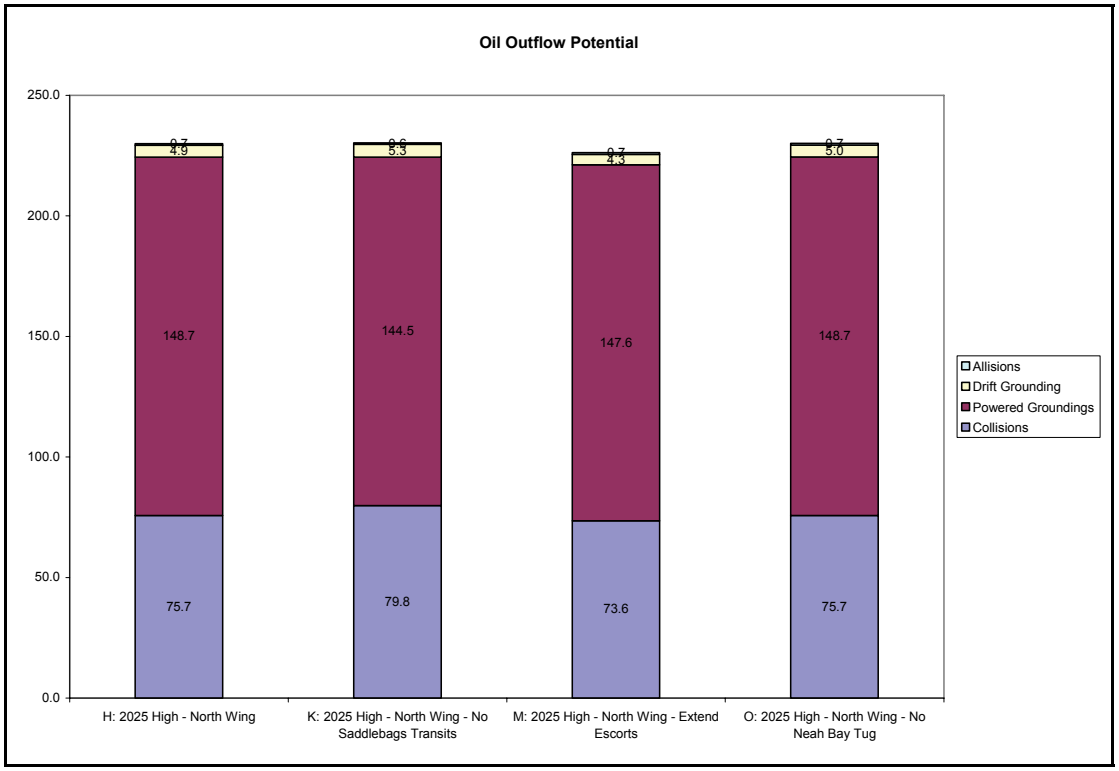


Figure 43. The oil outflow potential by accident type for each intervention in 2025.

It should be noted though that in case B a BP tanker is only diverted to Anacortes anchorage two times because the BP Cherry Point docks are full; the Cherry Point and Vendovi Island anchorages are used first. There are also very few transits between BP Cherry Point and the Shell and Tesoro docks at Anacortes. So this change does not affect many transits and, therefore, overall has a small affect. For this reason, we also assessed the affect in the high traffic scenario for 2025 to see if the difference is more pronounced at higher traffic levels. Case H is set at this traffic level and has tankers use the Saddlebags route; Case K is set at this traffic level and does not use the Saddlebags route. At these higher traffic levels, Figures 42 and 43 show that it is slightly better to use Saddlebags both in terms of accident potential and oil outflow, but this difference is still small, with a 2% decrease in accident potential and a 0.1% decrease in oil outflow. These small differences are not discernable on the geographic profiles either.

Let us now examine the concept of extending the escorting of tankers along the Straits of Juan de Fuca to Buoy J. The primary intent of a close escort by a tug is to save a tanker if it becomes disabled through total loss of either propulsion or steering. However, the crew of the escort tug also provides additional external vigilance of the tankers movements, meaning that collision and powered grounding potential is also affected. There is a limit though to the effect of extending escorts. Drift groundings only account for 3% of all accident potential in case B and drift groundings in this extended escort area only 0.1%. Oil outflow from drift groundings only account for 4% of all oil outflow potential and oil outflow from drift groundings in this extended escort area only 2%. Thus the effect that extending escort tugs through this area can have is limited in an overall sense, especially as even escort tugs do not reduce the risk of drift grounding to zero. In fact, extending the escorts reduces the drift grounding potential in the extended escort area by 17% and the oil outflow potential from drift groundings in this area by 25%. However, this corresponds to only a 1% reduction in drift grounding potential in the whole study area as there is much more drift grounding in other areas where the tankers transit closer to shore. There is a larger effect on a reduction of collision potential due to the external vigilance effect as there is more collision potential than drift grounding potential.

Overall, the effect of extending escorts is a 1.5% reduction in accident potential and a 3% reduction in oil outflow, hardly discernable in Figures 40 and 41. To give an idea of the highest reduction possible, if we assume that any time a laden tanker or ITB[9] is escorted in this area the chance of drift grounding is zero, then we would see the same 1.5% reduction in total accident potential and a 4% reduction in total oil outflow potential. At the high traffic scenario when we compare case H with the original escort system to case M with extended escorts in Figures 42 and 43, we see a 1% decrease in total accident potential and a 1.5% reduction in total oil outflow potential (with a highest possible reduction of 1% and 3%, respectively). Thus we see that drift grounding accident and oil outflow potential in the extended escorting area between Port Angeles and Buoy J is quite small compared to the total accident and oil outflow potential for the whole study area.

The final alternative to be examined is the Neah Bay tug. Before we examine this question for our cases, we must first point out the limited nature of our analysis of this problem. Firstly, the Neah Bay tug is not stationed just to assist BP tankers; it is also intended to assist non-BP tankers, bulk carriers, container vessels, and all other vessels. Secondly, our analysis has a strict geographic scope as shown in Figure 2. The Neah Bay tug can also assist vessels outside this area, along the Olympic coast and out to sea. Thus our results should be interpreted as only applying to BP vessels and only up to 8 miles outside Buoy J. Perhaps even more importantly, the VTRA geographic scope includes the area consisting of the approaches to and passages through the San Juan Islands and Anacortes, the Puget Sound North and South typically beyond the Neah Bay tug's operating range. Hence, if one combines this with our result that drift grounding in the extended escort area (only a portion of which is covered by the Neah Bay tug) constitutes only 0.1% of the total accident potential in case B, the effectiveness of the Neah Bay tug relative to the VTRA geographic scope and to the vessels within the VTRA scope is rather limited almost by definition.

In cases N and O, the Neah Bay tug is assumed to not be on standby. In all other cases, it is assumed to be on standby to assist a BP tanker in the case of total propulsion or steering

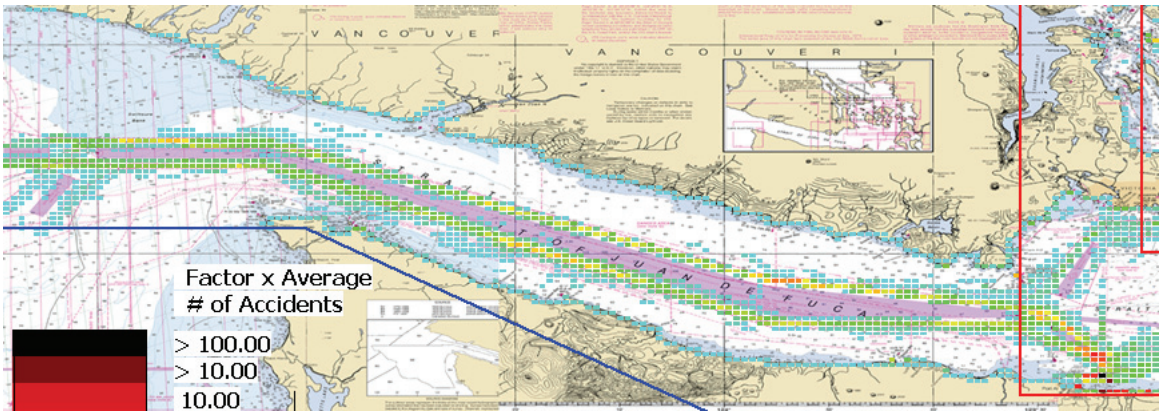
[9] Unladen tankers are not escorted, but still have some oil outflow potential as they carry fuel. ATBs are not escorted because they are smaller than the 40,000 DWT minimum for escorting.

loss. However, a standby tug is not the same as a close escort. There is no external vigilance effect as the tug is at Neah Bay, not transiting with the tanker; thus it does not affect the powered grounding or collision potential as the continuous escorting did in cases L and M. Furthermore, it cannot immediately attempt to attach a towing line to the tanker when it becomes disabled. It must transit to the tanker and has less time than a close escort to attempt a save. This also means that there is a more limited range from Neah Bay in which the tug will be able to assist a drifting vessel as compared to the extending escorting scheme of case L and M.

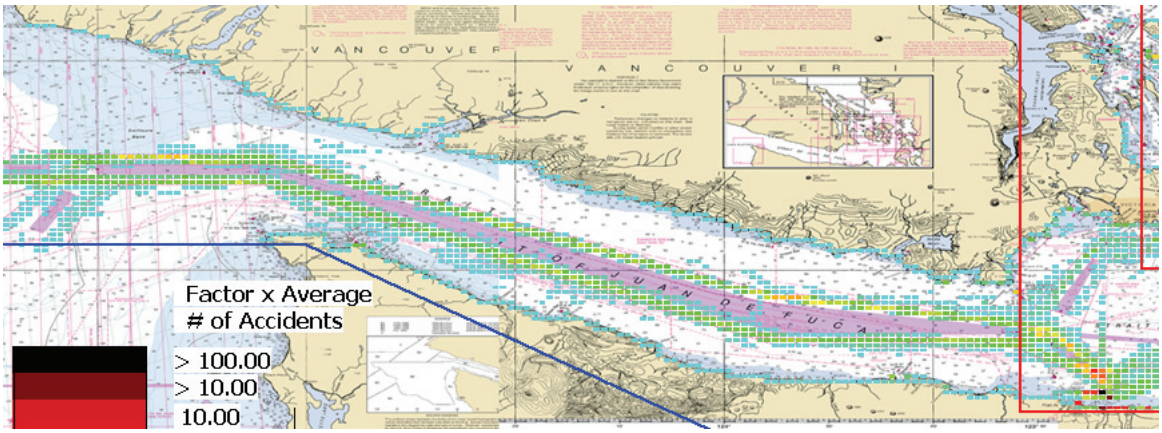
Comparing case B with the Neah Bay tug to case N without it at the 2005 traffic levels in Figures 40 and 41 and case H with the Neah Bay tug to case O without it at the high traffic scenario for 2025 in Figures 42 and 43, we see no appreciable difference in total accident potential or in total oil outflow potential for the entire VTRA study area. Again, we may test the highest possible effect of the Neah Bay tug, by assuming that if the Neah Bay tug can reach a drifting tanker, ATB, or ITB before it runs aground, then it will always save the vessel. With this assumption, we still only see a 0.03% reduction in total accident potential and a 0.8% reduction in total oil outflow potential over the entire VTRA study area. This should not be construed to mean that there could not be a significant effect of the Neah Bay tug outside our limited scope; there may be more effect for vessels outside our study area where they could drift for longer allowing the Neah Bay tug to reach them and perform a save; there could also be more effect for non-BP vessels. Finally, effectiveness analysis for the Neah Bay tug should be confined to its operating range. But for our limited scope in terms of vessels we were tasked to consider combined with the geographic scope of the VTRA study, we find that drift groundings that are within reach of the Neah Bay tug are not a major part of the total accident potential for the whole study area.

Similar conclusions can be drawn from the geographic profiles snapshots in Figure 44 and 45 where only in the middle figures an ever so slight lightening of color can be observed along the Olympia coast line and the traffic lanes.

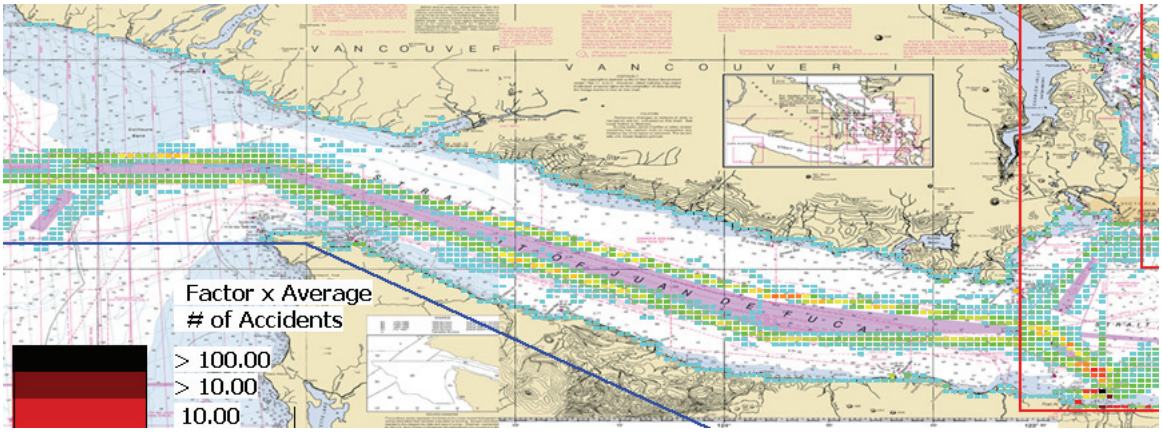
Accident Potential



Year 2005 without extended escorts, but with Neah Bay tug



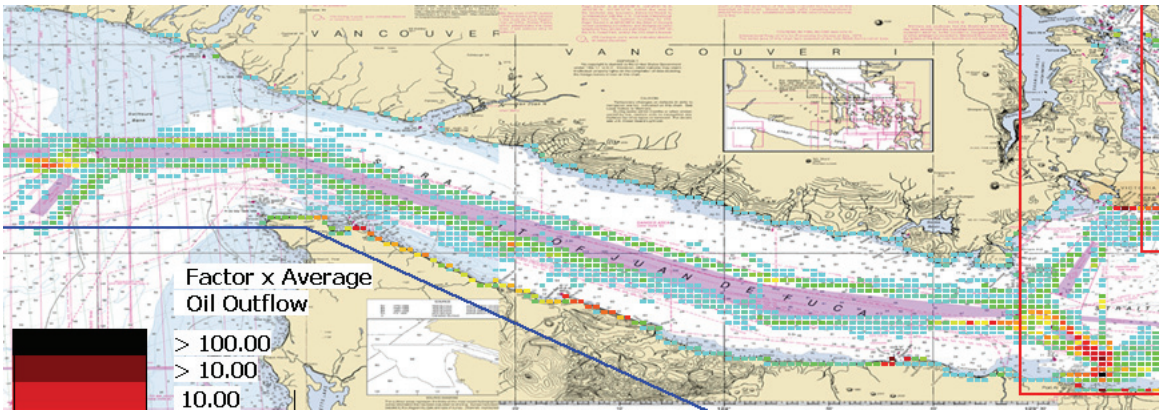
Year 2005 with extended escorts and Neah Bay tug



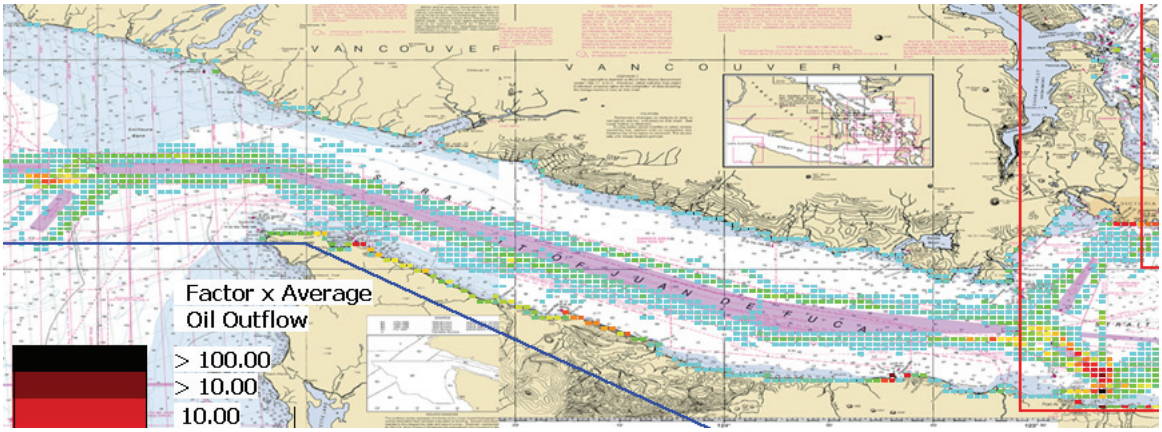
Year 2005 without extended escorts and without Neah Bay tug

Figure 44. Geographic profiles of accident potential with and without the Neah Bay tug and extended escorts.

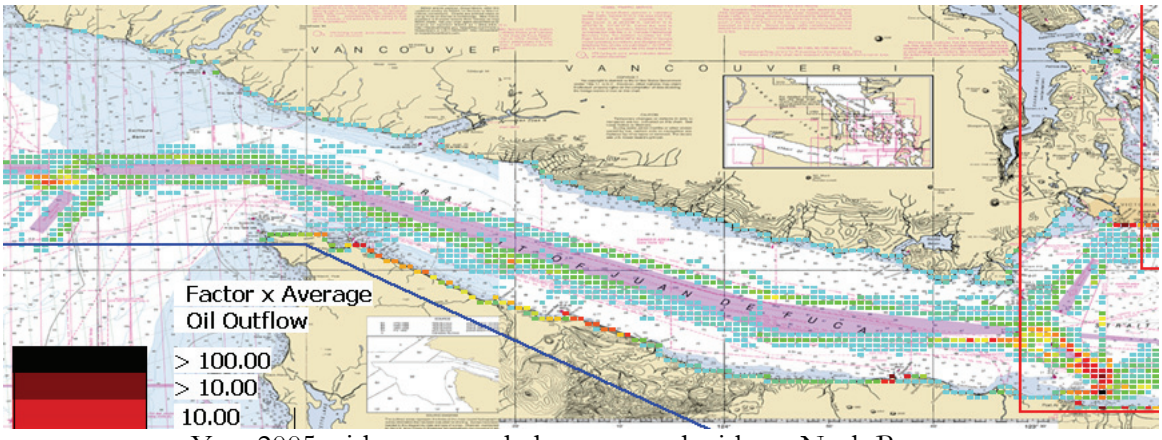
Oil Outflow Potential



Year 2005 without extended escorts, but with Neah Bay tug



Year 2005 with extended escorts and Neah Bay tug



Year 2005 without extended escorts and without Neah Bay tug

Figure 45. Geographic profiles of oil outflow potential with and without the Neah Bay tug and extended escorts.

6. Conclusions

Conclusions below pertain to accident frequencies of vessels that dock at BP Cherry Point. We refer to these vessels as BPCHPT vessels. Average annual accident frequencies have been analyzed for collisions, powered grounding, drift grounding and allisions. Conclusions are derived from the content of the main report and the technical appendices.

As per the VTRA scope, only oil outflow from BPCHPT vessels has been analyzed as well as the potential oil outflow from vessels that potentially collide with them. We refer to these later vessels as interacting vessels (IV). These oil outflows include BP persistent oil outflow (crude cargo oil and heavy fuel on board of BPCHPT vessels), BP non-persistent oil outflow (petroleum products and diesel fuel of BPCHPT vessels), IV persistent oil outflow (crude cargo oil and heavy fuel on board of IV's), IV non-persistent oil outflow (petroleum products and diesel fuel on board of IV's).

Below we provide conclusions than one may draw from our VTRA analysis results for our VTRA study area. They will be separated in four main categories. Firstly, we present conclusion regarding the risk profile of the 2005 analysis with the North Wing Dock present (which we consider to be our base case). Secondly, we discuss conclusions pertaining to a comparison of our 2000 and 2005 analysis. Thirdly, we present conclusions regarding our future scenario analysis and fourthly, we present conclusions regarding the risk intervention measures that were analyzed in this study as per our project scope.

The 2005 risk profile conclusions are further separated into system context, accident frequency and oil outflow conclusions for the entire VTRA study area. Separate accident frequency and oil outflow conclusions are also provided for an area inside and outside our largest red rectangular area as defined by, for example, Figure 28. This rectangular area approximately includes all of the areas East Strait of Juan de Fuca, Haro-Strait/Boundary pass, Rosario Strait, Cherry Point, Guemes Channel and Saddle Bag as defined by Figure 2 in this report. This rectangular area excludes approximately all of the areas West Strait of Juan de Fuca, Puget Sound North and Puget Sound South as defined by Figure 2 in this report.

2005 analysis system context conclusions - north wing operational:

- Of the total annual simulated traffic, the BP CHPT vessel traffic constitutes 1.1%. Vessels docking at the BP Cherry Point are tankers, articulated tug barges (ATB's) and integrated tug barges (ITB's).
- Of the total annual simulated traffic, all tankers, ATB's and ITB's constitute 3%.
- Of the total annual simulated deep draft traffic, the BP CHPT vessel traffic constitutes 7%.
- Of the total simulated deep draft traffic, all tankers, ATB's and ITB's constitute 16%.

2005 analysis aggregate VTRA study area conclusions - north wing operational:

- Of the total annual average accident frequency of 4/11, 1/11 (25%) to collisions, 0.079 (21.8%) can be attributed to powered groundings, 0.012 (3.2%) to drift groundings and 2/11 (50%) to allisions.
- Of the total annual average accident frequency of 4/11, about 0.320 (88%) can be attributed to the area inside our largest red square of our geographic profiles results.
- Of the total annual average oil outflow of 141.0 cubic meters analyzed, 47.0 (33.2%) to collisions, 87.3 (62%) can be attributed to powered groundings, 5.5 (3.9%) to drift groundings and 1.2 (0.9%) to allisions.
- Of the total annual average oil outflow of 141.0 cubic meters analyzed, about 92% can be attributed to the area inside our largest red square of our geographic profiles results.
- Of the total annual average oil outflow of 141.0 cubic meters analyzed, 137.4 cubic meters (97.5%) originated from BP Cherry Point vessels and 3.6 cubic meters (2.5%) from IV's. IV's include tank vessels that do not dock at Cherry Point. Hence, we may cautiously infer that of the total annual average oil outflow that we analyzed for VTRA CASE B only a small percentage can be attributed to diesel fuel of heavy fuel losses and the dominant part results from cargo losses.

2005 analysis conclusions inside largest rectangular area[10,11] - north wing operational

- Of the total annual average accident frequency of about 0.320 (88%) for this area, about 0.066 (18.2%) can be attributed to collisions, about 0.074 (20.3%) to powered groundings, about 0.011 (3.0%) cubic meters to drift groundings and about 0.169 (46.5%) to allisions.
- Of the total annual average oil outflow of about 130 (92%) cubic meters analyzed for this area, about 85.5 (61%) can be attributed to powered groundings, about 40.9 (29%) to collisions, about 3.2 (2%) to drift groundings and about 1.2 (1%) to allisions.
- Of the total annual average oil outflow of about 130 (92%) cubic meters analyzed, 127 cubic meters (90.1%) originated from BP Cherry Point vessels and 3 cubic meters (1.9%) from IV's. IV's include tank vessels that do not dock at Cherry Point.

2005 analysis conclusions outside largest rectangular area[12 13] - north wing operational

- Of the total annual average accident frequency of 0.044 (12%) for this area, 0.025 (6.7%) can be attributed to collisions, 0.006 (1.5%) to powered groundings, 0.001 (0.3%) to drift groundings and 0.013 (3.5%) to allisions.
- Of the total annual average oil outflow of about 11 (8%) cubic meters analyzed for this area, about 7 (4.8%) can be attributed collisions, 1.9 (1.4%) to powered groundings, 2.6 (1.9%) to drift groundings and almost 0 (0.0%) to allisions.
- Of the total annual average oil outflow of about 11 (8%) cubic meters analyzed for this area, 10 cubic meters (7.4%) originated from BP Cherry Point vessels and 1 cubic meters (0.6%) from IV's. IV's include tank vessels that do not dock at Cherry Point.

[10] Percentages of accident frequencies are of the total annual average accident frequency of 4/11 per year.

[11] Percentages of oil outflow are of the total annual average oil outflow of 141.0 cubic meters.

[12] Percentages of accident frequencies are of the total annual average accident frequency of 4/11 per year.

[13] Percentages of oil outflow are of the total annual average oil outflow of 141.0 cubic meters.

2000-2005 comparison conclusions derived from VTRA analysis results:

- If BP had restricted operations to the south wing in 2005, it could have served 96% of the BPCHPT vessels in 2005 actually served by both wings.
- In a 2005-2005 comparison, the addition of the north wing allowed the BP Cherry Point terminal to serve slightly more calling vessels, while reducing the potential for BPCHPT vessel accidents by 21% and decreasing oil outflows by 38%[14].
- With the north wing in operation in 2005 (but not in 2000), the potential for accidents involving BPCHPT vessels decreased by 10% between 2000 and 2005, and the oil outflow potential decreased by 21% between 2000 and 2005 in spite of the changes in vessel traffic during the same period.
- With only the south wing in operation in both 2000 and 2005, the potential for accidents involving BPCHPT vessels would have increased by 12% between 2000 and 2005 and the potential outflows would have increased by 18% between 2000 and 2005.

2000-2025 analysis conclusions derived from VTRA analysis results:

- At each of the low, medium, and high traffic scenarios for 2025, having the north wing leads to lower average accident potential and oil outflow potential for BPCHPT vessels than not having it.
- Assuming the north wing being operational in a 2025 analysis with medium traffic increases, results in a total annual average oil outflow of 174.4 cubic meters, which is quite similar to the 177.7 cubic meters of the previous 2000 analysis when the dock was not operational (but a reduction of 1.8%).
- Assuming the north wing being operational in a 2025 analysis with high traffic increases, results in a total annual average oil outflow of 229.9 cubic meters, compared to the 177.7 cubic meters of the same 2000 analysis when the dock was not present (an increase of 29.4%).

[14] For consistency percentages are evaluated here as percentages of 2000 levels.

- Hence, with additional traffic increases it remains possible that even with the addition of the north wing dock, oil transportation risk rises above a level previously experienced in 2000 when the north wing dock was not operational.

Risk intervention conclusions derived from VTRA analysis results:

- At the 2005 traffic levels, and not allowing the use of the Saddlebags route from BP Cherry Point to Anacortes in our maritime risk simulation model, leads to no appreciable change in either average accident potential or average oil outflow potential. In the high traffic scenario for 2025, not allowing the use of the Saddlebags route from BP Cherry Point to Anacortes in our maritime risk simulation leads to a 2% increase in average accident potential and a 0.1% increase in average oil outflow.
- At the 2005 traffic levels, extending the escorting of BP tankers and ITBs up to Buoy J in our maritime risk simulation model, leads to a decrease in both drift groundings and collisions in the extended escorting area. The overall effect is a 1.5% decrease in total average accident potential and a 3% decrease in total average oil outflow potential. In the high traffic scenario for 2025, these decreases are 1% and 1.5%, respectively.
- A restricted analysis of the risk reduction potential of the Neah Bay Tug, considering only BP tankers (about 1.1% of the total modeled traffic and about 7% of the total modeled deep draft traffic) within the VTRA study area (i.e. up to 8 miles of Buoy J where traffic separation commences and, more importantly, <u>including</u> the area consisting of the approaches to and passages through the San Juan Islands and Anacortes typically beyond the Neah Bay tug's operating range) our maritime risk simulation model evaluated that the Neah Bay tug has no appreciable effect on total VTRA study area average accident potential and reduces its total average oil outflow potential by 0.1%.

- In the restricted analysis performed, and assuming the Neah Bay tug has the capability to save any disabled[15] BPCHPT vessel that it could get to in time, regardless of the situational context, it was shown that the Neah Bay tug could reduce total average VTRA study area accident potential by 0.03% and total average VTRA study area oil outflow potential by 0.75%.

Quantitative results in our study are presented as average point estimates commonly used for the evaluation of alternatives in a decision analysis context. These are derived from uncertain quantities as described in each step of the analysis as described in this report and its technical appendices. As with any risk assessment model, our model too represents an abstraction of reality and its results must be interpreted with care and with awareness of scoping, data limitations and modeling assumptions. In particular, the forecasts of maritime traffic, accident frequencies, and oil outflows in 2025 must be treated with care.

One primary limitation of the VTRA study is that, due to scoping constraints, the results reflect only on a small percentage (1.1%) of the vessel traffic described in the maritime simulation. If risk interventions have an appreciable effect beyond the BPCHPT vessels analyzed in this study, they should also be tested against this larger class of vessels to determine their effects on system wide accident frequencies and oil outflows. For example, a risk intervention that reduces accident frequency and or oil outflow of BP Cherry Point vessels, but results in a larger potential increase of accident frequency and/or oil outflows from the other traffic should not be implemented. Conversely, risk mitigation measures that have little or no impact on the BP Cherry Point vessels accident frequency or oil outflow may in fact significantly reduce risk to other vessels.

As such, a full evaluation of the risk reduction potential of the Neah Bay tug was not within the scope of the VTRA, as the analysis was restricted to BPCHPT vessels in the VTRA geographic scope. A full evaluation of the risk reduction potential of the Neah Bay tug requires (1) inclusion of all non-BP vessel traffic within the VTRA study area in its

[15] Our definition of a disabled BPCHPT vessel here is one that experienced either a steering or propulsion failure.

effectiveness analysis and (2) inclusion of all vessel traffic beyond the boundaries of our VTRA study area (i.e. beyond the beginning of the Traffic Separation Scheme approximately 8 nautical miles beyond Buoy J offshore of Cape Flattery), but both limited to the tug's operating range. Neither was part of the scope of the VTRA study.

REFERENCES

M. Grabowski, J.R.W. Merrick , J.R. Harrald, T.A. Mazzuchi, and J.R. van Dorp (2000).“Risk Modeling in Distributed, Large Scale Systems”, *IEEE Transactions on Systems, Man, Cybernetics – PART A: Systems and Humans*, Vol. 30, No. 6, pp. 651-660.

J.R.W. Merrick, J.R. van Dorp, J.P. Blackford, G.L. Shaw, T.A. Mazzuchi and J.R. Harrald (2003). "A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model", *Reliability Engineering and System Safety*, Vol. 81 (2): pp. 119-132.

J.R.W. Merrick, J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn and M. Grabowski (2002). "The Prince William Sound Risk Assessment". *Interfaces*, Vol. 32 (6): pp.25-40.

National Research Council (2001). *Environmental Performance of Tanker Designs in Collision and Grounding*, Special Report 259, Marine Board, Transportation Research Board, The National Academies.

R. Sanderson (1982). *Meteorology at Sea*. Stanford Maritime Limited.

P. Szwed, J. R. van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). "A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information", *European Journal of Operations Research*, Vol. 169 (1): pp. 157-177.

J.R. van Dorp, J.R.W. Merrick , J.R. Harrald, T.A. Mazzuchi, and M. Grabowski (2001). "A Risk Management procedure for the Washington State Ferries", *Journal of Risk Analysis*, Vol. 21 (1): pp. 127-142.

SUB-APPENDIX:

J.R.W. Merrick, J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn and M. Grabowski (2002). "The Prince William Sound Risk Assessment". *Interfaces*, Vol. 32 (6): pp. 25-40.

The Prince William Sound Risk Assessment

Jason R. W. Merrick
Department of Statistical Sciences and Operations Research, Virginia Commonwealth University, PO Box 843083, 1001 West Main Street, Richmond, Virginia 23284

J. René van Dorp • Thomas Mazzuchi • John R. Harrald • John E. Spahn
Department of Engineering Management and Systems Engineering, George Washington University, 1776 G Street NW, Suite 110, Washington, DC 20052

Martha Grabowski
Business Department, Le Moyne College, and Department of Decision Sciences and Engineering Systems, Rensselaer Polytechnic Institute, 5555 Mount Pleasant Drive, Cazenovia, New York 13035
jrmerric@vcu.edu • dorpjr@seas.gwu.edu • mazzuchi@seas.gwu.edu • harrald@seas.gwu.edu • grabowsk@lemoyne.edu

This paper was refereed.

After the grounding of the Exxon Valdez and its subsequent oil spill, all parties with interests in Prince William Sound (PWS) were eager to prevent another major pollution event. While they implemented several measures to reduce the risk of an oil spill, the stakeholders disagreed about the effectiveness of these measures and the potential effectiveness of further proposed measures. They formed a steering committee to represent all the major stakeholders in the oil industry, in the government, in local industry, and among the local citizens. The steering committee hired a consultant team, which created a detailed model of the PWS system, integrating system simulation, data analysis, and expert judgment. The model was capable of assessing the current risk of accidents involving oil tankers operating in the PWS and of evaluating measures aimed at reducing this risk. The risk model showed that actions taken prior to the study had reduced the risk of oil spill by 75 percent, and it identified measures estimated to reduce the accident frequency by an additional 68 percent, including improving the safety-management systems of the oil companies and stationing an enhanced-capability tug, called the Gulf Service, at Hinchinbrook Entrance. In all, various stakeholders made multimillion dollar investments to reduce the risk of further oil spills based on the results of the risk assessment.
(*Decision analysis: risk. Industries: petroleum, transportation. Reliability: system safety.*)

On March 24, 1989, the Exxon Valdez ran aground on Bligh Reef, spilling an estimated 11 million gallons of crude oil into Prince William Sound, Alaska. The oil spill (Figure 1) spread rapidly, affecting more than 1,500 miles of shoreline. The spill had both immediate and lingering effects on fish and wildlife resources and on the lives of people in coastal communities. The cost to Exxon Corporation for cleanup operations was estimated to be $2.2 billion (Harrald et al. 1990).

After the accident, all parties with interests in Prince William Sound (PWS) agreed to work to prevent such an event from happening again. They implemented several ideas for reducing the risk of an oil spill. They introduced weather-based closure restrictions that stopped all transits through Valdez Narrows and Hinchinbrook Entrance (Figure 2) during periods of high winds. The US Coast Guard designated Valdez Narrows a special navigation zone by restricting passage through the narrows to one way for deep-draft traffic, including oil tankers. The oil companies introduced escort tugs to accompany oil-laden tankers in their

0092-2102/02/3206/0025$05.00
1526-551X electronic ISSN

Figure 1: The stricken Exxon Valdez spilled oil into Prince William Sound, Alaska, affecting over 1,500 miles of shoreline.

transit out of PWS. These tugs were to assist a tanker if it had propulsion or steering failures, attaching lines to the disabled tanker and holding it fast, thus preventing grounding accidents. The Oil Pollution Act (1990) stated that two escort tugs should accompany each oil-laden tanker; depending on the wind conditions and the size of the tanker, three tugs were sometimes used.

In early 1995, questions arose concerning the effectiveness and benefits of existing and proposed risk-intervention measures. The PWS shipping companies (ARCO Marine Inc., BP Oil Shipping Company, USA, Chevron Shipping Company, SeaRiver Maritime Inc., and Tesoro Alaska Petroleum Company) concluded that they needed a comprehensive risk assessment to evaluate all proposals. They formed a steering committee along with the PWS Regional Citizens Advisory Committee (RCAC) ⟨http://www.pwsrcac.org⟩, the Alaska Department of Environmental Conservation (ADEC) ⟨http://www.state.ak.us/dec/⟩, and the US Coast Guard (USCG). The members consisted of presidents of oil-shipping companies, local fisherman and environmentalists representing the RCAC, senior representatives of ADEC, and the USCG captain of the port for Valdez. Although the members of the group had different perspectives on the operation of the oil-transportation system, the committee captured the substantive expertise of the PWS oil-transportation and ecosystem.

By forming the steering committee, the PWS community formalized its preference for a collaborative analysis approach rather than an adversarial one (Charnley 2000). Up to this point, the adversarial approach had prevailed in PWS risk and safety studies, pitting expert against expert. The adversarial approach often leads to a lack of trust in the decision-making process and subsequently may hamper the implementation of regulations and procedures aimed at reducing risk. Many see lack of trust as the major reason for the failure of sophisticated technological risk assessments to influence public policy in the nuclear-power arena (Slovic 1993).

The steering committee decided to fund a risk-assessment effort for the PWS oil-transportation system and engaged a consultant team from George Washington University (GWU), Rennselaer Polytechnic Institute (RPI), and Det Norske Veritas (DNV). The committee stipulated the objectives of the risk-assessment effort:

—to identify and evaluate the risks of oil transportation in PWS,

—to identify, evaluate, and rank proposed risk-reduction measures, and

—to develop a risk-management plan and risk-management tools that could be used to support a risk-management program.

In this paper, we present an overview of the modeling and analysis we used in addressing the first two objectives and discuss the effect of the analysis on the third objective and the implementation of the recommendations.

Risk Assessment and Management in Maritime Transportation

The National Research Council identified the assessment and management of risk in maritime transportation as an important problem domain (NRC 1986, 1991, 1994, 2000). In earlier work, researchers concentrated on assessing the safety of individual vessels or marine structures, such as nuclear-powered vessels (Pravda and Lightner 1966), vessels transporting liquefied natural gas (Stiehl 1977), and offshore oil and gas platforms (Paté-Cornell 1990). The USCG tried to

prioritize federal spending to improve port infrastructures using a classical statistical analysis of nationwide accident data (USCG 1973, Maio et al. 1991). More recently, researchers have used probabilistic risk assessment (PRA) (US Nuclear Regulatory Commission 1975) in the maritime domain (Hara and Nakamura 1995, Roeleven et al. 1995, Kite-Powell et al. 1996, Slob 1998, Fowler and Sorgard 2000, Trbojevic and Carr 2000, Wang 2000, Guedes Soares and Teixeira 2001) by examining risk in the context of maritime transportation systems (NRC 2000).

In a maritime transportation system (MTS), traffic patterns change over time in a complex manner. Researchers have used system simulation as a modeling tool to assess MTS service levels (Andrews et al. 1996), to perform logistical analysis (Golkar et al. 1998), and to facilitate the design of ports (Ryan 1998). The dynamic nature of traffic patterns and other situational variables, such as wind, visibility, and ice conditions, mean that risk levels change over time. The PWS risk assessment differs from previous maritime risk assessments in capturing the dynamic nature of risk by integrating system simulation (Banks et al. 2000) with available techniques in the field of probabilistic risk assessment (Bedford and Cooke 2001) and expert judgment elicitation (Cooke 1991).

Defining Risk

Lowrance (1976) defined risk as a measure of the probability and severity of the consequences of undesirable events. In the PWS risk assessment, we defined the undesirable events to be accidents involving oil tankers, specifically the following:

—Collisions: An underway tanker colliding with or striking another underway vessel as a result of human error or mechanical failure and lack of vigilance (intervessel collision) or striking a floating object, for example, ice;

—Drift groundings: A drifting tanker out of control because of a propulsion or steering failure making contact with the shore or bottom;

—Powered groundings: An underway tanker under power making contact with the shore or bottom because of navigational error or steering failure and lack of vigilance;

—Foundering: A tanker sinking because of water ingress or loss of stability;

—Fire or explosion: A fire occurring in the machinery, hotel, navigational, or cargo space of a tanker or an explosion occurring in the machinery or cargo spaces; and

—Structural failure: The hull or frame cracking or eroding seriously enough to affect the structural integrity of the tanker.

The consequence of interest was oil outflow into PWS. The initial measure the steering committee wanted was the expected volume of oil outflow per year for each accident type and specified locations. However, after further discussion, it decided that any accident involving an oil tanker was an undesirable event, and thus the focus shifted to the expected number of accidents per year again broken down by accident type and location. We defined boundaries for seven locations to use in the study (Figure 2).

The basic technique used in the PWS risk assessment is probabilistic risk analysis (PRA) (Bedford and Cooke 2001). In performing a PRA, one identifies the series of events leading to an accident, estimates the probabilities of these events, and evaluates the consequences of the accident. Garrick (1984) noted that an accident is not a single event but the culmination of a series of events. A triggering incident is defined to be the immediate precursor of an accident. In the PWS risk assessment, we separated triggering incidents into mechanical failures and human errors. The mechanical failures considered to be triggering incidents were propulsion failures, steering failures, electrical power failures, and hull failures. The classifications of human errors used were diminished ability; hazardous shipboard environment; lack of knowledge, skills, or experience; poor management practices; and faulty perceptions or understanding. We based these on current USCG classifications.

We constructed an accident probability model using the relationships between the vessel's operating environment, triggering incidents, and accidents (Roeleven et al. 1995). The combination of organizational and situational factors that describes the state of the system in which an accident may occur is termed an opportunity for incident (OFI). We based our accident model on the following conditional probabilities:

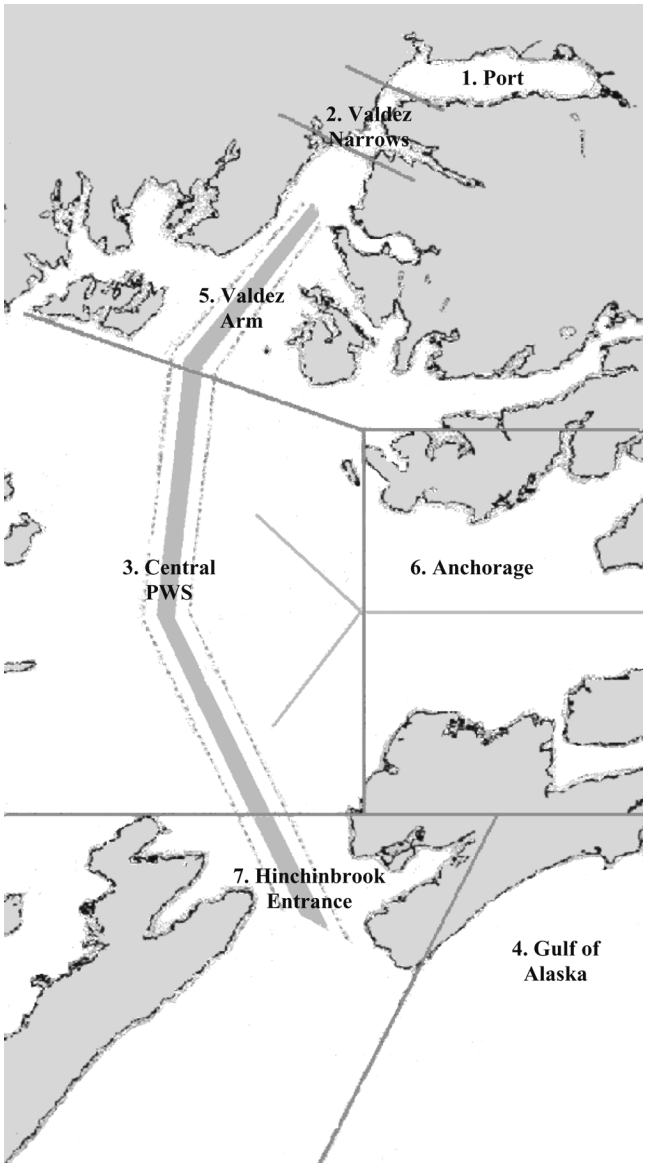


Figure 2: We divided Prince William Sound into seven locations for reporting risk.

—P(OFI): the probability that a particular system state occurs,

—P(Incident | OFI): the probability that a triggering incident occurs in this system state, and

—P(Accident | Incident, OFI): the probability that an accident occurs given that a triggering incident has occurred in this system state.

Once one has specified these probabilities, one can find the probability of an accident occurring in the system by summing the product of the conditional probabilities over all types of accidents and triggering incidents and all combinations of organizational and situational factors according to the law of total probability. Thus to perform an assessment of the risk of an accident using this model, one must determine an operational definition of an OFI and then estimate each of the terms in the probability model. Harrald et al. (1998) discuss the operational definition of an OFI in the PWS risk assessment.

The System Risk-Simulation Model

The first term to estimate is the frequency of occurrence of each combination of organizational or situational factors, that is, each OFI. Although data is collected on vessel arrivals and environmental conditions, the combinations of these events are not. Traffic rules, such as a one-way zone, mean that the movements of vessels are dependent, while weather-based closure restrictions cause dependence between vessel movements and environmental conditions. A discrete-event simulation of the system captures the complex dynamic nature of the system and accurately models the interactions between the vessels and their environment.

We created the simulation model using operational data, such as vessel-type and vessel-movement data from the USCG vessel traffic service, tanker arrival and departure information from the ship escort/response vessel system (SERVS), and publicly available data, such as meteorological data from the National Oceanographic and Atmospheric Administration weather buoys. More difficult to obtain were data on open fishing times, locations, and durations, which required local community surveys. Based on the data, we developed traffic-arrival models and weather models. In addition, because all deep-draft vessels transiting PWS must participate in the USCG vessel traffic service and follow a defined set of traffic rules, such as weather-based closure restrictions, one-way zones, the tug escort scheme, and docking procedures, we programmed these rules into the simulation.

We used the simulation as an event counter, that is,

Location	Central Sound	Likelihood of Collision		Location
Traffic proximity	Vessels 2 to 10 miles	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9		Traffic proximity
Traffic type	Tug with tow			Traffic type
Tanker size and direction	Inbound more than 150DWT			Tanker size and direction
Escort vessels	Two or more			Escort vessels
Wind speed	More than 45			Wind speed
Wind direction	Perpendicular/On shore			Wind direction
Visibility	Greater than 1/2 mile			Visibility
Ice conditions	Bergy bits within a mile		No bergy bits in a mile	Ice conditions

Table 1: We elicited judgments from the substantive experts using pairwise comparison questionnaires in which we defined a given scenario and varied only one attribute, in this example changing whether there is ice in the traffic lanes.

we used it to count the number of occurrences of individual OFIs throughout PWS for a given time period. The simulation calculated the state of the system once every five minutes based upon the traffic arrivals, the weather, and the previous state of the system. We ran the simulation for 25-years of simulation time and, for each five-minute period, tabulated the OFIs that occurred, and thus determined OFI frequencies (Merrick et al. 2000).

We estimated the two levels of conditional probability of triggering incidents and accidents. The preferred method for estimating these probabilities is through data. The steering committee required that we use only PWS specific data in the risk assessment, rather than worldwide accident data that might not be representative. Each of the PWS shipping companies supplied proprietary mechanical-failure data. However, at the time we could obtain no reliable PWS human-error data in the maritime domain, and we could obtain very little from near-miss reports (Harrald et al. 1998). Large databases of local accident data were not available for standard statistical analysis of the organizational and situational factors that could affect risk. Cooke (1991) cites the use of expert judgment in areas as diverse as aerospace programs, military intelligence, nuclear engineering, and weather forecasting. We used expert judgment to assess relative conditional probabilities and data to calibrate these relative probabilities.

Using the log-linear accident probability model (Roeleven et al. 1995), we obtained relative conditional probabilities through a regression analysis of pairwise comparison surveys (Bradley and Terry 1952) constructed for the pilots, captains, and chief engineers with operational experience in PWS. PWS oil-shipping companies, SERVS, and regional representatives on the PWS steering committee made these substantive experts available for elicitation sessions. An example of the type of questions posed is the following taken from the expert-judgment questionnaire for collisions given that a propulsion failure has occurred (Table 1). In each situation, there is an inbound tanker, greater than 150,000 DWT in size, which has just experienced a propulsion failure. It is within two to 10 miles of a tug with tow in winds over 45 MPH blowing on shore to the closest shore point with visibility greater than half a mile in Central PWS. The only difference between the two situations is that the first situation includes an ice flow in the traffic lane, while the second does not. We ask the expert to picture the two situations, to determine which situation is more likely to result in a collision, and to indicate his or her sense of magnitude in the choice through a nine-point scale, with one indicating equally likely (Saaty 1977).

For each question, we changed only one attribute so that the experts could estimate the difference in risk between the two situations. The experts could answer a book of 120 questions in one to one-and-a-half hours. We put the questions in the books in random order and statistically tested the results to ensure nonrandom responses and to minimize response bias. All participants had very extensive knowledge with at least 20 years of experience at sea. We treated the expert responses as ratios of the probabilities of an accident

in each scenario. We estimated the parameters of the accident probability model using statistical regression and calibrated the model to available data. The *Prince William Sound Risk Assessment Study Final Report* (PWS Steering Committee 1996) contains specific details of the development of the simulation model, the design and analysis of the expert-judgment questionnaires, and the integration of the simulation model and the accident probability model.

The integrated system risk-simulation model was capable of assessing the current risk of accidents involving oil tankers operating in PWS and of evaluating risk-intervention measures. We also implemented an oil-outflow model, created by DNV, in the system risk-simulation program. The program displayed risk in PWS dynamically (Figure 3) and we could interrogate it to determine the expected frequencies of accidents or the expected oil outflow per year broken down by accident type, location, and any of the organizational or situational factors.

Results of the Risk Assessment

The steering committee's first objective was to identify and evaluate the risks of oil transportation in PWS. We chose accident scenarios as the method of reporting, defining an accident scenario to be an accident type in a given location. We programmed the simulation to represent the shipping fleet, traffic rules, and operating procedures in place in 1996, the year we performed the study. We ran the simulation program for 25 years (simulation time) and estimated the expected frequency of accidents. We broke the frequencies down by location and accident type to obtain the accident-scenario results. As the primary interest was accident scenarios with the highest expected frequencies, we reported the results by sorting the accident scenarios from highest to lowest (Figure 4).

Before the risk assessment, people in PWS commonly believed that the most likely accident scenario was a drift or powered grounding in the Valdez Narrows or Hinchinbrook Entrance. However, we showed that the first seven accident scenarios accounted for 80 percent of the total expected frequency of accidents, with 60 percent coming from collisions in the port, in the Valdez Narrows, and in the Valdez Arm. We performed a further analysis to find the primary cause of these accidents. We found that the primary risk was collisions with fishing vessels that operate in large numbers in these locations during fishing openers. Although they introduce a relatively high risk of collision, few fishing vessels are large enough to penetrate the hull of a tanker. Thus the expected oil outflow from these events was low. The perceived high-risk scenarios of drift or powered groundings contributed approximately 15 percent of the expected frequency of accidents.

Integrating the oil-outflow model with the estimated frequencies of accident scenarios allowed us to estimate the expected volume of oil outflow as a measure of risk, again reported from highest to lowest (Figure 5). We discovered a surprising result using this metric. Potential collisions of outbound tankers with inbound SERVS' tugs (returning from escort duty) are a large contributor to the total expected oil outflow. Escort tugs leaving port with a tanker are intended to save the tanker in case of a propulsion or steering failure, but on their return from escort they introduce a risk of collision and can cause enough damage to tankers to spill oil. Less suprising, however, was the confirmation of the risk of drift or powered groundings in the Valdez Narrows or Hinchinbrook Entrance.

The steering committee's second objective was to identify, evaluate, and rank proposed risk-intervention measures. We developed a set of risk-intervention measures for evaluation in consultation with the PWS steering committee. We classified risk-interventions in terms of their effect on modeling parameters and analyzed them accordingly. The modeling required was extensive, but because of the level of granularity incorporated in the system risk-simulation model, we could change parameters of the accident probability model or simulation code to reflect the effects of risk-intervention measures. By stripping away previously implemented risk-intervention measures, we estimated the risk prior to the Exxon Valdez accident. Comparing this risk to the baseline case, representing the PWS system during the study period, we estimated that the accident frequency had been reduced 75 percent since the Exxon Valdez accident.

We identified further effective risk-intervention mea-

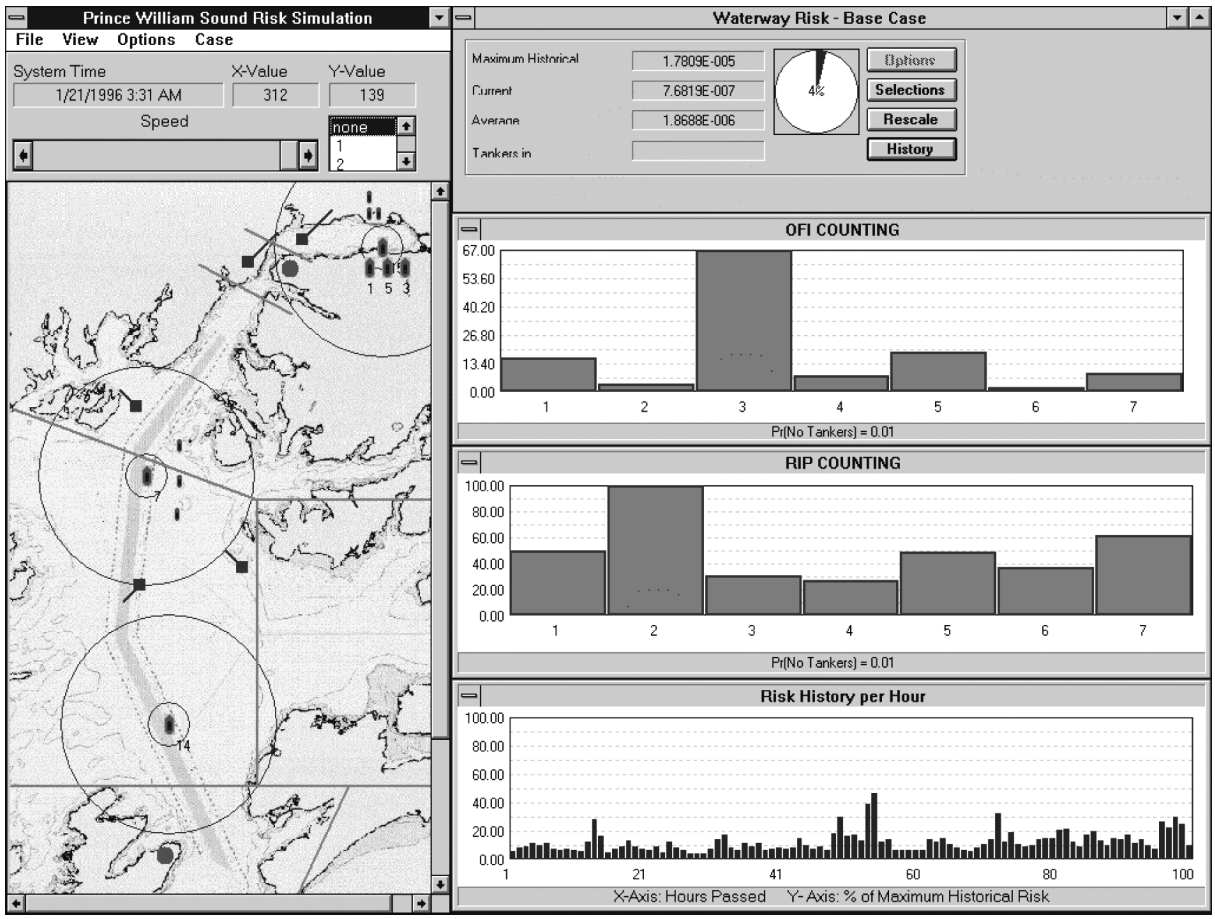


Figure 3: We created the system risk-simulation program to perform the analysis and demonstrate the results to the steering committee. On the left is a display of the dynamic behavior of the Prince William Sound marine transportation system including traffic patterns and environmental conditions, such as wind speed and direction. On the right, the analysis shown is broken into seven locations (Figure 2), with estimates of the probability of an opportunity for an incident, the probability of an accident given such an opportunity, and finally the dynamic variation in the expected frequency of accidents for the whole region.

sures (Figure 6). Under the current system, interactions with fishing vessels and escort tugs were significant contributors to the overall risk. We developed rules to reduce the number of these interactions in cooperation with the steering committee and programmed them into the simulation. We demonstrated that modifying the escort scheme to reduce interactions with tankers and managing the interactions of fishing vessels and tankers led to a major reduction in risk. The model also indicated that improving human and organizational performance through the International Safety Management (ISM) program would further reduce risk. We estimated the reduction in risk obtained by reducing the frequency of human errors in the accident probability model, with the reduction being estimated by personnel from DNV with experience in implementing the ISM program. We showed that some proposed risk-intervention measures increase risk, for example, we showed that additional weather-based closure restrictions would increase traffic congestion.

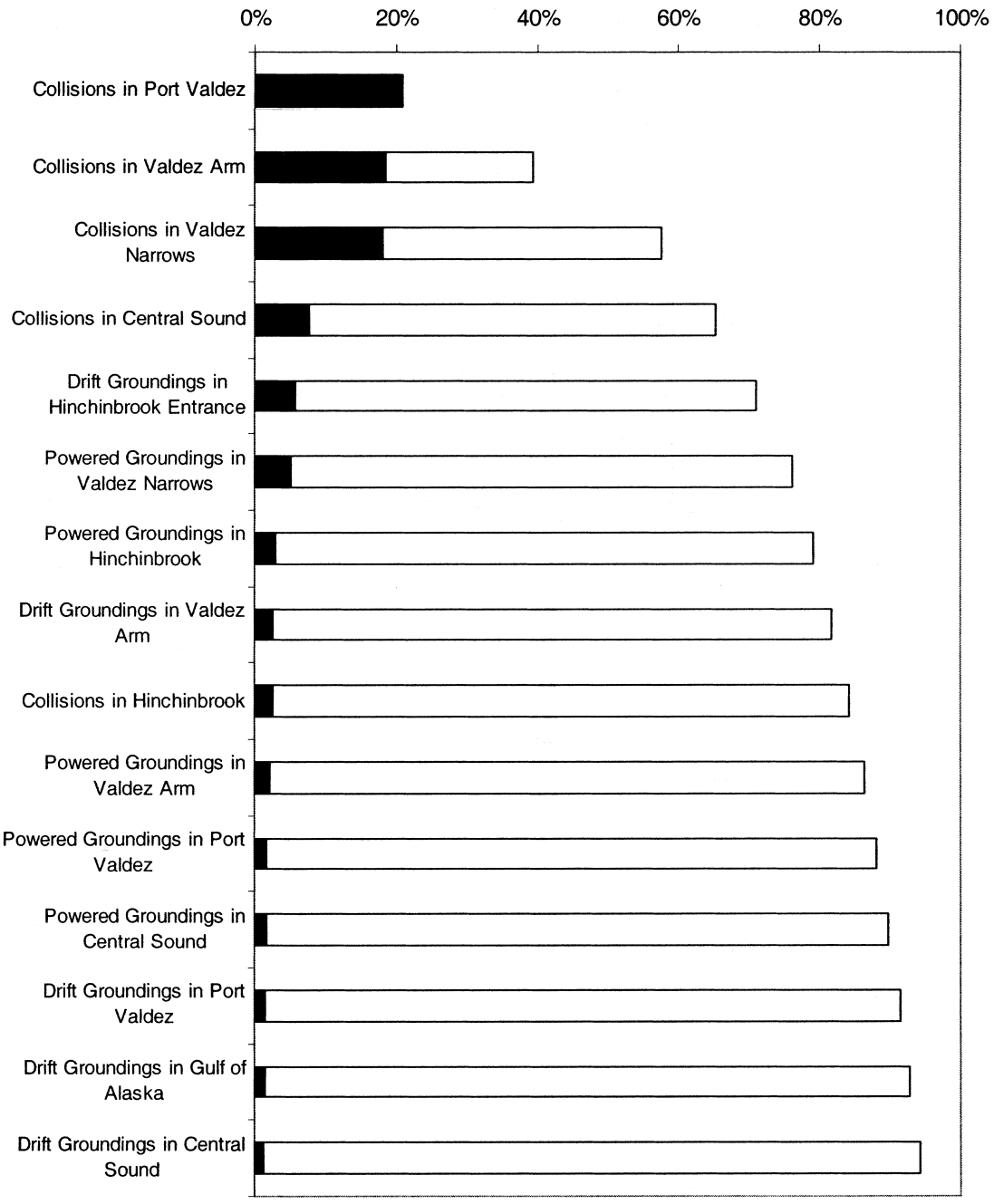


Figure 4: We sorted the combinations of accident types and locations by their expected frequency (dark bars). The cumulative percentage of the total expected frequency up to each such combination (white bars) is indicated by the total height of each bar. For example, we found that the first seven accident scenarios account for 80 percent of the total expected frequency of accidents.

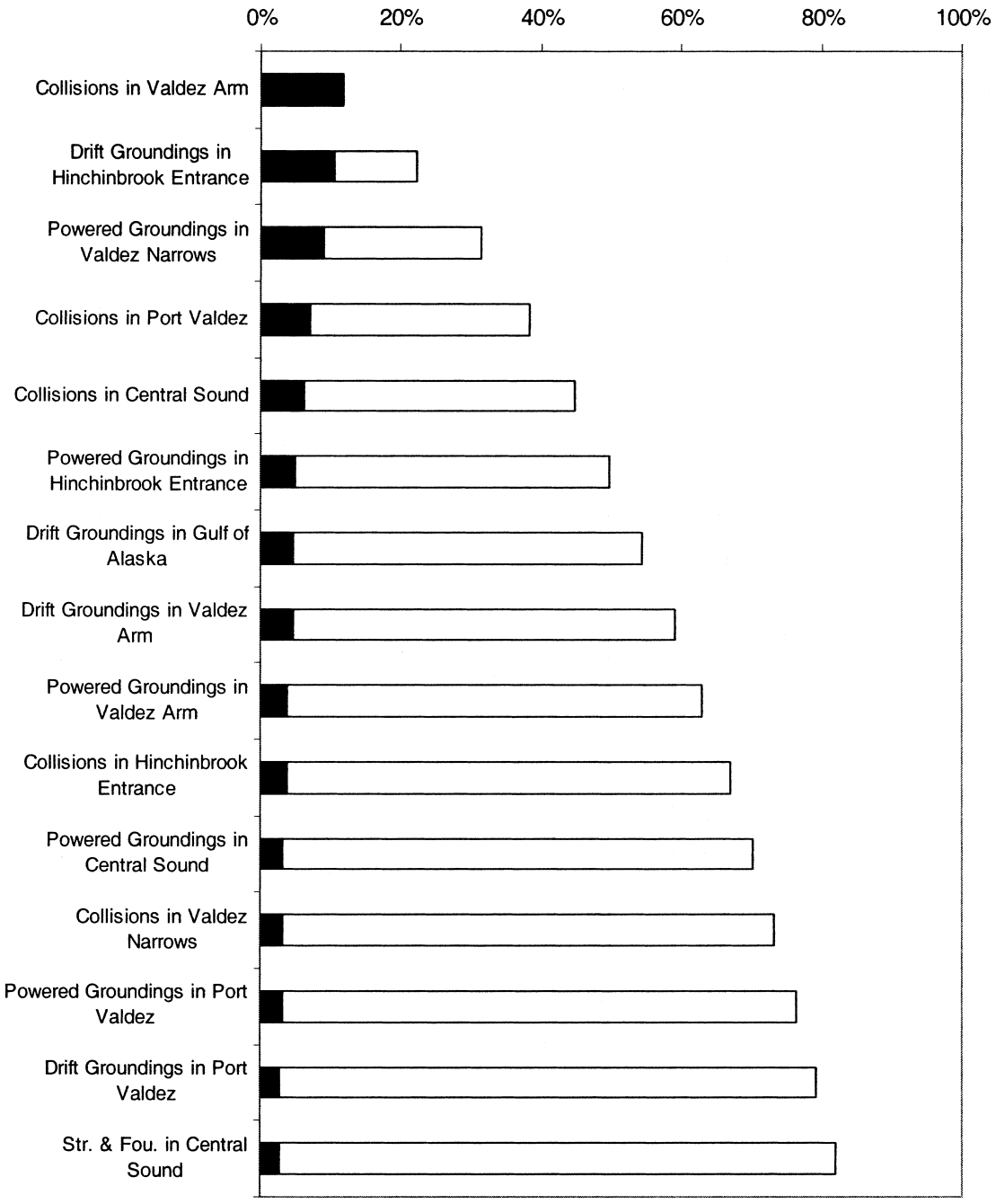


Figure 5: We sorted the combinations of accident types and locations by their expected oil outflow (dark bars). The cumulative percentage of the total expected oil outflow up to each such combination (white bars) is indicated by the total height of each bar. For example, we found that the first seven accident scenarios account for 55 percent of the total expected oil outflow.

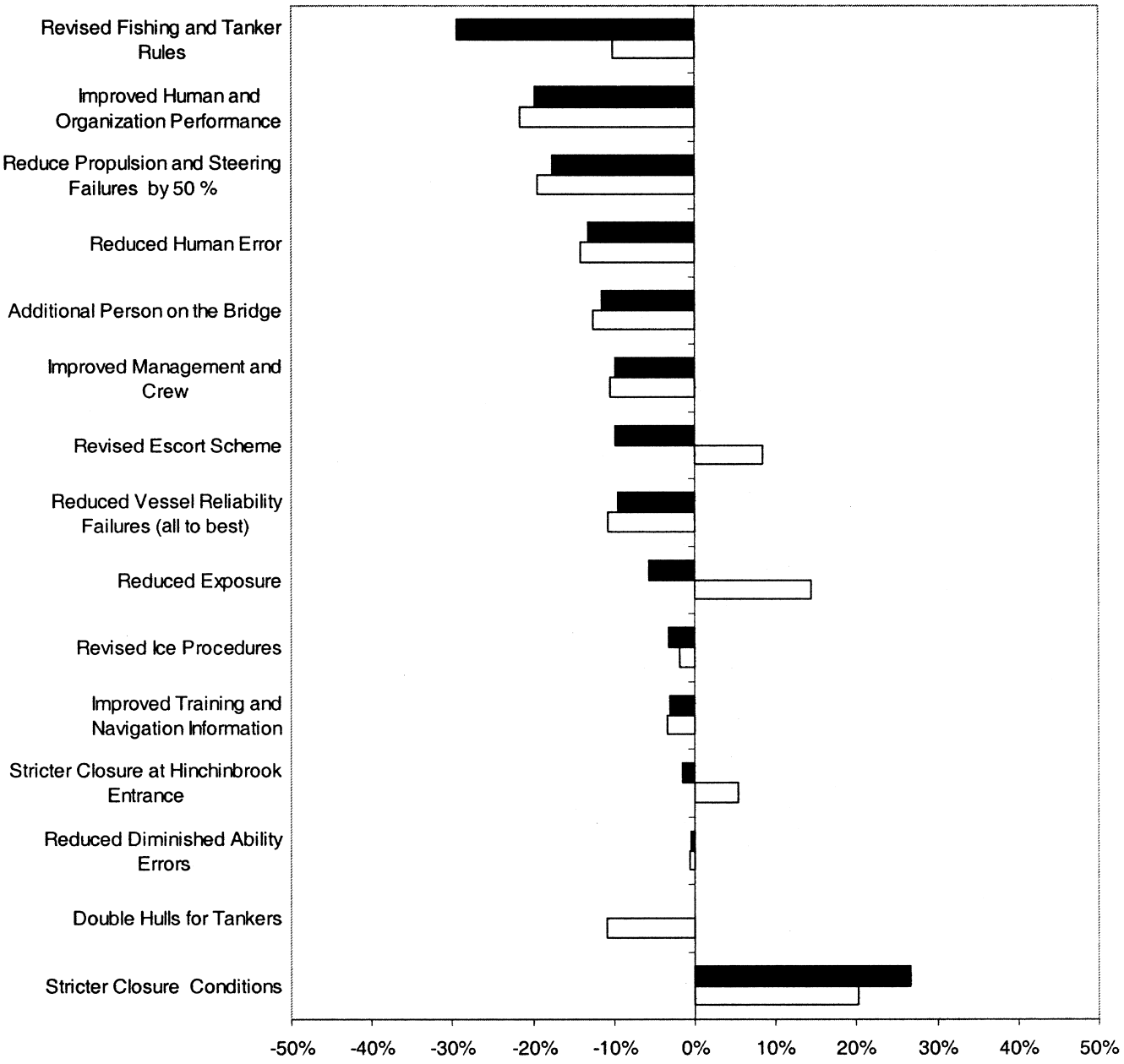


Figure 6: We tested proposed risk interventions in the system risk simulation and ranked them by percentage reduction from the study year in the expected frequency of accidents (black bars) and expected oil outflow (white bars) per year.

Estimates of expected accident frequency and expected oil outflow by accident scenario are point estimates of risk. The preferred method for reporting accident risk would be a distribution that also represents the degree of uncertainty in the results (Paté-Cornell 1996). Although we proposed an uncertainty analysis to the steering committee, time and budgetary constraints did not allow it. This was a drawback in the

study, and additional research is needed to develop a technique to assess uncertainties in the system risk-simulation model. The value of an analysis, however, is not only in the precision of the results but in understanding system risk. Unlike risk assessments in more traditional areas, for example, nuclear power, our focus was the dynamic risk behavior of the system. For risk-management purposes, it is valuable to identify the peaks, patterns, unusual circumstances, and trends in system risk and in changes in system risk made by the implementation of risk-intervention measures.

Validity of the Results

In any study, it is important to validate the results. To assess the validity of our results, we need to validate both the simulation of the PWS system and the expert-judgment-based estimates of accident and incident probabilities. We used graphical comparison to the actual system and numerical comparison using summary statistics to validate the simulation part of the model. Specifically, USCG personnel from the Vessel Traffic Service (VTS) in PWS, who monitor traffic using screens resembling the graphical simulation output, verified the general behavior of traffic in the simulation regarding adherence to traffic rules, and patterns of vessel arrivals and departures. In addition, we compared summary statistics from the simulation, such as the average number of trips to the anchorage area as a result of weather-based closure conditions, the average number of tanker diversions due to ice in tanker lanes and the average number of closed waterways at separate locations due to weather restrictions, to those observed in the VTS system.

However, estimates of accident and incident probabilities based on expert judgments are more difficult to validate. While the use of proper procedures, such as structured and proven elicitation methods, can reduce uncertainty and bias in an analysis, they cannot eliminate them. As one referee noted, our use of mariners with experience in PWS could introduce a group bias. For example, had the Exxon Valdez not run aground, the opinions of the experts might have been quite different. The bias the referee refers to is availability bias (Cooke 1991), that is, people make assessments in accordance with the ease with which they can retrieve similar events. In the case of the Exxon Valdez accident, the effect of the availability bias would be to increase perceived levels of accident risk. However, each question in the PWS questionnaires required the comparison of two carefully defined scenarios. One could argue that both scenarios would be affected by the availability bias in a similar manner. As a result, the effect of the availability bias would be reduced. The Exxon Valdez accident scenario (a powered grounding of a tanker in the Valdez Arm) received only a modest ranking of 10 out of 17 accident scenario's that contribute to approximately 95 percent of total accident risk (Figure 4).

Risk assessments typically deal with low probability, high consequence events, and thus statistical validation of their results is difficult even when using nationwide or global accident databases. Using nationwide or global accident data in localized risk assessments is also questionable in terms of validity, prompting the PWS steering committee to require our use of only PWS specific data. This requirement meant we could not validate our risk assessment in the traditional sense. In the case of the probability of triggering incidents, such as mechanical failures, where available data and expert judgments overlapped, we observed good correspondence. Such correspondence could add to the validity of the other expert-based estimates, where such comparisons could not be made.

In the PWS risk assessment we followed a collaborative analysis approach (Charnley 2000). This included educating the steering committee in the language and modeling of risk. As we developed a common framework for analyzing risk, we discussed proposed risk-intervention measures at the level of their detailed effect on the whole system, rather than their gross effects on one part. We discussed the assumptions behind the model with the steering committee. The members of the steering committee were able to challenge the assumptions upon which they based their own opinions concerning the operation of the oil-transportation system in PWS.

We presented all our results to the steering committee in monthly meetings. The members questioned various results and often required more detailed analysis to reach a deeper understanding. The simulation

model allowed us to demonstrate many results graphically, giving the steering committee a better intuition and trust in their validity. Members challenged certain results and often identified problems with the analysis, such as incorrect implementation of vessel traffic rules in the simulation, which we corrected. The committee put no pressure on us to change results merely because members disagreed. In the end, the steering committee unanimously accepted the results we obtained with the system risk-simulation model despite members' diverse perspectives at the onset of the study. Using the collaborative analysis approach, we built on the substantive knowledge represented in the steering committee and instilled trust in our results and recommendations, normally acquired through the use of classical statistical validation procedures.

Actions Taken

At the conclusion of the study, our contract team delivered a final report to the steering committee (PWS Steering Committee 1996). This report included technical documentation of the methodology used in the study, the results of the modeling, and recommendations based on these results. Following the risk-assessment project, the steering committee split up into risk-management teams charged with implementing the recommendations in specific areas.

One of the key questions the steering committee asked at the start of the study was whether the current escort system was capable of stopping drift groundings in the Valdez Narrows. The study showed that the current escort tugs were capable of saving a disabled tanker in the environmental conditions experienced in the Valdez Narrows. However, because of other considerations, the PWS shipping companies decided to accept proposals for two tractor-tugs. The designers used our result extensively in the design process. Crowley Maritime Services have invested $30 million to build the tugs Nanuq (Figure 7) and Tan'erliq to fulfill the requirements developed.

To date the various organizations comprising the risk-management teams have taken the following actions based on our results:

—The oil companies have introduced an enhanced-capability tug called the Gulf Service (Figure 8) to escort oil-laden tankers through Hinchinbrook Entrance, which is being replaced by new azimuthing stern-drive escort vessels designed for higher transit speed/open water assist scenarios that include the Hinchinbrook Entrance transit.

Figure 7: The 153-foot, 10,000 horsepower, state-of-the-art tractor-tug Nanuq has been put in service to escort tankers through Valdez Narrows.

—We have completed a further project to find an improved escort scheme, which SERVS have adopted, minimizing interactions between oil tankers and escort tugs, while maintaining the ability to save disabled tankers.

Figure 8: The enhanced capability tug Gulf Service has been stationed at Hinchinbrook Entrance to save disabled tankers even in extreme environmental conditions.

—The Coast Guard VTS manage interactions between fishing vessels and tankers.

—SERVS has increased the minimum required bridge crew on board escort tugs from one to two to add additional error-capture capability.

—The International Maritime Organization has approved a change to the tanker route through central PWS, reducing the number of course changes required.

—The shipping companies have made long-term plans for quality-assurance and safety-management programs.

The Benefits of the Risk-Assessment Process

It is difficult to compare this project with other more traditional projects in operations research and management science, whose benefits are typically measured in terms of reduced operating costs or increased profits. The benefits of risk assessments are less tangible as the objective is to reduce the occurrence of future accidents. However, because clean-up operations for the Exxon Valdez accident cost over $2 billion, the benefits of preventing a single such accident would be of similar magnitude. We can only estimate the reduction in the frequency of accidents using our models and can only estimate the benefits of the study in terms of clean-up cost. Using our risk models, we estimated that accident frequency had been reduced by 75 percent since the Exxon Valdez accident. According to our risk models, the further reduction in accident frequency from all measures taken as a result of the PWS risk assessment is 68 percent, with a 51 percent reduction in the expected oil outflow. This means that, since the Exxon Valdez accident, the accident frequency has been reduced by an estimated total of 92 percent. The costs of the risk assessment, roughly $2 million over a two-year period, pale in comparison to the potential clean-up costs for a single major oil spill resulting from a tanker accident. However, the benefits go beyond clean-up costs and include the protection of pristine environments, and the prevention of loss of life and injury to vessel crews. In addition, the shipping companies have used the results of the PWS model in making decisions to invest in multimillion dollar equipment.

While the stakeholders in PWS all recognized the need for a rational method to evaluate the merits of risk-intervention measures, to improve the allocation of resources, and to avoid implementing measures that would adversely affect system risk, they did not trust each other at the beginning of the project. The steering committee wanted to use the project as a forum to build trust amongst stakeholders, to educate all interested parties, and to provide a common understanding of oil-transportation risk. The PWS risk assessment fostered a cooperative risk-management atmosphere involving all stakeholders.

At the end of the project, the stakeholders published the final report as their document, not just as a report from the consultant team. Members of the steering committee from environmental groups, the fishing industry, and the oil companies wrote joint press briefings and formed risk-management teams to manage implementation of the model results. The unified acceptance and presentation of the results of the study by all stakeholders and the level of implementation of the results can be primarily considered a benefit of the collaborative analysis process. All stakeholders finished the project convinced that they had reduced risk of further multibillion dollar accidents and, with the cooperation fostered by the collaborative analysis process, the stage has been set for further improvements in managing risk.

The success of the PWS risk assessment has not gone unnoticed, and the National Science Foundation has awarded other researchers funding (for example, NSF SBR-9520194, NSF SBR-9710522) to study the risk-assessment process we followed. Our study is described as an example of collaborative analysis by Busenberg (2000) and Charnley (2000). Busenberg (1999) commented as follows:

> "All ten of the participants who were interviewed agreed that this process allowed the steering committee to gain a better understanding of the technical dimensions of maritime risk assessment . . . The results of the risk assessment were released in late 1996, and were unanimously accepted as valid by the RCAC, oil industry, and government agencies involved in this issue. The participating groups agreed that the study showed the need for an ocean rescue tug vessel in the Sound. In 1997, the oil industry responded by deploying a vessel of this class in the Sound."

Acknowledgments

The authors are indebted to the editor and associate editor of *Interfaces* and the referees for their valuable comments and suggestions that substantially improved the first version of this paper.

References

Andrews, S., F. H. Murphy, X. P. Wang, S. Welch. 1996. Modeling crude oil lightering in Delaware Bay. *Interfaces* **26**(6) 68–78.

Banks, J., J. S. Carson, B. L. Nelson, D. M. Nicol. 2000. *Discrete-Event System Simulation.* Prentice Hall, Upper Saddle River, NJ.

Bedford, T. M., R. M. Cooke. 2001. *Probabilistic Risk Analysis: Foundations and Method.* Cambridge University Press, Cambridge, U.K.

Bradley, R., M. Terry. 1952. Rank analysis of incomplete block designs. *Biometrica* **39** 324–345.

Busenberg, G. 1999. Collaborative and adversarial analysis in environmental policy. *Policy Sci.* **32**(1) 1–11. Supported under NSF SBR-9520194.

——. 2000. Innovation, learning, and policy evolution in hazardous systems. *Amer. Behavioral Sci.* **44**(4) 1–11. Supported under NSF SBR-9520194, NSF SBR-9710522.

Charnley, G. 2000. *Enhancing the Role of Science in Stakeholders-Based Risk Management Decision-Making.* HealthRisk Strategies, Washington, DC.

Cooke, R. M. 1991. *Experts in Uncertainty: Expert Opinion and Subjective Probability in Science.* Oxford University Press, Oxford, U.K.

Fowler, T. G., E. Sorgard. 2000. Modeling ship transportation risk. *Risk Anal.* **20**(2) 225–244.

Garrick, G. J. 1984. Recent case studies and advancements in probabilistic risk assessment. *Risk Anal.* **4**(4) 267–279.

Golkar, J., A. Shekhar, S. Buddhavarapu. 1998. Panama Canal simulation model. D. J. Medeiros, E. F. Watson, J. S. Carson, M. S. Manivannan, eds. *Proc. 1998 Winter Simulation Conf.* 1229–1237.

Guedes Soares, C., A. P. Teixeira. 2001. Risk assessment in maritime transportation. *Reliability Engrg. System Safety* **74**(3) 299–309.

Hara, K., S. Nakamura. 1995. A comprehensive assessment system for the maritime traffic environment. *Safety Sci.* **19**(2–3) 203–215.

Harrald, J., H. Marcus, W. Wallace. 1990. The Exxon Valdez: An assessment of crisis prevention and management systems. *Interfaces* **20**(5) 14–30.

——, T. Mazzuchi, J. Merrick, R. van Dorp, J. Spahn. 1998. Using system simulation to model the impact of human error in a maritime system. *Safety Sci.* **30**(1–2) 235–247.

Kite-Powell, H. L., D. Jin, N. M. Patrikalis, J. Jebsen, V. Papakonstantinou. 1996. Formulation of a model for ship transit risk. MIT Sea Grant Technical Report, Massachusetts Institute of Technology, Cambridge, MA, 96–119.

Lowrance, W. W. 1976. *Of Acceptable Risk.* William Kaufman, Los Altos, CA.

Maio, D., R. Ricci, M. Rossetti, J. Schwenk, T. Liu. 1991. Port needs study. Report No. DOT-CG-N-01–91–1.2. Prepared by John A. Volpe, National Transportation Systems Center, U.S. Coast Guard, Washington, DC.

Merrick, J., J. R. van Dorp, J. Harrald, T. Mazzuchi, J. Spahn, M. Grabowski. 2000. A systems approach to managing oil transportation risk in Prince William Sound. *Systems Engrg.* **3**(3) 128–142.

National Research Council. 1986. *Crew Size and Maritime Safety.* National Academy Press, Washington, DC.

——. 1991. *Tanker Spills: Prevention by Design.* National Academy Press, Washington, DC.

——. 1994. *Minding the Helm: Marine Navigation and Piloting.* National Academy Press, Washington, DC.

——. 2000. *Risk Management in the Marine Transportation System.* National Academy Press, Washington, DC.

Paté-Cornell, M. E. 1990. Organizational aspects of engineering system safety: The case of offshore platforms. *Science* **250**(4985) 1210–1217.

——. 1996. Uncertainties in risk analysis: Six levels of treatment. *Reliability Engrg. System Safety* **54**(2–3) 95–111.

Pravda, M. F., R. G. Lightner. 1966. Conceptual study of a supercritical reactor plant for merchant ships. *Marine Tech.* **4** 230–238.

Prince William Sound Steering Committee. 1996. Prince William Sound risk assessment study final report.

Roeleven, D., M. Kok, H. L. Stipdonk, W. A. de Vries. 1995. Inland waterway transport: Modeling the probabilities of accidents. *Safety Sci.* **19**(2–3) 191–202.

Ryan, N. K. 1998. The future of maritime facility designs and operations. D. J. Medeiros, E. F. Watson, J. S. Carson, M. S. Manivannan, eds. *Proc. 1998 Winter Simulation Conf.* 1223–1227.

Saaty, T. 1977. A scaling method for priorities in hierarchical structures. *J. Math. Psych.* **15**(3) 234–281.

Slob, W. 1998. Determination of risks on inland waterways. *J. Hazardous Materials* **61**(1–3) 363–370.

Slovic, P. 1993. Perceived risk, trust and democracy. *Risk Anal.* **13**(6) 675–682.

Stiehl, G. L. 1977. Prospects for shipping liquefied natural gas. *Marine Tech.* **14**(4) 351–378.

Trbojevic, V. M., B. J. Carr. 2000. Risk based methodology for safety improvements in ports. *J. Hazardous Materials* **71**(1–3) 467–480.

U.S. Coast Guard. 1973. Vessel traffic systems: Analysis of port needs. Report No. AD-770 710. U.S. Coast Guard, Washington, DC.

U.S. Nuclear Regulatory Commission. 1975. Reactor safety study: An assessment of accident risks in U.S. commercial nuclear power plants. WASH-1400 (NUREG-75/014).

Wang, J. 2000. A subjective modeling tool applied to formal ship safety assessment. *Ocean Engrg.* **27**(10) 1019–1035.

Richard L. Ranger, Manager, Operational Integrity, Polar Tankers, Inc., 300 Oceangate, 11th Floor, Long Beach, California 90802-4341, writes: "During the period from September 1995 through December 1996, I was one of the representatives of ARCO Marine, Inc.

on the multi-stakeholder Steering Committee established to oversee the work of the consultant team on Prince William Sound Risk Assessment project. In the period that followed I represented ARCO Marine (now Polar Tankers, Inc.) in a succession of multi-stakeholder discussions which considered implementation of risk mitigation measures identified during the PWS Risk Assessment.

"In its review of the system then in place for marine transportation of crude oil in Prince William Sound, Alaska, the PWS Risk Assessment tested the capabilities of current methods of probabilistic risk analysis, and established some new benchmarks for use of certain analytical methods in combination. To the participating stakeholders, who use, regulate, or benefit from the PWS marine transportation system, the principal value of the PWS Risk Assessment was the fact that it undertook quantitative risk characterization in the context of the values, norms, and expectations of our diverse group. Science and method were tested against assumptions based upon policy and perception. In turn, science and method tested and challenged these other means of decision making. Researchers learned from stakeholders, and vice versa. The outcome was not simply a detailed project report but a deepened understanding by all stakeholders regarding where improvements in the system might be possible, of realistic expectations for those improvements, and of the nature and significance of uncertainties about both.

"The years since the publication of the report from the PWS Risk Assessment have not been free from disagreement among the stakeholders, but they have been years of a substantially improved quality of dialogue, and of more informed decision making. They have also been years marked by steady incremental improvement in the capability of the PWS marine transportation system to prevent vessel casualties and pollution incidents from occurring. The PWS Risk Assessment was clearly a catalyst in achieving these outcomes. It marks a unique convergence of technical inquiry and stakeholder dialogue that balanced analysis appropriate to the problem with deliberation over the needs and interests of affected parties.

"Like many pathbreaking efforts, the PWS Risk Assessment did not reach such results easily, nor necessarily within the original budget and schedule expectations of any of the participants. Still, it represents an important reference point for future projects that involve assessment of operational risk in the context of public dialogue about such risk, its components, its acceptability, and its potential consequences."

A. Elmer III, President, SeaRiver Maritime, Inc., PO Box 1512, Houston, Texas 77251-1512, writes: "The PWS Risk Assessment was proposed by PWS Shipping Companies to foster an environment in which the often misunderstood and complex concept of maritime risk could be discussed and reviewed by all stakeholder parties concerned with the safety of marine transportation in Prince William Sound. To facilitate the process, the consultant team was asked to join with the PWS Steering Committee in studying and evaluating the risks associated with the transporting of Alaskan North Slope crude oil from Valdez through Prince William Sound, Alaska.

"The consultant team developed a framework that described, qualitatively, the risks and built models based upon this framework. The PWS Steering Committee was first educated in the concept and language of risk and risk management and the framework in which to study risk. The PWS Steering Committee then participated in the development of the modeling assumptions upon which the models were based. This process fostered continual open discussion and dialogue on the detailed and specific effect of proposed changes to the marine transportation system.

"The close coordination of the risk model development through the PWS Steering Committee led to a high level of trust in the results and consensus on changes to be made to the system. Following the project, results of the risk assessment study have been implemented, including the following:

- The stationing of an enhanced-capability tug at Hinchinbrook Entrance.
- A redesigning of the tanker escort system to ensure that tankers are escorted by suitable escort tugs in each area of Prince William Sound.

• Establishing improved coordination between tankers and escort tugs and maintaining the ability to respond to a disabled tanker.

• The implementation of close coordination of tanker movement with other PWS activities (e.g., commercial fishing season openings) to ensure safety of transit.

• Continual improvement of shipping companies' Safety Management Systems and training programs.

"The PWS Risk Assessment project consultants brought industry, industry service groups, state and federal regulators, and public stakeholders together to work through the defining and assessment of marine transportation risk and the development of risk-reduction measures for the PWS Marine Transportation System."

J. P. High, Acting Assistant Commandant for Marine Safety and Environmental Protection, United States Coast Guard, 2100 Second Street SW, Washington, DC 20593-0001, writes: "The U.S. Coast Guard was one of the sponsors of the Prince William Sound Risk Assessment and remains heavily involved in past and ongoing efforts to manage risks associated with commercial shipping in Prince William Sound and elsewhere.

"The submitted risk assessment was the first such assessment of its size and was groundbreaking relative to both the scope of the effort and the large number of diverse stakeholders. The results of the assessment were used to directly support decisions made by the stakeholders that have reduced risks in the area. Additionally, as the first of its size, this study has been a very useful benchmark for other similar risk assessments.

"The U.S. Coast Guard strongly supports efforts to improve maritime safety, especially those like this one that focused on risk identification, evaluation, and management."

SUB-APPENDIX:

J.R. van Dorp, J.R.W. Merrick , J.R. Harrald, T.A. Mazzuchi, and M. Grabowski (2001). "A Risk Management procedure for the Washington State Ferries", *Journal of Risk Analysis*, Vol. 21 (1): pp. 127-142.

Risk Analysis, Vol. 21, No. 1, 2001

A Risk Management Procedure for the Washington State Ferries

Johan R. van Dorp,[1]* Jason R. W. Merrick,[2] John R. Harrald,[1] Thomas A. Mazzuchi,[1] and Martha Grabowski[3]

The state of Washington operates the largest passenger vessel ferry system in the United States. In part due to the introduction of high-speed ferries, the state of Washington established an independent blue-ribbon panel to assess the adequacy of requirements for passenger and crew safety aboard the Washington state ferries. On July 9, 1998, the Blue Ribbon Panel on Washington State Ferry Safety engaged a consultant team from The George Washington University and Rensselaer Polytechnic Institute/Le Moyne College to assess the adequacy of passenger and crew safety in the Washington state ferry (WSF) system, to evaluate the level of risk present in the WSF system, and to develop recommendations for prioritized risk reduction measures, which, once implemented, can improve the level of safety in the WSF system. The probability of ferry collisions in the WSF system was assessed using a dynamic simulation methodology that extends the scope of available data with expert judgment. The potential consequences of collisions were modeled in order to determine the requirements for onboard and external emergency response procedures and equipment. The methodology was used to evaluate potential risk reduction measures and to make detailed risk management recommendations to the blue-ribbon panel and the Washington State Transportation Commission.

KEY WORDS: Maritime risk assessment; system simulation; expert judgment

1. INTRODUCTION

The Washington state ferry (henceforth WSF) system is the largest ferry system in the United States. In 1997, total ridership for the ferries serving the central Puget Sound region was nearly 23 million, a 4% increase over 1996 ridership, and more passengers than Amtrak, the U.S. passenger rail carrier, handles in a year. The state of Washington instituted the ferry system in 1951 to connect King and Snohomish Counties with Kitsap County, saving travelers the long drive around Puget Sound via the Tacoma Narrows Bridge, and to provide mainland access to Vashon Island and Whidbey Island. Prior to 1951 private ferry system(s) offered these services. Figure 1 shows the current ferry routes for the central Puget Sound region. This map illustrates the ferry system's role in linking together the Washington state highway system in the Puget Sound region.[1]

Though to date the Washington state ferries have had an exceptional safety record, the WSF system is facing a number of important changes. First, its regulatory environment, which has been relatively inactive, has changed significantly with the implementation of 46 C.F.R. 199, Subchapter W, of the Code of Federal Regulations, Lifesaving Systems for Certain Inspected Vessels.[2] The WSF system is required by these regulations to address the response to cata-

[1] The George Washington University, Washington, DC.
[2] Virginia Commonwealth University, Richmond, VA.
[3] Rensselaer Polytechnic Institute, Troy, NY.
*Address correspondence to: Johan René van Dorp, Engineering Management and Systems Engineering Department, The George Washington University, 707 22nd Street N.W., Washington, DC 20052; dorpjr@seas.gwu.edu.

0272-4332/01/0200-0127$16.00/1 © 2001 Society for Risk Analysis

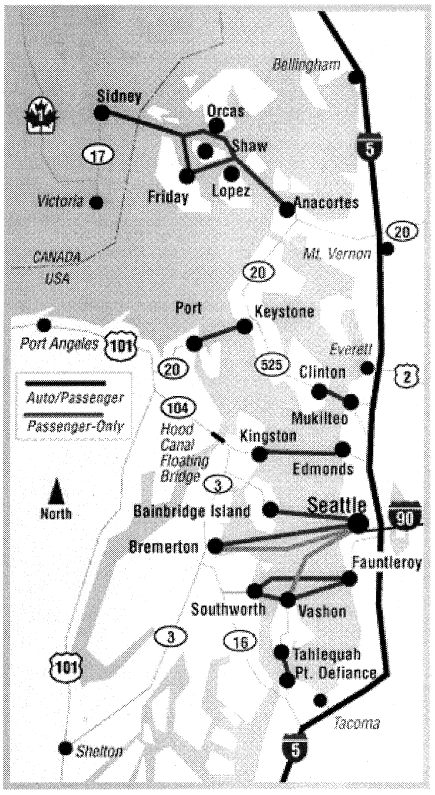


Fig. 1. Washington state ferry system map.

strophic accidents and the requirements for ensuring that passengers could survive such accidents. Specifically, the regulations require the WSF system, within 5 years, either to equip all ferries with adequate survival craft or to provide a safety assessment, a comprehensive shipboard safety management system, and shipboard contingency plans approved by the U.S. Coast Guard (USCG), the U.S. regulatory body for maritime affairs.

A second set of changes in the WSF system stems from pressures to develop a seamless, intermodal transportation system in Washington state in the face of simultaneous increases in the volume and mix of riders on the ferries. Because increasing numbers of Washington state residents are riding the ferries to work, and because connections to other transportation modes (bus, bicycle, car) from the ferries are critical to the success of such an intermodal system, the WSF system is under increased pressure to perform in ways different from those of the past, to measure and report its performance in different ways, and to increase the fluidity with which connections to other transportation modes are made from the ferries.

A third set of changes in the WSF system stems from new technology, for example, high-speed ferries, being introduced into the system to address some pressures for faster transport–passenger-only ferries. These new technologies are being introduced into an aging fleet with some consideration given for how best to mix new and old vessels, new and old technology, new and old operational dynamics, and varying degrees of sophisticated automation. In addition, the International Maritime Organization (IMO) has enacted implementation of the Standards for Training and Certification of Watchkeeping (STCW)[3] for all vessels above 200 gross tons (GT) and has begun the process of developing a high-speed code for vessels. To date the WSF has been exempt from STCW requirements and is in full compliance with all prevention regulations. The focus on high-speed ferries could change this status.

In light of these changes, the state of Washington established the independent Blue Ribbon Panel on Washington State Ferry Safety to assess the adequacy of requirements for passenger and crew safety aboard the Washington state ferries. On July 9, 1998, the panel engaged a consultant team from The George Washington University and Rensselaer Polytechnic Institute/Le Moyne College to assess the adequacy of passenger and crew safety in the WSF system, to evaluate the level of risk present in the WSF system, and to develop recommendations for prioritized risk reduction measures, which, once implemented, can improve the level of safety in the WSF system.

This article provides a discussion of (1) a framework for risk assessment and risk management of maritime transportation systems, (2) an overview of the modeling approach used in the WSF risk assessment, (3) an overview of WSF baseline risk assessment results, (4) WSF risk intervention evaluation results, and (5) recommendations to the panel and the Washington State Transportation Commission.

2. A FRAMEWORK FOR RISK ASSESSMENT AND MANAGEMENT

In order to evaluate proposed risk interventions, one must first define a measure of risk. Risk is often defined by combining the likelihood of an undesirable event and relevant consequences in a single quantitative measure. For example, consequences may include injury, loss of life, or economic losses. It is also possible to define some surrogate measure of risk that indirectly accounts for such attributes. Next, one needs to understand the events and situations that lead to

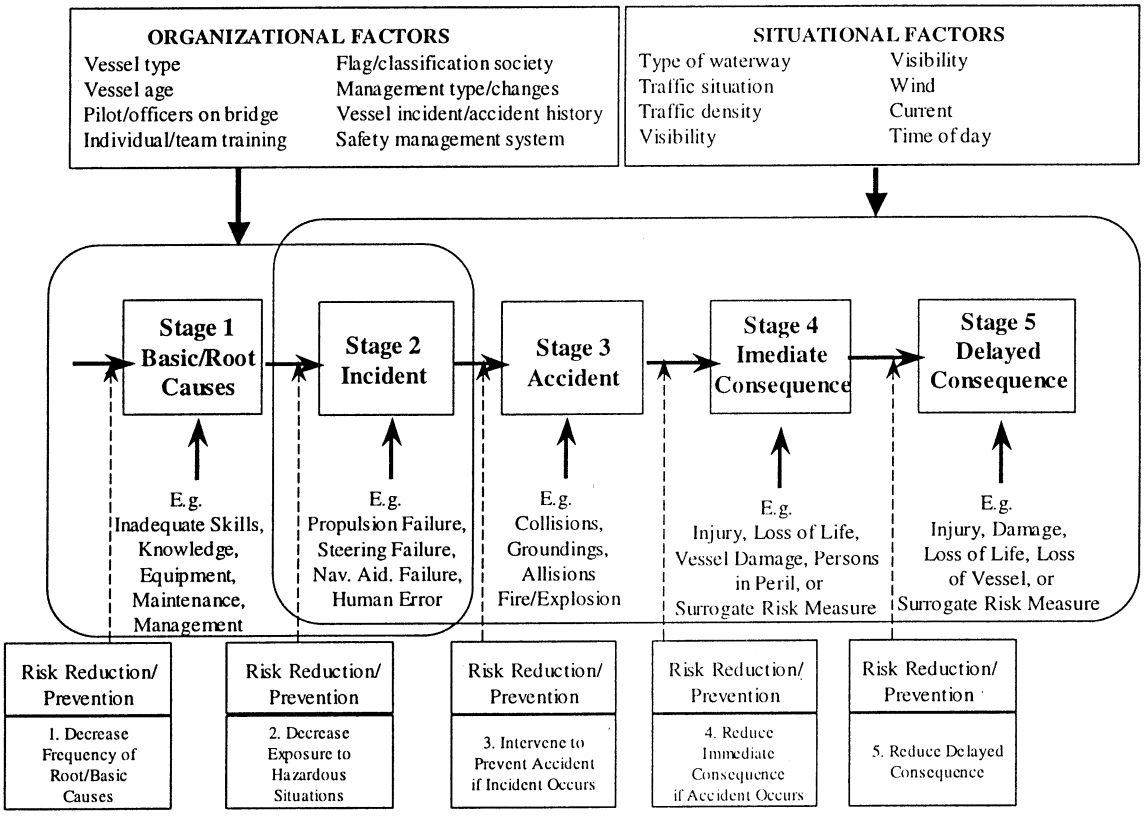


Fig. 2. The maritime accident event chain.

the undesirable event and the impact of proposed risk interventions on these events and situations. Figure 2 shows the maritime risk taxonomy used by the study team and illustrates the importance of organizational and situational factors in both the occurrence and severity of an accident.

In addition, Fig. 2 identifies five categories of risk interventions based on intended impact on the accident event chain. Three categories of impact intend to reduce the likelihood of occurrence of accidents and two categories of impact intend to reduce the consequences of accidents that could occur. Note that a single risk intervention may belong to multiple impact categories.

The objective of risk management is to structure, evaluate, rank, and implement policies and procedures that reduce the threat to life, property, the environment or all of the above posed by hazards. The structuring and evaluation of risk management alternatives/risk interventions herein is based on a multistep process. The first step is to define a quantitative measure of risk. In this study a surrogate consequence measure was defined focusing on response time alternatives as required by Subchapter W while addressing risk communication concerns of the blue-ribbon panel in terms of providing the results to the public. This surrogate measure will be introduced in Section 3.1. The second step is to identify potential risk interventions and determine their impact on the accident event chain (see, for example, Fig. 2). The third step is to develop a comprehensive quantitative model for comparing the risk interventions in a meaningful manner. The fourth step is to establish a baseline level of risk by defining a baseline scenario and using the developed model to quantify its risk. Additional risk intervention measures may be identified by focusing on high-risk contributors to the baseline level of risk. The fifth step is to model the effect of all the risk interventions in terms of changes to model parameters. The final step is to implement these changes to the model and evaluate the risk interventions relative to the established baseline level of risk.

The ranking and implementation of risk interventions involves assessment of tradeoffs of risk reduction with respect to other measures of interest, such as cost, implementation time, and political acceptability. While this was an important part of the

WSF risk assessment, the ranking and implementation is not a topic discussed further in this article. Rather, the focus is on the assessment of baseline risk and the evaluation of risk interventions.

3. RISK INTERVENTION MODELING IN THE WSF SYSTEM

The six-step process used for structuring and evaluating risk interventions in the WSF risk assessment will be discussed in the sections below.

3.1. Defining Risk for the WSF System

The focus of this study was on passenger safety, including consideration of both the probability of occurrence and the severity of consequence of accidents. Accident types that are a potential threat to the Washington state ferries include collisions (or striking of another vessel), fires or explosions, allisions (or striking of a fixed object), and groundings (or strandings). The potential vulnerability to these accidents is determined by the internal factors previously described and by factors external to the system, such as high levels of traffic congestion, the emergency coordination and response capabilities of external organizations, and the intentional or unintentional presence of hazardous materials on board.

The consequence evaluation focused on defining the appropriate accident response alternatives as required by Subchapter W. Hence, the risk analysis focused solely on WSF passengers. Accidents with vessels not putting WSF passengers in peril were not considered in the study. A measure termed "Maximum required response time" (MRRT) was developed as a surrogate measure for the potential accident impact. The MRRT was defined as the maximum allowable time for response to avoid additional (post-accident) injuries or fatalities due to a failure to respond in time. Three categories of MRRT were deemed appropriate: less than 1 hr, between 1 and 6 hr, and greater than 6 hr. In conjunction with the consulting team, the blue-ribbon panel judged that accidents in the first category primarily require an effective external emergency response, for example, other ferries or vessels, to prevent additional injuries or fatalities since the time would probably not permit in-time launching of survival craft. For accidents in the second category, time is available for evacuation to a safe haven. In order to meet Subchapter W requirements, the WSF system must demonstrate the ability to mobilize evacuation vessels or plan to provide survival craft adequate for all passengers. For accidents in the third category, adequate response in all cases can be provided without evacuating the passengers from the ferry. Of course, in any accident it is desirable to respond in the shortest amount of time possible. The MRRT measure merely provides an upper bound on the desirable response time.

Historical records for all accident events involving Washington state ferries were collected for an 11-year period and analyzed. Fire and explosions were limited, historically, to stack fires that were contained while under way. Allisions were incidents occurring at the dock and led primarily to property damage and not casualties or injuries as the impact speeds were low. Groundings occurred at shallow areas with small tide fluctuations. In each case, the ferry involved remained a stable, safe platform for the passengers until an orderly evacuation was performed. There were two collisions in an 11-year period of accident data. In each collision, the ferry was able to return to dock and safely disembark the passengers. Summarizing, the Washington state ferries have a commendable safety record in terms of casualties and injuries, with no fatalities.

Potential accident scenarios that could lead to high consequences in injuries and fatalities were, however, developed in conjunction with the Blue Ribbon Panel on Washington State Ferry Safety. Specifically, collisions involving high-speed ferries, collisions between ferries and deep-draft vessels, and acts of intentional fire/explosion were deemed to be events that could possibly fall in the 1–6 hr MRRT and less than 1 hr MRRT categories. Due to the sensitivity of acts of intentional fire/explosion, the panel decided that it was not appropriate to discuss the vulnerability to these acts in the open public forum of the WSF risk assessment. Based on the characteristics of the WSF system, allisions and groundings were judged by the project team, in conjunction with maritime experts, to fall in the more than 6 hr MRRT category. The blue-ribbon panel accepted this assumption. Hence, the main focus was the development of models for collision risk estimating the frequency of collisions and their associated consequences in terms of the three MRRT categories identified.

3.2. Identification and Structuring of Risk Interventions

In the WSF risk assessment, the project team collected a total of 40 risk reduction measures that had been proposed for this system and for other maritime systems, and structured the measures. The

Table I. Summary of Risk Interventions Classes Tested

Risk reduction class	Intervention
1	Adopt international safety management standard fleetwide
2	Implement all mechanical failure reduction measures fleetwide
3	Implement high-speed ferry rules and procedures
4	Implement weather, visibility restrictions
5	Implement traffic separation for high-speed ferries
6	Implement traffic control for deep-draft traffic
7	Increase time available for response

sources of these measures were (1) interviews with ferry system and U.S. Coast Guard personnel, (2) the Revision of the HSC Code, Formal Safety Assessment of High Speed Catamaran (HSC) Ferries Submitted by the United Kingdom,[4] (3) the *Final Report: Prince William Sound Risk Assessment*,[5] (4) Scoping Risk Assessment, Protection against Oil Spills in the Maritime Waters of Northwest Washington State,[6] and (5) alternatives specified in 46 CFR 199, Subchapter W. The 40 risk reduction measures were synthesized to seven classes of risk reduction measures, listed in Table I. The intended impact of these classes on the causal chain of Fig. 2 is displayed in Fig. 3. Note that some classes intervene at multiple points in the accident event chain.

3.3. An Overview of the Modeling Approach for WSF System Collision Risk

The situational and organizational factors, indicated in Fig. 2, that influence the probability of occurrence of events in the causal chain lead to dynamic fluctuations in system collision risk. Identifying how and when these risk spikes occur is a fundamental objective of the use of dynamic system simulation as a risk assessment methodology. As an example of the contribution of situational factors to collision risk, it is clear that a ferry traveling on a clear day with no other traffic nearby is at lower risk than a ferry in foggy conditions with many other vessels nearby. Modeling the contribution of risk factors asks for a quantitative evaluation of collision risk in both situations, that is, how much more risky the first situation is compared to the other. In the WSF risk assessment, a constructive modeling approach combining system simulation, expert judgement, and available data was used to allow for estimation of the contribution of these situational and organizational factors to collision risk.

A specific combination of situational and organizational factors in a given time point for a specific ferry is an opportunity for incident (OFI). Thus each OFI consists of variables that may be considered contributing risk factors. The risk factors considered in the WSF risk assessment are listed in Table II. Modeling the system in terms of the factors in Table II, re-

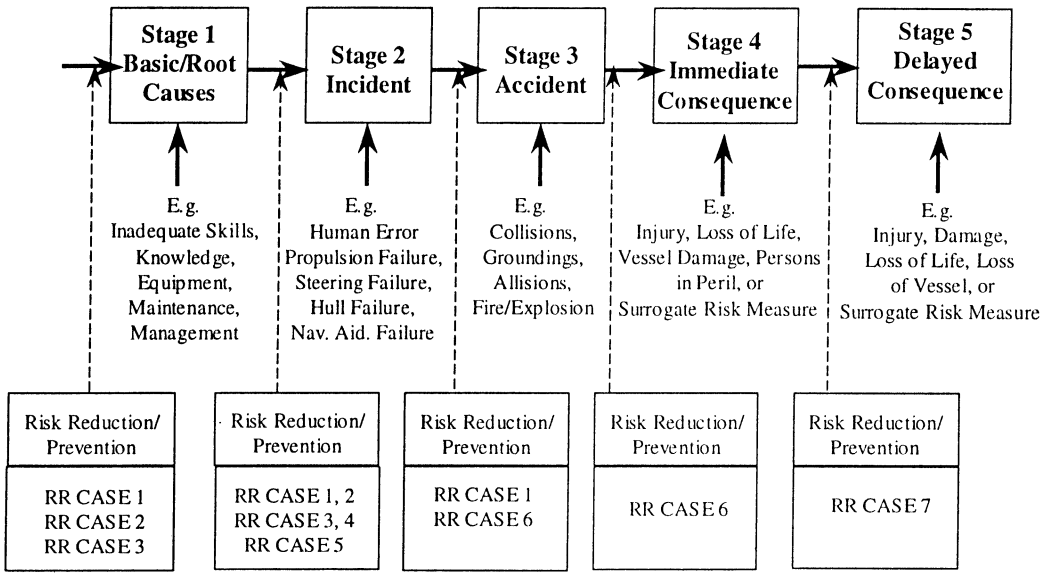


Fig. 3. Impact of risk reduction classes on the causal chain. RR = risk reduction.

Table II. The Variables Considered in the Collision Risk Model

Variable name	Possible values
Ferry route	Seattle-Bremerton, Anacortes-Sidney, etc.
Ferry class	Issaquah, Jumbo, Chinook, etc.
Interacting vessel type	Container, bulk carriers, other ferries, etc.
Type of interaction	Crossing, meeting, overtaking
Proximity of interacting vessel	Less than 1 mile, from 1 to 5 miles
Wind speed	0 knots, 10 knots, 20 knots
Wind direction	Perpendicular to ferry, along ferry
Visibility	Less than 0.5 mile, more than 0.5 mile

quires extensive collection of traffic and weather data. Traffic data are available from the USCG logging arrivals of deep-draft vessels to the Puget Sound area. Ferry schedules are published by the Washington State Ferry Service. Weather data was obtained from the National Oceanic and Atmospheric Administration (NOAA) and local airport data. A visibility model was created using a land visibility model developed with local airport data and a sea visibility model using dew point temperature data and water temperature data from NOAA weather buoys.

Traffic data in terms of annual statistics alone cannot be used to infer how often interactions between these vessels occur and in what conditions. Thus, a simulation of the WSF system was built to represent the movement of the Washington state ferries, the movement of other vessels in the area, and the environmental conditions at any given time. Figure 4 gives a screen capture of the WSF system simulation capturing the southern Puget Sound area and central Puget Sound Area. Figure 4 displays (1) ferry routes in central Puget Sound, (2) two wind fans modeling direction and strength in the central Puget Sound and southern Puget Sound regions, (3) bad-visibility conditions (less than 0.5 miles) in southern Puget Sound, and (4) good visibility in central Puget Sound.

Using this simulation, a counting model was developed that observed and recorded snapshots of the study area at regular intervals and counted the occurrences of the various OFIs in terms of the variables displayed in Table II. The simulation is called the OFI generator and the counting model is called the OFI counter. Using the OFI counter, summary statistics on, for example, the number of OFIs involving crossing situations of a high-speed ferry and a container vessel on the Seattle Bremerton route in bad visibility conditions can be analyzed. The next step is to assess the likelihood of triggering incidents and collisions given the risk factors in Table II.

The preferred method for estimating these probabilities is through data. Accident database information is typically limited, however, to accident and immediate-consequence data, as indicated by Fig. 5. For evaluation of the risk intervention measures impacting early on in the causal chain, the assessment of probabilities in the beginning of the causal chain is required. The assessment of incident probabilities leading to an accident, however, is often not supported by available data in accident and consequence databases. Cooke[7] cites the use of expert judgment in areas as diverse as aerospace programs, military intelligence, nuclear engineering, evaluation of seismic risk, weather forecasting, economic and business forecasting, and policy analysis. Paté-Cornell[8] discusses the necessity of using expert judgment when sufficient data are not available, and Harrald, Mazzuchi, and Stone[9] proposed the use of expert judgment in the analysis of risk in maritime environments.

In the WSF risk assessment, the average likelihood of system events along the maritime accident event chain was estimated using both historical data and expert judgment. A database containing 11 years of incident, accident, and transit data for Puget Sound and the inland waters of the state of Washington was created for this project, reconciling USCG, state of Washington, Marine Exchange, U.S. Army Corps of Engineers, and ferry system databases through rigorous data selection and cross validation. Expert judgment was obtained from WSF captains, USCG personnel, and members of the Puget Sound Pilots Association using elicitation methods based on pairwise comparisons of OFIs. The expert judgment was combined with and calibrated to the accident and incident data available and was used to model the effect of the variables in Table II on the accident and incident probabilities. Figure 6 summarizes the use of the different modeling techniques to establish collision frequencies.

The final step in modeling the maritime accident event chain is consequence modeling. Engineering models of collision impact damage scenarios were used to assess the damage to each ferry class in various collision scenarios. The damage model follows the method of Minorsky.[10] The Minorsky method determines damage size as a function of the collision energy, the colliding-vessel bow angle, and the effective deck thickness of the Washington state ferries. The collision energy is calculated using the masses of both the struck ship (ferry) and the striking ship. The dam-

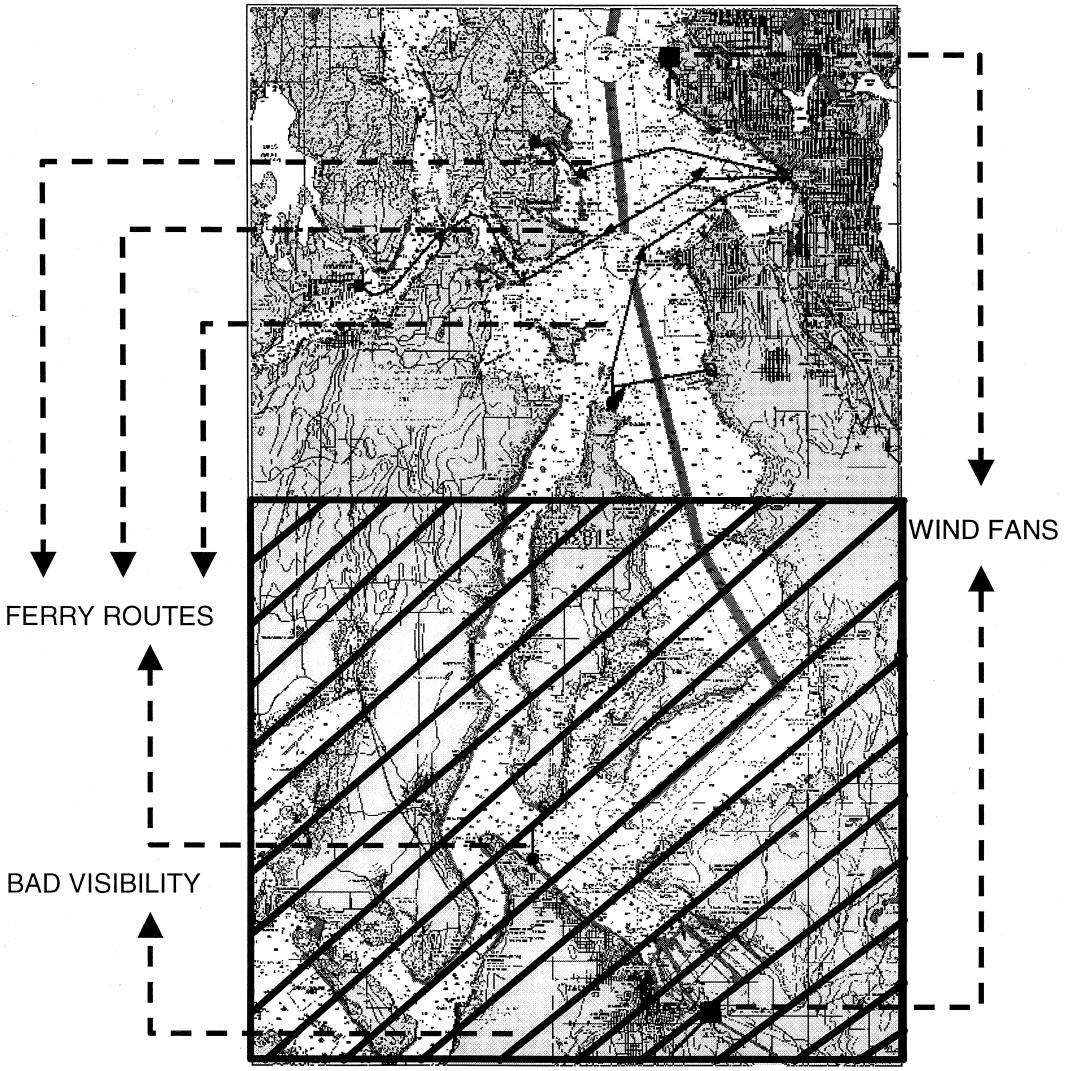


Fig. 4. Screen capture of the Washington state ferry system simulation.

age calculation results in a damage penetration along the waterline (DP_w) and damage width (DW) for every collision scenario. Figure 7 illustrates the importance of location of impact, angle of impact, and horizontal bow angle (α) in these calculations.

To establish the distribution over the three MRRT categories given calculated damage, a response time model was developed. Structural plans of the ferries were used to estimate the damage to bulkheads given calculated damage width and penetration. In case of damage below the waterline of the ferry and damage of enough bulkheads, flooding of multiple compartments of the ferry is possible.

To help address the response time question given the potential flooding of multiple compartments, the concept of MRRT is used. In the event that the possible number of flooded compartments is lower than the design limit of the ferry, the MRRT is judged to be long. If the possible number of flooded compartments is higher than the design limit, the MRRT may be judged to be short. The analysis was conducted for each possible class of striking vessel and each possible class of ferry in order to determine MRRT categories for each possible collision scenario.

Readers interested in a more in-depth discussion of the modeling approach—for example, the treatment of the expert-judgment elicitation procedure and subsequent analysis—are referred to Technical Appendix III of Harrald, van Dorp, Mazzuchi, Merrick, and Grabowski.[11]

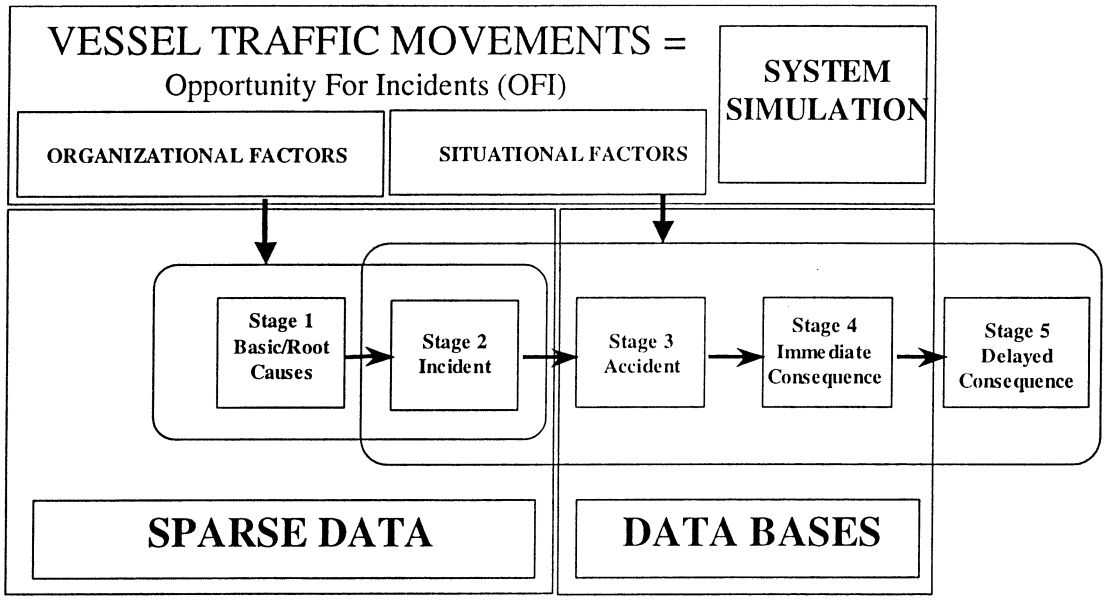


Fig. 5. Typical data availability relative to the maritime accident event chain.

3.4. Defining a Baseline Scenario

A representative simulation scenario was developed for the 11-year period for which historical data were collected. This simulation scenario (referred to as the calibration scenario) was developed for calibration purposes of the accident probability model to the historical data collected. The fall, spring, and summer sailing schedules in the last year (1997) of this 11-year period were used for the calibration scenario. These schedules are published by the WSF and comprise a full year of service. The WSF ferry schedules had remained fairly stable during this 11-year period. The WSF supplied the assignments of ferry classes to routes for the year 1997. The assignments of ferry classes to routes had remained fairly stable as well over this 11-year period. The blue-ribbon panel and WSF scheduling staff approved the use of the fall 1997, spring 1997, and summer 1997 sailing schedules and 1997 ferry class assignments for the calibration scenario.

To evaluate the risk reduction measures in Table I, a baseline level of risk needed to be established and thus a baseline scenario needed to be defined. The Washington state ferry risk assessment project started in July 1998. At this time, one high-speed ferry, the *Chinook*, had been delivered and was operating on the Seattle to Bremerton route. Two Jumbo Mark II class ferries also had started service or would start service on the Seattle to Bainbridge

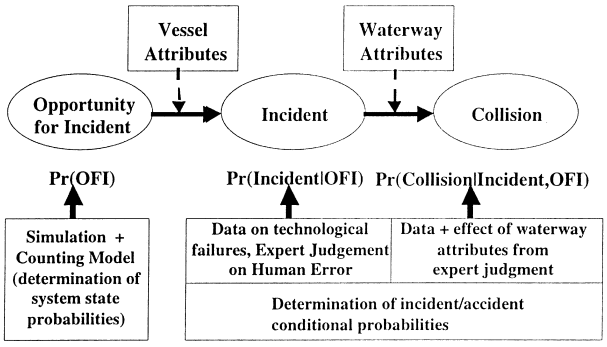


Fig. 6. Summary of modeling methodologies to establish collision risk.

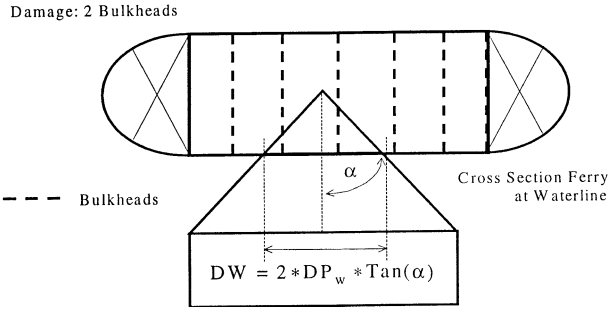


Fig. 7. Illustration of damage model calculations. DW = damage width, DP_w = damage penetration along the waterline.

Island route during 1998. The WSF schedule after the introduction of these ferries was considered the basis for the baseline scenario. Therefore, the calibration scenario was modified using 1998 schedules to represent a WSF schedule and assignments of ferries to routes after the introduction of these two new ferry classes: one high-speed ferry, the *Chinook*, and two Jumbo Mark II class ferries. The modified calibration scenario was defined as the baseline simulation scenario. The baseline simulation scenario was used to establish the baseline level of risk for risk intervention evaluation.

3.5. Modeling the Effect of Risk Interventions

The seven intervention classes described in Table I reduce accident probabilities, consequences, or both by intervening in the causal chain. The effect of a risk intervention measure may be modeled by changing model parameters from the baseline scenario. As shown in Fig. 3, some measures have an impact early on in the maritime accident event chain. Therefore, to model the effect of these risk interventions in a meaningful way, it is important that the system risk model represents events that far back in the causal chain. Rather than making worst case or best case assumptions concerning the effect of risk interventions on model parameters, the approach of reasonable assumptions following data analysis on human error in other transportation modes and mechanical-failure data of the WSF was taken, followed by sensitivity analysis.[12] The assumptions made to represent the seven intervention classes are listed in Table III. These assumptions were made in cooperation with maritime experts and were presented to and accepted by the Blue-Ribbon Panel on Ferry Safety.

4. BASELINE RISK AND RISK INTERVENTION EVALUATION RESULTS

In this section, a detailed discussion of baseline risk will be given in terms of the distribution of annual collision frequencies per year over the three MRRT categories by (1) ferry route and (2) ferry route and interacting vessel. Following the discussion of baseline risk, the effectiveness of risk intervention measures will be evaluated and presented. Results on the sensitivity analysis will be discussed as well.

4.1. Baseline Risk Results

Table IV presents the evaluated expected annual frequency of collisions per year over the three MRRT categories for the baseline scenario defined in Section 3. The average time between consecutive collisions in Table IV is the reciprocal of the statistical expected number of collisions per year.

Table IV summarizes the level of collision risk in the WSF system as a whole. The baseline statistical frequency of collisions per year, calculated using the baseline simulation, is 0.223 per year. The calibration statistical frequency of collisions per year, calculated using the calibration simulation, is 0.182 per year (equals two collisions over an 11-year period). Further analysis showed that this 22.7% increase in statistical frequency of collisions was mainly a result of replacing one of the older, slower passenger-only ferries on the Seattle–Bremerton route by the high-speed passenger-only ferry, the *Chinook*. It should be noted that the increase in statistical frequency of collisions is primarily of the 0–1 hr MRRT category due to the impact resulting from a high-speed collision with another vessel.

Table IV does not provide insight into which ferry route contributes most to the baseline level of

Table III. Summary of Modeling Effect of Risk Interventions Classes Tested

Class	Intervention	Assumed impact
1	Adopt ISM (International Safety Management) standard fleetwide	Reduce human error incidents by 30%, reduce mechanical failures by 3.7%, reduce consequences by 10%
2	Implement all mechanical-failure reduction measures fleetwide	Reduce mechanical-failure incidents by 50%
3	Implement high-speed ferry rules and procedures	Reduce human error incidents on high-speed ferries by 30%, reduce mechanical-failure incidents on high-speed ferries by 3.7%
4	Implement weather, visibility restrictions	Reduce the interactions with other vessels in bad visibility conditions by 10%
5	Implement traffic separation for high-speed ferries	Reduce interactions with high-speed ferries within 1 mile by 50%
6	Implement traffic control for deep-draft traffic	Set maximum allowable traveling speed in Admiral Inlet, north Puget Sound, central Puget Sound, and south Puget Sound at 15 knots
7	Increase time available for response	Improve response time in the 1–6 hr MRRT category by 50%

Note: MRRT = maximum required response time.

Table IV. Baseline Risk

Category	Statistical expected number of collisions per year per category	Average time between consecutive collisions per category (years)
0–1 hr MRRT	0.055	18.1
1–6 hr MRRT	0.015	67.5
>6 hr MRRT	0.152	6.6
Total	0.223	4.5

Note: MRRT = maximum required response time.

system collision risk. To further the understanding of the baseline collision risk levels, Fig. 8 shows the contribution to collision risk by ferry route. Table V gives the abbreviations used for the 13 different ferry routes displayed in Fig. 8.

In Fig. 8, the annual frequency of collisions for each route is further broken down into the three MRRT categories. Figure 8 shows that the six routes that contribute most to the level of system collision risk are (1) the Seattle to Bremerton car ferries, (2) the Seattle to Bremerton passenger ferries, (3) the Seattle to Bainbridge Island ferries, (4) the Edmonds to Kingston ferries, (5) the Fauntlerory to Vashon Island ferries, and (6) the Seattle to Vashon ferries. These routes are geographically centered around the main Seattle metropolitan area.

It cannot be concluded from the information in Fig. 8 whether the risk levels for the ferry routes are driven by (1) high numbers of interactions with other vessels, that is, traffic congestion relative to the other ferry route, (2) high collision risk per interaction, or (3) both. Hence, the next step in understanding baseline risk is to further decompose the collision risk levels by the type of vessels that the ferries interact with on a particular ferry route. The type of interacting vessel contributes both to the collision probability for each interaction and the MRRT categorization of each interaction.

The results will be presented in three-dimensional graphs displaying the collision risk levels by ferry route and interacting vessel type. The keys for these graphs are given in Table V and Table VI. Figure 9 shows the number of interactions per year by ferry route and by interacting vessel type. The higher bars to the right of the Vessel Class Index axis shows that the number of interactions is much higher with Washington state ferries (Keys 13 to 22 in Table VI) than with non-WSF vessels (Keys 1 to 12). For the Ferry Route Index axis, the highest bars are on Route indices 1 through 3. These are the Seattle to Bremerton routes and the Seattle to Bainbridge route.

Figure 10 shows the average collision probability per interaction by ferry route and interacting vessel type. The higher bars to the left of the Vessel Class Index axis (Keys 1 to 12) show that the interactions with

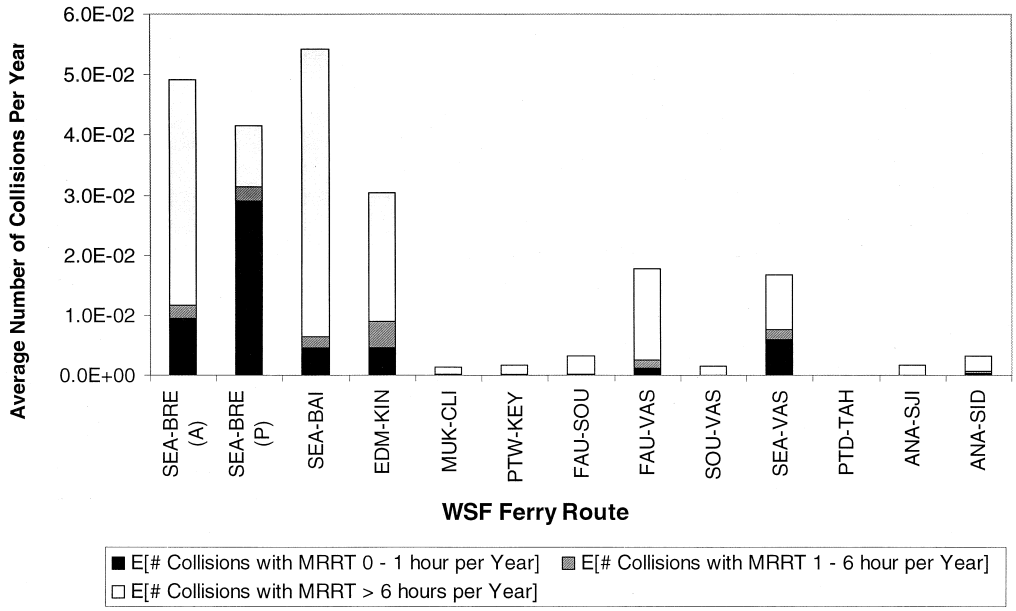


Fig. 8. Statistical expected number of collisions per year by ferry route. See Table V for abbreviations. WSF = Washington state ferries. MRRT = maximum required response time.

Table V. Numbering Keys and Abbreviations for Ferry Routes

Route index	Ferry route	Abbreviation
1	Seattle–Bremerton car ferries	SEA-BRE (A)
2	Seattle–Bremerton passenger ferries	SEA-BRE (P)
3	Seattle–Bainbridge	SEA-BAI
4	Edmonds–Kingston	EDM-KIN
5	Mukilteo–Clinton	MUK-CLI
6	Port Townsend–Keystone	PTW-KEY
7	Fauntleroy–Southworth	FAU-SOU
8	Fauntleroy–Vashon	FAU-VAS
9	Southworth–Vashon	SOU-VAS
10	Seattle–Vashon	SEA-VAS
11	Port Defiance–Tahlequah	PTD-TAH
12	Anacortes–San Juan Islands	ANA-SJI
13	Anacortes–Sidney	ANA-SID

non-WSF vessels are more likely to lead to a collision than interactions with Washington state ferries (Keys 13 to 22). Figure 11 shows the annual collision frequency by ferry route and type of interacting vessel and is a combination of the information in Figs. 9 and 10. The highest bars are on Routes 1 to 3, the Seattle–Bremerton routes and the Seattle–Bainbridge route. Overall, there are relatively high bars for the annual collision frequency for interactions with both other WSF ferries and non-WSF vessels on these routes.

From Fig. 10 it can be observed that the annual frequency of collisions with non-WSF vessels is driven by the collision probability for each interaction. From Fig. 9 it can be observed that the annual frequency of collisions with WSF ferries are driven by the number of interactions per year.

In terms of emergency response, accidents that fall in the less than 1 hr MRRT category are of particular concern. Using the damage model and the response time model, the annual collision frequencies in Fig. 11 can be filtered to include only those in the less than 1 hr MRRT category. The results are shown in Fig. 12. It can be concluded from Figs. 11 and 12 that the Seattle–Bremerton passenger-only route (Ferry Route Index Key 2) and the vessels that interact with it have a larger statistical expected number of collisions with an MRRT of less than 1 hr. The Seattle to Vashon passenger-only route (ferry Route Index Key 10) also has a relatively high annual frequency of collisions in the less than 1 hr MRRT category. The new high-speed passenger-only ferry is solely assigned to the Seattle–Bremerton passenger-only route. Collisions involving the high-speed passenger-only ferries are always assessed to require a maximum response time of less than 1 hr. The older passenger-only ferries are used for both the Seattle to Bremerton and the Seattle to Vashon passenger-only routes and interact with both large car ferries and deep-draft non-WSF vessels, as shown in Fig. 9. A proportion of the collisions of the older passenger-only ferries with large car ferries and deep-draft non-WSF vessel fall in the less than 1 hr MRRT category.

The information in Fig. 12 may be summarized in the form of a ranked cumulative risk contribution chart, as presented in Fig. 13. The ferry route and interacting vessel combinations are ordered from left to right by the percentage contribution to the statistical expected number of collisions per year. The dark part of each bar in Fig. 14 indicates the percentage contribution to the statistical expected number of collisions in the less than 1 hr MRRT category for that collision scenario. The total height of the bar indicates the cumulative percentage including all colli-

Table VI. Numbering Keys for Interacting Vessels

Vessel index	Vessel class	Vessel index	Vessel class
1	Passenger	12	Misc.
2	Tug/barge	13	Jumbo Mark II
3	Freight ship	14	Jumbo
4	Container	15	Super
5	Bulk carrier	16	Issaquah
6	Refrigerated cargo	17	Evergreen
7	Tanker	18	Steel electric
8	Product tanker	19	Rhododendron
9	Other	20	Hiyu
10	Roll-on, roll-off	21	Passenger-only vessel
11	Naval	22	Chinook

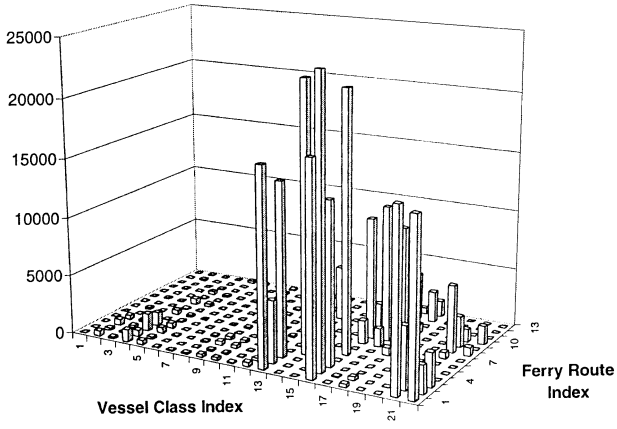


Fig. 9. Number of interactions per year by ferry route and vessel class.

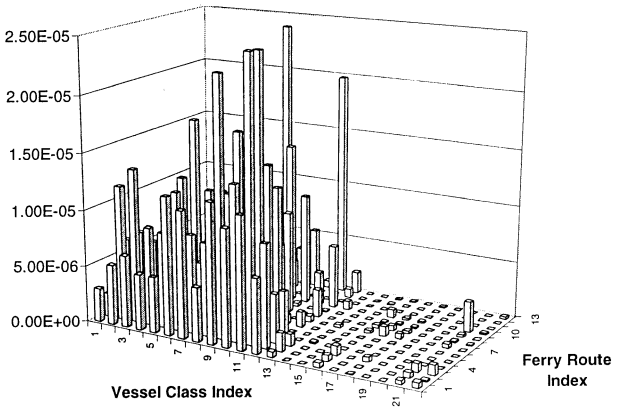


Fig. 10. Average collision probability per interaction by ferry route and vessel class.

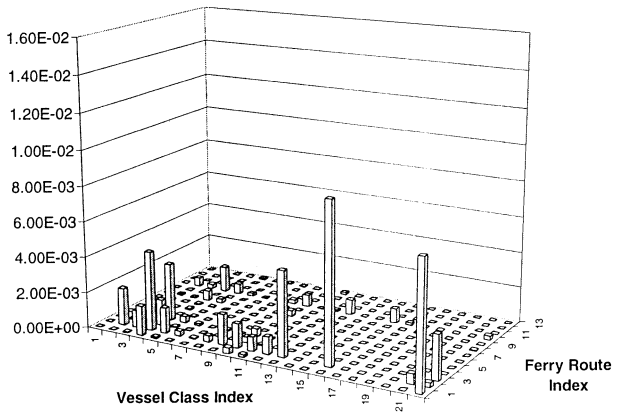


Fig. 12. Statistical expected number of collisions per year with a maximum required response time of less than 1 hr by ferry route and vessel class.

sion scenarios to the left. In other words, Fig. 13 contains the top collision scenarios that accumulate to 88% of the statistical expected number of collisions per year in the less than 1 hr MRRT category.

4.2. Evaluation of Risk Interventions

All cases were tested to evaluate their effect on the annual frequency of collisions and on the annual frequency of collisions in each of the MRRT categories. The results of these analyses are represented in Fig. 14. For each risk intervention class, the total percentage reduction in the statistical frequency of collisions is comprised of the percentage reduction in the statistical frequency of collisions in each of the three MRRT categories relative to the baseline scenario in Table IV.

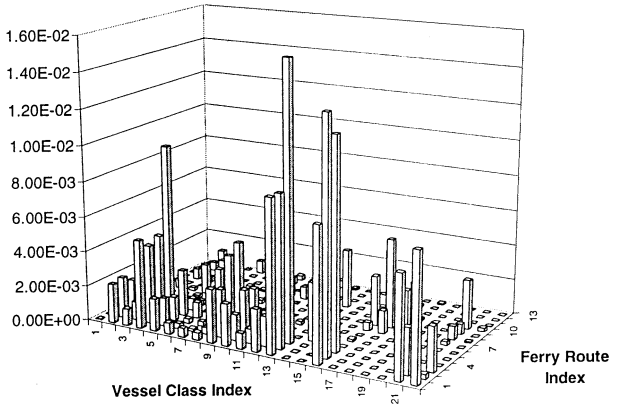


Fig. 11. Statistical expected number of collisions per year by ferry route and vessel class.

Case 1 has the largest risk reduction at 16% and reflects the effect of the fleetwide implementation of the International Safety Management (ISM) code. Noted is a large reduction for both the less than 1 hr and the more than 6 hr MRRT categories. Case 2, the implementation of mechanical-failure-reducing measures, is the next most effective at 11%. Of note is a large reduction in each MRRT category as well as the large reduction predicted for collisions with a MRRT of 1 to 6 hr. The implementation of traffic separation rules for the high-speed ferries, Case 5, causes a 6% reduction in the total statistical expected number of collisions. As this reduces the statistical expected number of collisions involving high-speed ferries, all this reduction is for collisions with an MRRT of less than 1 hr. A 5% reduction in the total statistical expected number of collisions is predicted for the implementation of visibility restrictions, Case 4. The implementation of high-speed ferry rules (ISM restricted to high-speed ferry routes), Case 3, decreases the total statistical expected number of collisions by 2%, with all the reduction being for collisions with an MRRT of less than 1 hr. Case 7 is aimed at reducing the consequences if a collision occurs, not the probability of occurrence. This case reflects the implementation of procedures to evacuate passengers to a safe haven in the event of collision with an MRRT of 1 to 6 hr—survival craft. Reducing the speed of commercial vessels in Puget Sound, Case 6, also does not reduce the total statistical expected number of collisions. The statistical expected numbers of collisions with an MRRT of less than 1 hr and an MRRT of 1 to 6 hr are both reduced, however, while the statistical expected number of collisions with an MRRT of more than 6 hr increased by the same amount.

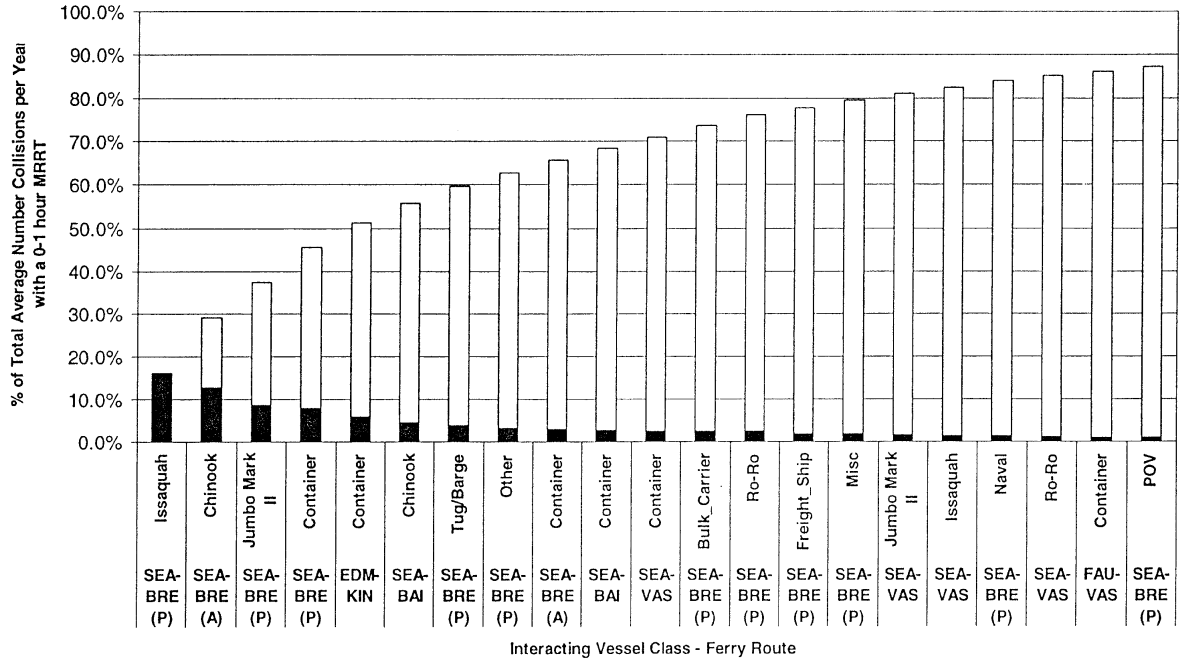


Fig. 13. Distribution of the statistical expected number of collisions per year with a maximum required response time (MRRT) of less than 1 hr by ferry route and vessel class. See Table V for abbreviations.

5. SENSITIVITY ANALYSIS RESULTS

The analysis of the WSF risk assessment provides the basis for determining how the risk in the system could be reduced to even lower levels. The findings of a quantitative study must be interpreted with care, however, as uncertainty is introduced at various levels of the analysis. Sources of this uncertainty include incomplete or inaccurate data, biased or uninformed expert judgment, modeling error, and computational error. Testing for the level of uncertainty in an analysis requires accounting for both parameter uncertainty and model uncertainty and their impact on the results and conclusions. This is referred to as an "uncertainty analysis."[12]

While the use of proper procedures such as rigorous data selection and cross validation—structured and proven elicitation methods for expert judgment and use of accepted models—can reduce uncertainty and bias in an analysis, it can never be fully eliminated. The reader should recognize that the value of an analysis is not only in the precision of the results, but also in the understanding of the system. Of great value is the identification of peaks, patterns, unusual circumstances and trends in system risk, and changes in system risk through risk mitigation measure implementation.

The methodology in this study has been reviewed for rigor and tested in operational settings.[13] The methodology thus provides many safeguards to remove bias and to detect error. The general approach toward modeling assumptions in the WSF risk assessment was that of reasonableness rather than pursuing one worst case assumption after the other. The latter approach may lead to risk assessment results related to highly unlikely scenarios and therefore less-useful results. The approach of using reasonable assumptions rather than worst case assumptions is supported by scientists in the field of risk analysis.[12]

Although a formal uncertainty analysis has not been presented with these results, sensitivity of the results to some of the more contentious modeling assumptions has been tested. The assumptions tested/challenged through the sensitivity cases were

1. All collisions involving a high-speed ferry fall in the category of collision with an MRRT of 0–1 hr
2. The vertical bow angle reduces the damage penetration below the waterline
3. The horizontal bow angle for vessels in the WSF system is, on average, 66°

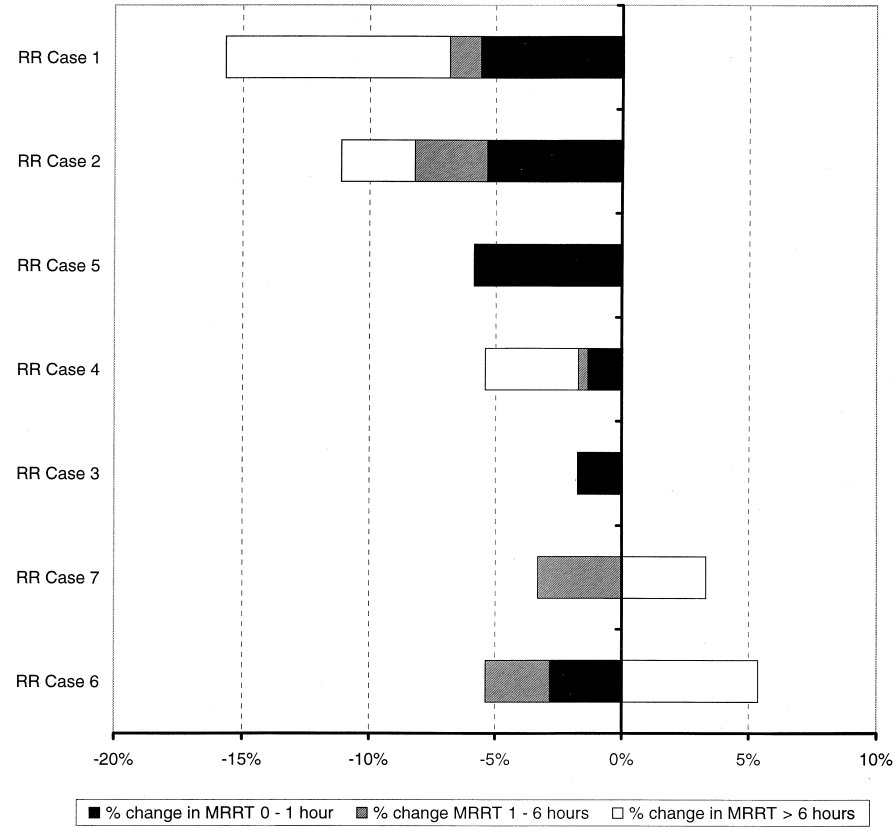


Fig. 14. Estimated risk reduction (RR) for the seven tested cases. MRRT = maximum required response time.

4. The collision speed for non-WSF vessels is 80% of the traveling speed, and the collision speed of WSF vessels is 50% of the traveling speed
5. The relative depth penetration (RDP = percentage damage penetration relative to the beam of the WSF-ferry) threshold beyond which the RDP determines the distribution of collisions over the three MRRT categories is 50%
6. The steel electric vessel has parts that satisfy one-compartment vessel characteristics and two compartment vessel characteristics

To test these six assumptions, nine sensitivity cases were developed and analyzed. For demonstrative purposes, the first listed assumption (Assumption 1) is that all collisions involving the new high-speed passenger-only ferries fall in the less than 1-hr MRRT category. This assumption was modified so that all three MRRT categories are equally likely in case of a collision involving the high-speed passenger-only ferry and is henceforth referred to as Sensitivity Case 1. This assumption is more optimistic than Assumption 1. The results of the sensitivity analysis are shown in Fig. 15.

Figure 15 shows that the statistical frequency of collisions in the less than 1 hr MRRT category reduces by 9% in Sensitivity Case 1. Also of note is that the combined percentage increase in statistical frequency of collisions in the 1–6 hr MRRT category and more than 6 hr MRRT category equals the percentage reduction in the less than 1 hr MRRT category. In other words, the effect of the modified assumption is a redistribution of the total statistical frequency of collisions over the three different MRRT categories. The same observation can be made for all the other sensitivity cases tested as well.

Figure 16 summarizes the collision analysis by ferry route under Sensitivity Case 1. Comparing Figs. 8 and 16, it can be observed that by altering Assumption 1 the statistical frequency of collisions in the less than 1 hr MRRT category has primarily been reduced on the Seattle Bremerton passenger ferries, Seattle

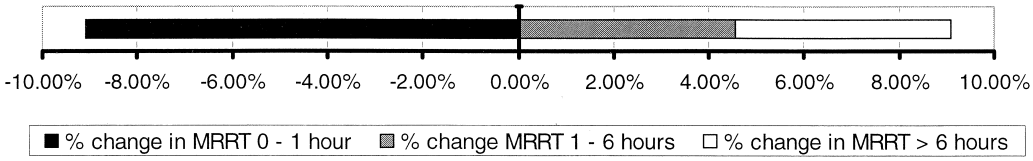


Fig. 15. Percent change in the annual collision frequency in each maximum required response time (MRRT) category under Sensitivity Case 1.

Bremerton car ferries, and the Seattle Bainbridge ferries. The predominant WSF ferry routes in terms of the statistical frequency of collisions in the less than 1 hr MRRT category, however, are the same under the original assumption and the modified assumption for high-speed passenger-only ferries. Similar conclusions can be drawn when analyzing these results for the other sensitivity cases as well.

6. GENERAL CONCLUSIONS

Sixteen specific risk reduction recommendations are cited in Harrald *et al.*[11] Recommendations derived from the analysis were divided into three categories: (1) general risk management recommendations for the Washington state ferries to manage risk in the system, (2) recommendations for reducing the likelihood of accidents, and (3) recommendations for minimizing the potential consequences of accidents. Interested readers are referred to Harrald *et al.*[11] for the specific recommendations. Below are general conclusions in terms of the previous three categories of risk management recommendations.

In terms of general risk management, it was recommended that the Washington state ferries should improve their capabilities to detect and manage risk and to prepare for potential emergencies. This requires a continuing set of systems, capabilities, and structures in order to be effective. Maintaining and enhancing safety in the WSF system requires management and resources devoted to risk prevention, accident response, and consequence management. The WSF risk assessment report supports the currently planned and funded fleetwide implementation of the ISM system.

In terms of reducing the likelihood of accidents, it was recommended that the WSF should continue to implement safety management and training programs, provide adequate relief crews as necessary to accomplish training, and coordinate with the USCG to minimize the likelihood of an accident. It was

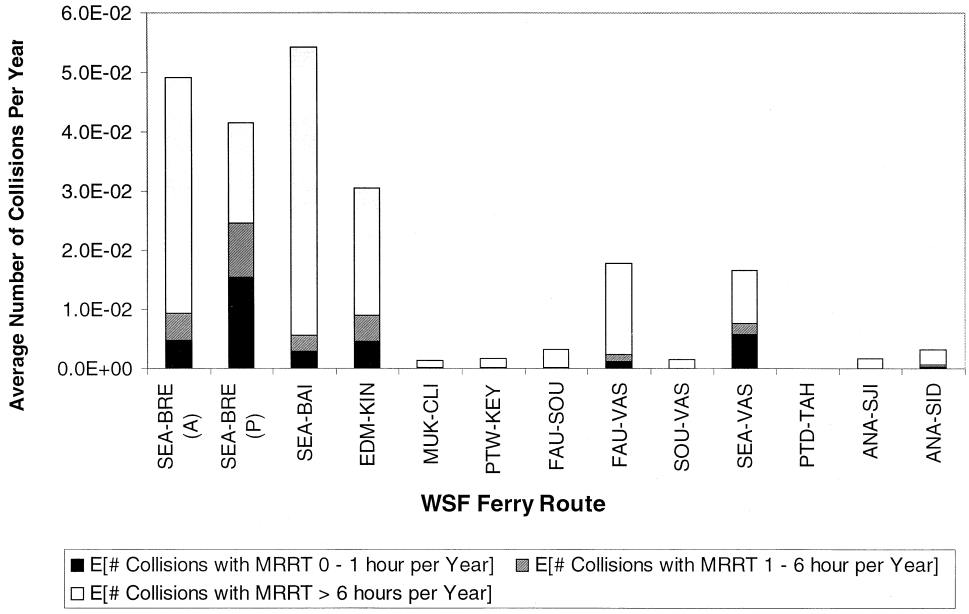


Fig. 16. Distribution of statistical frequency of collisions over the three maximum required response time (MRRT) categories by ferry route—Sensitivity Case 1. See Table V for abbreviations.

noted that since the consequences of an intentional act of destruction (sabotage or attack) aboard a ferry could be severe, the WSF should work with the Washington State Patrol and federal agencies to determine the need for additional security measures to combat the threat of intentional acts of destruction aboard ferries.

In terms of minimizing the potential consequences of accidents, it was recommended that the WSF, the USCG, and other response organizations should work collaboratively to ensure that consequences will be minimized for any accident that does occur. Specifically, it strongly recommends that the WSF and the USCG and other public safety agencies address the problem of minimizing injury and loss of life from very low-probability but potentially high-consequence accidents through planning, implementing, and exercising adequate response plans and procedures. It recognizes that the skills of the ferry crew will be crucial in any emergency situation and strongly recommends enhancing these emergency skills through training, certification, drills, and exercises.

The report finally concludes that the most cost-effective way to minimize the risk of potential accidents is to invest in WSF people and systems and to make improvements and changes to WSF policies, procedures, and management systems—rather than to merely invest in capital equipment such as survival craft. The creation of a safety culture that will enable these recommendations to be realized will require the support and leadership of WSF management; shoreside operations; and fleet deck officers, engineers, and other shipboard personnel.

The conclusions and recommendations made to the WSF were driven by the total statistical frequency of collisions and by the distribution of the total statistical frequency of collisions over the three MRRT categories. Based on the results of the sensitivity analysis performed, it was concluded that the conclusions and recommendations made were robust relative to the modified assumptions tested.

As a closing note, it might be of interest to mention that it is impossible for any risk analysis performed in a dynamic public arena to foresee changes as a result of political processes. An example is the passage of Initiative 695, which eliminated the state motor vehicle excise tax. The effect for the WSF is a disproportional loss in operating and capital budget potentially impacting the level at which recommendations from this study will be implemented. Loss of operating budget already temporarily interrupted the service of two high-speed ferries, the *Chinook* and the *Snohomish*. The current legislative plan, includes funding to maintain the operations of the *Chinook* and *Snohomish*. A simulation scenario including two high-speed ferries in the WSF schedules was analyzed in the WSF risk assessment report as well. For detailed results interested readers are referred to the WSF risk assessment report in Harrald *et al.*[11]

ACKNOWLEDGMENTS

The authors would like to thank the associate editor and the referees for their most helpful comments, which benefited this article in quality of content and readability.

REFERENCES

1. Washington State Ferries. (2000). http://www.wsdot.wa.gov/ferries/info_desk/route-maps/. (9 January 2001).
2. Lifesaving Systems for Certain Inspected Vessels, 46 C.F.R. 199, Subchapter W (1 October 1998).
3. Implementation of the 1995 Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW). 62 Fed. Reg. 123, 34506–34541.
4. International Maritime Organization, Subcommittee on Ship Design and Equipment. (1998). Revision of the HSC Code, Formal Safety Assessment of High Speed Catamaran (HSC) Ferries Submitted by the United Kingdom (41st Session, Agenda Item 5), E/DE/41/5–6.
5. Harrald, J. R., Mazzuchi, T. A., Merrick, J. R. W., Shrestha, S. K., Spahn, J. E., & van Dorp, J. R. (1996). *Final report: Prince William Sound risk assessment.* Submitted to the Prince William Sound Risk Assessment Steering Committee, Anchorage, AK.
6. Dyer, M. D., Schwenk, J., Watros, G., & Boniface, D. (1997). *Scoping risk assessment, protection against oil spills in the maritime waters of northwest Washington State.* Cambridge, MA: John Volpe National Transportation Systems Center.
7. Cooke, R. M. (1991). *Experts in uncertainty: Expert opinion and subjective probability in science.* New York: Oxford University Press.
8. Paté-Cornell, M. E. (1996). Uncertainties in risk analysis: Six levels of treatment. *Reliability Engineering and System Safety, 54*(2–3), 95–111.
9. Harrald, J. R., Mazzuchi, T. A., & Stone, S. M. (1992). Risky business: Can we believe port risk assessments? In D. Torseth (Ed.), *Ports '92 Conference Proceedings* (pp. 657–669). New York: American Society of Civil Engineers.
10. Minorsky, V. U. (1959). An analysis of ship collisions with reference to protection of nuclear power plants. *Journal of Ship Research, 3*, 1–4.
11. Harrald, J. R., van Dorp, J. R., Mazzuchi, T. A., Merrick J. R. W., & Grabowski, M. (1999). Final report: Washington state ferry risk assessment. Submitted to the Washington State Transportation Commission, Seattle, WA.
12. Hattis, D., & Anderson, E. L. (1999). What should be the implications of uncertainty, variability, and inherent "biases"/"conservatism" for risk management decision making. *Risk Analysis, 19*, 95–107.
13. Marine Board, National Research Council. (1998). *Review of the Prince William Sound, Alaska, risk assessment study.* Washington, DC: Committee on Risk Assessment and Management of Marine Systems, National Academy Press.

SUB-APPENDIX:

J.R.W. Merrick, J.R. van Dorp, J.P. Blackford, G.L. Shaw, T.A. Mazzuchi and J.R. Harrald (2003). "A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model", Reliability Engineering and System Safety, Vol. 81 (2): pp. 119-132.

Available online at www.sciencedirect.com
SCIENCE DIRECT®
Reliability Engineering and System Safety 81 (2003) 119–132
RELIABILITY ENGINEERING & SYSTEM SAFETY
www.elsevier.com/locate/ress

A traffic density analysis of proposed ferry service expansion in San Francisco Bay using a maritime simulation model

Jason R.W. Merrick[a,*], J. Rene van Dorp[b], Joseph P. Blackford[b], Gregory L. Shaw[b], Jack Harrald[b], Thomas A. Mazzuchi[b]

[a]*Department of Statistical Sciences and Operations Research, Virginia Commonwealth University, P.O. Box 843083, 1001 West Main St, Richmond, VA 23284, USA*
[b]*Department of Engineering Management and Systems Engineering, The George Washington University, 1776 G St NW, Suite 110, Washington, DC 20052, USA*

Received 24 November 2002; accepted 12 February 2003

Abstract

A proposal has been made to the California legislature to dramatically increase the frequency and coverage of ferry service in the San Francisco Bay area. A major question in the approval process is the effect of this expansion on the level of congestion on the waterway and the effect this will have on the safety of vessels in the area. A simulation model was created to estimate the number of vessel interactions in the current system and their increases caused by three alternative expansion plans. The output of the simulation model is a geographic profile showing the frequency of vessel interactions across the study area, thus representing the level of congestion under each alternative. Comparing these geographic interaction profiles to a similar one generated for the current ferry service in the San Francisco Bay allows evaluation of the increase in exposure of ferries to adverse conditions, such as, for example, the interaction of high-speed ferries in restricted visibility conditions. This analysis has been submitted to the legislature as part of the overall assessment of the proposal and will be used in the expansion decision.
© 2003 Elsevier Science Ltd. All rights reserved.

Keywords: Maritime transportation; Simulation; Safety; Accident prevention

1. Introduction

In an effort to relieve congestion on freeways, the state of California is proposing to expand ferry operations on San Francisco (SF) Bay by (1) phasing in up to 100 ferries in addition to the 14 currently operating, (2) extending the hours of operation of the ferries, (3) increasing the number of crossings, and (4) employing some high-speed vessels. The state of California has directed the SF Bay Area Water Transit Authority (WTA) to produce an *Implementation and Operations Plan*, part of which requires working with the US Coast Guard (USCG), the California Maritime Academy, and SF Bay Area ferry operators in preparing a 'plan for ensuring safety of vessel operations traveling on the SF Bay.' The purpose of this plan is to realistically evaluate the levels of safety relative to various aspects of ferry operation.

In the process of developing the safety plan the WTA used data from the Federal Transit Administration National Transit database to describe the current safety level. Federal databases describe the past safety performance of the existing ferry services. Between 1996 and 2000, ferry service appeared to be the safest federally subsidized transit mode in the SF Bay Area. The WTA's comparison showed that ferry transportation had: (1) no fatalities for patrons, employees, or others (i.e. bystanders). The average for the rail and roadway transit modes was 0.004 fatalities per 1,000,000 passenger miles; (2) less than one-fourth the patron injury rate of the rail and roadway transit modes. Ferry operations averaged 0.28 injuries per 1,000,000 passenger miles; (3) about two-thirds the bystander injury rate of the rail and roadway transit modes. Ferry operations averaged 1.5 injuries per 1,000,000 vehicle miles; (4) on average 5.6 reported accidents per 100,000 transits, or 3.8 reported accidents per year for the 10-year period from 1992 to 2001; this is in line with the rates for similar marine transportation systems.

* Corresponding author. Tel.: +1-804-828-1301x136; fax: +1-804-828-8785.
E-mail address: jrmerric@vcu.edu (J.R.W. Merrick).

0951-8320/03/$ - see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0951-8320(03)00054-1

The WTA safety plan further documents a wide range of risks and associated risk controls. For risks and necessary risk controls that are already documented in codes, standards, and regulations, the plan provides a very brief overview. In conclusion, the safety plan indicates that analysis of the existing ferry services show that those services provide safe transit and are currently effectively managing risks. However, the question remains whether this 'safe' operation can continue with the new pressures of aggressive service expansion. The three proposed expansion scenarios are: (1) Alternative 3: Enhanced Existing System; (2) Alternative 2: Robust Water Transit System and (3) Alternative 1: Aggressive Water Transit System. From these, Alternative 3 is the least aggressive expansion scenario and Alternative 1 is the most aggressive one. The WTA tasked the author's to investigate the impact of ferry service expansion on maritime traffic congestion in the SF Bay area by developing a maritime simulation model of the SF Bay. Due to time and budget constraints a full-scale risk assessment, such as the authors' previous work in the Prince William Sound Risk Assessment [1–3] or the Washington State Ferries Risk Assessment [4,5], was not feasible. In these studies, a simulation of the traffic and weather patterns was used to count interactions between the vessels and an expert judgment based accident probability model was used to estimate the likelihood of a collision if such an interaction occurs. Instead, to assess the impact of aggressive ferry expansion, the scope of the SF Bay study was limited to the simulation part of the model, leaving the accident probability part to a later project if the expansion proposal is approved.

Limiting the scope of the analysis to interactions, however, will still allow meaningful conclusions regarding potential effect of the ferry service expansions on observed collision rates. In fact, interactions are known to be one of the drivers in collision risk [5]; an increase in interactions will typically result in an increase in collision risk if additional risk interventions are not put in place. The purpose of the simulation is to assess the interactions of vessels in the current ferry system and to compare their geographic profile to the interactions seen under the proposed scenarios. For instance, if the daily volume of ferry transits increases 10-fold does the number of interactions increase 10-fold? Is it possible that, since the proposed alternatives include new routes to new areas of the SF Bay, the additional interactions are distributed in such a manner that no additional high-traffic density areas occur that could indicate safety problems? Due to its unique visibility conditions, one of the main safety concerns in the SF Bay is transiting through restricted visibility. If there are additional high-traffic density areas, do they perhaps occur in restricted visibility conditions? The simulation study in this paper attempted to answer such critical safety questions.

An outline of the paper is as follows. Previous work in maritime risk assessment and simulation are discussed in Section 2. Sections 3–5 discuss the construction of the simulation, specifically the interaction-counting model in Section 3, vessel movements in Section 4 and restricted visibility modeling in Section 5. The results of the study are outlined in Section 6. Conclusions and recommendations are presented in Section 7.

2. Literature review

The National Research Council has repeatedly identified the assessment and management of risk in maritime transportation as an important problem domain [6–9]. In earlier work, researchers concentrated on assessing the safety of individual vessels or marine structures, such as nuclear powered vessels [10], vessels transporting liquefied natural gas [11], and offshore oil and gas platforms [12]. The USCG has used a classical statistical analysis of nationwide accident data to prioritize federal spending to improve port infrastructures [13,14]. More recently, researchers have used probabilistic risk assessment (PRA) [15] in the maritime domain [16–23] by examining risk in the context of maritime transportation systems (MTS) [9].

In a MTS, traffic patterns change over time in a complex manner. Researchers have used system simulation as a modeling tool to assess MTS service levels [24], to perform logistical analysis [25], and to facilitate the design of ports [26]. The dynamic nature of traffic patterns and other situational variables, such as wind, visibility, and ice conditions, mean that risk levels change over time. Recent PRAs [27] in the maritime domain have used simulation to model the dynamic nature of the transportation system.

The Prince William Sound Risk Assessment [1–3] used a simulation of the oil transportation system to evaluate changes in the dynamic pattern of traffic caused by proposed risk intervention measures, such as weather-based closure conditions for certain parts of the transit and modifications to the tug escort service put in place to save disabled tankers from running aground. Accident and incident data was augmented using expert judgment to take the simulations interaction counts and arrive at estimates of accident frequency and the expected volume of oil outflow. The Washington State Ferries Risk Assessment [4,5] used an improved version of the technique, but with the consequence of interest being passenger safety rather than environmental damage.

As mentioned previously, the study in this paper used the simulation part of this approach to only assess the impact of ferry expansion on the level of vessel interactions in the Bay. If the expansion proposal is approved, the simulation analysis can be extended to a full PRA through an accident probability model based on available accident, incident data and expert judgments.

3. The simulation: interaction counting model

In the simulation program, a snapshot of the simulation is taken every minute; counts of the interactions are taken and

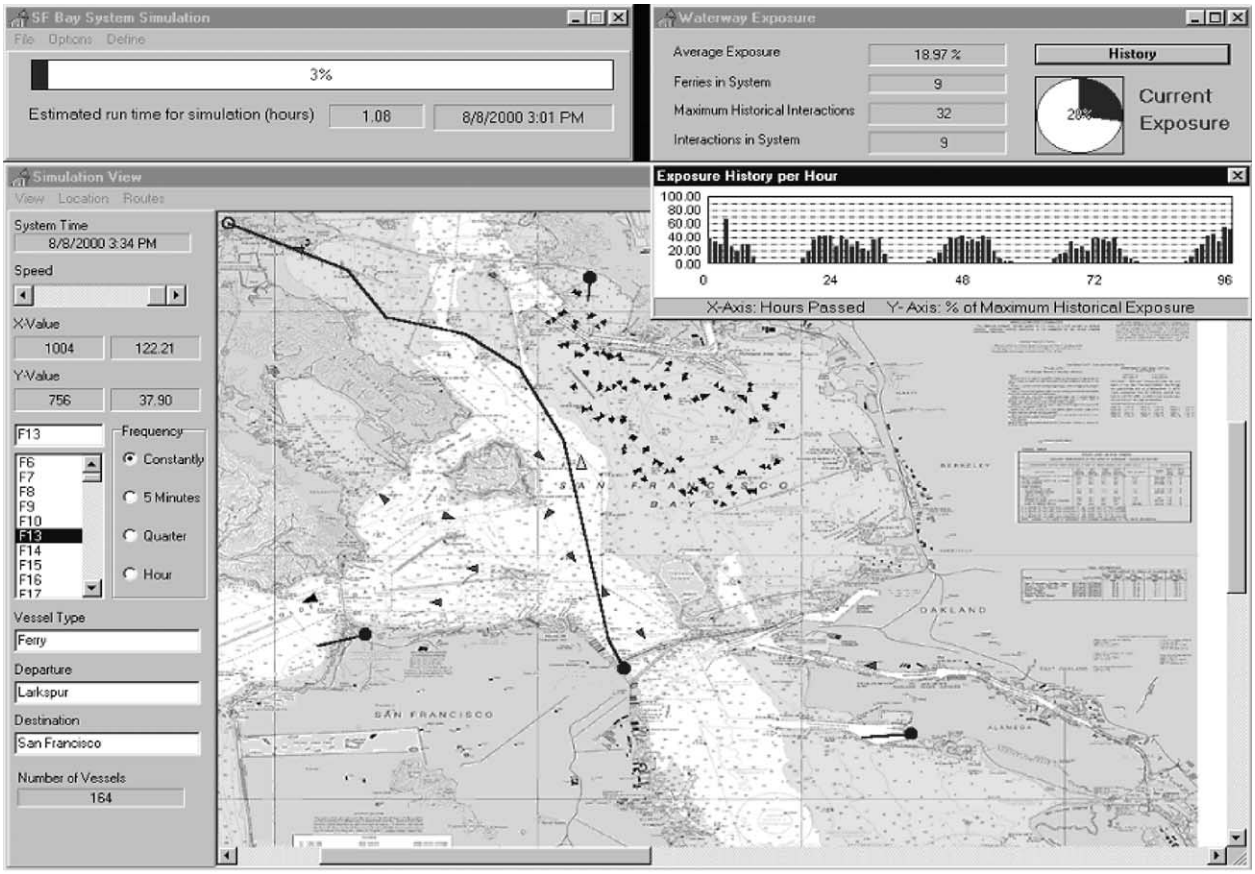


Fig. 1. A snapshot of the SF Bay maritime simulation model.

recorded in an event database. Fig. 1 shows such a snapshot of the SF Bay maritime simulation. Moving boats are represented by the triangles. Which pairs of vessels are interacting? This depends on both the distance between the vessels the time until the vessels meet.

The interaction model is based on Closest Point of Approach type arguments and stems from the considerations that a ferry captain will make when considering interactions with other vessels. For example, vessels close in at different speeds, thus in evaluating a situation involving other vessels, a captain is interested in which will arrive first, not necessarily which is closest.

Consider a ferry transiting through the system. As a default, any other vessel within a half a nautical mile[1] of the ferry is counted as interacting; half a nautical mile is too close for comfort to most professional mariners. If another vessel is more than half a mile away and in addition is more than five minutes away from crossing the track of the ferry, it is not counted as an interaction. If a vessel is within five minutes of crossing the ferry track and in addition this crossing will occur within one nautical mile in front of the ferry or within half a mile behind the ferry, the vessel is counted as interacting with ferry. Experts with maritime experience outside the ferry service and a group of ferry captains from the Washington State Ferry Service provided input for this methodology [5,28].

The snapshot of the simulation at a specific time is analyzed to determine whether the ferries in the system are interacting with other vessels (including other ferries) using the interaction model above. For each interaction found, the information about the type of the other vessel, the type of interaction (crossing, meeting or passing), the visibility conditions and the coordinates of the vessels are recorded and written to an interaction database. This database is then used to find the number of interactions occurring in a simulation run in each of a grid of cells across the SF Bay.

This information can then be represented in the form of a colored map, with the colors representing the number of interactions in each cell of our grid. This map may be interpreted as a geographic profile of ferry interactions. The color gradient for the grid cells is established using a simulation of the current ferry service on the SF Bay (to be referred to as the Base Case). The Base Case analysis allows existing trouble spots to be identified, thereby not attributing these to the planned ferry service expansions. Next, using the Base Case color scale, similar geographic profiles can be generated for these expansions. Emerging hot spots resulting from the expansions can be visually observed by

[1] One nautical mile equals approximately 1.15 miles.

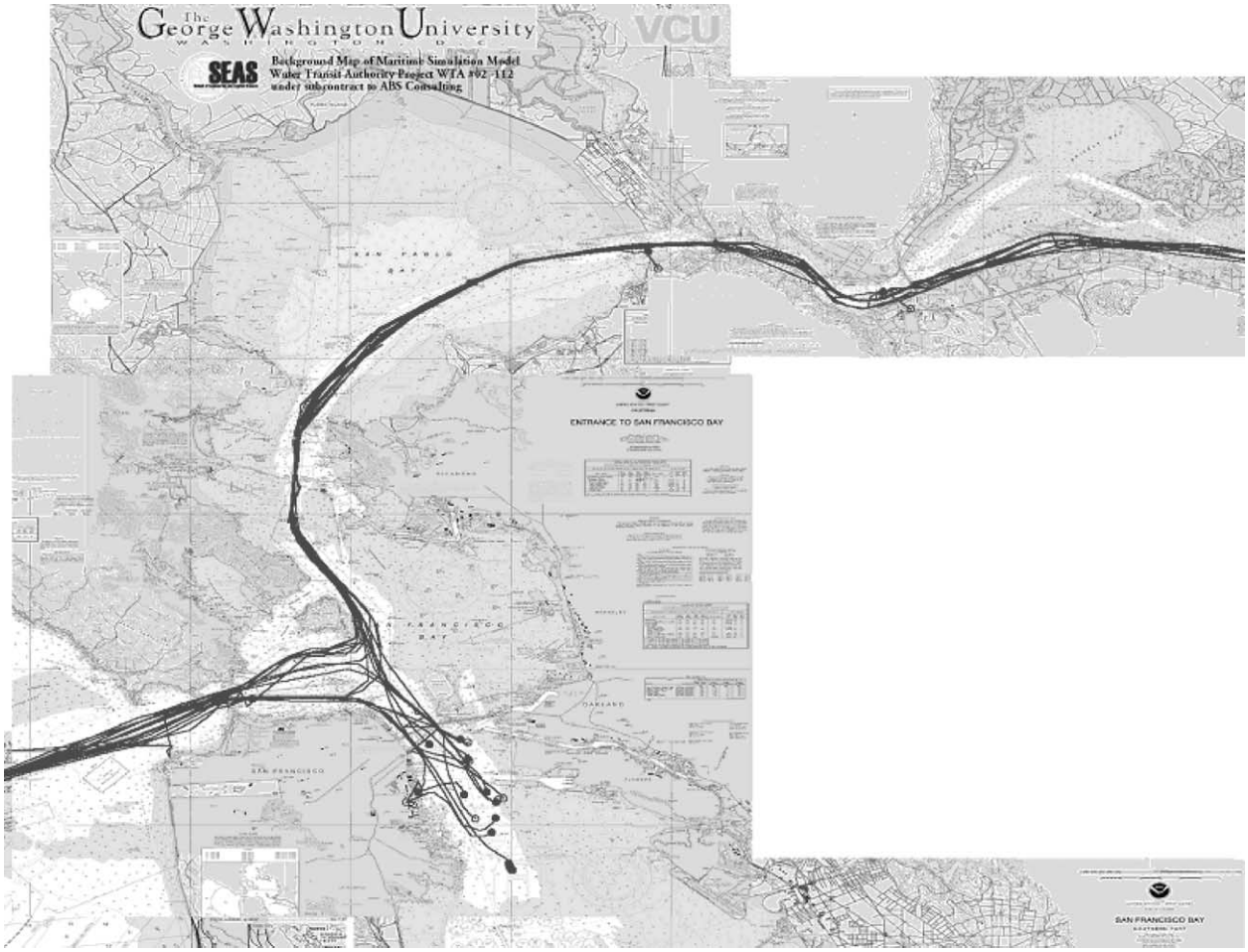


Fig. 2. Vessel routes for LPG vessels in the SF Bay maritime simulation model.

comparing their geographic profile to that of the Base Case. For further discussion of the interaction-counting model, see Ref. [27].

4. The simulation: vessel movement

To achieve an accurate count of the number of interactions, we must have an accurate simulation of the vessel movements. This means we need an accurate background map of the Bay, an accurate representation of the movement of the ferries themselves and an accurate representation of the movements of the other vessels in the Bay. The background map of the maritime simulation model for the SF Bay area (Fig. 1) was constructed from NOAA electronic charts, which were converted to bitmaps for use with the simulation program. This allowed accurate representation of the vessel coordinates and speed.

Ferry movements for the base case simulation were obtained from ferry schedules collected from ferry operators for the years 1998–2001. Each proposal for expansion of the ferry service included the number of transits per day, the time between transits, and the start time. At the current stage of the proposed expansions, the schedules are simply defined by operations starting at 6 a.m. and running every 15, 30, or 60 min depending on the route.

The ferry routes configurations for the base case simulation and proposed expansions were obtained from GIS maps created by the URS Corporation for the WTA. In all, 18 ferry routes were considered for the base case simulation and up to 64 ferry routes for the proposed expansion alternatives. The cruising speed of each ferry class along their route is a known, constant speed when underway. The ferries slow down when leaving and entering dock. Ferries also slow in restricted visibility. Ferries that usually maintain between 25 and 35 knots will reduce speed to 12 knots. Slower excursion ferries will slow to 10 knots. These speeds were determined in discussions with ferry captains and were confirmed by the ferry companies. To reflect this behavior in the simulation model, restricted visibility needs to be represented adequately. The modeling of visibility conditions in the simulation is discussed in Section 5.

In building maritime simulation models, non-ferry traffic is usually modeled by analyzing traffic arrival/departure

data to construct probability distributions for vessel inter-arrival times. These distributions are then used to simulate vessel arrivals and transits in the system [27]. However, the presence of the San Francisco Vessel Traffic System (SF VTS) eliminated the need for this approach. Data on date, time, and transits for 6000 routes for up to 26 different vessel types were obtained from the VTS for the 1998–2001 period. Waypoint data obtained from the SF VTS was used in conjunction with the bitmap of the SF Bay area to produce the total vessel transit picture. Fig. 2 shows an example of the routes of a particular class of vessels. Again average vessel speeds for each class are maintained during transits with the exception of vessels slowing down in restricted visibility. Average vessel speed information was obtained through personal communication with SF Bar Pilots. In restricted visibility, deep-draft traffic slows to about 70% of its usual transit speed. This rule was determined by discussions with members of the SF Bay Pilot's Association and operators from the VTS. These databases of traffic arrivals and routes were read in to the simulation program, removing the problem of validation of arrivals models [28].

Unfortunately, the SF VTS does not routinely record the movements of small vessels such as recreational yachts. As at certain times this can be the most numerous type of traffic on the Bay, special events, such as regattas, were modeled in the simulation as well. The USCG supplied their Marine Event List for over 1000 special events for the year 2001. Due to time and budget constraints only the main type of special events were modeled in the maritime simulation, i.e. 828 scheduled regattas in 2001. The data on regatta times and areas were obtained from the USCG data. Through discussions with the SF VTS, 13 locations were defined for these regatta events. Regattas were modeled by blocking the defined areas (Fig. 3) during their times and dates and then randomly moving the assigned number of participating vessels within each area.

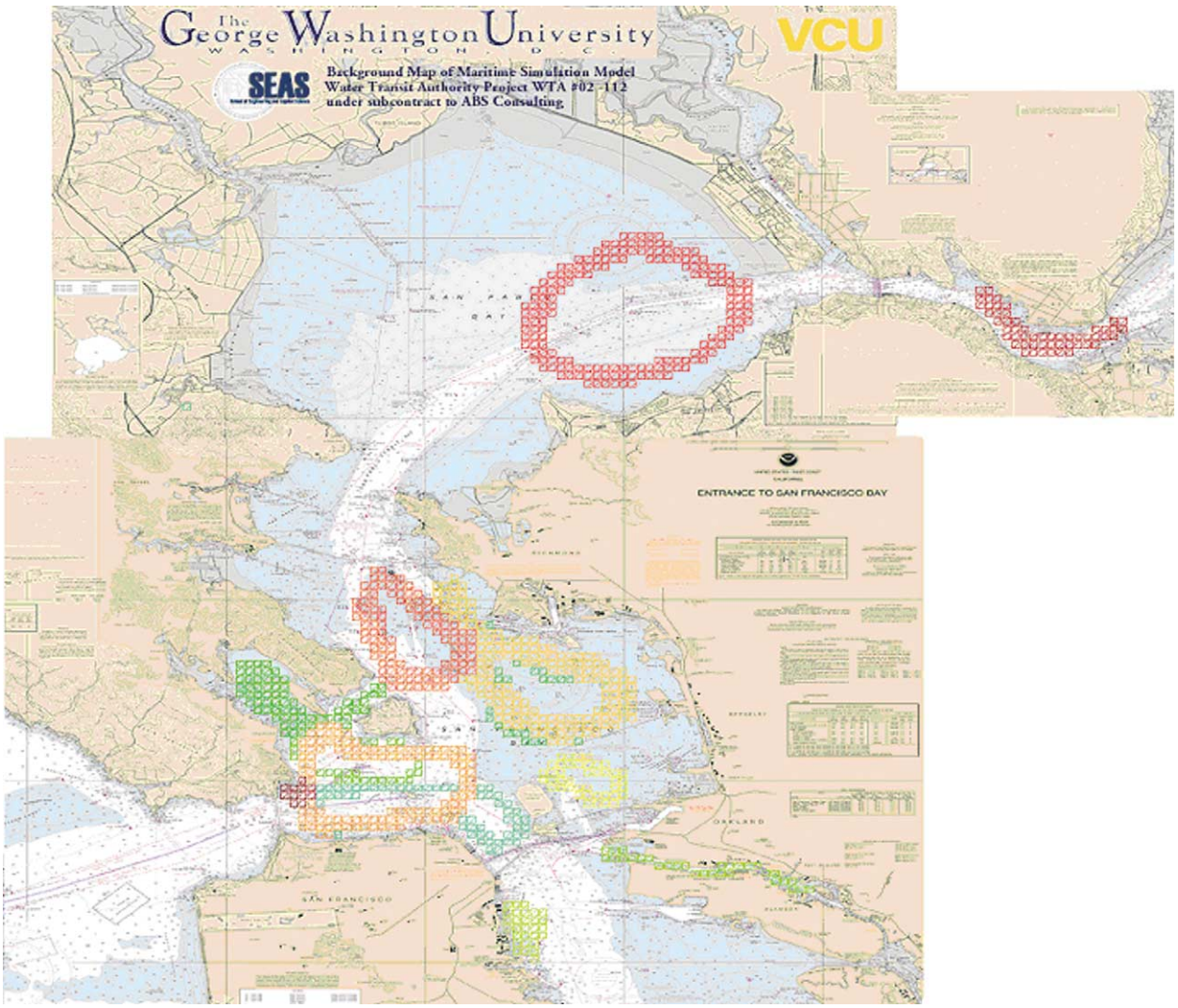


Fig. 3. Definition of regatta locations in the SF Bay maritime simulation model.

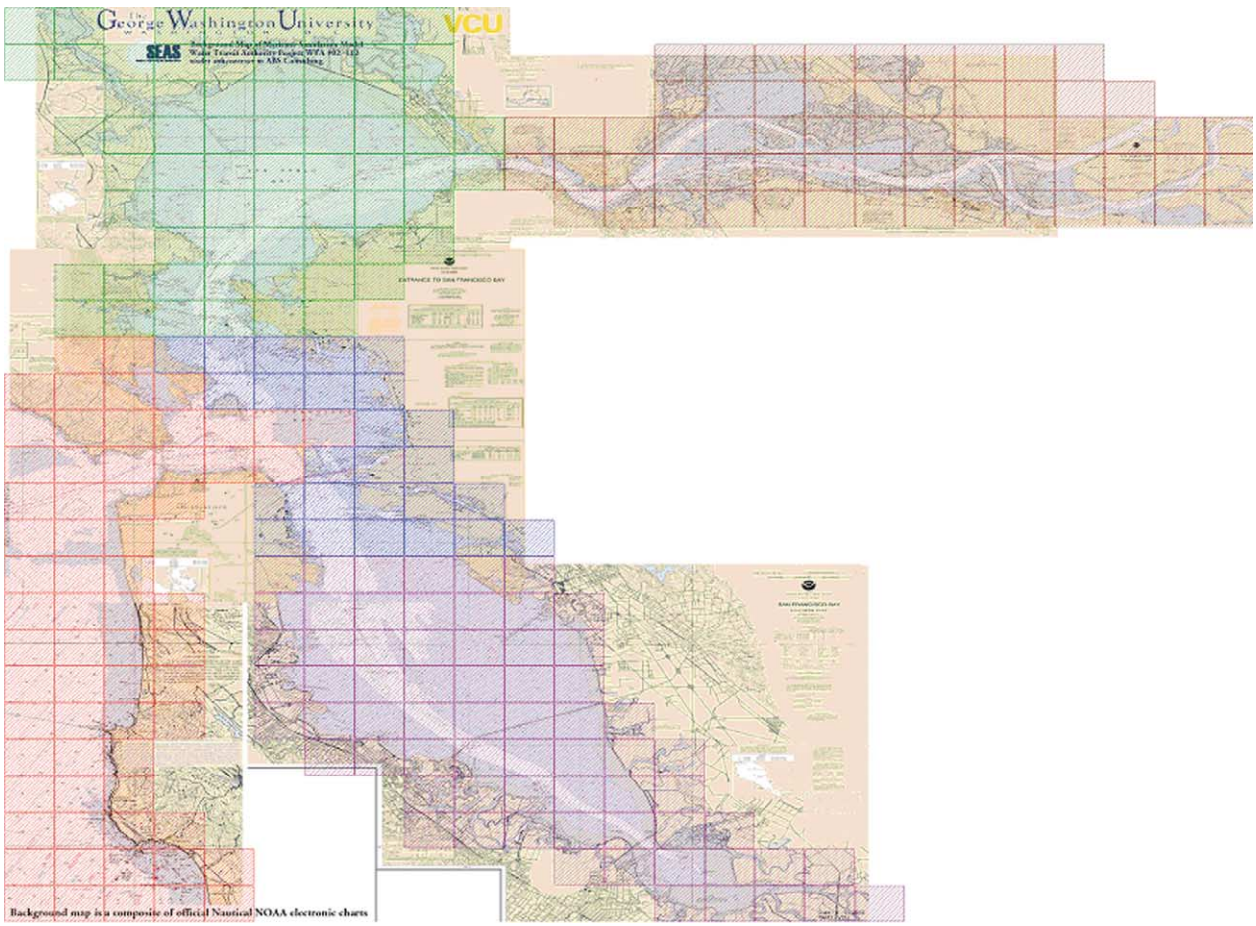


Fig. 4. Definition of visibility locations in the SF Bay maritime simulation model: Golden Gate (Red), San Pablo Bay (Green), Alameda (Blue), South Bay (Purple) and Grizzly Bay (Maroon).

5. The simulation: restricted visibility

Restricted visibility conditions have a significant impact on the pattern of traffic in the SF Bay in part due to the channel fog phenomenon at the Golden Gate Bridge during the third quarter of the year. To model these traffic patterns, visibility conditions were modeled in the simulation and, as mentioned previously, the movements of vessels were modified depending on these conditions. For the purposes of visibility modeling, the SF Bay area was divided into five regions; Golden Gate, San Pablo Bay, Alameda, South Bay and Grizzly Bay. The locations for visibility were defined using a square-grid breakdown of the study area. Fig. 4 identifies the different visibility locations used in the maritime simulation model. The location definitions

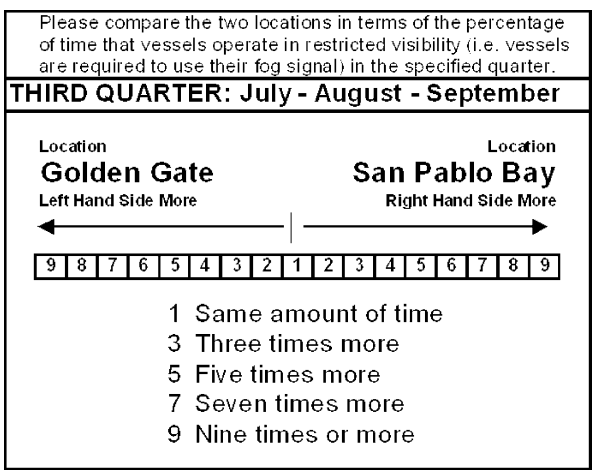


Fig. 5. Example pair wise comparison question for the location Golden Gate.

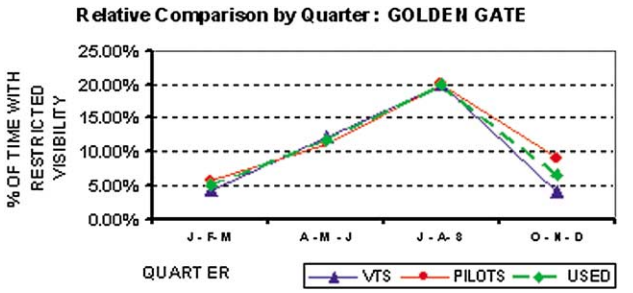


Fig. 6. Restricted visibility analysis results for the location Golden Gate for the first quarter of the year (J–F–M), second quarter (A–M–J), third quarter (J–A–S) and fourth quarter (O–N–D).

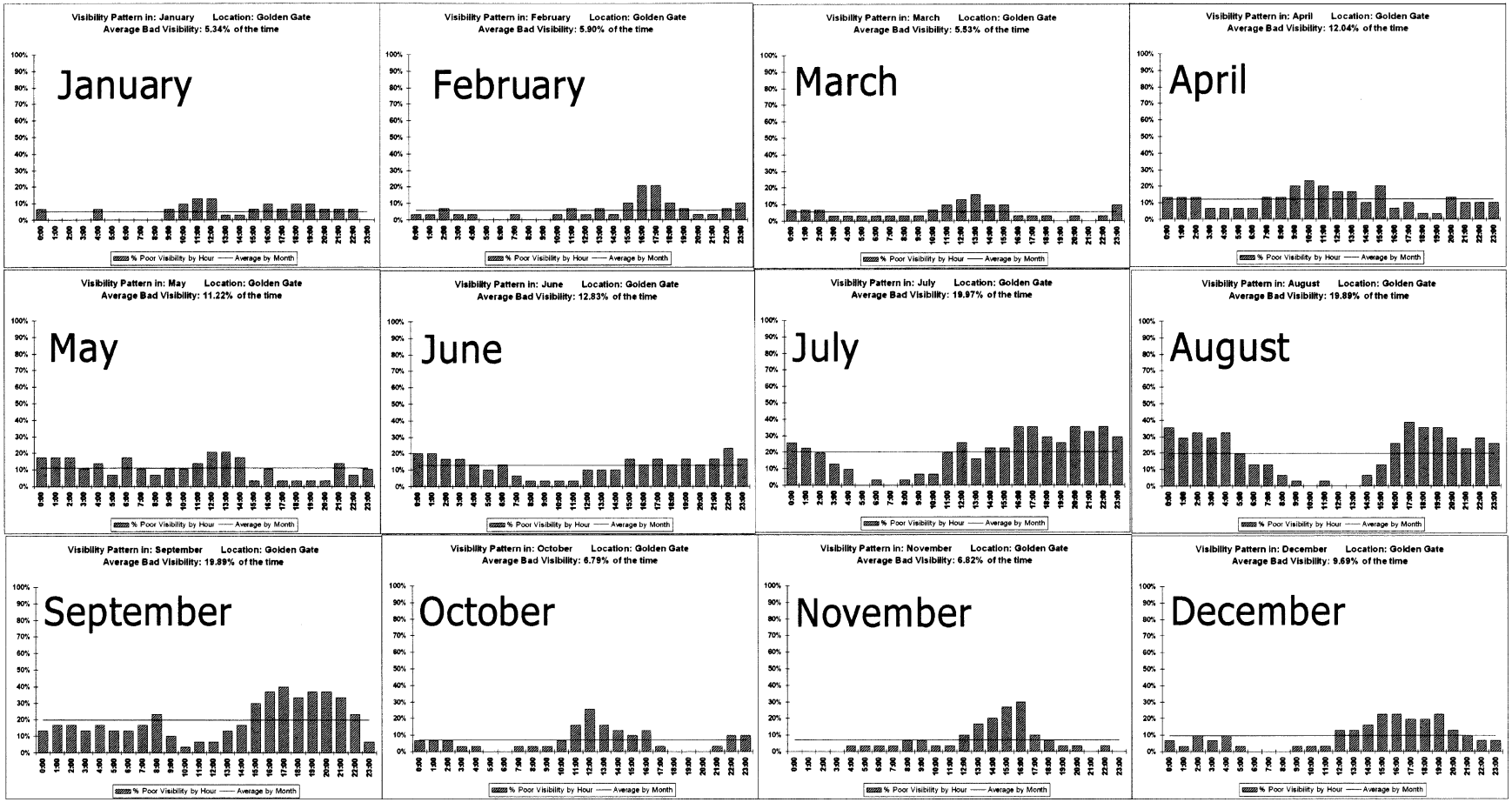


Fig. 7. Hourly percentages of restricted visibility for the location Golden Gate by month.

displayed in Fig. 4 were in part used to model the phenomenon of channel fog observed at the Golden Gate Location. Hourly wind speed and direction data is recorded via NOAA buoys for the period 1998–2001 at the five locations as well as dew point and water temperature data. Visibility data, however, is not gathered and thus a visibility model had to be developed.

The visibility model used in the simulation is based on a model described in Ref. [29]. The model stated that if the dew point is above the water temperature, then visibility will be restricted, otherwise the visibility will be good. In such a model, visibility is defined as good if it is greater than or equal to 0.6 miles and bad otherwise. Dew point and water temperature are recorded by the NOAA buoys, making such modeling of visibility possible. Rather than using this definition, we adhere to the rules of the road definition of restricted visibility (i.e. vessel operators are required to use their fog signals). A calibration constant was introduced into the visibility model to allow for this disparity, requiring the difference between the dew point and the water temperature to be above the calibration constant for such restricted visibility conditions to occur.

The calibration constant for the Golden Gate location for the third quarter of the year (July, August and September) was calculated from the US Coast Pilot's [30] data. The US Coast Pilot [30] states that restricted visibility conditions occur at Golden Gate approximately 20% of the time during the third quarter, the worst quarter for visibility in the Golden Gate location. However, no percentages are provided in the US Coast Pilot for the remaining quarters of the year; only anecdotal data is provided. Expert judgment was used to determine the calibration constants for restricted visibility conditions in the remaining three quarters at Golden Gate by comparing them to the third quarter. The experts involved were 7 operators from the SF VTS and 5 SF Bar Pilots with extensive experience throughout the SF Bay Area.

The process followed to elicit the remaining calibration constants utilizes the well-known Analytical Hierarchy Process [31,32]. Fig. 5 provides an example pair wise comparison question used in this process. Each expert is asked to assess whether restricted visibility is more likely in the quarter on the left-hand side or that on the right-hand side and by how much. The experts' assessments are used to calculate a relative multiplier for each quarter. By simple averaging of each expert's assessed values, for example, the resulting relative multiplier for the first quarter of the year was 0.258. This means that the experts indicated that the percentage of time that restricted visibility conditions occur in the first quarter of the year at Golden Gate should be 0.258 times the 20% of the third quarter (for which data was available) or 5.17%. Fig. 6 provides the results for the location Golden Gate. Note the (perhaps remarkable) agreement between the USCG VTS experts and SF Bar Pilots displayed in Fig. 6 for the remaining quarters of the year.

Table 1
Estimated percentages of time that restricted visibility occurs by quarter and by location

	First quarter, J–F–M	Second quarter, A–M–J	Third quarter, J–A–S	Fourth quarter, O–N–D
Golden Gate	5.17%	11.66%	20.00%	6.69%
San Pablo Bay	12.38%	6.17%	6.30%	9.62%
Alameda	7.49%	7.61%	10.61%	7.02%
South Bay	4.92%	5.00%	5.53%	4.74%
Grizzly Bay	14.40%	5.17%	5.34%	11.06%

The green line in Fig. 6 indicates the percentages that were used for calibration of the modified visibility model [29] for the Golden Gate location. Fig. 7 provides the monthly model results for this location for the year 2000. Note that, in the third quarter (July, August and September) the model reflects early morning fog that burns off during the late morning hours and early afternoon hours and reestablishes itself during the late afternoon. The latter daily pattern is typical for the channel fog phenomenon for this quarter at the Golden Gate location [30].

No visibility data, in terms of percentage of time that restricted visibility occurs, was available for the remaining locations San Pablo Bay, Alameda, South Bay and Grizzly. Hence, we had to rely once again on expert judgment to determine calibration constants for restricted visibility conditions. We followed the same process as above, comparing these four locations by quarter to the previously established percentage of time that restricted visibility occurs in Golden Gate (Fig. 6). For example, a multiplicative factor of 2.397 was assessed for the location San Pablo Bay during the first quarter of the year when compared to the Golden Gate location. Utilizing the previously established 5.17% for restricted visibility in Golden Gate during this quarter, the percentage of time that restricted visibility occurs in San Pablo Bay was set at 2.397 times 5.17% or 12.38%. Table 1 provides the estimated percentages of time that restricted visibility occurs by

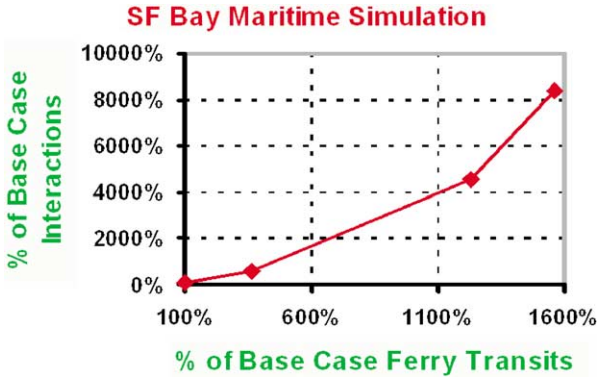


Fig. 8. Exponential growth in interactions due to ferry service expansion.

Table 2
Percentage comparisons to the Base Case under various criteria

	Base Case ferry transits (%)	Base Case grid cells covered (%)	# Base Case total interactions (%)
Base Case	100	100	100
Alternative 3	365	116	624
Alternative 2	1228	233	4620
Alternative 1	1559	240	8359
Alternative 3-BVI	–	91	110

quarter of the year and by location. The information in Table 1 was used to calculate the calibration constants for the visibility model for the remaining locations, San Pablo Bay, Alameda, South Bay and Grizzly.

6. Results

Fig. 1 shows a screen shot of the simulation program created to perform the vessel interaction analysis. For a more detailed look, movies of the simulation for each of the cases can be viewed at http://www.people.vcu.edu/~jrmerric/SFBayMovies/. Recall that the simulation was intended to answer certain specific questions. For the defined scenarios, what is the increase in the number of interactions involving ferries? What is the increase in the area in which such interactions occur? Are there any high-density areas that could be a cause of concern, either in the current ferry system or in any of the proposed scenarios? As interactions in restricted visibility are of particular concern, what is the affect of the proposed scenarios on frequency and density of such interactions?

We will start our discussion of the results of the simulation analysis with some basic comparisons to current ferry operations. The current ferry operations, or the Base Case, are used as a reference point to compare the proposed alternatives and to give an understanding of the traffic patterns currently seen by ferries in the study area. Fig. 8 summarizes the analysis findings. Observe from Fig. 8 that the number of ferry to vessels interactions grows exponentially with the number of ferry transits, not linearly. This result was somewhat of a revelation for the WTA. Table 2 gives the detail of

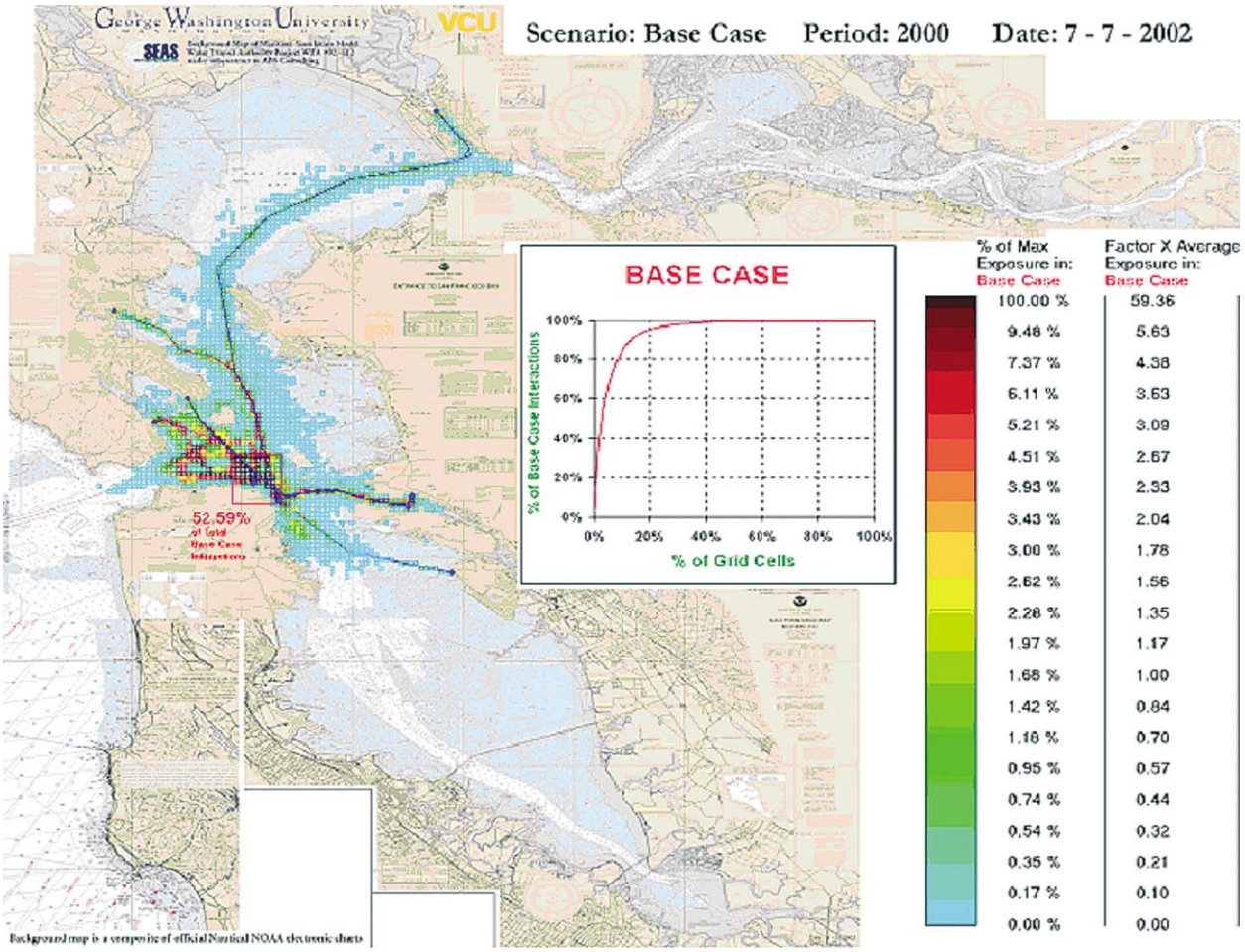


Fig. 9. The full base case simulation results.

the comparison of the three alternative cases to the Base Case.

Alternative 3 (the least aggressive expansion) has 3.65 times as many transits as the Base Case, but covers only a little larger area, with 16% more grid cells having at least one interaction in them in the simulation. In all over 6 times as many interactions occur in Alternative 3 than occurred in the Base Case, while the coverage area of these interactions only increases by a factor of 1.16. Thus Alternative 3 makes the current operating area more congested with more interactions. In addition, the fourth row in Table 2 displays results for Alternative 3 counting only those interactions that occur in restricted visibility. Note that, 1.10 times as many interactions occur in Alternative 3 in restricted visibility than the whole Base Case (regardless of visibility). Moreover, these interactions cover only 91% of the coverage area in the Base Case and are thus more concentrated. We will return to this important observation.

Alternative 2 has 12.28 times as many transits as the Base Case, but covers a much larger area, with 2.33 times as many grid cells having at least one interaction. In all over 46 times as many interactions occur in Alternative 2 than occurred in the Base Case. Thus Alternative 2 increases the operating area from the Base Case and leaves the system much more congested with many more interactions. Finally, Alternative 1 (the most aggressive expansion) has 15.59 times as many transits as the Base Case, but covers only a little larger area than Alternative 2, with 2.4 times as many grid cells having at least one interaction than in the Base Case. In all over 83 times as many interactions occur in Alternative 1 than occurred in the Base Case. Thus Alternative 1 increases the operating area by about the same factor as Alternative 2, but significantly increases congestion with many more interactions compared to Alternative 2.

Fig. 9 shows the geographic interaction profile for the Base Case. The Base Case ferry routes are shown in color. Fig. 9 is quite complex, as it attempts to convey all the Base Case results in one figure. We will examine the pieces of Fig. 9 one by one. The analysis is broken down across a grid of approximately 1/4 mile by 1/4 mile cells. The cells are

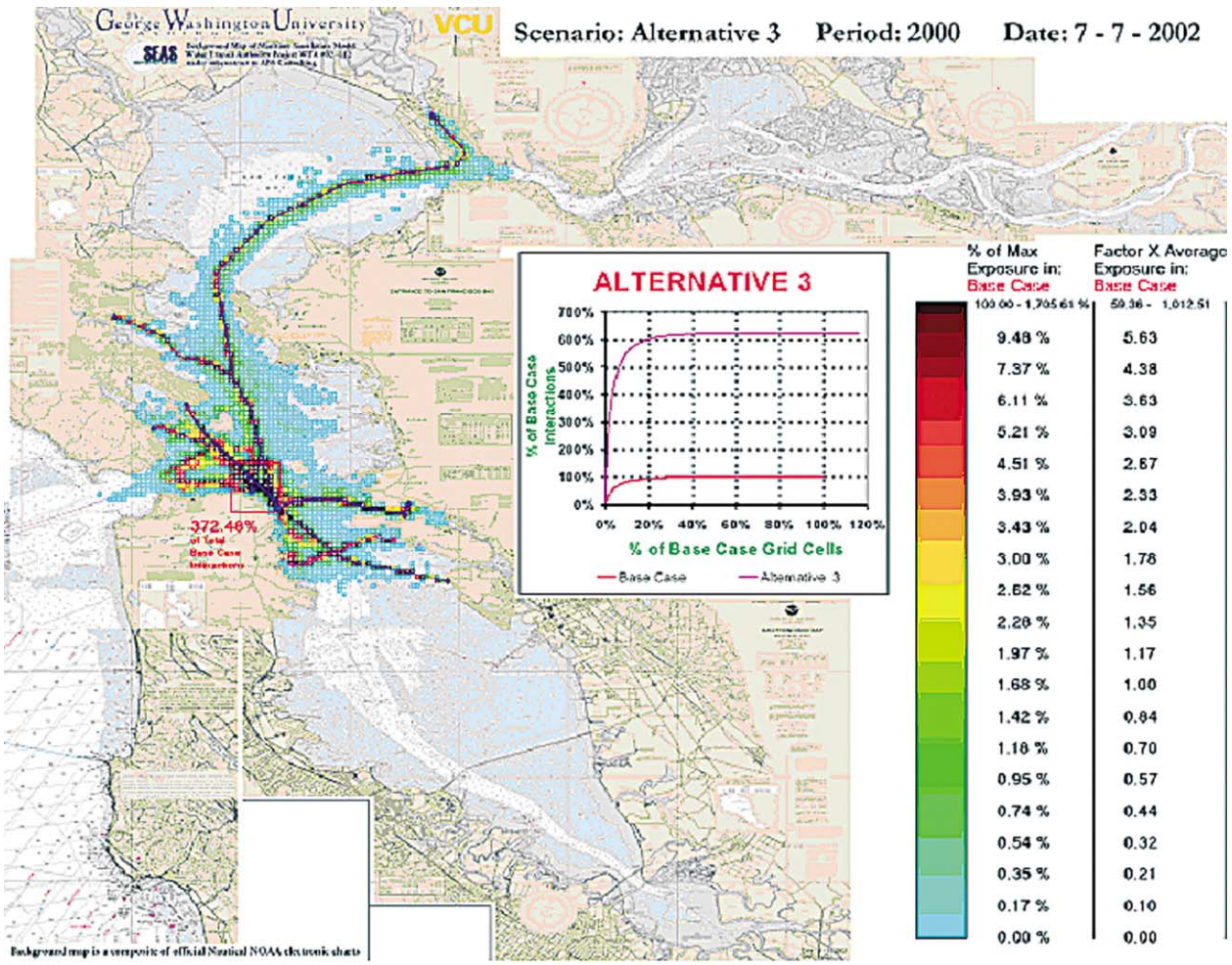


Fig. 10. The full Alternative 3 simulation results.

color coded in Fig. 9 to represent the number of interactions that occur in that cell over the 1-year simulation time. Both the cell containing the ferry and the cell containing the interacting vessel are recorded; hence the colored cells away from the ferry routes.

To the right of Fig. 9, the legend gives an interpretation for the color-coding of the cells. The scale goes from blue, with the fewest interactions, to black with the most interactions. The solid black cell has the most interactions of any cells in the base case simulation. This Base Case maximum is used as a reference point for the legend. The percentages shown in the legend are calculated as a percentage of this maximum number of interactions. For example, an orange cell has an interaction count that is only 3% of the maximum number of interactions observed in a grid cell in the Base Case. Another reference scale is also provided. The average number of interaction per cell in the Base Case has 1.68% of the maximum number of interactions in a cell observed in the Base Case. Returning to our example, an orange cell has 1.78 times the number of interactions seen in the average cell in the Base Case. A solid black cell, with the most interactions, has over 60 times as many interactions as the average in the Base Case, indicating that some cells are highly congested when compared to the average cell. One can also see that the legend is not numerically linear. Since some of the cells are much more congested than others, we have had to develop a color gradient following a power curve to highlight their differences.

What can we learn about the current ferry operations, or Base Case, from Fig. 9? The majority of the dark colored grid cells are in the Central Bay area, particularly close to the Ferry Building. In fact, if we take the red square around the Ferry Building, almost 53% of all the interactions in the Base Case occur in this area. This is the area with most ferries, a great deal of other VTS Traffic and organized recreational events operating, combined with the worst visibility for a large part of the year (especially in the third quarter of each year).

Figs. 10 and 11 examine Alternative 3 (the least aggressive expansion) and Alternative 1 (the most aggressive expansion) and compare their results to the Base Case in the same figures. A similar geographic interaction profile was generated for Alternative 2 (the future ferry expansion

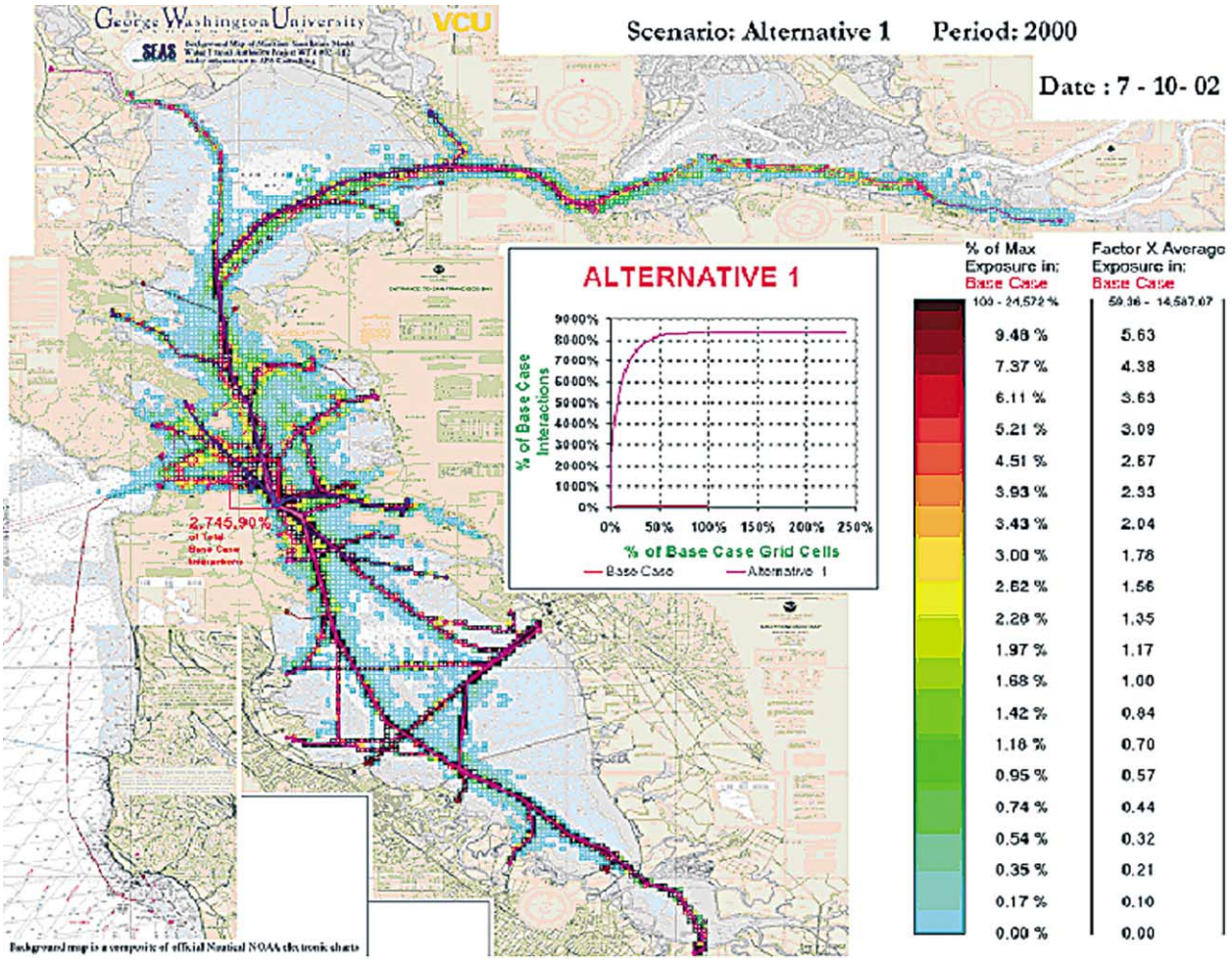


Fig. 11. The full Alternative 1 simulation results.

between Alternative 1 and Alternative 3). Note that the legend has not changed to allow the comparison to the Base Case. Notice that the same red square around the Ferry Building in Alternative 3 (Fig. 10) now contains 3.7 times as many interactions as the whole Base Case and that much of the area within the red square is now colored solid black, indicating that there are more interactions in those grid cells than the maximum for any grid cell in the Base Case. Similar conclusions can be drawn from Fig. 11 showing the geographic interaction profile for Alternative 1 (the most aggressive expansion of future ferry service). Notice that, the same red square around the Ferry Building now contains approximately 27 times as many interactions as the whole Base Case and again much of the area is colored solid black, indicating that there are more interactions in those grid cells than the maximum for any grid cell in the Base Case.

Of particular concern are interactions that occur in restricted visibility. Recall from Table 2 that 1.10 times as many interactions occur in Alternative 3 in restricted visibility than the whole Base Case (regardless of visibility). Moreover, these interactions cover only 91% of the coverage area in the Base Case. Fig. 12 displays the results for Alternative 3 counting only those interactions that occur in restricted visibility. Concentrating on the red square in Fig. 12, it follows that 57.92% of the interactions in the whole Base Case (regardless of visibility) are now occurring in the red square in restricted visibility conditions in Alternative 3. In the Base Case, 6.57% of the total interactions occurred in restricted visibility in the red square. Hence, although Alternative 3 (the least aggressive ferry expansion) resulted in an increase from the Base Case of 3.65 times as many interactions overall, an approximate increase of 8.82 (= 57.92/6.57%) times as many interactions are observed in the red square in Fig. 12 in restricted visibility. These restricted visibility interactions involve both regular and high-speed ferries in an area that is already the most congested in the Base Case. Findings of this nature should be of concern to those planning for future ferry expansions.

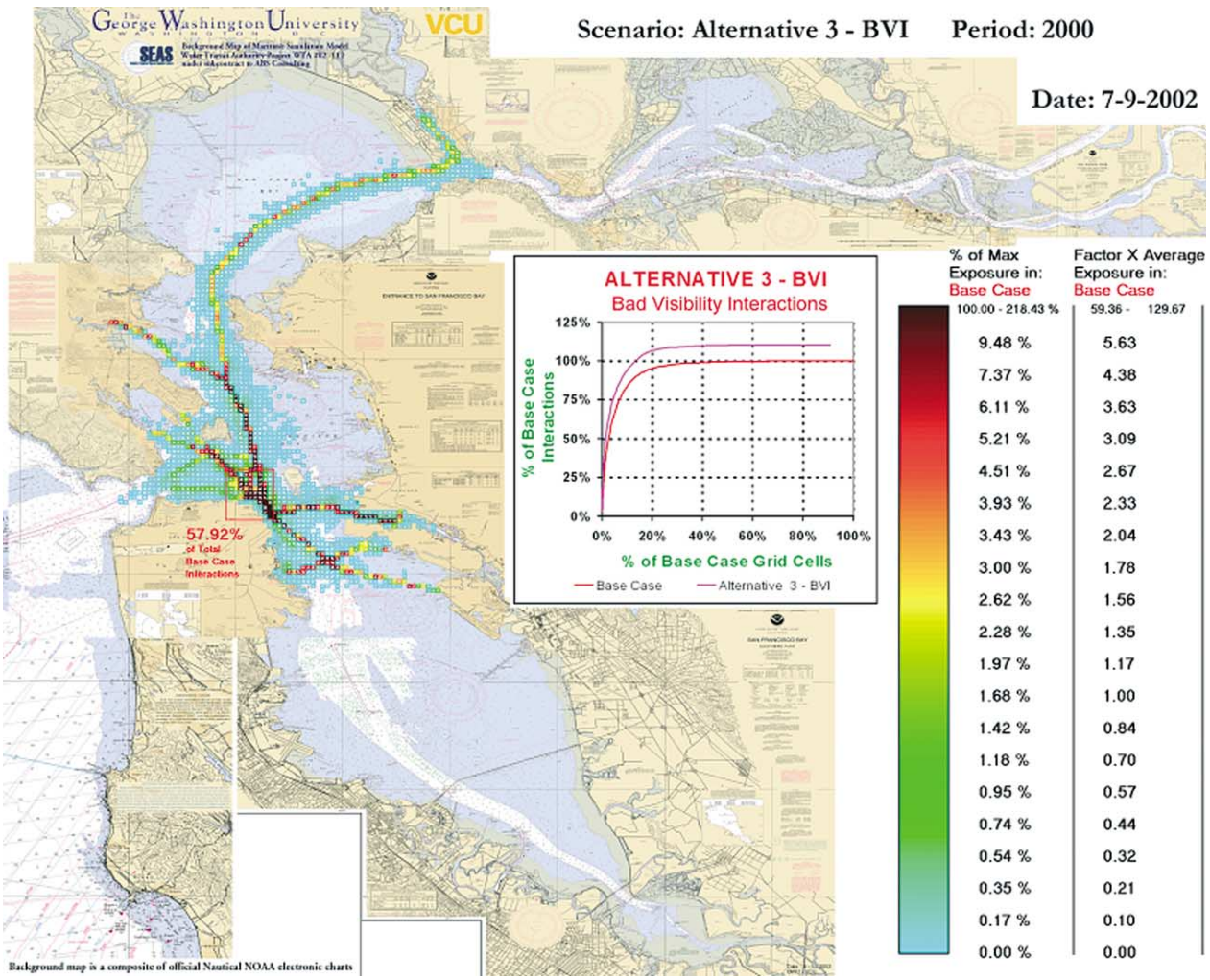


Fig. 12. Alternative 3 results counting only restricted visibility interactions.

7. Conclusions and recommendations

The analysis discussed herein is only one part of the overall assessment of the proposed ferry service expansion by the WTA. Digital movies of the simulation were requested by the WTA allowing the decision-makers to visualize the reality of their proposed ferry service expansions. In addition, other projects are underway or have been completed examining environmental issues, ferry terminal expansions, ridership, intermodal transportation issues, and new technologies (http://www.watertransit.org). Each of these studies will be summarized in the *Implementation and Operations Plan* to be submitted to the California Legislature on December 12th 2002, with review continuing through the summer of 2003.

The vessel interaction analysis presented in this paper provides a foundation for examining the risk inherent in such a major expansion of service and is a first step in a full risk assessment that would satisfy the requirements of the US Coast Guard Captain of the Port. The vessel interaction analysis results can be combined in follow on steps with a conditional accident probability model and an accident damage model for an overall estimate of MTS accident risk [5]. These results, however, do give an initial indication of where high accident risk spikes may occur by illustrating the occurrences of added congestion and their location. In addition, the results seem to indicate that the safety levels currently enjoyed by the SF Bay ferry service cannot be maintained under the planned expansion scenarios without equally aggressive investment in risk intervention. With the broader picture of risk in mind, the project team made the following recommendations to the WTA at the conclusion of the project:

1. Use the results of the simulation analysis in a PRA similar to that of the Washington State Ferry Risk Assessment, where output analyses is presented in terms of expected number of accidents per year.
2. Consider the current SF Bay Ferry Operations and future planned ferry operations as a MTS rather than a collection of individual ferry routes by
   a. Designing a ferry traffic routes system that allows for increased ferry traffic while limiting the increase in expected number of accidents per year.
   b. Designing ferry schedules utilizing this ferry traffic route system that allow for increased ferry traffic while limiting the increase in expected number of accidents per year. A consideration in the development of these future schedules should be the time between arrivals and departures at ferry terminals to allow for sufficient time of loading and unloading passengers.
3. Develop other risk intervention measures that can reduce the number of interactions and the probability of accidents given an interaction.
4. Investigate the effect of proposed risk intervention measures on the accident probability using the full PRA model.
5. Perform an uncertainty analysis of accident risk and risk intervention evaluation to provide estimates of annual accident risk and risk intervention effectiveness in terms of probability intervals rather than point estimates.

> The truth is that we are uncertain. The language of uncertainty is probability. Therefore, speaking the truth means to develop analyses results in terms of probability curves rather than in terms of point estimates [33].

Acknowledgements

Special thanks to the San Francisco Bay Area Water Transit Authority for the opportunity to conduct this project. We would also like to extent our gratitude to the following project members for their support: Walt E. Hanson from ABS Consulting provided project management and data collection support; Stacey W. Shonk from the California Maritime Academy provided detailed knowledge about the Maritime Transportation System in the San Francisco Bay, facilitated meetings with local area users and provided data collection support; Philip B. Harms, Jr. from the California Maritime Academy provided help in constructing a large scale nautical map of the San Francisco Bay Area; Lt. Black and Alan M. San from US Coast Guard Vessel Traffic Service San Francisco provided traffic data, recreational vessel information and experts willing to fill out in the restricted visibility questionnaires; URS Corporation provided maps detailing existing and future planned ferry routes; The San Francisco Bar Pilots donated their time and knowledge on vessel movements and visibility; the ferry operators Blue and Gold and Golden Gate Bridge allowed us to ride ferries and providing access to ferry captains for discussions while underway.

Finally, we would like to thank the Editor in Chief and the referee for their helpful comments, which substantially improved the first version of this paper. The research described herein was partially supported by San Francisco Bay Water Transit Authority Project WTA #02-112 and partially supported by NSF grants SES 0213627 and SES 0213700.

References

[1] Harrald J, Mazzuchi T, Merrick J, van Dorp JR, Spahn J. Using system simulation to model the impact of human error in a maritime system. Safety Sci 1998;30(1/2):235–47.

[2] Merrick J, van Dorp JR, Harrald J, Mazzuchi T, Spahn J, Grabowski M. A systems approach to managing oil transportation risk in Prince William Sound. Syst Engng 2000;3(3):128–42.

[3] Merrick J, van Dorp JR, Harrald J, Mazzuchi T, Spahn J, Grabowski M. The Prince William Sound risk assessment. Interfaces 2002;32(6): 25–40.
[4] Grabowski M, Merrick J, Harrald J, Mazzuchi T, van Dorp JR. Risk modeling in distributed, large-scale systems. IEEE Syst, Man Cybernet Part A: Syst Humans 2001;30(6):651–60.
[5] van Dorp JR, Merrick J, Harrald J, Mazzuchi T, Grabowski M. A risk management procedure for the Washington State ferries. Risk Anal 2001;21:127–42.
[6] National Research Council. Crew size and maritime safety. Washington, DC: National Academy Press; 1986.
[7] National Research Council. Tanker spills: prevention by design. Washington, DC: National Academy Press; 1991.
[8] National Research Council. Minding the helm: marine navigation and piloting. Washington, DC: National Academy Press; 1994.
[9] National Research Council. Risk management in the marine transportation system. Washington, DC: National Academy Press; 2000.
[10] Pravda MF, Lightner RG. Conceptual study of a supercritical reactor plant for merchant ships. Mar Technol 1966;4:230–8.
[11] Stiehl GL. Prospects for shipping liquefied natural gas. Mar Technol 1977;14(4):351–78.
[12] Paté-Cornell ME. Organizational aspects of engineering system safety: the case of offshore platforms. Science 1990;250(4985): 1210–7.
[13] US Coast Guard. Vessel traffic systems: analysis of port needs. Report No. AD-770 710. Washington, DC: US Coast Guard; 1973.
[14] Maio D, Ricci R, Rossetti M, Schwenk J, Liu T. Port needs study. Report No. DOT-CG-N-01-91-1.2. Prepared by John A. Volpe, National Transportation Systems Center. Washington, DC: US Coast Guard; 1991.
[15] Bedford TM, Cooke RM. Probabilistic risk analysis: foundations and method. Cambridge, UK: Cambridge University Press; 2001.
[16] Hara K, Nakamura S. A comprehensive assessment system for the maritime traffic environment. Safety Sci 1995;19(2/3):203–15.
[17] Roeleven D, Kok M, Stipdonk HL, de Vries WA. Inland waterway transport: modeling the probabilities of accidents. Safety Sci 1995; 19(2/3):191–202.
[18] Kite-Powell HL, Jin D, Patrikalis NM, Jebsen J, Papakonstantinou V. Formulation of a model for ship transit risk. MIT Sea Grant Technical Report, Cambridge, MA, 96–19; 1996.
[19] Slob W. Determination of risks on inland waterways. J Hazard Mater 1998;61(1–3):363–70.
[20] Fowler TG, Sorgard E. Modeling ship transportation risk. Risk Anal 2000;20(2):225–44.
[21] Trbojevic VM, Carr BJ. Risk based methodology for safety improvements in ports. J Hazard Mater 2000;71(1–3):467–80.
[22] Wang J. A subjective modeling tool applied to formal ship safety assessment. Ocean Engng 2000;27(10):1019–35.
[23] Guedes Soares C, Teixeira AP. Risk assessment in maritime transportation. Reliab Engng Syst Safety 2001;74(3):299–309.
[24] Andrews S, Murphy FH, Wang XP, Welch S. Modeling crude oil lightering in Delaware Bay. Interfaces 1996;26(6):68–78.
[25] Golkar J, Shekhar A, Buddhavarapu S. Panama canal simulation model. Proceedings of the 1998 Winter Simulation Conference; 1998. p. 1229–37.
[26] Ryan NK. The future of maritime facility designs and operations. Proceedings of the 1998 Winter Simulation Conference; 1998. p. 1223–7.
[27] Merrick J, van Dorp JR, Mazzuchi T, Harrald J. Modeling risk in the dynamic environment of maritime transportation. Proceedings of the 2001 Winter Simulation Conference; 2001. p. 1090–8.
[28] Sargent RG. Validation and verification of simulation models. Proceedings of the 1999 Winter Simulation Conference; 1999. p. 39–48.
[29] Sanderson R. Meteorology at sea, Stanford Maritime Limited; 1982.
[30] Evans DL, Grudes SB, Davidson MA. United States Coast Pilot Volume 7, Pacific Coast, California, Oregon, Washington and Hawai. Washington, DC: National Ocean Service, US Department of Commerce; 2001.
[31] Saaty T. The analytic hierarchy process. New York: McGraw-Hill; 1980.
[32] Vargas LG. An overview of the analytic hierarchy process and its applications. Eur J Oper Res 1990;48:2–8.
[33] Kaplan S. The words of risk analysis. Risk Anal 1997;17(4):407–17.

SUB-APPENDIX:

P. Szwed, J. R. van Dorp, J.R.W.Merrick, T.A. Mazzuchi and A. Singh (2006). "A Bayesian Paired Comparison Approach for Relative Accident Probability Assessment with Covariate Information", *European Journal of Operations Research*, Vol. 169 (1): pp. 157-177.

Available online at www.sciencedirect.com
SCIENCE DIRECT®
European Journal of Operational Research 169 (2006) 157–177
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

Stochastics and Statistics

A Bayesian paired comparison approach for relative accident probability assessment with covariate information

P. Szwed [a,b], J. Rene van Dorp [b,*], J.R.W. Merrick [c], T.A. Mazzuchi [b], A. Singh [b]

[a] *Department of Management, US Coast Guard Academy, 31 Mohegan Avenue, New London, CT 06320-8103, USA*
[b] *Engineering Management and Systems Engineering Department, The George Washington University, 1776 G Street NW, Suite 110, Washington, DC 20052, USA*
[c] *Department of Statistical Sciences and Operations Research, Virginia Commonwealth University, P.O. Box 843083, VCU, Richmond, VA 23284-2014, USA*

Received 23 September 2003; accepted 22 April 2004
Available online 3 August 2004

Abstract

One of the challenges managers face when trying to understand complex, technological systems (in their efforts to mitigate system risks) is the quantification of accident probability, particularly in the case of rare events. Once this risk information has been quantified, managers and decision makers can use it to develop appropriate policies, design projects, and/or allocate resources that will mitigate risk. However, rare event risk information inherently suffers from a sparseness of accident data. Therefore, expert judgment is often elicited to develop frequency data for these high-consequence rare events. When applied appropriately, expert judgment can serve as an important (and, at times, the only) source of risk information. This paper presents a Bayesian methodology for assessing relative accident probabilities and their uncertainty using paired comparison to elicit expert judgments. The approach is illustrated using expert judgment data elicited for a risk study of the largest passenger ferry system in the US.
© 2004 Elsevier B.V. All rights reserved.

Keywords: Applied probability; Expert judgment; Risk analysis

1. Introduction

The concepts of risk analysis and management is becoming more and more relevant in our complex technological environment. Numerous papers and books have been written in the last 20 years on this topic

* Corresponding author. Tel.: +1 202 994 6638; fax: +1 202 994 0245.
E-mail addresses: pszwed@cga.uscg.mil (P. Szwed), dorpjr@gwu.edu (J. Rene van Dorp), jrmerric@vcu.edu (J.R.W. Merrick), mazzu@gwu.edu (T.A. Mazzuchi), amitas@gwu.edu (A. Singh).

0377-2217/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.ejor.2004.04.047

(see, e.g., Shrader-Frechette, 1985; Paté-Cornell, 1996; Kumamoto and Henley, 1996; Kaplan, 1997; Koller, 2000; Bedford and Cooke, 2001). Risk analysis, also known as risk assessment, is widely recognized as a systematic, science-based process for quantitatively describing risk (see, e.g., Vose, 1996). Risk, itself, is commonly defined as a quantitative measure combining the likelihood of the occurrence of an undesirable event (accident) and its consequences. Assessment of risk may be separated into the quantitative assessments of accident probabilities and consequences. Kaplan (1997) among others discusses the definition of risk in more detail. Regardless of exactly how these quantitative measures are combined into a single risk measure, separate information about accident probability and consequences are critically important to managers who are charged with risk mitigation because different risk interventions follow from accident probability reduction and consequence reduction.

The quantification of risk models for policy and decision-making often requires the elicitation of expert judgments (see, e.g., Moslesh et al., 1988; Bonano et al., 1989; Morgan and Henrion, 1991; Cooke, 1991). In fact, as long as the fundamental mechanisms that drive a system remain poorly known, the encoding of expert knowledge will be required (see Paté-Cornell, 1996). Nevertheless, as noted by Anderson et al. (1999), expert judgment must be used with care. It is not evidence per se, but an individual's or group's inference based on available evidence. Kahneman et al. (1982) (a Nobel Prize winner in 2002) discuss the numerous biases and heuristics that are introduced when humans process information and attempt to provide judgments.

Winkler (1996) points out that due to the general belief that "several heads are better than one", information is usually elicited from several experts. Numerous techniques exist for the aggregation of multiple experts' responses (see, e.g., Morris, 1974; Winkler, 1981; Genest and Zidek, 1986; Clemen, 1989; Mendel and Sheridan, 1989; Cooke, 1991; DeWispelare et al., 1995). In recent reviews of the techniques, Clemen and Winkler (1990, 1999) note that often the simple aggregation techniques may work just as well as the more complex methods. The Bayesian paradigm, however, seems to supply at the present the most natural and unambiguous approach towards the aggregation problem while addressing uncertainty in the expert judgment at the same time.

While a number of different elicitation methods are available (see, e.g., Cooke (1991) for an excellent overview), the paired comparisons elicitation method seems to be quite popular. The elicitation method to be discussed in this paper belongs to this class. In the next section we reflect on the origins of the paired comparisons elicitation method.

1.1. Paired comparisons elicitation approaches

Origins of this class can be traced back to Thustone's (1927a,b) pioneering work where Weber's and Fechner's law were used to quantify the intensity of psychophysical stimuli using a discriminative process. An extension of this concept found application in the field of consumer research (see Bradley, 1953) via the Bradley and Terry (1952) paired comparisons method. An examination of the latter method is provided by Cooke (1991), among other numerous sources.

Another popular paired comparison elicitation technique is called the Analytical Hierarchy Process (AHP) developed by Saaty (1977, 1980). The AHP Process is primarily used for the construction of value functions $V(\underline{X})$ involving multiple contributing factors $\underline{X}=(X_1, X_2, \ldots, X_p)$ (see, e.g. Foreman and Selly, 2002). The construction of a value function in this manner extends the construction of a utility function based on paired comparisons. The theoretical foundation for developing the latter has been provided by the Nobel Laureate G. Debreu (see, e.g., Debreu, 1986). The popularity of the elicitation methods above can perhaps be contributed to the observation that experts are more comfortable making paired comparisons rather than directly assessing a quantity of interest. It should however be mentioned that paired comparisons may lead occasionally to the so-called Simpson paradox-lack of transitivity (see Simpson, 1951).

To the best of our knowledge, Pulkkinen (1993, 1994a,b) was first to introduce a Bayesian paired comparison aggregation method for the elements of a multivariate random vector $\underline{\beta}=(\beta_1,\beta_2,\ldots,\beta_p)$ by multiple experts. Experts are asked to compare the pair of random variables β_i to β_j, $i\neq j$, $i=1,\ldots,p$, and respond in terms of an indicator function $1_{[\beta_i \geqslant \beta_j]}$ (i.e. 1 when the expert judges $\beta_i \geqslant \beta_j$ and 0 otherwise). The paired judgments in Pulkkinen's analysis are assumed to be consistent. Pulkkinen's (1993, 1994a,b) exposition is mainly theoretical and limited to a discussion of mathematical properties of the aggregation method, but mentions that applications of his method in the reliability engineering and system safety domain are self-evident.

We shall report herein on what appears to be a novel paired comparison elicitation method for accident probabilities. We take as an application of this approach an actual case study "The Washington State Ferry (henceforth WSF) Risk Assessment" where paired comparisons were elicited from experts. The next section discusses an overview of the WSF Risk Assessment (see also Van Dorp et al. (2001) for a more detailed description).

1.2. Overview of the WSF risk assessment

The WSF system is the largest ferry system in the United States. In 1997, total ridership for the ferries serving the central Puget Sound region was nearly 23 million, a 4% increase over 1996 ridership, and more

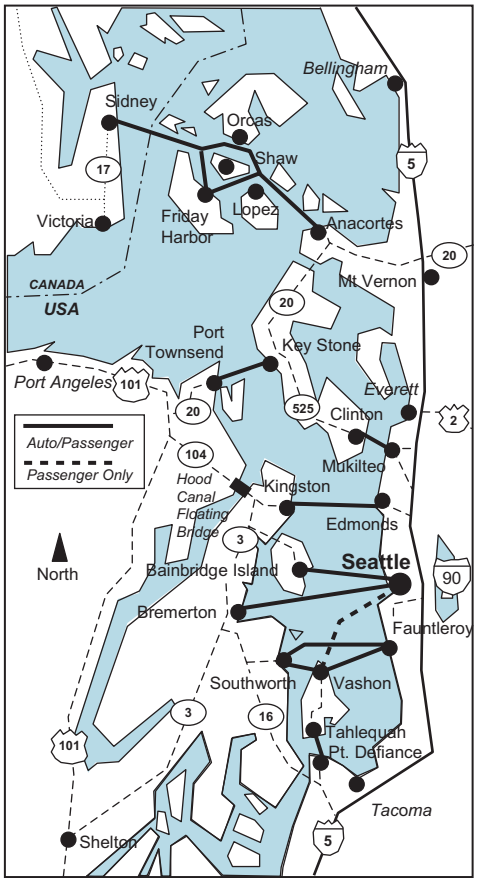


Fig. 1. Washington state ferry system map.

passengers than Amtrak, the US passenger rail carrier, handles in a year. Fig. 1 shows the current ferry routes for the central Puget Sound region. This map illustrates the ferry system's role in linking together the Washington State highway system in the Puget Sound region.

In part due to the introduction of high speed ferries, the State of Washington established an independent Blue Ribbon Panel to assess the adequacy of requirements for passenger and crew safety aboard the Washington State Ferries. On July 9, 1998, the Blue Ribbon Panel engaged a consultant team from The George Washington University and Rensselaer Polytechnic Institute/Le Moyne College to assess the adequacy of passenger and crew safety in the WSF system, to evaluate the level of risk present in the WSF system, and to develop recommendations for prioritized risk reduction measures which, once implemented, can improve the level of safety in the WSF system. The probability of ferry collisions in the WSF system was assessed using a dynamic simulation methodology that extends the scope of available data with expert judgment.

Experts were selected amongst WSF captains and WSF first mates who had extensive experience with all 13 different ferry routes over an extended period of time (more than 5 years). During the WSF risk assessment in 1998 expert responses to paired comparisons were aggregated by taking geometric means of their responses and using them in a classical log linear regression analysis approach to assess relative collision probabilities. The classical analysis conducted during the WSF risk assessment only resulted in point estimates of relative collision probabilities. We shall improve on the previous classical analysis by providing distributional results on these relative collision probabilities by developing a Bayesian inference engine for the paired comparison questionnaires administered during the WSF Risk Assessment. This is in compliance with the almost classical "speaking the truth in risk assessment" argument (see, e.g., Kaplan, 1997, p. 412) originating from the early 1980's when the International Society for Risk Analysis was founded: "*Since the truth is, we always have uncertainty, we say that speaking in probability curves is telling the truth*". The paired comparison elicitation method developed herein is not limited to the maritime domain and may generally be applicable to relative accident probability estimation when limited or no data is available. The research conducted by us is part of a larger project funded by the National Science Foundation to address uncertainty in large scale maritime risk assessments in a coherent manner.

1.3. Bayesian paired comparison approach for relative accident probabilities

Similar to the AHP process, we are interested in the functional relationship between contributing factors $\underline{X}=(X_1, X_2, \ldots, X_p)$ and an accident probability (rather than a value function). Our accident probability behaves much like a value function. That is, not only is the order amongst different sets of contributing factors (or covariates) $\underline{X}$ important, but also the differences in their values. Whereas Pulkkinen's focus (1993, 1994a,b) is on the multivariate distribution of a random vector $\underline{\beta}$, our focus is more applied and based on the distribution of an accident probability $\Pr(Accident|Incident, \underline{X})$ defined by

$$\Pr(Accident|Incident, \underline{X}) = P_0 Exp(\underline{\beta}^{\mathrm{T}} \underline{X}), \tag{1}$$

where $\underline{X}=(X_1, X_2, \ldots, X_p)$ describes a system state during which an incident (e.g. a mechanical failure) occurred. The accident probability model (1) has been proposed in previous maritime risk assessments (see, e.g., Roeleven et al., 1995; Merrick et al., 2000; Van Dorp et al., 2001), resembles the well-known proportional hazards model originally proposed by Cox (1972) and builds on the assumption that accident risk behaves exponentially rather than linearly with changes in covariate values. Our goal is to establish the uncertainty distribution of the accident probability $\Pr(Accident|Incident, \underline{X})$ in entirety rather than a point estimate. Similarly to Pulkkinen (1993, 1994a,b), our aggregation method of the expert judgment paired comparisons will follow the Bayesian paradigm. A questionnaire of paired comparisons is used to elicit the relative contribution of the elements of $\underline{X}$ to the accident probability and update its uncertainty, initially captured by (1) and a prior multivariate distribution of the random vector $\underline{\beta}$.

The Bayesian analysis conducted herein exploits the structure of (1) to result in a conjugate analysis (i.e. the prior and posterior distributions belong to the same family of distributions) involving a multivariate normal prior for the parameter vector $\underline{\beta}$ and a univariate gamma prior on an expert's precision (or, perhaps more appropriately, imprecision). In Section 2, we provide some background surrounding the use of the accident probability model (1) in large maritime risk assessments drawing primarily from the Washington State Ferry (WSF) Risk assessment (see Van Dorp et al., 2001). The likelihood of the expert responses to the paired comparison questionnaire is presented in Section 3. The prior distribution on the parameter vector $\underline{\beta}=(\beta_1,\beta_2,\ldots,\beta_p)$ and the expert judgment's precision is discussed in Section 4. The conjugate analysis deriving the posterior distribution of $\underline{\beta}=(\beta_1,\beta_2,\ldots,\beta_p)$ and the expert judgment's precision is presented in Section 5. In addition, parameter uncertainty in $\underline{\beta}=(\beta_1,\beta_2,\ldots,\beta_p)$ and uncertainty in the expert judgment is propagated through the accident probability model $\Pr(Accident|Incident,\underline{X})$ to arrive at closed form expressions for prior and posterior distributions of relative accident probabilities. A calculation example is presented using expert judgment data elicited during the WSF risk assessment (see, Van Dorp et al., 2001) in Section 6. Some concluding remarks are provided in Section 7.

2. Accident probability model

An accident is not a single event, but can be considered to be the culmination of a series of cascading events (see Garrick, 1984) starting with a triggering incident. In the maritime accident probability model in Merrick et al. (2000) and Van Dorp et al. (2001), triggering incidents have been further categorized as mechanical failures and human errors. Accidents and triggering incidents occur within the context of a system defined by ever changing combinations of contributing factors. Contributing factors may be further classified in organizational factors (OF) and situational factors (SF). In the WSF risk assessment an example of an organizational factor is a specific ferry route and ferry class combination (since operating teams are assigned by ferry class and route), whereas examples of situational factors are the changing weather conditions and traffic patterns while a ferry is underway. Fig. 2 provides an example of an accident probability model, the time sequence of the accident event chain and the influence of contributing factors on this chain. The accident probability model in Fig. 2 is based on the notion of conditional probability. The levels of conditional probability reflected in Fig. 2 are

- $\Pr(OF,SF)$: the probability that a particular set of organizational and situational factors occur in the system,
- $\Pr(Incident|OF)$: the probability that an incident occurs given the organizational factors and
- $\Pr(Accident|Incident,OF,SF)$: the probability that an accident occurs given that a triggering incident has occurred under the organizational and situational factors.

To perform an assessment of the annual accident risk and its uncertainty using this model, each term in the probability model and its uncertainty distribution needs to be estimated and propagated through the law of total probability.

Bayesian simulation techniques may be used to assess the exposure distribution of contributing factors, i.e. the distribution of $\Pr(OF,SF)$ (see, e.g., Merrick et al., 2003). As more data tends to be available at the triggering incident level rather than at the accident level, the distribution of $\Pr(Incident|OF)$ may be assessed utilizing the traditional Bayesian estimation techniques. For example, by updating a Poisson process for the occurrences of mechanical failures with a gamma prior distribution on the rate of occurrences, with mechanical failure data. In this paper we shall concentrate on the assessment of $\Pr(Accident|Incident,OF,SF)$ where the contributing factors (OF,SF) are described by a vector $\underline{X}=(X_1,X_2,\ldots,X_p)$ and only limited accident data is available.

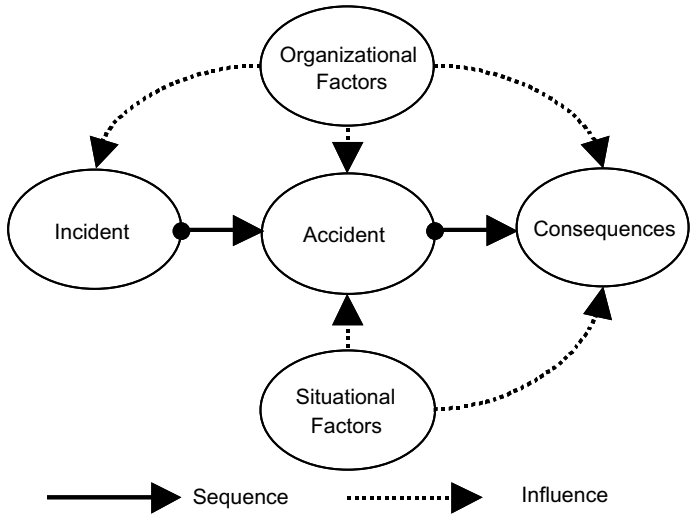


Fig. 2. The accident probability model.

For example in the WSF Risk Assessment only two collisions occurred over a period of 11 years (see Van Dorp et al., 2001). As an example, Table 1 provides a description of the contributing factors used in the WSF risk assessment. The heading "discretization" in Table 1 indicates the different number of possible scenarios for a contributing factor. For example, any of the following four traffic scenarios applies to the factor TS_1: meeting, passing, crossing astern and crossing the bow. Note that from the description in Table 1 it follows that a WSF Ferry may be interacting with more than one vessel at the same time.

The calculation model suggested for the accident probability given contributing factors $\underline{X}$ is given by (1), where $\underline{X} \in [0,1]^p$, $\underline{\beta} \in R^p$ and $P_0 \in (0,1)$. The covariates X_i, $i=1,\ldots,p$, are normalized so that $X_i=1$ describes the "worst" case scenario and $X_i=0$ describes the "best" case scenario. For example, for the 10th attribute X_{10} in Table 1, $X_{10}=1$ relates to the maximum wind speed typically observed in the given geographic area and $X_{10}=0$ relates to a wind speed of 0 knots. The calibration constant P_0 equals the accident probability when $\underline{X}=\underline{0}$.

In the previous example (dealing wind speed) the ordering from worst to best as it relates to an accident probability is self-evident, but this may not be the case for, for example, the second covariate in Table 1 indicating *vessel class*. In that case, a scale needs to be constructed ranking interacting vessel types

Table 1
Description of 10 contributing factors to $\Pr(Accident|Incident,\underline{X})$ in WSF risk assessment

	Designation	Description	Discretization
X_1	FR_FC	Ferry route—class combination	26
X_2	TT_1	1st Interacting vessel type	13
X_3	TS_1	Scenario of 1st interaction	4
X_4	TP_1	Proximity of 1st interaction	Binary
X_5	TT_2	2nd Interacting vessel type	5
X_6	TS_2	Scenario of 2nd interaction	4
X_7	TP_2	Proximity of 2nd interaction	Binary
X_8	VIS	Visibility	Binary
X_9	WD	Wind direction	Binary
X_{10}	WS	Wind speed	Continuous

according to a level of concern (from a collision perspective) when WSF captains or first mates encounter them on the water way. In the WSF risk assessment (see Van Dorp et al., 2001) a separate Bradley and Terry (1952) paired comparison procedure was used for that purpose, involving also WSF captains and first mates as experts. The Bradley–Terry procedure assumes that each object i is associated with a true scale value. For example, the value $X_2(i)$ is the scale value associated with the vessel type i, $i=1,\ldots,13$, of the first interacting vessel (see Table 1). Next, experts are asked to respond whether a traffic interaction with a vessel of type j would be preferred over that of type i, $i,j=1,\ldots,13$, $j\neq i$. Fig. 3 presents the resulting scale values $X_2(i)$, $i=1,\ldots,13$, from the Bradley–Terry analysis for the second covariate in Table 1 involving 13 different vessel types.

It follows from Fig. 3 that when encountering these vessel types, the level of concern is the largest when encountering a Naval Vessel and the smallest when encountering a large WSF Ferry. One may argue that the construction of the scale in Fig. 3 introduces a motivational bias as Washington State Ferries consistently received the lowest rankings. On the other hand, when these results were presented to the Blue Ribbon Panel on Ferry Safety (see Van Dorp et al., 2001) it was noted that WSF Ferries interacting with WSF Ferries is an everyday occurrence involving common actors, rather than the far less frequent Naval Vessel whose captain is unknown to the WSF Ferry operators. In a similar manner, covariate scales had to be constructed for $X_1, X_3, \ldots, X_7$ to allow for the use of (1) and their contribution to $\Pr(Accident|Incident,\underline{X})$. Note that some of the elements in X may be used to describe interaction effects. For example, if X_1 relates to the Ferry Route-Ferry Class combination and X_2 relates to the traffic type of the first interacting vessel, one may introduce an 11th factor X_{11} equal to $X_1 \cdot X_2$ to model that accident probability may increase more (or less) as a result of a combined increase in both X_1 and X_2. In principle more complex interactions can be included.

Having selected the contributing factors for $\Pr(Accident|Incident,\underline{X})$ and having constructed the covariate scales of the elements in $\underline{X}$, a paired comparison questionnaire may be designed, each question comparing two different system states $\underline{X}^1$ and $\underline{X}^2$. Fig. 4 provides an example question appearing in one of the questionnaires used in the WSF risk assessment (see Van Dorp et al., 2001). For ease of comparison $\underline{X}^1$ and $\underline{X}^2$ (situations 1 and 2 in Fig. 4) differ only in one contributing factor. By circling a "1" or the midpoint

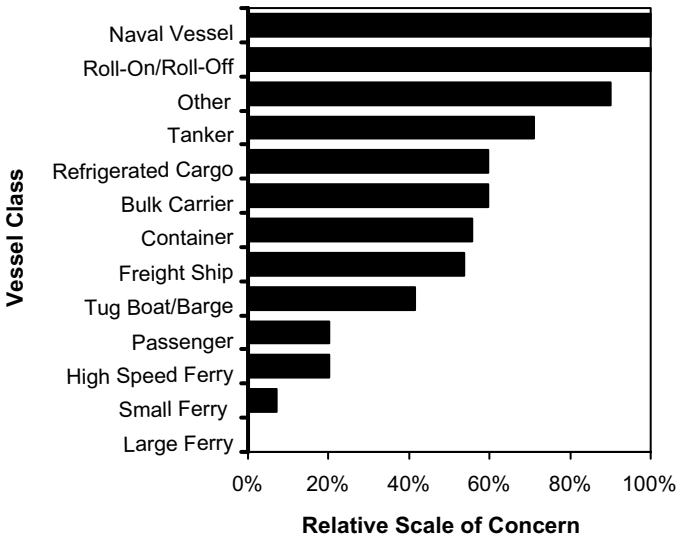


Fig. 3. Constructed covariate scale for interacting vessels.

Question: 32 48

Situation 1	Attribute	Situation 2
Super	**Ferry Class**	-
SEA-BAI	**Ferry Route**	-
Naval Vessel	**1st Interacting Vessel**	-
Crossing the bow	**Traffic Scenario 1st Vessel**	-
1 to 5 miles	**Traffic Proximity 1st Vessel**	-
Deep Draft	**2nd Interacting Vessel**	-
Crossing the bow	**Traffic Scenario 2nd Vessel**	-
1 to 5 miles	**Traffic Proximity 2nd Vessel**	-
more than 0.5 mile	**Visibility**	less than 0.5 mile
Along Ferry	**Wind Direction**	-
40 knots	**Wind Speed**	-
	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Situation 1 is worse	**<==========X==========>**	**Situation 2 is worse**

Fig. 4. An example question appearing in one of the questionnaires used in the WSF risk assessment.

of the scale, the expert has indicated that he/she judges the likelihood of a particular accident type to be the same in system state $\underline{X}^1$ as in system state $\underline{X}^2$. If he/she circles, e.g. the number 9 towards Situation 2 (i.e. to the right) we interpret that he/she considers the likelihood of a particular accident type to be 9 times as high in $\underline{X}^2$ as in $\underline{X}^1$ given a particular incident has occurred. In the WSF risk assessment (see Van Dorp et al., 2001) the focus was on collision accidents and incidents were further classified as propulsion, steering and navigation equipment failures, and human error.

If one is interested in paired comparison of accident risk between two different systems states $\underline{X}^1$ and $\underline{X}^2$ given an incident occurred, it is sufficient to estimate the parameter vector $\underline{\beta}$, as the relative accident probability in $\underline{X}^1$ compared to $\underline{X}^2$ (denoted by $P(\underline{X}^1, \underline{X}^2|\underline{\beta})$) follows from (1) yielding

$$P(\underline{X}^1, \underline{X}^2|\underline{\beta}) = Exp\{\underline{\beta}^{\mathrm{T}}(\underline{X}^1 - \underline{X}^2)\}. \tag{2}$$

Note that the relative accident probability is not restricted to the support [0,1] but $P(\underline{X}^1, \underline{X}^2|\underline{\beta}) \in [0, \infty]$ and

$$\log\{P(\underline{X}^1, \underline{X}^2|\underline{\beta})\} = \underline{\beta}^{\mathrm{T}}(\underline{X}^1 - \underline{X}^2) \in (-\infty, \infty). \tag{3}$$

On the other hand, if one is interested in an absolute accident probability, one is required to estimate P_0 in addition to the parameter vector β. The calibration constant P_0 may be estimated by applying the law of total probability using all probability terms in Fig. 2, the maritime system simulation and average annual accident data, for example the 2 collisions over an 11 year period as was the case in the WSF risk assessment (see Van Dorp et al., 2001). In the following sections, the discussion will be limited to presenting prior and posterior analysis for relative accident probabilities given by (2).

3. The likelihood of a single expert's response

Let Y_j be the response of an expert to a paired comparison question j, comparing two different situations $\underline{X}_j^1$ and $\underline{X}_j^2$ in terms of accidents proneness given an incident has occurred (e.g. a navigation equipment failure), i.e.

$$Y_j = \text{Experts response to ratio } \frac{\Pr(Accident|Incident, \underline{X}_j^1)}{\Pr(Accident|Incident, \underline{X}_j^2)}.$$

Define

$$Z_j = \log Y_j,\ j = 1, \ldots, n,$$

to be experts' log response to question j. The response of the expert to such a question is uncertain and will assumed to be normal distributed such that

$$(Z_j|\mu_j, r) \sim N(\mu_j, r), \tag{4}$$

where $r = 1/\sigma^2$ is the precision that does not depend on the question index j and σ is the standard deviation of the normal distribution in (4), $\sigma > 0$. This is the most common uncertainty model encountered in practice, which seems to be appropriate at least given the support indicated by (3). Utilizing the structure of the accident probability model (1) and (3) we set

$$\mu_j = q_j^{\mathrm{T}} \underline{\beta}, \tag{5}$$

where $\underline{q}_j = (\underline{X}_j^1 - \underline{X}_j^2)$ is a $p \times 1$ vector. The relevance of the paired comparison of situations $\underline{X}_j^1$ and $\underline{X}_j^2$ appears in the distribution (4) of Z_j only via the vector $\underline{q}_j$ (cf. (5)). The likelihood of an expert responding z_j to question j, $f_{Z_j}(z_j)$, follows from (4) as

$$f_{Z_j}(z_j) \propto \sqrt{r} \exp\left\{-\frac{r}{2}(z_j - \mu_j)^2\right\}, \tag{6}$$

where the symbol $\propto$ means "being proportional to".

Suppose the expert answers n paired comparison questions defined by the vectors $q_j = (\underline{X}_j^1 - \underline{X}_j^2)$, $j = 1, \ldots, n$, define Q to be the $p \times n$ questionnaire matrix

$$Q = [\underline{q}_1, \ldots, \underline{q}_n] \tag{7}$$

and let the answers of the expert be summarized in the $n \times 1$ response vector

$$\mathscr{Z} = (z_1, \ldots, z_n). \tag{8}$$

Assuming conditional independence between an individual expert's responses to different questions given the precision r and parameter vector $\underline{\beta}$, the likelihood $\mathscr{L}(\mathscr{Z}|\underline{\beta}, r, Q)$ of an expert responding $\mathscr{Z}$ to questionnaire Q, may be derived from (6) as being proportional to

$$r^{\frac{n}{2}} \exp\left\{-\frac{r}{2}\left(\sum_{j=1}^{n} z_j^2 - 2\sum_{j=1}^{n} \mu_j z_j + \sum_{j=1}^{n} \mu_j^2\right)\right\}. \tag{9}$$

The conditional independence assumption implies that the sole source for *dependence* amongst an individual expert's responses to the different questions are the unknown precision r and the unknown parameter vector $\underline{\beta}$ (which seems to be reasonable). In addition, in a Bayesian analysis the standard conditional independence assumption given the unknown parameters is quite natural and is often not explicitly mentioned (see, e.g. Pulkkinen, 1994a). Substituting $\mu_j = q_j^{\mathrm{T}} \underline{\beta}$ (cf. (5)) in (9), yields

$$\begin{aligned}\mathscr{L}(\mathscr{Z}|\underline{\beta}, r, Q) &\propto r^{\frac{n}{2}} \exp\left\{-\frac{r}{2}\left(\sum_{j=1}^{n} z_j^2 - 2\left[\sum_{j=1}^{n} \underline{q}_j z_j\right]^{\mathrm{T}} \underline{\beta} + \underline{\beta}^{\mathrm{T}}\left[\sum_{j=1}^{n} \underline{q}_j \underline{q}_j^{\mathrm{T}}\right]\underline{\beta}\right)\right\} \\ &\propto r^{\frac{n}{2}} \exp\left\{-\frac{r}{2}(c - 2\underline{b}^{\mathrm{T}}\underline{\beta} + \underline{\beta}^{\mathrm{T}} A \underline{\beta})\right\},\end{aligned} \tag{10}$$

where

$$A = \sum_{j=1}^{n} \underline{q}_j \underline{q}_j^{\mathrm{T}}; \quad \underline{b} = \sum_{j=1}^{n} \underline{q}_j z_j; \quad c = \sum_{j=1}^{n} z_j^2. \tag{11}$$

The matrix A will be referred to as the design matrix of the questionnaire Q. Note that, $A^T = A$. Hence, A is symmetric. Furthermore, for $\underline{x} \neq \underline{0}$ it follows that

$$\underline{x}^{\mathrm{T}} A \underline{x} = \underline{x}^{\mathrm{T}} \left[\sum_{j=1}^{n} \underline{q}_j \underline{q}_j^{\mathrm{T}} \right] \underline{x} = \sum_{j=1}^{n} \underline{x}^{\mathrm{T}} \underline{q}_j \underline{q}_j^{\mathrm{T}} \underline{x} = \sum_{j=1}^{n} (\underline{x}^{\mathrm{T}} \underline{q}_j)^2 > 0 \tag{12}$$

as long as the columns $\underline{q}_j$ of Q span R^p. If the latter condition holds for the questionnaire matrix Q, it follows from (12) that A is positive definite and symmetric and therefore invertible.

4. Prior distribution

To allow for a conjugate Bayesian analysis a multivariate normal/gamma prior is proposed for the joint distribution of $(\underline{\beta}, r)$ similar to the one described in West and Harrison (1989). Conjugate Bayesian analysis is motivated mainly by the desire to simplify calculations of the posterior probability. Nevertheless it proved to be a reliable approach yielding invariably meaningful results.

A Gamma$(\frac{\alpha}{2}, \frac{v}{2})$ will be defined on the precision r and is given by the pdf

$$\prod(r|\alpha, v) = \frac{\frac{v^{\frac{\alpha}{2}}}{2}}{\Gamma\left(\frac{\alpha}{2}\right)} r^{\frac{\alpha}{2}-1} \exp\left(-\frac{r}{2} v\right). \tag{13}$$

The distribution of $(\underline{\beta}|r)$ is assumed to be multivariate normal (MVN) with a prior $p \times 1$ dimensional mean vector $\underline{m}$ and $p \times p$ precision matrix $r\Delta$, i.e.

$$\prod(\underline{\beta}|r) \propto r^{\frac{p}{2}} \exp\left\{-\frac{r}{2} (\underline{\beta} - \underline{m})^{\mathrm{T}} \Delta (\beta - m)\right\}. \tag{14}$$

Hence, from the structure of the MVN it follows that $(r\Delta)^{-1}$ is the variance covariance matrix of $(\underline{\beta}|r)$. The joint prior distribution on $(\underline{\beta}, r)$ follows from (13) and (14) to be

$$\prod(\underline{\beta}, r) \propto r^{\frac{\alpha}{2}-1} \exp\left(-\frac{r}{2} v\right) \times r^{\frac{p}{2}} \exp\left\{-\frac{r}{2} (\underline{\beta} - \underline{m})^{\mathrm{T}} \Delta (\underline{\beta} - \underline{m})\right\}. \tag{15}$$

The marginal distribution of $\underline{\beta}$ may be derived from (15), yielding

$$\prod(\underline{\beta}) \propto \left[1 + \frac{1}{v} (\underline{\beta} - \underline{m})^{\mathrm{T}} \Delta (\underline{\beta} - \underline{m})\right]^{-\frac{\alpha+p}{2}} \tag{16}$$

and is recognized as a p-dimensional multivariate t-distribution with α degrees of freedom, location vector $\underline{m}$ and precision matrix

$$\frac{\alpha}{v} \Delta. \tag{17}$$

Note that, α/v in (17) is the mean value of the precision $r \sim \text{Gamma}(\frac{\alpha}{2}, \frac{v}{2})$ and hence the marginal distribution of β integrates the precision given by (13) and that of $(\underline{\beta}|r)$ (cf. (14)). The marginal distribution of β_i, $i = 1, \ldots, p$, follows from (16) as a univariate t-distribution with α degrees of freedom, location parameter m_i and precision parameter $\frac{\alpha}{v} \delta_{ii}$, given by

$$\prod(\beta_i) \propto \left[1 + \frac{\delta_{ii}}{v} (\beta_i - m_i)^2\right]^{-\frac{\alpha+1}{2}}, \tag{18}$$

where δ_{ii} is the ith diagonal element of the precision matrix Δ. From (16) and (3) follows that the log-relative probability $log\{P(\underline{X}^1, \underline{X}^2|\beta)\}$ has a prior t-distribution with mean

$$\underline{m}^{\mathrm{T}}(\underline{X}^1 - \underline{X}^2) \tag{19}$$

and precision

$$\frac{\alpha}{v}(\underline{X}^1 - \underline{X}^2)^{\mathrm{T}}\Delta(\underline{X}^1 - \underline{X}^2). \tag{20}$$

The prior distribution of the relative probability $P(\underline{X}^1, \underline{X}^2|\beta)$ (cf. (2)) thus follows a log-t distribution (see, e.g., McDonald and Butler, 1987) with parameters specified via (19) and (20).

4.1. Prior parameter specification

A prior chi-squared distribution with α degrees of freedom (equivalent to a gamma distribution Gamma$(\frac{\alpha}{2}, \frac{v}{2})$ with $v=1$) will be selected for the prior distribution of precision r requiring only specification of the prior parameter α. From (13) it follows that $E[r|\alpha, v=1]=\alpha$. The prior parameter α will be set equal to the reciprocal of the variance of an expert responding to the n paired comparison questions completely at random and depends on the scale that is used in the paired comparison questions to collect the expert responses. In the example of Fig. 4, responses range from $\frac{1}{9}, \frac{1}{8}, \ldots \frac{1}{2}, 1, 2, \ldots, 9$ totaling 17 possible responses per question. With different responses being equally like and mutually independent for an expert responding at random and noting that $\log^2(x^{-1})=\log^2(x)$ it follows that a priori

$$\alpha = E[r|\alpha, v=1] = \frac{1}{\frac{2}{17}\sum_{k=2}^{9}\{\log(k)\}^2} \approx 0.380341. \tag{21}$$

Consistency within an individual expert's response can be observed when the posterior variance decreases as compared to an expert responding at random. The conjugacy of the posterior analysis will allow for straightforward sequential updating using the responses of the k individual experts. Agreement amongst the experts can be identified by further reduction (increase) in the posterior variance (precision) using sequential updating.

During the WSF risk assessment in 1998 geometric means amongst the expert responses were used in a classical log-linear regression analysis approach to assess relative accident probabilities given by (2). Using a best subset regression approach 6 interactions indicated Table 2 were selected and will also be used herein to allow for a comparison in Section 6 between the classical and Bayesian point estimates. Hence, the vector $\underline{\beta}$ to be utilized in our example in Section 6 will be a 1×16 vector.

For the distribution of $(\underline{\beta}|r)$ we may select a priori a location vector

$$\underline{m} = (0, \ldots, 0)^{\mathrm{T}} \tag{22}$$

Table 2
Interaction variables associated with the contributing factors in Table 1

	Designation	Description
X_{11}	FR_FC·TT_1	Interaction
X_{12}	FR_FC·TS_1	Interaction
X_{13}	FR_FC·VIS	Interaction
X_{14}	TT_1·TS_1	Interaction
X_{15}	TT_1·VIS	Interaction
X_{16}	TS_1·VIS	Interaction

and the unit precision matrix

$$\Delta = \begin{pmatrix} 1 & & \emptyset \\ & \ddots & \\ \emptyset & & 1 \end{pmatrix}, \tag{23}$$

as long as the resulting marginal distributions of β_i (cf. (18)) are flat, or (perhaps more importantly) as long as the resulting prior distribution on the relative accident probabilities (2) are non-informative. The motivation for a non-informative prior is to "let the evidence speak" (i.e. the expert judgment) (see, e.g., Kaplan, 1997, p. 414). Expression (22) specifies that a priori none of the attributes contribute to accident risk and expression (23) indicates a priori independence between the elements of the parameter vector $\underline{\beta}$.

Fig. 5 below depicts the prior distribution on $(\underline{\beta},r)$ utilizing (21), (22) and (23). Fig. 5A depicts a graph of the prior density function of the precision r. Fig. 5B displays the 90% credibility intervals of $\beta_i, i=1,\ldots,16$ and Fig. 5C provides a graph of prior distribution of the relative probability $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ associated with the

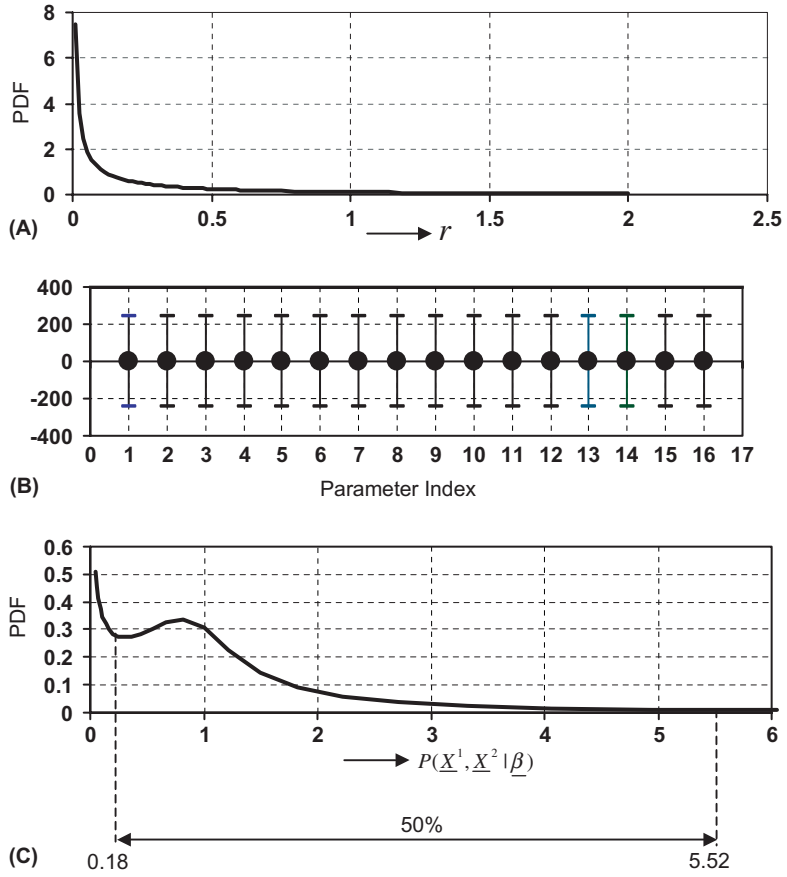


Fig. 5. Prior distribution on $(\underline{\beta},r)$ and $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ (cf. (2)) for the two scenarios in Fig. 4. (A) Prior marginal distribution on r; (B) Prior 90% credibility intervals for the parameters β_i, $i=1,\ldots,16$; (C) Prior distribution of relative probability $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ associated with Fig. 4.

paired comparison in Fig. 4. The probability density in Fig. 5C is one of a log-t distribution (see, e.g., McDonald and Butler, 1987) with prior parameters (cf. (19) and (20))

$$\underline{m}^{\mathrm{T}}(\underline{X}^1-\underline{X}^2)=0,\ \ \alpha=0.380341,\ \ v=1,\ \ \delta_{ii}=(\underline{X}^1-\underline{X}^2)^{\mathrm{T}}\Delta(\underline{X}^1-\underline{X}^2)=4.$$

The prior median of $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ equals 1 (indicating indifference in collision likelihood between system states $\underline{X}^1$ and $\underline{X}^2$). A 50% credibility interval of $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ in Fig. 5A equals [0.181, 5.515]. A 75% credibility interval of $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ equals $[2.012\cdot 10^{-5}, 4.971\cdot 10^{4}]$ (which is quite wide) and hence our prior specification utilizing (21)–(23) may be viewed as sufficiently non-informative.

Previous credibility intervals above and those in Fig. 5B were evaluated utilizing

$$A(u|\alpha,v,\delta_{ii})=\frac{1}{B(\frac{1}{2},\frac{\alpha}{2})}\sqrt{\frac{\delta_{ii}}{v}}\int_{m_i-u}^{m_i+u}\left[1+\frac{\delta_{ii}}{v}(\beta_i-m_i)^2\right]^{-\frac{\alpha+1}{2}}\mathrm{d}\beta_i,$$

where $A(u|\alpha,v,\delta_{ii})$ is the probability mass in a credibility interval $[m_i-u,m_i+u]$ around the location parameter m_i of a t-distribution with precision $\frac{\alpha}{v}\delta_{ii}$. The latter quantity $A(u|\alpha,v,\delta_{ii})$ is related to the well known incomplete beta function

$$B(x|a,b)=\frac{1}{B(a,b)}\int_0^x u^{a-1}(1-u)^{b-1}\,\mathrm{d}u, \tag{24}$$

where $a,b>0$, $x\in[0,1]$, and $B(a,b)=\frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$ via the relationship

$$A(u|\alpha,v,\delta_{ii})=1-B\left(\frac{v}{v+\delta_{ii}u^2}\middle|\frac{\alpha}{2},\frac{1}{2}\right)$$

(see, e.g., Press et al., 1989). Numerical routines for evaluating the incomplete beta function (24) are widely provided in standard PC software such as Microsoft Excel. It should also be noted that due to the value of α (cf. (21)), the moments of β_i, at least a priori, do not exist. However, since the t-distribution is symmetric around m_i, a natural point estimate for β_i is provided by its median value m_i indicated in Fig. 5B, $i=1,\ldots,16$.

5. Posterior analysis

Applying Bayes theorem utilizing the likelihood (10), the prior distribution (15) and data specified via (7) and (8), it follows that the posterior distribution $\prod(\underline{\beta},r|\mathscr{Z},Q)$ is proportional to

$$r^{\frac{n}{2}}\exp\left\{-\frac{r}{2}(c-2\underline{b}^{\mathrm{T}}\underline{\beta}+\underline{\beta}^{T}A\underline{\beta})\right\}\times r^{\frac{\alpha}{2}-1}\exp\left(-\frac{r}{2}\right)\times r^{\frac{p}{2}}\exp\left\{-\frac{r}{2}(\underline{\beta}-\underline{m})^{\mathrm{T}}\Delta(\underline{\beta}-\underline{m})\right\},$$

where c, $\underline{b}$, and A are given by (11). Combining like terms we obtain

$$\begin{aligned}\prod(\underline{\beta},r|\mathscr{Z},Q)\propto{}& r^{\frac{\alpha+n}{2}-1}\exp\left\{-\frac{r}{2}(1+c+\underline{m}^{\mathrm{T}}\Delta\underline{m})\right\}\times r^{\frac{p}{2}}\\ &\times\exp\left\{-\frac{r}{2}\left(-2[\underline{b}+\Delta\underline{m}]^{\mathrm{T}}\underline{\beta}+\underline{\beta}^{\mathrm{T}}[A+\Delta]\underline{\beta}\right)\right\}.\end{aligned} \tag{25}$$

Defining Δ^u to be

$$\Delta^u=A+\Delta, \tag{26}$$

it follows from the symmetry and positive definiteness of A (cf. (12)) and Δ, that Δ^u is symmetric and positive definite, and hence invertible. Implicitly defining $\underline{m}^u$ satisfying

$$[\underline{b}+\Delta\underline{m}]^{\mathrm{T}}\underline{\beta}=[\Delta^u\underline{m}^u]^{\mathrm{T}}\underline{\beta} \tag{27}$$

for all $\underline{\beta}$, it follows that

$$\underline{b} + \sum \underline{m} = \Delta^u \underline{m}^u \iff \underline{m}^u = (\Delta^u)^{-1}(\underline{b} + \Delta \underline{m}). \tag{28}$$

Utilizing (27) and (28) we derive from (25) that

$$\prod(\underline{\beta}, r|\mathscr{L}, Q) \propto r^{\frac{\alpha+n}{2}-1} \exp\left\{-\frac{r}{2}(1 + c + \underline{m}^{\mathrm{T}} \Delta \underline{m} - [\underline{m}^u]^{\mathrm{T}} \Delta^u \underline{m}^u)\right\} \times r^{\frac{p}{2}} \times \exp\left\{-\frac{r}{2}[\underline{\beta} - \underline{m}^u]^{\mathrm{T}} \Delta^u [\underline{\beta} - \underline{m}^u]\right\}. \tag{29}$$

From (29) it follows, utilizing (11), that $(\underline{\beta}|r, \mathscr{L}, Q) \sim MVN(\underline{m}^u, r\Delta^u)$ where

$$\begin{cases} \Delta^u = \sum_{j=1}^{n} q_j q_j^{\mathrm{T}} + \Delta \\ m^u = (\Delta^u)^{-1}\left(\sum_{j=1}^{n} \underline{q}_j z_j + \Delta \underline{m}\right) \end{cases} \tag{30}$$

and $(r|\mathscr{L}, Q) \sim \text{Gamma}(\frac{\alpha^u}{2}, \frac{\nu^u}{2})$ with

$$\begin{cases} \alpha^u = \alpha + n \\ \nu^u = \nu + \sum_{j=1}^{n} z_j^2 + \underline{m}^{\mathrm{T}} \Delta \underline{m} - [\underline{m}^u]^{\mathrm{T}} \Delta^u \underline{m}^u \end{cases} \tag{31}$$

and $\underline{m}^u$ and Δ^u are given by (30). From (30), (31), (13) and (14) we deduce that the Bayesian updating procedure above is in fact a conjugate Bayesian analysis. In the next section we shall illustrate the inference procedure using the responses of eight experts to a paired comparison questionnaire containing 60 questions similar to the one in Fig. 4 and administered during the WSF risk assessment in 1998.

6. Example with data elicited during WSF risk assessment

An individual questionnaire was administered to experts for each of the following possible incidents on the Washington State Ferry: propulsion failure, steering failure, navigation equipment failure, human error, as well as an individual questionnaire given an incident (either human error or mechanical failure) which occurred on the nearby vessel. As an illustrative example, we shall demonstrate our Bayesian conjugate analysis utilizing the responses of the 8 experts to the questionnaire involving the navigation equipment failure to derive the posterior distribution of the relative accident probability given by (2) associated with Fig. 4. Combination of the responses of these 8 experts follows naturally by exploiting the conjugacy of the analysis in Section 3–5 through sequential updating.

During the WSF risk assessment in 1998 expert responses were aggregated by taking geometric means of their responses and using them in a classical log linear regression analysis approach to assess relative accident probabilities given by (2). Classical point estimates for the parameters β_i, $i = 1, \ldots, 16$, associated with the contribution factors (the so-called main effects) in Table 1 and interaction effects in Table 2 will be compared to their Bayesian counterparts following our Bayesian aggregation method.

6.1. The elements A, $\underline{b}$ and $\underline{c}$ of the likelihood given by (11)

Experts were instructed to assume that a navigation equipment failure had occurred on the Washington State Ferry and were next asked to assess how much more likely a collision is to occur in Situation 1 (good visibility in Fig. 4) as compared to Situation 2 (bad visibility in Fig. 4) taking into account the value of all

the contributing factors. The additional factors in Fig. 4 (besides visibility) are used to assess interaction effects but also play a role in terms of designing a meaningful question. For example, a question that simply asks an expert to assess the likelihood of collision given a navigation equipment failure in bad visibility compared to good visibility is not meaningful since the expert would have to know for example whether another vessel nearby is crossing or passing and its proximity. Table 3 provides the answers of the eight experts to the question in Fig. 4. Note that Expert 8 responded (presumably inconsistently) that Situation 2 (with bad visibility) has a lower accident probability than Situation 1 (with good visibility). An expert aggregation method combines the responses in Table 3 into a single one.

The questionnaire consisted of sixty questions similar to the one displayed in Fig. 4. The questions were randomized in order and were distributed evenly over the 10 contributing factors in Table 1 (i.e. 6 questions per changing contributing factor). The 16×16 design matrix A of the questionnaire (cf. (11)) is of the following form:

$$A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, \tag{32}$$

where A_{11} is a 10×10 diagonal matrix with diagonal elements

$$(4.56, 4.33, 2.89, 6, 1.5, 2.44, 6, 6, 6, 0.375) \tag{33}$$

and associated with the contributing factors $X_1, \ldots, X_{10}$. (The matrix A_{11} in (32) is a diagonal matrix since the paired comparison scenarios $\underline{X}^1$ and $\underline{X}^2$ only differed in one covariate (see Fig. 4)). The matrix A_{22} in (32) is a symmetric 6×6 matrix with elements

$$\begin{bmatrix} 3.45 & 0.33 & 0 & 1.44 & 0.76 & 0 \\ 0.33 & 3.45 & 0.44 & 0.33 & 0 & 1 \\ 0 & 0.44 & 4.11 & 0 & 1 & 2.39 \\ 1.44 & 0.33 & 0 & 1.89 & 0.36 & 0.08 \\ 0.76 & 0 & 1 & 0.36 & 3.02 & 2 \\ 0 & 1 & 2.39 & 0.08 & 2 & 6.67 \end{bmatrix} \tag{34}$$

and associated with the interaction effects $X_{11}, \ldots, X_{16}$. Finally, the matrix $A_{21} = A_{12}^{\mathrm{T}}$ is a sparse 10×6 matrix

$$\begin{bmatrix} 1 & 2.82 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 2.26 & 0 & 2.12 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1.13 & 0 & 0 & 0 & 0 & 0 & 0 & 3.06 & 0 & 0 \\ 0 & 2.13 & 0.52 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.02 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 1.56 & 0 & 0 & 0 & 0 & 5.33 & 0 & 0 \end{bmatrix} \tag{35}$$

with only positive elements associated with the contributing factors X_1, X_2, X_3 and X_8 that are included in the interaction effects $X_{11}, \ldots, X_{16}$. The questionnaire was designed in a manner such that the resulting matrix A is positive definite (and thus invertible), but equally important, involved meaningful paired comparisons consistent with realistic scenarios on the Puget Sound. The latter required maritime knowledge about the WSF Ferry system acquired by the team conducting the WSF Risk Assessment.

Table 3
Expert response to the paired comparison in Fig. 4

Expert index	1	2	3	4	5	6	7	8
Response	5	5	3	9	7	9	3	0.5

Fig. 6 below summarizes the vector $\underline{b}$ cf. (11) for each of the eight expert responses to 60 questions in terms of $\sum_{j=1}^{60} q_{ij} z_j$ for each of the contributing factors X_i, $i=1,\ldots,10$, in Table 1 and interaction effects X_i, $i=11,\ldots,16$, in Table 2. Hence, Fig. 6 consists of 16 histograms each one plotting the ith element of the vector $\underline{b}$ cf. (11) for all eight experts. From Fig. 6 we may (visually) assess the consistency in the expert judgment with respect to the ordering of the covariate scale of the elements X_i, $i=1,\ldots,16$. A positive (negative) value indicates agreement with the ordering of that particular scale. For example, the histogram in Fig. 6 associated with the contributing factor TP1 (Traffic Proximity of first interacting vessel) shows that all experts responded (not surprisingly) that vessels further away pose less (immediate) collision risk. The histogram in Fig. 6 associated with the contributing factor VIS provides a similar result to that in Table 3, i.e. that Expert 8 inconsistently rated lower visibility with lower collision risk throughout the questionnaire. The largest discrepancy with the ordering of a covariate scale amongst the 8 experts is observed in the first histogram and is associated with the variable FR-FC (Ferry Route-Ferry Class combination).

The elements $c = \sum_{j=1}^{60} z_j^2$ (cf. (11)) for each individual expert are provided in Table 4. Note that on aggregate particularly both Expert 3 and Expert 8 assessed lower collision likelihoods in their paired comparisons questions.

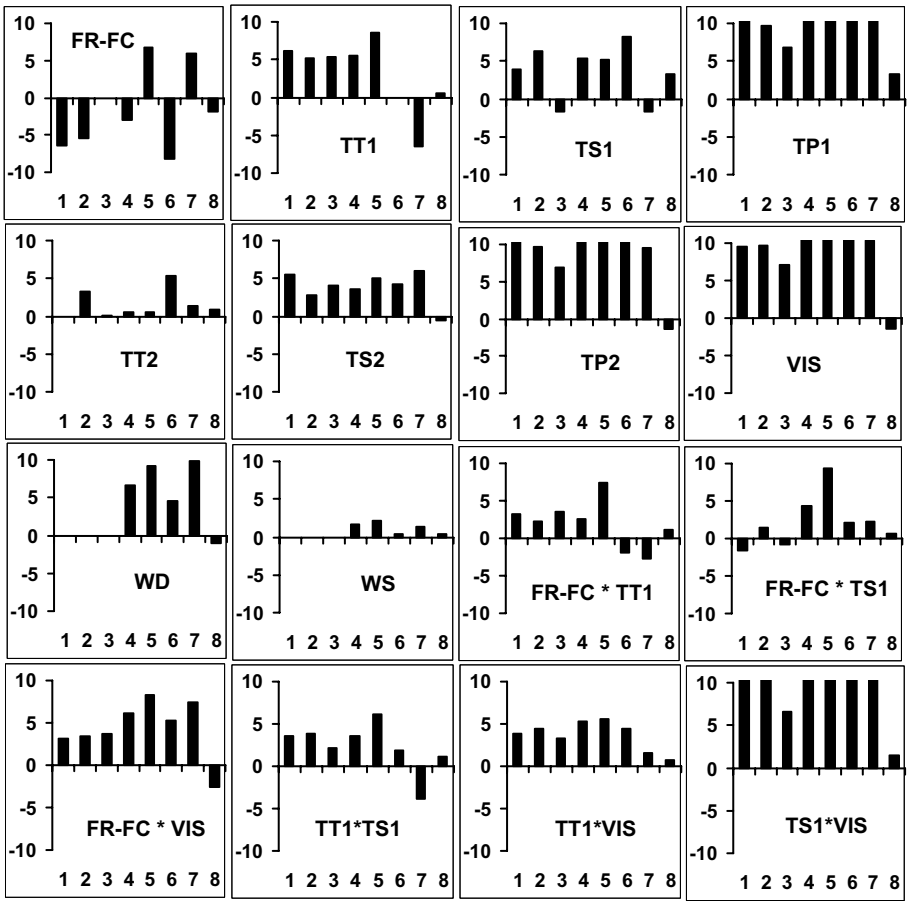


Fig. 6. Summary of individual expert response for 8 WSF experts in terms of ith element of the vector $\underline{b}$ (cf. (11)) for each of the contributing factors X_i, $i=1,\ldots,10$ in Table 1 and interaction effects X_i, $i=11,\ldots,16$ in Table 2.

Table 4
Values for c (cf. (11)) for the eight individual experts

Expert index	1	2	3	4	5	6	7	8
Scalar c	149.07	95.28	55.74	147.93	185.71	177.30	147.12	44.94

6.2. Posterior analysis

Utilizing the aggregate individual expert responses (vectors $\underline{b}$) in Fig. 6, the matrix A specified by (32)–(35), the scalars c in Table 4, we update the prior distribution of $(\underline{\beta},r)$ depicted in Fig. 5 in a Bayesian manner using sequential updating. The resulting posterior distribution on $(\underline{\beta},r)$ is displayed in Fig. 7. Fig. 7A contains a plot of a $\Gamma(\frac{\alpha^u}{2},\frac{\nu^u}{2})$ density with parameters

$$\alpha^u = 480.38, \quad \nu^u = 530.95. \tag{36}$$

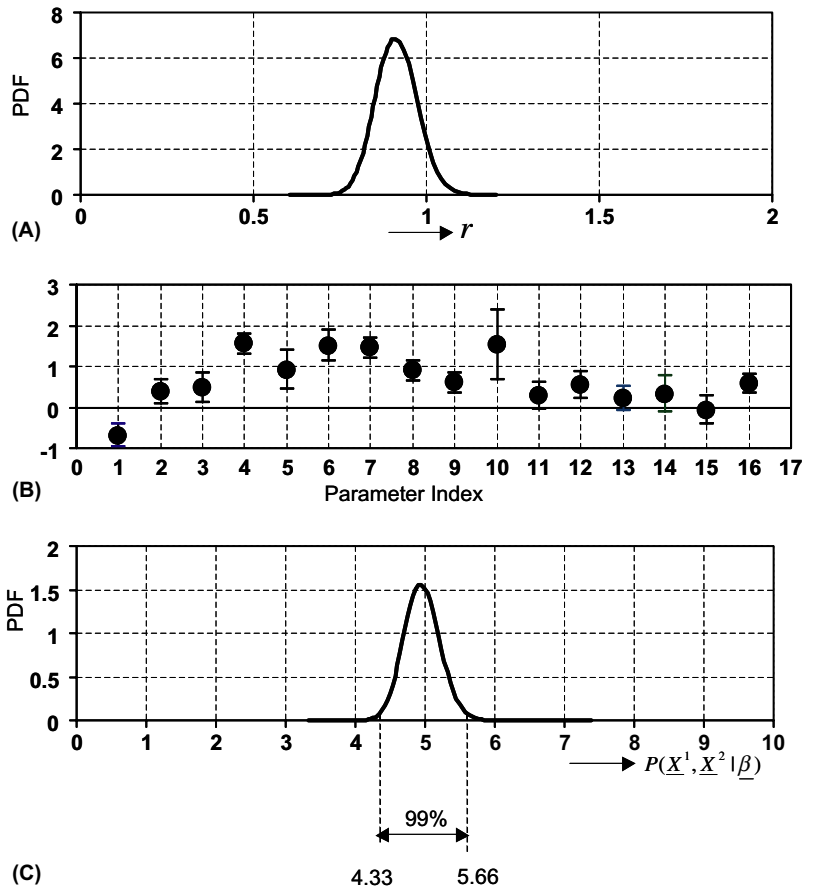


Fig. 7. Posterior distribution on $(\underline{\beta},r)$ and $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ (cf. (2)) for the two scenarios in Fig. 4. (A) Posterior marginal distribution on r; (B) Posterior 90% credibility intervals for the parameters β_i, $i=1,\ldots,16$; (C) Posterior distribution of relative probability $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ associated with Fig. 4.

Fig. 7B displays 90% credibility intervals of the posterior distributions of β_i, $i=1,\ldots,16$ and the location parameters m_i^u. The posterior distribution of the parameter vector $\underline{\beta}$ is a multivariate t distribution with location vector $\underline{m}^u$ and precision matrix $\frac{\alpha^u}{v^u}\Delta^u$, where α^u, v^u are given by (36) and

$$\Delta^u = \Delta + 8A$$

(cf. (26)) where the unit matrix Δ is given by (23) and the matrix A by (32)–(35). It can be concluded from Fig. 7B that traffic proximity of the first and second interacting vessel (X_4 and X_7, respectively), traffic scenario of the second interacting vessel X_6 and wind speed X_{10} are the largest contributing factors to accident risk. In addition, the manner in which the first interacting vessel approaches the ferry route–ferry class combination (X_{12}), i.e. crossing, passing or overtaking, and in what visibility conditions (X_{16}) are the largest interacting factors. The posterior location vector m^u is displayed in Fig. 8 together with their classical counterpart estimated via a log-linear regression method utilizing the geometric means of the expert responses. A remarkable agreement should be noted between the Bayesian and classical point estimates provided in Fig. 8, except for a discrepancy associated with the contributing factor WS (Wind Speed). From Fig. 7B, however, it follows that the classical point estimate associated with WS in Fig. 8 is well within the 90% credibility bounds of β_{10}. Finally, Fig. 7C displays the posterior distribution of the relative probability $P(\underline{X}^1, \underline{X}^2|\underline{\beta})$ associated with Fig. 4. We now have for the 50% posterior credibility interval of $P(\underline{X}^1, \underline{X}^2|\underline{\beta})$ the interval [4.78, 5.13]. (Compare this interval with the 50% prior one of [0.18, 5.52] in Fig. 5C.) In addition, the 99% posterior credibility interval [4.33, 5.66] of $P(\underline{X}^1, \underline{X}^2|\underline{\beta})$ is indicated in Fig. 7C (which is remarkably narrow compared to the prior 75% credibility interval of $[2.012\times10^{-5}, 4.971\times10^{4}]$) containing its median point estimate 4.94. Hence, Situation 2 inFig. 4 is approximately 5 times more likely to result in a collision than Situation 1 given that a navigation equipment failure occurred on the ferry.

Fig. 9 below provides a posterior analysis of point estimates α^u/v^u of the precision r, where α^u and v^u are given by (31). Fig. 9A depicts $E[r|Experti]$ obtained by updating the prior precision with the individual

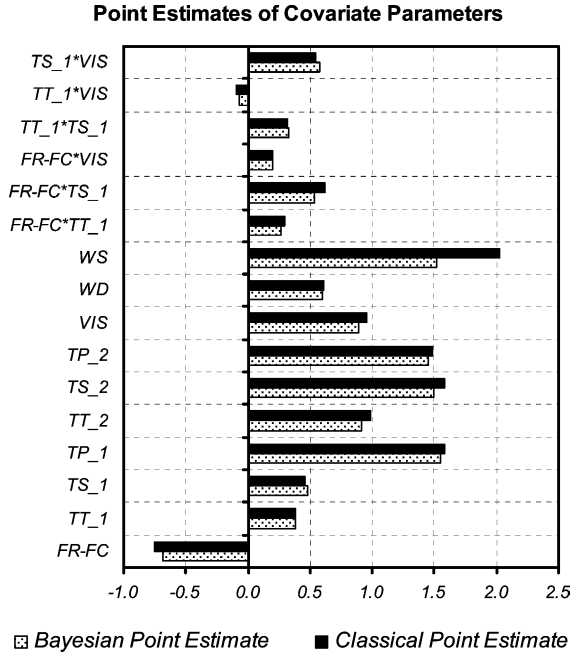


Fig. 8. Comparison of Bayesian and classical point estimates of the parameters β_i, $i=1,\ldots,16$.

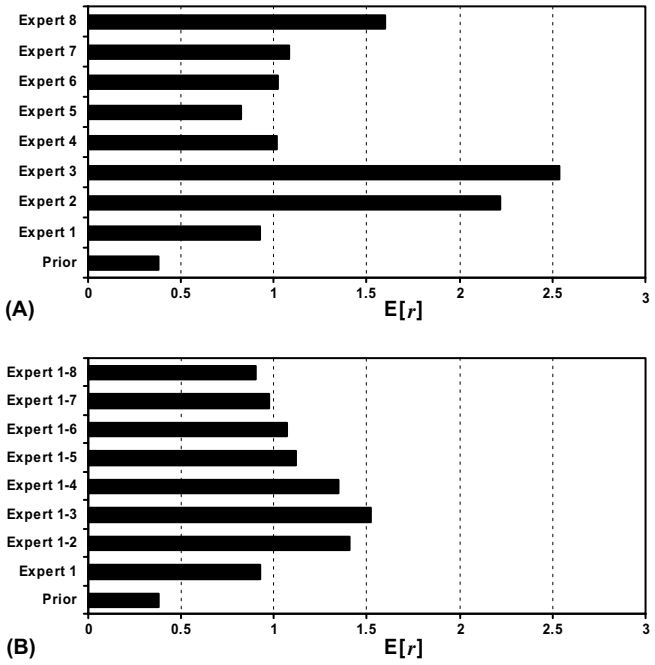


Fig. 9. Prior and posterior points estimates of the precision r (cf. (4) and (13)): (A) Individual posterior estimates for Experts i, $i=1,\ldots,8$; (B) Sequential posterior estimates involving Experts 1 through i, $i=1,\ldots,8$.

responses of Expert i, $i=1,\ldots,8$. Fig. 9B displays $E[r|Expert1-i]$ derived using sequential updating involving Expert 1 through Expert i, $i=1,\ldots,8$. From Fig. 9A it may be concluded that each expert responded consistently in the sense that posterior precision increased when compared to the precision of an expert responding at random (the prior precision in Fig. 9A). In addition, from Fig. 9B we conclude that at first agreement is present amongst Experts 1–3 due to a continued increase in posterior precision utilizing sequential updating. From Expert 4 onward and including Expert 8, however, a continued disagreement is observed in Fig. 9B due to a continued decline in posterior precision. Note the increasing pattern in Fig. 9A from Expert 5 on compared to the continued decreasing pattern in Fig. 9B from Expert 4 and up. The latter indicates that consistency of an individual expert response does not necessarily result in an increase in agreement amongst a group of experts.

7. Concluding remarks

A Bayesian aggregation method has been developed using responses from multiple experts to a paired comparison questionnaire to assess the distribution of relative accident probabilities. The classical analysis conducted during the WSF risk assessment only resulted in point estimates of relative accident probabilities, not full posterior distributional results as indicated in Fig. 7C. In addition, utilizing posterior distributional results for the parameter vector $\underline{\beta}$ credibility statements can be made for any arbitrary paired comparison. For example setting Situation 1 in (2) to the best possible scenario ($\underline{X}^1=\underline{0}$) and Situation 2 to the worst possible scenario ($\underline{X}^2=\underline{1}$) a 99% credibility interval of $P(\underline{X}^1,\underline{X}^2|\underline{\beta})$ equals [31142, 36749]. Therefore, informally, collision risk in the worst possible scenario differs at least by 4 orders of magnitude to that of the best possible scenario while taking uncertainty of the expert judgments into account.

Worst case scenario's however may have a very low incidence of occurrence, which is why all conditional probabilities in Fig. 2 and their uncertainties need to be estimated to assess the distribution of collision risk on for example a per year basis. This paper only provided distributional results for the relative probability given by (2). Merrick et al. (2003) assesses the distribution of $\Pr(OF, SF)$ using Bayesian Simulation techniques. A subsequent paper will integrate the approach herein with that of Merrick et al. (2003) to assess collision risk and its uncertainty in a Bayesian (and therefore coherent) manner.

Acknowledgements

This material is based in part upon work supported by the National Science Foundation under Grant Nos. SES 0213627 and SES 0213700. Any findings, opinions, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Special thanks to our colleague Sam Kotz for his helpful comments that improved both the content and presentation of this paper. We are also indebted to the referees and the editor of *EJOR*, whose comments improved the presentation of the first version.

References

Anderson, E., Hattis, D., Matalas, N., Bier, V., Kaplan, S., Burmaster, D., Conrad, S., Ferson, S., 1999. Foundations. Risk Analysis 19 (1), 47–68.

Bedford, T., Cooke, R., 2001. Probabilistic Risk Analysis: Foundations and Methods. Cambridge University Press, Cambridge, UK.

Bonano, E., Hora, S., Keeney, R., von Winterfeldt, D., 1989. Elicitation and use of expert judgment in performance assessment for high-level radioactive waste repositories. SAND89-1821, NUREG/CR-5411, Sandia National Laboratories, Albuquerque, NM.

Bradley, R., 1953. Some statistical methods in taste testing and quality evaluation. Biometrics 9 (1), 22–38.

Bradley, R.A., Terry, M., 1952. Rank analysis of incomplete block designs I. The method of paired comparisons. Biometrika 39, 324–345.

Clemen, R.T., 1989. Combining forecasts: a review and annotated bibliography. International Journal of Forecasting 5 (4), 559–583.

Clemen, R.T., Winkler, R., 1990. Unanimity and compromise among probability forecasters. Management Science 36 (7), 767–779.

Clemen, R.T., Winkler, R., 1999. Combining probability distributions from experts in risk analysis. Risk Analysis 19 (2), 187–203.

Cooke, R.M., 1991. Experts in Uncertainty: Opinion and Subjective Probability in Science. Oxford University Press, Oxford, UK.

Cox, D.R., 1972. Regression models and life tables (with discussion). Journal of the Royal Statistical Society, Series B 34 (2), 187–220.

Debreu, G., 1986. Theory of Value: An Axiomatic Analysis of Economic Equilibrium. Yale University Press, New Haven, CT.

DeWispelare, A., Herren, L., Clemen, R., 1995. The use of probability elicitation in the high-level nuclear waste recognition program. International Journal of Forecasting 11 (1), 5–24.

Foreman, E.H., Selly, M.A., 2002. Decision by Objectives: How to Convince Others That You Are Right, first ed. World Scientific Pub Co, River-Edge, NJ.

Garrick, B.J., 1984. Recent case studies and advancements in probabilistic risk assessment. Risk Analysis 4 (4), 267–279.

Genest, C., Zidek, J., 1986. Combining probability distributions: A critique and annotated bibliography. Statistical Science 1 (1), 114–148.

Kahneman, D., Slovic, P., Tversky, A., 1982. Judgments Under Uncertainty. Cambridge University Press, Cambridge, UK.

Kaplan, S., 1997. The words of risk analysis. Risk Analysis 17 (4), 407–417.

Koller, G.R., 2000. Risk Modeling for Determining Value and Decision Making. Chapman & Hall, New York.

Kumamoto, H., Henley, E., 1996. Probabilistic Risk Assessment and Management for Engineers and Scientists. IEEE Press, Piscataway, NJ.

McDonald, J.B., Butler, R.J., 1987. Some generalized mixture distributions with an application to unemployment duration. Review of Economics and Statistics 69 (2), 232–240.

Mendel, M., Sheridan, T., 1989. Filtering Information from Human Experts. IEEE Transactions on Systems, Man & Cybernetics 36 (1), 6–16.

Merrick, J.R.W., van Dorp, J.R., Harrald, J.R., Mazzuchi, T.A., Grabowski, M., Spahn, J.E., 2000. A systems approach to managing oil transportation risk in Prince William Sound. Systems Engineering 3 (3), 128–142.

Merrick, J.R.W., Dinesh, V., Singh, A., van Dorp, J.R., Mazzuchi, T., 2003. Propagation of uncertainty in a simulation-based maritime risk assessment model utilizing Bayesian simulation techniques. In: Chick, S., Sanchez, P.J, Ferrin, D., Morrice, D.J. (Eds.), Proceedings of the 2003 Winter Simulation Conference, pp. 449–455.

Morgan, M., Henrion, M., 1991. Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press, Cambridge, UK.
Morris, P., 1974. Decision analysis expert use. Management Science 20 (9), 1233–1241.
Moslesh, A., Bier, V., Apostolakis, G., 1988. A critique of current practice for the use of expert opinions in probabilistic risk assessment. Reliability Engineering and System Safety 20 (1), 63–85.
Paté-Cornell, M., 1996. Uncertainties in risk analysis: six levels of treatment. Reliability Engineering and System Safety 54 (2–3), 95–111.
Press, W.H., Flannery, B.P., Teukolsky, S.A., Vettering, W.T., 1989. Numerical Recipes in Pascal. Cambridge University Press, Cambridge.
Pulkkinen, U., 1993. Methods for combination of expert judgments. Reliability Engineering and System Safety 40 (2), 111–118.
Pulkkinen, U., 1994a. Bayesian analysis of consistent paired comparisons. Reliability Engineering and System Safety 43 (1), 1–16.
Pulkkinen, U., 1994b. Gaussian paired comparison models. Reliability Engineering and System Safety 44 (2), 207–217.
Roeleven, D., Kok, M., Stipdonk, H.L., de Vries, W.A., 1995. Inland waterway transport: modeling the probabilities of an accident. Safety Science 19 (2–3), 191–202.
Saaty, T., 1977. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, New York 15, 234–281.
Saaty, T., 1980. The Analytic Hierarchy Process. McGraw-Hill.
Shrader-Frechette, K., 1985. Risk Analysis and Scientific Method. Reidel, Dordrecht, The Netherlands.
Simpson, E.H., 1951. The interpretation of interaction in contingency tables. Journal of the Royal Statistical Society, Series B 13 (2), 238–241.
Thurstone, L.L., 1927a. A law of comparative judgment. Psychology Review 34, 273–286.
Thurstone, L.L., 1927b. Psychophysical analysis. American Journal of Psychology 38, 368–389.
Van Dorp, J., Merrick, J., Harrald, J., Mazzuchi, T., Grabowski, M., 2001. A Risk Management Procedure for the Washington State Ferries. Risk Analysis 21 (1), 127–142.
Vose, D., 1996. Risk Analysis: A Quantitative Guide to Monte Carlo Simulation Modeling. Wiley, New York.
West, M., Harrison, J., 1989. Bayesian Forecasting and Dynamic Models. Springer-Verlag, New York.
Winkler, R., 1981. Combining probability distributions from dependent information sources. Management Science 27 (5), 479–488.
Winkler, R., 1996. Uncertainty in probabilistic risk assessment. Reliability Engineering and System Safety 54 (2–3), 127–132.

Natural Resources

Cherry Point Environmental Aquatic Reserve Management Plan

November 2010

Acknowledgements

Cherry Point Workgroup

Brokes, Brendan. Washington Department of Fish and Wildlife
Carten, Terry. Washington Department of Natural Resources
Chalfant, Jeff. British Petroleum
Chapman, Alan. Lummi Natural Resources Department
Cook, Cyrilla. People for Puget Sound
Doremus, Llyn. Nooksack Indian Tribe
Dupre, Robyn. RE Sources
Fairbanks, Chris. Whatcom County Marine Resources Committee
Felleman, Fred. Friends of the San Juans
Hitchman, Marie. Whatcom County Beachwatchers
Irving, Steve. North Cascades Audubon
Johnson, Tim. ConocoPhillips
Kyte, Michael. ENSR.
Landis, Wayne. Institute for Environmental Toxicology, Western Washington University
Larson, Gerald. Birch Bay Association
Markiewicz, April. Western Washington University
McCreery, Scott. British Petroleum
McNair, Fran. Washington Department of Natural Resources
Middleton, Roland. Whatcom County
Morris, Ted. Birch Bay State Park
Palazzi, David. Washington Department of Natural Resources
Pedersen, Mark. Margenex International
Roberts, David. Washington Department of Natural Resources, Work Group Facilitator
Sahlin, Skip. SSA Marine
Schlotterback, Rebecca. PUD No. 1 of Whatcom County
Schon, Jim. Alcoa
Scott, Gordon. Whatcom Land Trust
Steffensen, Wendy. RE Sources
Wenger, Barry. Washington State Department of Ecology
Woodcock, Paul. North Cascades Audubon

Inovlvement in the Cherry Point Workgroup does not imply agreement with the Cherry Point Aquatic Reserve or this management plan.

Additional Information Provided by:

Fredrickson, Angie. Hershman Policy Fellow, Aquatic Resources Program, Washington Department of Natural Resources
Murphy, Kyle. Aquatic Reserves Program Manager, Aquatic Resources Program, Washington Department of Natural Resources
Elizabeth Ellis. Environmental Planner, Aquatic Resources Program, Washington Department of Natural Resources
Nightengale, Barbara and Piening, Carol Environmental Planners formerly with Aquatic Resources Program, Washington Department of Natural Resources
Snoey, Janis. Assistant Attorney General, State of Washington.

GIS and Mapping

Grilliot, Michael. Aquatic Reserves Program, Washington Department of Natural Resources
Strickler, Tim. Aquatic Resources Program, Washington Department of Natural Resources

Copies of this report may be obtained from the Aquatic Reserves Program Manager or copied from the web page.

Contact Information

Washington State Departmernt of Natural Resources
Aquatic Reserve Program Manager
Phone: 360-902-1100
E-mail: aquaticreserve@dnr.wa.gov

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Cherry Point Environmental Aquatic Reserve Management Plan

November 2010

Acronyms

ARCO	Atlantic Richfield Company
ACOE	Army Corps of Engineers
BP	British Petroleum
CBI	Chicago Bridge and Iron
CAA	Clean Air Act
CIG	Climate Impacts Group
CO	Carbon monoxide
CO2	Carbon dioxide
CP	Cherry Point
CWA	Clean Water Act
DNR	Washington State Department of Natural Resources
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
ET&S	Endangered, Threatened and Sensitive Species
GIS	Geographic Information Systems
GMA	Growth Management Act
gpm	gallons per minute
GPT	Gateway Pacific Terminal
GSX	Georgia Strait Crossing
HII	Heavy Impact Industrial
HPA	Hydraulic Project Approval
MESA	Marine EcoSystems Analysis
MHHW	Mean Higher High Water
MHW	Mean High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water
MRC	Marine Resource Committee
MYA	Million Years Ago
NO_X	Oxides of nitrogen
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWCAA	Northwest Clean Air Agency
OHWM	Ordinary High Water Mark
PAR	Photosynthetically Active Radiation
PDO	Pacific Decadal Oscillation
$PM_{2.5}$	Particulate matter 2.5 microns in diameter
PM_{10}	Particulate matter 10 microns in diameter
PHS	Priority Habitat and Species (WDFW)
PNW	Pacific Northwest
PSAMP	Puget Sound Ambient Monitoring Program
PSI	Puget Sound Initiative
RCW	Revised Code of Washington
SAV	Submerged Aquatic Vegetation
SEPA	State Environmental Policy Act
SMA	Shoreline Management Act
SMP	Shoreline Master Program
SO_x	Oxides of sulfur
SVMP	Submerged Vegetation Monitoring Plan
U&A	Usual and Accustomed
UGAs	Urban Growth Areas
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
VEAT	Vessel Entries and Transit reports, produced by the Washington State Department of Ecology, Spill Program
VOC	Volatile organic compounds
WAC	Washington Administrative Code
WCC	Whatcom County Code
WDFW	Washington State Department of Fish and Wildlife
WMU	Watershed Management Unit
WRIA	Water Resource Inventory Area
WWU	Western Washington University

Table of Content

1. Executive Summary 1
2. Introduction 4
   - Purpose and Content of This Plan 4
   - Cherry Point Aquatic Reserve Background 7
   - Plan Development and the Cherry Point Workgroup 9
   - Current Ownership 10
   - Relationship to Federal, State, Local and Tribal Management 11
   - Local Land Use Designations 15
   - County Shoreline Master Program 16
3. Resource Characterization 21
   - Site Characterization 21
   - Geographic Description 21
   - Ecosystem Description 21
   - Current Conditions 25
   - Potential Future Impacts 27
4. Management Goals and Objectives 31
   - Desired Future Conditions 31
5. Management Actions 34
   - Conservation of Ecosystems, Habitats and Species 35
   - Water and Sediment Quality Protection and Ballast Management 37
   - Protection of Cultural Resources 40
   - Restoration and Enhancement 41
   - Education and Outreach 42
   - Monitoring, Data Collection and Research 42
   - Data Gap Analysis 43
   - Baseline Monitoring 44
   - Trend Monitoring 45
   - Research 47
   - Allowable Uses 49
   - Existing Use Authorizations 49
   - Prohibited Uses 54
6. Plan Implementation 55
   - Coordination with Community Groups 55
   - Funding 55
   - Adaptive Management 56

Glossary 58
References 66
Appendix A - Cherry Point Aquatic Reserve Resource Characterization 93
Appendix B - Risks to Ecosystems at Cherry Point 129
Appendix C - Archaeological, Cultural, and Historical Resources 172
Appendix D - Existing Encumbrances and Applications directly adjacent to the Aquatic Reserve 176
Appendix E – Legal Description 180
Appendix F – Cherry Point Workgroup Activities 181

Figures & Tables

Figure 1: Existing and proposed aquatic reserves
Figure 2: Cherry Point Aquatic Reserve
Figure 3: Whatcom County Zoning
Figure 4: Strait of Georgia and Pacific Northwest
Figure 5: Cherry Point Bathymetry
Figure 6: Drift Cells at Cherry Point
Figure 7: Submerged Aquatic Vegetation
Figure 8: Puget Sound ESA Salmon Recovery Domain, showing Chinook ESU
Figure 9: Forage Fish Spawning and Holding areas
Figure 10: Cherry Point herring stock spawning biomass and fishery landings (short tons), 1973-2008
Figure 11: Documented spawning grounds and pre-spawner holding area for Cherry Point herring stock.
Figure 12 Documented and peak spawning times for herring stocks
Figure 13: Range of Southern Resident Killer Whale in the Eastern North Pacific Ocean
Figure 14: Primary area of occurrence for Southern Resident Killer Whales when present in Georgia Basin and Puget Sound
Figure 15: Western and Eastern populations of Northern (Stellar) sea lion
Figure 16: Shoreline armoring at Cherry Point
Figure 17, 18: Spawning escapement for Cherry Point Herring: 1973 – 1980
Figure 19: Close up picture of rosin pile at TreOil property
Figure 20: Impervious Surfaces and Point Sources
Figure 21: Georgia Basin/Puget Sound Airshed
Figure 22: Postcard, mailed 1908 showing logging train heading to Bellingham

Table 1: Timeline of Major Events at Cherry Point
Table 2: DNR Nearshore Survey from 1995
Table 3: Whatcom County Nearshore Survey from 1995
Table 4: SAV coverage observed at Cherry Point in August, 2004
Table 5: State of Bottomfish Report,
Table 6: Data from Ecology VEAT reports showing vessel traffic patterns in Puget Sound
Table 7: Emission inventory, in tons, from large industrial facilities leasing state-owned aquatic land at Cherry Point, compared to Whatcom County total, 2004 and 2005

1. Executive Summary

The Cherry Point Aquatic Reserve is a unique aquatic ecosystem located in the Strait of Georgia in northern Puget Sound—on the western shores of Whatcom County, Washington. It is bounded on the north by the southern boundary of Birch Bay State Park, and on the south by the northern boundary of the Lummi Indian Nation Reservation. Its environment includes cobble intertidal areas, submerged aquatic vegetation, and a steep gradient into deep water that supports a high diversity of fish and wildlife including: Cherry Point herring and other forage fish, marine and shore birds, and migratory waterfowl; ESA listed salmon; Dungeness crab; groundfish; bivalves and marine invertebrates and, marine mammals. Its marine waters and aquatic lands are a portion of Treaty-protected Usual and Accustomed grounds and stations of local Native American Indians, and are used by the Indians for commercial, ceremonial, and subsistence purposes. The aquatic lands in the reserve are also used by non-Indians and provide significant economic benefits, recreational opportunities, and other social values. Cherry Point's distinctive bathymetry provides deepwater access for large vessels without the need to dredge out shipping channels or berthing areas. Major water-dependent industries have located on the shores, bringing jobs in manufacturing, petroleum oil refining, shipping and commerce.

The Washington State Department of Natural Resources (DNR) is responsible for managing state-owned aquatic lands to provide a balance of public benefits. In 2000, DNR recognized the need to protect the significant environmental resource of aquatic lands at Cherry Point and designated those state-owned lands not already under a lease agreement as the Cherry Point Aquatic Reserve, in order to ensure long-term environmental protection. All aquatic lands within the Cherry Point Aquatic Reserve are state-owned and managed by DNR. The aquatic reserve does not include aquatic lands within the boundary of Birch Bay State Park, privately owned lands, or tribal lands. The effect of designating the aquatic lands at Cherry Point as a reserve was to withdraw the lands from further leasing, but at that time DNR did not develop a site-specific plan to guide management decisions for the Reserve.

This plan was created to identify the natural resources—habitats and species—existing within the Cherry Point Reserve, and the proposed uses, future threats, and management actions that will be employed by DNR to protect these resources. The aquatic reserve addresses the management of aquatic lands; it does not address the harvest of finfish or shellfish within the aquatic reserve. The harvest of finfish and shellfish are managed by affected tribal governments and the Washington Department of Fish and Wildlife pursuant to treaties and court decisions. The plan was developed with the help of independent scientists, federal, tribal and state resource agencies, site users, lessees, environmental and citizen groups who recognized the ecological importance of the site to both Puget Sound recovery and to commerce and industry.

The Technical Advisory Committee and the Cherry Point Workgroup identified the following current and potential threats to habitats and species of the Cherry Point Aquatic Reserve: shoreline modification, including overwater structures, loss of riparian vegetation, armoring, and derelict gear; pollution from groundwater contamination, stormwater runoff, point discharges, and air deposition; disturbance from unsustainable recreational activities; artificial light and excessive intermittent sound; vessel traffic, including oil spills; invasive species; and habitat impacts due to climate change. A number of species and habitats addressed in this plan have experienced declines over the past 40 years, such as the Cherry Point herring stock, which has shrunk from approximately 15,000 tons to between 800 and 2,100 tons over the last ten years. Other key species in decline include Puget Sound

Chinook salmon, bull trout, and certain species of rockfish, surf scoter, and Southern Resident orca whales (PSSS, 2005; WDFW, 2009; National Marine Fisheries Service, 2008) .

This plan identifies the management emphasis for Cherry Point Aquatic Reserve as environmental protection above all other management actions. The following goals are established for the Reserve:

Goal One: Identify, protect, restore and enhance the functions and natural processes of aquatic nearshore and subtidal ecosystems that support endangered, threatened and sensitive species and aquatic resources identified for conservation in the Reserve.

Goal Two: Improve and protect water quality to maintain public health, support fish and wildlife species and healthy functioning habitats.

Goal Three: Protect and help recover indicator fish and wildlife species and habitats, with primary focus on Cherry Point herring, Nooksack Chinook salmon, groundfish, marine mammals, seabird/duck and shorebird communities, Dungeness crab, and submerged native aquatic vegetation.

Goal Four: Facilitate stewardship of habitats and species by working in cooperation with lessees, recreational users and federal, state and tribal resource agencies to minimize and reduce identified impacts of human activities on the species and habitats within the Reserve.

Goal Five: Identify, respect, and protect archaeological, cultural, and historical resources within the Reserve. Continue to respect the right of Washigntons tribes to use their own natural and cultural resources as recognized by treaties, statutes, executive orders, and court decisions.

The plan includes actions related to: protection, enhancement and restoration; outreach and education; monitoring, data collection, and research; and allowed and prohibited uses within the Reserve. DNR management will emphasize the long-term protection of the aquatic resources within and directly adjacent to the Reserve. In general and consistent with its statutory authority, the DNR will limit new uses in the Reserve to those that are consistent with this management plan. New activities authorized on state-owned aquatic lands within or adjacent to the reserve must support desired future conditions described in Chapter 4, through avoiding and minimizing adverse impacts to habitats and species. The existing industrial uses at Cherry Point do not conflict with aquatic reserve status. If the facilities are managed according to this plan and the lessees actively work to further goals for the Reserve, the uses can serve the objectives of the Reserve. Because DNR, Tribes, local, and state and federal regulatory agencies all are responsible for the state's aquatic resources, and DNR's authority is limited to proprietary management of state-owned aquatic lands, achieving the plan's goals requires partnerships among federal, state, and tribal natural resource agencies, landowners, and others. A Memorandum of Understanding or other forms of agreement may be used as a means for resource managers to address issues of mutual interest in the Cherry Point Aquatic Reserve. Other tools include use of existing regulatory and government decision processes and creation of advisory committees for specific projects.

'Adaptive management' is a key component of the Cherry Point Aquatic Reserve Management Plan. Adaptive management is a systematic process for improving management actions by learning from the outcomes of actions previously taken. It requires managing and sharing data, tracking progress in

carrying out the plan, making technical assessments about effectiveness of plan actions, evaluating and communicating progress, and determining course corrections needed to make the plan more effective over time. Because DNR does not have the resources to immediately implement all the plan's management actions, the following adaptive management actions are a high priority for the first five years of implementation:

1) Monitor the effectiveness of the protection actions in this plan that address existing and proposed use authorizations, and
2) Research the decline of targeted species (mentioned above in Goal Three) to reduce uncertainties that can directly improve the effectiveness of management actions.

This management plan will be reviewed and updated at least every ten years. Changes in ecosystem condition and existing uses of state-owned aquatic lands will be included in the updates. Actions include development of an evaluation process to set quantitative and qualitative goals for achievement, monitoring to measure success in meeting those goals, and learning from actions taken in order to make better decisions in the future. Research and monitoring will be used to guide DNR and cooperators in determining whether management actions are supporting the objectives of the Reserve. If management actions are not supporting the objectives of the Reserve, they will be modified, monitored and evaluated during the following 10-year review period in accordance with adaptive management strategies.

2. Introduction

Purpose and Content of This Plan

Cherry Point is a unique and very important place. It is located on the Strait of Georgia, on the western shores of Whatcom County. It is bounded on the north by the southern boundary of Birch Bay State Park, and on the south by the northern boundary of the Lummi Indian Nation Reservation. Cherry Point has a unique marine and freshwater ecosystem that supports a variety of natural resources, fish and wildlife. Aquatic diversity along this reach is very high with cobble intertidal habitat, large rocks and boulders, sandy beaches, eelgrass beds, and kelp. Additionally, the deep area close to shore and the steep intertidal gradient along this reach may be important to marine diversity. At one time Cherry Point provided spawning habitat for the largest herring population of Puget Sound and the Strait of Juan de Fuca. The area is a nearshore migratory corridor for juvenile salmon, and provides significant habitat and foraging areas for marine seabirds and migratory waterfowl populations. Five species of salmon — sockeye, Chinook, coho, chum, and pink — and three species of forage fish: Pacific herring, sand lance, and surf smelt rely upon these habitats. Various species of ground fish have been surveyed offshore. Cherry Point supports a large recreational, commercial (both tribal and non-tribal), and tribal ceremonial and subsistence Dungeness crab fishery, and a smaller spot shrimp fishery is located offshore to the west (Whatcom County MRC, 2001).

In addition to the unique habitat features of Cherry Point, the distinctive bathymetry and water depths of more than 70 feet relatively close to shore provide deepwater access for large vessels. Major water-dependent industries have located on the shores of Cherry Point, bringing jobs in manufacturing, shipping and commerce. In recognition of the importance of this economic base to the region, Whatcom County established the Cherry Point Management Area to provide a framework for balancing special port, industrial and natural resource needs.

This plan identifies the habitats and the species of the Reserve and the management actions that will be employed by the Washington State Department of Natural Resources (DNR) to conserve these resources with the management emphasis on environmental protection above all other management actions. This plan is being developed in accordance with the State Environmental Policy Act (SEPA), and will serve as DNR's primary management guidance for the 90-year term of the Reserve. At least every ten years after the adoption of this plan, it will be reviewed, and as necessary, updated with current scientific, management, and site-specific information. As with the development of this plan, DNR will update the plan through work with other jurisdictions, Tribes, interest groups, landowners and lessees, and local citizens to establish cooperative management actions for activities within and adjacent to the Reserve to conserve, enhance and restore habitats and species within the Reserve.

The primary focus of this plan is to protect, enhance and restore habitats used by Cherry Point herring stock, salmon, migratory and resident birds, Dungeness crab, groundfish rearing areas and marine mammals, as well as the protection of submerged aquatic vegetation and water quality. This management plan does not address the harvest of finfish or shellfish within the aquatic reserve.

The people who assisted with the development of this plan realize that the aquatic environment of Cherry Point: provides essential habitat and irreplaceable biological and ecological functions; is a portion of Treaty-protected usual and accustomed (U&A) grounds and stations of local Native

American Indians; and provides significant economic benefits, recreational opportunities and other social values.

The plan is intended to provide the basis for greater understanding of factors affecting the aquatic ecosystem of the Cherry Point Aquatic Reserve, provide site-specific guidance for management actions, and allow for adaptive management in order to protect these resources, while recognizing the importance of the continued industrial and other water-dependent uses located in and adjacent to the Cherry Point Aquatic Reserve. The plan contains the following chapters:

1. **Introduction:** This section describes the role of the Washington State Department of Natural Resource, the background on the aquatic reserve, how the plan was developed, the aquatic reserve boundary, relationship to federal, state, local and tribal management, and local land use designations.
2. **Cherry Point Resources Characterization:** This section provides an overview of the ecological characteristics and current conditions of the site, and provides a summary of the current and potential future impacts.
3. **Management Goals and Objectives:** This section describes the desired future ecological conditions for the Cherry Point Aquatic Reserve, and the goals and policies to help ensure the desired conditions can be met.
4. **Management Actions:** This section contains the management actions developed to address the goals and objectives of this plan. It includes actions for protection, enhancement, and restoration; outreach and education; monitoring, data collection, and research; and allowed and prohibited uses within the Reserve.
5. **Plan Implementation:** This section describes recommendations for how the plan should be implemented, including monitoring and adaptive management to assess the success of the recommended actions in achieving future desired conditions.

Washington State Department of Natural Resources

DNR is responsible for protecting and managing 5.6 million acres of state-owned land for the people of Washington. Much of the land (3 million acres) is state trust land that provides revenue to help pay for construction of public schools, universities, and other state institutions, and funds many county services. The state-owned aquatic lands within the Cherry Point Aquatic Reserve are not held in trust for beneficiaries and are, instead, lands that are held as a 'public trust' for the people of the state and managed in accordance with statutory directive.

Upon statehood, all states received title to lands underlying navigable waters within state boundaries from the Federal Government. In its Constitution, Washington State claims ownership to its aquatic lands:

> "*The state of Washington asserts its ownership to the beds and shores of all navigable waters in the state up to and including the line of ordinary high tide, in waters where the tide ebbs and flows, and up to and including the line of ordinary high water within the banks of all navigable rivers and lakes*…" (Article XVII, §1).

The State has sold about two-thirds of all tidelands[1] and some shorelands[2] to local and private interests. In 1971, the Legislature prohibited the sale of tidelands and shorelands to private parties.

[1] (the area in marine water between ordinary high tide and extreme low tide)
[2] (the area in freshwater between ordinary high water and the line of navigability)

The State retains ownership of all bedlands[3]. The Legislature directs DNR to manage a majority of state-owned aquatic lands (approximately 2.6 million acres). In some cases, treaties between Tribes and the United States reserved tidelands as part of Indian Reservations prior to statehood and were never tidelands managed by the state. Further detail on state aquatic lands can be found on http://www.dnr.wa.gov.

In the Revised Code of Washington (RCW) 79.105.030, the Legislature gave DNR general management guidance to manage aquatic lands for a balance of public benefits. Benefits that are to be provided by state-owned aquatic lands include:

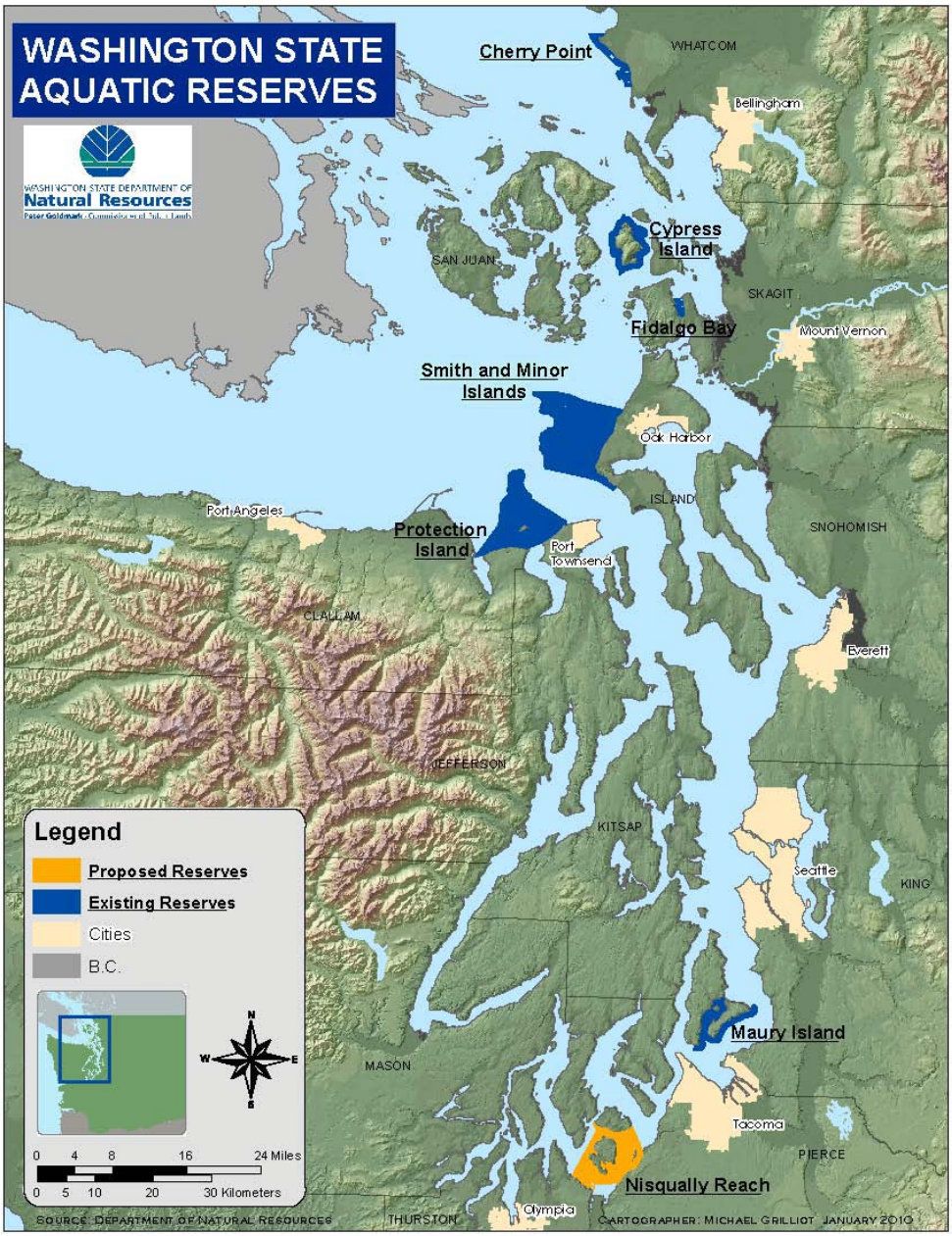
1. Encourage direct public use and access;
2. Foster water-dependent uses;
3. Ensure environmental protection;
4. Utilize renewable resources.

When consistent with the above public benefits, revenue generation is also considered a public benefit. DNR generates revenue from aquatic lands by leasing these lands for private and commercial use (such as docks and marinas) and by selling the materials harvested from aquatic lands. Such materials vary from gravel to wild geoducks. These revenues fund DNR aquatic land management activities as well as other local and state programs to restore and enhance aquatic lands habitat and improve public access to these lands.

DNR's proprietary management of state-owned aquatic lands is governed by RCW Chapters 79.105-.140 and WAC Chapter 332-30. In addition, federal laws, Treaties, intergovernmental agreements, and court decisions affect DNR's management activities. Other entities, such as the U.S. Army Corp of Engineers, Washington State Department of Fish and Wildlife and the Washington State Department of Ecology have responsibilities to regulate certain activities on both private and publicly-owned aquatic lands, and DNR's management is subject to such regulations. The Public Trust Doctrine also applies to DNR managed lands. This common-law principle protects public use and access to navigable waters for navigation, fishing, and recreational activities.

DNR is authorized to identify and protect state-owned aquatic lands for their natural ecological systems. RCW 79.105.030 identifies environmental protection — the overarching goal of the Aquatic Reserve Program — as one of DNR's primary mandates for the management of state-owned aquatic lands. RCW 79.10.210 authorizes DNR to identify and withdraw from all conflicting uses public lands that can be utilized for their natural ecological systems. RCW 79.105.210 further authorizes DNR to withhold lands with significant natural values from leasing or to provide for protection of natural values within any lease. WAC332-30-151 directs DNR to consider lands with educational, scientific, and environmental values for aquatic reserve status, and identifies management guidelines for aquatic reserves. WAC 332-30-106(16) defines environmental reserves as sites of environmental importance, which are established for the continuance of environmental baseline monitoring and/or areas of historical, geological, or biological interest requiring special protective management. WAC 332-30-151(2) states that aquatic reserve designation should not conflict with current or projected uses of the area. Figure 1 identifies the location of existing and proposed aquatic reserves.
Figure 1. Existing and Proposed Aquatic Reserves.

[3] (the area below extreme low tide or the line of navigability)



Cherry Point Aquatic Reserve Background

DNR has been involved in aquatic land management in the Cherry Point area since the 1950s when the first refinery pier was constructed on state-owned aquatic lands. As additional facilities were proposed at Cherry Point, DNR and other stakeholders recognized the need for striking a balance between economic development and environmental protection. In 2000, then Commissioner of Public Lands, Jennifer Belcher designated an environmental aquatic reserve for state-owned aquatic lands at Cherry Point not already under a lease agreement, ensuring environmental protection as a long-term management objective. While state aquatic lands at Cherry Point were reserved and withdrawn from conflicting uses, there was no site-specific plan to guide management decisions for the Reserve. This set in motion DNR's actions to develop a plan that protects the Cherry Point Aquatic Reserve's unique ecosystem while managing the area consistent with Whatcom County's "Cherry Point Special Management Unit" shoreline designation.

In 2001, interim management guidance was finalized and applied to Cherry Point Aquatic Reserve. This guidance was modeled after the Interim Management Guidance was finalized and approved for the Aquatic Reserves Program, and applied to the Cherry Point Aquatic Reserve until a management plan was adopted.

DNR began discussing the future management plan for the Cherry Point Aquatic Reserve in 2003. In 2003, the Technical Advisory Committee (TAC), an independent group of scientists tasked with evaluating the Cherry Point site against DNR aquatic reserve criteria, unanimously recommended managing the site as an environmental aquatic reserve. In developing their recommendation, the committee recognized Cherry Point as an extraordinary stretch of shoreline with excellent potential to maintain the relatively undeveloped character of the area. The herring spawning in the area was recognized as a unique biological feature of Puget Sound and its importance to the ecosystem was emphasized. Additionally, it was recognized that aquatic diversity along this reach is very high with cobble intertidal habitat, large rocks and boulders, and kelp just offshore. The deep area close to shore and the steep gradient of the intertidal along this reach could be important to marine diversity.

The Techinical Advisory Committee specifically noted:

> *"…while initially disturbing, industrial development associated with the piers appears to be compatible with aquatic reserve status and noted the opportunity to facilitate multiple-uses as an example where commercial activities and environmental resources can co-exist."*

DNR staff and scientists prepared preliminary documents providing background information regarding the uses in the area and a list of potential issues of concern relating to the aquatic ecosystem in the Cherry Point area. Outreach included the various resource agencies and interest groups in the area. Information was gathered to broaden the issues to be considered in the planning process. Public meetings were held to further refine the scope of the planning process. This led to the development of an outline for future discussion of planning needs.

The planning process was put on hold temporarily in 2004 while DNR attempted to address concerns by the Cherry Point industries regarding the continued designation of Cherry Point as an aquatic reserve. In 2005 DNR considered revising the language of WAC 332-30-151 —*Reserves* —to address industry concerns; however, attempts to successfully resolve these issues to the satisfaction of all stakeholders could not be achieved and resulted in further delays in the planning process. DNR completed management plans for three other reserves while issues at Cherry Point were being addressed. Simultaneously, the county was updating their critical area inventory and shoreline analysis leading to an updated Critical Area Ordinance (CAO) that covered Cherry Point, which was adopted in September 2005.

In 2006 DNR staff working with Whatcom County Shoreline planners and their consultants examined the opportunity to merge planning efforts. The County Shoreline Master Plan (SMP) update was underway and needed to examine and plan for environmental and public access considerations in the Cherry Point Management Area. Believing there were common interests to be addressed, the County and DNR considered the option of incorporating certain aspects of an aquatic reserve management plan into the Shoreline Master Plan and at the same time provide a potential alternative to the Cherry Point Aquatic Reserve. DNR agreed to this process based on the understanding that any alternative approach to managing this area must meet or exceed the protection

for resources provided under the Aquatic Reserves Program, and its management plan. The Cherry Point Workgroup was formed to evaluate this and other resource planning alternatives.

Plan Development and the Cherry Point Workgroup

In 2007, DNR brought together a group of stakeholders with a wide range of interests in the community and Puget Sound to assist DNR in evaluating management options for the Cherry Point Aquatic Reserve. The Cherry Point Workgroup first met in July 2007 for a preliminary discussion of the goals and possible outcomes of the process.

Between July 2007 and April 2008 the Workgroup and several subcommittees examined the management of activities in the vicinity of Cherry Point during the previous 10 years. The group sought out information and answers from a wide range of professionals regarding all aspects of resource and industrial management in the area. The Workgroup developed a common aim to provide consistent guidance for the development of this management plan. They contributed technical information and developed recommendations for actions to be included in the management plan. As a result of the Workgroup's efforts, DNR determined that state-owned aquatic lands within the Cherry Point Aquatic Reserve would continue to be managed as an aquatic reserve. The Workgroup took an ecosystem-based approach towards identifying the habitats, species and threats associated with the Cherry Point Aquatic Reserve.The common aim and the key tasks of the Workgroup are described in Appendix G.

Areas outside the Reserve are discussed in this plan to provide an ecosystem-based approach to habitat and species protection, minimize the gaps in understanding of Cherry Point resources, and facilitate coordination of plan implementation amongst the agencies, stakeholders, and others. DNR will work collaboratively with resource managers that have authority under federal, state, and local laws to help address off-site impacts on the aquatic reserve and achieve the goals and objectives of this plan.

Cherry Point Aquatic Reserve Boundary

The Cherry Point Aquatic Reserve (Figure 2.) is within the state-defined Water Resources Inventory Area 1, known as the "Nooksack WRIA". The existing boundary for the aquatic reserve includes all state-owned tidelands and bedlands within approximately 5,000 feet of the marine shoreline and any adjacent state-owned bedlands within the -70-foot bathymetric contour as shown in Figure 2. The legal description for the Reserve is located in Appendix G.

Figure 2. Cherry Point Aquatic Reserve

Current Ownership

All bedlands within the Cherry Point area are owned by the State of Washington and managed by Washington State Department of Natural Resources. Of the approximately 296 acres of tidelands in the Cherry Point area, 69 acres are privately owned and approximately 227 acres are managed as part of the Cherry Point Aquatic Reserve and are not under a lease. Figure 1 depicts ownership at Cherry Point Aquatic Reserve.

Also, there are no existing use authorizations on state-owned aquatic lands within the reserve. There are four existing use authorizations and one proposed use in the "cutouts" directly adjacent to or abutting the reserve (see Figure 2 showing leased areas and cutouts). These include:

- BP (lease and outfall easement),
- Intalco (lease and outfall easement),
- ConocoPhillips (lease and outfall easement),
- Birch Bay Water and Sewer District (outfall easement),
- Proposed Pacific Internaltional Terminals industrial pier (no use authorization with DNR has been developed/approved and no federal permits obtained)

The bulk of the uplands adjacent to the Reserve are privately owned, primarily by five entities: BP, Pacific International Terminals, Intalco-Alcoa, Conoco Phillips, and Cherry Point Industrial Park. North of the industrial area, private residential lots exist with the exception of a small county-owned public access area just east of Point Whitehorn. Birch Bay State Park is located to the north of the residential lots and the aquatic reserve. The Lummi Indian Reservation is located to the south of the Aquatic Reserve.

Relationship to Federal, State, Local and Tribal Management

This plan is promulgated under DNR's proprietary authority to manage state-owned aquatic lands. However, a number of other federal, state, local and tribal authorities regulate activities within the Cherry Point Aquatic Reserve and the watershed that drains into it. The successful management of these activities and resources requires coordination and collaboration with public and private entities as well as local, state, federal, and affected Tribal governments, and non-government organizations. The entities which share management authority for natural resources at Cherry Point are referred to as the 'resource managers.' The following provides information regarding ongoing management interests at Cherry Point Aquatic Reserve.

Tribal Treaty Rights and Interests

Tribes manage cultural and natural resources located on adjacent reservation lands, and those resources related to the right to fish off-reservation at usual and accustomed places. DNR is obligated to conduct government-to-government consultations with all federally recognized tribes, under the 1989 Centennial Accord (www.goia.wa.gov/Government-to-Government/Data/CentennialAccord.htm), DNR Tribal Relations Commissioner's Order # 201029. In addition, pursuant to numerous court rulings and Presidential Executive Orders, all federal agencies are required to consult with affected Indian tribes in a government-to-government manner and ensure that impacts to tribal treaty rights are avoided and/or minimized and any unavoidable impacts are mitigated to the satisfaction of the affected tribal governments.

DNR will continue to engage in a government-to-government dialog with the affected tribes to help ensure this plan's conformance with treaty rights, and that tribal historical and cultural ties to the Cherry Point Aquatic Reserve are maintained. DNR will work cooperatively with the tribes to protect fisheries, archaeological sites, and allow access to cultural sites; and allow for treaty-protected hunting and gathering of resources in a manner that fosters the sustainability of those resources. Tribes and the State of Washington have developed a cooperative framework which provides for fisheries management and habitat protection.

This plan recognizes the policy statement developed by the Northwest Indian Fisheries Commission on behalf of member Northwest Tribes discussing the importance of considering the impacts conservation measures can have on tribal economics, subsistence and culture. Under this, Northwest Tribes highly recommend that the creation of any Marine Protected Area (local, state, federal or otherwise) not occur in the absence of any demonstrated need. In the face of such demonstrated need, Northwest Tribes do recognize that Marine Protected Areas may be useful tools for protecting or sustaining resources (NWIFC memo, 2003). In line with this policy, one of the primary goals of this management plan is to help demonstrate where there is a need for protecting and sustaining resources.

Cherry Point is located within the usual and accustomed areas of several federally recognized tribes, including the Lummi, Nooksack, Swinomish, Suquamish, and Tulalip Tribes. The cultural resources department of each Tribe has specific interests in the long-term cultural resource protection and management of this area. Cherry Point is within the homeland of the aboriginal Lummi Tribe whose sole successor is the present-day Lummi Nation. Cherry Point contains homelands of the Lummi Tribe that were ceded to the United States in the Point Elliot Treaty for considerations, including the right to fish in common with the citizens of the territory at the Tribe's usual and accustomed fishing grounds and stations. Tribes exercise their interest based on the specific location and particular impacts associated with local planning processes and project proposals. The federal government is obligated to protect the long-term interests of tribes by limiting permits that impact cultural objectives of tribes. All projects and plans for this area shall require government-to-government consultation with appropriate tribal governments under the State Centennial Accord. Local entities are strongly advised to consult regarding permitted activities and local plans. It is essential that conservation goals and management standards be established in cooperation with these Tribes. Regular discussions should be planned with affected tribes to ensure that this plan remains consistent with cultural resource goals and Treaty rights of the Tribes.

U.S. Coast Guard

The U.S. Coast Guard manages vessel activity and responds to pollution reports within Puget Sound through the Marine Safety Office. The Coast Guard also helps ensure the safety of vessels during transit and while in port. The U.S. Coast Guard (USCG) manages commercial vessel traffic throughout Washington's waters, including at Cherry Point, and is responsible for reviewing designated anchorage sites. The Coast Guard is the lead response agency for spills in coastal waters and deepwater ports, implements federal ballast water laws, and discharge of onboard sewage in federal waters.

U.S. Army Corps of Engineers

Under Section 10 of the Rivers and Harbors Act, the U.S. Corps of Engineers (Corps) oversees any in-water construction in navigable waters. Additionally, the Corps has been delegated authority under the Clean Water Act for the issuance of Section 404 permits. The Corps supports navigation by maintaining and improving channels; develops projects to reduce flood damage, and regulates dredging and filling activities in wetlands and waterways including the construction of any structures such as bulkheads or piers. Like all federal agencies, the Corps of Engineers must ensure that tribal trust resources are protected prior to taking any action that could potentially affect treaty-protected resources, including fishing and cultural or traditional cultural properties.

U.S. Environmental Protection Agency

The Environmental Protection Agency (EPA) is the lead federal response agency for oil spills occurring in inland waters and jointly administers Section 404 of the Clean Water Act (CWA) with

the Corps of Engineers. The EPA has delegated the administration of other sections of the Clean Water Act (e.g., Section 401, Section 402) to the Washington State Department of Ecology and the Lummi Nation but still retains the responsibility to ensure that those sections of the CWA are effectively administered and that their trust responsibilities to tribal governments are upheld.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service is charged with protecting those species listed under the Endangered Species Act and the Migratory Bird Treaty Act and the habitats those species rely upon.

NOAA Fisheries

NOAA Fisheries is responsible for protection of marine and freshwater species under the Endangered Species Act and the Marine Mammal Protection Act. NOAA Fisheries also is responsible for consultation under the Magnuson-Stevens Fishery Conservation and Management Act and the designation of critical fish habitat.

Washington State Department of Health

The state Department of Health regulates opening and closing of recreational and commercial shellfish zones and advises the public as to the healthy recreational harvest of shellfish.

Washington State Department of Ecology

The Washington State Department of Ecology (Ecology) contributes to resource protection through the Spill Prevention, Preparedness and Response Program; Air Quality; Water Quality; Toxics Cleanup; Shorelands Assistance; Water Resources; Solid Waste (Industrial Section – permitting); Hazardous Waste and Toxic Reduction. Ecology has a Spill Prevention, Preparedness and Response Program that focuses on prevention of oil spills to Washington waters and land, as well as planning for an effective response to any oil and hazardous substance spills that may occur. Vessel traffic in Washington State is tracked by Ecology's spill program and published in Vessel Entries and Transits (VEAT) for Washington Reports (see Appendix B for recent tracking information). Ecology reviews and must approve local Shoreline Master Plans and all plans for major substantial development permits involving construction in waters of the state.

Ecology also works to maintain water and sediment quality standards, such that listing of waterbodies or segments as impaired under section 303(d) of the Clean Water Act is unnecessary. They are responsible for developing and approving National Pollutant Discharge Elimination System (NPDES) permits for industrial and municipal discharges. Nonpoint source pollution is managed through a variety of state and local programs; Ecology has developed a nonpoint pollution plan that focuses on local land use activities. Finally, Ecology issues water quality consistency certifications under Section 401 of the Clean Water Act, which help ensure compliance with the law's Antidegradation Policy (Ecology website, 2008).

Washington State Department of Fish and Wildlife

The Washington Department of Fish and Wildlife (WDFW) has authority over the management of the non-tribal commercial and recreational shellfish harvesting and fisheries. WDFW are co-managers with tribal governments and collaborates on the management of commercial and recreational finfish and shellfish harvesting. WDFW also plays an important role in oil spill response, ballast water monitoring and Natural Resources Damage Assessments. The agency also protects natural resources from development through its Hydraulic Project Approval (HPA) process.

The State Legislature gave WDFW the responsibility of preserving, protecting, and perpetuating all fish and shellfish resources of the State. To assist in achieving that goal, the State Legislature in 1949 passed a state law now known as the "Hydraulic Code" (Chapter 77.55 RCW). The law requires that any person, organization, or government agency wishing to conduct any construction activity that will use, divert, obstruct, or change the bed or flow of State waters must do so under the terms of a permit (called the *Hydraulic Project Approval-HPA*) issued by WDFW. The purpose of the permit is to address any damage or loss of fish and shellfish habitat which is considered to result in direct loss of fish and shellfish production (WDFW website, 2008).

Washington State Parks and Recreation Commission

The State Parks and Recreation Commission plays a vital role in educating the public regarding appropriate recreation. Washington State Parks manages the Birch Bay State Park to the north of Cherry Point Aquatic Reserve, and has an existing lease for aquatic lands offshore of the state park. Birch Bay State Park is a 194-acre camping park with 8,255 feet of saltwater shoreline on Birch Bay and 14,923 feet of freshwater shoreline on Terrell Creek. The park is rich in archeological significance and offers panoramic views of the Cascade Mountains and Canadian Gulf Islands. Birch Bay State Park is one of the largest recreational shellfish areas in the State. Birch Bay State Park is located justa outside of the Reserve boundary.

Puget Sound Partnership

In 2007, the Legislature established the Puget Sound Partnership. The Partnership is charged with developing an action agenda to restore the environmental health of Puget Sound by the year 2020. DNR is a member of the Ecosystem Coordination Board that advises the Partnership's Leadership Council. In December 2008, the Partnership released the final Action Agenda. The Action Agenda includes the following recommendations related to the Cherry Point Aquatic Reserve:

- Complete the management plan for the Cherry Point Aquatic Reserve.
- Coordinate the plan with Whatcom County Cherry Point Management Area policies.
- Protect high value habitat by developing a strategy to protect large intact marine and nearshore habitat.
- Quantify impacts and strategically remove derelict fishing gear, starting with Cherry Point.
- Continue efforts to manage industry at Cherry Point to minimize pollution.
- Integrate and coordinate nearshore and marine protection and restoration efforts (e.g., pollution cleanup, Shoreline Master Program, Cherry Point Marine Managed Area) with watershed recovery efforts (e.g., Critical Areas Ordinances, Instream Flow Action Plan, Watershed Management Plan, Salmon Recovery Plan, MRC plans, Shellfish District Protection Plans).
- Continue to work cooperatively with Canadian neighbors on transboundary water quality, water quantity, fish habitat, and flooding issues, specifically to recover Cherry Point herring. (PSP, 2008).

Achieving many of the desired future conditions described in Chapter 6 of this plan will depend on funding and implementation of the state's Puget Sound Action Agenda[4]. DNR will continue to work with the Puget Sound Partnership and other cooperating agencies to implement the Action Agenda.

Whatcom County

[4] See Puget Sound Partnership Action Agenda: Table 1-1: Ecosystem recovery goals, desired outcomes and provisional indicators, page 14 – 16. Goals 4, 5, and 6 (December 1, 2008)

Whatcom County regulates upland and shoreline land uses within its jurisdiction. The Whatcom County Comprehensive Plan and the Whatcom County Shoreline Master Program, described on the next pages, are the key tools for managing land use. The county also manages its parks and recreational lands, transportation network, and other facilities. In addition, the county regulates clearing, grading, and construction activities and provides pollution control through their management of stormwater runoff and their regulation and inspection of onsite septic systems.

Local Land Use Designations

Currently, much of Whatcom County maintains a rural character, with large tracts of commercial forest lands and agricultural land used for pasture and commodity crops. Whatcom County population increased by 100 percent between 1950 and 1990 and was 184,300 in 2006. Continuing population increases in the county are projected to result in a transition to more residential, commercial and industrial uses. (Kyte et al, 1999; OFM, 2006).

Between 1954 and 1971, three industries moved into the Cherry Point vicinity. In 1954, General Petroleum Corporation constructed an oil refinery near Cherry Point, which was subsequently managed as the Ferndale, Mobil, BP, and Tosco refinery. On September 17, 2001, the Tosco Company was bought by Phillips 66. On August 30, 2002, Phillips merged with Conoco, to become ConocoPhillips. In 1966, Intalco Aluminum built an aluminum smelter north of ConocoPhillips. The aluminum smelter now is owned by Alcoa-Intalco Works. In 1971 Atlantic Richfield Company (ARCO) constructed another oil refinery even further north, later selling it to British Petroleum (please see Appendix D: *Existing Encumbrances and Applications* , for further details on these facilities). This is the northernmost pier along the Cherry Point.

Under the latest Comprehensive Growth Management Plan issued by Whatcom County, the uplands adjacent to the Cherry Point Aquatic Reserve are designated as Urban Growth Areas (UGA). An Urban Growth Area is an area that must include cities and other areas characterized by urban growth or adjacent to such areas, and are to be designed to accommodate the projected population growth for twenty years. Any growth that occurs outside these areas cannot be urban in nature.
The county has designated two UGAs adjacent to the Reserve. The Cherry Point UGA, containing approximately 7,000 acres, is designated for future industrial development, and the Birch Bay UGA north of it is designated primarily for residential The existing industrial developments occupy about 4,100 acres of the total Cherry Point industrial lands and may add a new 1,100-acre bulk commodities shipping port. On the average, land consumption at Cherry Point has been about 1,000 acres per facility, which includes sufficient land to avoid wetlands and provide buffer areas. Based on this consumption figure, Whatcom County concluded in their County Growth Management Plan (p. 2-52, 2008) that there is only sufficient remaining land in the Cherry Point industrial area to support two additional industrial complexes similar to those presently located there.

Whatcom County states that Cherry Point has special characteristics and regional significance for the siting of large industrial facilities. The County predicts that this demand will most likely result in the remaining undeveloped acreage being absorbed by the end of their 20 year planning period (Whatcom County, 2005). Characteristics that make Cherry Point attractive include the fact that since the 1960s, it has a history of operating as a major industrial area in Whatcom County. This has developed the infrastructure to support not only these industries, but future industries as well. Other attractive characteristics include:

- **Shipping Access** – Marine deep water access is present for shipping. This was a major consideration for the three major industries currently located at Cherry Point (Whatcom County 2008).

- **Rail Access** – Burlington Northern has long served Whatcom County, and access is available to the Burlington Northern mainline serving western Washington from Blaine to Portland. Rail service is particularly important for many types of water borne commerce; for example, the BP refinery at Cherry Point uses the railroad to ship calcined coke to U.S. markets and to other port facilities for transshipment to foreign markets (Whatcom County 2008).

- **Proximity to Canada, Alaska and Foreign Ports** – Cherry Point occupies a unique location for the siting of industry because of its close proximity to Canada and because of its shorter travel distance than other regional port facilities for shipping to Alaska and to other Pacific Rim locations. The Cherry Point industrial area benefits from proximity to Canada, as trade between the U.S. and Canada grows in response to the lifting of trade barriers under the Free Trade Agreement of 1989. An increase in vessel traffic is being noted through the Strait of Juan de Fuca, as vessels move towards Vancouver (VEAT, 2008). Marine terminals at Cherry Point could serve a portion of the potential growth in Canadian marine cargo (Whatcom County 2008).

Whatcom County considers these industries a substantial part of the economic base of Whatcom County, with the region and the economic welfare of the county strongly tied to the health of these industries and their ability to flourish and expand as opportunities present themselves. The County has designated the area as "Heavy Impact Industrial" to support the requirements of heavy manufacturing uses that require water deep enough to accommodate large vessels (Kyte, et al 1999; Whatcom County, 2006). This protects the area from incompatible uses that would prevent their ability to expand, particularly residential development (see Whatcom County Code Chapter 20.74, revised March 2008). Whatcom County has also developed a policy for Cherry Point which will limit the number of future piers (see page 2-55, Policy 2BB-10, of the June 2008 Comprehensive Plan for further information).

County Shoreline Master Program

For purposes of local shoreline planning, Whatcom County places Cherry Point in the Birch Bay Watershed Management Unit (WMU), a 31 square mile coastal watershed between Drayton Harbor and Lummi Bay. It includes the marine shoreline from the north end of Semiahmoo Peninsula, and includes Birch Point, Neptune Beach, Birch Bay State Park, Point Whitehorn, and Cherry Point. The WMU extends inland to the City of Ferndale, and includes Lake Terrell and Terrell Creek. The Birch Bay and Cherry Point UGA make up a significant percentage of the watershed.

Shorelines of the state include the marine shoreline, the lower 3.1 miles of Terrell Creek and Lake Terrell. The marine shoreline from Birch Point to Point Whitehorn is also shoreline of statewide significance. To plan for and manage these shorelines, Whatcom County submitted their updated SMP in 2007, and under Whatcom County Code (WCC) 23.100.17, zoned and adopted the Cherry Point Management Area. Whatcom County's authority under the SMP includes protecting critical areas located within shorelines, such as riparian vegetation, saltmarsh, eelgrass beds, salmon migratory corridors, and pocket estuaries. This plan has been accepted by the Department of Ecology.

According to Whatcom County (WCC 23.100.17.A.1) the Cherry Point Management Area can be described as follows:

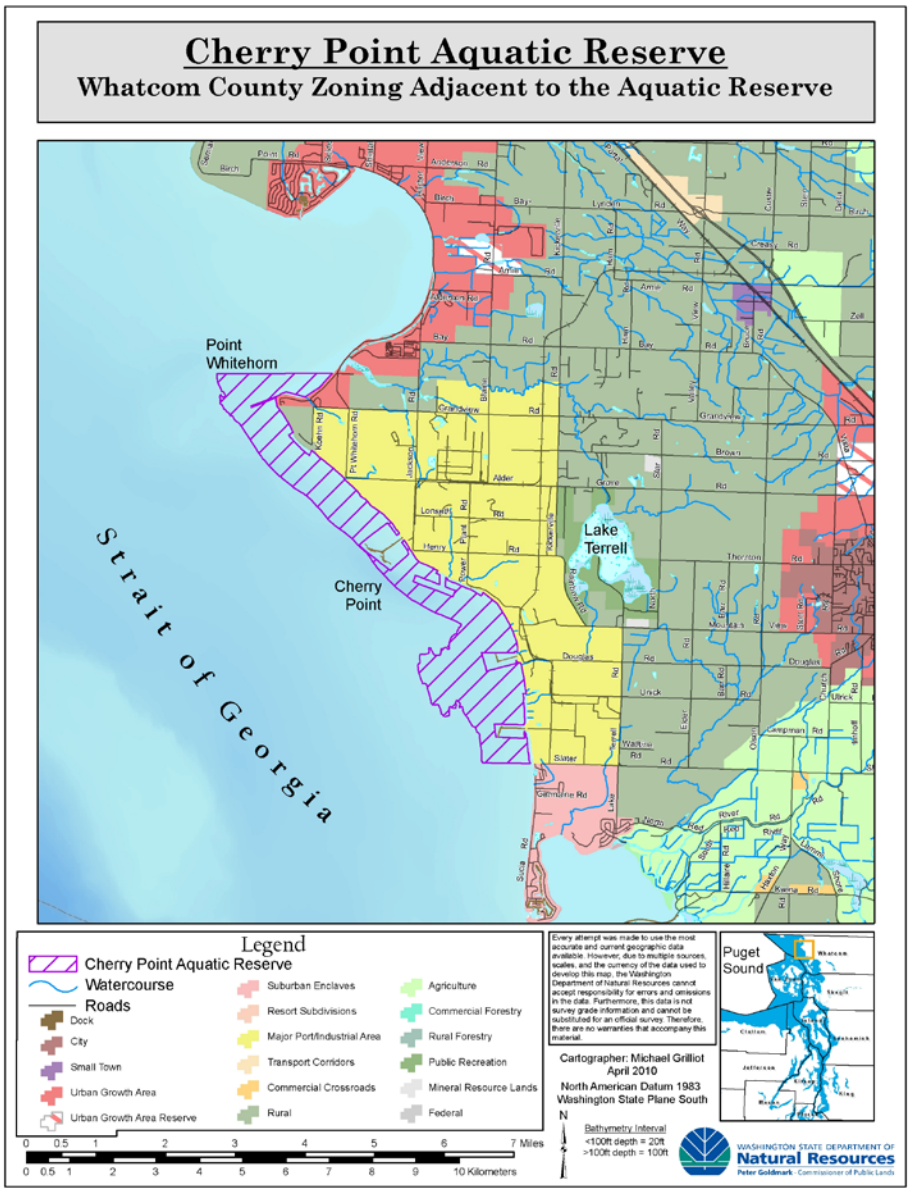
> The purpose of the Cherry Point Management Area is to provide a regulatory framework which recognizes and balances the special port, industrial and natural resource needs associated with the development of this marine resource…Washington State natural resource agencies and Whatcom County have identified certain portions of the Cherry Point Management Area as providing herring spawning habitat that warrant special consideration due to their importance to regional fisheries and other elements of the aquatic environment…Development of the Cherry Point Major Port/Industrial Area will accommodate uses that require marine access for marine cargo transfer, including oil and other materials. For this reason, water-dependent terminal facilities are encouraged as the preferred use in the Cherry Point Management Area. Due to the environmental sensitivity of the area, it is the policy of Whatcom County to limit the number of piers to one (1) pier, in addition to those in operation or approved as of January 1, 1998 (p. 181).

Paragraph (d) of WCC.23.100.100.17.A.1 describes how Whatcom County:

> "…should consider participation with local, state, and federal agencies, tribal governments and other stakeholders in the development of a plan to address integrated management of the uplands and public aquatic lands within the Cherry Point Management Area. The development of such a plan could provide a forum and process for addressing aquatic resources by all stakeholders. Elements of the plan could be adopted as future amendments to this Program as appropriate."

The facilities located at Cherry Point have already provided important resource monitoring data and will play an important role in plan implementation. Maintaining partnerships with existing facilities will be important for implementing many potential management activities.

Figure 3: Whatcom County Zoning



Point Whitehorn Park

Opened to the public in the summer of 2008, the 51-acre Point Whitehorn Park focuses on the site's abundant natural attributes comprised of wildlife, forests, bluffs, natural shoreline and magnificent views of the San Juan Islands. A joint project between the Whatcom Land Trust and Whatcom County, the site provides parking and walking trails to wetlands, overlooks and over one third of a mile of beach along the Strait of Georgia. Point Whitehorn Marine Park is envisioned to be the first phase of a larger regional park at this site (Whatcom County, personal communication, 2008).

History of Land Use at Cherry Point

The following timeline provides a chronological summary of major construction events, land use decisions and proposals, fisheries management decisions, and selected dates of laws and rules with specific importance at Cherry Point.

Table 1 Timeline of Major Events at Cherry Point

Date	Event	Type
Time Immemorial	Ceremonial, subsistence, and commercial harvest of finfish and shellfish and other commerce by Native American Indians	Tribal Law
1855	Treaty of Point Elliot signed	Federal/Tribal Law
1889	Washington Statehood	Federal/State Law
1954	The General Petroleum Corporation begins operation of the Ferndale refinery, pier, and outfall.	Major construction
1966	The Intalco Aluminum Corporation builds a second pier and outfall at Cherry Point.	Major construction
1971	The ARCO refinery constructs a third pier and outfall at Cherry Point now owned by British Petroleum.	Major construction
1971	Washington's Shoreline Management Act was enacted.	State law
1972	Federal Water Pollution Control Act is enacted.	Federal law
1974	State herring sac roe fishery is opened.	Fishery management
1975	Whatcom County Water District Number Eight constructs a secondary wastewater effluent outfall at Point Whitehorn.[5]	Major construction
1976	First Shoreline Management Program adopted designating Cherry Point uplands as a "conservancy," shoreline allowing water-dependent industrial use of the shoreline as an outright permitted use and recognizing the state and local importance of such uses at Cherry Point.	Land use
1976	Final Decision of *United States v. Washington* (384 F. Supp. 312, 377 [W.D. Wash. 1974], aff'd, 520 F.2d 676 [9th Cir. 1975], cert. Denied, 423 U.S. 1086 [1976])	Federal/State/Tribal Law
1976	Chicago Bridge and Iron (CBI) proposes to build offshore oil drilling rigs at Cherry Point.	Land use
1977	Whatcom County "Interim Zoning" adopted identifying Cherry Point as an industrial area.	Land use
1977	Federal Clean Water Act is enacted, by amending the 1972 Water Pollution Control Act.	Federal law
1979	Cherry Point-Ferndale Subarea Plan adopted by Whatcom County designating Cherry Point for industrial use.	Land use
1981	Whatcom County updates the "Official Zoning Map" re-affirming Cherry Point as an industrial area. Ordinance No. 81-99	Land use
1982	State herring sac roe fishery permanently closed.	Fishery management
1982	CBI's proposal to build oil drilling rigs is ended by governor's veto of legislation that would have exempted CBI from provisions of the Shoreline Management Act.	Land use
1983	Kiewit proposes to build offshore oil drilling rigs on the Cherry Point uplands	Land use
1984	Kiewit's permits denied by Ecology and DFW	Land use
1987	State herring spawn-on-kelp fishery are opened.	Fishery management
1992	Joseph Schecter proposes to build the Cherry Point Industrial Park (CPIP), including a shipping pier.	Land use
1992	SSA proposes to build the Gateway Pacific Terminal (GPT) pier at Cherry Point.	Land use
1995	Letter from Commissioner of Public Lands states that DNR will consider at most one additional pier at Cherry Point.[6]	Land use
1996	State herring spawn-on-kelp fishery is closed.	Fishery management
1996	State sediment management standards become effective.[7]	State rule
1996	*Northwest Sea Farms v. U.S. Army Corps of Engineers,* 931 F.Supp. 1515 (WD	Federal Law

[5] The operator of this outfall is now the Birch Bay Water and Sewer District.
[6] The letter, dated October 5, 1995, was written by then-commissioner Jennifer Belcher to Tim Winn, District Engineer, US Army Corps of Engineers. Copies filed in CPIP Negotiations with DNR file.
[7] State sediment management standards are codified at WAC 173-204. They are administered by Ecology.

Date	Event	Type
	WA 1996)	
1998	The 1992 CPIP proposal is abandoned; legally they have a shoreline permit until the county rescinds the permit.	Land use
1998	Executive Order 13084 issued by the White House, Consultation and Coordination with Indian Tribal Governments	Federal Law
1998	Whatcom County and Washington State adopt the 1998 Shoreline Program Update designating the Cherry Point Management Area – re-affirming the use of the reach for water-dependent industrial uses.	Land use
1999	NMFS accepts petition to list 18 species of marine fish under ESA, including all Puget Sound Herring.	Legal
2000	Second wing is added to the ARCO pier.	Major construction
2000	National Marine Fisheries Service (NMFS) decides Cherry Point herring do not merit listing under the federal Endangered Species Act.[8]	Fishery management, federal law
2000	Ocean Advocates et al sues Corps for granting ARCO/BP permit for refinery dock expansion w/o EIS or consideration of Magnuson restrictions	Legal
2000	Commissioner's Order establishes Cherry Point as an aquatic reserve	Land Use/Order
2001	Washington Department of Health re-opened 1.5 miles of beaches around Pt. Whitehorn previously closed to recreational shellfishing, reducing the closure zone from 2,640 feet to 1,380 feet.	Land Use
2001	DNR applies Interim Guidance to Cherry Point Aquatic Reserve	Land Use
2002	New leases are issued for Intalco/Alcoa pier and wastewater outfall.	Land use
2002	Birch Bay Water and Sewer District withdraws its proposal for wholesale service to Blaine, who has chosen to construct reclaimed water plant instead.	Land use
2003	Williams Pipeline (also known as Georgia Strait Crossing) proposes placement of a natural gas pipeline across the Cherry Point Withdrawn Area. Proposal later withdrawn.	Land use
2003	The Cherry Point Withdrawn Area scheduled for review, determining whether the area will remain an aquatic reserve.	Land use
2005	The authorization for the Birch Bay Water and Sewer District outfall expires. DNR postpones the application.	Land use
2006	ConocoPhillips lease is renewed with DNR	Land use
2007	Cherry Point BP lease is modified by DNR to accommodate required spill control structures	Land use
2007	Whatcom County adopts updated Shoreline Master Program including protection of shoreline critical areas	Land use
2008	Trillium sells large parcel west of BP facility to BP	Land use
2008	Whatcom County Parks purchase of Trust lands	Land use
2009	Birch Bay Water and Sewer District receives a 30-year easement for the Birch Bay outfall	Land Use

[8] The notice, Endangered and Threatened Species: Puget Sound Populations of Copper Rockfish, Quillback Rockfish, Brown Rockfish, and Pacific Herring, Notice of determination of status review was published in the Federal Register, Volume 66, Number 64, April 3, 2001, pp. 17659 – 17668.

3. Resource Characterization

Site Characterization

This section provides an overview of the environmental and natural resource characteristics for the Cherry Point Aquatic Reserve and adjacent areas. Understanding the processes and functions at Cherry Point and their relationship to the larger ecosystem and species interactions provides a foundation for development of management actions. A more detailed analysis is found in Appendix A.

Geographic Description

Cherry Point is located on the western shores of Whatcom County, located on the Strait of Georgia (see Figure 4, page 96). Washington's marine ecosystems can be divided into three primary systems - the Columbia River Littoral Cell, the Olympic Coast, and the Puget Sound. The Cherry Point Aquatic Reserve is located within the Puget Sound biogeographic region, a region delineated as the marine waters of Washington to the east entrance to the Strait of Juan de Fuca. This biogeographic region can be further subdivided into nine subregions or basins; the reserve is in the southeastern portion of the Georgia Strait Basin (Georgia Basin).

Ecosystem Description

Geomorphic characteristics of the Whatcom County shoreline include glacial sediments, limited sea level rise, moderate tidal range, considerable wave exposure, rock strewn cobbly beaches with moderate to high backshore bluffs. Because of its combination of exposure, fetch, and glacial makeup, Cherry Point has a unique beach type of large coggle/boulders with lower areas of mixed sand and pebble infill. Seasonal changes in wave energy create a highly diverse and productive nearshore (Mumford, pers. Comm.) The proximity of Cherry Point to Georgia Strait sets it apart from many other locations in the Northwest corner of Washington. The Strait of Georgia is distinctly different from Puget Sound, influenced to a higher degree by the Pacific Ocean and the Fraser River, resulting in different biodiversity. Many oceanic species are relatively common in the Strait of Georgia, compared to the Puget Sound estuary (Whatcom County 2006). The site is also distinctive for its bathymetry with water depths reaching more than 70 feet just offshore (see Figure 5, page 97).

Diverse habitats found at the Cherry Point Aquatic Reserve include: the cobble-boulder beaches, mixed fine to sandy intertidal areas that steeply slope to deepwater, mixed macroalgae, kelp and eelgrass beds. The shoreline provides critical rearing and migratory habitat for juvenile salmonids. A salt marsh and two small streams discharge into the reserve. Terrell Creek discharges just north of the reserve into a pocket estuary that supports juvenile salmonids (Whatcom County Shoreline Characterization Inventory 2006). The Birch Bay Great Blue Heron colony is located on the creek upland of the reserve. The shoreline above the reserve contains a relatively high amount of intact riparian vegetation that supports the health of the reserve, including: contributing large woody debris, nutrients and insects; providing slope stability, moderating temperature, and protecting water quality. Moderate to tall, eroding bluffs above the reserve feed sand and gravel to the beaches. The Fraser River and Nooksack River (located outside the reserve) also provide sources of fine sediment to the reserve, creating a habitat conducive to supporting submerged vegetation and forage fish, including Pacific herring (Center for Biological Diversity et al, 2004). Drift cells, which describe the movement of beach sediment by wind-driven wave forces along the shoreline, are an important shoreline component at the reserve. Three drift cells characterize the net shore-drift at Cherry Point;

they are shown in Figure 6, page 99.

Flora and Fauna

The reserve contains a high diversity of algal species which are an important component of nearshore primary production rates (Nybakken 2001). Submerged aquatic vegetation at Cherry Point is shown in Figure 7. Marine algae supports salmon, forage fish, groundfish, Dungeness crab, and other invertebrates important to the food web that supports many wildlife species, such as resident and migratory birds, and marine mammals. Eelgrass beds include both native and non-native species. Bladed kelps, such as *Saccharina latissima* and *Costaria costata*, filamentous brown algae such as *Desmarestia* spp., and a variety of red foliose and filamentous algae dominate the macroalgae community. Mixed eelgrass and *Sargassum* extend along much of the shoreline, with sparse kelp (*Nereocystis*) beds beginning to appear near Point Whitehorn. *Sargassum* is a non-native lower intertidal/subtidal floating brown alga (not a kelp), that herring often spawn upon (Pentilla 2001). It is notable that the distribution of *Sargassum* along the reserve and Birch Bay is restricted primarily to the lower intertidal zone, while elsewhere in Puget Sound its distribution is mostly within the subtidal zone.

Numerous species of salmon and trout have historically been, or are currently found in the nearshore environment at Cherry Point and Birch Bay, including: pink salmon (Onchorynchus gorbuscha); chum (*O. keta*), coho (*O. kisutch*), Chinook (*O. tshawytsha*), and sockeye (*O. nerka*). The nearshore is designated as habitat for the following salmon species listed under the federal Endangered Species Act: Puget Sound Chinook salmon, Nooksack Coastal Cutthroat, and Puget Sound Bull Trout, and Puget Sound Stealhead. The Cherry Point nearshore is also used by char and cutthroat tagged in British Columbia (Ptlomey, R. pers. comm.)

The Puget Sound Evolutionary Significant Unit (ESU) for Chinook salmon includes the Cherry Point site and major waterbodies (see Figure 8, page 108). The Puget Sound Chinook ESU was listed as federally threatened in March of 1999 and includes runs from the North Fork Nooksack River in northeast Puget Sound to the southern Puget Sound watersheds, Hood Canal and the Strait of Juan de Fuca. The Puget Sound Chinook is estimated to be at only ten percent of historic numbers. There are two independent populations of Puget Sound Chinook salmon in the Nooksack basin: North Fork Nooksack River (including Middle Fork), and South Fork Nooksack River. These salmon are distinctive from Chinook salmon in the rest of Puget Sound in their genetic attributes, life history, and habitat characteristics. They are the only populations in the Strait of Georgia region, and they are two of only six Chinook runs left in Puget Sound that return to their rivers in spring (as opposed to fall spawners). For these reasons, the Nooksack populations are considered to be essential to the recovery of the Puget Sound Chinook ESU (Puget Sound TRT 2006). Georgia Strait/Puget Sound coho are also in decline, listed as a federal species of concern.

Three species of forage fish use the Cherry Point Aquatic Reserve: surf smelt (*Hypomesus pretiosus*), northern anchovy (*Engraulis mordax*), and Pacific herring (*Clupea pallasii*). See Figure 9, page 109 depicting known spawning locations. Surf smelt spawn in the upper intertidal zones of the aquatic reserve during the summer months. They are an important food source for seabirds and a variety of fish, including salmon. Northern anchovy spawn from May to September; spawning has been documented from Semiahmoo Bay to Bellingham Bay, including within the reserve.

The area between the south shore of Birch Bay south to Neptune Beach, which is included in the reserve, is one of the most important Pacific herring areas in Washington State. This area serves as the “core” region of spawn deposition for the largest single herring spawning stock in Washington

waters, a stock that historically provided spawning habitat for more than 50 percent of the entire herring population of Puget Sound and the Strait of Juan de Fuca. The Cherry Point herring stock was estimated at a peak of 15,000 tons in the early 1970's. This population has been declining since the late 1970s and although recent surveys suggest the population may have stabilized at approximately 1,000 tons of escapement, the stock status has been downgraded to 'critical' meaning that permanent damage to the stock is likely or has already occurred (Stick, personal communication). Figure 10, page 111, graphs Cherry Point herring spring biomass and fishery landings between 1973 -2008. The Cherry Point stock has historically spawned from the Canadian border to Hale Passage (see Figure 11, page 113), but in recent years the primary spawning grounds has been substantially smaller (EVS 1999). Despite continuing declines in the stock, spawn deposition intensity and frequency in the Cherry Point area has been maintained and spawn surveys encounter 'medium' or 'heavy' spawn deposits more commonly in the Cherry Point area than anywhere else in Puget Sound (Penttilla 1994).

Herring spawn is deposited on eelgrass and more than 25 species of rock-dwelling marine algae found between about +3 feet MLLW to the lower limit of algal growth at around –10 ft (Penttila 1994). Spawn is most frequently found on *Zostera marina* (native eelgrass), *Gracilaria*, *Laminaria*, *Saccharina*, *Sargassum*, and *Botryoglossum* (Penttila, personal communication). Eelgrass beds are found along the sand bars in southern Birch Bay and are then interspersed with a diverse algal community from Point Whitehorn to Neptune Beach. Pacific herring that lay demersal eggs upon the vegetation during the winter and spring months have used these habitats extensively. In addition to suitable spawning grounds, herring also need pre-spawn holding areas, which allow adults to congregate approximately three to four weeks prior to spawning. The pre-spawn holding area for Cherry Point herring is located along the Whatcom County shoreline between Birch Bay and Sandy Point, and includes the aquatic reserve (see Figure 11, page 113).

Recent studies have suggested that the Cherry Point Pacific herring stock is genetically distinct from other Washington and British Columbia stocks (Beacham et al. 2002; Small et al. 2005, Mitchell 2006). Unlike other Pacific herring populations found in Puget Sound, the Cherry Point herring spawn in open, high energy shoreline areas (O'Toole et al. 2000). Furthermore, while other stocks spawn between early January and early April, the Cherry Point herring spawn from early April through June (see Figure 12, page 113 documented and peak spawning times). Research provides a preliminary indication that the Cherry Point herring may have evolved a tolerance for warmer water than other regional herring due to their late spawning time (Dinnel 2008). If so, these genes would be important to ensuring species resilience and adaptation to climate change. Conservation of herring spawning habitat and minimizing disturbance in the pre-spawning holding areas is key to the preservation of the herring stocks inside Puget Sound (WDFW, 2009).

Groundfish that utilize Cherry Point include: Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), rock soles (*Lepidopsetta bilineata*), starry flounder (*Platychythus stellatus*), and Pacific and speckled sanddabs (*Citharichthys sordidus* and *C. stigmaeus, respectively*) (Palsson, pers. Comm.). Occasionally adult butter sole (*Isopsetta isolepsis*) have been found, along with lingcod (*Ophiodon elongatus*) (Whatcom County MRC, 2009). During the juvenile phase of their lives, many species of groundfish, such as lingcod and rockfish, use submerged aquatic vegetation for feeding, refuge from predators, and nursery grounds (Mumford, 2007). Many rockfish species in Puget Sound are in decline due to such factors as overfishing, derelict gear, water quality degradation, and food web interactions (Washington State Department of Fish and Wildlife, 2009). NOAA's Fisheries Service recently listed three populations of rockfish in Washington's Georgia Basin for protection under the Endangered Species Act. The populations of two of the rockfish species – canary and yelloweye –

have been designated as “threatened” and a third rockfish species – bocaccio – as “endangered.”

Cherry Point is considered one of 18 significant bird habitats in the Strait of Juan de Fuca and Georgia Strait (Wahl et al. 1981), attracting Surf Scoters, grebes, loons, and other fish-eating birds and migratory waterfowl. The area between Sandy Point and Point Whitehorn provides year-round habitat for high numbers of fish-eating loons, grebes, alcids, and diving ducks. It is an important wintering ground for migratory birds, including Brant, Harlequin Duck, loons, and Surf Scoters. Marbled Murrelet, listed as threatened under the ESA, have been documented at Cherry Point, likely foraging on herring.The site also supports Peregrine Falcon, Bald Eagle, and Great Blue Heron. Historically, birders observed flocks of up to 25,000 scoters, Pacific Loons, gulls, murres and other species that come to feed on forage fish and eggs (Audubon, 2009). Surveys conducted in the last several years indicate that more than 14 of the 37 most common over-wintering species in the Strait of Georgia are experiencing significant declines. For Cherry Point, a 79 percent decline in species was documented. Studies of the role of herring spawn in movements and energetics of scoters have resulted in the finding that spawn at Cherry Point is used by Surf Scoters to acquire reserves for migration and breeding (Anderson et al 2009). Concurrent with declines in spawning herring biomass, numbers of scoters foraging on spawn at Cherry Point have declined from about 60,000 to 6,000 for the period 1980-1999 (Nysewander, unpublished data). During spring migration of Surf Scoters in late April to May, no feeding opportunities equivalent to historical levels of spawn at Cherry Point are known to exist in the Puget Sound-Georgia Basin.

One of the Pacific Northwest’s largest Great Blue Heron rookeries is located north of the aquatic reserve, along Terrell Creek; it supports more than 300 breeding pairs. Heron forage along marine shorelines, the intertidal zone, wetlands and riparian areas of the aquatic reserve. Migratory and wintering eagles are found in seasonally high numbers along the Reserve’s shoreline (Eissinger 1994). Peregrine Falcons are also thought to use Cherry Point for foraging habitat (Hayes and Buchanan 2002).

Marine mammals that may use the Reserve based on their presence in the southeast Strait of Georgia include: harbor seals, Pacific harbor porpoise, Dall’s porpoise, Stellar sea lions, California sea lions, Gray whales, the Southern Resident Killer Whale, and humpback whale (Calambokidis and Baird 1994, Falcone et al. 2005). Seals use the Cherry Point shoreline for foraging and haulout. (See Figures 13 -15 for additional information on marine mammal distribution). The Southern Resident Killer Whale is listed endangered under the Endangered Species Act. Prey availability, environmental contaminants, impacts from vessels, noise, oil spills, and disease are the key stressors for Southern Resident Killer Whales. Salmon, groundfish, and herring are key prey for Southern Resident Killer Whales.
A number of benthic invertebrates, clams, cockles, crabs, shrimp, snails and marine worms are found in the Cherry Point Aquatic Reserve, many serve as prey for birds, fish and mammals. Dungeness crabs are found at Cherry Point and are important recreationally and commercially. Dungeness crabs are an important predator and prey organism at all life stages, their pelagic larvae are preyed upon by copper rockfish, coho and Chinook salmon, halibut, dogfish, hake, and lingcod. Many invertebrate species observed at Cherry Point include species that rely partially upon herring in their diet. Examples include, amphipod (*Anisogammarus pugetensis*), the ochre sea star (*Pisaster ochraceus*), and unspecified sea anemones.

Non-native Fauna and Flora

The composition of non-native organisms established at Cherry Point has not been adequately characterized. Two speices of non-native marine vegetation were identified at Cherry Point as part of

an inventory of submerged aquatic vegetation: the Japanese brown alga, *Sargassum muticum*, which has widespread distribution along Cherry Point, and the eelgrass *Zostera japonica*, which has been documented in numerous patches from Birch Bay to south of Gulf Road (Fairbanks et al, 2005).

As a major shipping port, the Cherry Point industries receive most of their vessel traffic from ports in Alaska, and California with additional vessel visits from Pacific Northwest ports, as well as, some Asian and Australian ports. Ballast and fouling organisms arriving with visiting vessels represent a potential invasion vector for numerous species. The EPA has identified ballast water as one of the most "universal and ubiquitous vectors" for the transport and discharge of non-native species in marine and coastal areas (2008).

Current Conditions

A number of species that occur within the Cherry Point Aquatic Reserve have shown signs of decline in the past, or are still in decline. Cherry Point herring stocks have been vastly reduced, which is likely affecting the health of other species at Cherry Point, such as birds and salmon. Non-indingenous submerged aquatic vegetation has found a foothold in the nearshore and is displacing certain types of native algae. The causes of species decline in and around the Cherry Point Aquatic Reserve have not been well studied or understood. Know threats to Rreserve resources are described in the next section. Addressing uncertainties related to species decline is a priority within the plan.

The water quality and ecological conditions at the Cherry Point Aquatic Reserve are affected by immediate and adjacent land use and in-water activities, the Georgia Strait, the Fraser and Nooksack Rivers, and the general climatic conditions of northwest Washington. In-water development directly adjacent or abutting the Cherry Point Aquatic Reserve includes three large piers supporting major industrial facilities (EVS 1999) and one municipal outfall. The majority of the adjacent shorelines are undeveloped and unarmored with intact riparian vegetation (Figure 16, page 133). There are no recreational overwater structures or mooring buoys located within the Aquatic Reserve. A small amount of fill located on private tidelands provides footings for the two southern piers. The footings extend into the intertidal and are heavily armored with rip rap and likely intercept sediment within the drift cell during high tide cycles (DNR 2001). Armoring also occurs along the shoreline at Gulf Road, as well as, residential bulkheads located at Point Whitehorn. Loss of submerged aquatic vegetation has likely occurred from overwater structures, and may be limited to the vicinity of such stuctures, but this has not been well studied at the site. A study of the Arco pier found that shading from the pier appears to limit the growth of marine vegetation (Shapiro & Associates, 1994). The extent of the impacts of the three facilities would depend on the height of the structure and its orientation, bathymetry of the site, as well as the substrate below them.

Impervious surfaces are overall relatively low in the watershed that drains into the Reserve (Figure 20, page 151). Stormwater runoff is generated from industrial piers, buildings, roads, and upland residential development located directly adjacent to the Reserve. Some residential properties use tightlines to pipe stormwater over bluffs onto the beach. All industrial facilities at Cherry Point have National Pollutant Discharge Elimination System (NPDES) permits to discharge effluents into the Reserve. Another facility permitted to discharge into the reserve is the Birch Bay Sewage Treatment Plant. Together, these outfalls contribute millions of gallons of water and runoff into this part of Georgia Strait. While initial testing indicated presence of certain potentially historical contaminants at the Alcoa Intalco site, current work by state agencies, as addressed in recent NPDES permits, indicate improvements (Ecology 2007). In general, chemical concentrations in receiving waters and sediment at Cherry Point are relatively low, compared with other locations. Sediment studies performed in the last decade detected contaminants at all three industrial facilities, but levels were

not at concentrations sufficient for listing under Ecology's 303(d) list or the imposition of "sediment impact zones". Contaminants include Polyaromatic Hydrocarbons around discharge locations, contaminants were also detected in sediment adjacent to creosote pilings. Contaminated sediment in the area of the Alcoa pier has been traced to historical spills or releases from the aluminum smelter.

Legacy sources of contamination from historic, unregulated industrial waste disposal are likely to exist on uplands adjacent to the Reserve. Ecology is concerned about the TreOil Industries Limited site at 4242 Aldergrove Road; contaminants such as pulp and paper manufacturing by-products have leached into the groundwater which later discharge into Puget Sound (see Figure 20, 151). Ecology has identified the site as potentially hazardous to human health and the environment, and it is ranked number two on their list of hazardous sites awaiting cleanup (Ecology 2008). Ecology notes the potential of this site to be contributing to herring mortality through groundwater transport to the nearshore (Marshall, pers. Comm.).

Marine vessel traffic is extensive in the Strait of Georgia in the vicinity of the Reserve. Cherry Point contains the largest refineries in Washington State; over half of all the crude and refined oil and petroleum products are loaded and offloaded here. Also present is the Alcoa-Intalco aluminum facility and a proposal for a fourth pier. Numbers are not available regarding current vessel traffic into the Reserve. This information will be collected during plan implementation to inform management actions related to dock operations and traffic risk mitigation strategies. Vessel traffic patterns in Puget Sound are tracked by Ecology (see Appendix B). Ecology has also begun tracking oil spills over 150 gallons at Cherry Point. Between December 1997 and June 2008, there have been seven spills (see Appendix B).

Airborne pollution at Cherry Point is considerable, but the potential effect of atmospheric deposition on aquatic ecosystems is unknown. The primary sources of emissions affecting the proposal are vessel traffic and stationary sources. In the larger Georgia Basin (where the Cherry Point Aquatic Reserve is located), marine vessels account for 22 percent of nitrogen dioxide emissions, with light-duty vehicles responsible for 23 percent. Marine vessels are the largest single source of sulfur dioxide in the airshed, emitting 33 percent of emissions. Agriculture is the dominant source of particulate matter, along with space heating. Whatcom County has just 7 percent of the entire population in the Georgia Basin, but also has several major industries, contributing 29 percent of thesmog-forming emissions.

The Northwest Clean Air Agency (NWCAA) monitors Whatcom, Skagit and Island counties and produces annual emission inventories from large stationary industrial facilities within its jurisdiction, including facilities located within the Cherry Point site. The NWCAA reports that for Whatcom County in 2004 and 2005, the primary stationary sources of particulate matter, sulfur dioxide, nitrogen dioxide, volatile organic compounds, and carbon monoxide were the industrial facilities located at Cherry Point: Alcoa Primary Metals (Intalco), BP West Coast Products, and ConocoPhillips (NWCAA, 2006).

These facilities at Cherry Point contributed an average of 92 percent of all monitored industrial air pollutants from stationary sources in Whatcom County in 2005 and 2006. Results of monitoring showed that four of the five monitored pollutants decreased between 2004 and 2006 (NWCAA, 2004, 2005, and 2006). The county is currently in attainment (meeting requirements) under EPA standards set forward by the Clean Air Act and administered by the NWCAA.

Public recreational activities such as boating, fishing, shellfish harvesting, swimming, and beach

walking are popular at Cherry Point. Disturbance to the beach by recreational shellfish digging is altering the ecosystem in several areas of the Cherry Point Aquatic Reserve (Kyte, 2007). Public and private property has been impacted, including the shoreline from Point Whitehorn to south of Gulf Road. Area scientists believe the direct and indirect impacts from shellfish digging activity are significant to herring and shellfish reproduction. The impact is primarily in boulder and cobble substrates where a relatively small number of recreational shellfish harvesters do not refill holes as required by WDFW regulations. The mounded material dug from the hole is not typically restored by tidal and wave action, resulting in permanent alteration to beach and intertidal habitat.

Other recreational activities that may impact habitat and wildlife in the area include disturbance of birds and marine mammals by dogs and human activities. Beach fires are reducing habitat and threaten riparian areas. Trampling of sensitive vegetation can result in impacts to sea grasses and algae. As public access increases, these issues could be amplified. There is a need for public education and outreach regarding the sensitive nature of many of the systems and resources along Cherry Point.

Offshore areas have traditionally been used for tribal commercial, ceremonial, and subsistence harvest of numerous species including salmon, herring, Dungeness crab, and bottomfish using a variety of methods, including gillnets, setlines, trawl, and purse seine and crab pots. Valuable natural resources continue to play an important role in the local and tribal communities. Docks and other hardened structures may impact currents and tidal action and preclude and/or interfere with the exercise of tribal treaty rights to fish in this area.

Potential Future Impacts

The Cherry Point Workgroup identified the following known and potential threats to Cherry Point natural resources: shoreline modification, including overwater structures, loss of riparian vegetation, armoring, and derelict gear; pollution from groundwater contamination, stormwater runoff, point discharges, and air deposition; disturbance from recreational activities; artificial light and excessive intermittent sound; vessel traffic, including oil spills; ballast water and invasive species; and habitat impacts due to climate change. The Technical Advisory Committee (TAC) earlier identified a number of threats to the aquatic reserve, including impacts of fill and pilings associated with the piers, industries and the expanding threat posed by residential development along the northern and southern boundaries of the reserve. A detailed description of risks to the aquatic habitats and species of the Cherry Point Aquatic Reserve is provided in Appendix B.

Shoreline Modifications

Construction of the new pier or expansion of existing overwater structures could degrade shoreline ecological processes, habitats and species proposed for conservation. Depending on the location, design, level of use, and management, overwater structures may have a significant impact on ecosystems and species. Of particular concern are the potential impacts of additional shoreline modifications, such as, how the new pier will affect juvenile salmon rearing, migration corridors, herring spawning and pre-spawn holding habitat (Settlement Agreement, 1999). Construction of new recreational overstructures is unlikely, given the severe weather conditions in the area.

Shading is a primary concern, as the reduction of light available for photosynthesis for aquatic vegetation can impact habitat structure, complexity, and the surrounding food web. Nighttime attraction to artificial lighting by certain fish species, including salmon, and congregations of salmon predators, is of particular concern. Wave shading from pilings and other inwater structures may disrupt water flow patterns, energy and sediment flow. Propeller wash could result in physical habitat

alterations. Impacts to water quality from increased impervious surface runoff, ballast water and waste discharges, fuel spills, hydraulic fluid spills, material spills, and other activities associated with overwater structures may directly and indirectly impact aquatic flora and fauna (Nightingale and Simenstad 2001). The potential adverse impacts of light, noise, shading, and vessel traffic on Cherry Point herring spawning, prespawn holding behavior, and preferred migratory corridors have not been well studied; research on these issues is a priority and is addressed further in the management actions.

Additional shoreline armoring, fill, land clearing associated with industrial, residential, recreational land use and activities have the potential to adversely impact riparian and submerged vegetation and bluff habitats, leading to loss of habitat functions. Removal of native riparian vegetation can impair water quality, reduce recruitment of large woody material and terrestrial insects that serve as salmon prey, affect sediment transport processes by either accelerating or limiting input, and increase erosion. Construction of new hard shoreline armoring in residential areas, or to support the new pier could result in similar impacts, such as, interrupting sediment transport processes that sustain habitats, modifying intertidal slopes and substrates, and removing aquatic and riparian vegetation. As a result, degradation of habitats used by forage fish, salmon, Dungeness crabs, groundfish and other fish and wildlife species could occur. Figure 16, page 133, shows the current shoreling armoring at Cherry Point.

Water and Sediment Quality

Increases in stormwater runoff from impervious surfaces can alter biotic communities that have adapted to the salinity regime, as well as, carry pollutants into the reserve. Increases in contaminants could include: excess fertilizers, herbicides, and insecticides from residential areas; oil, grease, metals, and toxic chemicals from road and commercial facilities; soil from erosion on construction sites and eroding bluffs due to drainage problems on residential properties; bacteria and nutrients from pet wastes, and faulty septic systems. Unless the Treiol site is cleaned up, it will likely continue to contaminate groundwater that may be entering the reserve and contributing to herring mortality.

Buildout of residential and industrial uses at Cherry Point are likely to increase stormwater and municipal wastewater discharges. Increases in industrial, municipal, and stormwater outfalls can alter salinity regimes and increase ambient temperatures and pollutants in receiving waters and sediment at Cherry Point. Increases in both nonpoint and point sources at Cherry Point, including sediment and groundwater legacy sources, could contribute endocrine disrupting compounds, persistent organics, or other toxic compounds that may affect the health of fish and wildlife species**.** Contaminants may also increase due to airborne emissions associated with increases in vessel traffic. The cumulative impacts of increased temperature and pollutants could be significant.Temperature increases could increase invasions of non-native species, or affect herring spawning times. Climate change may worsen the impacts of contaminants due to increased water temperature and photo enhanced toxicity. Herring, groundfish, marine mammals, crab larvae and seabirds are particularly at risk due to chemical contamination**.** For herring, PCBs and other persistent organic pollutants with the ability to alter immune function may make the fish more susceptible to infection. Studies show chemical contamination is also a moderate risk to groundfish reproduction (WDFW 2009). Killer whales are candidates for accumulating high concentrations of pollutants because of their position atop the food web and long life expectancy (NMFS, 2008).

Other potential impacts to the aquatic reserve from climate change and global warming include ocean acidification, sea level rise, and increased storm severity. Nearshore resources that are temperature sensitive, such as crab larvae and herring spawning, may be affected by increases in water temperatures. Projections vary, but range from a 7- to- 23 inch rise in global average sea level by

2090-2099. Climate change could result in increased coastal erosion, all or some of which may result in changes to species abundance and distribution. Sea level rise and increased erosion can increase pressure to install hard shoreline armoring structures. A reduction in the availability of tidal marsh/tidal flat habitats could occur, as sea levels rise combined with increased river flow increases the salinity of the nearshore area while decreasing the availability of tidal marsh areas. Commercial shellfish communities (e.g., oysters and clams) and migratory shorebird populations that utilize these flats for habitat and feeding may also decline.

Recreational Activities

Population growth in the region is likely to increase demand for recreation opportunities and harvesting of renewable resources. Habitat degradation due to unfilled shellfish holes, trampling of sensitive vegetation, wildlife disturbance by dogs and human activities, and beach fires is likely to continue or worsen. Impacts to aquatic vegetation and water quality impacts could likely occur from increased recreational boat traffic and overwater structures. Derelict gear from recreational and commercial activities can continue to catch crabs, groundfish and other species.

Vessel Traffic

Vessel traffic within the Cherry Point region is predicted to increase within the next 10 to 20 years. In general, increased vessel traffic can increase the risk of spills, discharges, potential impacts from fugitive dust and noise, introductions of invasive (non-native) species from ballast water, and wildlife strikes. Major expansions at the Port of Vancouver will likely increase vessel traffic density in the approaches to and from Cherry Point. The area is also frequently used by commercial and recreational crab-fishing vessels, commercial trawlers and by seasonal whale-watching tours. Large vessels load and unload raw materials and products at the three current facilities located in the Cherry Point area. These facilities have shown a steady increase in productivity, expansion, and commercial growth, which along with the proposed pier, could result in a significant increase in regional and international vessel traffic transporting raw material and finished products. The refineries have necessary procedures and technologies in place to significantly reduce the likelihood of oil spills or minimize spill volumes, such as the Oil Spill Prevention Plan, the Oil Spill Response Plan, the Spill Prevention, Control, and Countermeasure Plan, the Integrated Contingency Plan, and Oil Handling Personnel Training. However, the possibility exists for future spills, which could be particularly catastrophic to Cherry Point herring, Southern Resident Killer Whales and diving bird populations.

The rising levels of maritime shipping increase the risk of invasion by non-native species in Puget Sound and the Strait of Georgia. Un-exchanged ballast water discharges from commercial ships are a primary vector for introducing non-indigenous species. As commercial shipping has been increasing at Cherry Point, this is an area that has been monitored over the years. The risk of invasive (non-native) aquatic plant and animal species being introduced through ballast water is a serious one. Non-native aquatic plant and animal species can displace, disturb, consume, and compete with native species (CRS 2007). Non-native organisms may also be attached to the hulls of commercial vessels. This is an identified problem at Cherry Point (Markiewicz, A. et al, 2005). Other introductions result from recreational boaters, commercial aquaculture, indirect Canadian maritime sources, and some natural sources. European Green Crab (*Carcinus maenas*) is a potential threat to Cherry Point, having been captured along Vancouver Island.

Increased vessel traffic also increases the possibility of “strike” to wildlife in the vicinity of the vessel. Species may include fish, diving birds, seals, and dolphins, but the most commonly followed example is that of ships or vessels striking whales.

Noise

Noise from vessel traffic is expected to increase over time. Noise has been identified as a potential stressor on Pacific Herring (EVS 1999; Schwartz and Greer 1984). Most commercial fish react to loud noise; these reactions are most pronounced in migratory schooling fish which rely on hearing to detect environmental cues, such as approaching predators. Physical impacts have been documented with construction project noise, such as pile driving (Laughlin 2005). Noise is expected to increase from construction and operation of the new pier. The proposed pier alignment encroaches on the Cherry Point herring prespawn holding area, making potential impacts of noise associated with vessel traffic, barging and berthing, and loading and offloading materials of particular concern. It is unclear how vessels frequenting herring spawning grounds or industry pier operations affect herring spawning success, feeding behavior, or individual health (Settlement, 1999). Further study is needed to comprehensively assess the impacts.

4. Management Goals and Objectives

Desired Future Conditions

The Cherry Point Aquatic Reserve was designated to conserve (preserve, restore, and/or enhance) the aquatic habitats and species that make the site unique. This section of the plan provides goals and objectives to help ensure that these desired conditions can be met.The proposed goals are broad statements of desired future condition, formulated to conserve the sites natural aquatic communities, habitats, ecosystems, and processes, and the ecological services, uses and values they provide to current and future generations.

Achieving the desired future conditions of this plan will require partnerships between regulatory and proprietary agencies, tribes, businesses, non-government, property owners, resource users and the public. Several desired future conditions require actions to be taken on a broader scale, such as implementation of the state's Puget Sound Action Agenda[9].

Goal One: **Identify, protect, restore and enhance the functions and natural processes of aquatic nearshore and subtidal ecosystems that support endangered, threatened and sensitive species and aquatic resources identified for conservation.**

Objectives

1.1 Protect and restore naturally functioning environmental processes (nearshore drift and high energy intertidal environment) through application of standards for new and expanded uses and activities. Support voluntary efforts to reduce impacts of shoreline modification and carry out restoration.

1.2 Prevent non-indigenous organisms from invading or disrupting the ecosystem through implementation of management actions.

1.4 Consider climate change when planning restoration projects and future development.

1.5 Ensure future land use and permit decisions do not alter natural system forming processes, degrade habitat or result in impacts to key species.

Goal Two: **Improve and protect water quality to protect public health, support fish and wildlife species and healthy functioning habitats.**

Objectives

2.1 Work cooperatively to identify and minimize existing and potential future water quality impacts on the nearshore environment resulting from outfalls, runoff, groundwater contamination, ballast, airborne sources, and other discharges to the Reserve. Monitor nearshore water quality and temperature and support local efforts to reduce adverse impacts over time.

2.2 Protect the reserve from new sources of water pollution, including airborne sources.

2.3 Reduce the risk of oil and toxic spills and increase regional capacity to respond.

2.4 Coordinate with resource agencies to continue to maintain state and federal standards for water and sediment quality.

Goal Three: **Protect and help recover indicator fish and wildlife species and habitats, with primary focus on Cherry Point herring, Nooksack Chinook salmon, groundfish, marine mammals, seabird/duck and shorebird communities, Dungeness crab, and submerged aquatic**

[9] See Puget Sound Partnership Action Agenda: Table 1-1: Ecosystem recovery goals, desired outcomes and provisional indicators, page 14 – 16. Goals 4, 5, and 6 (December 1, 2008)

vegetation.

Objectives

3.1 Protect, restore and enhance habitat that supports breeding, nesting, feeding habitat and migratory corridors for fish and wildlife.

3.2 Prevent impacts of new structures, shoreline modification, intakes and outfalls on aquatic vegetation, forage fish spawning, and fish migration, and minimize risks of environmental impacts from existing industrial, residential, and recreational uses.

3.3 Remove and reduce the impact from derelict fishing gear, debris and structures.

3.4 Support the recovery and protection efforts for federal and state threatened and endangered species, species of special concern and those that are the primary focus of this plan, and their habitats. Support efforts to increase Cherry Point herring biomass to 3,200 tons by year 5 and 5,000 tons by year 10 of the plan.

3.5 Carry out research and monitoring on the causes of species decline within the Reserve in order to develop actions that will be effective in helping with species recovery.

3.6 Encourage the removal or redesign of shoreline modifications to minimize or eliminate impacts on aquatic vegetation, forage fish spawning, and fish migration, particularly where the modifications are not necessary for the owners' use and enjoyment of the land.

Goal Four: **Facilitate stewardship of habitats and species by working in cooperation with lessees, tribes, recreational users and resource agencies to minimize and reduce identified impacts of human activities on the species and habitats of the Reserve**.

Objectives

4.1 Work with lessees to promote responsible management of existing uses in a manner consistent with Reserve goals. Support research efforts, monitoring, and adaptive management approaches that will assist lessees in reducing site-specific impacts over time.

4.2 Provide education and outreach opportunities and support others in efforts to educate homeowners abutting the shoreline and site users regarding the importance of managing runoff, riparian vegetation protection and other habitat values.

4.2 Make information and results readily available to the public, regulatory agencies, tribes and educational institutions.

4.3 Support regulatory agencies in using best available science, technology and management practices in permits for new development and activities to prevent harm to key habitats and species in the Reserve.

4.4 Coordinate with resource agencies and others to ensure recreational users will be informed and follow existing laws so that impacts to habitats and species are avoided or minimized.

4.5 Support and carry out research and monitoring to identify actions to increase resilience of habitats in the face of climate change, provide a greater understanding of the ecosystem, and reduce uncertainty about habitat and species interactions and threats.

4.6 Work with Whatcom County, State Parks and others to preserve and enhance existing opportunities for public access and environmental education.

4.7 Coordinate with lessees, US Coast Guard, and other cooperators to minimize conflicts between different sectors of commercial and other vessel traffic, and prevent impacts to marine mammals and other species.

Goal Five: **Identify, respect, and protect archaeological, cultural, and historical resources on state-owned aquatic lands.**

Objectives

5.1 Ensure that authorized activities in or directly adjacent to the Reserve cause no harm to the archaeological, cultural or historical resources in or adjacent to the Reserve.

5.2 Ensure significant historical findings are documented as a condition of any new or expanded use authorizations.

5.3 Support cultural uses at the site through responsible management of natural resources that are part of their tradition and are required to sustain and enhance the quality of life of the tribes are protected and preserved for sustainable use.

5. Management Actions

Management actions have been developed to address the potential threats identified in Chapter 3 and the goals and objectives identified in Chapter 4. These management actions should be carried out over the first 10 years after plan adoption. The actions should maintain or improve the ecological condition of the Reserve and will assist in the adaptive management process that will occur after the first 10 years of plan implementation. Because the management actions in this plan will take several years to implement, actions have been prioritized to identify those that should be completed sooner versus those that may be completed in late as time and resources permit. Actions that should be initially undertaken, preferably within the first five years, are identified as tier one, and actions that may be initiated as time and resources permit, are identified as tier two. DNR actions related to use authorizations are considered tier one and should be implemented throughout the 90-year period or until amended through adaptive management processes. This prioritization is based upon the analysis of risks and the future desired conditions of the plan, and should be periodically revisited as our understanding of the relationship between ecological processes, anthropogenic stressors, and species or habitat conditions decline at the Reserve improves.

DNR will use this plan to guide decisions regarding authorizations for uses of state-owned aquatic lands within and directly adjacent to the aquatic reserve. The management emphasis for new authorizations on state-owned lands will place protection of native aquatic habitats above all other management actions. For existing uses located on state-owned aquatic lands directly adjacent to the reserve, the focus will be to reduce their existing impacts over the 90-year time frame of the reserve. Since impacts to sensitive habitats and species within the reserve may also be attributed to activities that DNR does not have explicit authority to manage, such as upland uses, DNR will seek management cooperation and collaboration from others resource management agencies. DNR will work with regulatory agencies, tribes and others to ensure that existing, future uses and activities contribute to the management goals of this plan.

The management actions for the Cherry Point Aquatic Reserve focus on protection and restoration of sensitive aquatic resources in the context of planning for existing, future industrial, recreational, stewardship, and cultural uses of state-owned lands. The actions are grouped under six categories:

- Conservation of Ecosystems, Habitats and Species
- Restoration and Enhancement
- Outreach and Education
- Monitoring, Data Collection, and Research
- Allowed Uses
- Prohibited Uses.

Conservation of Ecosystems, Habitats and Species

Tier 1

DNR will protect ecosystems, habitats and species at the site through appropriate limits on use authorizations. DNR will:

- Manage existing and future activities on state-owned aquatic lands with an emphasis on protection of the aquatic habitat and species identified in this plan over other actions. (See the allowed uses section for specific standards).

- Ensure through use authorizations that structures, uses, and operations are designed to avoid impacts to wave energy, nearshore sediment drift, aquatic and riparian vegetation, fish and wildlife species and their habitats. Development and operation of the new overwater structure and modification or expansion of existing structures must be designed to avoid and or minimize noise, light, wave shading, and artificial light based on required studies, scientific research and monitoring, and knowledge of the ecosystem characteristics. Prior to approval, the required studies listed in the 'allowed uses' section must be completed. *Meets objectives 1.1, 1.4, 3.1, 3.2, 3.4, 5.3.*

- Facilitate the development of site-specific habitat protection plans when appropriate. Habitat protection efforts may include: placement of important habitat on adjacent lands into conservation easements, or acquisition of tidelands, wetlands, and shoreline property through gifts. *Meets objectives 1.4, 2.2, 3.1, 3.2, 3.4, 4.6, 5.3.*

  Support recovery efforts for Cherry Point herring. Work with WDFW, the Tribes, and other agencies to reverse the decline and bring the population to a spawning herring biomass of 3500 tons by the end of 5 years and 5000 tons at the end of 10 years.*Meets objectives 1.4, 2.2, 3.1, 3.2, 3.4, 4.6, 5.3.*

- Prohibit new "hard" structured shoreline armoring on state-owned aquatic lands. . Habitat-friendly alternatives may be authorized if designed to avoid and minimize impacts (as recommended by the Integrated Streambank Protection Guidelines, Washington State Aquatic Habitat Guidelines Program, 2002). However, replacement of existing shoreline armoring with hard armoring, when the only alternative to adequately protect existing structures, may be authorized when consistent with the Whatcom County SMP. *Meets objectives 1.1, 1.4, 3.1, 3.2, 3.4, 5.3.*

- Prohibit the following in the reserve: underwater cable or pipeline structures, or new saltwater intakes, except when necessary for the installation and use of firefighting equipment at industrial piers. *Meets objectives 1.1, 1.4, 2.1, 3.2, 3.4*

- Prohibit additional residential docks within the reserve. Mooring buoys may be installed to avoid impacts to marine vegetation and species. *Meets objectives 1.1, 1.4, 3.1, 3.2, 3.4, 5.3.*

- Determine the need for mooring buoys to address interaction between tug and tow operations and crab fisheries. *Meets objectives 1.1, 1.2, 1.4, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1, 4.5, 4.6, 5.1, 5.3.*

The following management actions are collaborative and DNR will seek partnerships to facilitate voluntary stewardship activities on private property and public lands adjacent to the aquatic reserve:

- Request that WDFW enforce existing shellfish harvest regulations with emphasis on the ecological impacts of unfilled holes. Promote partnerships with WDFW, Whatcom County, beachwatchers, and others to place informational signs and placards at key beach access points, and provide education and outreach. In the event continued damage to the herring spawning grounds is occurring, despite several years of public outreach efforts, discuss with WDFW whether seasonal or complete closures are warranted. *Meets objectives 3.1, 3.4, 4.4, 5.3.*

- Maintain natural slope stability characteristics through vegetation management requirements. *Meets objectives 1.1, 1.3, 1.4, 2.2, 3.1, 3.2, 3.4, 5.3.*

- Where opportunities arise, partner with state and local government, tribes, non-profit organizations, businesses, and adjacent landowners to identify and implement protection of adjacent aquatic areas and uplands. Special consideration should be given to protection of the salt marsh at Gulf Road. *Meets objectives 1.4, 2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.4, 4.1, 5.3.*

- Support public education, outreach and incentive programs for the protection of existing native vegetation to maintain wooded buffers within the setbacks landward of the top of the bluff. DNR will support development of a plan addressing maintenance and restoration of bluff vegetation. *Meets objectives 1.1, 1.4, 3.1, 3.2, 3.4, 4.2, 5.3.*

- Encourage Whatcom County to implement the following restrictions and/or recommendations on the public beaches accessible from the new park at Point Whitehorn:

- No dogs should be allowed on the beach. They cause disturbance and harassment of birds and wildlife. A seal haul-out area is near the park access.

- Education should be provided regarding the sensitivity of the Cherry Point ecosystem. Visitors should be advised to “stay on bare rock and sand” to avoid trampling of sensitive aquatic plants and organisms. This could be accomplished through the placement of informational signs and placards at key beach access points.

- No beach fires should be allowed.

- Visitors should be advised to avoid illegal removal of marine organisms (see WDFW regulations), wood and substrate. *Meets objectives 1.1, 1.4, 2.2, 3.1, 3.2, 3.4, 4.2, 4.4, 4.6, 5.3.*

- Encourage Whatcom County to coordinate with the owner of the beach in the area of Gulf Road so that public access may be improved and developed in the future, and strive for the same levels of protection provided at the Point Whitehorn Park. *Meets objectives 1.1, 1.4, 2.2, 3.1, 3.2, 3.4, 4.3, 4.6, 5.3.*

- Review and comment on proposed Coast Guard vessel traffic risk mitigation efforts. Consider vessel traffic studies conducted for BP and Gateway Pacific Terminal and other available vessel traffic information in environmental review and determinations related to the permitting of dock operations and potential impacts on herring, marine mammals, and other species. Data from these studies and future studies may also be used to develop vessel traffic risk mitigation strategies, as appropriate, in coordination with: Coast Guard, WDFW, Ecology, Whatcom County, Cherry Point industries, pilot associations (Puget Sound Pilots) and affected tribes and public interest groups. *Meets objectives 1.1, 1.4, 2.3, 3.1, 3.2, 3.4, 4.1, 4.3, 4.7, 5.3.*

- Review and comment on federal and state rules proposed to mitigate impacts to natural resources from any future changes or increases in risk from vessel traffic along Cherry Point to include vessel anchorage options. In coordination with Coast Guard,WDFW, Ecology, DNR, Whatcom County, Cherry Point industries, pilot associations (Puget Sound Pilots), industries, affected tribes and public interest groups.

- In coordination with Coast Guard, industries, pilot associations (Puget Sound Pilots), commercial and tribal fishermen, analyze vessel interference and evaluate options for reducing impacts from anchoring and barge in tow on habitat and loss of fishing gear. Consider viability of open water mooring systems. *Meets objectives 3.1, 3.2, 3.3, 3.4, 4.1, 4.7, 5.3.*

- Provide input regarding future additional Geographic Response Plan updates focusing on protecting heavily used herring spawning areas. *Meets objectives 2.2, 2.3, 3.1, 3.4, 5.3, 4.7, 5.3.*

Water and Sediment Quality Protection and Ballast Management

Tier 1

- DNR will protect the reserve from pollution through appropriate limits on use authorizations. Specifically, DNR will:Require lessees to demonstrate that new point source discharge outfalls for stormwater, or industrial wastewater, and increases in discharges from existing DNR authorized facilities are designed to avoid or minimize individual and cumulative adverse impacts to Cherry Point herring stock, other aquatic habitat, and water quality (see allowed uses section). *Meets objectives 1.4, 2.1, 2.2, 3.1, 3.2, 3.4, 5.3.*

- For modification of existing point source discharge outfalls or stormwater conveyance pipes, lesee must demonstrate that the water does not exceed water quality standards. Monitoring reports demonstrating compliance with standards must be submitted to DNR prior to completion of modification.

- Require that construction of the new pier or modification and expansion of existing overwater structures be designed and installed in a manner that avoids or minimizes impacts on the water quality of the Cherry Point Reserve, including avoiding or minimizing runoff impacts and removing treated wood from below the water line to the maximum extent practical to eliminate leaching.

- Work with dischargers to reduce impacts of existing discharges, exploring opportunities for treatment, reuse, and other methods.

The following management actions are collaborative and DNR will work cooperatively with others to formulate and implement strategies to address point and non-point source impacts. DNR will:

Tier 1

- Encourage Ecology to fund and implement the Treoil Site Emergency Interim Actions (March 2000) to characterize and stabilize waste and releases at the site. Ecology should raise this site to a higher priority on their Contaminated Sites List for remedial action because of questions for potential contamination of the reserve and clean-up plan for groundwater contamination from the Treoil site, if warranted. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 5.3.*

- Work with resource agencies to increase the rates of ballast water exchange monitoring for vessels that dock with the Cherry Point Reserve. *Meets objectives 1.2, 2.2, 3.1, 3.2, 4.1, 4.5, 5.3.*

- Work with WDFW, Ecology, and leaseholders to develop strategies for dealing with ballast water from ships that call at Cherry Point terminals consistent with Chapter 77.120 RCW, WDFW ballast water management, the interim ballast water management laws, and upcoming recommendations of the Ballast Water Working Group. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 4.1, 4.3, 5.3.*

- Work with Whatcom County, Ecology, and industries to minimize or prevent any new sources of nonpoint pollution to the Cherry Point Aquatic Reserve. Special emphasis should be placed on limiting impacts from stormwater runoff. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 5.3.*

- Work with Ecology and dischargers to address any known permit or regulatory violations to ensure ongoing compliance with State Water Quality Standards and Sediment Management Standards**.** *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.2, 4.1.*

- Encourage Ecology to require sediment quality studies as a part of all NPDES permits. *Meets objectives 1.5, 2.1, 2.2, 2.4, 3.1, 3.2, 3.4, 4.1, 4.3, 5.3.*

- Support Whatcom County in implementing the programmatic solutions identified as recommendations in the Birch Bay Comprehensive Stormwater Plan (2006), including low impact development designs where appropriate. *Meets objectives 2.1, 2.2, 2.4, 3.1, 4.1, 4.3.*

- Encourage Ecology to establish proposals for water quality treatment system upgrades to the existing discharges where needed, ensuring that they will minimize impacts to habitats and species. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.2, 4.1, 5.3.*

- Work with Whatcom County, Whatcom Public Utility District (PUD), Birch Bay Water and Sewer District, Ecology, and dischargers in support of proposals for the treatment and re-use of stormwater, re-use of treated wastewater and re-claimed water, and water conservation programs in order to reduce discharges. Assist existing dischargers with alternatives for water re-use, designs, permits, and information on applicable grant funds. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.2, 3.4, 4.1, 5.3.*

- Support Whatcom County and Birch Bay Water and Sewer District in designing and implementing strategies to reduce onsite wastewater systems that contribute pollution to the reserve. Seek funding alternatives to encourage landowner participation. *Meets objectives 2.1, 2.2, 2.4, 3.1.*

- Review and comment on ballast water treatment/management methods to reduce the possibility of introducing invasive species from tankers and other cargo vessels. Work with WDFW, Ecology, Coast Guard, EPA, leaseholders, the Invasive Species Council, U.W. Sea Grant, and others to limit testing of unproven treatment methods that have the potential to negatively impact native habitat and species. *Meets objectives 1.2, 2.1, 2.2, 2.4, 3.1, 4.7.*

- Work with WDFW, Ecology, Coast Guard, EPA, leaseholders, the Invasive Species Council, U.W. Sea Grant and others to develop and implement a management plan, including monitoring and adaptive management plans, to reduce the risks of non-native species to the valued ecological resources at Cherry Point. Strategies should include controlling the introduction of non-native plant and animal species and their management and eradication to protect native plant and animal communities. Ensure that protocols and monitoring efforts are expanded to address increased threats of non-native species from increased vessel traffic. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 4.1, 4.3, 4.7, 5.3.*

- Review and comment on Ecology's five-year review of Oil Spill Contingency Plans and stay apprised of changes that occur to plans in the interim. Coordinate with WDFW, affected tribes, ship, tug and barge companies, and Puget Sound Pilots. *Meets objectives 2.2, 2.3, 2.4, 3.1, 3.4, 5.3.*

- Review and comment on Ecology's five-year review of Oil Handling Facility Operations Manuals and stay apprised of changes that occur in the interim. Coordinate with WDFW, affected tribes, ship, tug and barge companies, and Puget Sound Pilots. *Meets objectives 1.4, 2.1, 2.2, 2.3, 2.4, 4.3, 5.3.*

- Request that Whatcom County and Ecology ensure that new shoreline related development does not cause erosion and nonpoint source pollution from upland activities. *Meets objectives 1.1, 1.4, 2.1, 2.2, 2.4, 3.1, 3.2, 3.4, 4.3, 5.3.*

- Review and comment on any proposed changes to tug escort requirements. Coordinate with WDFW, affected tribes, non-profit organizations, and Puget Sound Pilots. *Meets objectives 3.3, 4.7, 5.1.*

- Support the Coast Guard, NOAA and industries in updating the ballast water harbor care safety plan. *Meets objectives 2.2 2.3.*

Tier 2

- Encourage Whatcom County to provide technical assistance and incentives to property owners to retrofit existing tightline drains. Many are inadequate, resulting in erosion due to leaks and breaks. *Meets objectives 1.1, 2.1, 2.2, 2.4, 3.1, 3.4, 5.3.*

- Support Whatcom County in encouraging homeowners to intercept increased surface water and shallow groundwater resulting from alterations of the natural hydrology of upland

portions of bluff properties to maintain and restore natural rates of erosion from Point Whitehorn to Birch Bay State Park, specifically the Holeman, Birch Bay Drive Bluffs, and high berm segments (identified in Johannessen, 2003). *Meets objectives 1.1, 2.1, 2.2, 3.1, 3.4, 3.4, 5.3.*

- Work with the Coast Guard to ensure compliance with all state and federal regulations for the discharge of onboard sewage while transiting the Cherry Point Aquatic Reserve and while berthed at industry piers. *Meets objectives 1.4, 2.1, 2.2, 2.4, 3.1, 3.4, 4.3, 5.3.*

The following management actions are collaborative and DNR will work cooperatively with others to formulate and implement strategies related to atmospheric deposition:

- Assist participating industries with implementation of applicable measures from the Northwest Ports Clean Air Strategy, in coordination with EPA, Ecology, the Northwest Clean Air Agency, and participating industries. *Meets objectives 2.2, 2.4, 4.1.*

- When reviewing project proposals, DNR will consider information collected on Georgia Strait climate, microclimate, and sea level rise collected by the Office of the Washington State Climatologist (OWSC) and the Climate Impacts Group. *Meets objectives 1.1, 1.3, 1.4, 3.1, 3.4., 4, 5.3.*

Protection of Cultural Resources

Tier 1

- DNR will ensure that existing and proposed restoration and development activities on state-owned aquatic lands comply with all applicable mandated federal, state, and tribal cultural protection laws prior to any construction commencing along the Cherry Point shoreline, including, but not limited to: Archaeological Resource Preservation Act; National Historic Preservation Act; Clean Water Act; River and Harbors Act; Resource Conservation and Recovery Act; Safe Water Drinking Act; Clean Air Act; Endangered Species Act, National Environmental Policy Act; and Coastal Zone Management Act. *Meets objectives 3.4, 5.1, 5.2, 5.3.*

- DNR will ensure consistency of plan implementation with protection of tribal culture and values, treaty rights, and is consistent with the Northwest Tribes policy on Marine Protected Areas (NWIFC, 2003). *Meets objectives 5.1, 5.2, 5.3.*

- DNR will work with tribes, in coordination with the applicant, and the State Historic Preservation Office, the U.S. Army Corps of Engineers, and WDFW, to develop a 'Cultural Resources Protection Protocol' for activities on state-owned aquatic lands within or adjacent to the reserve. The protocol would include, but not limited to, requirements for appropriate pre-construction surveying, procedures for addressing inadvertent discoveries during clean-up and construction, and procedures for repatriation or re-interment. *Meets objectives 5.1, 5.2, 5.3.*

Restoration and Enhancement

Tier 1

DNR will develop restoration plans for specific areas and species within the reserve, partnering with state and local governments, tribes, non-profit organizations and adjacent landowners where possible. DNR will partner with various entities to identify restoration needs, develop and implement restoration plans within the reserve and seek funding for their completion. DNR will approve new proposals for restoration projects within the reserve when those proposals are determined to be consistent with the management goals and objectives of the reserve.

Specific areas where restoration efforts are being considered and/or pursued either by DNR or others include:

- Inventory and removal of harmfull debris and derelict fishing gear in the Cherry Point Aquatic Reserve. *Meets objectives 3.1, 3.3, 3.4.*

- Mapping and removal of rogue creosote logs along the beach at Cherry Point in coordination with City of Bellingham, Ecology, Beachwatchers, industrial landowners and the Whatcom Marine Resources Committee. *Meets objectives 2.2, 3.1, 3.2, 3.3.*

- Ensure that protection and restoration plans address the need to mitigate the effects of climate change upon the valued ecological resources described in this plan. Using likely scenarios of climate change developed through careful monitoring, data collection and vulnerability assessment, working in coordination with the Climate Impact Group of the University of Washington, Whatcom County, and others. *Meets objectives 1.3, 2.2, 3.1, 4.5, 5.3.*

DNR will support the following restoration projects through technical and funding assistance, or other support as appropriate:

- Annual marine debris beach cleanups conducted by industries, Beachwatchers, and Whatcom Marine Resources Committee. *Meets objectives 2.1, 3.1, 3.2, 3.3.*

- Whatcom County proposal to restore areas impacted by recreational shellfish digging activities to natural beach contours and documentation of the impacts/effects of restoration. *Meets objectives 1.1, 3.1, 3.2, 3.4, 4.4.*

- Voluntary landowner removal of the derelict gravel conveyor at Gulf Road to eliminate creosote pilings and allow recolonization of marine vegetation in the footprint of the structure. *Meets objectives 1.1, 2.1, 2.2, 3.1, 3.2, 3.3.*

- Whatcom County and Marine Resources Committee proposals for restoration of native plant species most adapted to the local conditions in areas of freshwater or marine shorelines where riparian habitat has been either removed or eliminated as a result of past human activities. *Meets objectives 1.1, 1.2, 3.1, 3.2, 3.4.*
- Whatcom County projects with various entities to encourage enhancement of native vegetation along shoreline, particularly along county-designated setback zones landward of the tops of bluffs. *Meets objectives 1.1, 1.2, 3.1, 3.2, 3.4.*

- Whatcom County, WDFW, and Ecology efforts to provide technical assistance and incentives to shoreline property owners to assist with removal of bulkheads or their replacement with soft bank or other alternatives to shore forms that promote natural processes. Sites include north side of Point Whitehorn and armoring at Gulf Rd. *Meets objectives 1.1, 1.3, 1.4, 3.1, 3.2, 3.4, 4.2, 4.3.*

- WDFW, Whatcom County, Ecology, and industrial pier owner proposals to evaluate and encourage options for restoring natural transport processes of sediment across impediments at the Cherry Point Aquatic Reserve, such as the pier aprons at Alcoa-Intalco Works and ConocoPhillips marine facilities, to help reduce impacts from existing structures and associated fill. *Meets objectives 1.1, 2.1, 3.1, 3.2, 3.4, 4.1, 5.3.*

- Cooperative efforts by Ecology, WDFW, affected tribes, and owners of overwater structures to encourage voluntary retrofitting improvements on older facilities with wave and light shading impacts. *Meets objectives 1.1, 3.1, 3.2, 3.4, 4.1, 5.3.*

- Efforts to identify and remediate unauthorized dump sites that may contribute contaminated runoff or groundwater into the reserve. *Meets objectives 2.1, 2.2, 2.4, 3.1, 5.3.*

Education and Outreach

DNR will work with resource agencies, tribes, user groups, local environmental groups, local clubs, and other interested citizens to implement the following education and outreach actions:

Tier 1

- Increase outreach to shellfish harvesters, fishing and crabbing industry, and recreational boaters about location of forage fish habitat.

- Outreach to the Puget Sound Pilot about efforts they could take to prevent impacts to forage fish habitat during spawning season.

- Provide signage at appropriate locations specifying regulations and interpretive education information related to impacts of recreational shellfish harvest.

- Education regarding the sensitivities of the Cherry Point ecosystem with emphasis on trampling of aquatic vegetation and disturbance of birds and seals (in haulout areas).

- Efforts targeting recreational boaters to reduce the introduction of non-indigenous species. Education and outreach on the use of eco-friendly fertilizers, herbicides, pesticides and riparian vegetation. *Meets objectives 1.1, 1.2, 2.2, 3.1, 3.2, 3.4, 4.2, 4.4.*

- Provide outreach to the public regarding issues and progress on the reserve. Develop a listserve, webpage, or email list to send updates. Work with interested parties to co-sponsor periodic conferences on Cherry Point reserve science, progress, and other issue of interest to the public.

Monitoring, Data Collection and Research

There are four components of research and monitoring within the reserve:

- Data gap analysis

- Establishing baseline conditions
- Trend monitoring to determine the effectiveness of management activities and document natural variation; and
- Research to better understand observed changes and the interactions between management activities and natural resource conditions.

Data gap analysis will help managers determine baseline conditions that represent the current quality of the Cherry Point ecosystem. These conditions set the baseline for monitoring ecosystem health to which future conditions will be compared in order to judge progress and effectiveness. Baseline monitoring will document current conditions by combining existing data with new characterizations of resources and ecological processes proposed in this plan.

After baseline conditions have been identified, continued monitoring for trends in habitat and species conditions should be conducted. Trend monitoring will be used to assess the success of management actions in attaining or exceeding the goals identified previously in this management plan. Trend monitoring is necessary in order to assess the need for course corrections related to improving the management actions. Research can compliment trend monitoring by providing possible answers for why species and habitats may be declining or improving.
Because there are many management actions related to data collection, monitoring and research, the following actions are a high priority over the first five years of plan implementation: 1) monitoring the effectiveness of protection actions that address existing and proposed use authorizations, and 2) research to reduce uncertainties about the decline of species targeted for conservation that can directly improve the effectiveness of management actions.

Data Gap Analysis

Participants in the development of this plan have identified the need for the following data. DNR will seek to partner with local, state and federal governments, tribes, research institutions, industrial users, and nonprofits to help reduce data gaps.

Tier 1

- Identify and catalog habitat protection, enhancement, and restoration opportunities with special emphasis on native submerged aquatic vegetation. *Meets objectives 1.2, 3.1, 3.4, 3.5.*

- Identify any additional necessary and immediate protections for forage fish spawning habitats, marine and terrestrial bird habitat, and submerged vegetation. *Meets objectives 2.2, 3.1, 3.2, 3.3, 3.4.*
- Monitor toxicity in the nearshore to assess potential impacts of contaminated groundwater discharges.

- Evaluate relationship of the Treoil site on groundwater and intertidal water quality. *Meets objectives 2.1, 2.2, 3.1, 3.2, 4.5*

Tier 2

Prepare a quarterly tabulation or annual summary reports of the following vessel traffic and spill data within the Cherry Point Aquatic Reserve:

- Seasonal vessel traffic and anchorage use
- Ecology boom reporting form submissions
- Quarterly summaries of the Cherry Point PORTS data
- Spill history and reporting
- Fuel/oil transfer interruptions due to weather conditions

- Near miss/incident data for vessels
- Recreational boating data, as available
- Changes to vessel traffic bound to and from the Cherry Point Aquatic Reserve area relative to existing and proposed regional commercial, recreational and port operations. e.g., DeltaPort Phase 3, Roberts Bank T-2 expansion, Gateway, marina expansions, etc. *Meets objectives 2.3, 3.1, 3.3, 4.7.*
- The impact on the Cherry Point Reserve for atmospheric deposition is unknown and currently not being researched. Investigate the potential impacts of vessel and other emission sources and global transport of air pollutants on water quality and sediment in the reserve. Support ongoing efforts to monitor deposition from air pollution and evaluation of its impacts in the vicinity of Cherry Point. *Meets objectives 2.1, 2.2.*

Baseline Monitoring

While a substantial amount of information has been collected for the Cherry Point Aquatic Reserve, gaps in characterizing the baseline still exist. DNR will seek to partner with local, state and federal governments, tribes, research institutions, industrial users, and nonprofits to conduct baseline monitoring. The following needs for baseline monitoring have been identified:

Tier 1

- Complete validation of the herring larval survival and growth test in a commercial lab to finalize protocol for use by regulated community. This action is a high priority because lessees are required to carry out studies as a condition of any lease authorizations associated with increases in stormwater or wastewater discharges (see Allowed Uses section). *Meets objectives 3.1, 3.2, 4.5.*

- Conduct detailed seafloor mapping and analyze habitat characteristics within the management area. *Meets objectives 3.5, 4.5.*

- Conduct detailed survey for derelict fishing gear. *Meets objectives 3.1, 3.3, 3.4.*

- Identify the location, extent and quality of other forage fish (e.g., surf smelt, sand lance) spawning habitat. *Meets objectives 3.1, 3.4, 3.5.*

- Measure the diversity, distribution, and abundance of intertidal species adjacent to and within the Cherry Point Aquatic Reserve. Work with WFDW to assess ballast water exchanges to inform methods of reducing invasive species transport. *Meets objectives 1.2, 3.4, 3.5.*

- Conduct research on the seasonal occurrence of larval organisms present along the Cherry Point Aquatic Reserve to help inform dispersant use decisionmaking by Incident Command in the event of a spill. *Meets objectives 1.2, 2.1, 2.2.*

- Coordinate with NOAA, WDFW, Industries, pilot associations (Puget Sound Pilots), USCG, Whale Network, commercial and tribal fishermen, scientists and researchers to collect and maintain a tabulation of presence/absence of marine mammals, including the following data to improve advice to mariners on when and where whales are most likely to occur:

- Proximity to vessel or ship if seen

- Behavior (feeding, breaching, other)
- Species (if known)
- Habitat use (if known)
- Date/time, tide and season *Meets objectives 3.1, 3.4, 3.5, 4.5, 4.7.*

Tier 2

- Reduce potential for vessel interference with marine mammals by identifying migratory pathways and habitat preferences; develop collision risk plan for ships and vessels in the area. *Meets objectives 3.1, 3.2, 3.4, 3.5, 4.1, 4.7.*

Trend Monitoring

DNR will partner with local, state and federal governments, tribes, research institutions, businesses, and nonprofits to identify and conduct trend monitoring for ecological conditions in and around Cherry Point Aquatic Reserve. If funding is available, monitoring plans will be developed to establish ecological trends and conditions at the site. Current and future trend analysis data identified to help guide management of the reserve include:

Tier 1

- Surveys to determine abundance, distribution, and population trends of nearshore and riparian bird species, such as ongoing studies including Western Washington University (WWU) and Pugert Sound Assessment and Monitoring (PSAMP) programs. All avian studies should be conducted throughout the year for a complete understanding of the use and trends in the Cherry Point Aquatic Reserve. *Meets objectives 3.1, 3.4, 3.5, 4.5.*
- Inventory and characterization of existing riparian condition, monitor condition at regular intervals, and evaluate trends and environmental effects of management. *Meets objectives 1.1, 3.2, 3.5.*
- Support and encourage partner agencies to undertake fish and wildlife surveys along the reach and increase surveys of herring spawn timing and behavior in response to light and noise. *Meets objectives 3.1, 3.2, 3.4, 3.5, 4.1, 4.5, 4.7, 5.3.*
- Continue monitoring of local fish (salmon, flatfishes, forage fish) and shellfish (Dungeness) populations to evaluate trends and effectiveness of management. *Meets objectives 3.1, 3.2, 3.4, 3.5, 4.1, 4.5, 5.3.*
- Continue the mapping of submerged aquatic vegetation within the reserve at five-year intervals to provide a dynamic inventory. Evaluate trends and environmental effects of management. Methodologies should be comparable with previous inventories. *Meets objectives 1.2, 3.1, 3.2, 3.4, 3.5, 4.1, 5.3.*
- Continued monitoring of the Cherry Point herring stock population and spawning events to evaluate trends and effectiveness of management. Track changes in the timing and location of

herring or other species that use the Cherry Point area as a spawning ground. These may be altered by changes in currents, temperature or other clues used by the Cherry Point Pacific herring to set spawning time and location. *Meets objectives 3.1, 3.2, 3.4, 3.5, 4.1, 4.3, 4.5, 5.3.*

- Track changes in species composition and the sensitivity of the community to shading effects and other factors. *Meets objectives 1.2, 3.1, 3.4, 3.5, 4.5.*

Tier 2

- Prepare summary reports of discharge data to evaluate long term trends. *Meets objectives 2.1, 2.2, 2.4, 2.4, 3.2, 4.1, 4.5.*

Track and report on facilities' efforts to reduce air pollution, the regional and global investigations, and look at new technology to address potential impacts. *Meets objectives* 2.2, 3.2, 4.1.

- Track changes in sedimentation and fill due to changes in currents or storm frequencies. Current and storm frequency and energy can be altered compared to historical conditions. Rates and direction of sediment transport may be altered as a result. *Meets objectives 1.1, 1.3, 3.1, 3.5, 4.5.*

- Develop a comprehensive monitoring strategy for climate change, considering the following:

- How alterations in climate will also change the patterns of occurrence of invasive species already established in the region. *Meets objectives 1.2, 2.2, 3.1, 3.5, 4.5.*

- Monitor temperature and currents entering the reserve, and map changes in species location, density of sea grasses, location of shellfish and other variables that may indicate long-term changes due to climate alterations or other factors. *Meets objectives 3.1, 3.4, 3.5, 4.5*

- Examine the effect of increased phototoxicity and temperature on PAHs and other key chemicals as the climate changes. It is already known that exposure to sunlight can lead to enhanced toxicity effects from PAHs. *Meets objectives 1.3, 2.1, 2.2, 3.1, 3.2, 3.4, 4.1, 4.5*
.
- Track the type and extent of habitat within the management area using models to predict likely outcomes. Habitat patterns will shift due to change in sea and air temperature, the type of disturbance regime and the colonization of the region by species adapted to warmer temperatures. There may be a tendency for some types of habitats to move in a north-south direction depending upon temperature and other habitat variables. It may prove necessary to create new habitats able to support species that can exist in a transformed region. *Meets objectives 1.3, 3.1, 3.4, 4.5.*

- Assess major changes in Fraser River and Nooksack River annual flow regime and water quality on local habitat and species. *Meets objectives 1.4, 3.4, 3.5.*

- DNR will support efforts to establish a consensus on sea level rise estimates statewide and coast-wide, through the National Academy of Sciences. *Meets objectives 1.3, 4.5.*

- Coordinate with WDFW and Whatcom County to measure and mitigate climate change among other management questions in the document. Since climate change is an all encompassing aspect of the Cherry Point Aquatic Reserve, coordination should take place to ensure that a mitigation plan for one area does not impact another area of management. An example would be protection against sea level rise by altering a shoreline; or providing protection against an increase in invasive species, which would be able to colonize the region because of an increase in water temperature. *Meets objectives 1.1, 1.2, 1.3, 2.1, 2.2, 2.4, 3.2, 3.4, 4.5.*

Research

DNR will seek to partner with local, state and federal governments, tribes, research institutions, industrial users and nonprofits to identify and develop research projects within the reserve. Any research activities that occur within the reserve must not result in damage to the ecosystem and must meet the goals and objectives of the reserve. Research opportunities may include, but are not limited to:

Tier 1

- Determine causes for small size, low hatch rate, and the high rate of abnormal development in Cherry Point herring stock both as an assessment of the intrinsic health of the stock and in regards to the geographical pattern of abnormalities seen in outplants along the shoreline in the 1990s. *Meets objectives 1.4, 3.1, 3.2, 3.4, 4.1, 4.5, 5.3.*

- Research ways to reduce shading of herring and forage fish habitat where necessary, and reduce evening illumination during spawning season. *Meets objectives 3.1, 3.2, 4.1, 4.3, 4.5, 5.3.*

- Assess effects of sound from commercial vessel traffic and dock operations on the spawning behavior of herring. *Meets objectives 3.1, 3.2, 3.4, 3.5, 4.1, 4.5, 4.7, 5.3. .*

- Evaluate recreational harvest impacts on the Cherry Point Aquatic Reserve nearshore marine environment to inform management strategies. *Meets objectives 1.1, 3.1, 3.2, 3.5, 4.4, 4.5.*

- Repeat and expand on the herring embryo temperature tolerance study. This is a requirement of lease authorizations involving expansion of discharge outfalls; see the 'Allowed Uses' section. *Meets objectives 2.2, 3.1, 3.2, 4.5*

- Develop monitoring protocols to track likely vectors (sources for introduction) of non-native organisms and support methods of treatment that reduce risks and avoid impacts to the Cherry Point Aquatic Reserve. Where non-native species have become established, characterize the occurrence and dynamics of non-native species at Cherry Point and study measures to safely eradicate the invaders and/or mitigate impacts. *Meets objectives 1.2, 2.2, 3.1, 3.2, 3.5, 4.1, 4.5.*

- Repeat and expand on the ambient water toxicity study to evaluate cumulative effects of industrial and municipal wastewater outfalls using protocols accepted by EPA and Ecology. Consider and/or evaluate the use of caged mussel, harbor seal blood chemistry, sediment monitoring, and other biological impact assessments for monitoring indicators of potential problems. (This is a requirement of lease authorizations involving increases in stormwater or wastewater discharges. See 'Allowed Uses' section). *Meets objectives 2.1, 2.2, 3.2, 4.1, 4.5.*

- Provide ongoing groundwater characterization with specific focus on nearshore contamination. *Meets objectives 2.1, 2.2, 3.1, 4.5.*

- Observe and review lessons learned from oil or other hazardous material spill preparedness drills and from spills. *Meets objectives 2.2, 2.3, 3.2.*

Tier 2

- Characterize sediment chemistry throughout the reserve. Areas outside *sediment impact zones* should be evaluated with particular attention to the intertidal and upper subtidal zones. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 4.5.*

- Characterize sediment, groundwater, and surface water sources and quality within the depositional zone of the surface water runoff at Unick Road. *Meets objectives 2.1, 2.2, 2.4, 3.1, 3.4, 4.5.*

- Examine changes in runoff frequency, volume and the fate of contaminants. The physical characteristics of the receiving water can change due to alterations in temperature, pH and other factors that alter the fate of the contaminants and the sensitivity of organisms. Patterns of stormwater quantity and timing are also susceptible to change as the climate is altered. Ambient toxicity testing should also take into account changes in receiving water temperature and changes in species composition of the appropriate receiving waters. Locate freshwater seeps and describe groundwater movement patterns from upland areas to nearshore. Describe volume of flows and effects on the marine ecosyste*m. Meets objectives 2.1, 2.2, 3.1, 4.5.*

- Assess the impact of shore armoring near Point Whitehorn and Gulf Road. *Meets objectives 1.1, 3.1, 3.2, 3.5, 4.5.*

- Characterize the occurrence and dynamics of non-native species at Cherry Point and sources of non-native species that can immigrate to the region. The study would also evaluate the probability of invasive species by vector. *Meets objectives 1.2, 2.2, 3.1, 3.2, 3.5, 4.1, 4.5.*

- Examine the pathways and threat of additional invasions and changes in the patterns of *Sargassum*. The change in physical parameters (currents, pH, oxygen, temperature) and the change in the composition in local community structure will alter the likelihood of invasion by organisms being transported by ballast water, currents or other vectors. *Meets objectives 1.2, 2.2, 3.1, 3.5, 4.5.*

- Collect and summarize data on natural climate change (El Nino, PDO) and human induced climat*e* change *(field research, models)* that may affect the Cherry Point Aquatic Reserve. This effort should include change in ocean currents, migration of species, changes in ocean acidity on the pH of the receiving water, and the toxicity of the wastewater streams and temperature regimen at the reserve. A contingency plan should cover what ecological resources are likely to be affected by climate change and which can be preserved given reasonable model outputs. *Meets objectives 1.3, 4.5.*
  Re-examine dilution models if currents change due to climate induced factors, including output volumes. There are uncertainties regarding how a changing climate might affect water quality in the reserve. Examine the need to adjust dilution ratios for temperature mixing zones in facility discharge permits as ocean temperatures rise. *Meets objectives 2.2, 4.5.*

- Assess changes in Fraser River annual flow regime and water quality on Cherry Point habitat and species. *Meets objectives 4.5,*

Allowable Uses

DNR will consider the following new uses for state-owned aquatic lands within or directly adjacent to (abutting) the aquatic reserve:

- Easement for Birch Bay Water and Sewer District outfall (see below for specific guidance)
- Existing industrial piers and associated outfalls (see below for specific guidance)
- One new pier as per 1995 DNR letter and the adopted Whatcom County SMP (see below for specific guidance)
- Sustainable recreational activities, including shellfish harvesting (see below for specific guidance)
- Environmental education where consistent with reserve objectives and appropriate public access
- Ecological monitoring if conducted under a monitoring plan approved by DNR
- Research in support of the reserve's goals and objectives
- Restoration projects that are consistent with the management of the reserve
- Commercial and recreational fisheries will be managed by WDFW, responsible tribal governments, and DNR shellfish section staff.
- Authorize mooring buoys if determined to be appropriate to address interaction between tug and tow operations and crab fisheries. *Meets objectives 1.1, 1.2, 1.4, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1, 4.5, 4.6, 5.1, 5.3.*

Existing Use Authorizations

As described in Chapter 1, there are no existing use authorizations on state-owned aquatic lands within the Cherry Point Aquatic Reserve. The existing use authorizations are located in the "cutouts" directly adjacent to or abutting the reserve. DNR cannot alter the terms and conditions of an existing lease, easement, or other use authorization without consent of the tenant or grantee.

This management plan does not alter existing contractual rights and obligations. Existing tenants or grantees may continue to conduct their activities in conformance with their current use authorization and in compliance with other local, state and federal regulations. DNR will encourage voluntary and cooperative efforts of existing lessees to implement the elements of this plan.

Water-dependent, industrial uses that require marine access are the preferred use of the Cherry Point Management Unit in the Whatcom County SMP. The SMP also recognizes the importance of the areas as herring spawning habitat and other key habitat characteristics that warrant special consideration, and limits the number of new piers to one (1) pier. Similarly, DNR recognizes the

Cherry Point reach to be of both great economic and ecological importance to the region. This plan provides guidance for DNR to facilitate authorizations for one future industrial lease, and modifications or renewals to existing leases at Cherry Point, while ensuring environmental protection and promoting species recovery.

The existing industrial uses at Cherry Point are not incompatible with goals for the long-term protection of the aquatic resources within and adjacent to the aquatic reserve. Therefore, the existing industrial uses do not conflict with aquatic reserve status at Cherry Point. The uses can further serve the objectives of the reserve if the facilities are managed according to this plan and lessees actively take steps to enhance compatibility of their facilities with reserve goals. Decisions for reauthorization for existing uses will be made by DNR, based on the facts and circumstances at the time of request for approval.

Reauthorization of Existing Uses

DNR will achieve the desired future outcomes for the Cherry Point Aquatic Reserve by integrating contemporary knowledge, research findings, and recommendations for action identified in this management plan into future lease and use agreements. DNR will also work with lessees to find ways to assure that their future use authorizations serve the reserve's long-term management objectives.

Consistent with statutory authority and agency policy for all applications to use any state-owned aquatic land, DNR will consider an application to reauthorize existing uses at Cherry Point when existing agreements expire. At the time of application for reauthorization, DNR will evaluate whether the proposal by the applicant conforms to this management plan based on the criteria specified below. As needed, DNR will work with the applicant to develop plans to reduce, over the term of the new agreement, any environmental impacts that may arise from existing facilities and uses. Such plans will be based on best available science, research and monitoring findings at the time of reauthorization. The content of such plans may vary between leaseholds depending on the extent to which a lessee had addressed environmental impacts during the term of the expiring agreement.

Consistent with DNR proprietary authority, reauthorizations may include terms requiring monitoring to help identify or reduce uncertainty regarding environmental impacts. This will allow DNR to determine conditions to include in subsequent future use authorizations in order to successfully provide environmental protection for the Cherry Point Aquatic Reserve, while also fostering water-dependent uses. If DNR adopts a habitat conservation plan for all state-owned aquatic lands, the agency will also integrate the habitat conservation plan's programmatic measures with the requirements of the Management Plan to address endangered species protection.

DNR will consider the following questions when evaluating applications from existing Cherry Point lessees and to determine consistency with this plan:

- Is the lessee in good financial and contractual standing with DNR?
- Is the lessee in compliance with conditions of federal, state and local laws and permits?
- Is the use managed in accordance with this plan and consistent with the objectives of the aquatic reserve, the Desired Future Conditions of this Plan, and, if the application for reauthorization includes a discharge outfall, have the additional reauthorization requirements related to discharge outfalls been met?

- Has the lessee submitted a plan proposing actions to reduce existing site-specific impacts to specific habitats and species identified for conservation?

While there is no environmental baseline for Cherry Point at present (developing a quantitative baseline is a goal of this plan), enough is known about many resources to make informed decisions about use authorizations. DNR will work with other resource management authorities to identify regulatory and proprietary actions necessary to protect resources.

Additionally, DNR will expect cooperation from lessees and the support of other interested parties to enhance the quality of habitat and provide long-term protection to the Reserve. If Cherry Point herring continue to decline at a statistically significant level, DNR will discuss approval of any future use authorizations at the site with WDFW, to determine how to reauthorize a use in a way to ensure protection of herring. *Meets objectives 1.1, 1.2, 1.4, 2.1, 2.2, 2.3, 3.1, 3.2, 3.4, 4.1, 5.1, 5.2, 5.3.*

Additional Reauthorization Requirements Related to Discharge Outfalls

Consistent with RCW 79.105.210, RCW 90.48.386 and WAC 332-30-122(2)(a) DNR may reauthorize, or approve lease modifications for existing discharge outfalls, or allow new discharge outfalls serving existing authorized uses under the following conditions:

- The outfalls must meet all current local, state and federal regulatory requirements, and water quality standards.
- The applicant must take all appropriate steps to avoid or minimize substantial or irreversible damage to the environment.
- The applicant must complete the following studies to determine potential impacts of the proposed activities on habitats and species, and identify appropriate measures for impact avoidance and minimization. DNR will use the results of such studies to ensure that leases include conditions to avoid or minimize damage to the environment. Studies include:
  - Herring larval survival and growth test protocol validation by commercial laboratories, to determine the relative sensitivities to the effluent from approved outfalls, as per Herring Agreed Order # 3192.
  - Completion of herring embryo temperature tolerance study, as per Herring Agreed Order #3192.
  - Repeat and expand testing to investigate the cause of herring embryo abnormalities as described by Hershberger, P.K., R.M. Kocan, 1999
  - For municipal outfall, assess cumulative impacts of wastewater to the waters of the Cherry Point Aquatic Reserve, including pharmaceuticals and other endocrine disrupters using analytical methods as described in Lubliner et. al. (2010). *Meets objectives 2.1, 2.2, 3.1, 3.2, 4.1, 4.5.*
  - Repeat and expand on the ambient water toxicity study including water temperature changes, as required by Herring Agreed Order # 3192, using protocols accepted by EPA and Ecology to evaluate cumulative effects of industrial wastewater outfalls and groundwater seeps on nearshore species survival and water quality.
  - Reassess bioaccumulation of PAH, PCB, and heavy metals in caged mussels as described by Applied Biomonitoring, 2002.

- For stormwater outfalls discharging to Birch Bay, implement the solutions recommended in the Birch Bay Comprehensive Stormwater Plan (2006) for the Birch Bay watershed. Completion of proposals that investigate treatment and re-use of stormwater, treated wastewater (currently discharged at Cherry Point) and re-claimed water, and water conservation programs in order to reduce discharges. *Meets objectives 1.1, 1.4, 2.1, 2.2, 3.1, 3.2, 3.4, 5.3.*

Approvals for Changes to Existing Uses and Facilities

Under certain conditions, this Management Plan allows for new uses of existing facilities, as well as expansion and significant modification of existing facilities (the type of work that under DNR's standard lease agreement would be considered new work rather than routine maintenance and repair). The proposal for such modifications must meet certain standards described below for alterations to existing facilities. Additionally, any structural modifications or operational changes to existing facilities that would result in increased artificial light, noise, wave or light shading, runoff, pollution, or other discharges must meet the standards below for alterations to existing facilities.

Alterations to Existing Facilities: Overwater Structures

DNR will not authorize alterations to the overwater footprint of existing facilities until the following conditions are met or studies complete. The purpose of these conditions is to assess potential adverse impacts of the proposed alteration on species and habitats to inform development of measures for impact avoidance and minimization that can be incorporated into lease agreements.

- Proposed changes to DNR authorized uses at Cherry Point shall avoid or minimize noise and artificial light impacts based on the recommendations formulated in existing studies, future research and monitoring.

- Modification to existing structures must be designed to avoid disruption of herring migratory patterns from deep water to the nearshore and along the nearshore.

- Proposed alteration of existing overwater structures must minimize wave and light shading to the maximum extent feasible and avoid adverse impacts to areas with significant biological aquatic resource value, such as sediment transport processes, aquatic vegetation, spawning areas, pre-spawn holding areas and migratory corridors. This should be accomplished through managing location, orientation, design, materials, construction best management practices, operation of structures and activities contributing to shading.

Approval of Authorizations for New Uses

To determine if a proposal is consistent with this plan and serves the objectives of the reserve, DNR will consider the following when reviewing applications for new uses.

New Overwater Structures

Due to the environmental sensitivity of the area, and consistent with the Whatcom County SMP, DNR will not authorize any overwater structures on state-owned aquatic lands in or adjacent to the Cherry Point Aquatic Reserve in addition to those existing as of 2010, except for one new structure currently planned where Pacific International Terminals proposes to build an industrial pier. If constructed, the additional pier will bring the number of overwater structures to a total of four piers. The additional new pier must meet the requirements of this management plan, serve the objectives of the reserve, meet all regulatory requirements, and conform to the terms and conditions of the 1999 Settlement Agreement, resolving Shoreline Hearings Board Appeals Numbers 97-22 and 97-23

concerning Pacific International Terminals' Shoreline Substantial Development Permit SHS 92-0020 (1999 Settlement Agreement).

DNR will not approve a lease for the new pier until the following conditions are met or studies complete. The purpose of these studies is to assess potential adverse impacts of the project on species and habitats to inform development of measures for impact avoidance and minimization that can be incorporated into lease agreements. Completion of the studies or fulfillment of the conditions does not guarantee that DNR will approve a lease. DNR will make a decision to issue a new lease based on the facts and circumstances at the time of application.

- Identify potential impacts and extent of salmon and herring behavior and distribution changes over time due to the artificial light and noise from the piers at Cherry Point. The studies should also investigate the potential changes in species abundance and dominance resulting from increased prey access under artificial lighting, and address ways to reduce or eliminate any identified impacts. The resulting recommended actions shall be incorporated into the plan of operations. This study shall be performed in coordination with: U.S. Coast Guard, Washington Dept. of Labor and Industries, Ecology, WDFW, ACOE, and affected tribes.

- Proposed designs shall avoid or minimize noise and artificial light impacts based on the recommendations formulated in existing studies, future research and monitoring.

- New structures must be designed to avoid disruption of herring migratory patterns from deep water to the nearshore and along the nearshore.

- The new pier must minimize wave and light shading to the maximum extent feasible and avoid adverse impacts to areas with significant biological aquatic resource value, such as sediment transport processes, aquatic vegetation, spawning areas, pre-spawn holding areas and migratory corridors. This should be accomplished through managing location, orientation, design, materials, construction best management practices, operation of structures and activities contributing to shading.

- Vessel traffic analysis must be completed and an assessment of traffic management needs evaluated as per 1999 Settlement Agreement.

New Discharge Outfalls

Consistent with RCW 79.105.210, RCW 90.48.386, and WAC 332-30-122(2)(a) DNR may issue new leases for outfalls to serve the one new industrial pier. As a condition of a potential lease authorization, DNR will require studies to be completed to determine the potential impacts of the proposed activities on habitats and species and identify appropriate measures for impact avoidance and minimization. DNR will use the results of such studies to ensure the leases are conditioned to avoid or minimize damage to the environment. The conditions and studies required for authorization consideration include:

- The outfalls meet all local, state and federal regulatory requirements, and water quality standards.

- Appropriate steps are taken to avoid or minimize substantial or irreversible damage to the environment.

- All Supplemental Permit Conditions of the 1999 Settlement Agreement have been met.

- Conduct ambient water toxicity study using protocols accepted by EPA and Ecology to evaluate cumulative effects of existing industrial wastewater outfalls and groundwater seeps on nearshore species survival and water quality. Caged mussel studies and/or harbor seal bioassays may be used as biological indicators of toxicity. Study design may be based on similar study required by Herring Agreed Order # 3192. Project proponent may coordinate study with existing authorized uses that are also required to conduct ambient water toxicity study, as identified in Additional Reauthorization Requirements Related to Discharge Outfalls section above.

- Assess bioaccumulation of PAH, PCB, and heavy metals in caged mussels as described by Applied Biomonitoring, 2002.

Shoreline modification along Cherry Point

New structures or proposed modifications to existing structures must be designed to avoid impacts to wave energy, nearshore sediment drift, and aquatic and riparian vegetation. Only aquatic habitat-friendly methods of shoreline armoring (as recommended by the Integrated Stream bank Protection Guidelines, Washington State Aquatic Habitat Guidelines Program, 2002) will be authorized on state-owned aquatic lands. Exceptions will be made for replacement of existing shoreline armoring to protect existing structures, as long as consistent with the Whatcom County SMP. *Meets objectives 1.1, 1.4, 3.1, 3.2, 3.4, 5.3.*

Prohibited Uses

Saltwater Intake Structures

DNR will not authorize saltwater intake structures within or directly adjacent to the reserve, except in those cases when it is necessary for the installation and use of firefighting equipment at the industrial piers.
Meets objectives 1.1, 1.4, 2.1, 3.2, 3.4.

Cable or Pipeline Installations

DNR will not authorize cross-channel cable or pipeline installations within or directly adjacent to the reserve.*Meets objectives 1.1, 1.4, 2.1, 2.2, 3.1, 3.2, 3.4.*

Other Uses

DNR will not consider authorizing any uses in the reserve other than those identified above, unless the use is consistent with the purpose of the reserve management objectives of this plan. Any uses proposed on state owned aquatic lands directly abutting the reserve must not conflict with the purpose of the reserve designation or with the protection of habitat and species identified for conservation within the reserve.
Meets objectives 1.1, 1.2, 1.4, 2.2, 2.3, 3.1, 3.2, 3.4, 5.1, 5.2, 5.3.

6. Plan Implementation

The successful management of the Cherry Point Aquatic Reserve will require coordination and collaboration with public and private entities as well as local, state, federal, and tribal government, and non-government organizations. Review and evaluation of sound scientific and management information by resource managers should guide the future development, restoration and protection decisions. To increase collaboration in decision making, resource managers should consider forming a permanent workgroup whose purpose would be to guide the implementation of this plan and coordinate decisions that will affect the long-term health of resources and ecosystems of the Cherry Point Aquatic Reserve.

To enhance coordination and cooperation the resource managers are encouraged to jointly develop a Memorandum of Understanding (MOA) to address issues of mutual interest in the Cherry Point area. The MOA should describe how these entities will coordinate the discharge of their authorities and responsibilities, and state how they intend to work together to achieve desired outcomes for resource protection as presented in this plan for the Cherry Point Aquatic Reserve. The resource managers and their entities should seek information and review recommendations for action from this plan and other locally developed plans, the Puget Sound Partnership, the scientific community, local industry, Whatcom County Marine Resources Committee, environmental stakeholders, and other local interest groups in making decisions.

The resource managers may choose to establish advisory committees to enhance review and input on specific research, protection or restoration efforts.The resource managers should rely on existing regulatory and governmental decision processes as the basis for managing activities of the regulated community including general land use. Decisions by the resource managers should support the long-term objectives as stated in this plan and the MOA.

In addition to coordinating with each other, the resource managers should coordinate decisions and activities related to the maintenance of navigation, water quality and habitat protection with U.S. Corps of Engineers, U.S. Fish and Wildlife Service, NOAA Fisheries and U.S. Environmental Protection Agency. Decisions and activities related to vessel traffic management, spill prevention, and clean-up should be coordinated with U.S. Coast Guard, Ecology, Northwest Area Committee, interested tribes, and the fishing industry. Under the MOA, significant decisions and documents should be shared and discussed with resource managers prior to implementation.

Coordination with Community Groups

Many actions will require the assistance of nongovernmental entities. Such as, monitoring, research, restoration and environmental education.These largely non-regulatory actions can support plan implementation and will require careful coordination and clear delineation of responsibility and activity. DNR will make sure that group efforts are regularly coordinated with the resource managers and opportunities for discussion are established. Emphasis should be on making information available to the public and community groups for review and feedback on priorities selected by the resource managers.

Funding

Implementation of this plan is anticipated to be a cooperative effort. A coordinated approach to funding for the activities will be a key to successful achievement of the plan’s goals. DNR seeks to

coordinate funding efforts to ensure that the plan is implemented based on priorities established in this plan and with input by the resource managers. DNR will seek funding to ensure the completion of all management actions required for approval of new leases, lease modifications, and lease renewals, however, DNR also encourages current and potential future leases to seek funding for these required studies as well. This will ensure that studies are funding and completed consistent with leesee needs Funding will be sought from a variety of sources including grants, agencies and other sources. As obligated by their permits, lessees will fund required regulatory mitigation associated with the ongoing operations of their facilities. DNR will encourage lessees and other governmental agencies to consider proactively participating in cooperative efforts to assist in ensuring the funding of issues identified in this plan.

Adaptive Management

Adaptive management is a key component to success of the Cherry Point Aquatic Reserve Management Plan. Adaptive management is a systematic process for improving management programs by learning from the outcomes of actions taken. Adaptive management requires tracking progress in carrying out the plan, making technical assessments about effectiveness of plan actions, managing and sharing data, evaluating and communicating progress, and determining whether course corrections are needed to make the plan more effective over time. Adaptive Management also allows for science-based approaches to fill data gaps and provides a framework to address uncertainties in the coming years.

The successful management of the Cherry Point Aquatic Reserve will require coordination and collaboration with public and private entities as well as local, state, federal, and tribal government, and non-government organizations. Review and evaluation of sound scientific and management information by resource managers should guide the future development, restoration and protection decisions.

This plan contains numerous actions that will be implemented by DNR and others. DNR will be responsible for tracking implementation of actions, research, and monitoring for the reserve. DNR will also assist with management of data collected through research, monitoring and other sources. DNR will develop a monitoring database to coordinate and compile the data collected by DNR and other entities during ongoing monitoring activities within and adjacent to the reserve. This will require the cooperation of agencies, affected tribes, industry, community groups and research institutions.

Because the management actions in this plan will take several years to implement, actions have been prioritized to identify those actions that should be completed in the first five years. Considerable gaps exist in our understanding of ecological processes and the relationship of the risk factors to the decline of targeted species within the aquatic reserve. Therefore, actions in the first five years will focus on establishing priorities for research to reduce uncertainties about the cause of species decline that can directly improve the effectiveness of actions, and on effectiveness monitoring. The purpose of effectiveness monitoring is to assess the success of management actions in attaining the future desired conditions. With increased understanding of the relative role various risk factors play in species decline, and the effectiveness of proposed management actions, management activities can be further refined and targeted. Quantifiable management goals and actions will be developed and adjusted over time based upon the established baseline conditions to aid in attaining the desired long-term future conditions for the resources of the aquatic reserve.

Through the adaptive management process, the resource managers will need to focus on the achievement of the desired future outcomes. An evaluation process shall be established early in the implementation process that will provide the basis for determination if implementation of actions in

this plan is achieving outcomes in all areas. Adaptive management of the reserve will integrate changes in scientific knowledge concerning the site, conditions of habitats and species, and existing uses of state-owned aquatic lands. Data and reports generated from research and monitoring activities will also be used to guide DNR in determining if management actions are meeting the goals and objectives of the reserve. If management actions are not successfully contributing to the goals and objectives for the reserve, then they will be modified, monitored, and evaluated during the following 10-year review process in accordance with adaptive management strategies.

DNR will review and update this management plan at least every 10 years, or more frequently if deemed appropriate. Among other things, changes in scientific knowledge concerning the site, conditions habitats and species, and existing encumbrances will be included in the updates. Additionally, data and reports generated from research and monitoring activities will be evaluated in attempts to determine if management actions are meeting the goal and objectives of this plan.

Glossary

Antidegradation Policy — The Clean Water Act's (CWA) antidegradation policy is found in section 303(d) (and further detailed in federal regulations) and its goals are to 1) ensure that no activity will lower water quality to support existing uses, and 2) to maintain and protect high quality waters. States must adopt an antidegradation policy and methods for implementation.

Aquatic Lands — All state-owned tidelands and bedlands. "Aquatic lands" means all state-owned tidelands, shorelands, harbor areas, and the beds of navigable waters (RCW 79.105.060(1)). Aquatic lands are part of the public lands of the state of Washington and include many public places, waterways, bar islands, avulsively abandoned beds and channels of navigable bodies of water, managed by the department of natural resources directly, or indirectly through management agreements with other governmental entities.

Aquatic Reserve Program — The Aquatic Reserve Program is an ecosystem-based program created to establish aquatic reserves on selected state-owned aquatic lands to protect identified important native aquatic ecosystems. Aquatic reserves are lands of special educational or scientific interest, or of special environmental importance (WAC 332-30-151).

Authorization instrument — A lease, material purchase, easement, permit, or other document authorizing use of state-owned aquatic lands and/or materials.

Ballast water: — Ballast water is held in tanks and/or cargo holds of ships to provide stability and maneuverability during a voyage when ships are not carrying cargo, are not carrying heavy enough cargo, or require more stability due to rough seas.8 Ballast water may be either fresh or saline. Ballast water may also be carried so that a ship rides low enough in the water to pass under bridges and other structures.

Beach: — The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach is the extreme low water line. A beach includes a foreshore and a backshore.

Bedlands, Beds of navigable waters: — Those submerged lands lying waterward of the line of extreme low tide in navigable tidal waters and

	waterward of the line of navigability in navigable lakes, rivers and streams.
Benthic Zone:	The benthic zone is the lowest level of a body of water, such as in an ocean or a lake. It is inhabited by organisms that live in close relationship with (if not physically attached to) the ground, called benthos or benthic organisms.
Biological Diversity:	The various plant and animal species representative of and native to a site. "Regional biological diversity" is protected when habitat is provided to species that are becoming locally rare due to loss of habitat.
Biotoxin (marine):	Marine biotoxins are poisons caused by microscopic toxin-producing algae (a type of phytoplankton) that naturally occur in marine waters, normally in amounts too small to be harmful. However, a combination of warm temperatures, sunlight, and nutrient-rich waters can cause rapid plankton reproduction, or "blooms."
Bluff:	An unvegetated high bank composed largely of unconsolidated deposits with a near-vertical face overlooking a body of water.
Cliff:	A high, very steep to perpendicular or overhanging face of rock rising above the shore.
Coastal Zone:	The sea-land fringe area bordering the shoreline where to coastal waters and adjacent lands exert a measurable influence on each other.
Commerce:	The exchange or buying and selling of goods and services. As it applies to aquatic land, commerce usually involves transport and a land/water interface.
Critical Habitat:	Those areas necessary for the survival of threatened, endangered, sensitive species, as designated under the Federal Endangered Species Act and Washington State Forest Practices Rules.
Cultural Resources:	Archeological and historic sites and artifacts, whether previously recorded or still unrecognized, as administered by Department of Archaeology and Historic Preservation (DAHP) and protected under Title 27 RCW.
Dredging:	The enlarging or cleaning out a river channel, harbor, etc.

Ecosystem:	An ecological community consisting of all the living and non-living components of the physical environment.
Endangered, Threatened and Sensitive Species (ET&S):	Plants and animals protected under the federal Endangered Species Act or state designation.
Enhance:	To intentionally re-create elements that existed on site before disturbance, or introduce new functions or characteristics to a site.
Epibenthic:	Living on the bottom of the ocean.
Extreme low tide:	The line as estimated by the federal government below which it might reasonably be expected that the tide would not ebb. Varies by location.
Habitat:	The components of the ecosystem upon which a plant or animal species relies for its life cycle.
Hydraulic Project Approval:	Permit issued by the Washington State Department of Fish and Wildlife, the purpose of which is to address any damage or loss of fish and shellfish habitat which is considered to result in a direct loss of fish and shellfish production.
Intertidal:	The intertidal zone is also known as the foreshore and is that area exposed to the air at low tide and submerged at high tide, for example, the area between tide marks. This area can include many different types of habitats, including steep rocky cliffs, sandy beaches or vast mudflats.
Littoral zone:	The littoral zone of the coast is also called the foreshore, or intertidal zone, and is the section of the coast that is periodically covered by high tides and exposed during low tides.
lux:	The **lux** (symbol: **lx**) is the SI unit of illuminance and luminous emittance. It is used in photometry as a measure of the *apparent* intensity of light hitting or passing through a surface. (
Maintain:	To protect natural site characteristics and ecosystem processes, such as wildlife habitat, soil conservation and succession of native plant communities.

Mean Low Water: A tidal datum. The average of all the low water heights observed over the National Tidal Datum Epoch.

Mean Lower Low Water (MLLW): A tidal datum. The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean High Water (MHW) - The average height of the highest tidal waters reached during the year over a National Tidal Datum Epoch.

Mean Higher High Water (MHHW): The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

Monitor: To collect and analyze data for the purpose of answering management questions. A baseline is established and periodic measurements are taken to determine the extent and rate of change over time. Topics include: Beneficial and negative impacts of stewardship activities, natural events and public use.

Moorage facility: A marina, open water moorage and anchorage area, pier, dock, mooring buoy, or any other similar fixed moorage site.

Natural Landscape Elements: The natural watercourses, topography, hydrology and vegetation which comprise a particular site.

Natural processes: Phenomena that shape the landscape's appearance and habitat potential.

Non-point source discharge: Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. Technically, the term "nonpoint source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act (see definition of point source).

Ordinary high tide: The same as mean high tide or the average height of high tide. In Puget Sound, the mean high tide line varies from 10- to-13 feet above the datum plane of mean lower low water (0.0).

Ordinary high water: The line of permanent upland vegetation along the shores of non-tidal navigable waters. In the absence of vegetation, it is the line of mean higher high water.

Open moorage: Moorage slips and mooring floats that have completely open sides and tops.

Open water moorage and anchorage areas: Areas of state-owned aquatic lands leased for moorage and anchorage that do not abut uplands and do not include a built connection to the uplands. May contain mooring buoys, floating moorage docks, other moorage facilities not connected to the shoreline or anchorage areas in accordance with WAC 332-30-139(5).

Pelagic Zone: The pelagic zone is the part of the open sea or ocean and does not include the seafloor.

Percent Slope - The direct ratio (multiplied by 100) between the vertical and the horizontal distance for a given slope; e.g., a 3-foot rise in a 10-foot horizontal distance would be a 30 percent slope.

Photic zone: The photic zone or euphotic zone is the depth of the water whether in a lake or an ocean that is exposed to sufficient sunlight for photosynthesis to occur. The depth of the euphotic zone can be greatly affected by seasonal turbidity.

Point source discharge: The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture (taken from section 502(14) of the Clean Water Act).

Polycyclic aromatic hydrocarbons (PAH): A group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. There are more than 100 different PAHs. PAHs generally occur as complex mixtures (for example, as part of combustion products such as soot), not as single compounds. PAHs usually occur naturally, but they can be manufactured as individual compound. Can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment. Health effects vary depending upon compound.

Public lands:	Lands belonging to or held in trust by the state, which are not devoted to or reserved for a particular use by law, and include state lands, tidelands, shorelands and harbor areas as herein defined, and the beds of navigable waters belonging to the state (RCW 79.02.010).
Public use:	To be made available daily to the general public on a first-come, first-served basis, and may not be leased to private parties on any more than a day use basis.
Public use beach:	A state-owned beach available for free public use but which may be leased for other compatible uses.
Restore:	To recover natural site features and processes that existed on site prior to disturbance.
Riparian:	Relating to or living or located on the bank of a natural water course, such as a stream, lake or tidewater.
Runoff	That part of the precipitation from rain, snowmelt or irrigation that is not absorbed into the ground, instead often flowing over impervious surfaces, or directly into streams and other surface waters or land depressions.
Saturated	A condition in which the interstices of a material are filled with a liquid, usually water.
Sediment Impact Zone (Ecology)[10]:	A sediment impact zone is an area where the specific sediment quality standards may be exceeded in conjunction with an authorized discharge permit. In authorizing a sediment impact zone, Ecology must find that the discharge is in the public interest and may require that best management practices be employed or that all known, available, and reasonable technology ("AKART") be applied to minimize the adverse impact of the discharge on sediments.
Shore:	That space of land which is alternately covered and left dry by the rising and falling of the water level of a lake, river or tidal area.

[10] WAC Chapter 173-204 establishes sediment standards. Section 173-204-420 specifies sediment quality criteria for Puget Sound that may not be exceeded, and section 173- 204-120 provides that existing beneficial uses (of the benthic environment) must be protected, and no degradation which would interfere with those uses will be allowed (see definition of Antidegradation Policy). The regulations, while requiring adherence to sediment quality criteria, also recognize that goal may not always be attainable. The result of that regulatory conflict is the authorization of sediment impact zones.

Shoreline	The intersection of a specified plane of water with beach; it migrates with changes of the tide.
State Environmental Policy Act	**SEPA;** State law that requires agency decision makers to consider the environmental consequences of a proposal prior to making a decision. It includes a procedure, public involvement opportunities, and supplemental authority to require mitigation for identified adverse environmental impacts.
State-owned aquatic lands:	Those aquatic lands and waterways administered by the department of natural resources or managed under department agreement by a port district. State-owned aquatic lands does not include aquatic lands owned in fee by, or withdrawn for the use of, state agencies other than the department of natural resources (RCW 79.105.060(20)).
Subtidal zone:	Also called the sublittoral zone of the coast. The subtidal zone (below low water) is a band that is affected only during the negative tides which occur periodically throughout the year
Supralittoral zone:	Also called the splash zone (above high water), this area of the beach or coast remains exposed the longest and whose inhabitants are only sprayed with water, although during episodic “flooding” it is covered by the tide.
Terminal:	A point of interchange between land and water carriers, such as a pier, wharf, or group of such, equipped with facilities for care and handling of cargo and/or passengers (RCW 79.105.060(21)).
Tidelands:	Lands between the lines of ordinary high tide and the line of extreme low tide.
Uplands:	Lands, including lakes, wetlands and streams, above the line of ordinary high tide.
Vessel:	A floating structure that is designed primarily for navigation, is normally capable of self propulsion and use as a means of transportation, and meets all applicable laws and regulations pertaining to navigation and safety equipment on vessels, including, but not limited to, registration as a vessel by an appropriate government agency.

Water-dependent use: A use which cannot logically exist in any location but on the water RCW 79.105.060(24)).

Wetlands: Lands where saturation with water is the dominant factor determining soil development and the types of plant and animal communities living in the soil and on its surface.

References

AE (Anchor Environmental, L.L.C.). 2003. Fish distribution and periodicity in WRIA 1 (draft). Prepared for the City of Bellingham, Public Works Department. Bellingham, WA. 33 pp. & app.

Access Washington, 2002. State Facts. Accessed on May 21, 2002 at http://access.wa.gov/government/awgeneral.asp].

Agency for Toxic Substances and Disease Registry. 1995. Public Health Statement: Polycyclic Aromatic Hydrocarbons. Accessed June 16, 2008. [Available at: http://www.atsdr.cdc.gov/toxprofiles/phs69.html]

Anderson, E. M., and J. R. Lovvorn. 2008. Gray whales may increase feeding opportunities for avian benthivores. Marine Ecology Progress Series 360:291–296.

Anderson, E. M., J. R. Lovvorn, and M. T. Wilson. 2008. Reevaluating marine diets of Surf and White-winged Scoters: interspecific differences and the importance of soft-bodied prey. Condor 110:285–295.

Anderson, E. M., J. R. Lovvorn, D. Esler, W. S. Boyd, and K. C. Stick. 2009. Using predator distributions, condition, and diet to evaluate seasonal foraging sites: sea ducks and herring spawn. Marine Ecology Progress Series *In press.*

Angliss, R. P. and R. B. Outlaw. 2005. Gray Whale (*Eschrichtius robustus*): Eastern North Pacific Stock. NOAA–TM-AFSC-161. Revised: 2/6/05. Available online. [Accessed June 28, 2007 at http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2005whgr-en.pdf]

Angliss, R. P., and B.M. Allen. 2007. (revised). North Pacific Right Whale (*Eubalaena japonica*): Eastern North Pacific Stock. NOAA-TM-AFSC-193. Hard copy on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

Applied Biomonitoring. 2002. 2000 Caged Mussel Study: Estimating Chemical Exposure to Herring Eggs at Selected Sites in the Puget Sound Region: Final Report. Submitted to Carol Piening, Washington Dept. of Nat. Res., Olympia, WA. Prepared by Applied Biomonitoring, John Boettner. 8 August 2002. Hard copy on file at Washington State Dept. of Natural Resources, Aquatics Division.

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship surveys. Fish. Bull. 86:417-432.

Barlow, J., C. W. Oliver, T. D. Jackson, and B. L. Taylor. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: II. Aerial surveys. Fish. Bull. 86:433-444.

Barnett, T.P., Pierce, D.W., AchutaRao, K.M., Gleckler, P.J., Santer, B.D., Gregory, J.M., and W.M. Washington. 2005. Penetration of Human-Induced Warming into the World's Oceans. *Science* 8 July 2005: Vol. 309. no. 5732, pp. 284 – 287.

Beacham T.D., Schweigert J.F., MacConnachie C., Le K.D., Labaree K., and K.M. Miller. 2002. Population structure of herring (*Clupea pallasi*) in British Columbia determined by

microsatellites, with comparisons to southeast Alaska and California. *Canadian Science Advisory Directorate, Research Document:* 2002/109.

Berger/ABAM Engineers Inc. 2000. ARCO Products Company Cherry Point Refinery Marine Terminal Pier Addition, Endangered Species Act Biological Evaluation. Prepared for the ARCO Cherry Point Refinery, Blaine, Washington. On file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Berry, H. D., J. R. Harper, T. F. Mumford, B. E. Bookheim, A. T. Sewell and L. J. Tamayo. 2001. The Washington State ShoreZone Inventory User's Manual. Olympia, WA, Nearshore Habitat Program, Washington State Dept. of Natural Res.**:** 29 p.

BirdWeb. 2008. Learn all about Washington's birds. Website maintained by The Seattle Audubon Society. Available online. [Accessed October 10, 2008 at http://www.birdweb.org/birdweb/bird_details.aspx?id=10]

Blackmon, D., Wyllie-Echeverria, T., and D. J. Shafer. 2006. The role of seagrasses and kelps in marine fish support. Wetlands Regulatory Assistance Program. February 2006. ERDC TN-WRAP-06-1. Seattle District, Regulatory Branch, U. S. Corps. Hard copy on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, Wa.

Bohannon, J. 2008. Wildlife biologist, Washington Department of Fish and Wildlife. La Conner, Washington. Personal communication via email and phone, October and November, 2008. Records on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Boothe, Chip. 2009. Prevention Section Manager. Spills Program, Washington State Department of Ecology. Personal communication. May 7 2009. Via email through David Byers. Records on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Bower, J. et al. 2005. Marine bird changes in northwest Washington inshore waters. Western Washington University, Fairhaven College.

Bower, J.L. 2009. Changes in marine bird abundance in the Salish Sea: 1975 to 2007. Fairhaven College, Western Washington University, Bellingham, Washington, 98225. Marine Ornithology 37: XX-XX (received 21 January 2009, accepted 14 March 2009). Hard copy on file Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Bower, J.L. 2009. Personal communication via phone with Elizabeth Ellis, environmental planner, June 19, 2009. Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Brennan, J. S. 2007. Marine Riparian Vegetation Communities of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-02. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

British Petroleum, 2003. Draft Environmental Impact Statement. BP Cherry Point Cogeneration Project. Volumes 1 and 2. Prepared for BP West Coast Products, LLC. Submitted by Golder Associates, Inc. March 2003.

Calambokidis, J. and R. W. Baird, 1994. Status of Marine Mammals in the Strait of Georgia, Puget Sound, and the Juan de Fuca Strait, and Potential Human Impacts. Abstract. Canadian Technical Report of Fisheries and Aquatic Sciences 1948:282-300.

Calambokidis, J., Laake, J. L., and Osmek, S. D. 1997. Aerial surveys for marine mammals in Washington and British Columbia inside waters. Final report to the National Marine Mammal Laboratory, Seattle, WA 98115

Calambokidis, J., Steiger, G.H., Ellifrit, D.K., Troutman, B.L. & Bowlby, C.E. (2004) Distribution and abundance of humpback whales (Megapter novaeangliae) and other marine mammals off the northern Washington Coast. *Fisheries Bulletin*, **102**:563-580.

Calambokidis, J., Klimek, A. and Schlender, L. 2009. Summary of collaborative photographic identification of gray whales from California to Alaska for 2007. *Final Report.* AB133F-05-SE-5570. Available online at Cascadiaresearch.org.

Campbell, M.H. 1934. *Calanus tonsus* Brady as an economic factor in the Strait of Georgia. Proceedings of the V. Pan-Pacific Science Congress. 3:2003-2008.

Canning, Douglas. The Future Ain't What it Used to Be: Planning for Climate Disruption 2005 Regional Climate Change Conference. Washington Department of Ecology and Climate Impacts Group, University of Washington. Seattle – 27 Oct 2005

Carlson, Roy L. 1990. "Cultural Antecedents." In *Handbook of North American Indians.* Vol. 7.Northwest Coast. pp.60-69. Ed. Wayne Suttles. Smithsonian Institution, Washington D.C.

Carman, Randy. 2009. Environmental Specialist, Habitat Program, Washington Department of Fish and Wildlife. Personal communication regarding no net loss concept. June 4, 2009. Records on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Carretta, J.V. et al. 2007. U.S. Pacific Marine Mammal Stock Assessments: 2006. NOAA Tech. Mem. NOAA-TM-NMFS-SWFSC-398. Available online. [Accessed June 28, 2007 at http://www.nmfs.noaa.gov/pr/sars/species.htm]

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Johnston, D., Hanson, B., & Muto, M. M. Lynch, D., & Carswell, L. 2007. U.S. Pacific marine mammal stock assessments: 2008. U. S. Department of commerce. NOAA-TM-NMFS-SWFSC-434

Center of Biological Diversity et al. 2004. Petition to list Cherry Point population of Pacific herring *Clupea pallasi,* as "endangered" or "threatened" under the Endangered Species Act. 16 U.S.C. § 1531 et seq. Available online. [Accessed July 12, 2007 at http://www.nwr.noaa.gov/Other-Marine-Species/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=20335]

Christoforou, C. 2008. Environmental Engineer, Northwest Clean Air Agency. Personal communication with Elizabeth Ellis, November 2008. Records on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.Climate Impact Group. 2008. Climate Variability. November 6, 2008. Available online. [Accessed November 2008 at http://cses.ashingotn.edu/cig/pnwc/clvariability.shtml]

Colnar, A.M. and W.G. Landis. 2007. Conceptual model development for invasive species and a regional risk assessment case study: the European Green Crab, *Carcinus maenas*, at Cherry Point, Washington USA. Human and Ecological Risk Assessment. 13:120-155.

Congressional Research Service. 2007. Ballast Water Management to Combat Invasive Species. Buck, Eugene. Resources, Sciences and Industry Division. July 20, 2007. Available online. [Accessed June 17, 2008 at: http://www.anstaskforce.gov/Documents/BallastWater2007.pdf]

Department of Fisheries and Oceans, Canada. 2004. Underwater World: Sand Lance. Available online. [Accessed July 13, 2007 at: http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/SandLance/sandlanc_e.htm]

Dethier, M.N. 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA. 56 p.

Dethier, M.N. 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington

Dickson, D. L., and H. G. Gilchrist. 2002. Status of marine birds of the southeastern Beaufort Sea. Arctic 55(S1):46–58.

Dinnel, P., R. Hoover, L. Lechuga, K Tobiason, and J. Elphick. 2008 Development of Larval Pacific Herring, *Clupea pallasi*, Bioassay Protocols: Refinement, Validation, Refinery Effluent and Cherry Point Ambient Water Testing During 2007. Western Washington University Shannon Point Marine Center. Final Report For Washington Department of Ecology June 2008.

Duffy-Anderson, J. T., and K.W. Able. 1999. Effects of municipal piers on the growth of juvenile fishes in the Hudson River Estuary: a study across a pier edge. Marine Biology._____.2001. An Assessment of the Feeding Success of Young-of-the-Year Winter Flounder (*Pseudopleuronectes americanus*) near a Municipal Pier in the Hudson River Estuary, U. S. A. *Estuaries*, Vol. 24, No. 3 (Jun., 2001), pp. 430-440.

ENSR. 1992a. ARCO Products Company Cherry Point Refinery, Whatcom County, Washington Environmental Report for the Dock Completion Project. Prepared for the ARCO Products Company. ENSR/AECOM Consulting and Engineering, 401 Harris Avenue, Suite 200, Bellingham, Washington 98225.

EVS. 1999. Cherry Point Screening Level Ecological Risk Assessment. Proj. No. 2/868-01.1 Prepared for Washington Department of Natural Resources, Olympia, WA. EVS Environmental Consultants, Seattle WA.

Easterbrook, D.J. 1999. Surface Processes and Landforms. New Jersey: Prentice Hall, 352 p.

Eisenberg, T., S. Gohrman, D. Heimer, D. Kolby, S. Moreno, K. Murphy, B. Reeves, S. Riggs, B. Rogers, J. Phell, S. Wirth. 2001. Spartina management plan for north Puget Sound. Washington Department of Agriculture. 32 p.

Eissinger, A. M., Nahkeeta Northwest, Marine and Shoreline Wildlife Areas, Whatcom County, Washington. June 1994.

Emmet, R.L., M.E. Monaco, S.A. Hinton and S.L. Stone. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: Species life history summaries. Rockville, MD: Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Energy Information Administration (EIA). 2009. Crude Oil Production: Alaska – 1971 – 2007. Available online. [Accessed March 3, 2009 at: http://tonto.eia.doe.gov/dnav/pet/hist/mcrfpak2a.htm]

Everitt, R. D., Fiscus, C.H. and R.L. DeLong. 1980. Northern Puget Sound Marine Mammals: Prepared for the Marine Ecosystems Analysis Puget Sound Project, Seattle, Washington. Seattle, WA: National Marine Mammal Laboratory, National Marine Fisheries Service, National Oceanic and Atmospheric Administration. 134 p.

Fairbanks, C. and M. Terra. 2000. Georgia Strait Crossing Project nearshore marine habitat survey and review of existing information of marine biology and fisheries resources. Tech. rep. by Duke Engineering & Services for WESTECH Environmental Services, Inc.

Fairbanks Environmental Services, Inc. 2005. Whatcom County Submerged Aquatic Vegetation Survey Final Report. Prepared for Whatcom County Public Works, Water Resources Division and Whatcom County Marine Resources Committee.

Falcone, E., Calambokidis, J., Steiger, G. H., Malleson, M. & Ford, J. (2005) Humpback whales in the Puget Sound/Georgia Strait Region. *Proceedings of the 2005 Puget Sound Georgia Basin Research Conference*, 4 pp.

Field, L.J., 1988. Pacific sand lance *Ammodytes hexapterus*, with notes on related Ammodytes species. Pages 115-33 in J.J. Wilimovsky, L. S. Incze, and S.J. Westrheim (eds.) Species Synopses: Life Histories of Selected Fish and Shellfish of the Northeast Pacific and the Bering Sea. Washington Sea Grant and Fisheries Research Institute, University of Washington.

Flaherty, C. 1990. Whales of the Northwest. Cherry Lane Press. Seattle, WA. 24 p.

Fresh, K.L. 1981. Food habits of Pacific salmon, baitfish, and their potential competitors and predators in the marine waters of Washington, August 1978 to September 1979. State of Wash. Dept. Fis. Progr. Rep. No. 145

Fresh, K.L., D. Rabin, C. Simenstad, E.O. Salo, K. Garrison, and L. Matheson. 1979. Fish ecology studies in the Nisqually Reach area of southern Puget Sound, Washington. Univ. of Wash. Fish. Res. Inst. FRI-UW-7904.

Fresh, K.L. 2006. Juvenile Pacific Salmon and the Nearshore Ecosystem of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington...

Gardner, G.A. 1976. Analysis of zooplankton population fluctuations in the Strait of Georgia, with emphasis on the relations between *Calanus plumchrus* Marukawa and *Calanus marshallae* Frost. Ph.D. thesis, The University of British Columbia.

Gardner, G.A. 1977. Analysis of zooplankton population fluctuations in the Strait of Georgia, British Columbia. J. Fish. Res. Board Can. 34: 1196-1206

Gaskin, D. E. 1984. The harbour porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Commn. 34:569-586.

Gearin, P. et al. 1999. Prey of Steller's Sea Lions in Washington State. Abstract. 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii. November 28th – December 3rd, 1999. p. 65.

Georgia Strait Alliance. 2007. Georgia Strait Coastal Waters. Website. Available online. [Accessed March 2, 2007 at http://www.georgiastrait.org/whogeorgia.php].

Glick, Patty. 2005. Fish Out of Water. *A Guide to Global Warming and Pacific Northwest Rivers*. National Wildlife Federation.

Glick, Patty. 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest *An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon.* National Wildlife Federation.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

Goreau, T.J. PhD. 1997. Coral Reef Health in the Negril Area: Survey and Recommendation. President, Global Coral Reef Alliance. 324 North Bedford Road. Chappaqua, New York 10514 Telephone 1-914-238-8788 or 1-914-238-8768. Available online. [Accessed May 9 2008. http://www.reefrelief.org/jamaica_body_2.html#health]

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnel, and K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Ch. 1, *In:* Brueggeman, J. J. (ed.), Oregon and Washington marine mammal and seabird surveys. Final Report, OCS Study MMS 91- 0093, Minerals Management Service, U.S. Dept. of Interior, Los Angeles, CA.

Greene, H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, J.E. McRea, Jr., and G.M. Cailliet. 1999. A classification scheme for deep seafloor habitats. Oceanologica Acta 22(6)663-678.

Grette Associates. 2007. New Whatcom Redevelopment Project: Plants and Animals Technical Report. Prepared for the Port of Bellingham. Grette Associates, 151 South Worthen, Wenatchee, Washington, 98801. 14 December 2007.

Gustafson, R. G., Wainwright, T.C., Winans, G.A. , Waknitz, F. W., Parker, L.T. and R.S. Waples. 1997. NOAA Technical Memorandum NMFS-NWFSC-33: Status review of Sockeye Salmon from Washington and Oregon. Available from : National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division 2725 Montlake Boulevard East, Seattle, Washington 98112-2097.

Haas, M. E., Simenstad, C.A., Cordell, J.R., Beauchamp, D.A. and B.R. Miller. 2002. Effect of large overwater structures on juvenile prey assemblages in Puget Sound, Washington.

University of Washington School of Aquatic and Fishery Sciences. Report No. WA-RD 550.1 Prepared for: Washington State Department of Transportation Commission. June 2002. Seattle, WA.

Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J. Del Genio, A., Roch, D., Locis, A., Lo, K., Menon, J., Novakov, T., Perlwitz, J., Russel, G., Schmidt, G.A., and Tausnev, N. 2005. Earth's energy imbalance: Confirmation and implications. Science: Vol. 308: 1431-1435. 30 June 2005.

Hanson, D.K. and H.A. van Gaalen. 1993. Subsistence at Cherry Point, Washington (45 WH 1).

Harrald, J.R. et al. 2006. The Vessel Traffic Risk Assessment Methodology: Presentation to the Marine Board. November 2006. George Washington University.Available online . [Accessed June 16, 2008 at: http://www.seas.gwu.edu/~dorpjr/tab3/NSFProject_GWU_VCU/NSFProgress1.html]

Hart, J.L., 1973. Pacific Fishes of Canada. Fish. Res. Bd. Canada. Bull. 180. 740p.

Hauser, D. D. W., Logsdon, M. G., Holmes, E. E., VanBlaricom, G. R., Osborne, R. W. 2007. Summer distribution patterns of southern resident killer whales Orcius orca: core areas and spatial segregation of social groups. Marine Ecology Progress Series. Vol. 352:301-310

Hayes, G. E. and J. B. Buchanan. 2002. Washington State status report for the Peregrine Falcon.Washington Dept. Fish and Wildlife, Olympia. 77 pp.

Hayward, J. L. 2003. Sexual aggression by a male northern elephant seal on harbor seal pups in Washington. Northwestern naturalist. 8(3):148-150.

Healey, M.C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). In C. Groot and L. Margolis (eds.), Life history of Pacific salmon, p. 311-393. Univ. B.C. Press, Vancouver, B.C.

Hershberger, P.K., R.M. Kocan, N.E. Elder, T.R. Meyers, J.R. Winton. 1999. Epizootology of viral hemorrhagic septicemia virus in Pacific herring from the spawn-on-kelp fishery in Alaska, USA Dis. Aquat. Org. 37: 23-31.

Hershberger, P.K. and R.M. Kocan. 1999. Final Report – 1999, Survival potential of Cherry Point herring: larval abnormalities and weight at hatch following in situ incubation of developing embryos. Washington Department of Natural Resources #FY00-092.

Hershberger P.K., Stick K, Bui B, *et al.* 2002. Incidence of *Ichthyophonus hoferi* in Puget Sound fishes and its increase with age of adult Pacific herring. Journal of Aquatic Animal Health, 2002; 4:50–56.

Hershberger, P.K., Elder, N.E., Wittouck, J., Stick, K. and R.M. Kocan. 2005. Abnormalities in Larvae from the Once-Largest Pacific Herring Population in Washington State Result Primarily from Factors Independent of Spawning Location. Transactions of the American Fisheries Society 134:326–337, 2005. Hard copy on file at: Washington Department of Natural Resources, Olympia, WA.

Hershberger P.K., J Gregg, C Pacheco, J Winton, J Richard, G. Traxler. 2007. Larval Pacific herring, Clupea pallasii (Valenciennes), are highly susceptible to viral hemorrhagic septicemia and survivors are partially protected after their metamorphosis to juveniles. Journal of Fish Diseases 30: 445-458.

Hodges, J. I., J. G. King, B. Conant, and H. A. Hanson. 1996. Aerial surveys of waterbirds in Alaska 1957–94: population trends and observer variability. U.S. Department of the Interior, National Biological Service Information and Technology Report 4.

IPCC, 2007: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available online. [Accessed June 18, 2008 at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm]

Jauquet, J.M. 2002. Coastal cutthroat trout (*Oncorhynchus clarki clarki*) diet in South Puget Sound, Washington, 1999-2002. M.Sc. thesis, Evergreen State College. Olympia, WA. 79 pp.

Jauquet, J. 2003. Washington Department of Fish and Wildlife. The occurrence of diet items in coastal cutthroat trout collected in South Puget 1999 – 2002. Sound Georgia Basin Puget Sound Research Conference. 19 p. Available online. [Accessed July 13, 2007 at: http://www.psat.wa.gov/Publications/03_proceedings/PAPERS/ORAL/10d_jauq.pdf]

Jefferies, S., H. Huber, J. Calambokidis, and J. Laake. 2003. Trends and status of harbor seals in Washington state: 1978-1999. Journal of Wildlife Management 67(1):208-219.

Johanneseen, J. and M. Chase. 2006. Final Technical Memorandum: Whatcom County Feeder Bluff Mapping and Drift Cell Ranking Analysis: Prepared for Parametrix Inc., & Whatcom County Planning and Development Services. Coastal Geologic Services, Bellingham, Washington.

Johannessen, J. and A. MacLennan. 2007. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Johnson, O.W., Grant, W.S. Kope, R.G. Neely, K., Waknitz, F.W. , and R.S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-32, 280 p. Available online. [Accessed July 13, 2007 at: http://www.nwfsc.noaa.gov/publications/techmemos/tm32/]

Johnson, O.W., Ruckelshaus, M.H., Grant, W.S., Waknitz, F.W., Garrett, A.M, Bryant, G.J., Neely, K. and J.J. Hard. 1999. Status Review of Coastal Cutthroat Trout from Washington, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS – NWFSC – 37. 320 p. Available online [Accessed May 13 2009 at: www.nwfsc.noaa.gov/assets/25/4236_06172004_110752_cutthroat.pdf]

June, J.A. 1981. Life history and habitat utilization of cutthroat trout (*Salmo clarki*) in a headwater stream in the Olympic Peninsula, Washington. M. S. Thesis. University of Washington, Seattle. 116 pp.

Kidd, Robert S. 1964. “A Synthesis of Western Washington Prehistory from the Perspective of Three Occupational Sites.” M.A. thesis, Department of Anthropology, University of Washington, Seattle, Wash.

Kirschenbaum, M. 1996. Western grebe (*Aechmophorus occidentalis).* National Park Service, Chihuahuan Desert. July 1996.

Knight, R.L., P. J. Randolph, G. T. Allen, L. S. Young, and R. J. Wigen. 1990. Diets of nesting bald eagles, *(Haliaeetus leucocephalus*), in western Washington. Canadian Field Naturalist 104:545-551.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein, and R. S. Waples. 2002. Status review of southern resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC- 54, Available from the U.S. Department of Commerce, Seattle, Washington.

Kyte, M.A. 1990. Results of 1990 Biological and Chemical Monitoring in the Southeast Strait of Georgia for the BP Oil Company - Ferndale Refinery. Prepared by Ardea Enterprises.

_____. 1994. The Use by Flatfish and Dungeness Crab of the Atlantic Richfield Company Cherry Point Refinery Facility. Project Final Report. Project # 138-002. Submitted by Pentec Environmental, Inc.

_____. 2007. Recreation at Cherry Point. PowerPoint presentation. Submitted by Entrix, Inc. for Cherry Point Work Group. Copies available through Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA

_____. 2009. Personal communication via email on second draft of Cherry Point Resource Protection and Enhancement Plan. Submitted via David Roberts. Hard copy on file. Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA

Kyte, M. A., E. Doyle, S. Rodman, and B. Shepard. 1999. Cherry Point Literature Review. Prepared for ARCO Cherry Point Refinery, Intalco Aluminum Corporation, and Tosco Ferndale Refinery. Lease Jacket 20-A09122. Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA

Lackey, R.T. 2001. Values, policy, and ecosystem health, *BioScience* 51, 437–443.

_____. 2007 Science, Scientists, and Policy Advocacy, *Conservation Biology* 21, 12–17.

Lacroix, D. L., S. Boyd, D. Esler, M. Kirk, T. Lewis, and S. Lipovsky. 2005. Surf Scoters (*Melanitta perspicillata*) aggregate in association with ephemerally abundant polychaetes. Marine Ornithology 33:61–63.

Landis, W. G., Colnar, A.M., Chen, V.C.,, Kaminski, L., Kushima G., and A. Seebach. 2005. Development of a conceptual model for non-indigenous species for the Mid-Atlantic states. USEPA Grant Number 1-54068. Project Rept. September 30 2005.

Landis WG. 2008. Application of population modeling using RAMAS® to a causal analysis of the decline the Cherry Point Pacific herring (*Clupea pallasi*) stock. In Akçakaya HR,

Stark JD, Bridges TS (eds). Demographic Toxicity: Methods in Ecological Risk Assessment. Oxford, UK: Oxford University Press, 2008. pp 213- 228.

Lanzer, E.L. 1999. Aquatic Land Area Estimation 1999. Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA.

Latterell, J. 2002. Nonmigratory coastal cutthroat trout: evidence for restricted gene flow among neighboring creeks (abstract). Pages 9-10 *in* University of Washington, Center for Streamside Studies and Center for Urban Water Resources Management. Seattle, WA. Available online. [Accessed May 20, 2009 at: http://water.washington.edu/Outreach/Events/AnnualReview/Abstracts/2002abstracts.html)]

Laughlin, J. 2005. Impacts of pile driving on fish and wildlife. Powerpoint presentation. Washington State Department of Transportation. P.O. Box 330310, 15700 Dayton Ave, Seattle, WA. 98133.

Le Boeuf, B. J., Crocker, D., Blackwell, S., and Morris, P. 1993. Sex differences in diving and foraging behavior of northern elephant seals. *In:* I. Boyd (ed). Marine Mammal: Advances in behavioral and population biology. Oxford Univ. Press.

Lee, K. S., F. T. Short and D. M. Burdick. 2003. Development of a Nutrient Indicator Using the Seagrass, *Zostera marina*, along Nutrient Gradients in Three New England Estuaries. Aquatic Botany 1694, pp. 1-19.

Légaré, J.E.H. 1957. The qualitative and quantitative distribution of plankton in the Strait of Georgia in relation to certain oceanographic factors. J. Fish. Res. Bd. Can. 14(4): 521-552.

Levitus, S., Antonov, J.I., Wang, J., Delworth, T.L., Dixon, K. W., Broccoli, A. J. 2001. Anthropogenic warming of the earth's climate system. *Science* 13 April 2001: Vol. 292. no. 5515, pp. 267 – 270.

Lewis, J.C. and D. Kraege. 1999. Harlequin duck (*Histronicus histronicus*). *In* E. M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Available online at: wdfw.wa.gov/hab/phs/vol4/harlequin_duck.pdf

_____. 2000. Cavity nesting ducks. *In* E. M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Hard copy on file at Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA.

Lewis, J.C. and J. M. Azzerad. 2003. Pileated woodpecker *In* E. M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Available online at: wdfw.wa.gov/hab/phs/vol4/pileated_woodpker.pdf

Lewis, T. L., D. Esler, and W. S. Boyd. 2007. Foraging behaviors of Surf Scoters and White-winged Scoters during spawning of Pacific Herring. Condor 109:216–222.

Lewis, T. L., D. Esler, W. S. Boyd, and R. Žydelis. 2005. Nocturnal foraging behavior of wintering Surf Scoters and White-winged Scoters. Condor 107:637–647.

Long, E.R., M. Dutch, S. Aasen, K. Welch, and M.J. Hameedi. 2003. Chemical contamination, acute toxicity in laboratory tests, and benthic impacts in sediments of Puget Sound: a summary of results of the joint 1997-1999 Ecology/NOAA survey. Washington State Department of Ecology and National Oceanic and Atmospheric Administration. October 2003.

Lowry, M. Unpublished. Sea lion diet study. Available online. [Accessed October 15, 2008.: swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=148&id=1252]

Lubliner, B., M. Redding and D. Ragsdale. 2010. Pharmaceuticals and personal care products in municipal wastewater and their removal by nutrient treatment technologies. Washington State Department of Ecology. Publication No. 10-03-004. Available online at http://www.ecy.wa.gov/pubs/1003004.pdf.

Lummi Indian Nation. 2008. Letter to David Roberts, Assistant Division Manager, from Merle Jefferson, dated March 18th concerning Lummi Nation and the proposed Cherry Point Reserve. On file with Orca District, Aquatic Resources Program, Washington Department of Natural Resources, Sedro-Woolley, WA.

Madden, Christopher J., Dennis H. Grossman, and Kathleen L. Goodin. 2005. *Coastal and Marine Systems of North America: Framework for an Ecological Classification Standard: Version II.* NatureServe, Arlington, Virginia.

Marty GD, Quinn TJ, Carpenter G, Meyers TR, Willits NH. 2003. Role of disease in abundance of a Pacific herring (*Clupea pallasi*) population. Canadian Journal of Fisheries and Aquatic Sciences, 2003; 60(10):1258-1265.

Marine Mammal Center. 2000. Harbor seal *Phoca vitulina*. The Marine Mammal Center. San Francisco, California. 2pp.

Markham, M.V. 1993 . A Historic Euroamerican Fish Trap Camp at Cherry Point (45WH1). Thesis presented to the faculty of Western Washington University in partial fulfillment of the requirements for the degree Master of Arts. February 1993.

Markiewicz, A., A. Seebach, A. Colnar, G. Kushima, A. Schular, and W. Landis. 2005. Cherry Point, WA: Interactive Risk Management Model. Prepared for the Washington Department of Natural Resources Aquatic Resources Division, by the Institute of Environmental Toxicology, Western Washington University. January 15 2005. Hard copy on file at Washington Department of Natural Resources, Olympia, WA.

Marshall, Randall. 2009. WET Coordinator, Washington State Department of Ecology. Personal Communication, May 15 2009. Comments on file at Washington Department of Natural Resources. Olympia, WA.

Marshall, R.R. and G.G. Bargmann. 2005. *Indirect Effects: Environmental Changes, Copepods and Herring*. SETAC Globe 6(3): 30-31.

McCann, T. S. 1985. Size, status and demography of southern elephant seal (Mirounga leonine) populations. In J. K. Ling and M. M. Bryden (eds.), Studies of sea mammals in the south latitudes. South Australia Museum. 132 pp.

McCrae, J. 1994. Oregon developmental species Pacific herring (*Clupea pallasi*). Oregon Department of Fish and Wildlife. 5pp.

Michal, Hal. 2009. Personal Communication. May 20 – 29th and through June 2009. District 11 Fish Biologist, Washington State Department of Fish and Wildlife. Email record on file at Washington Department of Natural Resources, Olympia, WA.

Miller, B.S., C.A. Simenstad, L.L. Moulton, K.L. Fresh, F.C. Funk, W.A. Karp, and S.F. Borton. 1978. Puget Sound Baseline Program Nearshore Fish Survey. Final Report July 1974 - June 1977. Washington Department of Ecology North Puget Sound Baseline Study Appendix D. Baseline Study Report No. 10. January 1978. *in* Berger/ABAM Engineers Inc. 2000. ARCO Products Company Cherry Point Refinery Marine Terminal Pier Addition, Endangered Species Act Biological Evaluation. Prepared for the ARCO Cherry Point Refinery, Blaine, Washington.

Mitchell, Danielle M. 2006. Biocomplexity and metapopulation dynamics of Pacific herring (*Clupea pallasii*) in Puget Sound, Washington. Master's Thesis submitted in partial fulfillment for the requirements of Masters of Science, Aquatic and Fisheries Science Program, University of Washington. Hard copy on file with Washington Department of Natural Resources, Olympia, WA. [Accessed October 8, 2008 at: www.fish.washington.edu/research/publications/ms_phd/Mitchell_D_MS_Au06.pdf]

Moerman, Daniel E. 1999. *Native American Ethnobotany*. Timber Press, Portland, Ore.

Mumford, T.F. 2007. Kelp and Eelgrass in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-05. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Myers, K. W., N. Davis, W. W. Dickhoff, S. Urawa. 1998. Blood plasma levels of insulin-like growth factor-I in Pacific salmon in offshore water in winter. North Pacific Anadromous Fish Commission Bulletin, 1:129-137.

National Library of Canada Publication. 2007. Characterization of the Georgia Basin/Puget Sound airshed. Available online. [Accessed February 28, 2007 at www.epa.gov/region10/psgb/media/pdf/airshed_characterization.pdf]. Co-published by the United States Environmental Protection Agency.

National Marine Fisheries Service. 2008. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS). 1991. Recovery Plan for the Humpback Whale (*Megaptera novaeangliae*). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. 105 p.

_____. 1997. Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-28, 172 p.

_____. 2005. NOAA Fisheries Services Says Cherry Point Herring Don't Qualify for Protection. News Release. June 6, 2005.Available online . [Accessed June 2009 at: www.nwr.noaa.gov/Other-Marine-Species/Puget-Sound-Marine-Fishes/Herring.cfm]

_____. 2008. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington. _____. 2006. Review of the Status of the Right Whales in the North Atlantic and North Pacific Oceans. Prepared by NOAA, National Marine Fisheries Service. December 2006.Available online. . [Accessed June 2 2009 at: www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rightwhale_northatlantic.htm]

_____. 2009. Fishwatch. Sockeye Salmon. Website monitored and maintained by National Marine Fisheries Service. Available online. [Accessed June 10, 2009 at: www.nmfs.noaa.gov/fishwatch/species/sock_salmon.htm]

National Oceanic and Atmospheric Administration. 2008. Stock Assessment Report for the Humpback Whale, Eastern North Pacific. NOAA, National Marine Fisheries Services, Protected Resources Division. Available online. [Accessed June 9, 2009 at: www.nmfs.noaa.gov/pr/pdfs/sars/po2008whhb-cow.pdf]

_____. 2009. Coho Salmon (*Oncorhynchus kisutch*). Website fact sheet. Available online. [Accessed June 10, 2009 at: http://www.nmfs.noaa.gov/fishwatch/species/coho_salmon.htm]

_____. 2009. Sockeye Salmon (*Oncorhynchus nerka*). Website fact sheet. Available online. [Accessed June 10, 2009 at www.nmfs.noaa.gov/pr/species/fish/sockeyesalmon.htm]

_____. 2009. National Marine Fisheries Service, Protected Resources Division. Changes in vessel operations may reduce risk of endangered whale shipstrikes. News Release: May 26, 2009. Contact Teri Frady, NOAA, 774-266-8711 or available online at www.nmfs.noaa.gov/pr/pdfs/shipstrike/atba_tss_pressrelease.pdf

_____. 2009. Species: Marine Mammals. Available online. [Accessed May and June 2009 at: http://www.nmfs.noaa.gov/pr/species/mammals/]

NatureServe Explorer. 2008. An online explorer of life. Available online. Accessed October, November, December 2008 at: www.natureserve.org/explorer]

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: June 9, 2009).

Nearshore Habitat Program. 2001. The Washington State ShoreZone Inventory. Washington State Department of Natural Resources, Olympia, WA.

Nelson, Charles M. 1990. "Prehistory of the Puget Sound Region." In *Handbook of North American Indians*. Vol. 7. Northwest Coast. pp.481-484. Ed. Wayne Suttles. Smithsonian Institution, Washington D.C.

Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel. 2002. Washington State Marine Water Quality in 1998 through 2000. Washington State Department of Ecology, Environmental Assessment Program, Publication #02-03-056, Olympia, WA. Available online. [Accessed June 15, 2007 at www.ecy.wa.gov/pubs/0203056.pdf].

Nicholas, J.W. 1978. A review of literature and unpublished information on cutthroat trout (*Salmo clarki clarki*) of the Willamette watershed. Oreg. Dep. Fish. Wild. Res. Sect., Inf. Rep. Ser. Fish. No. 78-1. 20 p.

Nightingale, B.J. and C.A. Simenstad.2001. Overwater Structures: Marine Issues. Washington State Transportation Center (TRAC). Washington Dept. of Fish and Wildlife. Washington Dept. of Ecology. Northeast Pacific Minke Whale Project. 2007. Ongoing Research. Available online. [Accessed June 27, 2007 at www.northeastpacificminke.org/currentresearch.htm]

Northwest Clean Air Agency. 2006. NWCAA Emission Inventory for Island, Skagit & Whatcom counties: 2004, 2005. Available online. [Accessed February 28, 2007 at www.nwcleanair.org/pdf/airQuality/inventories/2005%20emission%20inventory.pdf].

Northwest Indian Fisheries Commission. 2003. Tribal Policy Statement on Marine Protected Areas, Marine Reserves, Marine Sanctuaries, and Fishery Conservation Zones. Letter signed by Billy Frank, Jr. to Hon. Donald Evans, Secretary of Commerce, Washington D.C., dated July 11, 2003. Hard copy on file at Washington Department of Natural Resources, Aquatic Resources Program, Olympia, WA.

Nybakken, J.W. 2001. Marine biology: An ecological approach. 5th Ed. Benjamin Cummings, San Francisco, USA. 516 p.

Nysewander, David R. et al. 2006. Report of marine bird and marine mammal component: Puget Sound Ambient Monitoring Program, for July 1992 to December 1999 period. Available from Wildlife Management Program, Washington Department of Fish and Wildlife, Olympia, WA. 194 p.

Office of Financial Management (OFM). 2006. Whatcom County Population Estimates: 1980 – 2006. Available online. [Accessed July 17, 2007 at www.ofm.wa.gov/pop/coagemf/whatcom.pdf]

Office of Washington State Climatologist (OWSC). 2008. Website. Available online. [Accessed June 18, 2008 at www.climate.washington.edu/]

Olsen, J.B., Lewis, C.J., Kretschmer, S.L. and J.E. Seeb. 2002. Characterization of 14 tetranucleotide microsatellite loci derived from Pacific herring. Alaska Department of Fish and Game, Gene Conservation Laboratory, 333 Raspberry Road, Anchorage, Alaska 99518–1599, USA. Molecular Ecology Notes (2002) **2**, 101–103.

Osborne, R., Calambokidis, J., Dorsey, E. M. (ed.) D. Haley. 1988. A guide to marine mammals of greater Puget Sound. Island publishers, Anacortes, WA. 191 pp.

Palsson, W.A. 1998. Monitoring the response of rockfishes to protected areas. Marine harvest refugia for west coast rockfish: a workshop. August 1998. Pacific Grove, CA. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-255.

Palsson, W. E. 2003 Personal communication: July 7, 2003. Research Scientist, Washington Department of Fish and Wildlife, Fish Program. Mill Creek, WA.

Palsson, Wayne A., Tien-Shui Tsou, Greg G. Bargmann, Raymond M. Buckley, Jim E. West,Mary Lou Mills, Yuk Wing Cheng, and Robert E. Pacunski. The Biology and

Assessment of Rockfishes in Puget Sound. 2009. Fish Management Division, Fish Program Washington Department of Fish and Wildlife.

Parsons, T.R., R.J. LeBrasseur, J.D. Fulton and O.D. Kennedy. 1969. Production Studies in the Strait of Georgia. Part II. Secondary Production under the Fraser River plume, February to May, 1967. Journal of Experimental Marine Biology and Ecology. 3: 39-50.

Pauley, G.B. , K. Oshima, K. L. Bowers, and G. L. Thomas. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) – sea run cutthroat trout. U.S. Fish and Wild. Serv. Biol. Rep. 82(11.86) U.S. Army Corps of Engineers. TR EL-82-4. 21 p.

Pease, M. 2000. *Aechmophorus occidentalis* Western Grebe. University of Michigan Animal Diversity Web. May 2000.

Penttila, D., 1995a. The WDFW's Puget Sound intertidal baitfish spawning beach survey project. Pp. 235-241 in Puget Sound Research-95 Conference Proceedings, Vol. 1. Puget Sound Water Quality Authority, Olympia, Washington.

_____. 1995b. Investigations of the spawning habitat of the Pacific sand lance, (*Ammodytes hexapterus*), in Puget Sound. Pages 885-859 in Puget Sound Research-95 Conference Proceedings, Vol. 2. Puget Sound Water Quality Authority, Olympia, Washington.

_____. 2001. Documented Spawning Areas of the Pacific Herring, *Clupea*, the Surf Smelt, *Hypomesus*, and the Pacific Sand Lance, *Ammodytes*, in Whatcom County, Washington. Washington Department of Fish and Wildlife, LaConner, WA.

_____. 2007. Marine Forage Fishes in Puget Sound. Wash. Dept. Fish and Wildlife Tech. Rpt 2007-03, 22p.

_____. 2008. Personal communication re sand lance and northern anchovy. Washington Department of Fish and Wildlife. Region 4. La Conner, Washington.

Pew Center. 2008 (updated). The causes of global climate change. Science Brief 1. Updated August 2008. Available online. [Accessed October 17, 2008 at: www.pewclimate.org/docUploads/global-warming-science-brief-august08.pdf]

Piening, C., Boettner, J. Graeber, B. and T. Mumford. 2001. Risk Assessment Needs for Land Management Decisions at Cherry Point, Whatcom County, Washington. Washington Department of Natural Resources, Aquatic Resources Division: On File. Olympia, Washington. 8 p.

Pratt, C. 2007. Personal Communication. Washington Department of Natural Resources SEPA Program. March 8, 2007.

Prinslow, T.E., E.O. Salo and B.P. Snyder. Studies on Behavioral Effects of Lighted and an Unlighted Wharf on Outmigrating Salmonids, march-April 1978. University of Washington Fisheries Research Institute Final Report FRI-UW-7920. 35 pp.

Ptolemy, R. 2009. Rivers Biologist/Instream Flow Specialist. Fisheries Science Section, Ecosystems Branch, Ministry of Environment. P.O. Box 9338 Stn Prov Govt. Victoria BB

V8W 9M1. Personal communication via email May 29 2009. Records on file at Washington State Dept. of Natural Resources, Aquatics Division, Olympia, WA.

Puget Sound Action Team. 2005. Regional Nearshore and Marine Aspects of Salmon Recovery. June 28, 2005. Records on file at Washington State Dept. of Natural Resources, Aquatic Division, Olympia, WA.

Puget Sound Action Team. 2006. Puget Sound Georgia Basin Ecosystem Indicators. Joint report with the U.S. Environmental Protection Agency. Available online. [Accessed February 22, 2007 online at: www.epa.gov/region10/psgb/]
Puget Sound Ambient Monitoring Program, 2006. Marine Bird Density Atlas. Available online. [Accessed June 4 – 6, 2007 at: wdfw.wa.gov/mapping/psamp/index.html]

Puget Sound Clean Air Agency. 2003. Regional air monitoring network data. Available online. [Accessed through the Puget Sound Clean Air Agency web page on January 5, 2004 at www.pscleanair.org/airq/datareq.aspx]

Puget Sound Partnership. 2007. Puget Sound Update: Publications – Biological Resources. Available online. [Accessed May 13, 2009 at: http://www.psparchives.com/publications/puget_sound/update/07update/sections/07_updatebiological- resources.pdf]

_____. 2008. Action Agenda. [Accessed March 31, 2009 online at: www.psp.wa.gov/downloads/ACTION_AGENDA_2008/Action_Agenda.pdf]

Puget Sound Nearshore Partnership. 2009. www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=PSNERP&pagename=Change_Analysis

Puget Sound Shared Strategy (PSSS). 2005. Puget Sound salmon recovery plan. Available at http://www.sharedsalmonstrategy.org/.

Puget Sound Technical Recovery Team. 2006. Draft Working Paper: Ecological Integrity of Chinook Salmon Watersheds in the Puget Sound and Population Status. May 2006. [Accessed October 4, 2008 online at: www.nwfsc.noaa.gov/trt/trt_documents/]

Puget Sound Water Quality Action Team. 2000. 2000 Puget Sound Update: Seventh Report of the Puget Sound Ambient Monitoring Program.

Puget Sound Action Team. 2007. *2007 Puget Sound Update: Ninth Report of the Puget Sound Assessment and Monitoring Program.* Olympia, Washington.

Quinn, T. and D.E. Schneider, 1991. Respiratory adaptation of the teleost fish. *Ammodytes hexapterus*, in relation to its burrowing behavior. Comparative Biochemistry and Physiology 97(A):57-61.

Quinn T., 1999. Habitat characteristics of an intertidal aggregation of Pacific sandlance (*Ammodytes hexapterus*) at a north Puget Sound beach in Washington. Norwest Science 73(1):44-49.

Quinn, T., and R. Milner. 1999. Great blue heron (*Ardea herodias*). *In* E. M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Available online at: www.wa.gov/wdfw/hab/phs/vol4/gbheron.htm

Rice, C.A. 2006. Effects of Shoreline Modification on a Northern Puget Sound Beach: Microclimate and Embryo Mortality in Surf Smelt (*Hypomesus pretiosus*). National Marine Fisheries Service, Mukilteo Field Facility, Mukilteo, Washington and University of Washington School of Aquatic and Fishery Sciences, Seattle, Washington . 9 p. Available online. [Accessed July 13, 2007 at: www.psat.wa.gov/Programs/orca/forage_fish/smelt-and-armoring_Rice_2006.pdf]

Richardson, S., D. 1997. Washington state status report for the gray whale. Washington Department of Fish and Wildlife, Olympia. 28 p.

Richardson, S., D. Hays, R. Spencer, and J. Stofel. 2000. Washington state status report for the common loon. Washington Department of Fish and Wildlife, Olympia. 53 p.

Robers, Callum M. 2001. James A. Bohnsack, Fiona Gell, Julie P. Jawkis, and Renata Goodridge. Effects of Marine Reserves on Adjacent Fisheries. Science 294(5548):1920 – 1923.

Rodway, M.S. and F. Cooke. 2002. Use of fecal analysis to determine seasonal changes in the diet of wintering Harlequin Ducks at a herring spawning site. Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia. Journal of Field Ornithology: Vol 73:4. pp. 363 – 371.

Ruby, Robert H. and John A. Brown. 1986. *A Guide to the Indian Tribes of the Pacific Northwest*. University of Oklahoma Press, Norman, Okla.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78, 125 p.

Scheffer, V. B., and J. W. Slipp. 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. Am. Midl. Nat. 39(2):257-337.

Schwartz, A. L. and Galen L. 1984. Responses of Pacific Herring, *Clupea harengus pallasi*, to Some Underwater Sounds. Can. J. Fish. Aquat. Sci. 41(8): 1183–1192 (1984)
Schwartz, M.L., M. Chrzastowski, B. Harp, and B.E. Taggart. 1991. Net shore-drift in Washington State: Volume 3, Central Puget Sound Region. Shorelands and Coastal Zone Management Program, Washington Department of Ecology. June 1991. Olympia, Washington.

Scientific Consensus Statement on Marine Reserves and Marine Protected Areas. 2001. Annual Meeting of the American Association for The Advancement of the Sciences, February 17.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184. 966 p.

Sea Duck Joint Venture. Species Status Report. Continental Technical Team. 2003. 85 p.

Seattle Audubon Society. 2008. BirdWeb website. [Accessed October. Available at: www.birdweb.org/birdweb/index.aspx]

Shaffer, A. 2002. Nearshore mapping of the Strait of Juan de Fuca: II. Preferential use of nearshore kelp habitats by juvenile salmon and forage fish. A report to the WDFW and Clallam County Marine Resources Committee. 17 March 2002. Region 4 Fish Program, P.O. Box 1100, La Conner, WA. 98257. Hard copy on file with Washington Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Shaffer, J. A. 1998. Kelp Bed Habitats of the Inland Waters of Western Washington. Washington Department of Fish and Wildlife.

Shapiro and Associates, Inc. 1994. Cherry Point Natural Resources Baseline Studies, prepared for Pacific International Terminals. Seattle, Washington.

Shay, R. and J. Bottorff. 2007 (rev). *Cavity Nesting Ducks:* Woodland Fish and Wildlife Series. Publication MISC0142. 8 p. Issued by the Washington State University Extension Coop. Hard copy on file with Washington Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Shipman, H. 2008. A Geomorphic Classification of Puget Sound Nearshore Landforms. Puget Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Short, F. T., D. M. Burdick, S. Granger and S. W. Nixon. 1996. Long-term Decline in Eelgrass, *Zostera marina* L., Linked to Increased Housing Development. Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia, 25 -29, January 1996. Ed. J. Kuo, R. C. Phillips, D. I. Walker, and H. Kirkman. Pp. 291-98. Nedlands, Western Australia: Sciences UWA.

Shuford, W. D., and D. P. Craig. 2002. Status Assessment and Conservation Recommendations for the Caspian Tern *(Sterna Caspia)* in North America. U.S. Department of the Interior, Fish and Wildlife Service, Portland, OR. 95 p.

Sikes, J. J., Shaffer, A. and D. Penttila. 2002. Nearshore mapping of the Strait of Juan de Fuca: III Pacific Herring Spawning Habitat. A Survey. Washington Department of Fish and Wildlife 30 April 2002. Region 4 Fish Program, P.O. Box 1100, La Conner, WA. 98257. Hard copy on file with Washington Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Silber, G.K., S. Bettridge, and D. Cottingham. 2009. Report of a workshop to identify and assess technologies to reduce ship strikes of large whales, 8-10 July, 2008, Providence, Rhode Island. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-42. 55 p.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of Ferry Terminals to Migrating Juvenile Salmon Along Puget Sound Shorelines. Washington State Transportation Center (TRAC). Washington State Transportation Commission. U.S. Dept. of Transportation.

Small, M.P., Loxternman, J.L., Frye, A.E., VonBargen, J.F., Bowman, C. and S.F. Young. 2005. Temporal and Spatial Genetic Structure among Some Pacific Herring Populations in Puget Sound and the Southern Strait of Georgia. Genetics Laboratory, Washington

Department of Fish and Wildlife, Olympia, Washington 98501-1091, USA: Transactions of the American Fisheries Society 134:1329–1341, 2005.

Speich, S.M. and T.R. Wahl. 1989. Catalog of Washington Seabird Colonies. U.S. Fish and Wildlife Service Biological Report 88(6). Washington, D. C.

Stalmaster, M.V. 1987. The Bald Eagle. Universe Books, New York, New York, USA.

Stewart, B. S., and Huber, H. R. 1993. *Mirounga angustirostris*. Mammalian species 449:1-10.

Stewart, B. S., Le Boeuf, B. J., Yochem, P. K., Huber, H. R., DeLong, R. L., Jameson, R. J., Sydeman, W., and Allan, S. G. 1994. History and present status of the northern elephant seal population. In: B. J. Le Boeuf and R. M. Laws (eds.) Elephant seals. Univ. Calif. Press, Los Angeles.

Stick K. 2005. 2004 Washington State herring stock status report. Report. Washington State Department of Fish and Wildlife, Fish Management Division, May 2005. Hard copyon file at Washington Department of Natural Resources, Olympia, WA.

_____. 2008. Personal communication regarding Cherry Point herring. Washington Department of Fish and Wildlife. Region 4. La Conner, Washington. Records on file at Washington Department of Natural Resources, Aquatics Division, Olympia, WA.

Stick K., Costello, K., Herring, C., Lindquist, A., Whitney, J., and D. Wildermuth. 2005. Distribution and abundance of Pacific herring (*Clupea pallasi*) spawn deposition for Cherry Point, Washington stock, 1973-2004. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Hard copy on file at Washington Department of Natural Resources, Olympia, WA.

Stinson, D. W., J. W. Watson, and K. R. McAllister. 2001. Washington State status report for the bald eagle. Washington Department of Fish and Wildlife, Olympia, Washington

Stinson, D. W., J. W. Watson, and Kelly R. McAllister. 2007. Washington State Status Report for the Bald Eagle. Washington Department of Fish and Wildlife, Olympia. 86 + viii pp.

Stouder, Deanna J. Peter A. Bisson, Robert J. Naiman, editors. 1997. Pacific Salmon & their ecosystems: status and future options. Chapman & Hall. New York, NY.

Stout, H.A., R.G. Gustafson, W.H. Lenarz, B.B. McCain, D.M. VanDoornik, T.L. Builder, and R.D. Methot. 2001. Status review of Pacific Herring in Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC- 45, 175 p.

Stratton, Laura (Captain). 2008. Personal Communication on May 7, 2008 by phone with Elizabeth Ellis, Planner, DNR Aquatic Resources Program, Olympia, WA. Re: Vessel traffic patterns and VEAT reports, Ecology Spill Response Program, Lacey WA.

Sullivan, L. 2007. Annual Growing Area Review: Birch Bay. Washington State Department of Health Office of Shellfish and Water Protection. Available online. [Accessed June 16, 2008 at: www.doh.wa.gov/ehp/sf/Pubs/gareports/birch.pdf]

Suttles, Wayne. 1990. "Central Coast Salish." In *Handbook of North American Indians*. Vol. 7. Northwest Coast. pp.453-475. Ed. Wayne Suttles. Smithsonian Institution, Washington D.C.

Swanton, John Reed. 1978. *Indian Tribes of Washington, Oregon, and Idaho*. Ye Galleon Press, Fairfield Wash.

Taylor, E.B. and A.B. Costello. 2006. Microsatellite DNR analysis of coastal populations of bull trout (*Salvelinus confluentus*) in British Columbia: zoogeographic implications and its application to recreational fishery management. Can. J. Fish. Aquat. Sci. **63**: 1157–1171.

Thurman, Harold V. 1990. Essentials of Oceanography. Third Edition. Merrill Publishing Company. Bell & Howell Information Company. Columbus, Ohio. 43216

Trumble R. 1983. Management plan for baitfish species in Washington State Department of Fisheries Progress Report. No. 195. *in* Bargmann, G. Forage fish management plan: A plan for managing the forage fish resources in the state of Washington. 1998. Adopted by the Washington State Fish and Wildlife Commission on January 24, 1998. Hard copy available at Washington Department of Natural Resources, Aquatic Resources Division, Olympia, WA.

_____. 1983. Management plan for baitfish species in Washington State. Wash. Dept. of Fish. Prog. Rept. no. 195, 106 p.

University of Washington Climate Impacts Group. Access on the web: http://cses.washington.edu/cig/

U.S. Department of Energy. 2004. British Petroleum (BP): Cherry Point Cogeneration Project. Final Environmental Impact Statement. DOE/EIS-0349. Available online. [Accessed March 8, 2007. www.eh.doe.gov/nepa/eis/eis0349/]

U.S. Environmental Protection Agency. 1997. Office of Policy, Planning and Evaluation. September 1997. Climate Change and Washington. Publication: EPA 230-F-97-008uu. Available online. [Accessed June 18, 2008 at: yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BWJBX/$File/wa_impct.pdf]

_____. 1999. Commercial Marine Activity for Deep Sea Ports in the United States. Final Report. 30 June 1999. Prepared for the Assessment and Modeling Division, by ARCADIS Geraghty & Miller, Inc. Mountain View, California. Ref. SJ007264. Hard copy on file. Available at DNR Headquarters, 1111 Washington Street, Olympia, WA.

_____. 2004. Transportation and Office of Air Quality. Characterization of the Georgia Basin-Puget Sound Airshed Report. Developed by EPA and Environment Canada. Available online. [Accessed June 17, 2008 at www.pyr.ec.gc.ca/air/gb_ps_airshed/summary_e.htm]

_____. 2008. Office of Climate Change. Available online. [Accessed October 17, 2008 at www.epa.gov/climatechange/basicinfo.html]

_____. 2008. Office of Transportation and Air Quality. Oceangoing Vessels. Available online. [Accessed October 17, 2008 at www.epa.gov/OMS/oceanvessels.htm]

_____. 2008. Office of Wetlands and Watersheds - Oceans Coasts and Estuaries: Invasive Species. Available online. [Accessed June 17, 2008 at www.epa.gov/owow/invasive_species/]

_____. 2009. Transportation and Air Quality. NonRoad Engines, Equipment, and Vehicles – Oceangoing Vessels. Available online [Accessed 2008, 2009 at: www.epa.gov/otaq/oceanvessels.htm#tier1]

U.S. Fish and Wildlife Service. 1998. Fact Sheet: Bull Trout Facts. Hard copy on file. Available at DNR Headquarters, 1111 Washington Street, Olympia, WA.

_____. 2004. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). Volume I - III: Puget Sound Management Unit. Portland, Oregon. 389 + xvii pp. Available online. [Accessed July 13, 2007 at: www.fws.gov/pacific/bulltrout/jcs/vol_I.html]

_____. 2004. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). Volume I (of II): Puget Sound Management Unit. Portland, Oregon. 389 + xvii pp.

_____. 2006. News release. Revised critical habitat proposed for marbled murrelet. September 12, 2006. Available online. [Accessed June 27, 2007. www.fws.gov/pacific/marbledmurrelet/MAMU_PCH_finalNR_091206.pdf]

_____.2007. Threatened and Endangered Species Site (TESS). Available online. [Accessed June through July, 2007. www.fws.gov/endangered/wildlife.html]

_____. 2007. San Juan Islands National Wildlife Refuge. Pacific Region. Website. [Accessed April 2, 2008 at: www.fws.gov/pacific/refuges/field/wa_sanjuanis.htm]

Vadas. R.L. , et. al. 2008. Washington Departments of Fish and Wildlife and Ecology. Coastal Cutthroat Trout Ecohydrology and Habitat Use in Irely Creek, Washington. ***In*** Anderson, J. D. 2008. Coastal cutthroat trout in Washington state: status and management. Pages 11-23 *in* P. J. Connolly, T. H. Williams, and R. E. Gresswell, editors. The 2005 coastal cutthroat trout symposium: status, management, biology, and conservation. Oregon Chapter, American Fisheries Society, Portland. Hard copy available at Washington Department of Natural Resources, Aquatic Resources Division, Olympia, WA.

_____. 2009. Research Scientist. Washington State Department of Fish and Wildlife. Personal communication via email. May 20 – 29th. Records available at Washington Department of Natural Resources, Aquatic Resources Division, Olympia, WA.

Vadas, R.L. and Michal, H. Joint talk on coastal cutthroat trout and bull trout in Olympia, WA. May 27th, 2009 at Casa Mia, 7:00 – 8:00 p.m.

Vermeer, K., M. Bentley, K.H. Morgan, and G.E.J. Smith. 1997. Association of Feeding Flocks of Brant and Sea Ducks with Herring Spawn at Skidegate Inlet In: The Ecology, Status, and Conservation of Marine and Shoreline Birds of the Queen Charlotte Islands. K. Vermeer and K.H. Morgan, editors. Canadian Wildlife Service Occasional Paper No. 93. Ottawa, Ontario, Canada.

Wahl, T. R., S. M. Speich, D. A. Manuwal, K. V. Hirsch, and C. S. Miller. 1981. Marine bird populations of the Strait of Juan de Fuca, Strait of Georgia, and adjacent waters in 1978 and 1979 (MESA). U.S. Department of Commerce, Interagency Energy/Environment R&D Progress Report EPA-600/7-81-156.

Wailes, G.H. 1936. The food of *Clupea pallasii* in southern British Columbian waters. Journal of the Biological Board of Canada. 1(6):477-486

Waldichuck, M. 1957. Physical oceanography of the Strait of Georgia, British Columbia. J. Fish. Res. Board Can. 14:321-486.

Washington State Department of Ecology Water Quality Program, 1998 303d List of Impaired and Threatened Water Bodies. Available online. [Accessed on May 21, 2002 at www.ecy.wa.gov/programs/wq/303d/1998/1998-index.html#background]

_____. 2000. North Puget Sound Long-Term Oil Spill Risk Management Panel: Final Report and Recommendations. Ecology Publication No. 00-08-024. Compiled by National Center Associates. July 2000.

_____. Water Quality Assessment, Year 2002 Section 305(b) Report. Water Quality Program. Available online. [Accessed on January 25, 2007 at: www.ecy.wa.gov/programs/wq/303d/2002/2004_documents/summary_info-062005.pdf]

_____. 2003. Puget Sound Shorelines Website. Available online. [Accessed October 7, 2008 at: www.ecy.wa.gov/programs/sea/pugetsound/]

_____. 2004. Vessel Entries and Transits for Public Waters Report (VEAT) for 2003. Washington Department of Ecology Publication 04-08-002. Spill, Prevention and Preparedness Program, Lacey, WA.

_____. 2004. Water Quality Assessment, Year 2004 Section 303(d) Report. Water Quality Program. Available online. [Accessed on January 25, 2007 at: www.ecy.wa.gov/pubs/0203026.pdf] 283 p.

_____. 2005. Vessel Entries and Transits for Public Waters Report (VEAT) for 2004. Washington Department of Ecology Publication 05-08-003. Published May, 2005. Spill, Prevention and Preparedness Program, Lacey, WA.

_____. 2006. Vessel Entries and Transits for Public Waters Report (VEAT) for 2005. Washington Department of Ecology Publication 06-08-003. Published April, 2006. Spill, Prevention and Preparedness Program. Lacey, WA.

_____. 2006. Personal communication by memo. Cherry Point Sediment Status Update memo (unsigned). From Ecology, Water Quality to David Palazzi, Aquatic Reserves. March 10, 2006. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

_____. 2007. Climate Change: Disrupting our Economy, Environment and Communities. Available online. [Accessed June 18, 2008 at: www.ecy.wa.gov/climatechange/reducedsnow.htm]

_____. 2007. Fact Sheet for NPDES Permit WA-000295-0. Water Quality Program, Lacey, Washington.

_____. 2007. Vessel Entries and Transits for Public Waters Report (VEAT) for 2006. Washington Department of Ecology Publication 07-08-005. Published April, 2007. Spill, Prevention and Preparedness Program. Lacey, WA.

_____. 2009. Oil Spill Response Program. Personal communication by memo, email. From Dale Jensen and Sarah Boyle to Elizabeth Ellis, CC: Dave Roberts, David Palazzi. Cherry Point Spills. March 17-18, 2009. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

Washington State Department of Fish and Wildlife (WDFW). 2009. Draft Puget Sound Rockfish Conservation Plan. Washington State Department of Fish and Wildlife, Olympia, WA. 2009.

Washington State Department of Fish and Wildlife (WDFW). 1998. Bargmann, Greg. Forage Fish Management Plan. Adopted by the State Fish and Wildlife Commission, January 24 1998.

_____. 1998. Fact Sheet: What is a bull trout and a Dolly Varden? Available online. [Accessed May 29, 2009 at: wdfw.wa.gov/factshts/bultrout.htm]

_____. 2000. Critical spawning habitat for herring, surf smelt, sand lance, and rock sole in Puget Sound, Washington. Washington Department of Fish and Wildlife Fish Program. March 2000.

_____. 2000. Blakey, Ann. Leland, Bob, and Jim Ames, eds. Salmonid Stock Inventory: Coastal Cutthroat Trout. Available online. [Accessed May 20, 2009 at: wdfw.wa.gov/fish/sassi/cutthroat.htm]

_____. 2001. Washington Department of Fish and Wildlife studies causes of Cherry Point herring decline. Bargman, Greg. Marine Fish Unit. Available online. [Accessed January 30, 2007 at: wdfw.wa.gov/science/articles/herring/].

_____. 2001. Fish and Wildlife Science, April 2001. Marine Refuges offer haven for Puget Sound fish. Available online. [Accessed September 30, 2009 at: wdfw.wa.gov/science/articles/marine_sanctuary/index.html].

_____. 2003. Puget Sound chum salmon runsize and escapement data. Downloaded from Washington Department of Fish and Wildlife web page. Available online. [Accessed December 17, 2003 at: www.wdfw.wa.gov/fish/chum/chum-5e.htm].

_____. 2005. Washington's Comprehensive Wildlife Conservation Strategy. Final Draft. Submitted September 19, 2005. Available online. [Accessed via J. Bohannon, WDFW biologist, November 22, 2008 at: wdfw.wa.gov/wlm/cwcs/cwcs.htm]

_____. 2006. Whatcom County Wildlife Area Management Plan (draft). Available online. [Accessed on June 27, 2007 at: wdfw.wa.gov/lands/wildlife_areas/management_plans/pdfs/draft_whatcom_plan.pdf] 91 p.

_____. 2007. Forage Fish – Herring – Habitat Issues. Washington Department of Fish and Wildlife Fish Program. Website. Available online. [Accessed March 8, 2007 at wdfw.wa.gov/fish/forage/herring.htm#comfish]

_____. 2007. Personal communication – Terry Johnston, WDFW GIS Specialist, Olympia, Washington. RE: Marine mammal data in Cherry Point area. June 28, 2007. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

_____. 2008. Puget Sound Commercial Salmon Management and Catch Reporting Areas. Available online. [Accessed June 15, 2008 at wdfw.wa.gov/fish/regs/commregs/commsalmon__reportareas08.pdf]

_____. 2008a. Puget Sound Commercial Crab Regulations. Available online. [Accessed June 15, 2008 at wdfw.wa.gov/fish/shelfish/crabreg/comcrab/index.shtml]

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, Washington. 212 p.

Washington State Department of Fish and Wildlife (WDFW). 2007. Whatcom Wildlife Area. Website. [Accessed April 2, 2008 at: wdfw.wa.gov/lands/wildlife_areas/tennantlake/index.htm]

_____. 2009. Salmon Facts. An informational guide to our state's natural treasure. Available online. [Accessed June 9, 2009 at: wdfw.wa.gov/outreach/fishing/salmon.htm]

_____. 2009. Washington State 2009 Sport Fishing Regulations. WDFW. Available online. [Accessed September 30, 2009 at: wdfw.wa.gov/fishing/regs_seasons.html]

_____. 2009. Puget Sound Rockfish Conservation Plan (PSRCP), Draft Environmental Impact Statement**.** Draft. Accessed December 15, 2009 at: [http://wdfw.wa.gov/fish/management/rockfish/]

Washington State Department of Health. 2007. Office of Shellfish and Water Protection: Recreational Shellfish website. Available online. [Accessed July 16, 2007 at: www.doh.wa.gov/ehp/sf/default.htm]

Washington State Department of Natural Resources, 1995. State of Washington Natural Heritage Plan: 1993/1995 Update. Olympia, WA: Cherry Point Workgroup. 191 pp.

_____. 2002. Piening, C. et al. Reference Guide to Cherry Point. Internal working document. Planning Unit, Olympia, WA: Cherry Point Workgroup. 58 p.

_____. 2003. Lease Jacket 20-008488: Intalco Aluminum Corporation. Exhibit B: Plan of Operations. Volume 4 of 5. Olympia, WA.

_____. 2006. Lease Jacket 20-B11714: ConocoPhillips Ferndale Refinery. Exhibit B: Plan of Operations. Olympia, WA.

_____. 2007. Potential Effects and Expected Outcomes Research paper. Planning Unit, Olympia, WA: ESA Team. 210 pp.

Washington State Office of Financial Management. 2006. Official April 1, 2006 Population Estimates. Available online. [Accessed on January 25, 2007 at: www.ofm.wa.gov/pop/april1/default.asp]

Washington State Parks and Recreation Commission. 2007. Birch Bay State Park. Website. Available online. [Accessed April 2, 2008 at: parks.wa.gov/parkpage.asp?selectedpark=Birch+Bay]

Watson, J.W. and D. J. Pierce. 1998. Ecology of bald eagles in western Washington with an emphasis on the effects of human activity. Final Report, Washington Department of Fish and Wildlife, Olympia, Washington,

Weitkamp, L. A., T. C. Wainwright, G. J . Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commer., NMFS-NWFSC-24, 258 p.

Wenger, Barry. 2009. Washington State Department of Ecology, Bellingham Field Office. Personal Communication, May 26, 2009. Hard copy of comments on file at Washington Department of Natural Resources, Olympia, WA.

West, J. 1997. Protection and Restoration of Marine Life in the Inland Waters of Washington State. Puget Sound/Georgia Basin Environmental Report Series: Number 6. Prepared for the Puget Sound/Georgia Basin International Task Force, Washington Workgroup on Protecting Marine Life.

West J, O'Neill S, Lippert G, Quinnell S. 2001. Toxic Contaminants in Marine and Anadromous Fishes from Puget Sound, Washington: Results of the Puget Sound Ambient Monitoring Program Fish Component, 1989-1999. Olympia, WA: Washington Department of Fish & Wildlife, 2001.

West JE, O'Neill SM, Ylitalo GM. 2008. Spatial extent, magnitude and patterns of persistent organochlorine pollutants in Pacific herring (*Clupea pallasi*) populations in Puget Sound (USA) and Strait of Georgia (Canada). Science of the Total Environment, 2008; 394:369-378.

Western Climate Initiative. 2008. Website. Accessed October 17, 2008. [Available at: www.westernclimateinitiative.org/WCI_Documents.cfm]

Whatcom County. 1996. Gateway Pacific Terminal Draft Environmental Impact Statement, Volumes I and II. Whatcom County Planning and Development Services, Bellingham, WA.

_____. 2003. Whatcom Salmon Recovery. Whatcom County Water Resources. Available online. [Accessed October 7, 2008 at: whatcomsalmon.wsu.edu]

_____. 2005. Whatcom County Comprehensive Plan. Revised. Whatcom County Planning and Development, Bellingham, Washington. Available online. [Accessed August 13, 2007 at: www.co.whatcom.wa.us/pds/planning/comp_plan/comp_plan.jsp]

_____. 2008. Whatcom County Comprehensive Plan. Whatcom County Planning and Development, Bellingham, Washington. Available online. [Accessed June 2 2009 at: http://www.co.whatcom.wa.us/pds/planning/comp_plan/comp_plan.jsp]

_____. 2006. Shoreline Master Program Update: Shoreline Characterization and Inventory. June, 2006. Part 1 (Chapters 1 – 3). Prepared by Parametrix, Bellevue, WA. 98004. [Accessed on February 6, 2007 at: www.co.whatcom.wa.us/pds/shorelines_critical_areas/smp_update.jsp]

_____. 2007. Website: Historical information on Whatcom County. Available online. [Accessed July 16, 2007 at: www.co.whatcom.wa.us/history.jsp]

_____. 2008. Zoning Maps. Available online. [Accessed June 18, 2008 at: www.co.whatcom.wa.us/pds/pdf/planning/gis/t20zon9.pdf]

Whatcom County Marine Resources Committee. 2001. The marine resources of Whatcom County. Prepared by Anchor Environmental, LLC for Whatcom County MRC. April 2001. Available online. [Accessed June 18, 2008 at: www.whatcom-mrc.wsu.edu/mrc/projects/studies/MarineResourcesReport_finalApril2001.pdf]

Whatcom County Marine Resources Committee. 2007. Whatcom County Marine Resources Committee – Fish Facts: Surf Smelt. Available online. . [Accessed on July 13, 2007 at: whatcom-mrc.wsu.edu/Fact_Sheets/surf_smelt.pdf]

Wigfield, Kim. 2008. Washington State Department of Ecology. Personal Communication via electronic correspondence on Friday, January 18, 2008 6:16 PM with David Palazzi. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA..

_____. 2008. Washington State Department of Ecology. Personal communication via electronic correspondence during December 2008 with Elizabeth Ellis. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

Wildermuth, Darcy.2008. Personal communication re surf smelt. Washington Department of Fish and Wildlife. Region 4. La Conner, Washington. Records on file with Washington Department of Natural Resources, Aquatic Division, Olympia, WA.

Wiles, G. J. 2004. Washington State status report for the killer whale. Washington Department Fish and Wildlife, Olympia. 106 pp.

Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J. P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance assessment of the state of the nearshore ecosystem: eastern shore of Central Puget Sound, including Vashon and Maury islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization. Volume 1. Puget Sound Region. Washington Department of Fish and Wildlife.

Williams, R. & Thomas, L. 2007. Distribution and abundance of marine mammals in the coastal waters of British Columbia, Canada. J. Cetacean Res. Manage. 9(1):15-28

Willson, M. F., and J. N. Womble. 2006. Vertebrate exploitation of pulsed marine prey: a review and the example of spawning herring. Reviews in Fish Biology and Fisheries 16:183–200.

Wydoski, R. S., and R. R. Whitney. 2003. Inland fishes of Washington, 2nd edition. American Fisheries Society, Bethesda, Maryland and University of Washington Press, Seattle.

Yates, Steve. 1988. Marine Wildlife of Puget Sound, the San Juans, and the Strait of Georgia. Globe Peqot Press. Chester, CT. 06412. 262 p.

Yeh, S. and Kirtman, B.P. 2004. Global climate anomalies and decadal North Pacific SST variability in a coupled GCM. Center for Ocean-Land-Atmosphere Studies, 4041 Powder Mill Road, Suite 302 Calverton, MD 20705. March 2004. Hard copy available at Department of Natural Resources, Aquatic Resources Program, Olympia, WA. 32 pp.

Appendix A - Cherry Point Aquatic Reserve Resource Characterization

This section provides detailed information regarding the ecological zones, habitats, species and other resources found within or adjacent to the Cherry Point Aquatic Reserve. Understanding the ecological processes and functions at Cherry Point can guide decision-making regarding aquatic land management that influences the Reserve and its associated ecological relationships**.**

Background

The Georgia Basin was created about 150 million years ago when colliding continental plates created the Georgia Depression. The Puget Sound and the Strait of Georgia were created by the repeated advance and scouring of glacial ice-sheets, the most recent of which moved into the area around 15,000 to 13,000 years ago (Easterbrook 1999). This glaciation, referred to as the Fraser, flowed through the Fraser Valley and formed the Strait of Juan de Fuca. The Fraser Glaciation moved as far south as Olympia, with huge glaciers forming the hills and valleys that characterize the Georgia Basin today and depositing the Vashon Till that covers much of the region (Williams et al. 2001).

The Strait of Georgia or the Georgia Strait, is a strait between Vancouver Island (as well as its nearby Gulf Islands) and the British Columbia mainland. The Canada-US border runs through the southern part of the Strait. To the south, Georgia Strait adjoins Puget Sound (which extending to near the bottom of the map) and to the west, it adjoins Haro Strait, then the Strait of Juan de Fuca (bisected by the order). The Strait is approximately 240 kilometers (150 mi) long and varies in width from 18.5 to 55 km (11.5 to 34 mi). Cherry Point Reach lies within the Strait of Georgia – see below. [11]

[11] This image is from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Project and more than 5 years old. Satellite data captured by the SeaWIFS sensor are released into the **public domain** 5 years after capture.

Figure 4. Strait of Georgia and Pacific Northwest- The Strait of Georgia at center, the Strait of Juan de Fuca below, Puget Sound at the lower right. Sediment from the Fraser River clearly visible.

Nearshore Environment

The nearshore environment includes estuarine and marine shoreline areas representing the interface between freshwater, air, land, and the open marine waters of Puget Sound and Georgia Strait (Fresh et. al, 2004). The nearshore includes upland and backshore areas that directly influence conditions along the shoreline, extending seaward to the greatest depth of the water column that encompasses the photic zone (Fresh, et al. 2004). Within this area, a complex interplay of biological, geological, and hydrological processes interact across the terrestrial-marine interface to maintain the nearshore environment (Johannessen and MacLennan 2007).

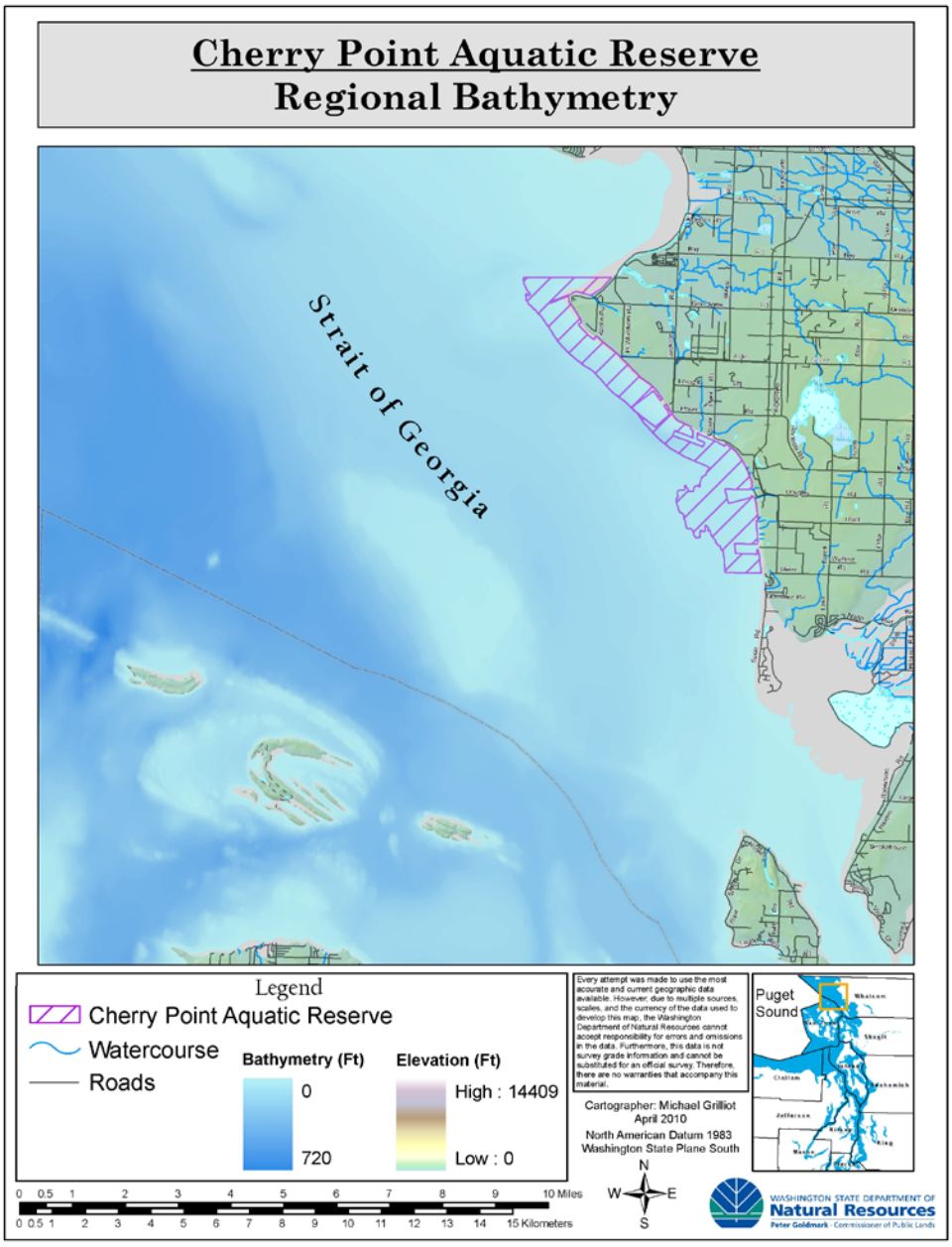
Shoreline Characteristics

Geomorphic characteristics of the Whatcom County Shoreline, including Georgia Strait, include glacial sediment, limited sea level rise, moderate tidal range and considerable wave exposure. These characteristics create geomorphic systems, based upon the availability of and sources of sediment, and the influence of waves, tide and river energy (Shipman, 2008).

The character of the beach at Cherry Point is described as consisting of moderate to high feeder bluffs, with broad storm berms, which likely buffer wave erosion. The berm crest is composed of pebble and granula with minor cobble, and the upper foreshore of the beach is dominated by pebble and cobble with substantial amounts of sand in most locations. The lower foreshore/high tide beach is cobble and pebble dominant with sand and boulders. Beach material along the low tide terrace is typically composed of finer sediment with cobble and boulder lag deposits. Active bluff erosion

contributes large woody debris to the upper beach (Whatcom County Shoreline Characterization Inventory, 2006). The site is also distinctive for its bathymetry with water depths reaching more than 70 feet just offshore (see Figure 5).

Figure 5, Bathymetry at Cherry Point



Bluffs and Drift in Whatcom County

Bluffs are present throughout a majority of Whatcom County waterways. Bluffs are relatively recent landforms, created as an after effect of the most recent glaciations (Fraser). A large sheet of ice advanced from British Columbia through Georgia Strait on the tail of advancing outwash composed of sands and gravels, and moved south through Puget Sound to below Olympia. It extended out beyond Cape Flattery. This is called the Vashon Advance, and is response for many of the sediment

in Puget Sound (“Vashon Till”) and beach landforms seen today. It occurred approximately 5,000 years ago (Johannessen, 2006).

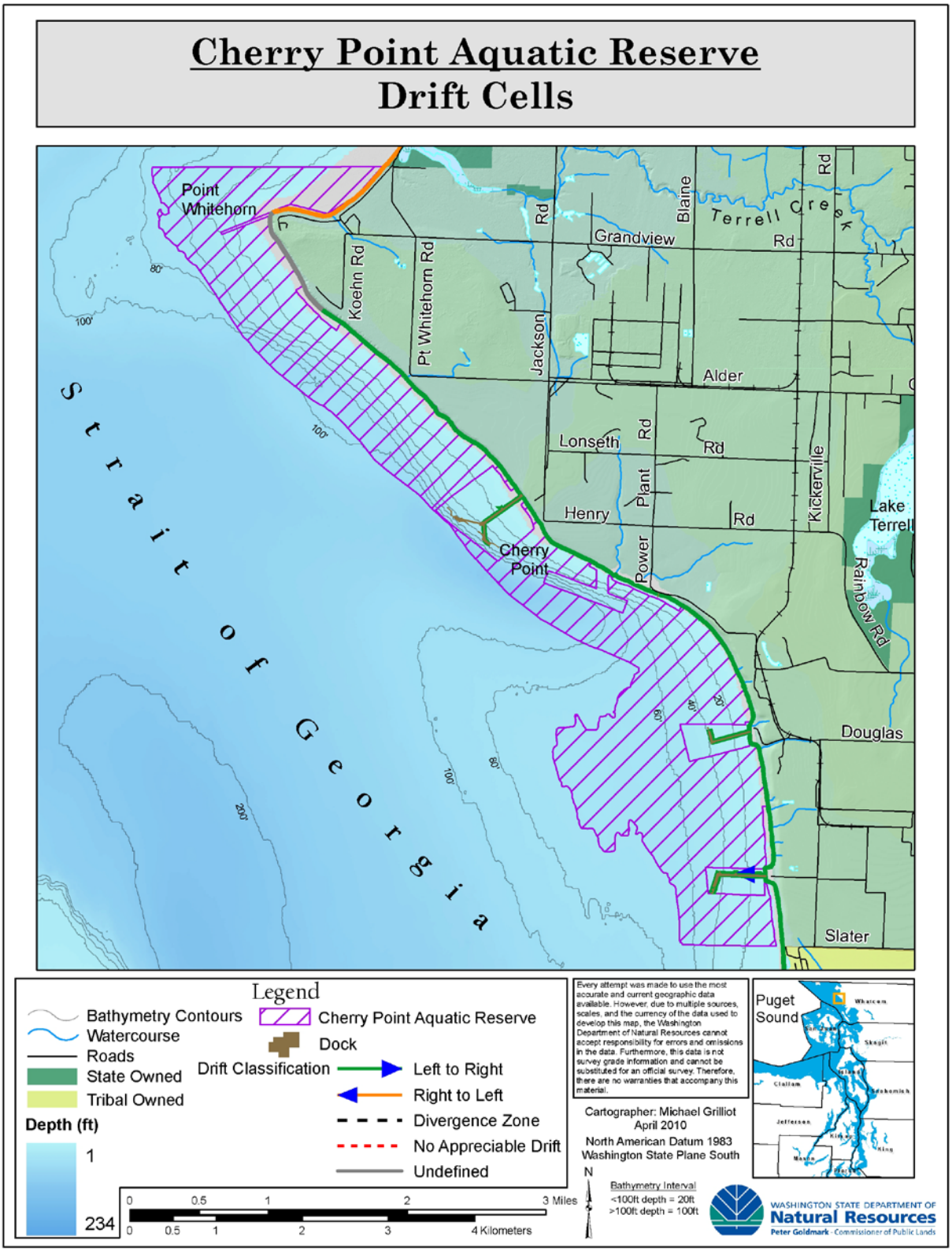
In Whatcom County, the Vashon Advance created bluffs that reach heights reach up to 200 feet. Many of these bluffs actively erode, creating beaches and large areas of accretion, composed of this glacially derived sediment. These bluffs help feed the constant river of sand and gravel that flows along beaches. Shore drift or "littoral drift" can move materials from eroding bluffs and streams to shorelines miles away. Weather and waves pick up particles in one area and drop them off in another area. The direction of shore drift is determined by the prevailing direction of the waves and currents in the drift cell. Drift cells are an important shoreline component at the Cherry Point Aquatic Reserve; there are three within Reserve or the immediate vicinity adding to the areas uniqueness, and these cells will be discussed in detail next.

Drift cells are important because they are the mechanism that supplies nearshore environments with the majority of the sediments they require. Drift cells nourish beaches, and provide fine sediments to flats, and maintain sand spits and other coastal landforms. According to the Whatcom County 2006 Shoreline Characterization and Inventory, there are three drift cells located at or in the immediate vicinity of Cherry Point: (1) Birch Bay, (2) Point Whitehorn, and (3) Cherry Point. Structures such as marinas, docks and groins can erode and damage beach habitat by blocking supplies of sand to downdrift beaches, flats and sand spits (Ecology website, 2008). Figure 6 depicts the drift cells at Cherry Point.

Birch Bay Drift

Shore drift moves from Birch Point south and east towards the jetty located at Birch Bay Village Marina. A second drift cell starts east of the Marina and extends to the northeastern corner of Birch Bay (Whatcom County, 2006).

Figure 6, Cherry Point Drift Cells



Point Whitehorn Drift

A drift cell originates at Point Whitehorn, drifting northeast to converge with a cell in the northeast corner of Birch Bay. Bluff erosion at Point Whitehorn is substantial and significantly contributes to the drift cell. Visible evidence of this dynamic process at Point Whitehorn includes broad sand flats, spits, and protruding shorelines. Beaches at Point Whitehorn mark the start of a large accretionary beach, which forms around Birch Bay, just to the north. Ninety-four percent of the beaches in this Reach are considered accreting beaches (compared to eroding beaches) (Whatcom County, 2006).

Cherry Point Drift

A northwesterly fetch from the Strait of Georgia moves sediment south, through a narrow divergence zone located at Point Whitehorn. This cell includes the Cherry Point area and terminates at the spit at Sandy Point. According to Whatcom County's Shoreline Inventory and Characterization, which examined sediment transport along the coastline, sediment sources are abundant within this drift cell, accounting for approximately 54 percent of the Cherry Point shore reach. Feeder bluffs make up an additional 9 percent. The Cherry Point Aquatic Reserve is also characterized by recent landslides, representing over 18 percent of the shore reach. Toe erosion was identified along 38 percent of the Reserve. Human modifications that directly affected geomorphic processes were identified along 9 percent of the Cherry Point Aquatic Reserve. (Whatcom County, 2006).

Riparian areas are generally defined as the interface between terrestrial and aquatic ecosystems. As Brennan (2007) explains, riparian areas are part of the transition zone between aquatic and terrestrial systems. The riparian area within the Cherry Point Aquatic Reserve includes forests, meadows, streams, and a brackish wetland. The primary functions and processes within the marine riparian zones include nutrient and sediment input, maintenance of water quality, soil/slope stability, shade/temperature control, and recruitment of large woody material.

Salt Marshes

At Cherry Point, a large brackish marsh habitat complex can be found along Gulf Stream Road. Salt marsh and brackish marsh habitats thrive in areas influenced by tides, often located above mean high high water (MHHW), in locations where sediment accretion or supply is high (Whatcom County, 2006; Kyte, M. pers. comm., 2009).

Cherry Point Nearshore Zone

As earlier emphasized, the nearshore environment is a dynamic area. It also provides for a wide range of commercial, navigational, and residential activities such as marinas, ferry docks, and log storage. Due to the ecological sensitivity of the nearshore environment and its value for human activities, protecting nearshore processes and functions is a critical component of this management plan.

The intertidal zone at Cherry Point is rocky, running the length from Point Whitehorn to Sandy Point and containing a wide variety of biological habitats. The most common habitat consists of various sizes of boulders, mixed with, cobble, gravel and sand. Large boulders are prevalent north of Cherry Point, near the Alcoa-Intalco facility, and immediately south of the ConocoPhillips refinery. Boulder habitat has the function of providing substrate shelter for mobile and sessile organisms (ENSR 1992a). Moving from the intertidal towards the low-tide line, the boulders mix with and sandy patches. Many of these sand patches support eelgrass (*Zoestra marina*) and/or assemblages of marine algae (ENSR 1992a).

The sublittoral zone extends from the low-tide line out to 200 meters. The sublittoral refers to areas where sunlight reaches the ocean floor; that is, the water is not deep enough to remove the photic zone. At the Cherry Point Aquatic Reserve, the sublittoral zone is generally depositional, with fines, silt and mud prevailing. Subtidal (sublittoral) mudflats are also abundant below approximately 5 to 10 meters below mean lower water because of the depositional nature of the offshore environments within the Reach (Kyte, M. 2009, personal communication). Some boulders are present, covered in silt. Sediment in the upper sublittoral zone immediately below the intertidal zone are generally sandy mud (ENSR 1992a). The inner sublittoral extends out to about 160 feet, the boundary of the Cherry Point Aquatic Reserve. However, the actual seaward limit of the sublittoral will vary because it is determined by that depth at which we find no plants growing on the ocean bottom. It is determined to a major extent by the amount of solar radiation that penetrates the surface water, or the end of the photic zone. This could be influenced, in part, by turbidity (Thurman, 1990) and any type of spill.

The sublittoral is considered the end of the nearshore environment, with the open ocean (marine) beyond this area. Beyond this, we find open ocean conditions, where local and regional currents, temperature, salinity and water quality become important to consider.

Oceanography

Today, the Strait of Georgia is fed by the 850-mile long Fraser River to the north, which moves large amounts of silt and fresh water long distances. This river drains over one quarter of British Columbia and has the largest salmon runs in North America (Georgia Strait Alliance, 2007). The Fraser River has a profound influence on the water flow and quality within the Strait of Georgia. Over 80 percent of the freshwater entering the Strait of Georgia comes from the Fraser River; run-off is driven by glacier melt, occurring during June and July. Other rivers drain into the Strait of Georgia from Vancouver Island during periods of intense precipitation, generally around November (Waldichuck 1957). For comparison, the annual amount of freshwater entering Puget Sound is only 10-20 percent of the amount that enters the Strait of Georgia.

Freshwater

The Strait of Georgia receives freshwater input from rivers and streams, compared to Puget Sound, which receives freshwater runoff from the encircling Olympic Mountains to the west and the Cascade Mountains to the east (Whatcom County 2006). For Cherry Point, one of the major sources of nearby freshwater supports two genetically distinct salmonids – Nooksack Chinook and Nooksack Coastal Cutthroat. This sediment rich river has been heavily modified in the upper and mainstem areas, and currently drains just south of the Reserve. Salmonids migrating to the Nooksack use the Cherry Point nearshore area.

The Fraser River has been the primary source of freshwater for Cherry Point and the Strait of Georgia. The Fraser brings a high level of fine sediment to the Reserve, when combined with the Nooksack input to the south of the Reserve, and constant erosion of feeder bluffs along the shoreline, have created a habitat conducive to supporting submerged vegetation and Pacific herring (Center of Biological Diversity et al, 2004)..

The Nooksack River, located south of the Reserve and its delta has been diverted and reduced in size, due in part to levees and isolating meanders. Historically, until the 1950's, the Nooksack River discharged into the Bellingham Bay. Diversions of the Nooksack occur for irrigated agriculture, industrial uses at the Cherry Point refinery complex and the cities of Lynden and Ferndale. In all these cases flow is reduced from within the Nooksack channel (PSAT 2005).

Smaller freshwater streams discharge in or near the Cherry Point Aquatic Reserve. Terrell Creek discharges just north of Cherry Point through Birch Bay State Park, along with two unnamed freshwater creeks identified as streams “01.0100” and “01.0101”. Terrell Creek is 8.7 miles in length and is mapped as a pocket estuary that provides feeding, refuge, and osmoregulatory functions for juvenile salmonids (Washington State Department of Parks and Recreation, 2007; Whatcom County Shoreline Characterization Inventory June 2006). It supports fair to good populations of coho plus some chum utilization. The Birch Bay great blue heron colony is located north of the creek and west of Jackson Road. The Birch Bay great blue heron colony is the third largest in the region, supporting over 300 breeding pairs (U.S. Department of Energy, 2004).

Stream 01.0100 is 1.25 miles long and drains 800 acres. The stream is characterized (according to WAC 222-16-030) as a Type 4 water below Henry Johnson Road (water may be intermittent) and a Type 5 above (water is intermittent) (Shapiro and Associates 1994). Field surveys suggest that few fish species use this stream. Based on previous reports the only anadromous fish likely to use the stream are cutthroat (Shapiro and Associates 1994). Based on personal observations made during annual beach walks from 1999 through 2008 that have included the mouths of these two streams in each year, Kyte reports personal observations that stream 01.0100 is ephemeral at its mouth and usually dry in the spring. Kyte concludes that it is very unlikely that this stream supports any finfish, especially anadromous species (Kyte, M. 2009, personal communication via email).

Less is known about stream 01.0101 and its ability to support anadromous fish is unknown. Stream 01.0101 drains through the Cherry Point saltmarsh, a nine-acre Category 1 wetland that includes 3.5 acres of estuarine emergent saltmarsh that is tidally controlled.. Based upon observations by Kyte during beach walks, Stream 01.0100 has always had flowing water at the mouth in the attached tidal marsh. In addition, on a number of occasions, coho salmon fry were observed at the mouth of this stream. Kyte states (personal communication via email) that coho may use this stream for spawning and initial rearing citing research by Williams et al. (1975).

Plant Species

Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) in the marine environment is an important component of the nearshore ecosystem. SAV includes eelgrass (*Zostera marina* and *Z. japonica*) and attached macroalgae such as kelps (brown algae), red algae such as Turkish towel (*Chondracanthus exasperatus*), and green algae such as sea lettuce (*Ulva fenestrate*). SAV functions as rearing and forage habitat for many commercially important species such as juvenile salmon (*Oncorhynchus* spp.), forage fish, and Dungeness crab (*Cancer magister*) (Fairbanks 2005). Eelgrass, *Zostera marina* L., is monitored by the DNR, the Puget Sound Partnership and other resource managers to assess the health of nearshore habitat in Puget Sound. Since 2000, the Submerged Vegetation Monitoring Project (SVMP) monitored the abundance and distribution of *Z. marina* in greater Puget Sound and outlying areas using underwater videography. *Zostera marina* is considered an indicator of ecosystem health and provides valuable nearshore habitat to ecologically and economically important species.

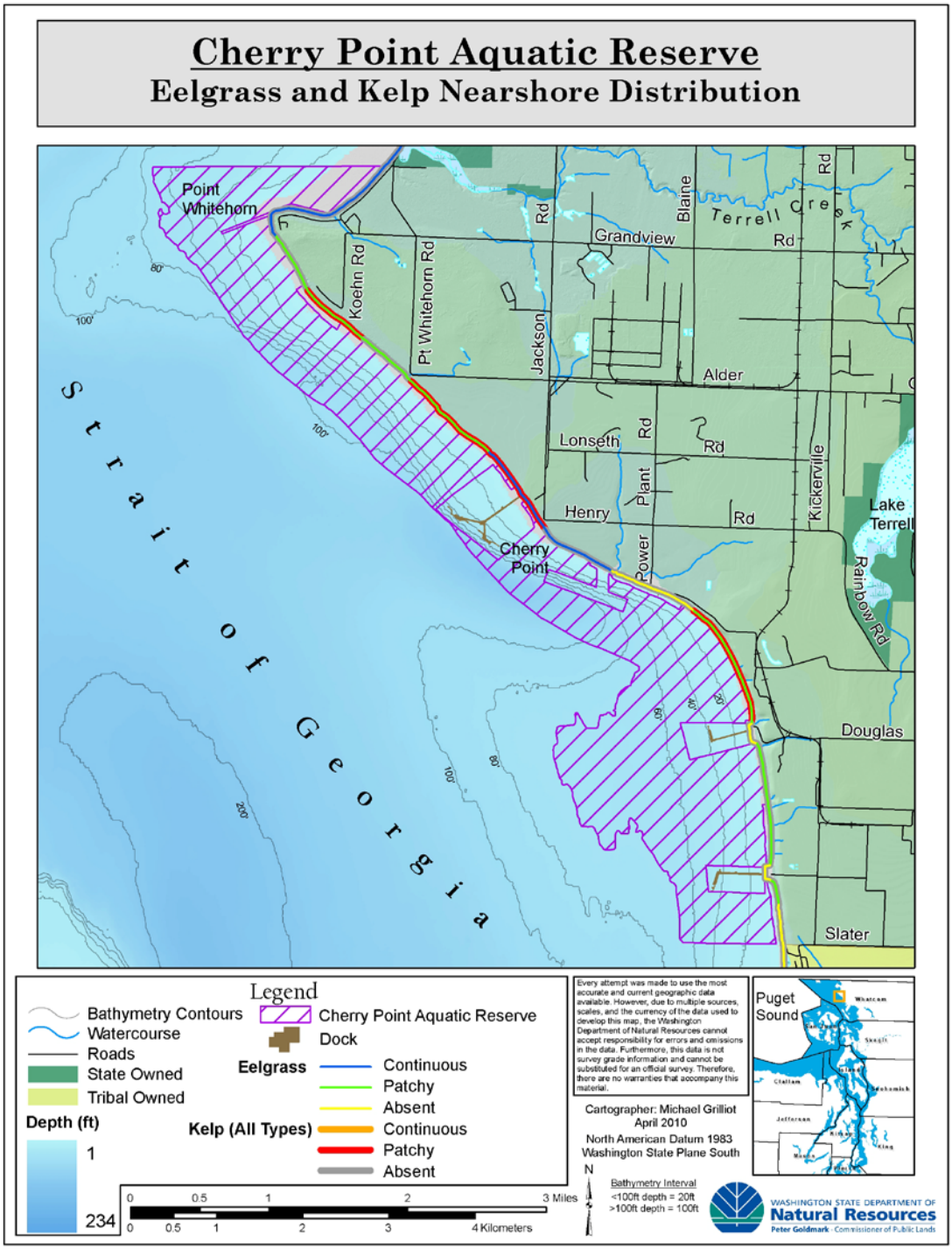
Eelgrass, Kelp and Algae at Cherry Point

Cherry Point Aquatic Reserve is historically known for having an extremely high diversity in both algal species and biomass, which is subject to change. Eelgrass and kelp beds are found at Cherry Point, the functions of which include providing food, habitat and shelter for a variety of organisms including salmonids, forage fish, phytoplankton, zooplankton and macroinvertebrates. In addition to being an important component of nearshore primary production rates (Nybakken 2001), kelp beds are critical habitat for a number of organisms including grazers such as snails and sea urchins, filter feeders like barnacles and mollusks, scavengers (i.e. crabs), predators such as rockfish and starfish, and a variety of smaller algae. Out-migrating smolts spend considerable time in nearshore eelgrass and kelp beds feeding and adapting to marine conditions as they mature. As a result, impacts to submerged aquatic vegetation and the communities they support also threaten rearing salmonids. These vegetated communities are an important part of the terrestrial food web and help support a variety of bird and mammal species.

Eelgrass beds of both native and and non-native species (*Zostera marina* and *Z. japonica*) are found along the sand bars in southern Birch Bay and are then interspersed with a diverse algal community from Point Whitehorn to Neptune Beach. These beds provide habitat for forage fish such as herring, and protecting shorelines from wave and current-drive driven erosion. Root systems help to anchor sediments in any shallow subtidal environments during low tides.

Bladed kelps such as *Laminaria saccarhina* and *Costaria costata*, large filamentous brown algae such as a few*Desmarestia spp.*, and a variety of red foliose and filamentous algae dominate the algae community. Mixed eelgrass and *Sargassum* extend along most (94 percent) of the Reserve with sparse kelp (*Nereocystis*) beds beginning to appear near Point Whitehorn. *Sargassum* is a non-native subtidal large brown algaer that herring often spawn upon (Pentilla, 2001). *Sargassum*'s distribution in most areas outside the Cherry Point Reach is within the lower intertidal to subtidal zone. However, it is notable that along the Cherry Point shoreline and in Birch Bay, the distribution of *Sargassum* is restricted primarily to the intertidal zone. Eelgrass beds in the Reserve support herring and surf smelt (*Hypomesus pretiosus*) spawning along the beach to the west of Terrell Creek mouth, and provide habitat for Pacific sandlance (*Ammodytes hexapterus*).

Figure 7, submerged aquatic vegetation at Cherry Point



Submerged Vegetation Monitoring Points (SVMP)

DNR has two sets of data on submerged aquatic vegetation within the Cherry Point Reserve. The data is presented here is not for comparison, as the collection methods were different but simply for informational purposes. Management actions) specify future inventories are needed.

In 1995, the DNR Nearshore Habitat Program surveyed Cherry Point and the following results were documented:

Table 2.0 DNR Nearshore Survey from 1995

DNR 1995 survey (sq ft of vegetation)		
Brown algae	356,245.2	3.7%
Eelgrass	419,888.1	4.3%
Green algae	209,110.4	2.1%
Kelp	7,719,611.6	79.3%
mixed algae	1,033,752.3	10.6%
Total:	9,738,607.6	100%

Table 3.0 Whatcom County (Fairbanks Environmental Services, 2005) Nearshore Survey from 2004: (see data from Table 4.0):

	Low Density (sq ft)	**High Density (sq ft)**	**Low Density (sq meters)**	**High Density (sq meters)**
Turf Algae	1,894,772.2	1,615,010.8	176,024.3	150,034.5
Canopy Algae	3,142,068.7	1,271,794.0	291,898.2	118,149.7
Bull kelp	2,329,223.2	0.0	216,384.8	0.0
Sargassum	2,089,646.6	0.0	194,128.2	0.0
Eelgrass	2,736,898.9	102,639.6	254,257.9	9,535.2

Table 4.0 Whatcom County Area SAV coverage observed at Cherry Point in August, 2004

Whatcom County (sq. feet of vegetation)		
Sargassum	2,089,646.6	13.8%
Eelgrass	2,839,538.4	18.7%
Bull kelp + canopy algae	6,743,085.9	44.4%
turf algae	3,509,783.1	23.1%
	15,182,054.0	100%

Animal Species

Salmonids

Juvenile salmon rear for a few weeks to several years in freshwater before heading to the estuary, where they may feed and adjust to saltwater (a process called smoltification) for a period of only days to as much as a year before continuing on to the ocean. In estuaries and freshwater, complex, meandering channels provide a network of riffles, pools and side channels for shelter and rearing. Juveniles are dependent upon native riparian vegetation for shading and cooler water temperatures, as well as a source of food from terrestrial insects, and shelter under/in large woody debris. Juvenile salmon experience the highest growth rates of their lives while in these highly productive estuaries and nearshore waters. Stable flows and high dissolved oxygen content (≥ 7.0 milligrams per Liter or mg/L) are also critical for the survival of both returning adults and rearing juveniles.

A large number of salmon and migratory trout species have been historically or currently located along or adjacent to the Reserve, and the area has been designated as habitat for listed species, including Chinook, Nooksack Coastal Cutthroat and bull trout (native char). Out-migrating smolts feed and adapt to marine conditions as they mature in Cherry Point eelgrass and kelp beds and around piers in the spring and summer before leaving the area in the fall (ENSR1992a). As a result, impacts to submerged aquatic vegetation and the communities they support also threaten rearing salmonids.

Cherry Point and the adjacent areas historically supported a flourishing salmon canning industry. Threats to vegetative communities within Cherry Point from shading, shoreline armoring, increased nutrients loads, and damage from anchors and buoys have combined with natural and anthropogenic stressors outside of Cherry Point to decrease shelter and food supplies for smolts, juveniles, and migrating adults.

Miller, B.S. et al (1977) found large numbers of pink salmon (*Onchorynchus gorbuscha*), chum (*O. keta*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) in cobble habitat located along the Cherry Point shoreline and in the protected eelgrass beds of Birch Bay. Juvenile sockeye salmon (*O. nerka*) were also found in Birch Bay, but were generally less abundant than other species (Berger/Abam, 2000). Adult Chinook, pink, coho, and chum salmon migrating to the Fraser and Nooksack rivers, Terrell Creek, and natal streams in Drayton Harbor can be expected to transit and feed along the Cherry Point shoreline (Berger/Adam 2000). Terrell Creek provides feeding, refuge, and osmoregulatory functions for juvenile salmonids (Whatcom County Shoreline Inventory, 2006). Adults of all these salmon species migrate though the Cherry Point Aquatic Reserve and are harvested for ceremonial, subsistence, and commercial purposes. River biologists in British Columbia state that the area is used by char and cutthroat tagged in British Columbia (Ptlomey, R. pers. comm.).

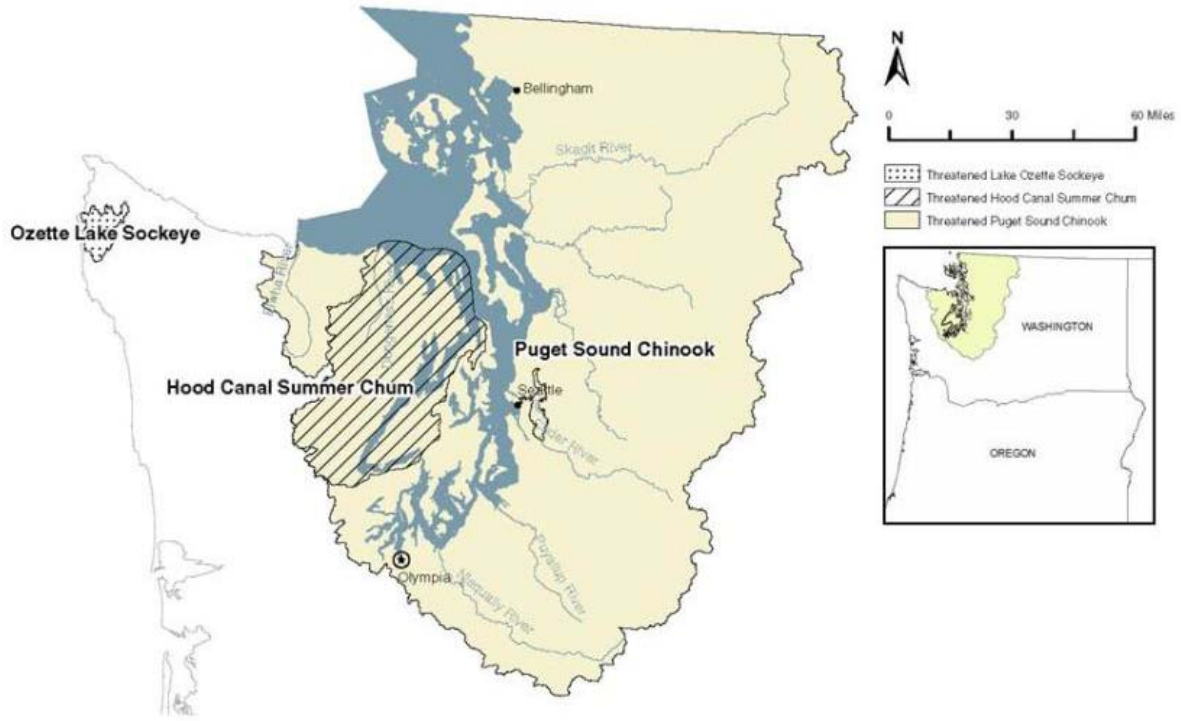
The Whatcom County WRIA 1 Salmon Recovery Plan lists Puget Sound bull trout species as "current presumed" and "presumed potential/historic" in waterbodies draining directly to Cherry Point (2007).In freshwater, Washington bull trout forage on salmonid eggs, fry and smolts, whitefish, and sculpin (USFWS 2004). In marine habitat along Cherry Point, native char are often found throughout the nearshore and estuarine habitat, seeking out surf smelt and other schooling fish, such as herring. Native char migrations and life history strategies are closely related to their feeding and foraging strategies. (Michal, H., pers. comm. 2009, USFWS 2004). The Cherry Point Aquatic Reserve falls within designated critical habitat for coastal forms of native char (*Salvelinus confluentus*).

In 1999, Coastal-Puget Sound bull trout populations were listed as threatened by the USFWS and critical habitat was designated in 2005 (September 26) for the lower 48 states. Coastal-Puget Sound bull trout are anadromous forms of the Washington bull trout, overlapping in habitat use with the sea-run Dolly Varden. The 2004 Recovery Plan designates the Nooksack marine habitat area located directly adjacent to Cherry Point Aquatic Reserve as an important core area. Without recovery of the herring population and associated habitat, the food base will remain at risk for the anadromous bull trout in the Northern Puget Sound Region. The maintenance of a healthy estuary and nearshore ecosystem is seen as key to maintaining fluvial and anadromous populations of Coastal-Puget Sound Bull Trout (Michal, H. pers. comm.; 2009; USFWS 2004).
In addition to the protections Coastal-Puget Sound bull trout received under the federal ESA as a threatened species, it is listed as a state candidate species by Washington Department of Fish and Wildlife.

The Puget Sound Evolutionary Significant Unit (ESU) for Chinook salmon includes the Cherry Point site and major waterbodies (see Figure 4). The Puget Sound Chinook ESU was listed as a federally threatened species in March of 1999 and includes runs from the North Fork Nooksack River in northeast Puget Sound to the southern Puget Sound watersheds, Hood Canal and the Strait of Juan de Fuca. Puget Sound Chinook are currently estimated to be at only ten percent of historic numbers. Over 2,300 miles of nearshore habitat in Puget Sound, including the Cherry Point Aquatic Reserve, has been designated critical habitat for Puget Sound Chinook under the ESA (70 CFR 52630, September 9, 2005.) Chinook salmon in the Nooksack River basin are distinctive from Chinook salmon in the rest of Puget Sound in their genetic attributes, life history, and habitat characteristics, indicating support for the geographical evidence of independence of these fish. Although some Chinook salmon from the Nooksack River basin may sometimes stray into other Puget Sound rivers (based on releases from Kendall Creek Hatchery), the low numbers probably have not had a significant effect on the population dynamics of other populations (Ruckelshaus et al, 2006), and this population remains distinct.

The Puget Sound Technical Recovery Team (TRT) identified two existing independent populations in the Nooksack River basin: (1) North Fork Nooksack River (including Middle Fork Nooksack River) and the (2) South Fork Nooksack River. The TRT found that the South Fork Nooksack stock was one of two populations most at risk, when asked to identify recovery priorities (the other was Cedar River) (Puget Sound TRT, 2006). The Nooksack salmon populations are the only two populations in the Strait of Georgia region of Puget Sound, and they are two of only six Chinook runs remaining in Puget Sound that return to their rivers in the spring (as opposed to fall spawning). For these reasons, the Nooksack populations are considered by the TRT to be essential to recovery of the ESU. Identification of priority estuarine and nearshore areas for protection and restoration is one of seven key recovery strategies towards recovery of the Nooksack salmon. For further information, please see *Independent populations of Chinook salmon in Puget Sound.* NOAA Tech. Memo. NMFS-NWFSC-78, developed by Ruckelsaus, et al., July 2006.

Figure 8. Puget Sound ESA Salmon Recovery Domain, showing Chinook ESU (NOAA, Northwest Regional Office, Accessed June 2009).

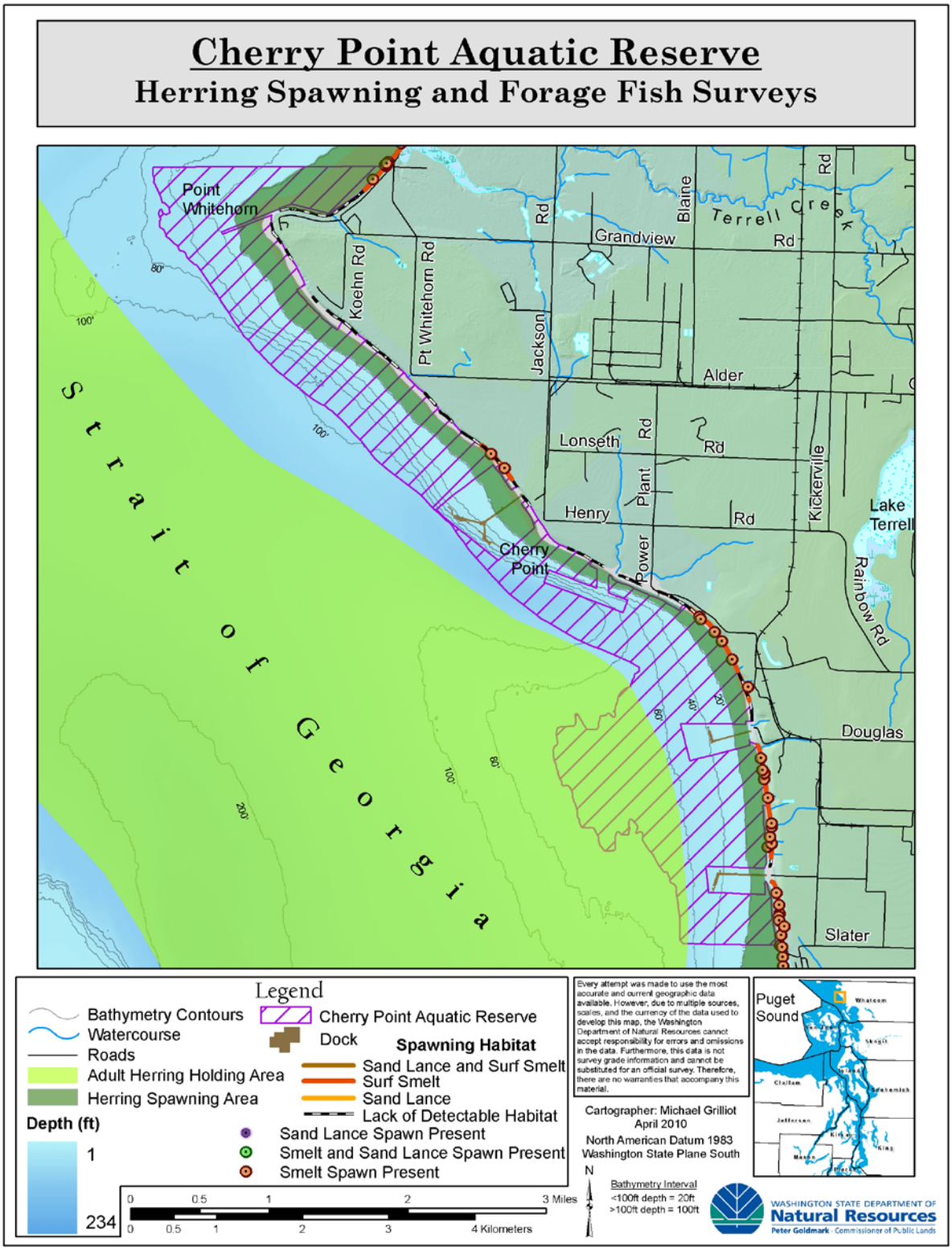


In Puget Sound the majority of steelhead populations are winter-run, meaning adults normally return to freshwater from November to December, and the peak of spawning occurs between March and May of the following year. Puget Sound Steelhead were listed as threatened by NOAA Fisheries in 2007; federal critical habitat has not been designated at the time of this document or Puget Sound Steelhead (Whatcom County 2003; NOAA 2007).

Forage Fish

Forage fish are an important and abundant fish species in Washington. The more common fish species identified as forage fish within Washington include Pacific herring (*Clupea pallasii*), surf smelt (*Hypomesus pretiosus*), Pacific sand lance (*Ammodytes hexapterus*), and northern anchovy (*Engraulis mordax*). All four species are known to use the Reserve. Pacific Herring and surf smelt are known to spawn on the intertidal beaches at Cherry Point (see Figure 9).

Figure 9, Forage fish spawning and holding areas.



Pacific Herring (*Clupea pallasii*)

Pacific herring (*Clupea pallasii*) are widely distributed around the Pacific Rim, with a range that includes northern Baja California to the Bering Sea, north into the seas of the Arctic Ocean and west

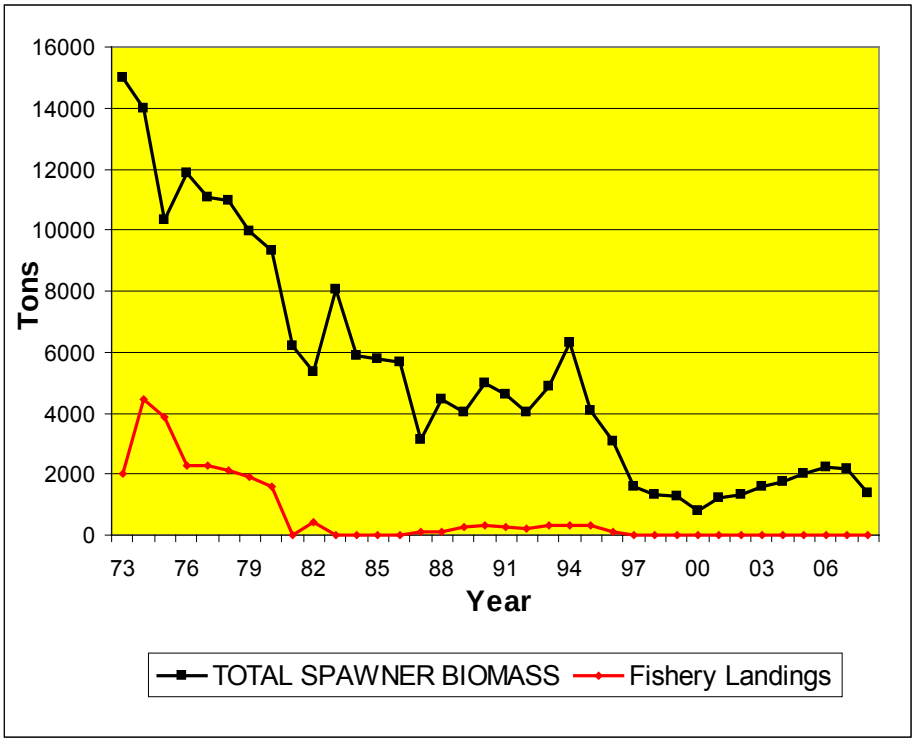
to Japan, Korea, and the Yellow Sea. Major concentrations of herring are found off the coast of British Columbia, the Bering Sea, and the Yellow Sea (Mitchell, 2006).

Adult herring stocks are often classified based upon their migratory behavior: migratory populations that move between oceanic feeding grounds in the summer and inshore spawning grounds in the winter, and resident populations that remain in coastal bays and inlets year-round. Cherry Point and Discovery Bay are also believed to be migratory stocks (Stout et al 2001; Stick et al, 2005), and recent genetic studies have suggested that the Cherry Point herring stock is genetically distinct from other Washington and British Columbia stocks (Beacham et al. 2002; Small et al. 2005, Mitchell 2006).

Pacific herring use the nearshore environment extensively and are often considered an "indicator" species of the overall functioning of a nearshore ecosystem. Pacific herring, including Cherry Point Pacific herring, are centrally located in the food web, acting as a prey species for salmon, marine mammals and birds, and as predators for copepods and larval fish. In its juvenile and adult form, Pacific herring is an important prey for Pacific salmon, Pacific cod, Pacific hake, walleye pollock, lingcod, spiny dogfish, Pacific halibut, rockfishes, common murres, tufted puffins, marbled murrelets, cormorants, gulls, harbor porpoise, California sea lions, harbor seals, and others (West 1997), while spawned eggs and larvae provide a prey base for birds,invertebrates, and fish. Herring are also a commercially valuable species for Washington (Piening et al. 2001). Commonly grouped together with surf smelt and sand lance under the generic terms "forage fish", herring do not utilize beach substrates to deposit their eggs. Instead, they deposit transparent adhesive eggs on intertidal and shallow subtidal sea-grasses and marine algae (Sikes et al. 2002).

In Washington State, Pacific herring consist of 21 isolated spawning stocks that are thought to return to the same area to spawn each year: 2 coastal stocks at Willapa Bay and Grays Harbor, 2 stocks in the Strait of Juan de Fuca, 6 stocks in the southern Strait of Georgia, and 11 stocks in the South and Central Puget Sound (Stick 2005, Mitchell 2006). Herring spawning grounds are very specific in location and the peak of spawning generally does not vary more than 7 days from year-to-year. Within Puget Sound, some herring stocks are highly variable in number from year to year and between locations (WDFW 1998). The Cherry Point herring stock is one that has experienced a drastic decline in abundance while other Washington stocks have maintained or increased abundance. Since the 1970s, the size of the Cherry Point stock has shrunk from a high of approximately 15,000 tons to a low of about 800 tons in the 2000 spawning season to an estimated 2,100 tons for 2007, followed by a decrease to 1,352 tons in 2008 (Figure 10 (WDFW unpublished data, 2008).

Figure 10 Cherry Point herring stock spawning biomass and fishery landings (short tons), 1973-2008 (WDFW unpublished data).



Herring require both spawning grounds and a pre-spawning holding area. The purpose of the pre-spawner holding area is for adults to congregate approximately 3- to 4-weeks prior to spawning. Generally this area is located near the spawning habitat. After this time, the adults migrate towards suitable spawning habitat, called spawning ground. For herring, suitable spawning ground for depositing eggs is located primarily on lower intertidal and shallow subtidal areas containing eelgrass and marine algae. In Washington most spawning activity takes place between 0 and -10 feet MLLW (0.0 to 3 meters) in tidal elevation (Stick 2005).

Cherry Point herring spawn from early April to mid-June, with peak spawning activity the first or second weeks of May. Spawn deposition can occur between +3.0 feet tidal elevation to the lower limit of macroalgal growth in this area, around -20 feet, with most occurring between 0 and -10 feet MLLW. Preferred spawning substrate includes eelgrass and more than 25 species of rock-dwelling marine algae (WDFW, 2007). Within the boundaries of the Reserve, herring spawn has been found most frequently found on native eelgrass (*Zostera marina)*, as well as *Desmerestia sp.*, *Botryoglossum sp., Laminaria saccarhina, Odonthalia sp., Ulva fenestrata, Nereocystis leutkeana,* and *Sargassum muticum* (WDFW, unpublished data, 2008).

Spawning is followed by a ten to fourteen day incubation period, and then emergence, after which larvae drift on prevailing nearshore currents for 2 to 3 months, followed by metamorphosis into juveniles. Following metamorphosis, herring are thought to spend their first year in Puget Sound. Some stocks of Puget Sound herring spend their entire lives within Puget Sound while other stocks summer in the coastal areas of Washington and southern British Columbia (Trumble 1983). Little is known about herring movements until they appear as 2 or 3 year olds in pre-spawner holding areas prior to spawning. For current spawning areas compared to escapement data collected between 1973 and 1980, please see Figures 17 and 18 below.

Genetics of Cherry Point Herring

Cherry Point herring are distinct in their spawning time. Other Pacific herring stocks in Washington spawn between early January through early April, with each stock generally spawning for approximately a 2-month period during this time period (Stick 2005). Most spawning in Puget Sound peaks in late February or early March. In contrast, Cherry Point herring spawn between early April and June, peaking in mid-May (Figure 12). Historically, the Cherry Point stock have spawned from the Canadian border to Hale Passage, when the abundance of the stock was much larger and spawning was laterally spread out north and south of the core Cherry Point spawning area (Stout et al, 2001; Meyer and Adair, 1978). See Figures 17 and 18.

Unlike other Pacific herring populations in Washington State, the Cherry Point herring spawn in open, high energy shoreline areas (O'Toole e al. 2000). The question of genetic divergence of Cherry Point herring from other Pacific herring stocks has been addressed in research. Work by Beacham et al (2002), Small et al (2005) and Mitchell (2006) have concluded that Cherry Point herring are genetically divergent and isolated from all other sampled Washington and B.C. herring stocks. Relatively unique (late) spawning timing is thought to be the primary cause of the observed genetic divergence of the Cherry Point herring stock. Work by Dinnel et al (2008) has produced a small dataset providing a preliminary indication that the Cherry Point herring may have evolved a tolerance for warmer water than other regional herring due to their late spawning time. If so, these genes would be important to regional herring in general as our climate warms.

The recent genetic studies previously mentioned indicate the genetic uniqueness of the Cherry Point herring stock, and support the continued management of this stock as a discrete management unit.

Figure 11. Documented spawning grounds and pre-spawner holding area for Cherry Point herring stock.

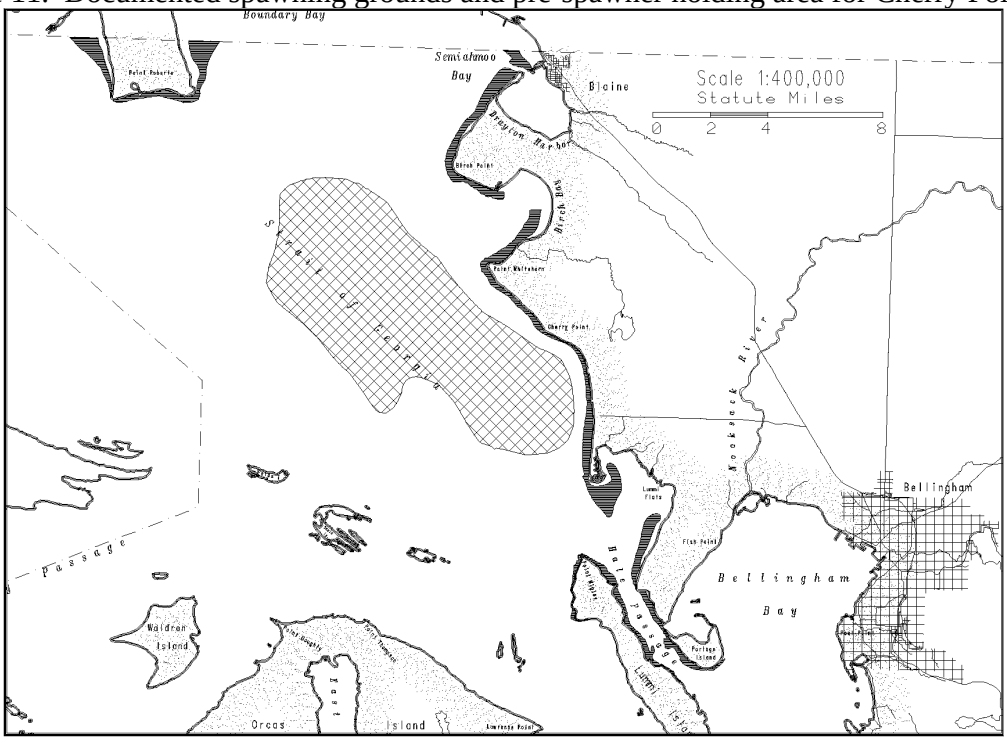
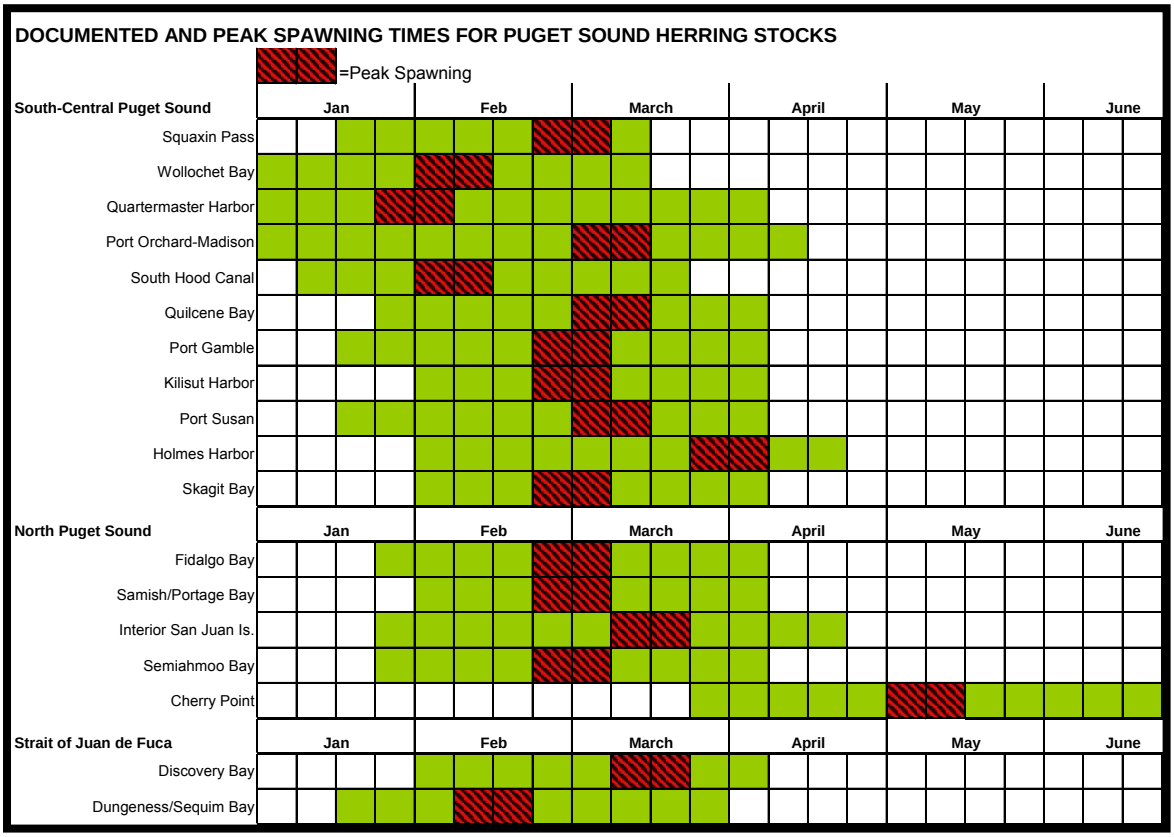


Figure 12.Documented (green) and peak (red) spawning times for herring stocks (WDFW unpublished data).



In 2005, NOAA Fisheries Service completed an updated Endangered Species Act (ESA) status review of Pacific herring, initiated in response to a petition received on May 14, 2004, to list the Cherry Point stock of Pacific herring as a threatened or endangered species. NOAA Fisheries Service determined that the Cherry Point herring stock does not qualify as a "species" for consideration under the ESA. NOAA concluded that the Cherry Point stock is part of the previously defined Georgia Basin distinct population segment (DPS) composed of inshore Pacific herring stocks from Puget Sound (Washington) and the Strait of Georgia (Washington and British Columbia). The Georgia Basin DPS of Pacific herring is not in danger of extinction or likely to become endangered in the foreseeable future throughout all or a significant portion of its range, and therefore does not warrant ESA listing at this time (NOAA 2005).

Surf Smelt (*Hypomesus pretiosus*)

Surf smelt spawning occurs in Whatcom County primarily in the summer months (Point Roberts, Cherry Point, Birch Bay, Bellingham Bay). Surf smelt spawn in the upper intertidal zones of mixed sand and gravel beaches, generally within a few feet of the high tide line. Adhesive and semitransparent eggs are deposited on beaches with this preferred mix of sand and pea gravel, and can occur in areas where there are seeps or shade, which increases the egg survival time in the summer (Wildermuth, D. pers. comm. 2008).

The Whatcom County shoreline characterization inventory (2006) found that surf smelt spawning areas are located in the higher intertidal beaches along the west shore of Point Roberts, Semiahmoo Spit to Birch Point and extending east to the northwest corner of Birch Bay. Additional areas include small stretches of shore between the mouth of Terrell Creek and Point Whitehorn, near Cherry Point,

north of Neptune Beach, along the eastern shore of the Lummi Peninsula, along the shoreline near Little Squalicum Creek, north of Padden Creek, and along the beach at Post Point. Shorelines along the Reserve have been documented as surf smelt spawning areas with the area from Gulf Road south to Neptune beach as being the largest contiguous stretch of spawning habitat (Figure 12). Smaller spawning areas have been documented just to the north of the northern BP Pier and just to the south of Birch Bay State Park.

Pacific Sand Lance (*Ammodytes hexapterus*)

Pacific sandlance occur throughout the coastal northern Pacific Ocean from the Sea of Japan to southern California and across Arctic Canada. Populations are widespread within Puget Sound, the Strait of Juan de Fuca and the coastal estuaries of Washington, commonly noted in more localized areas, such as the eastern Strait and Admiralty Inlet. The sand lance is abundant throughout British Columbia and Puget Sound in a variety of habitats (Hart 1973), including the upper intertidal zone along the Cherry Point Aquatic Reserve. In Whatcom County, sand lances are documented to spawn in Bellingham Bay, Gooseberry Point (Hale Passage), around Blaine, and on the eastern shore of Point Roberts, but not within the Planning Area.

Like all forage fish, sand lance are a significant component in the diet of many economically important species in Washington. On average, 35 percent of juvenile salmon diets are comprised of sand lance. Sand lance is particularly important to juvenile Chinook, where 60 percent of their diets are sand lance. Other economically important species, such as Pacific cod (*Gadus macrocephalus)*, Pacific hake (*Merluccius productus*) and dogfish (*Squalus acanthias*) feed heavily on juvenile and adult sand lance (WDFW 2008).

Northern Anchovy (*Engraulis mordax*)

The northern anchovy has resident populations throughout the Puget Sound basin, generally secondary in abundance to those of co-occuring herring. This species releases its distinctly oval eggs directly into the plankton, where they hatch within three days. The anchovy spawning season in Puget Sound is May-September. Anchovy eggs have been found in plankton samples from throughout western Whatcom County, from Semiahmoo Bay to Bellingham Bay, including the Cherry Point area (Stick, personal communication 2008).

Groundfish

Several groundfish species occur in Whatcom County. Groundfish live mainly on or near the bottom of the water column for most of their adult lives. Key groups of groundfish are: flatfish such as sole and flounder, skate, dogfish and surf perch; pelagic species, such as polluck, whiting and cod, and reef-dwellers including rockfish, lingcod, greenlings and cabezon. During the juvenile phase of their life histories, rockfishes associate with floating kelps, and several species of flatfishes use eelgrass beds for feeding, refuge from predators, and nursery (Mumford, 2007. Groundfish contain many links in the food web, connecting nearshore and midwater components to the benthos (PSAT, 2007). They are also economically important. All types are found within Whatcom County, including flounder, sole, lingcod, various rockfish species, cod, hake and pollock.

At Cherry Point, WDFW found that flatfish dominated the catch at a site with Dover (*Solea sole*a), English sole (*Parophrys vetulus*), rock soles (*Lepidopsetta bilineata*), starry flounder (*Platychythyus stellatus*), and Pacific and speckled sanddabs (Palsson, personal communication). This is consistent with the results of earlier trawls by Kyte (1990), who also found that the majority (more than 90%) of flatfish taken in samples were juveniles less than 100 mm in length.

Occasionally, adult butter sole (*Isopsetta isolepsis*) have been seen along the diving transects or caught in the trawls (Hanson, D.K. and H.A. Van Gaalen 1993). Lingcod (*Ophiodon elongatus*) adults are found in rocky habitats in Bellingham Bay, around the reef at Point Roberts and on Alden Bank, and along the shorelines of Birch Head, Cherry Point, and Lummi Island (Whatcom County MRC, 2009).

Table 5. State of Our Bottomfish Report – Funded by the Northwest Straits Intiative

Species	Georgia Strait/ San Juans	North Sound
Pacific Cod	**Depressed**	**Below Average**
Pollock	**Above Average**	**Above Average**
Whiting (Hake)	**Average**	**Unknown**
English Sole	**Above Average**	**Above Average**
Dover Sole	**Critical**	**Depressed**
Starry Flounder	**Above Average**	**Above Average**
Lingcod	**Above Average**	**Below Average**
Rockfish	**Unknown**	**Depressed**

Rockfishes and other groundfish are managed for non-tribal users following the 1998 Puget Sound Groundfish Management Plan and are co-managed with the Treaty Tribes of Washington. (Palsson et al, 2009). The present management plan by the Washington Department of Fish and Wildlife implements a precautionary policy for groundfish management. However, previous management efforts have ranged from targeting recreational and commercial fisheries on rockfish to passive management. As rockfish stocks declined during the past three decades, the Department has progressively restricted the harvest opportunities for rockfish by eliminating targeted commercial fisheries, reducing recreational bag limits, and discouraging or eliminating recreational fisheries targeting rockfish in Puget Sound.

Most adult rockfish are associated with high-relief, rocky habitats, but larval and juvenile stages of some rockfishes make use of open water and nearshore habitats as they grow. Nearshore vegetated habitats are particularly important for common species of rockfish and serve as nursery areas for juveniles and later provide connecting pathways for movement to adult habitats. Rockfishes are prey for a variety of predators including lingcod and other marine fishes, marine mammals, and marine birds. Rockfishes are very susceptible to barotrauma or being captured and brought to the surface from depth.

Invertebrates

Various Benthic Invertebrates, Bivalves[12] and Malacostracans[13] of Cherry Point

Benthic invertebrate assemblages along the Cherry Point Aquatic Reserve are determined by substrate type. In the uppermost, loose, sand-gravel berms, near the mean high water level, amphipod species are found often inhabiting drift vegetation. Cobble and boulder beds of the intertidal area along Cherry Point provide habitat for species such as barnacles (*Balanus glandula, Chthamalus dalli*), snails (*Nucella lamellosa, Littorina scutulata*), chitons (*Mopalia muscosa*), limpets (*Collisella strigatella*), mussels (*Mytilus edulis*), and seastars (*Leptasterias hexactis*, *Pisaster ocbraceus*, *Evasterias trocheli*). Red rock crab (*Cancer productus*) are also present on the surface of cobbles. Under and between cobble and boulders are found small shore crabs (*Hemigrapsus* spp.), polychaete worms (*Nereis* spp., *Neanthes* spp.,) and shrimp (families *Crangonidae* and *Hippolytidae*) (EVS 1999; Whatcom County 2006).

Invertebrates living in the sediment of the mixed cobble and sandy eelgrass habitats are dominated by annelid worms (capitellid polychaetes and oligochaetes), burrowing anemones (*Anthopleura artemisia*), amphipods, variety of bivalves, including cockles (*Clinocardium nuttallii*), native littleneck clams (*Protothaca staminea*), and butter clams (*Saxidomus giganteus*) (EVS 1999, Whatcom County 2006).

Seastars (*Pisaster brevispius, E. trocheli*), red rock crabs, small shrimp and a wide variety of infauna such as polychaetes and bivalves dominate the subtidal habitat, which contains kelp beds and gravelly substrate. Softer mud subtidal habitat includes the sea pen (*Ptilosarcus guerneyi*), nudibranchs, Dungeness crabs (*Cancer magister*), tanner crabs (*Chinocetes* spp.), sea cucumber (*Eupentacta pseudoquinquesemita*), and small crangonid shrimp. Geoduck clams (*Panope abrupta*) have been identified in the area (EVS 1999).

Dungeness crabs are present throughout the state's waters but in Puget Sound are most abundant in the northern portions. Adults are found primarily in the subtidal zone in soft sediments, but the juveniles rely heavily on intertidal habitats with structural complexity, such as eelgrass beds (Dethier, 2006). Their larvae spend long periods (months) in the water column before returning to the nearshore zone to settle. Dungeness crabs are an important predator and prey organism at all life history stages. They have pelagic larvae which are preyed on by many fishes, including copper rockfish, coho, Chinook salmon, halibut, dogfish, hake, and lingcod. Being planktivorous, the larvae may be exposed to pollutants that are present in the water column and plankton. Once they molt into the juvenile stage, they live on the bottom, feeding in the benthic food web. They can readily adjust their diet, but the younger/smaller crabs generally eat mollusks, progressing to shrimp and then to fish as they age and grow. The adults feed on mud-sand substrate, which provides a food-web pathway through which contaminants can move from sediments to humans. Dungeness crabs are relatively short-lived with a maximum lifespan of 8 to 10 years. They move between estuaries and offshore waters seasonally (WDFW, 2009).

[12] *Bivalves* are a class under the Phylum *Mollusca* characterized by two-part shells secreted by a mantle that extends in a sheet on either side of the body. The class has 30,000 species, including scallops, clams, oysters and mussels.
[13] *Malacostraca* are a large diversified group of crustaceans under the Phylum *Arthropoda*, and include the Order Decapoda - crabs, lobsters and shrimp. Source: Animal Diversity Web, University of Michigan Museum of Zoology; http://animaldiversity.ummz.umich.edu/site/accounts/pictures/Malacostraca.html

Dungeness crabs are important to the region recreationally and commercially by the Tribes. Recreational crabbing has been observed at Birch Bay, and off Neptune Beach just north of Lummi Island. Several crabbing methods are employed in the sport fishery, depending on local conditions; they are caught intertidally by hand or subtidally by crabpots, nets, or even hook-and-line. The Cherry Point Aquatic Reserve is located in Marine SubArea 7 North – Bellingham to Pt. Roberts – for recreational harvest of Dungeness and Red Rock Crab. Dungeness crabs support a valuable commercial and sport fishing industry in Whatcom County. Dungeness crabs are the only commercially significant crab harvested in Washington. Cherry Point is important to the commercial fishery operated by the Treaty Tribes. (WDFW website, 2009).

The cobble and fine sandy beaches, combined with undeveloped tidal sand and mud flats are important habitat for shellfish. Beaches along Cherry Point are characterized by habitat that could potentially support large numbers of shellfish, particularly bivalves such as manila, native littleneck, horse and butter clams. The nearby Birch Bay State park is classified as a "Land Access Beach with Abundant Clams and Oysters" for public shellfish sites of Puget Sound.
Washington State Department of Health has closed many of these shellfish beds due to water quality problems (Whatcom County 2006). Closed or open, shellfish beds perform a number of important ecological functions including nutrient cycling, substrate stabilization, habitat structure (e.g., oyster reefs), water quality enhancement (filtering and retention), and provide food for a wide variety of marine invertebrates, birds, fish and mammals.

Birds

Cherry Point is considered one of 18 areas of significant bird habitat identified for the Strait of Juan de Fuca and Georgia Strait (Wahl et al. 1981). The area from Sandy Point to Point Whitehorn possesses important habitat during all seasons, supporting high numbers of fish-eating loons, grebes and alcids, along with diving ducks. Among the many terrestrial bird species that are found along the Cherry Point Aquatic Reserve are great blue herons, bald eagles, and peregrine falcons. Peak avian activity levels occur in late winter through early spring, coinciding with herring spawning activities in March through May when huge concentrations of birds, particularly scoters and gulls, feed along the shoreline.

Three large-scale bird surveys have covered Cherry Point. One was the Marine EcoSystems Analysis (MESA) during the late 1970s and early 1980s. MESA was the first comprehensive effort to assess marine bird populations in Puget Sound, funded by the EPA and administered by NOAA. MESA researchers used a number of methods to document density, including transect counts from ferries and aerial surveys. The MESA survey results showed that Cherry Point registered the highest counts of birds per square kilometer in Puget Sound. MESA observers counted more than 13,000 birds per square kilometer at and adjacent to Cherry Point. Herring spawn-related flocks of surf scoters included 22,400 at Pt. Whitehorn (23 April 1978); 22,135 off Lummi Bay (30 April 1978) and 16,037 at Cherry Point on 27 April 1979 (Wahl et al. 1981). Another result of the MESA surveys was the recognition of how important Lummi Bay and Birch Bay were has significant bird habitats; Birch Bay had second highest bird use rating (Wahl et al. 1981).

The Puget Sound Ambient Monitoring Program (PSAMP) conducted surveys between 1992-99 and continues annually with trend data through 2006 to compare many of these bird counts to the MESA results. Survey transects were designed so that they were nearly identical to 54 transects flown during the MESA Puget Sound Project, allowing for a statistical analysis of bird species and numbers over a 30-year period (Marine Bird Density Atlas, WDFW, 2006). PSAMP comparisons revealed significant findings for marine birds throughout Puget Sound and the surrounding area. Many

populations have decreased - grebes, cormorants, loons, pigeon guillemot, marbled murrelets, scoters, scaup, long-tailed ducks, and brant). Some populations appeared stable or slowly decreasing - rhinoceros auklets, goldeneyes, bufflehead, and gulls species. There may be some degree of increase in harlequin ducks and probably mergansers (Nysewander, D.R. et al. 2005).

Data on non-breeding birds in the Georgia Strait has been collected again during 2003-2004 and 2004-2005 for comparison to the PSAMP and MESA results. Western Washington University has conducted shore-based and ferry-based counts (Bower, J.L., 2009, unpublished) in the Strait of Georgia. As part of the study, Christmas Bird Counts were considered from 11 sites. The results were then compared to both PSAMP and MESA surveys. This latest survey is called the WWU/MESA comparison (Bower, unpublished, 2009). All three will be discussed in detail next.

There are limitations to comparing PSAMP data to MESA counts. These limitations include but are not limited to how often the transects are flown, how loud the airplane is (may disturb birds), and the difficulty of identifying birds from an airplane. Scientists from Western Washington University (WWU), with funding from Washington Sea Grant and other sources, began conducting shore- and ferry-based marine bird counts that closely replicated the 1970s MESA research. WWU scientists, with help from students and volunteers, conducted monthly land and water surveys between September and May in the inner marine waters of north Puget Sound and south Georgia Straits. Data from Audubon Christmas Bird Counts was also collected. The goal was to provide a more robust count for comparison to the 1978-1979 MESA data.

The result is the WWU/MESA comparison. Results of this comparison showed that 14 of the 37 most common over-wintering species in the Strait of Georgia are experiencing significant declines, including 10 species declining over 50%. Detailed examination of the causes of the changing species abundance was beyond the scope of this study (Bower, J.L., 2009, unpublished). The largest declines were spread across different species, and included the Common murre *Unira aalge* (-92%), Western grebe *Aechmophorus occidentalis* (81%), Red-throated loon *Gavia stellata* (73.9%), and the Bonparte's gull *Larus philadelphia* (72.3%) (Bower, J.L., 2009, unpublished). The observed species trends from the WWU census were similar to those previously reported by PSAMP, with the exception of double-crested cormorant, pigeon guillemot, common loons and harlequin ducks (Puget Sound Update, 2007).

For Cherry Point specifically, two sites were monitored. Combined totals for both sites showed a 79.1% decline in species documented when WWU compared data to the MESA study (Bower, J.L., 2009, unpublished). Specific species-level detail can be found below.

Both Lummi, and to a lesser extent Birch Bay, were recognized during these surveys for their importance as shallow bays with extensive eelgrass beds that support wintering populations of diving and surface-feeding ducks, gulls and shorebirds in addition to migrating Black Brant. These adjacent areas should be considered when developing management actions for migratory species that may move from Lummi and Birch Bay into or through the Cherry Point Aquatic Reserve.

Bird species listed as Endangered, Threatened or Sensitive species, as well as other species that rely on Cherry Point aquatic habitats are listed below:

1) Marbled Murrelet. The Marbled Murrelet is federally and state listed as threatened. It forages within 2 to 5 kilometer of shore in coastal and nearshore waters, and within the top 50 meters of the water. Generally solitary, individuals have been documented where Pacific herring are spawning

(USFWS, 2006; Speich and Wahl 1989). It is also listed as a federally threatened species. Marbled Murrelets are unlikely to nest in the immediate vicinity of the Cherry Point Aquatic Reserve because most forests are extensively fragmented, small, and of second-growth class. ENSR (1995) documented marbled murrelets flying into forests near the Canyon Creek drainage of the North Fork Nooksack River, near the United States-Canadian border and about 37 miles (60 km) from Cherry Point. This was considered to be the nearest known murrelet nesting area to Cherry Point for quite some time (ENSR 1995). Marbled Murrelets have been later documented off of central and southern Cherry Point, approximately 5 to 10 kilometers offshore. The 2005 PSAMP surveys observed 1 – 2 animals off the northern boundary of Cherry Point, in the Point Whitehorn vicinity, during summer surveys (Whatcom County, 2006; Nysewander, D.R. et al. 2005).
Earlier surveys along Cherry Point have consistently noted use of the offshore area for feeding by small numbers (2 to 35 birds) of Marbled Murrelets. The WWU/MESA survey found that the percentage change for the marbled murrelet was a statistically significant decrease (-71.0%) compared with the MESA data and a similar statistically significant decline when compared with Christmas Bird Count data (-68.5%) (Bower, J.L., unpublished, 2009).

2) Common Loon. Washington State has listed the Common Loon as a Sensitive species. Loons are very reliant on nearshore resources during the winter months, and are flightless during winter, leaving them at a potentially higher risk to a variety of impacts in the marine and nearshore environment. The WWU/MESA survey found that the percentage change for the Common Loon was a statistically significant increase (+48.8%) compared with the MESA data and was not statistically significant when compared with Christmas Bird Count data (Bower, J.L., unpublished, 2009).

3) Cormorants.Three species of cormorants inhabit the waters off of Cherry Point, and two are located there year round. Double-crested Cormorants are found on both coastal and inland waters and consider Cherry Point part of their year round habitat. Population numbers declined dramatically in the 1960s and 1970s due to contaminants acquired from fish. Since the ban of DDT, populations have been increasing. The population of Double-crested in Washington along the outer coast increased slightly from 1978 to 1994, but has declined since 1995, most likely because of unfavorable ocean conditions (BirdWeb, 2008). Double-crested Cormorants may be increasing. The WWU/MESA survey found that the percentage change for this species was a statistically significant increase (+97.7%) compared with the MESA data and when compared with Christmas Bird Count data (+171.1) (Bower, J.L., unpublished, 2009).

Brandt's Cormorants (*Phalacrocorax penicillatus*) are listed as state candidate species. The WWU/MESA survey found that the percentage change for this species was not statistically significant (Bower, J.L., unpublished, 2009). The Pelagic Cormorant (*Phalacrocorax pelagicus*) has experienced significant increases in the Washington population between 1976 and 1992 (BirdWeb, 2008), and Pelagic Cormorants may still be increasing. The WWU/MESA survey found that the percentage change for this species was a statistically significant increase (+87.7%) compared with the MESA data; there was no statistically significant change when compared with Christmas Bird Count data (Bower, J.L., unpublished, 2009).

4) Bald Eagle. The Bald Eagle is a state sensitive species. Bald Eagles use shorelines for feeding and nesting, often building large stick nests in dominant trees near water. In Washington, Bald Eagle nests are most numerous near marine shorelines, but nests are also found on many of the lakes, reservoirs, and rivers. Fish are usually the most common prey taken by breeding Bald Eagles throughout North America, but Bald Eagles also capture a variety of birds (Stalmaster 1987. Bald Eagles are present in the Georgia Straits, and were documented during the 1992 – 99 Puget Sound

Ambient Monitoring Program (PSAMP) summer marine bird surveys as "Other species observed." (Nysewander, D.R. et al. 2005). Bald Eagles are sometimes seen disrupting cormorant and heron colonies in marine and nearshore areas. The Washington Department of Fish and Wildlife has identified seven eagle nest locations comprising three distinct territories along Cherry Point. Whatcom County references the value of this habitat to Bald Eagles in their Shoreline Characterization and Inventory Plan (see section 3.3: *Terrestrial Wildlife Habitat* - Whatcom County, 2006; Bohannon, J. WDFW, pers. comm., 2008). In addition to resident breeding pairs observed nesting along Cherry Point, upland of Lummi Bay, and along Terrell Creek, sub-adult non-breeders occur year-round. Migratory and wintering eagles are found in seasonally higher numbers along the Cherry Point's shoreline where they scavenge along the intertidal areas, fish in open water or hunt ducks and gulls (Eissinger, 1994).

WWU/MESA survey found that the percentage change for this species was a statistically significant increase (+187.0%) compared with the MESA data and there was no statistically significant change when compared with Christmas Bird Count data.

5) Peregrine Falcon. Peregrine Falcons are listed as a federal candidate and state sensitive species. It is typically found hunting in open areas, especially along the coast and near other bodies of water that provide habitat for their prey. Whatcom County, and Cherry Point, is located directly along the migratory corridor between Alaska and Washington. Knowledge of the peregrines that use this corridor, often during fall, is somewhat limited (Hayes, G. E. and J. B. Buchanan 2002), but it is thought that the Peregrine Falcon uses the Cherry Point area for foraging. The WWU/MESA survey did not cover this species.

6) Common Murre. The Common Murre is a large auk that spends most of its life at sea, coming to land only to breed on rocky cliff shores or islands. It is on the state candidate species list. These birds can be seen outside of breeding areas year round, including deep-water, inland and marine habitats (BirdWeb, 2008). The PSAMP summer marine bird surveys documented the presence of murres off the north shore of Cherry Point, at 10 - 25 Murres/km^2. Along the nearshore birds were counted at 0 – 5 murres/km^2 (Nysewander, D.R. et al. 2005). The WWU/MESA survey found that the percentage change for the common murre was a statistically significant decline compared with the MESA data (-92.4%) and when compared with Christmas Bird Count data (83.7%) (Bower, J.L., unpublished, 2009).

7) Surf scoter. Surf Scoters are often seen diving synchronously to locate small invertebrates such as mollusks, crustaceans, and polychaetes in the nearshore area. At night, they often rest in large flocks outside bays and estuaries in which they feed during the day. Surf Scoters are typically present along Cherry Point in winter; PSAMP winter surveys counted 10 – 50 scoters/km2 in the northern portion of the reach, and upwards of 50 – 250 scoters/km2 in the central to southern portion (Nysewander, D.R., et al 2005). Numbers of scoters at Cherry Point increase dramatically when herring spawn is available, although the size of these aggregations of scoters has declined concurrently with declines in spawning herring at Cherry Point.

Anderson et al. (unpublished manuscript, 2009) studied the role of herring spawn in movements and energetics of scoters, focusing on differences in the value of spawn to Surf Scoters versus White-winged Scoters (*M. fusca*). Their research indicated four main results:

a) Both Surf and White-winged Scoters gain mass by consuming spawn during late winter and spring.

b) The number of each scoter species that aggregates to consume spawn is positively related to the size of the spawning event (i.e., the biomass of spawning herring).
c) Numbers of Surf Scoters are especially abundant at spawning sites that occur later in spring (April to May), because migrating Surf Scoters use these sites as staging areas.
d) Spawn is a preferred food for White-winged Scoters, but appears much more important to Surf Scoters because they often lose fat reserves over winter.

The second and third results are particularly relevant to spawning events at Cherry Point. Specifically, spawning activity occurs later in spring at Cherry Point (late March through May) than at other spawning sites in the Puget Sound-Georgia Basin (January to mid-April). Thus, spawn at Cherry Point is used by surf scoters to acquire reserves for migration and breeding. However, concurrent with declines in the biomass of spawning herring at Cherry Point, numbers of scoters observed foraging on spawn there declined from about 60,000 to 6,000 in the period 1980–1999 (Nysewander, D. R., unpublished data). During spring migration of surf scoters in late-April to May, no feeding opportunities equivalent to historical levels of spawn at Cherry Point are known to exist in the Puget Sound-Georgia Basin.

Herring spawn is profitable to scoters for two main reasons: (1) it is highly aggregated and thus reduces foraging effort (Lewis et al. 2007), and (2) spawn has no shell matter, which likely increases nutrient and energy gain[14] relative to some foods scoters consume earlier in winter (Anderson, E.M. et al., unpublished manuscript, 2009).

Although less well studied than scoters, predators ranging from invertebrates, to marine birds, fish, and whales likely benefit from spawning events of herring (Wilson and Womble 2006). Moreover, such benefits generally occur during the critical period of the year when many predators are preparing for migration and reproduction. For this reason, Anderson et al. (unpublished manuscript, 2009) suggest that management of Pacific herring include protections for spawning areas that also preserve feeding opportunities for these diverse predators.

8) Great Blue Heron. The rookery located approximately one mile east of Birch Bay State Park on a riparian corridor along Terrell Creek is one of the largest in the Pacific Northwest. This colony was first identified in 1983 and over the last 10 years has supported an average of more than 300 breeding pairs. Additionally, this colony contains the unique Pacific Northwest subspecies, *Ardea herodias fannini*, and resides in the area year-round (Eissinger 1994).This rookery is often called the "Birch Bay Colony." Research has shown that members of this colony include Birch Bay, Drayton Harbor, Semiahmoo Bay, Lummi Bay, and Lake Terrell in their range, although with less concentration (Eissinger 1994). The WWU/MESA survey found that the percentage change for this species was not statistically significant. The rookery was studied extensively by British Petroleum. The research found that foraging areas include marine shorelines, the intertidal zone, wetlands, streams, riparian areas, and upland fallow fields. The most concentrated foraging during the nesting season occurs in the intertidal areas near the colony (British Petroleum, 2003).

9) Western Grebes are found in large numbers through marine waters, preferring deeper waters with relatively low currents such as bays or inlets, in Puget Sound during winter and summer; flocks often return to the same general area each year (Nysewander, D.R. et al., 2005). Cherry Point is located in the northern portion of the Western Grebes non-breeding winter habitat, and adjacent to migratory routes (BirdWeb 2008).Western Grebes are a state candidate species. The PSAMP winter marine bird

[14] Mussel soft tissue and herring spawn have approximately the same nutritional value. However, 85 – 90% of a whole mussel is shell, which must be processed and excreted because scoters ingest whole bivalves.

surveys documented Western Grebes in moderate to high densities (ranging from 25 to 1,954 animals per square kilometer) along the intertidal and nearshore area of central and southern Cherry Point, extending to approximately 5 kilometers offshore (Nysewander, D.R. et al. 2005). Comparison of nearly identical transects surveyed during the MESA time period (1978 – 79) and the PSAMP time period (1992 – 99) indicate this species could potentially be decreasing by as much as 95%, a conclusion further supported by the 2004 study funded through Washington Sea Grant study on marine bird population in western Washington (Bower, et al, 2005). The WWU/MESA survey found that the percentage change for this species was a statistically significant decrease (81.3%) compared with the MESA data and also with the when compared with Christmas Bird Count data (-85.9%).

10) Osprey. The Osprey is a species currently on the State Monitor list. It is a unique bird, the only species in its family, and it is found worldwide (WDFW 2005). Waterbodies (e.g., Nooksack River) surrounding Cherry Point support breeding habitat for the Osprey and necessary food resources, such as salmon. The WWU/MESA survey did not cover this species.

11) Cavity nesting ducks. Habitats identified as important wintering areas for Harlequin Ducks are located at Cherry Point, and were identified as such during the PSAMP marine bird surveys, including the eelgrass and kelp beds combined with rocky and cobble substrates, supporting the diverse mix of benthic invertebrate species that make up a prey base for this bird. The PSAMP summer marine bird surveys also documented high numbers in the northern portion of Cherry Point – between 50 – 65 animals/km^2, and 0 – 5 in the central portion of the nearshore area (Nysewander, D.R. et al. 2005). Overall, for the entire survey, comparison of nearly identical transects surveyed during the MESA time period (1978 – 79) and the PSAMP time period (1992 – 99) indicate this species show fluctuating numbers in this species. The WWU/MESA survey found that the percentage change is not statistically significant for this bird (Bower, J.L., unpublished, 2009).

The PSAMP winter marine bird surveys documented Buffleheads along the northern and central nearshore of Cherry Point at densities of 10 – 25 and 25 - 50 animals/km^2 (Nysewander, D.R. et al. 2005). The PSAMP winter marine bird surveys documented goldeneyes along the northern and central nearshore of Cherry Point at densities of 10 – 25 and along the southern nearshore at 0 – 10 animals/km^2 (Nysewander, D.R. et al. 2005). Of these cavity nesting ducks, the WWU/MESA survey found that the percentage change for the Common Goldeneye was a statistically significant decline (-47.8%) compared with the MESA data. For Buffleheads and Barrow's Goldeneye, the percentage change was not statistically significant for this bird. The survey did not look at the Wood Duck or the Hooded Merganser (Bower, J.L., unpublished, 2009).

Marine Mammals

Marine mammals that use the Cherry Point Aquatic Reserve, or could use the habitat based upon their presence in the southeast Strait of Georgia (Calambokidis and Baird 1994, WDFW 2007, Williams, 2007) include harbor seals (*Phoca vitulina*), Pacific harbor porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli*), Steller sea lions (*Eumetopias jubatus*), California sea lions (*Zalophus californianus*), Gray whales (*Eschrichtius robustus*), Pacific Minke whale *(Balaenoptera acutorostrata),* the Southern Resident Killer Whales (*Orca orcinus*) and the humpback whale (Calambokidis and Baird 1994. Falcone et al. 2005).

Although gray whales have become regular summer residents in the enclosed marine waters of Washington since the species recovery, early records do not document historical numbers of gray whales for these inland and coastal waters. These "seasonal residents" in the Puget Sound are part of

the Pacific Coast Feeding Aggregation (PCFA), and have been documented feeding in inland waters along Vancouver Island since the 1970's (Darling 1984). In 2007, sightings of gray whales in northern Puget Sound continued to reveal that this area is used as a springtime feeding area for a small, regularly occurring group of gray whales (Calambokidis, et al. 2009).

The humpback whale habitat includes nearshore, pelagic marine habitat, open waters of the ocean and inshore waters of the bays. This species is primarily dependent upon schooling fishes and krill (krill only in the Southern Hemispheres), and is active both day and night (NatureServe 2009). Humpback whales were once common in the inland waters of Washington and British Columbia; however, as a result of commercial whaling, humpback whales were formally listed as "endangered" under the Endangered Species Act (ESA) in 1973. Humpback whales are designated as "depleted" under the MMPA and considered endangered under the Priority Habitat and Species List for Washington State (NOAA Protected Resources 2009, WDFW 2009). While the North Pacific population is estimated to exceed 6,000 humpback whales (Calambokidis et al. 1997) this is still less than 50% of the amount taken during commercial whaling from the North Pacific (NOAA Protected Resources Division, 2008). Humpback whales have recently been seen more frequently in the historic feeding grounds along the Washington coast, and more often in inland waters of Washington (Calambokidis, et al., 2004; Falcone et al., 2005). In the spring of 2009, a humpback whale was spotted over multiple days in the southernmost part of Puget Sound (unpublished Cascadia Research sighting data). Threats to the humpback whales include entanglement in marine debris and ship strike (NOAA Protected Resources Division, 2008).

In general, there are three groups of killer whales – *transients, residents* and *offshore*. Division of these groups is based upon mitochondrial DNA (mDNA) samples combined with visual identification of over 73 samples collected from orcas ranging from California to Alaska. Significant genetic differences have been demonstrated between 'transient' killer whales from California through Alaska, 'resident' killer whales from the inland waters of Washington, and 'resident' killer whales ranging from British Columbia to the Aleutian Islands and Bering Sea. Resident killer whales are divided into two communities, a northern and southern, and rarely come in contact with each other (NMFS, 2005; Carretta, J.V. 2007).

Another significant difference between resident and transient killer whales is their choice of food; although not a whale, the term "*Killer Whale*" was earned by the transients, who are well known for incorporating other marine mammals into their diet. Transients have been seen chasing gray whales, and over 22 different species of marine mammals have been identified from the stomach of transients. *Southern* and Northern residents killer whales appear to prefer Chinook (*Oncorhynchus tshawytscha*), and follow the runs of these salmon in their area (Ford et al., 1998, NMFS, 2005; Flaugherty, 1990). It is possible for any of these groups to use habitat along the Strait of Georgia, near Cherry Point. However, the resident group is the most likely, as this group uses inland waters most frequently.

NMFS recognizes five killer whale stocks that can occur within the waters of the Exclusive Economic Zone (EEZ) of the Pacific Ocean, United States:

- Eastern North Pacific, Resident Stock – British Columbia through Alaska;
- Eastern North Pacific, Southern Resident Stock – inland waters of Washington and southern British Columbia;
- Eastern North Pacific, Transient Stock – Alaska through California;

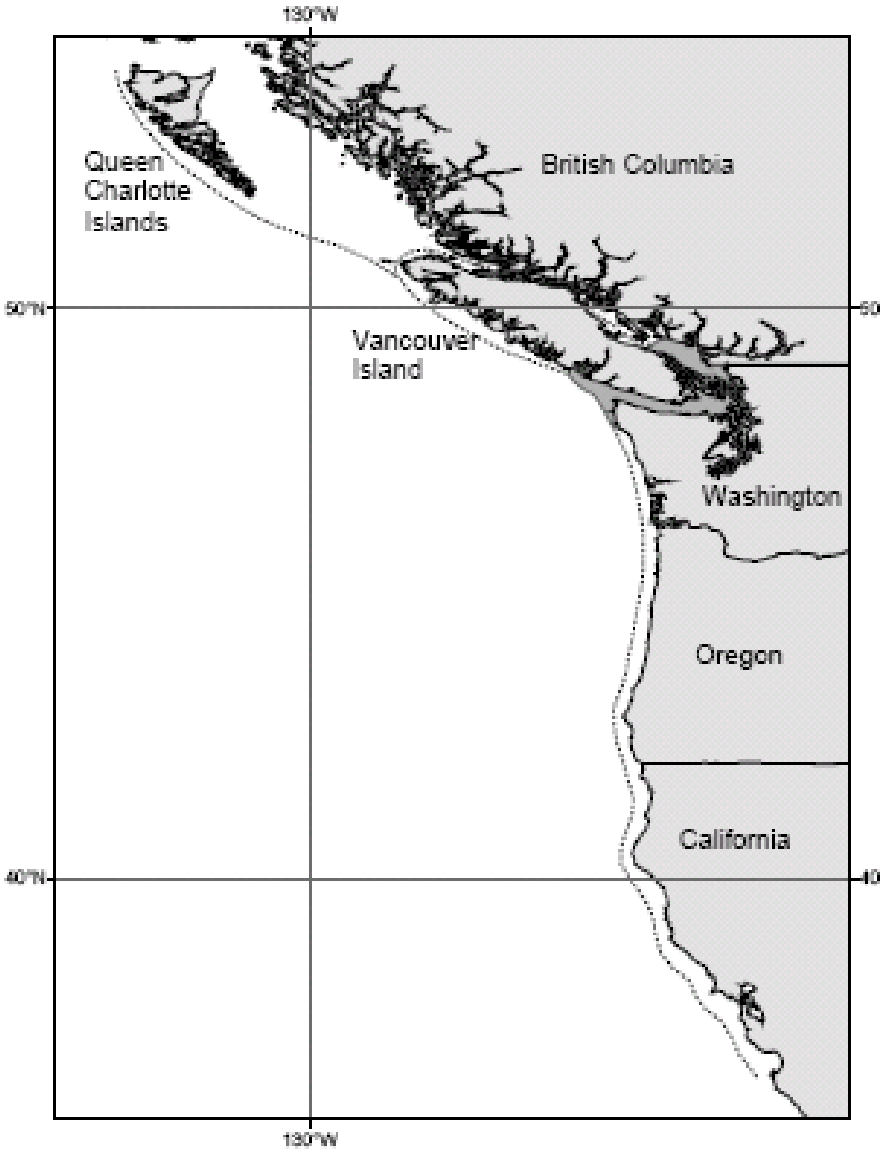
- Eastern North Pacific Offshore stock – neither transient or resident, from Southeast Alaska through California; and
- Hawaiian stock.

The killer whale most likely to occur near the Cherry Point Management Area are those from the *Eastern North Pacific, Southern Resident Stock* (often called the Southern Resident killer whale), which habituate the inland waters of Washington and southern British Columbia (Figure 13) (Carretta, J.V. 2007).

Three pods make up this stock – J, which is commonly found inshore during the winter months, and the K and L pods, often located farther offshore, even as far as Monterey Bay, California. NMFS (2005) describes the home range for all three pods in the conservation plan for the Southern Resident killer whale. Most information is gathered from late spring to early fall, when weather is best. During this period, all three pods are regularly present in the Georgia Basin, which is defined as the Georgia Strait, San Juan Islands, and Strait of Juan de Fuca (NMFS, 2005).

During the warmer months, all three pods concentrate around major salmon migration corridors, including Haro Strait, Boundary Passage, the southern Gulf Islands, the eastern end of the Strait of Juan de Fuca, and several localities in the southern Georgia Strait given the importance of the Fraser River as the region's largest source of salmon. The pods expand into Puget Sound in early fall, following chum and Chinook salmon runs (see Figure 14). Killer whales have been observed foraging within 50-100 m of shore and using steep nearshore topography to corral fish (Wiles, 2004).

Figure 13 Range of the Southern Resident Killer Whale (shaded area)



There is a limited amount of data on the Southern Resident killer whale's feeding preferences. Most information is based on a single study in British Columbia that focused primarily on northern residents, relied on surface observations and scale sampling, and reported on a relatively small sample of observations (Wiles, 2004). This data, which should be considered preliminary, indicates they prefer Chinook salmon during late spring to fall as much as their Northern cousins. This assumption was supported by toxicology studies, which found that the ratio of DDT and other contaminants in the blubber of the orca most closely matched that of salmon, compared to other fish species (see Kraughn, et al 2002). The British Columbia study found chum salmon are also taken in significant amounts, especially in autumn. Other species eaten include coho, steelhead, sockeye, and non-salmonids (e.g., Pacific herring and quillback rockfish [*Sebastes maliger*] 3 percent combined). These data on surface feeding may underestimate the extent of feeding on bottom fish; species such as rockfish (*Sebastes* spp.), Pacific halibut, a number of smaller flatfish, lingcod, and greenling are likely consumed on a regular basis. Pacific herring also contribute to the diet (Wiles, 2004).

Figure 14 Primary area of occurrence for Southern Resident killer whale when present in Georgia Basin and Puget Sound (NMFS, 2005)

Little is known about the winter and early spring foods of Southern and Northern Residents or whether individual pods or sexes have specific dietary preferences or have shifted preference for different prey species over time. A substantial amount of data exists on this stock's structure, behavior and movements, as a result of photo-identification of individual whales through the years. The first complete census of this stock occurred in 1974. Between 1974 and 1993, the stock increased by 35%, to 96 individuals. However, a substantial decline to 79 individuals by 2001 led to concern. By 2005, the stock had risen slightly again, to 91 individuals (Carretta, J.V. 2007). The stock was listed as endangered in 2005 by the NMFS.

As a top-level predator, killer whales occur at naturally low densities, are long-lived, have low reproductive rates and long generation times, and invest large amounts of parental effort in each offspring. These characteristics mean that the loss of relatively few individuals can have serious consequences for their populations, as well as hinder recovery rates. Because of the combination of low population numbers, the recent steep decline in L pod, and continued threats to the population, the Washington Department of Fish and Wildlife has determined that the southern residentsare at risk of extinction from all or a significant portion of their range in Washington and recommends that the species be listed as endangered in the state (Wiles, 2004). NMFS has listed the orca as federally endangered, and prepared a recovery plan. Prey availability, environmental contaminants, impacts

from vessels and sound (including aircraft), oil spills, and disease are discussed in length by NMFS as potential stressors to the Southern Resident killer whale (2005) and should be addressed by DNR in any management plan.It is appropriate to support conservation and recovery measures for prey species until more is known about their importance to the whales (NMFS, 2008).).

Harbor porpoise were once common in South Puget Sound, but are now considered rare. Harbor porpoise have been located at various times during the year in the vicinity of the inland trans-boundary waters of Washington and British Columbia, Canada (Osborne et al. 1988), and along the Oregon/Washington coast (Barlow 1988, Barlow et al. 1988, Green et al. 1992). Harbor porpoise feed on squid, octopus, herring, and small schooling fish (Yates, 1988).

NMFS recognizes two stocks off of the coast of Washington: the Oregon/Washington Coast stock (between Cape Blanco, OR, and Cape Flattery, WA) and the Washington Inland Waters stock (in waters east of Cape Flattery). The recognition of two stocks is a risk averse management strategy, based primarily on restrictions noted in the intermixing rates within the eastern North Pacific harbor porpoises and the significant decline in harbor porpoise sightings within southern Puget Sound since the 1940s (Carretta, J.V. 2007).

This species is considered a state candidate by the Washington State Department of Fish and Wildlife. Harbor porpoise are not listed as “depleted” under the MMPA or listed as “threatened” or “endangered” under the Endangered Species Act. The latest stock assessment states that the status of both coastal and inland stocks relative to its Optimum Sustainable Population (OSP) level and population trends is unknown (Carretta, J.V. 2007).

Dall's porpoise (*Phocoenoides dalli*)

The Dall’s porpoise remains year round in the Strait of Juan de Fuca, San Juan and Canadian Gulf Islands, and Admiralty Inlet and feeds on squid and small schooling fishes. It is known to possess very high powered sonar, but this ability has not prevented it from becoming frequently entangled with in gill nets (Yates, 1988). NMFS states no information in available about population trends, current or maximum net productivity, and there are insufficient data to evaluate potential trends in abundance. They are not listed as "threatened" or "endangered" under the Endangered Species Act nor as "depleted" under the MMPA (Carretta, J.V. 2007). The Washington State Department of Fish and Wildlife classifies this species as “State Monitor.”

Stellar Sea Lion (*Eumetopias jubatus*)

The Steller (or Northern) sea lion is the largest of the eared or otariid seals found in Washington waters and uses haulout sites primarily along the outer coast from the Columbia River to Cape Flattery, as well as along the Vancouver Island side of the Strait of Juan de Fuca. Although breeding rookeries are located along the Oregon and British Columbia coasts, no breeding rookeries are found in Washington (Jefferies et al. 2003).

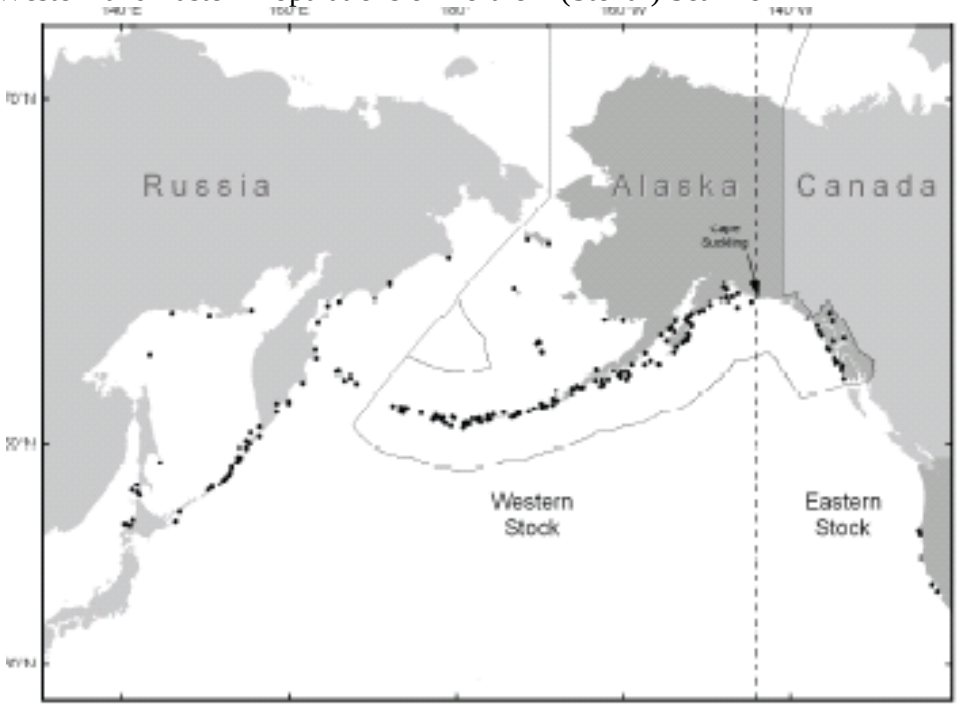
Haul out sites are found on jetties, offshore rocks and coastal islands. This species may also be found occasionally on navigation buoys in Puget Sound as well. Both sexes are found in Washington waters, with males considerably larger (to 2,200 lbs) than females (to 700 lbs). Coloration varies from tawny through yellowish brown to dark brown. Vocalizations from adults can be described as a deep growling sound (Yates, 1988; Everitt, 1980).

Over its range, Steller sea lion population numbers have declined significantly over the last 15 years. In Washington, Steller sea lion numbers vary seasonally with peak counts during the fall and winter

months. In 1980 a report was compiled on marine mammal population for the Marine Ecosystems Analysis project (MESA). This study found 10 known haulout sites in Washington and adjacent waters for Steller seals at that time, including Sucia Island, Sombrio Point, and Race Rocks. However, the study also noted a decline in number at favored haulout sites over the study period, noting that no more than 20 animals were observed at a haulout site between 1978 and 1979. The total count for the study period, including coastal and inland animals, reached a maximum of around 500 (Everitt, 1980). Again, one potential reason for this low number is that no rookeries currently exist in Washington; eastern population Stellar sea lions give birth in Oregon, California, and British Columbia.

The USFWS divides the population into two sub-species (see Figure 15), with the dividing line located at Cape Suckling, Alaska (144°W). Washington Stellar sea lions are east of this line.

Figure 15 Western and Eastern Populations of Northern (Stellar) Sea Lion



The USFWS has listed the eastern population as threatened and the western population as endangered. Washington State has also listed the species as state threatened (USFWS, 2007). Everitt (1980) reported that sea lions in Washington are most abundant in winter, and thus most susceptible environmental perturbations at this time at favored haul out locations, such as in the eastern Strait of Juan de Fuca.

California Sea Lion (*Zalophus californianus*)

The California sea lion is also an otariid, or eared seal. The USFWS divides the California sea lion into three stocks, only one of which is found in the United States. The United States stock has a range that extends along the west coast of North America, from Baja California to Vancouver Island (Carretta, J.V. 2007). In Washington and adjacent waters, California sea lions have been reported at 11 haul out sites, including but not limited to Race Rocks, British Columbia and a beached barge at Port Gardner, Washington (Everitt, 1980). A NOAA study in southern California investigated the diet of California sea lions, and found that the most common prey items included forage fish, and were (in order of abundance): Northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops*

sagax), Pacific whiting (*Merluccius productus*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), shortbelly rockfish (*Sebastes jordani*), and market squid (*Loligo opalescens*). The study suggests that population numbers are highly responsive to prey availability, particularly when these resources decline in El Nino years, and suggests that the increase in seal population numbers will eventually reach carrying capacity during an El Nino year (Lowry, M. unpublished).

The California sea lion is not listed as threatened or endangered under the ESA, and it is not listed as depleted or a strategic stock under the MMPA. The population of the United States stock appears to be growing around 5 – 6% per year, but is heavily influenced by El Niño events, which affects adult female survivorship (Carretta, J.V. 2007).

Harbor Seal (*Phoca vitulina richarsi*)

The habitat of the harbor seal encompasses coastal and estuarine waters off Baja California, north along the western coasts of the continental U.S., British Columbia, and Southeast Alaska, west through the Gulf of Alaska and Aleutian Islands, and in the Bering Sea north to Cape Newenham and the Pribilof Islands. The harbor seal is the most common, widely distributed pinniped found in Washington waters, and is frequently sighted using one of its hundreds of resting or haul out sites located along Washington's coast or inland waters. Harbor seals use the rocky beaches south of Point Whitehorn for hauling out and pupping for approximately 8500 feet along the shoreline. Group sizes typically range from small numbers of animals on some intertidal rocks to several thousand animals found seasonally in coastal estuaries (Yates, 1988; Jefferies et al. 2003). As managed by NMFS, harbor seals along the western continental United States have been divided into three coastal and inland stocks based upon differences in cranial morphology, pupping phrenology, and genetics (Jefferies, 2003; Carretta, J.V. 2007): (1) Washington inland waters (including Hood Canal, Puget Sound and the Strait of Juan de Fuca out to Cape Flattery), (2) Outer coast of Oregon and Washington, and (3) California (Carretta, J.V. 2007).

Jeffries et al. (2003) report that 8,949 harbor seals were detected during inland stock haul-out counts in 1999. Correct population estimates are difficult because the seal pups are precocious. The 2006 stock assessment for this marine mammal reports that the Oregon/Washington population of harbor seals is declining (Carretta, J.V. 2007). Harbor seals are not considered to be "depleted" under the MMPA or listed as "threatened" or "endangered" under the Endangered Species Act. The Washington State Department of Fish and Wildlife classifies this species as "State Monitor."

Elephant seal (*Mirounga angustirostris*) Although elephant seals are infrequent visitors to the Puget Sound, there are a usually a few animals that show up throughout the year with a peak in sightings occurring during summer (Osborne et al. 1988). Elephant seals encountered in Washington waters are generally males or young of the year. Elephant seals are generally found either floating at the surface or they are encountered hauled out on sandy beaches. In Washington State, if an elephant seal has hauled itself onto a beach, it may be molting and will remain on the beach until the molting process has finished. Human caused mortality primarily involve fishery entanglements, however from 2000-2004 stranding records from California, Oregon and Washington state's attribute three elephant seal deaths to boat collision (Carretta et al. 2008).

Non-native species

As a major shipping port, the Cherry Point industries receive most of their vessel traffic from ports in Alaska, and California with additional vessel visits from other Pacific Northwest ports and some Asia or Australian ports. Ballast and fouling organisms arriving with visiting vessels represent a potential invasion vector for numerous species. The United States Environmental Protection Agency (EPA)

has identified ballast water as one of the most “universal and ubiquitous vectors” for the transport and discharge of non-native species in marine and coastal areas (EPA 2008).

The composition of non-native organisms that have established at Cherry Point has not been adequately characterized. Two species of non-native marine vegetation were identified at Cherry Point as part of an inventory of submerged aquatic vegetation: the Japanese alga *Sargassum muticum*, which has widespread distribution along Cherry Point and the Japanese eelgrass *Zostera japonica*, which has been documented in numerous patches from Birch Bay to south of Gulf Road (Fairbanks et al, 2005).

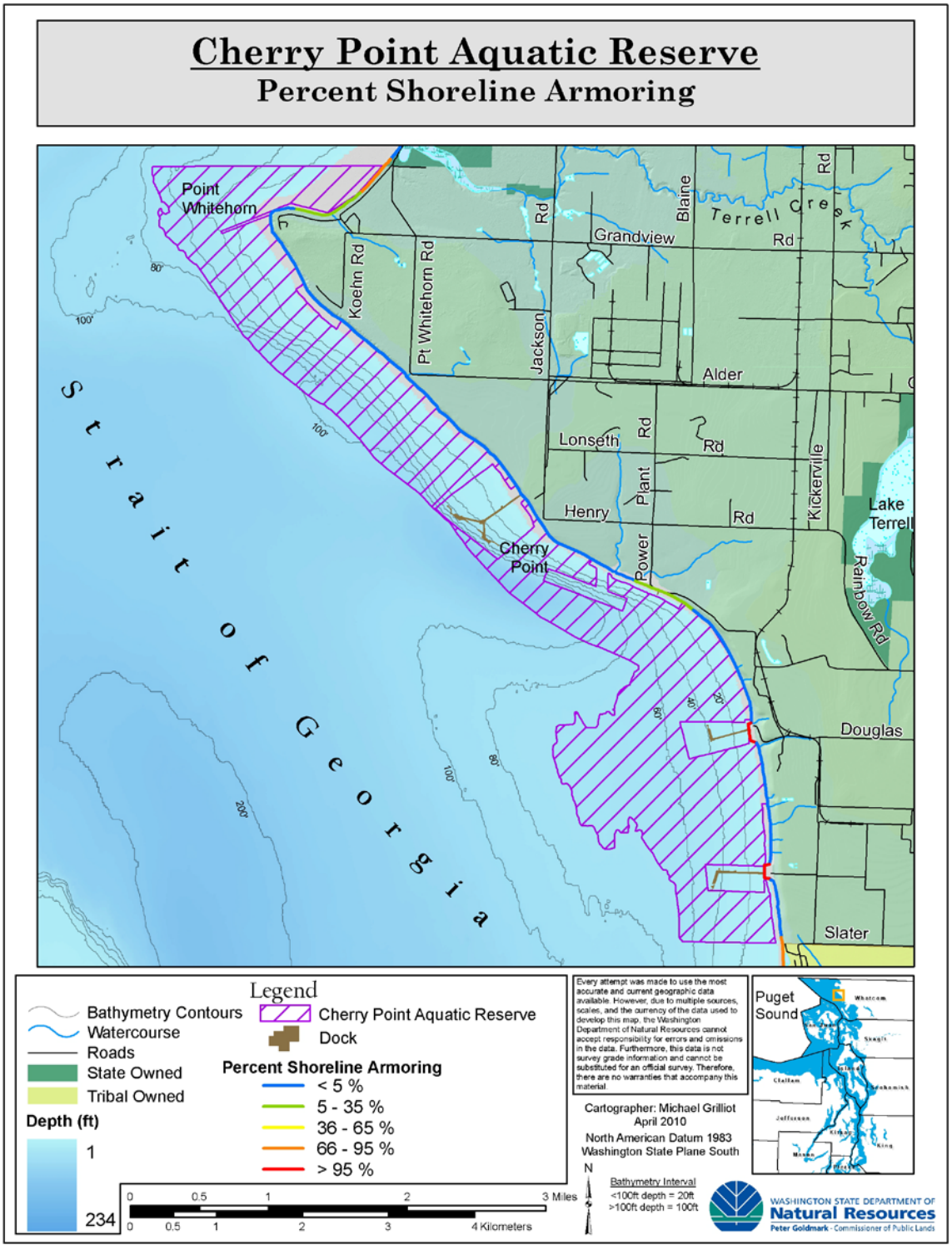
Appendix B - Risks to Ecosystems at Cherry Point

Overview of Risks

The Cherry Point Workgroup identified the following threats to Cherry Point natural resources, including: pollution from groundwater contamination, stormwater runoff, point discharges and air deposition; disturbance from recreational activities; shoreline modification, including overwater structures, loss of riparian vegetation, armoring, and derelict gear; artificial light and excessive intermittent sound; vessel traffic, including oil spills; ballast water and invasive species; and habitat impacts due to climate change. The Aquatic Reserves Program Technical Advisory Committee (TAC) noted the unique environment at Cherry Point and identified a number of threats to its resources, including: impacts associated with the piers and pilings, fill in the intertidal and the expanding threat posed by residential development along the northern and southern boundaries of the reserve.

Activities and physical changes that inhibit or modify the physical, biological, and chemical processes within the nearshore can lead to degradation of habitat structure and functions. Species dependent upon these habitats functions may be particularly sensitive to such changes. A potential source of data for identifying historical modifications to ecological processes, structures and functions and future risks is being developed by the Puget Sound Nearshore Partnership, lead by Washington State Department of Fish and Wildlife and the U.S. Army Corps of Engineers. This “change analysis” database was developed to investigate the fundamental causes of ecosystem decline due to human change to natural nearshore processes along Puget Sound's shoreline. It examined numerous existing datasets from two broad time periods, the advent of United States territorial settlement (circa 1850-1880) and present-day (2000-2009). The project is currently documenting how these changes will continue in the future if they aren't addressed, as well as how these changes affect ecosystem functions, goods, and services that the region depends on. The study will expand collaborations with stakeholders and the public to recommend a portfolio of restoration and protection solutions to address these problems and improve the condition of nearshore ecosystems.

Figure 16. Shoreline Armoring at Cherry Point



Risks to Indicator Fish and Wildlife Species at Cherry Point

Salmon

The decline of salmon species in Puget Sound has generally been attributed to four factors: habitat loss, hydropower, harvest and hatcheries. Natural variations in ocean-climate conditions, climate change, and other factors such as predation and the introduction of non-native species have also contributed to the deceline. For salmon in WRIA 1 using the nearshore, the primary threats to salmon populations are: modification of shorelines by armoring, overwater structures and loss of riparian vegetation; contamination of nearshore and marine resources through point sources, untreated runoff from impervious surfaces, and contaminated groundwater; alteration of biological populations and communities such as prey resources or eelgrass beds; colonization by invasive plants (Puget Sound Action Team, 2005), and water temperature and stream flow modifications due to human actions and climate change (Glick, 2005).These factors are discussed later in this chapter under the various subheadings.

Competition with pink salmon for prey resources has been hypothesized as affecting the survival of Puget Sound Chinook since the major 1982-1983 El Nino event (Fresh, 2006). In the Strait of Georgia, most pink salmon enter marine waters in April, before Chinook salmon, and during even-numbered years. Prior to the large El Nino event, Chinook experienced greater survival during even-years, but since the El Nino event of 1982-1983 survival has been reduced, and some have hypothesized this is because of increased competition with pink salmon for prey resources. As a result, juvenile Chinook salmon may be entering marine waters at a time of reduced prey availability. In addition, the substantial decline in spawning Cherry Point herring during the early 1980s coincides with the reduced survival of Chinook and an increase in pink salmon abundance. It has also been hypothesized that the survival of sub-adults and adults may beimpacted by a decrease in abundance of Cherry Point herring (PSAT, 2005).

Cherry Point Pacific Herring

Since the 1970s, the size of the Cherry Point stock has shrunk from a high of approximately 15,000 tons to a low of about 800 tons in the 2000 spawning season, to an estimated 2,100 tons for 2007, followed by a decrease to 1,352 tons in 2008 (see Figures 17 and 18). The annual mortality rate estimate for the Cherry Point herring stock has increased from a range of 20-40% in the late 1970s to an average of 68% since 1990. The mean estimated natural mortality rate for other Puget Sound stocks has averaged 75%. Worldwide, natural mortality rates in the 30-40 percent range are considered typical, while higher rates, like those presently observed for the Puget Sound stocks are considered unusual (Stick and Lindquist, 2008).

For the 2003-04 period, 50 percent of Puget Sound herring stocks are classified as healthy or moderately healthy. This is the lowest percentage of stocks meeting these criteria since development of the stock status summary in 1994; following 71% and 83% of stocks considered healthy or moderately healthy in 2000 and 2002, respectively. One stock, N.W. San Juan Island, was also added to the critical list in 2004. In the 1970s, the Cherry Point stock comprised more than half of the herring biomass in Puget Sound (Stick 2005).

The location of herring spawn deposition in lower intertidal and upper subtidal habitats and the geographically specific nature of herring spawning behavior make herring spawning grounds vulnerable to shoreline development. As a result, it is likely that one of the potential threats to herring within the boundaries of the management area is from damage to eelgrass spawning and rearing habitat. Washington Department of Fish and Wildlife manages Pacific herring and regulate project approvals for in-water projects located in areas where there are documented herring spawning grounds (See discussion on "no net loss" in section 5.3.2 or consult the Washington Administrative Code Hydraulic Code Rules, WDFW, 2007). Certain recreational activities, such as recreational shellfish digging, also have the potential to impact herring spawning substrate. This issue is discussed later under the section:" Disturbance from Recreational Activities".

Industrial activities along the Cherry Point shoreline, including petroleum offloading and processing and aluminum smelting, represent possible sources of environmental contaminants. However, larval abnormalities in Cherry Point herring larva can occur completely independent of conditions at the shoreline, and in fact, were reproduced independently from zygotes reared in clean water in a controlled laboratory setting (see Hershberger et al 2005). However, outplants of Cherry Point herring embryos along the shoreline in the 1990s (Hershberger et al, 1999) showed a geographical pattern of abnormalities unlikely to be due to chance alone, but testing to confirm the cause of these abnormalities has not yet been done (Marshall et al 2005).

The current age structure of Cherry Point herring is made up of relatively young fish. The estimated age composition in recent years has been dominated by 2 and 3 year old fish, compared to a much higher proportion of older fish in the 1970's. While the ratio of 2 and 3 year olds increased, an increase in the natural predators of herring, including Pacific hake, spiny dogfish, and harbor seals, was also noted in recent decades (Stout et al. 2001; Mitchell, 2006). The increase in predation rates combined with a higher rate of natural mortality (e.g., parasites) in the older age classes could be factors in the change in age class structure (WDFW, unpublished data, 2008). Relatively good two year old recruitment in recent years has been sustaining most stocks in Puget Sound despite high natural mortality rates. Recruitment failure, under the present natural mortality, would lead to dramatic stock biomass declines.

Because of their genetic uniqueness, and potential repository for variation, Cherry Point Pacific herring should be protected through careful management. This variation may include a greater tolerance for warm water in early lifestages than seen in other regional herring (Dinnel et al 2008.)

The role of persistent organic pollutants

Studies have been published (West et al, 2001) that address the concentrations of PCBs and other persistent organic pollutants (POPs) within Cherry Point Pacific Herring and Puget Sound Pacific Herring stocks.O'Neal and West et al. (2001) documented that Pacific herring from central and southern Puget Sound basins had higher levels of PCB body burdens when compared to herring stocks from northern Puget Sound and the Strait of Georgia. West *et al.* (2001) determined that mean total PCB body burden for the Cherry Point herring stock was 54.89 µg/kg (standard deviation (SD) 13.00 µg/kg). The Semiahmoo stock that spawns in the same region as the CPPHS had total PCBs measured at a mean of 51.24 µg/kg (SD 31.27 µg/kg). The more southerly stocks had higher concentrations of total PCBs. The Puget Sound herring stock at Port Orchard had mean total PCBs at 189.40 µg/kg (SD 63.29 µg/kg) and at Squaxin Pass the mean total PCBs were 195.90 µg/kg (SD 48.95 µg/kg). As demonstrated by the high standard deviation, the southerly stocks have a wide range of individual measurements. More southerly stocks do have higher concentrations of PCBs.

In a later study, West et al. (2008) made additional collections of age 2-3 fish from Squaxin Pass, Quartermaster, Port Orchard, Cherry Point and two other Strait of Georgia stocks. PCBs and other POPs were measured for each stock and normalized to nanogram of compound per grams of lipid content (ng PCBs/g lipid). The levels were compared to the 10th percentile residue effect threshold for the protection of juvenile salmonids, which was suggested by Meador et al (2002) to be set at 2400ng PCBs/g lipid (2002).

Port Orchard exceeded this benchmark, Cherry Point had concentrations at about ½ the threshold, and Squaxin Pass was intermediate. The results show that Puget Sound Pacific herring and Cherry Point Herring have PCB concentrations that are near or above the suggested threshold concentration for juvenile salmonids of 2.4 ug/g lipid (Meador et al. 2002). Uncertainty exists in extrapolating between species of such different phylogeny, and comparable data are not available for other Pacific herring stocks. Studies on PCB effects to Pacific herring stocks outside of Puget Sound and Cherry Point would be informative.

PCBs are known to have a plethora of effects on development and immune function that are typically not included in fish toxicity tests. Development of toxicity tests for Pacific herring has been underway (Dinnel et al. 2008) and exploration of the effects of PCBs and other persistent organic pollutants could be informative. PCBs are known to affect degrade the immune systems of fish species (Zelikoff et al. 2000, Duffy et al. 2002). A high priority should be placed on the effects of these contaminants on immune function in consideration of the high incidence of disease in Pacific herring of this region. DDT and hexachlorobenzene residues are also found in the Pacific herring stocks and the pattern of bioaccumulation was specific to CPPH and the PSPH. These data provide information that the two groups of Pacific herring utilize different segments of the landscape (West et al 2008).

The role of parasites and disease

Herring in Puget Sound and throughout the eastern North Pacific are impacted by at least three pathogens that exert population-level effects: Ichthyophonus hoferi, viral hemorrhagic septicemia virus (VHSV), and erythrocytic necrosis virus (Stick and Lindquist, 2008). Stressors associated with age in herring include increased incidence of parasitism and/or disease. The syndrome parasite Ichthyophonus hoferi is highly prevalent in herring populations throughout the eastern North Pacific, and increases with the age of herring in Puget Sound, ranging from 12% among juveniles to 55% among the oldest adults (Hershberger, 2002). Recent studies indicate that Ichthyophonus infected fish have a decreased swimming performance, resulting in preferential predation by salmon and sculpin. These data indicate both direct and indirect mortality from ichthyonphonus may contribute to the disappearance of the older herring age cohorts in Puget Sound and account for the truncation in observed age structure among Puget Sound herring stocks.

VHSV and other pathogens can also be found in Pacific herring in the Puget Sound region. (Hershberger *et al.* 2002; Landis *et al.* 2004, 2005, Landis 2008). A combination of disease from VHSV and Ichthyophonus is a leading hypothesis accounting for the crash and failed recovery of Pacific herring populations in Prince William Sound, Alaska (Stick and Lindquist, 2008). In Puget Sound, impacts of VHSV are typically most severe among the youngest herring age cohorts; cohorts that survive exposure develop strong resistance to the disease.

Pacific herring are also susceptible to viral erythrocytic necrosis, and is likely common among juvenile herring. It is thought that population level impacts likely occur, but are typically covert and not easily detected. Disease is a stressor widespread in the region. Routine monitoring of the

prevalence of disease within the various Puget Sound herring and Cherry Point herring stocks, in concert with the routine counting of the fish would be a useful tool in assessing the state of Pacific herring. As Hershberger has done, disease incidence should be determined for each age class and for each stock.

The role of interactions

As the change in ocean conditions occurred, diseases with broad host ranges, such as *I. hoferi* may have been introduced to the region. PCBs and other persistent organic pollutants with the ability to alter immune function may have made the fish more susceptible to infection. The combination could then lead to a persistent and widespread decline in the Pacific herring. No doubt other scenarios could be developed from this or similar datasets. Part of the issue is that the recognition of such an event could not have been done until recently.

The spring freshet of the Fraser River provides the nutrients and stable stratification needed for abundant primary and secondary production. Currents concentrate phytoplankton and zooplankton just south of Point Roberts very close to the Cherry Point herring spawning grounds (Legare, 1957; Parsons et al, 1969). It has been known since the 1920s that the zooplankton biomass of the upper layer of the Strait of Georgia peaks in April through early June and is at times dominated by one species, *Neocalanus plumchrus* (Campbell, 1934). Wailes (1936) examined the stomach contents of southern British Columbia herring in 1931-1934 and found samples from April and May with 98% to 100% *N. plumchrus* and rated this species along with *Euphausia pacifica* as most important for adult herring. The *Neocalanus plumchrus* population of the Strait of Georgia went into steep decline in 1971 while populations of smaller copepods such as *Calanus marshallae* increased (Gardner, 1977). Gardner (1976) predicted declines in Strait of Georgia fish populations due to the greater energy expenditure needed to acquire the same amount of nutrition from smaller copepods as from *N. plumchrus*.

Malnutrition both decreases disease resistance and increases sensitivity to the toxic effects of PCBs and other POPs. Animals stressed by disease and/or toxic chemicals have trouble finding food or avoiding predators due to sensory and metabolic impairment. Mutually reinforcing stressors can result in precipitous drops in populations while making cause and effect conclusions very complicated and controversial.

Current regulatory protection

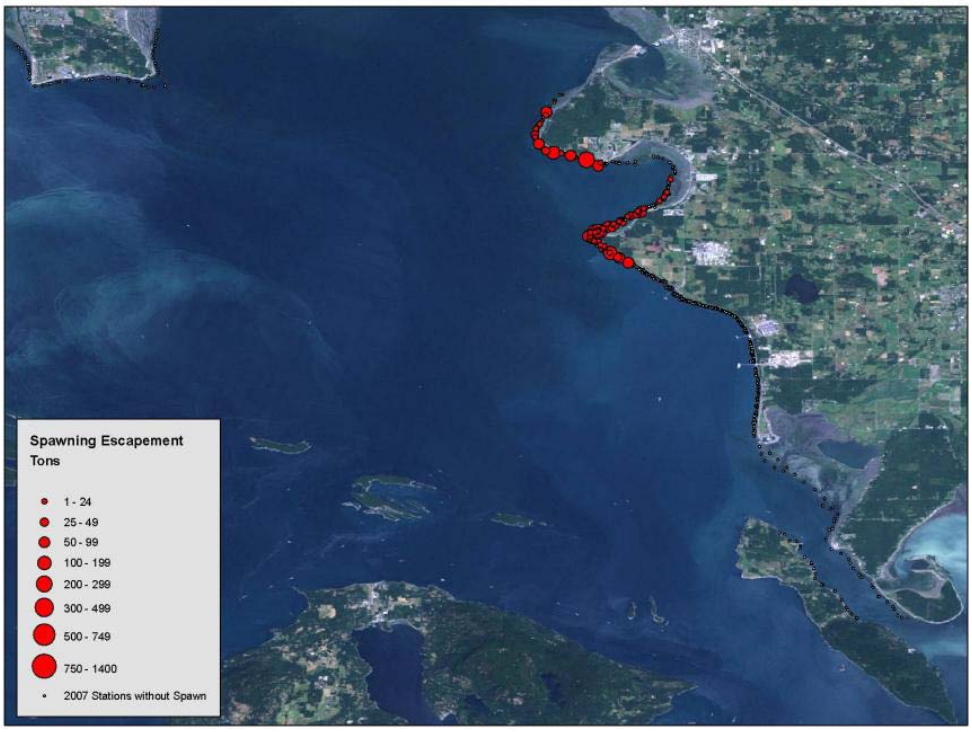
In response to a 1999 petition that addressed 18 species in Puget Sound, including Pacific Herring, the Department of Commerce, NOAA Fisheries, National Marine Fisheries Service, formed a Biological Review Team (BRT). While federal protection was not provided, the BRT stated (Stout, et al 2001):

> ". . .most members expressed concern that they could not entirely rule out the possibility that this Georgia Basin DPS at present is likely to become in danger of extinction, especially because some stocks within the Georgia Basin, such as Cherry Point and Discovery Bay, have declined to such an extent that they may meet the IUCN criteria to be considered "vulnerable" which is (of special concern), not necessarily endangered or threatened severely, but at possible risk of falling into one of these categories in the near future."

While the petitions to list the Cherry Point Stock as a federally listed species under the Endangered Species Act (ESA) were not successful, continuing declines in the Cherry Point stock have listed it as

"critical" by the Washington State Department of Fish and Wildlife. The Washington State Department of Fish and Wildlife also continues to list the Cherry Point stock as a candidate species.

Figures 17 and 18. Spawning escapement for Cherry Point Herring: 1973 – 1980 compared to 2007 (WDFW unpublished)



Surf smelt and Sand lance

Surf smelt and and sand lance spawn on relatively undisturbed beaches. This makes them extremely vulnerable to shoreline modifications that alter substrate composition, thereby destroying spawning habitat. Rice (2006) examined the effects of four physical parameters compared to a control on surf smelt spawning success. It was found that an armored beach with no terrestrial vegetation had significantly higher daily light maximum light intensity, higher daily maximum and minimum substrate temperature, significantly higher maximum daily air temperature, and a significantly lower

relative humidity. The altered beach also contained approximately half the live surf smelt embryos as the natural beach. Admittedly, the small number of sites limits this validity of the results, but prompts the needs for future studies into the relationship between beach modification and surf smelt survival. Cherry Point currently has a lower percentage of shoreline modification compared to many other areas, but pressure for additional shoreline armoring is a threat to healthy forage fish populations.

Shellfish

Dungeness crab populations in Whatcom County are fairly healthy, although there is extra pressure placedon the population from increasing harvests of Dungeness crab (Whatcom MRC 2009) Threats to crab habitat include shoreline development (bulkheads and dredging), loss of eelgrass beds, pollution and competition with invasive species. Impacts of shoreline development are described later in this chapter.

Effects of urban pollution on Dungeness adults are not well known, but they are not tolerant of low dissolved oxygen. Larvae are highly sensitive to insecticides and heavy metals as well as to variation in temperature and salinity (Dethier, 2006). All life stages show highest survival in higher salinity waters. The reliance of juveniles on estuaries, including eelgrass beds, suggests that this stage may be the most vulnerable to human impacts. Dredging in estuaries, for example, causes severe habitat alteration or loss for Dungeness crabs. Because crab larvae feed in the water column, in order to survive they require a predictable and non-toxic supply of plankton and edible detritus, and a minimal load of suspended sediment, which can clog their feeding structures. Toxic plankton blooms, even though they may not affect the shellfish themselves, can result in increased biological oxygen demand, resulting in reduced oxygen levels that are deadly to crabs. Harmful algal blooms of benthic algae, which may be caused by excess nutrients in the water column may smother organisms beneath them (Dethier, 2006).

Any human impacts that alter sediment size or supply can reduce settlement, reduce growth, or outright kill many species of shellfish. For Dungeness crabs, preferred sediments are fairly fine sand or mud, often associated with eelgrass in shallower habitats (Dethier, 2006). Crabs can also be affected by impacts to natural currents, as they relay on them for transport to nearshore settlement areas. Changes in the physical or chemical environment that causes physiological stress to organisms, such as loss of eelgrass beds, or changes in surface sediments, may make them more vulnerable to parasites or predators.

Introduced competitors and predators can also have negative effects on crab populations One species in particular, the European green crab (*Carcinus maenas*), has been shown to out-compete Dungeness crab of similar size for food and habitat. Although the European green crab population is currently fairly small in Washington, if it were to greatly increase, the Dungeness crab could lose more valuable habitat, thus placing additional pressures on the population. (Whatcom County MRC 2009). Spartina, Japanese eelgrass and other species may either alter habitat for crab, or compete with native plant species, making habitat unsuitable for shellfish.

Groundfish

Palsson et al (2009) recently used a modified version of the American Fisheries Society's Criteria for Marine Fish Stocks to establish rockfish stock status. These criteria are based upon life history parameters relating to population productivity and compare the magnitude of stock trends over ecologically appropriate time scales. Four status categories were based upon the magnitudes of trends and included Healthy, Precautionary, Vulnerable, and Depleted. Most rockfish species were in Precautionary condition, however, copper rockfish were Vulnerable in South Sound and quillback rockfishes were Vulnerable and Depleted in North and South Sound, respectively. Based upon stock

assessments in adjacent coastal waters, yelloweye and canary rockfish were in Depleted status in North and South Sound. The relatively deepwater greenstriped rockfish, redstripe rockfish, and shortspine thornyheads were in healthy condition as were stocks of Puget Sound rockfish in South Sound. As noted earlier, three populations of rockfish in Washington's Georgia Basin were recently listed for protection under the Endangered Species Act: canary and yelloweye have been designated as "threatened" and a third rockfish species bocaccio, as "endangered."

The health of rockfish stocks in Puget Sound is impacted by factors that remove excessive numbers of individuals, chronically alter or degrade their habitats and block life history pathways, or affect other species that increase predation, disease, or competition (Palsson, 2009). Many stressors potentially limit the productivity of rockfish stocks in Puget Sound and include fishery removals, age truncation, habitat disruption, derelict gear, hypoxia, predation, and fishery removals of larger and older individuals. These stressors may have even greater impacts when stocks are at low levels causing, higher mortality rates that can drive stocks to dangerously low levels. Among the potential stressors, fishery removals, derelict gear, hypoxia, and food
web interactions are the highest relative risks to rockfish in Puget Sound. Chemical contamination is a moderate risk manifested by undetermined reproductive dysfunction associated with exposure to endocrine disrupting compounds, loading of larvae with persistent organics via maternal transfer, exposure of pelagic larvae to toxics via contaminated prey, and exposure of long-lived adults to toxics like polychlorinated biphenyl compounds that accumulate over the life of the fish. These are most likely to impact rockfish living in urban areas but may be more widespread in the food web.

Populations of Strait of Georgia and San Juan Islands flatfish like English sole, rock sole, starry flounder, sand sole, and Pacific halibut are estimated to be in above average condition when compared to historic abundance by state fisheries managers. The population of Dover sole, however, is in critically depressed condition and could be as low as 25% of historic abundance (Whatcom MRC, 2009). Toxic chemical contamination in shallow bays and estuaries where flatfish live, spawn and grow accumulate in their tissues, impair growth, resistance to disease and reproductive capability. Disrupting eelgrass and kelp beds in bays and inlets where young fish find shelter and grow takes away important nursery areas.

Commercial fishing has occurred in the past at Cherry Point and derelict fishing gear is likely present on the seafloor in the Reserve. Lost nets, crab and shrimp pots associated with current commercial and recreational fishing can continue capturing target groundfish species as well as other fish, shellfish, marine mammals and birds

Birds

Key threats to seabirds and migratory waterfowl at Cherry Point include decrease in prey species such as salmon and herring, toxic contaminants, oil spills, derelict gear, and changing water temperatures. Threats to listed and indicator species are described below.

Marbled Murrelets

Marbled Murrelets (*Brachyramphus marmoratus*) are threatened by habitat loss and fragmentation, accidental by-catch of gill net fisheries, and environmental contamination from oil spills and pollution (WDFW 2005). Critical habitat was designated in 1996. Recently the United States Fish and Wildlife Service re-listed the bird, after conducting a 5-year review and determining that the bird continued to decline. The USFWS also determined that the bird was a Distinct Population Segment under the Endangered Species Act. The review team determined that the Marbled Murrelet population in Washington, Oregon and California continues to decline and faces a broad range of

threats, such as nesting habitat loss and fragmentation and predation. Although some threats, such as gillnet bycatch and lack of regulatory mechanisms, have been reduced since listing, most continue and the species faces new threats, such as abandoned fishing gear at sea, harmful algal blooms and observed changes in the quality of the bird's marine food supply. As Cherry Point provides foraging habitat for these species, management actions should address water quality and removal of derelict gear.

Loons

A comparison of the PSAMP survey data to the 1978-79 MESA survey shows a large decline (64% decrease, $p < 0.001$). (Nysewander, D.R. et al. 2005). Adjacent habitat to the Reserve provide quality wintering habitat for the common loon, and high winter counts have been documented along the Strait of Georgia, in Drayton Harbor, Lummi Bay, Hale Passage, Bellingham Bay and Padilla Bay (MESA; Wahl et al. 1981). However, the 1992 – 99 PSAMP surveys document fewer than 5 birds per square kilometer along the Cherry Point (Nysewander, D.R. et al. 2005), perhaps due to the lack of inlets and the presence of deeper waters.

Cormorants

Cormorants are sensitive to human disturbance to colonies. Cormornats as a group have been killed and harassed by people who believe that the birds damage the commercial fishing industry (pelagic cormorants, however, feed on fish that aren't fished by commercial fisheries). Population fluctuations may also be tied to the California current, which is associated with upwelling, deep ocean water, rich in nutrients. Changes in upwellings that occur in El Niño and La Niña years affect food availability for this species. El Niño events reduce the number of breeding pairs as well as the reproductive success of breeders.

Such disturbances, plus commercial fishing and pollution, oil spills, gill-net entanglement, and toxic contamination of prey also affect the cormorant populations (BirdWeb 2008). The sensitivity of cormorants to human disturbance, and its reliance on fish populations for food, can be used to help monitor overall the health of ocean currents, certain fish species, and habitat at Cherry Point.

Bald Eagle

Delisted in 2008 from the federal Endangered Species list, the bald eagle (*Haliaeetus leucocephalus*) will remain protected under the federal Bald and Golden Eagle Protection Act, federal Migratory Bird Treaty Act and the State Bald Eagle Protection Act RCW 77.12.655. The State law requires the establishment and enforcement of rules for buffer zones around Bald Eagle nest and roost sites. The majority of Bald Eagle nests are found on private land not dedicated to conservation (Bohannon, J. WDFW, pers. comm. 2008). Perching habitat along the shoreline has been severely reduced in Birch Bay as a result of residential development. The reliance of this bird on forested areas near waterbodies containing adequate amounts of fish, birds and mollusks for food can be used as an indicator for the overall ecosystem health at Cherry Point.

Common Murres

Common Murre numbers fluctuate annually, in response to food supply and climatic events. Common Murres are the most frequent avian victims of oil spills along the Washington coast. Other threats to the population include pollution, over-fishing of prey, gill net entanglement, and predators (WDFW 2005). The population experienced a crash as a result of the 1983 El Niño event, dropping from 30,000 to fewer than 3,000 birds. While some populations have recovered, others have yet to rebound, and the population is about one-third the former level (BirdWeb, 2008).

Common Murres are highly sensitive to human presence, whether humans are on foot, in a boat, or in a low-flying plane. When disturbed, the birds may knock eggs and chicks out of the nest sites in their haste to fly clear of the disturbance. The unguarded chicks and eggs become easy prey for gulls and other avian predators (WDFW 2005; BirdWeb, 2008). Common Murres can be used as an indicator of the overall water quality and presence/absence of marine debris, for the foraging areas at Cherry Point. Researchers should investigate and see if this significant decline is a result of the El Nino crash, or if the population is unable to recover because of other issues. Management actions should be developed, as appropriate, for any Murres within or adjacent to the Reserve.

Surf Scoter

North American populations of scoters (*Melanitta perspicillata*) have declined by about 60% over the past 30 – 50 years, including 57% declines for all three scoter species combined in a Puget Sound since the late 1970s (Hodges et al. 1996, Dickson and Gilchrist 2002, Nysewander et al. 2005). Reasons for these declines are becoming clear, as recent research by WWU (Bower, J.L. 2009) helps link the declines over time to the declines in herring populations. Other factors include heavy metal contamination and oil spills.

Scoters in general showed significant declines in both PSAMP/MESA (-57%) and the WWU/MESA (-33%) comparisons. The Surf Scoter declined by 60% when WWU compared results to MESA counts. Bower, J.L. (2009, unpublished) states that much of the decline in Surf Scoters in the WWU/MESA comparison resulted from greatly decreased numbers of Surf Scoters congregating at the collapsed Cherry Point herring spawn event (Stout *et al.* 2001). For example, during the MESA study, on 30 April 1978, MESA researchers counted 40,100 Surf Scoters at Cherry Point. However, WWU counted in late April of 2004 and 2005 in the Cherry Point area and there were less than a thousand surf scoters.

To show how herring impacts surf scoter population, removal of the spring Cherry Point spawn event from the WWU/MESA data set results in reduction of the census-wide decline in Surf Scoters by one half. In this case, the temporal and geographic resolution of the WWU/MESA comparison offers evidence that much of the apparent decline in Surf Scoters is tied to the collapse of the herring spawn in the Cherry Point area (Bower, J.L., unpublished, 2009).

As discussed in Appendix A, scoters both rely on herring spawn as a food source, but research shows that herring spawn may be critical for surf scoters to help build up fat reserves prior to migration. For this reason, Anderson et al. (unpublished manuscript, 2009) suggest that management of Pacific herring include protections for spawning areas that preserve feeding opportunities for these diverse predators.

Great Blue Heron

The Washington Department of Fish and Wildlife has placed great blue herons on the State Monitor List out of concern for its potential to become a species of concern as defined by WAC 232-12-297. Great Blue Herons can be vulnerable because of their tendency to aggregate during the breeding season. The availability of suitable great blue heron breeding habitat is declining as human population increases in Washington State. In addition, Great Blue Herons may abandon breeding colonies or experience reduced reproductive success when disturbed by humans. WDFW considers Great Blue Herons a “priority species” and has developed management recommendations to conserve great blue herons in the state (Quinn and Milner, 1999). While loss of nesting habitat may be an issue, adjacent to Cherry Point, the birds dependence on nearshore areas for food make them vulnerable to anthropogenic changes from shoreline armoring, increased nutrient loads, and shading.

During the 1992 – 99 PSAMP marine bird surveys, Great Blue Herons were the most common and widespread wading bird seen during summer surveys, often observed in shallow bays and estuaries. Although the most commonly observed wading bird, trends during this time period seemed to indicate a decrease in density, and the authors suggested further study.

Summer surveys were compared for two time periods: 1992-94 and 1995–1999. In the Cherry Point area, between 1992 and 1994, blue herons were observed in the northern and central portions at low to moderate densities (2 – 10 animals/km^2) and in the southern portion in higher densities (20 – 132 animals/ km^2). From 1995 through 1999, densities decreased in the southern portion to low (2 – 10 animals/km^2). Winter densities are reduced even further (0 – 2 animals / km^2 in Cherry Point) as females and young move to freshwater and males remain in marine areas (Nysewander, D.R. et al. 2005). Continued monitoring and support for the rookeries along and within the Cherry Point Aquatic Reserve are necessary for this species.

Western Grebes

Grebes, including western, used to be killed for their feathers. This practice was ended, and the birds have since recovered to the point where they are breeding in areas not occupied historically.However, wintering populations of Western Grebes have declined in all wintering sites in Puget Sound covered by Christmas bird counts. The winter aerial surveys in western Washington 1994-2005 (Nysewander et al. unpubl.) also confirm the same type of decline in wintering numbers for Western Grebes in the inner marine waters. This species exhibits the greatest percentage of decline (81 to 95 percent) over the last 30 years for any one marine species. Despite these declines, Washington continues to support globally significant numbers of Western Grebes between late autumn and early spring. Up to 20 to 25 percent of the world population of Western Grebes (Kushlan et al. 2002) over-winter in the state. This suggests that Washington will play an important role in any conservation effort expended towards this species. Fluctuating water levels, oil spills, gill nets, and poisons such as rotenone (used to kill carp) are factors that negatively affect the population. When approached by humans, the parents will leave the nest, leaving eggs vulnerable to predation and the elements. Thus, areas frequently disturbed by humans may have low productivity. Grebes are considered a Candidate species by the Washington Department of Fish and Wildlife (BirdWeb, 2008; Nysewander, D.R. et al., 2005).

Currently, the greatest threat to grebes is human development. In addition to shoreline armoring, decreasing forage fish spawning areas, loss of eelgrass beds due to increasing nutrient loads, and overwater structures leading to increased shading, the increased scour of forage fish habitat areas would significantly reduce available food supplies. This bird is an indicator of forage fish resources, invertebrates, and both freshwater and estuarine habitats. For these reasons, its numbers should be watched closely as an indicator of the resources it relies upon for survival.

Past (PSAMP, 1999; MESA 1979) and recent research (Bower, et al, 2005) which show this species is declining in large numbers and should be supported by the management actions in this plan. A discussion on the grebes decline by Bower makes the following statements (Bower, J.L., unpublished, 2009):

- The Western Grebe is showing a different pattern of decline in that it is declining across many locations, and in every month of the survey;

- Western Grebes over-wintering in industrial locations have been shown to contain high levels of industrial contaminants that approach levels needed to disrupt endocrine function in other birds;
- Western Grebes are known to be mortally impacted by oil spills;
- Western Grebe breeding colonies rely upon freshwater lakes, often impacted by development, pollution, and recreational activities, and
- Similar declines have been reported in the northeastern lakes and central Alberta lake

Peregrine Falcons

Peregrine Falcons (*Falco peregrines*) were severely endangered (and actually extirpated from eastern North America) in the mid-20th Century, mostly due to the pesticide DDT, which softens eggshells and results in widespread nest failure. With the ban of DDT in the United States, the falcons have begun to recover, but WDFW still considers environmental contaminants a specific problem with this bird. Another specific problem is disturbance by humans (WDFW 2005). The population is still small and is highly vulnerable to disturbance and environmental contaminants, but productivity levels are high and the population continues to increase (Bohannon, J. WDFW, pers. comm. 2008). The sensitivity of this species to environmental contaminants, and human disturbance, can be used as an indicator for both water and habitat quality at Cherry Point.

Osprey

The primary threat to the Osprey (*Pandion haliaetus*) has been organchlorine biocide use, such as DDT, which results in the thinning of eggshells. The ban of DDT in 1972 continues to support a strong recovery in much of North America. Artificial nest platforms have significantly increased nesting in many areas. The Breeding Bird Survey has reported a significant increase in the Osprey population in Washington. Other threats may include gunshots, steel traps, impacts with or electrocution by high-tension wires, and being caught or drowned in fishing nets (NatureServe, 2008; BirdWeb, 2008). The sensitivity of this species to environmental contaminants, human development, marine debris, quality of fish as a food source, and human disturbance, can be used as an indicator for a the overall health of the Cherry Point ecosystem.

Cavity Nesting Ducks

The diet of cavity nesting ducks includes a high percentage of aquatic insects, invertebrates, shellfish, crustaceans and small fish. Low benthic macroinvertebrate abundance may limit thre productivity of Harlequin Ducks (Bengtson and Ulfstrand 1971). Populations are highly sensitive to additional mortality from hunting, oil pollution or food contamination. Lease and Kraege (1999) recommend protecting rocky shoreline areas that are used during winter and limiting disturbances at traditional molting sites. The use of herbicides that affect emergent vegetation, and activities that may contribute contaminants which would bioaccumulate should be considered. The use of herbicides or pesticides near wetlands may affect cavity-nesting ducks by lowering the numbers of invertebrates, and by adversely affecting aquatic and emergent vegetation. These ducks are known to accumulate toxins in their tissues, especially in areas where toxins are elevated, such as downstream from mines, pulp and paper mills (Lewis and Kraege, 2000).

Marine Mammals

Generally speaking, threats to marine mammals at Cherry Point include: toxic contamination and oil spills, vessel strikes, entanglement in marine debris, disturbance from vessel noise, and loss of prey.

Gray Whale

Despite the reduction in stock abundance, the population of gray whales in the eastern Pacific is estimated to have increased compared to commercial exploitation in the mid-1800's. Numbers are around 23,000 and the U.S. Fish and Wildlife Service removed the species from the list of threatened and endangered species in 1994. The Washington State Department of Fish and Wildlife also down listed from "state threatened" to "state sensitive." (Angliss and Outlaw, 2005; Richardson, 1997).

Northern gray whales are summer residents in Northern Puget Sound. During these times, they are often found in shallow coastal waters, where feeding activities involve scooping up bottom sediment and benthic invertebrates, which are then strained. Because of the way gray whales feed, this species has the potential to ingest toxic contaminants in nearshore areas of Puget Sound and Georgia Straits (Richardson, 1997; Yates 1988). Potential impacts to the food source – benthic invertebrates - should be taken into consideration. Impacts to gray whale habitat include sounds generated for oceanographic research, disturbances related to oil and gas exploration, contaminants in the benthos, vessel traffic, and onshore and nearshore development (Richardson, 1997). From 1980 to spring, 2009, gray whales in Washington waters had the highest incidence of documented mortality due to blunt force trauma, which were generally attributed to ship strike (Douglas et al., 2008, unpublished stranding data, Cascadia Research Collective).

Killer Whale

Killer whales in Washington face three main potential threats: prey availability, pollution and contaminants, and effects from vessels (NMFS, 2008). Other risk factors include: demographics, small population size, and vulnerability to oil spills. Healthy killer whale populations are dependent on adequate prey levels. Reductions in prey availability, such as salmon, may force whales to spend more time foraging and might lead to reduced reproductive rates and higher mortality rates. The NMFS recovery plan addresses salmon restoration to ensure adequate food supply for the whales.

Recent studies have revealed that transient and southern resident whales are heavily contaminated with organochlorine pollutants, primarily PCBs and DDT residues. Both populations are now considered as among the most highly contaminated marine mammals in the world (Wiles, 2004). Killer whales are candidates for accumulating high concentrations of pollutants because of their position atop the food web and long life expectancy ((NMFS, 2008). While PCBs and DDT are no longer produced in Canada or the United States, a growing list of so-called "emerging" contaminants and other pollutants, such as brominated flame retardants (BFRs), perfluorinated compounds, persistant polycyclic aromatic hydrocarbons, and numerous other substances, are increasingly being linked to harmful biological impacts as well (nmfs, 2008). These pollutants come from a wide variety of sources, such as: municipal incinerators, runoff from sewage sludge, wood treatment, oil spills, electrical components and backings of televisions and computers, textiles and vehicle seats, pesticides and refrigerants, flame retardants, plasticizers, paints, sealants and additives in lubricating oils,, detergents, shampoos, plastics, and pulp and paper mills. The NMFS recovery plan addresses cleanup of existing contaminated sites, minimizing discharge of contaminants harmful to whales, and monitoring of emerging contaminants.

Commercial shipping, whale watching, ferry operations, and recreational boating traffic have expanded in many regions in recent decades, including the northeastern Pacific. Commercial fishing boats are also a prominent part of the vessel traffic in many areas. Vessels have the potential to affect whales through the physical presence and activity of the vessel, the increased underwater sound levels generated by boat engines or a combination of these factors (NMFS, 2008). Vessel strikes are rare, but do occur and can result in injury. In addition, underwater sound can be generated by a variety of other human activities, such as, dredging, drilling, construction, seismic testing, and sonar.

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. Increased levels of anthropogenic sound have the potential to mask echolocation and other signals used by the species, as well as to temporarily or permanently damage hearing sensitivity. Exposure to sound may be detrimental to survival by impairing foraging and other behavior, resulting in a negative energy balance. In other cetaceans, hormonal changes indicative of stress have been recorded in response to intense sound exposure (NMFS, 2008). Chronic stress is known to induce harmful physiological conditions including lowered immune function, in terrestrial mammals and likely does so in cetaceans. The threshold levels at which underwater sounds become harmful to killer whales remains poorly understood. The NMFS recovery plan addresses evaluation and improvement of guidelines and regulations for vessel activity near southern resident killer whales.

An important short-term risk to killer whales and their prey in the Georgia Basin and Puget Sound is the threat of sizable oil spills. Despite the great increase in killer whale research in Washington and British Columbia since the early 1970s, researchers remain divided on which of these threats are most significant to the whales. It may well be that a combination of threats are working to harm the animals, especially L pod.

WATER QUALITY

Nonpoint Pollution Management

Nonpoint source pollution, unlike permitted discharges from industrial and municipal sewage treatment plant outfalls, comes from many different sources as a result of rainfall and/or snowmelt moving over and through the ground. Runoff collects nutrients and toxics from upland surfaces and discharges them into streams and marine receiving waters without any treatment. Nonpoint sources of pollution include yards, roads, construction sites, marinas, forest lands and agricultural lands. all industrial sites monitor storm water runoff as required by NPDES permits, however there are many other potential sources of storm water runoff that aren't monitored in the Reserve area..

Nonpoint source pollution, if untreated, can contribute to water pollution. In many areas of Puget Sound it affects the flow, chemistry, mixing, temperature of receiving waters, and results in localized decreases in salinity and dissolved oxygen levels. It can also increase biological activity resulting from nutrient inputs and result in shellfish bed closures and other health issues.

The following are potential sources of nonpoint pollution to fresh and marine waters in the Cherry Point Aquatic Reserve:

- Excess fertilizers, herbicides, and insecticides from residential areas;
- Oil, grease, metals, and toxic chemicals from roads and impervious surfaces;
- Soil from erosion on construction sites and eroding bluffs due to drainage problems on residential properties;
- Bacteria and nutrients from pet wastes, and faulty septic systems.

Whatcom County (2006) describes the nearshore and marine waters as receiving inputs from natural sources of major nutrients, such as nitrogen and phosphorus, on a level several magnitudes greater than anthropogenic contributions to Puget Sound. The impact is offset by the continuous circulation and mixing between the nearshore and marine environments.

Nutrient loading is traced to river discharge and land uses within the watershed. Upland sources include agricultural operations, wastewater treatment plants, and residential runoff. The Nooksack River contributed the third highest annual nitrogen load and the fourth highest annual phosphorus load of all the major U.S. rivers entering Puget Sound from 1980 to 1993 (Whatcom County 2006). Nutrient contributions to the Cherry Point reach from the Nooksack River and the Fraser River have not been quantified. Nutrient input, whether natural or anthropogenic, can be detrimental at high levels. As the results from the Marine Water Quality Study showed (Newton et al 2002), nearshore areas along Whatcom County shorelines are susceptible to eutrophication from high levels of nutrients including Portage and Drayton Harbors (shellfish protection districts), and Bellingham Bay, an enclosed bay that receives large amounts of fresh water and nutrients from the Nooksack River. These sheltered bays are especially susceptible to elevated pathogen levels from upstream anthropogenic sources. However, the role fo nonpoint source pollution in affecting water quality at Cherry Point in not weel understood.

Researchers examining declines in the growth of eelgrass suggest a link to increased human development (Short et al 1996, Lee et al 2003). While there appears to be no direct link to increased nitrogen loads, the data suggest an indirect link as a result of increased competition from algae, eelgrass epiphytes and nutrient tolerant vegetation (Short et al 1996, Lee et al 2003). Impacts associated with increased freshwater inputs may also be a factor in the decline of eelgrass. As impervious surface increases, estuarine environments can receive greater amounts of freshwater decreasing salinity levels that can result in increased habitat for species more tolerant of freshwater (Short et al 1996). Decreases in the depth of the euphotic zone from increases in supended sediments and phytoplankton populations may also be a factor in eelgrass declines.

Groundwater Contamination

Ecology and others have expressed a concern that contaminated groundwater is discharging directly to the herring spawning zone in some locations along the Cherry Point reach (Wigfield, 2008, personal communication). Additional testing is needed to determine if this is the case and to identify potential sources if contamination is detected.

Legacy sources of contamination resulting from historic (unregulated) industrial waste disposal may still exist on adjacent uplands, such as the TreOil Industries Limited site (4242 Aldergrove Rd.). Contaminants may have leached into the groundwater which later discharges into the nearby marine receiving water. The abandoned TreOil site was historically used to process TreOil, a by-product of the kraft pulp and paper industry. An inspection by Ecology in 2000 revealed the presence of an unsecured laboratory in a modular-type home, a number of above-ground storage tanks and drums with unknown material, many of which were leaking, and other unsecured industrial waste. Some of the drums contained a rosin-type substance which was sampled by the inspectors (see Figure 19). A sand-blasting area was located on the property, and the presence of grit was noted.

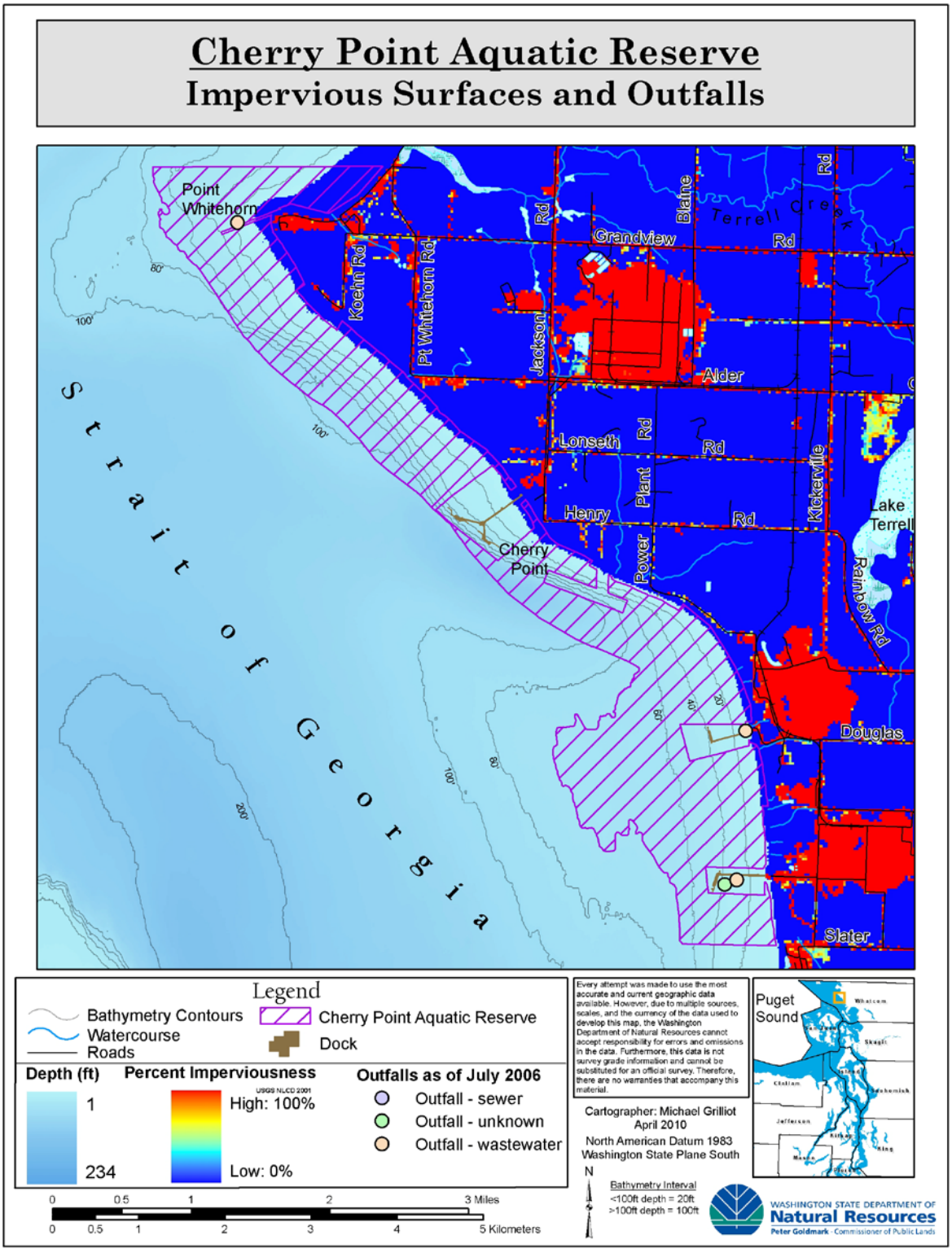
Ecology has identified the site as potentially hazardous to human health and /or the environment. Ecology also notes there is some potential for this site to be contributing to herring mortality through groundwater transport to the nearshore areas of management area (Marshall, R. personal communication). The TreOil site is ranked 2 on Ecology's list of Hazardous Sites awaiting cleanup as of February 20 2008 (Ecology Hazardous Sites List, 2008).

Figure 19. Close up picture of rosin pile at TreOil property, taken by Ecology Inspector in 2000

Point Source Pollution Management

As part of the requirements for obtaining industrial wastewater or stormwater permits, the three Cherry Point industries have allowed or conducted tests of the surrounding water column and sediments. While initial testing indicated the presence of certain potentially historical contaminants, current work by state agencies as addressed in recent NPDES permits indicates improvement (Ecology, 2007). In general, compared to other locations in Puget Sound and the Strait of Georgia, chemical concentration in receiving waters and sediment at Cherry Point is relatively low. The Cherry Point reach receives considerable dilution from freshwater inputs, as noted earlier in this document. The freshwater inputs increase dilution along the reach, decreasing the possibility of high nutrient load from industrial and municipal outfalls. Considerable dilution is believed to occur in the Cherry Point area and Georgia Strait due to the contributions of fresh water from the Fraser River (Wigfield, K. personal communication, 2008). Figure 20 shows the general number of NPDES permits, industrial discharge permits and outfalls that are permitted to discharge into or adjacent to the receiving waters of Cherry Point. Figure 20 also shows the percent of impervious surface, which is often associated with stormwater outfalls to control discharge (not necessarily shown on this map).

Figure 20. Cherry Point Area; Outfalls and Percent Impervious Surface



Sediment studies within the area have mostly consisted of monitoring conducted under the three industrial NPDES discharge permits. Although this monitoring has documented contamination associated with the three industries, Ecology cannot tie any sediment violations of Sediment Quality

Standards to existing industrial discharges. Contaminated sediment in the area of Alcoa-Intalco Works's pier has been traced to historical spills or releases from the aluminum smelter.

Sediment studies were performed at the BP facility in 2006, at ConocoPhillips in 2004, and at Alcoa in 2000. Although contaminants were detected at all three facilities, levels were not at concentrations sufficient to cause listing on the Washington Department of Ecology 303(d) list of "impaired waters" or the imposition of a "sediment impact zone" (SIZ). The contaminants were detected in a localized area around the discharge locations under the industrial outfalls with concentrations of Polyaromatic Hydrocarbons (PAH) below the current sediment quality standards (SQS), as set by the Department of Ecology. Contaminants were also detected in sediment at the pilings containing creosote, linked to the wood treatment materials for those pilings (Wigfield, 2008, personal communication).

Future Information Needs

Further information is needed regarding the environmental fate of the natural and anthropogenic discharges entering the Cherry Point Aquatic Reserve. Studies should build a better understanding of bioaccumulation in both flora and fauna species of interest at Cherry Point. These studies should pay particular attention to the intertidal and upper subtidal zones. Should adverse impacts be identified, management agencies should consider the need for additional controls to reduce or eliminate these impacts to the habitat and species identified for conservation in the Reserve.

The following elements of water quality in the Reserve should be monitored closely:

- Localized ambient water temperature changes and associated sources
- Exceedances of the State Sediment Management Standards and sources
- Exceedances of the State Water Quality Standards and sources.
  The potential cumulative effect from the natural discharges, anthropogenic discharges, and water current/temperature modeling. This evaluation will become more important as sea temperatures rise with climate change and increases become measurable in the Reserve.
- Relationship between nearshore species, survival and water quality

Modeling of the area needs to be revisited. Water quality within the Reserve is influenced by a variety of natural and anthropogenic sources including the Fraser and Nooksack rivers, outflow from Birch and Lummi Bays, industrial discharges, domestic discharges (sewage and septic), marinas, recreational and commercial vessel discharges, and stormwater runoff along the Cherry Point shoreline. A number of studies, particularly since 1954, have documented some of these influences and the natural or ambient water quality of the area. In 2001, at the request of the Cherry Point Technical Workgroup, ARCO, TOSCO, and Alcoa-Intalco contracted with ENSR/AECOM Consulting and Engineering to model the cumulative effects of the three effluent plumes from their plants to the Cherry Point Aquatic Reserve. The model consisted of a three-dimensional hydrodynamic circulation and effluent transport study. While the final model results concluded that accumulation of effluent from the three industries does not occur and water quality standards are not exceeded, there were several limitations to this model (Wigfield, 2008, personal communication).

The model did not include consideration of the following:

- Discharge from the outfall belonging to Birch Bay Water and Sewer District,
- Discharge from the Lummi reservation wastewater outfalls,
- Discharge from the stormwater runoff from Unick Road,

- Potential stormwater impacts from the proposed cargo terminal just south of the BP pier,
- The impacts of other varied sources of non-point source pollution such as groundwater seepage from hazardous waste cleanup sites,
- Influence of pollutants and freshwater from the Fraser River, and
- Evaluation of the potential for pollutants to accumulate in the nearshore during certain wind or storm conditions (Wigfield, 2008, personal communication).

While the three current industrial outfalls are in compliance with applicable permits, a more thorough analysis of cumulative water quality impacts should be conducted, preferably through the collection of in-water samples to verify the conclusions of the 2001 modeling effort (Wigfield, 2008, personal communication).

DISTURBANCE FROM RECREATIONAL ACTIVITIES

Disturbance to the beach by recreational shellfish digging is altering the ecosystem in several areas of the Cherry Point Aquatic Reserve (Kyte, 2007). Area scientists believe the direct and indirect impacts from this activity are significant to herring and other shellfish reproduction. Habitat alteration results in impacts to benthic habitat, intertidal biota, and particularly impacts to herring spawning substrate.

The impact is caused by a relatively small number of recreational shellfish harvesters who do not refill holes as required by WDFW regulations. This results in permanent alteration to Cherry Point beach and intertidal habitat. The impact is primarily in boulder and cobble substrates where the mounded material dug from the hole is not typically restored by tidal and wave action. Public and private property have been impacted, including Point Whitehorn to south of the Gulf Road.

Recreational activities other than shellfish harvest may impact habitat and wildlife in the area. Questions have been raised regarding disturbance of birds and marine mammals by dogs and human activities. Beach fires reduce habitat and threaten riparian areas. Trampling of sensitive vegetation can result in impacts to sea grasses and algae. As public access increases, these issues could be amplified. At this time there is a lack of education regarding the sensitive nature of many of the systems and resources along Cherry Point.

SHORELINE MODIFICATION AT CHERRY POINT

Despite the presence of three large industrial piers, the Cherry Point Aquatic Reserve has much less shoreline modification than many other comparable areas in Georgia Strait. Only 9% of the shoreline has been significantly modified (Whatcom County, 2006). This is far less than the Georgia Strait region where 32.6% of the shoreline has been modified (Berry et al. 2001).

Shoreline modifications occur in several locations within the Reserve, potentially influencing ecological characteristics of the shoreline at Cherry Point (see Figure 16). The primary forms of armoring are bulkheads in the area of Point Whitehorn on Birch Bay. In addition there is armoring along Gulf Road. Finally there are two large rock revetments and fills at the Conoco and Alcoa-Intalco piers. Evidence of adverse impacts from Birch Bay bulkheads has been the focus of Whatcom County managers for several years where they are requiring modifications of these bulkheads.

Riparian habitat acts as the interface or transition zone between aquatic and terrestrial ecosystems. Shoreline armoring and fill, overwater structures and land clearing associated with industrial, residential, and recreational land use and activities have the potential to adversely impact, the riparian areas along Cherry Point (Figure 18). Such impacts include disturbance and loss of habitat functions. Additional concerns include the removal of native vegetation, degradation of water quality, and altering recruitment of large woody material and sediment by either accelerating or limiting input. Climate change may also affect riparian areas. Species affected by impacts to the riparian habitat include peregrine falcon, bald eagle, great blue heron, and coho salmon.

Disturbance and loss of riparian habitat functions could lead to a net loss of resource values and function within the Cherry Point Aquatic Reserve. The level of habitat disturbance and alteration should be monitored. For example, tracking removal of native vegetation and any degradation of water quality are ways to monitor disturbance and loss of habitat function.

Armoring and modifications have the potential to disrupt sediment supply and transport. Shoreline armoring alters beach and subtidal substrates when sediment distribution patterns are changed or cut off. Often substrates become coarser, affecting the natural or successful growth of kelp, macroalgae and eelgrass. Natural nearshore drift processes are essential to the support and conservation of the resources identified in Section 4, particularly nearshore vegetation and the species that rely upon these ecosystem components, such as juvenile salmon and herring. The Cherry Point “feeder” bluff supplies sediment north to Birch Bay and further south toward the refineries and Sandy Point and into Lummi Bay. The Puget Sound Salmon Recovery Plan (2005) recommends these sediment transport processes be protected through critical areas and appropriate shoreline management designations as well as stewardship efforts.

Shoreline armoring, and/or filling intertidal areas impact wave energy by diverting it in different directions. This wave energy is needed to keep the natural hydrology intact, keep drift cells and sediment moving, and prevent the erosion of beaches. Hard shoreline armoring structures can also result in scouring, if this energy is re-directed to a different location along a shoreline (Jacobson 1980, Whatcom County 2006). Further research is needed to determine the type and magnitude of effect of shoreline armoring in the Reserve.

OVERWATER STRUCTURES AT CHERRY POINT

All heavy industrial facilities at Cherry Point possess wharves and piers for commerce of their materials. Design, level of use, and management, dictate the level of impact on ecosystems from structures such as these. Potential environmental impacts tend to be highly correlated with the level of light intensity below the structures, and research (DNR 2007) has shown that the spatial extent of the area influenced by an overwater structure is the sum of both the footprint of the activity and the areal extent of the alterations that are the result of the activity/structure (area of alteration).

Industrial wharves and piers can impact water quality, create diversions in the local hydrology, disrupt sediment flow along drift cells, shade aquatic vegetation, and diminish the euphotic zone in the area of the facility. There is also potential for impacts from vessel traffic, noise, prop wash, ballast water and waste discharges, fuel spills, hydraulic fluid spills, material spills, and other activities associated with these facilities that may directly and indirectly impact aquatic flora and fauna (Nightengale and Simenstad 2001). At this time, little information is available regarding the environmental affects of the existing piers or their operations.

Light Shading

One potential impact from overwater structures is the alteration of light in the surrounding area. During day, light under the piers may be limited due to shading. This is a function of the width of the dock and its orientation. At night, security and operational lights on the dock or moored vessels may brighten the otherwise naturally dark waters. Alteration of light conditions in the nearshore has been shown to alter fish migratory behavior and distribution, and affect the ability of predatory fish to see their prey (Simenstad et. al, 1999). Loss of submerged aquatic vegetation has likely occurred from overwater structures at Cherry Point, but this has not been well studied. A study of the ARCO pier found that shading from the pier appears to limit the growth of marine vegetation (Shapiro & Associates, 1994.)

Grette and Associates (2007) reports that in Bellingham Bay, Whatcom County, intertidal and subtidal shading decreased the availability of light under and surrounding overwater structures located in the Port of Bellingham. It is further discussed how shading is a primary concern because it reduces the amount of light available for photosynthesis by aquatic vegetation, which can have implications for habitat structure, complexity, and for the surrounding food web (Grette and Associates, 2007). The U.S. Corps Wetlands Regulatory Assistance Program reported that within seagrass habitats, increasing plant biomass and density (i.e. complexity) have been shown to be correlated with higher density and biomass of many fisheries species (Blackmon, D. 2006).

Studies in the Puget Sound region have suggested that under-pier light limitations could result in the following behavioral changes: 1) migration delays due to disorientation; 2) loss of schooling in refugia due to fish school dispersal under light-limited conditions, and 3) increased size-selective predation risk due to changes in migratory routes to deeper waters to avoid light changes (Nightengale and Simenstad, 2001). This behavioral relationship makes sense in light of the point that teleost fishes, a classification that includes all fish, depend upon sight for feeding, prey capture, and schooling. The underwater light environment determines the ability of fishes to see and capture their prey. There are also species-specific differences to consider with respect to how fish react to light. Species that occupy and defend stream territories, such as coho, tend to be quiescent at night while species that disperse to estuaries, such as chinook, pink and chum typically school, show nocturnal activity, and demonstrate an aversion to light (Nightengale and Simenstad, 2001).

Nighttime attraction to artificial lighting has been studied extensively at the Bangor Submarine Base Explosives Handling Wharf (EHW) in Hood Canal (Prinslow et al. 1979). The security lights at this facility are low-pressure sodium vapor lights and incandescent spotlamps, producing 1 to 19 lux[15] at the water surface. No significant difference in catch of chum was detected during period of lights on or lights off. However, at high levels of lighting, chum appeared to congregate, delaying migration (Prinslow et al 1979). These aggregations were observed in both 1977 and 1979, with different light

[15] The **lux** (symbol: **lx**) is the SI unit of illuminance and luminous emittance. It is used in photometry as a measure of the *apparent* intensity of light hitting or passing through a surface.

levels (24 to 61 lux in 1977, 1 to 19 lux in 1979). When considering these results it is important to note that the security lighting at the EHW is focused directly on the water.

Congregation of salmon predators has also been observed in freshwater environments. Nightengale and Simenstad (1999, 2001) report that increased artificial lighting levels at night on the dams of the Columbia, Snake and the Sacramento Rivers attracts juvenile chum and may delay outmigration while increasing predation. In a 2004 study on the Cedar River, Tabor et. al observed that increased light intensity caused out-migrating sockeye salmon fry to slow or stop, making them more vulnerable to capture by predators.

One of ongoing questions is how to quantify the amount of shading in order to appropriately assess if an adverse impact is occurring, and if so, how to mitigate for it. Nightengale and Simenstad (2001) addressed this question. In a laboratory setting, studies have shown that the threshold for the lowest levels of maximum prey capture for juvenile chum and pink salmon occurs between 10^{-1} and 1 foot-candles which is partially equivalent to 0.5 (PAR) Photosynthetically Active Radiation. This represents the lowest end of light levels characterizing dawn or dusk which ranges from 10^{-1} to 100 ft-candles. Measurements of light levels under ferry terminals have identified under-dock areas that drop below the threshold even in the high light conditions of summer. When light intensity falls below this threshold, the fish must "dark adapt" to rod vision. During this time they are in a state of blindness with visual adaptation taking between 35 to 50 minutes. This "dark adapt" process is likely what is reflected in fish pause or directional change behavior. To summarize, if an area on a pier is measured at dropping below 0.5 PAR, fish must adapt their eyesight, which can take 35 – 50 minutes, during which they are vulnerable to predation.

Nightengale and Simenstad concluded that during daylight hours, at very minimum, under-dock light levels must be maintained at levels above 0.5 PAR to avoid this behavioral interference. They point out that this lower threshold of light level only addresses migration delays and behavioral alterations associated with required visual adaptation to light intensity variations and transitions from cone to rod vision. Cone vision is often the only form of vision for larval marine fishes. Fish visual development takes place on varying levels. Within juvenile cone vision development stages, there are also varying levels of sensitivity to the full spectrum of ultraviolet wavelengths. As visual development proceeds, juvenile marine fishes are known to behave and feed in response to specific ultraviolet wavelengths, as compared to forms of artificial light, such as fluorescent lights. Note that artificial lighting does not contain both UV-A and UV-B spectra. Evidence reveals that juvenile fish, such as salmonids, feeding in shallow nearshore waters utilize natural ultraviolet wavelengths for prey capture. Therefore, Nightengale and Simenstad (2001) conclude that by allowing the transmission of increasing levels of natural light, and thus ultraviolet light spectra, to the under-dock environment this will reduce structural interference with fish ability to capture under-dock prey.

Wave Shading

Wave shading, also known as the breakwater effect, may impact sediment transport, vegetation, local temperature, and water quality. Few site-specific studies have been conducted at any of the existing marine facilities along Cherry Point pertaining to the impact of wave structures on wave sheltering and their effects on sedimentation. In 1999, DNR commissioned a risk assessment to investigate the potential impacts of ARCO/BP's request to build an addition to its existing pier to increase the efficiency of loading and unloading activities on the Cherry Point herring stock. In 1999, EVS performed a risk assessment based on a study provided in the *Gateway Pacific Terminal Draft Environmental Impact Statement* (EVS 1999) and in a subsequent memorandum (Isaacson, 1997). The study used a wave model that included various oceanographic processes, such

as wave climate, currents, tides, sediment and beach characteristics, and wave breaking, to determine the sheltering effects of the piled structures on wave propagation. These models are from a submitted proposal for a pier and that the design and proposed use of the pier are not approved by WDNR. The risks associated with a design specific to the Pacific International Terminal proposal are not considered in the above mentioned risk assessment.

The potential impacts of the existing marine facilities were generally assessed by considering the reduction of wave energy on the sheltered side of structures and docked vessels, and then considering how this change in wave energy might influence sediment transport behavior. Most winds (and therefore wave energy) come from the south, but also that there are major wind events occasionally from the west and west-northwest. The model indicated that waves would not be substantially attenuated by the piles for the proposed Gateway PacificTerminal. Waves from the west-northwest are estimated to undergo substantially more attenuation because they would need to propagate past many rows of piles, however, these waves are usually smaller. According to Whatcom County (1996), the estimated wave transmission coefficients for the Gateway Pacific Terminal were expected to underestimate the wave conditions on the sheltered side because some wave energy would also propagate into the sheltered area by diffraction around the ends of the wharf, and this was not taken into account in the estimates.

The ARCO/BP, Intalco, and Ferndale refinery piers are similar to the proposed Gateway Pacific Terminal pier in that they each have approach trestles extending to the wharfs used for berthing cargo vessels. The wharfs are generally substantially shorter than the approach trestles, with the exception of the proposed Gateway Pacific Terminal pier which would extend 860 m (2,820 ft). All of the wharfs are roughly parallel to the shoreline while the approach trestles are perpendicular to the shoreline. Although there are insufficient data to calculate transmission coefficients for each of the existing facilities, EVS (1999) concluded that results would be similar to those for the Gateway Pacific Terminal pier, such that there is probably no significant reduction in wave height resulting from any of the existing facilities.

The Gateway Pacific Terminal draft EIS did not address potential effects of moored ships and barges on wave propagation and sedimentation. Ships and barges moored at existing piers along the Cherry Point reach can interfere with wave propagation, the extent of this influence depending on the number of ships and barges visiting a facility per year, their length, and the total time vessels are moored. As an example, from the years 1982 through 1998, an average of 229 vessels per year called at the ARCO/BP facility (EVS, 1999). Assuming each vessel was moored for at least 24 hours, this represents, at a minimum, 229 days out of the year that vessels moored at the ARCO/BP facility would interfere with wave propagation. Issacson examined the sheltering effects of vessels to be docked at the proposed facility and wind and wave data, conducted an analysis of wave sheltering from the vessels, and modeled wave refraction and diffraction. From this analysis, he concluded that the impacts on the shoreline from the numerous vessels to be docked at the proposed facility would be small and estimated that the impacts of docked vessels at the existing structures would be very small, as the number of vessels docked at the existing facilities is much smaller.

Reduction in wave energy could lead to the deposition of material in the “sheltered areas” (Whatcom County 1996). In assessing the impact of the proposed Gateway Pacific Terminal pier on sedimentation, Whatcom County (1996) reported that waves propagating from the south, southwest, and west would not be expected to result in significant sediment deposition at the beach. Waves from the west and northwest were expected to give rise to the greatest reduction in wave energy on the

sheltered side of the pier, with the potential for some sediment accretion there. However, this was not expected to be significant (Whatcom County 1996).

The orientation of the existing piers and the proposed Gateway Pacific Terminal pier are generally north-south to northwest-southeast. Because of the proximity of the piers and their similar orientation, EVS concluded that sedimentation on the sheltered side of the piers would not be significant, as was reported for the Gateway Pacific Terminal. However, there have been no studies done to verify this.

The ARCO/BP, Intalco and Ferndale refinery piers are much shorter (20-25 percent) and much further offshore (1.5-1.8 times as far) than the proposed Gateway Pacific Terminal pier. In addition, processes such as wave refraction and diffraction were not considered in the original wave sheltering study. These processes would tend to cause rebuilding of the waves behind the individual structures. EVS concluded the impacts on beach processes from these individual structures to be even less than projected for the Gateway Pacific Terminal pier.

EVS (1999) concluded that existing structures and docked vessels along the Cherry Point reach would not likely cause substantial wave sheltering or increases in sedimentation. Furthermore, when compared to the total shoreline available along the Cherry Point reach, approximately 14.5 km (9 mi), the combined influence of these three piers would represent only a fraction of the available habitat. Thus any potential effects due to wave sheltering and sedimentation would be expected to be minimal when compared to the available habitat.

Changes in Epibenthic Assembles

Haas et. al. (2002) found a statistically significant difference in the epibenthic assemblages that exist around large overwater structures when examining ferry terminals in Puget Sound. These differences were demonstrated in both density and composition of the epibenthos at three ferry terminal structures, both over time (stratified-monthly sampling) and at several tidal elevations and habitat types (stratified-monthly sampling, eelgrass sampling, and cross-terminal sampling). While differences exist, the exact feature or features of the overwater structures which cause these differences was not determined in the study. Haas et. al. concluded that decreases or changes in epibenthos density, diversity, and assemblage composition are probably caused by the following four interacting factors:

(1) direct disturbance and/or removal by regular vessel disturbance;
(2) reduced benthic vegetation or compromised benthic vegetation function due to shading and physical disturbance;
(3) physical habitat alterations (e.g., altered grain-size distribution from propeller wash or piling effects), and
(4) biological habitat alterations (e.g., increased shell hash from sea star foraging and reduced eelgrass density due to benthic macrofauna disturbance)

However, while recognizing that nearshore vegetated habitats are highly productive and play an important role in ecosystem food chain support, the U.S. Army Corps of Engineers calls for further studies to gain a clear understanding of the overall importance of eelgrass and kelp habitats for food web productivity in the Pacific Northwest (Blackmon, D. 2006). More information is needed regarding epibenthic conditions around the Cherry Point piers before conditions can be evaluated.

POTENTIAL IMPACTS OF EXCESSIVE INTERMITTENT SOUND ON FORAGE FISH

Noise has been identified as a potential stressor on Pacific Herring and other commercial fish species. (EVS 1999; Schwartz and Greer 1984); most commercial fish react to loud noise, and these reactions are most pronounced in migratory schooling fish which rely upon hearing to detect environmental cues, such as approaching predators. Physical impacts can occur associated with construction project noise, such as pile driving, and have been documented (Laughlin 2005). Vessel noise is also intermittent, but the impacts are not well studied. Whether it is "loud" to various species of concern at Cherry Point is not understood. What is known is that despite vessel traffic and the associated noise, Cherry Point herring stock have continued to spawn on the Cherry Point shoreline and near the three existing marine industrial facilities.

Defining Noise at Cherry Point

There are three primary types of underwater noise:

- Physical – wind-driven, rainfall, breaking waves
- Biological – animal sounds
- Man-made – ship machinery, propellers, water disturbance.

Ambient noise conditions in the marine environment are dependent on source, propagation, and absorption conditions. Underwater noise in the natural environment is strongly affected by currents; bottom topography; water density variation due to salinity, turbidity, and temperature; the presence of manmade structures; noise from other sources; and surface conditions (wind and wave). Noise levels increase in shallow, hard bottom habitats. In the Cherry Point Aquatic Reserve, seafloor topography may create an unusual hydroacoustic situation. Alden Bank borders the western portion of the vessel-approach path. Sound produced by traveling vessels may reflect off Alden Bank and continue to resonate between the shore and the bank over the southern portion of the herring spawning area (EVS 1999).

It is unclear how vessels frequenting herring spawning grounds affect the fish. It is also unclear if the noise affects either herring spawning success or individual health. A preliminary study conducted during pier maintenance at the ConocoPhillips Ferndale Refinery is the only available study of underwater noise at Cherry Point. This study, conducted in 2007, measured ambient noise levels ranging from 139 to 159 decibels (dB). The ambient noise consisted of sounds generated by above-water construction (a crane on a barge), normal operations at the marine terminal, and natural sources. These levels are comparable to those cited by Washington State Department of Transportation of 115 to 135 dB measured in the Hood Canal replacement project, and 136 decibels dB in Eagle Harbor on Bainbridge Island. For comparison, a level of 150 – 220 dB generally occurs within pile driving, and at around 180 db, Atlantic Cod have been documented as losing hearing (Laughlin 2005).

Schwartz and Greer (1984) tried to address research questions by playing recorded natural and anthropogenic sounds on captive Pacific herring. Avoidance responses were elicited by sounds of large vessels approaching at constant speed, by smaller vessels but only when on accelerated approach, and by 11 different triads of the electronically synthesized sounds. Alarm response and less frequently, a startle response, were both elicited by those electronic sounds with an essentially instantaneous rise time in amplitude. Herring did not respond visibly to any of the taped sounds of natural origin or to sonar or echo sounders.

Post-spawning Atlantic and Pacific herring may be more sensitive to acoustic stimuli than pre-spawning or spawning adults (Mohr 1964; FAO 1970; Schwarz and Greer 1984). Post-spawning Pacific herring are voracious feeders (O'Toole pers. comm. 1999a) and vessels have been shown to disrupt feeding behavior (Schwarz and Greer 1984). It is not clear what long-term effects temporary startling has on herring schools (Olsen 1971). Sufficient uncertainty exists from published studies and local conditions that one cannot make a definite statement that ship noise does or does not have any effect. Additional study is necessary to judge the effects of current and future increases in vessel traffic. Research is necessary to ascertain whether underwater sounds like those found at Cherry Point can affect herring or other species of concern at any life stage.

VESSEL TRAFFIC

Cherry Point contains the largest refineries in Washington State; over half of all the crude and refined oil and petroleum products are loaded and offloaded here. Also present is the Alcoa-Intalco aluminum facility and a application for a fourth pier, a proposed deep-sea cargo shipping facility known as Gateway Pacific Terminal.

The industrial facilities located along Cherry Point have expanded considerably since their original construction, resulting in increased vessel traffic. BP is the largest refinery in Washington State, originally built by Arco in 1972 and has increased its capacity from 4 million to 9 million gallons of crude oil daily. The Conoco-Phillips refinery was originally built by General Petroleum in 1954 with a capacity of 1.5 million gallons per day; it as increased to nearly 4 million gallons a day. Most crude oil arrives by tanker, with a smaller amount coming from Canada by pipeline. Refined product is shipped out by pipeline, barge and rail.

The Alcoa-Intalco Works aluminum smelter was built in 1966. The capacity in 1993 was 256,000 tons of alumina processed per year, which has increased to 307,000 tons yearly or 841 tons per day. Alumina is brought to the smelter by bulk carrier to the marine terminal.

Large vessels load and unload raw materials and products at the three current facilities located in the Cherry Point area. Since these facilities have shown a steady increase in productivity, expansion, and commercial growth (market driven), it is concluded there is a corresponding increase in regional and international vessel traffic necessary to transport raw material and finished products. Vessel traffic within the Cherry Point region is predicted to increase within the next 10 – 20 years. Much of this predicted increase in traffic has been attributed to operations at a new terminal proposed for construction south of the BP pier.

The construction of a new major bulk cargo facility at Cherry Point would significantly increase vessel traffic. While this proposed facility is currently in the permitting phase, six ocean-going ship and barge berths are planned for the facility. Further information on the vessel traffic impacts will be available with the permits issued for this cargo facility. A separate project, the Cherry Point Industrial Project (CPIP) was never completed, but a shoreline permit was issued by the county. Unless this permit is rescinded, the applicant has authorization to continue with the project. Even if neither of these projects were completed, vessel traffic within the Cherry Point Aquatic Reserve is likely to continue to increase . For some time, a vessel traffic risk assessment has been in development for Cherry Point, similar to the one developed for the Washington State Ferries. This effort is supported by the Washington Maritime Association, and the Washington State Office of

Marine Safety (Harrald, 2006). The Vessel Traffic Risk Assessment is as part of the NEPA process resulting in an Environmental Impact Statement (EIS) for the proposed BP pier extension. The Risk Assessment will be made public with the EIS, providing further information on vessel traffic in and adjacent to Cherry Point. DNR's intention is to incorporate the information into the management strategies of this plan, if necessary, after the plan is released and in consultation with the management/regulatory agencies that have signed the MOU to implement this management plan. . Cherry Point is also frequently used by commercial and recreational crab-fishing vessels, commercial trawlers and by seasonal whale-watching tours.

Projected increases and other changes in marine vessel traffic in the area may increase the risk of spills, discharges, impacts from fugitive dust and introductions of non-native species. Increased vessel traffic also increases the possibility of "strike" to wildlife in the vicinity of the vessel. This may include fish, diving birds, seals, dolphins, but the most commonly followed example is that of ships or vessels striking whales. In the interest of brevity, while recognizing that strike can impact many species, the discussion will be limited to whales. Of all the animals, they are often the most difficult to see, the hardest to avoid, and can also damage many medium to smaller size ships and vessels.

Vessel traffic in Washington State is tracked by Washington State Department of Ecology's Spill Response Program. According to Ecology, tanker traffic heading to Canada has increased significantly between 2006 and 2007 (See table 6). Ecology's vessel inspector Captain Laura Stratton has stated that 99% of these tankers take the Strait of Juan de Fuca, passing by Cherry Point. The alternative is the shallower, narrower, and much more dangerous Queens Island Sound route.

The data below from Ecology's Vessel Entries and Transits (VEAT) System for Washington shows a fluctuating number in entries and transits for tankers and barge traffic, neither significantly increasing nor decreasing over the five years examined[16].

Table 6. Data from Ecology VEAT reports showing vessel traffic patterns in Puget Sound

Type of Tank Vessel[17]	Total					
Year	2008	2007	2006	2005	2004	2003
Tank ships bound for Puget Sound	508	614	627	575	609	588
Tank ships bound for Canadian ports via Strait of Juan de Fuca	31	231	94	50	66	55
Tank barge transits in Puget Sound	2,967	2,472	3,125	3,913	3,186	3,007

Currently, the majority of raw materials used by the facilities are delivered by vessel. While future trends are difficult to predict, increases in productivity, expansion and organic commercial growth

[16] It should be emphasized that these numbers represent a fraction of the overall vessel traffic entering, transiting within and leaving Washington state waters. Please see the VEAT reports for more information at: http://www.ecy.wa.gov/biblio/spills.html

[17] A "tank vessel" is defined as any ship that is constructed or adapted to carry, or that carries, oil in bulk as cargo or cargo residue [RCW 88.46.010(20)].

(market driven) reflect a steady increase in regional and international vessel traffic associated with raw material and finished product shipments. However, not all ship transits are of equal risk; risk is based upon size, type of vessel, cargo, weather, route, and other factors.

Risk of spills and strike Spills

The risk of a spill in the vicinity of Cherry Point is best measured by the amount of traffic traveling through the Strait of Juan de Fuca. As vessel traffic increases, the risk of a spill increases (Stratton 2008). It is not possible to gauge how a spill would affect Cherry Point resources, but the risk is present, it is increasing with the rate of vessel traffic, and impacts to threatened and endangered species could be catastrophic.

Spills have occurred at the BP and Conoco-Philips Cherry Point facilities on several occasions. There is a wide range in confidence as to the accuracy of the volume of oil that has been spilled in the area, especially in earlier accounts. Accurate reporting of spills is important in determining impacts to habitat and biota. Washington State Department of Ecology has prioritized efforts on stopping the source of the spill, containing the spill, recovering the spilled product, and protecting environmental and human health. It was standard practice to accelerate cleanup and disposal of the waste generated, not analysis of cleanup volume, to achieve the most immediate, effective response. Only recently has Ecology begun to track and calculate the volume of spilled oil recovered.

The following list was provided by Ecology Spill Response Program (personal communication, 2009) during March 2009. The list is for reported spills where over 25 gallons of oil impacted water. This standard initiates a Natural Resource Damage Assessment (NRDA) and the amount of oil recovered within the first 24 hours of a spill event will be determined. The location does not necessarily dictate a responsible party.

- December 12, 1997 – FNT-340 barge @ ARCO dock: Spill of JP-5 jet fuel occurred while pumping, the lines backed up and product came out of the vents. After the leak was discovered, the USCG ordered offloading of the fuel. A drop valve was left open, product overflowed onto the deck and into the water. NRDA settled on 30 gallons to water.
- June 27, 1999 – ARCO Texas @ TOSCO Ferndale: Spill occurred during offloading, when strong currents and winds pulled the vessel away from the pier and pulling the loading arm off of the dock. No containment was used and there was no documented recovery volume. The spill to water was 1,050 gallons of crude oil, and NRDA estimated and settled on 300 gallons to water.
- June 13, 2001 – T/V Overseas Boston, ATC @ TOSCO Ferndale: The loading arm broke and released under pressure on the ship's loading arm. A significant quantity of the spill went to the dock and the ship deck. It was determined that 2,436 gallons of ANS crude oil was spilled to water and 2,016 gallons were recovered. The vessel was quickly boomed, which prevented the oil from spreading.
- August 28, 2001 – ITB Baltimore @ BP Cherry Point: Slop oil from the tanker leaked through a hole into a separated ballast tank. This ballast tank was being discharged while the tanker was being unloaded, resulting in a spill of oily wastewater. 150 gallons of gasoline went to water during the discharge. The total volume of wastewater discharged cannot be confirmed by Ecology.
- January 18, 2005 – Tank barge Noho Hele @ Conoco Phillips Ferndale: A tug hit the barge while positioning it at the docks, and a bolt from the fender system on the tug punctured a hole into the side of the barge. Diesel spill of 416 gallons to water, and NRDA determined that 91 gallons were recovered.

- February 14, 2005 – Tank barge PB-20 @ Conoco Phillips Ferndale: A fracture in the hull allowed heavy black oil IFO 380 to spill into the water. 109 gallons went to water, 91 recovered.
- June 9, 2008 – Tug Tiger @ Conoco Phillips Ferndale: Diesel spilled from the starboard day tank while the Tug was maneuvering from the lay berth to the end of the dock, possibly caused by a slight list. 120 gallons went to water, 0 recovery was documented (though it was likely that >50 gallons was recovered). NRDA settled on 0 gallons recovered.

During two of these spills, there were herring larvae present. The impacts of large spills on resources, including herring and other fish and wildlife, have been widely studied in Prince William Sound. The Exxon-Valdez investigations indicated that oil spills can result in significant reproductive impacts to Pacific herring. It must be stated that the Exxon Valdez spill was an environmental catastrophe, and the scale of these studies was of similar magnitude. The relevance to Cherry Point may be limited. However, the investigations at Prince William Sound do provide helpful data for the potential impacts of a major spill impact. For more information, see study summaries in EVS (1999) pp 4-198 through 201.

Efforts to Address Potential for Spills

In Washington, a variety of ongoing efforts are being undertaken to better understand vessel traffic and spill risk along Cherry Point, including: major vessel traffic risk assessments required as part of new terminal developments, US Coast Guard review of designated anchorages, Department of Ecology oil spill contingency plan rules revisions and new oil transfer regulations, and ongoing Geographic Response Plan and Northwest Area Contingency Plan updates. Ecology has recently required that all refineries pre-boom tankers before oil is loaded and unloaded. Other measures to increase spill response requirements are being phased in slowly. Further study of dry cargo vessels may be needed, as they have been shown by the International Maritime Organization and Coast Guard to have the highest accidents rates among commercial vessels worldwide. Shipping companies mitigate these risks through thorough vetting processes. Vetting is a competitive process used by companies to gauge how well a vessel meets expected operating standards.

All tank vessels are also required under RCW 88.46.040 to prepare and submit an oil spill prevention plan, and all vessels greater than 300 gross tons must also submit a contingency plan per RCW 88.46.060. However, approval of a contingency plan by Ecology does not constitute an express assurance regarding the adequacy of the plan nor constitute a defense to liability imposed under that chapter of the RCW or other state laws (see RCW 88.46.040 (7) and RCW 88.46.060(10).

Since the industrialization at Cherry Point, significant efforts have been made by industry, government and the public to reduce the risk of oil spills and the impacts of commercial and recreational vessel traffic within this area. Recent investments by the tank vessel and barge industry in double hull and dual propulsion tankers are positive steps towards reducing the risk of a spill. As Alaskan oil continues to decline (Energy Information Administration, 2009) the number of tankers calling from distant ports increases the exposure of Washington waters to less capable ships.

Ship Strike

With vessels, ships and hydrofoils, whales are the marine mammal often most vulnerable to strike. Ship strike injuries to whales can take two forms: (1) propeller wounds characterized by external gashes or severed tail stocks; and (2) blunt trauma injuries indicated by fractured skulls, jaws, and vertebrae, and massive bruises that sometimes lack external expression (Laist, et al. 2001). The type of injury can differ according to species; for example, on both the east and west coast of the U.S., fin

whales appear highly susceptible to strike, and the cause is almost always blunt force trauma (Laist et al, 2001; Douglas et al, 2008). Laist, et al (2001) examined historical and anecdotal records, and worldwide stranding databases to locate information on whales and ship strikes. The researchers present a number of conclusions, some of which are supported by other studies in the Pacific Northwest:

- The most severe and lethal injuries are caused by ships travelling 14 knots are faster; historical records of collisions also increased sharply after 1950 when the average speed of most merchant ships increased to 15 knots.
- All types and sizes of vessels may hit whales, but the most lethal and serious injuries to whales are caused by relatively large vessels (generally 80 meters or longer).
- A great majority of ship strikes seem to occur over or near the continental shelf.
- The behavior of whales in the path of approaching ships is uncertain, but in some cases, last-second flight responses have been described or video-taped
- Ship collisions probably have a negligible impact on the status and trend of most whale populations, with the exception of very small populations or discrete groups. With the highly endangered populations, or smaller population segments, significant impacts may occur.

Douglas et al (2008) reported on ship strikes in Washington State. In their research, the increased vessel traffic through northern Washington, into the Strait of Juan de Fuca, and to Cherry Point, Seattle and Tacoma is discussed. An estimated 11,000 vessels greater than 300 gross tons passed through the Strait in 1999, and it is expected to increase to 17,000 by the year 2025. As traffic will increase, the risk of strike also increases. The types of ships that call upon the piers at Cherry Point, in general, are large tankers and cargo ships. While it is often assumed these ships travel at less than 14 knots, which would lower the risk of a strike, Douglas et al (2008) reports of a female fin whale on the bow of the “New York” Alaska tanker, which has a maximum speed of 16 knots. This tanker most likely struck the fin whale outside of the inland waterways and brought her in to the general vicinity of Cherry Point, near Ferndale, Washington. As Laist et al (2001) discusses the size of a ship and the speed are two risk factors, coupled with the increasing vessel traffic in an area used by whales, that can set the stage for a collision (Laist et al, 2001).

NOAA has researched ways to reduce the possibility of ship strikes and admits that this is a complex problem to address. No easy technological advances are present or are expected in the foreseeable future that would assist mariners in substantially reducing their chances of collisions. In Hawaiian waters where high-speed catamaran ferries operate between the islands year-found, at least one ferry has been outfitted with two thermal imaging cameras, which are reported to facilitate detection of whale and whale blows ahead of the vessel at night. During the winter months, humpback whales use the waters around the main Hawaiian Islands to calve and breed, attaching new detection technology on these ferries may be an effective way to assess how useful they will be in areas with lower densities of whales. To be useful, thermal imaging will have to detect whales in rough seas, at a distance far ahead of the ship so that the vessel operator has time to maneuver, and the number of false positive detections will have to be assessed (Silber, 2009).

Currently, NOAA suggests that reducing the potential for co-occurrence of whales and vessels in space and time is the only sure means of reducing ship strikes. In June of 2009, NOAA and the U.S. Coast Guard implemented regulations to reduce the risk of collisions between ships 300 gross tons and above and the endangered North Atlantic Right Whale. Vessels transiting into shipping lanes during months that the North Atlantic Right Whale would be present and feeding will be asked to use

slightly modified routes. These changes were adopted by the International Maritime Organization (Silber, G.K. et al. 2009).

BALLAST WATER MANAGEMENT

Washington is among the states that have chosen to regulate aspects of ballast water management. Other states include Maryland, California, Oregon, and Michigan. On an international level, voluntary efforts are guided by the International Maritime Organization. Congress is examining current EPA authorities to regulate ballast water in coastal areas. One of the primary incentives to better control of ballast water is to stem the introduction or re-introduction of non-native species to other countries or areas. Future efforts to control non-indigenous species introduced to the Cherry Point area will be directed by Ecology, WDFW, the U.S.Coast Guard, and EPA.

Ballast Water Issues

The rising level of maritime shipping is increasing the risk of invasion by non-native species in Puget Sound and the Strait of Georgia. Un-exchanged ballast water discharges from commercial ships are a primary vector for introducing non-indigenous species. As commercial shipping has been increasing at Cherry Point, this is an area that has been monitored over the years. Per the 2000 Ballast Water Law (RCW 77.120) managed by WDFW, most vessels entering Washington waters are now required to conduct an open-sea exchange prior to discharging ballast. The exchange must take place 50 nautical miles or more offshore. And, with improvements in travel technology, the rate of introductions of nonnative species has increased dramatically.

The risk of non-native aquatic plant and animal species being introduced through ballast water is a serious one. Non-native aquatic plant and animal species can displace, disturb, consume, and compete with native species (CRS 2007). Even harder to manage, non-native organisms may also be attached to the hulls of commercial vessels. This is an identified problem at Cherry Point (Markiewicz, A. et al, 2005). Other introductions result from recreational boaters, commercial aquaculture, indirect Canadian maritime sources, and some natural sources.

A 2007 Congressional Research Service report was developed as Congress was considering whether or not to reauthorize the *Nonindigenous Aquatic Nuisance Prevention and Control Act* (NANPCA), including amending it to add specific provisions that would modify how ballast water is managed.

The CRS report found that globally, an estimated 10,000 marine species each day may be transported across the oceans in the ballast water of cargo ships. The economic, social, recreational, and ecological losses/costs attributable to aquatic invasive species are difficult to quantify. Some costs have been estimated, such as the $5 billion in damages to water pipes, boat hulls, and other hard surfaces by zebra mussels in the Great Lakes. Other costs, such as the loss of native species and environment restoration to pre-invasion quality, are unknown (CRS 2007).

Ships can manage ballast water through exchange or treatment. Exchange means that before reaching port, the lower-salinity coastal water from the last port is released and replaced with higher-salinity ocean water. This reduces the number of non-native species by flushing them out to sea, and it is assumed they are less likely to survive in the higher salinity environment. However, there is no guarantee all organisms are flushed out (CRS 2007).

Another approach is to treat the water. Ballast water treatment is currently highly researched, and a number of methodologies are being proposed. One treatment involves ultraviolet light, another is filtration and separation, others propose using heat, or electric current, and finally there are chemical treatments, such as biocides. A combination of these treatments is also possible (CRS 2007).

Nonnative and Exotic Species at Cherry Point

The risks of nonnative and invasive species were analyzed for the region including Cherry Point. Funded by U.S. EPA as part of a program to calculate the risk of an invasive species, the study identified two species of risk to Cherry Point: the invasive species European Green Crab (*Carcinus maenas*), and the nonnative *Sargassum*, a non-native brown alga. At the time of the research, green crab were being captured along Vancouver Island – in relatively close proximity to Cherry Point (Landis et al. 2005; Colnar, A.M. and W.G. Landis. 2007). Conversely, *Sargassum* is clearly an important habitat component in Cherry Point, enhancing the underwater vegetated communities, although possibly posing a risk to native algae (Landis et al. 2005; Colnar, A.M. and W.G. Landis. 2007).

History of Federal Attempts to Regulate Ballast Water Management

In 1996, the National Invasive Species Act (NISA) created a national ballast management program modeled after the Great Lakes program. All ships entering U.S. waters after operating in the offshore, beyond the U.S. Exclusive Economic Zone, were directed to undertake high seas (i.e., mid-ocean) ballast exchange or alternative measures pre-approved by the Coast Guard as being equally or more effective.

Reporting was low during the first two years, as reporting was voluntary. The U.S. Coast Guard proposed mandatory reporting, with penalties for those failing to submit Ballast Water Management reports. The Coast Guard has implemented a similar program in the Great Lakes and other waterbodies, and it has proven very effective.

The CRS report states that other aspects of the NISA have been criticized as inadequate and faulted for several alleged shortcomings, including agency weakness or delay in implementing some of its provisions. Since then, NISA has exempted most coastal wide vessel traffic from ballast water exchange guidelines. Vessels traveling short distances between U.S. ports (e.g., from San Francisco Bay, which is highly invaded, to Puget Sound, which is less so) are exempt from controls. Some parties are critical of the provisions of 16 U.S.C. §4711(k)(2)(A) giving the vessel owner a blanket exemption to ignore any mandatory regulations if the master determines that the vessel might not be able to safely conduct a ballast water exchange on the open ocean. Finally, NISA has been criticized for its apparent failure to actually prevent additional introductions of damaging organisms into the Great Lakes, despite this being the one area where the requirements for managing ballast water have been the most stringent for the longest time (CRS 2007).

While the Coast Guard is responsible for managing the Ballast Water Management Program, and ensuring that vessels abide by it, the U.S. EPA is responsible for ensuring that the discharged water complies with the Clean Water Act.

On September 18, 2006, the federal district court ruled that EPA's regulations exempting ballast water discharges from the Clean Water Act was contrary to congressional intent and ordered EPA to promulgate new regulations within two years. This ruling essentially directs EPA to ensure that shipping companies comply with the Clean Water Act by restricting the discharge of invasive species in ballast water. The government has appealed the district court's ruling, and the parties are waiting

for a ruling from the appeals court. However, in June 2007, EPA also initiated steps seeking public comment on regulating ballast water discharges from ships, an information-gathering prelude to a potential rulemaking in response to the district court's order. (CRS 2007).

AIR QUALITY, GLOBAL WARMING, AND CLIMATE CHANGE

Airborne contaminants are included in this plan because of potential impacts of atmospheric deposition to Cherry Point Aquatic Reserve water and sediment quality. Cherry Point is located in the Georgia Basin/Puget Sound airshed, which is made up of two smaller and intertwined airsheds. The Georgia Basin airshed ranges from the lower Fraser Valley, and includes Whatcom County and the coast of the Strait of Juan de Fuca. The Puget Sound airshed encompasses counties located south of Whatcom County. Cherry Point air quality is influenced by air movement within this area. The Environmental Protection Agency has described the Georgia Basin/Puget Sound airshed (Figure 21) in order to gain a better understanding of the current status of and trends in air quality, particularly given the rapid development in the area. Further detail can be found in *Characterization of the Georgia Basin/Puget Sound Airshed* (2004).

Figure 21. Georgia Basin/Puget Sound Airshed

Common Air Contaminants

The group of air pollutants referred to as common air contaminants (CAC) in Canada and as "criteria" pollutants in the Unites States includes: sulfur dioxide (SO_2), nitrogen (NO_2, ozone (O_3), carbon monoxide (CO), fine particulate matter ($PM_{2.5}$) and lead (Pb). The effects of these pollutants have been well-documented by the Northwest Clean Air Agency (2008) and include:

- **Health effects -** These can be chronic (arising from long-term exposure), or acute,. For example, ozone is a very powerful oxidant which is an eye irritant and can also cause breathing difficulties, especially to older people or sick people or children.
- **Visibility impairment -** Small particles are very efficient at scattering light and therefore reduce visibility.
- **Materials damage -** Air pollutants may chemically alter the structure of a material. For example a sandstone sculpture will turn into gypsum after it has been exposed to sulfur dioxide, and gypsum is something that is much more brittle than sandstone. Ozone damages materials and causes fading to pigments.
- **Agricultural damage -** Ozone is responsible for damage to the leaves of plants, it reduces crop yield and stunts tree growth. Acid rain not only affects bodies of water but also trees and crops.
- **Climate change -** Global warming has been shown to be due to certain anthropogenic pollutants, also known as greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), ammonia (NH_3) and others. Particulate matter also might cause global cooling due to increased PM emissions.

Other pollutants include ammonia (NH_3), which is considered toxic and is involved with the formation of $PM_{2.5}$. Indeed, most $PM_{2.5}$ is secondary in nature[18], with sulfate $PM_{2.5}$ and nitrate $PM_{2.5}$ originating from SO_2 and NO_2 respectively. Particulate matter may include heavy metals such as mercury and arsenic. Volatile organic compounds (VOC) are a group of gases that react with other airborne pollutants to form O_3, $PM_{2.5}$ and other secondary compounds. VOC also include the airborne persistent organic pollutants (POP) that are of particular concern because of their ability to bioaccumulate in living organisms.

Within the Georgia Basin/Puget Sound air basin, just like in many other areas of the USA and Canada, the main air pollutants of interest are ozone and $PM_{2.5}$, mostly because both pollutants are secondary in nature, thus making their control difficult. Ozone is detrimental to human health and causes damage to vegetation and physical structures. $PM_{2.5}$ is linked to respiratory and other health problems and also impairs visibility. Therefore, ozone and $PM_{2.5}$ constitute the main air quality pollutants in the Basin.

POINT SOURCE EMISSIONS OF COMMON AIR CONTAMINANTS

In the *Characterization of the Georgia Basin/Puget Sound Airshed* (2004), EPA examined emissions from point sources. These are stationary emitters of pollution, such as refineries or power generating facilities, compared to an emitter that is not stationary (mobile sources, such as cars, or marine and locomotive engines) or a natural (biogenic) source. The EPA compared Puget Sound to the Georgia Basin and noticed that while some of the contaminants were similar, the contributors were slightly different.

In Georgia Basin, the most recent emissions inventory for 2000 (Department of Ecology in EPA, 2004) for the entire airshed shows the beginning of a change in important sources of contaminants. Marine vessels account for 22 per cent of the NOx emissions, with light-duty vehicles responsible for 23 per cent. Marine vessels are the largest single source of SO_2 in the airshed emitting 33 per cent of the SO_2 emissions. Agriculture is the dominant source of PM_{10} (21 per cent), with space heating responsible for 20 per cent of the $PM_{2.5}$. The 2000 inventory also shows how the use of a single surrogate (population) to compare emission levels can be misleading. Whatcom County has just 7% of the entire population in Georgia Basin, but also has several major industries, contributing 29 % of the-smog-forming emissions. Contrast this to the Greater Vancouver Regional District, with 83 % of the population, emitting 56% of smog-forming emissions, and the Fraser Valley Regional District, with 10 % of the population, producing just 15 % of the emissions (EPA 2004).

[18] Secondary pollutants are those which are not emitted directly into the atmosphere from identifiable sources but rather are created in the atmosphere from other pollutants. O_3 is such a pollutant, which is created in the atmosphere by VOC, oxides of nitrogen, and sunlight. Primary pollutants, on the other hand, are those which are emitted directly in the atmosphere from identifiable sources. CO from combustion sources is such a primary pollutant.

Local Air Quality

Between the years 1900 and 1970, the emissions of various pollutants increased significantly. In 1970, the Clean Air Act Amendments (CAAA) were signed into law, providing a departure from previous federal strategy on combating air pollution. Two types of pollutants were to be regulated according to these new laws:

- The criteria pollutants[19] which were to be regulated to achieve the attainment of the National Ambient Air Quality Standards (NAAQS), including primary standards for the protection of public health, and secondary standards for the protection of public welfare.
- The hazardous air pollutants[20] which were defined as those "to which no ambient air standard is applicable and that... cause, or contribute to… an increase in mortality or an increase in serious irreversible or incapacitating reversible illness."

The local clean air authority that monitors Whatcom, Skagit and Island counties is the Northwest Clean Air Agency (NWCAA). The NWCAA is one of seven regional air quality control agencies located throughout Washington State. It was established in 1967 after passage of the Washington State Clean Air Act (RCW 70.94). The agency is responsible for enforcing federal, state and local air pollution regulations in Island, Skagit and Whatcom counties. Also, the NWCAA monitors ambient air and emissions. Ambient air monitoring helps air quality authorities gather data about pollutants in the air, monitor for trends, judge progress, and determine if emergency measures are needed to alleviate air pollution episodes.

The NWCAA produces annual emission inventories from large stationary industrial facilities within its jurisdiction, including those located within the Cherry Point site. The data shown in the table below do not include emissions from mobile sources, biogenic sources, or area sources. The NWCAA reports that for the 2004 and 2005 years, for all of Whatcom County, the primary stationary sources of particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NOx), volatile organic compounds (VOC), and carbon monoxide (CO) were the industrial facilities located at Cherry Point: Alcoa Primary Metals (Intalco), BP West Coast Products, and ConocoPhillips (NWCAA, 2006).

These facilities at Cherry Point contributed an average of 92% of all monitored industrial air pollutants from stationary sources in Whatcom County in 2005 and 2006. Results of monitoring showed that four of the five monitored pollutants decreased between 2004 and 2006 (NWCAA, 2004, 2005, 2006).

[19] The current list of the six criteria pollutants are: ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter and lead.

[20] The list of 188 HAP, about half of which are either known or suspected carcinogens, includes benzene, mercury, asbestos, and others.

Table 7. Emissions inventory, in tons per year, from large industrial facilities leasing state-owned aquatic land at Cherry Point compared to Whatcom County total, for the years 2004, 2005, and 2006. From the Tri-County Emissions Monitoring Reports, Northwest Washington Clean Air Agency.

Cherry Point Facilities and County Total Emissions	Particulate Matter (PM_{10})	Sulfur Dioxide (SO_2)	Nitrogen Dioxide (NOx)	Volatile Organic Compounds	Carbon Monoxide (CO)
2004 County Total, including facilities	480	4,242	3,836	1,181	16,442
2004 Cherry Point Facilities (% of county total)	402 (84%)	4,186 (99%)	3,447 (90%)	1,070 (91%)	16,328 (99%)
2005 County Total, including facilities	450	3,676	3,793	1,359	12,586
2005 Cherry Point Facilities (% of county total)	363 (81%)	3,627 (99%)	3,420 (90%)	1,228 (90%)	12,462 (99%)
2006 County Total, including facilities	431	3,499	3,622	1,412	12,616
2006 Cherry Point Facilities (% of count total)	347 (81%)	3,478 (99%)	3,241 (89%)	12,96 (92%)	12,500 (99%)
Cherry Point Facilities Change 2004-2006	(-133)	(-764)	(-595)	+115	(-3,942)
County Change 2004-2006	(-49)	(-743)	(-214)	+231	(-3,826)

The county is currently in attainment (meeting requirements) under EPA standards set forward by the Clean Air Act and administered by the Northwest Clean Air Authority for this region (NWCAA, 2008).

While considerable work has gone into understanding and regulating air pollution in the region and specifically at the Cherry Point industrial facilities, little is actually known about the relationship of this pollution to the health of the aquatic ecosystem and the organisms that rely on it. Water quality studies in this area should attempt to quantify air deposition in their evaluation of sources.

Climate Change

Atmospheric concentrations of greenhouse gases are the primary contributor to climate change. The gases trap the sun's radiation as it passes through the atmosphere, altering natural climate variability through a mechanism known as "global warming," an average increase in the temperature of the atmosphere, which contributes to changes in global climate patterns. At Cherry Point, global warming will occur within the context of existing inter-annual and inter-decadal climate variability. The El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) influence PNW climate and natural resources on seasonal to interannual scales. There is no consistent indication at this time of discernible changes" in ENSO intensity or frequency in the 21st century (CIG 2009).

Climate change is expected to have significant impacts on the Pacific Northwest (PNW) by mid-21st century (CIG 2009). Global climate models scaled to the region project an increase in average temperature on the order of 0.2°-1.0°F (0.1°-0.6°C) per decade throughout the mid-21st century with a best estimate average of 0.3°C (0.5°F) per decade. Temperature increases occur across all seasons with the largest increases in summer. The best estimate rate of warming in the PNW through the mid-21st century -- 0.5°F (0.3°C) per decade -- is three times the rate of change per decade observed in the PNW during the 20th century (0.15°F [0.8°C] per decade). The per decade rate of change for the second half of the 21st century is dependent on the choice of emissions scenarios.

Changes in annual precipitation are less certain. Most of the models analyzed by CIG project decreases in summer precipitation and increases in winter precipitation with little change in the annual mean. Precipitation changes are projected to be small compared to the interannual and decadal variability observed during the 20th century. The majority of models show increases in winter precipitation and reduced summer precipitation.

Sea surface temperatures are expected to increase. Climate models project warming in summer sea surface temperature for the 2040s on the order of 2.7°F (1.5°C). This change is somewhat less than the warming projected in the 2040s for PNW land areas (3.5°F [2.0°C]), but is significant relative to the small interannual variability of the ocean. The highest increases in temperature are occurring in or adjacent to the shallowest areas, as would be expected. This may have implications for nearshore resources that are temperature sensitive, such as spawn, and may exacerbate the effects from warm water inputs already being discharged into the nearshore area, by increasing the surrounding ambient temperature.

Climate Change Impacts

Human and naturally induced climate change has the potential to significantly alter the physical and biological characteristics of the region and Cherry Point. Impacts include: ocean acidification, sea level rise, increased storm severity,changes in ocean upwelling, increased water temperature,and photo enhanced toxicity, all or some of which may result in changes to species abundance and distribution.

Researchers that the University of Washington's Climate Impacts Group estimate that average annual temperatures in the Pacific Northwest could rise by an additional 0.9 to 4.7° F by the 2020's and 2.7 to 5.8° F by the 2040's, contributing to higher stream and estuary temperatures as well. Warming by small incremental amounts such as a few degrees can have a wide variety of impacts. According to the EPA and Ecology, warmer temperatures can affect our snowpacks, time of peak snow melt, glaciers, lower stream flows, exacerbate the decline of salmonids, and increase sea level rise (Ecology 2007), as previously discussedSea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of bluffs and beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads, causeways, and bridges. In addition, sea level rise could increase the vulnerability of coastal areas to storms and associated flooding**.** Projections vary, but the most recent projections from the IPCC report show a 7-23-inch rise in global average sea level by 2090-2099. (IPCC, 2007.)

A reduction in the availability of tidal marsh/tidal flat habitats could occur, as sea level rise combined with increased river flow increases the salinity of the nearshore area while decreasing the availability of tidal marsh areas. A recent study that modeled the potential impact of sea-level rise on key coastal habitats in the Pacific Northwest estimated that the Nooksack Delta, Lummi Bay, and Bellingham Bay could result in a a 22-percent loss of swamp (including tidal swamp), a 22-percent loss of

brackish marsh, and a 42-percent loss of estuarine beach. No information was available for Cherry Point, which has several scattered salt marsh habitats that could be affected by changes in salinity and rising water levels. The EPA states that commercial shellfish communities (e.g., oysters and clams) and migratory shorebird populations that utilize these flats for habitat and feeding also may decline accordingly. The commercial and recreational shellfish activities in the Reserve may also be affected by these changes. And changes in the composition of tidal wetlands could diminish the capacity for those habitats to support salmonids, especially juvenile Chinook and chum salmon (Glick, 2007).

Washington's coastal region consists primarily of cliffs and a few low-lying tidal flats. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapting to it, and raising the land (e.g., by replenishing beach sand and/or elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. The cumulative cost of sand replenishment to protect Washington's coastline from a 20-inch sea level rise by 2100 is estimated at $143 million to $2.3 billion (EPA 1997).

Changes in Fish and Wildlife

The EPA stated in a 1997 report that the primary natural features of Washington that are vulnerable to climate change are its extensive rivers, streams, and coastal estuaries, noting that these three environments are critical for a wide diversity of wildlife, endangered species, and commercial and sport fisheries. Water temperatures are among the most important factors affecting the health and distribution of salmonids. Even a small increase in stream temperature above optimal ranges can result in changes in migration timing, reducing growth rates, reducing the availability of dissolved oxygen, and increasing susceptibility of fish to toxins, parasites, and disease (Glick, 2005). Food supply could also be reduced as a result of increased temperatures. Should climate change alter the flows of freshwater streams, whether seasonally or otherwise, it could reduce the amount of suitable salmon spawning habitat. Earlier peak spring flows and lower than normal summer flows can make it more difficult for adult fish returning from the sea and for juvenile fish to make it to the ocean. Excessively high winter flows can cause scouring events that result in loss of gravel beds and nesting sites. In recent years, populations of salmon and steelhead have been reduced to less than 10% of historical levels. The EPA states that these past losses cannot be attributed to climate change, but that pink and chum salmon – both of which are documented at Cherry Point - could lose all of their habitat with climate change. Other cold water species such as brook trout, brown trout, and mountain whitefish could lose most of their habitat.

Changes in sea temperatures can have both direct and indirect impacts on herring survival. The observed decline of the Cherry Point stock since the mid-1970s coincided with warmer/dryer than average conditions in the Pacific Northwest (Stout, 2001). Chapman et al (1941) considered Cherry Point and Discovery Bay populations to be at low levels in the 1930's when similar climatic conditions occurred. Conditions shifted back to cold/wet or average during the 1940s and 1950s, and it was reported that the Cherry Point and Discovery Bay populations had returned to relatively high levels of abundance during those decades (Stick and Lindquist, 2008).

There is some preliminary evidence that the Cherry Point herring are better suited to warm water than other herring stock and further investigation is needed (Marshall, R. 2009). Climate varies naturally over both short and long time-scales, but natural climate variability can be distinguished from human-caused climate change.

Initiatives to address emissions and global warming

Western States Climate Initiative

The Western States Climate Initiative (WCI) was launched in 2007 to identify, evaluate, and implement collective and cooperate ways that will reduce greenhouse gases in the region, focusing on a market-based cap-and-trade system. It is a collaboration involving seven U.S. governors and four Canadian Premiers. The goal of this program is to assist with a regional effort to reduce the pollution that causes global warming to 15% below 2005 levels by the year 2020 (WCI 2008).

MARPOL and other Initiatives

Air pollution from ships burning diesel, bunker oil and other fuels is a concern, according to the EPA. As mentioned earlier, a recent inventory of emissions in Georgia Basin airshed shows marine vessels account for 22 per cent of the NOx emissions, and also that marine vessels are the largest single source of SO2 in the airshed emitting 33 per cent of the SO2 emissions (EPA 2004). Vessel traffic at Cherry Point is expected to increase within the next two decades, partly as a result of extending the length of the BP pier. A majority of the vessels are tankers and barges – these oceangoing vessels often run engines large enough to be classified as a Category 3 marine diesel engine. These engines have a per-cylinder displacement at or above 30 liters per cylinder (For comparison, Dodge Viper's five-hundred-horsepower engine has ten cylinders, and displaces 8.3 liters.) These large engines have been targeted for new standards to promote new technology that will reduce NOx and SOx emissions within and outside U.S. waters.

Emissions from all types of oceangoing vessels have been monitored globally. The Member States of the International Maritime Organization (IMO) is a United Nations Agency that facilitates development of standards to control air exhaust emissions from engines that power ships. The international air pollution standards, which include estimates for international shipping and carbon emissions, are found in the Annex VI to the International Convention on the Prevention of Pollution from Ships (also called MARPOL).

During October of 2008, the IMO Marine Environment Protection Committee updated a 2000 study on greenhouse gas emissions from ships. Using activity data and international fuel statistics, the conclusion was that 2007 CO2 emissions from international shipping would be 2.7% of all global CO2 emissions, or 843 million tons. This is an increase from 1.8% estimated in 2000.In the absence of future regulations on CO2 emissions from ships, such emissions were predicted in the base scenarios to increase by a factor of 2.4 to 3.0 by 2050 (IMO 2008).
Recognizing that marine diesel engines and their fuels contributed to greenhouse gases, on October 9, 2008, the IMO adopted new international standards regulating oceangoing vessels. Details may be found in the amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships (also called MARPOL), or on EPA's website for oceangoing vessels (EPA 2008, 2009). Shortly after the MARPOL amendments were developed, EPA proposed new rules for oceangoing vessels. The EPA's proposed standards mirror MARPOL standards, as adopted under Annex VI, and can be found at EPA's website on oceangoing vessels. If adopted, the proposed changes would ensure the Clean Air Act and regulations for oceangoing vessels are consistent with global efforts by the IMO to control marine diesel and fuel emissions.

One change involves the designation of sensitive areas, or designated Emission Control Areas (ECAs). In these areas, ships will be required to use the most advanced technology-forcing engines, and monitor the sulfur and nitrogen content of the fuel. On July 17, 2009, the United States and Canada amended MARPOL Annex VI to designate specific areas of the coastal waters as Emission Control Areas or ECAs. The North American ECA may go into effect as early as 2012. The North

American ECA will require all vessels operating in designated ECAs to use fuel that does not exceed 1.0 percent sulfur (10,000 parts per million). In 2015, this requirement becomes more stringent, and vessels will need to change to fuel that does not exceed 0.1 percent sulfur (1,000 ppm). The following year, NOx requirements become applicable. (EPA 2009). In all other areas of the world, including on the high seas, engine emissions will be also be reduced, and the global fuel sulfur cap outside ECAs will drop to 5,000 ppm in 2020 (pending an availability review in 2018) (EPA 2008, 2009).

Summary of Climate Change Considerations

In summary, the alterations due to natural and human induced climate change will affect many of the actions listed in the remainder of the document. An adaptive management approach which considers climate change trends and indicators is recommended when planning research studies and evaluating impacts of new management. Adaptive management requires that the potential for change be measured, the effects monitored and that management actions be modified to meet the need. Further measurement and monitoring can then provide information on the effectiveness of the management activity. In the case of climate change it is unlikely that any one activity at Cherry Point can effectively alter the degree of the global warming trend, but if the impacts are identified early and understood, this will help develop appropriate mitigation and/or adaptive management actions for this resource protection and management plan.

Appendix C - Archaeological, Cultural, and Historical Resources

Native American History

The Puget Sound prehistoric record is divided into three broad chronological periods: the Early Period (15,000–5,000 Before Present), the Middle Period (5,000-1,000 Before Present), and the Late Period (1,000-250 Before Present).

The Early Period is characterized by chipped stone assemblages attributable to fluted projectile point, leaf-shaped projectile point, and cobble tool traditions. Subsistence patterns exhibit reliance upon inland hunting, supplemented with fishing and marine invertebrate procurement in riverine and coastal areas. Settlements were typically located on upland plateaus or river terraces, although coastal occupations may have been flooded because of seismic activity or changes in sea level related to glaciation (Carlson 1990; Kidd 1964; Nelson 1990)

The Middle Period represents a proliferation in tool diversity within regional assemblages. Notched stone projectile points were characterized by a decrease in size, and toolkits were supplemented with groundstone, bone, and antler industries. Subsistence practices showed an increased orientation toward marine and riverine habitats; shellfish, salmon, and sea mammals became more important resources; and shell middens appeared in the archaeological record. Occupation areas expanded to include modern shorelines and islands and the earliest evidence of seasonal village sites dates to this period (Carlson 1990; Kidd 1964; Nelson 1990).

The Late Period is characterized by assemblages containing exotic trade goods imported from indigenous populations in the Columbia Plateau as well as metal arrowheads and trade beads from Euro-American groups. Small side-notched and triangular stone projectile points persisted but were superceded by an emphasis on bone and antler tools. Salmon became a major staple as evidenced by elaborate fish traps; subsistence practices were supplemented by terrestrial hunting and plant procurement. Permanent, village sites described by Euro-American settlers and ethnographers were established and persisted into the historic period (Carlson 1990; Kidd 1964;
Nelson 1990).

Central Coast Salish Native Americans occupied the Puget Sound area during the late historic times. In the Cherry Point vicinity, three linguistic subdivisions of the Central Salish are recognized:

Halkomelem speakers lived north of Birch Point and along the lower Fraser River valley. *Nooksack* speakers lived in inland sections of the Nooksack River drainage, and *North Straits'* speakers occupied the coastal areas north of Anacortes as well as the San Juan and other islands in the southern section of the Strait of Georgia.

At that time, subsistence focused on seasonal harvests of marine foods such as salmon, herring and lingcod, which were eaten fresh or dried and stored for winter use. Terrestrial foods that were favored included deer, elk and bear, which were caught with pitfalls, snares, bow and arrow, while women gathered shellfish, sea urchins and barnacles along the coast. The Central Coast Salish also utilized western yarrow, creambush, oceanspray, western red cedar,

swordfern, salal, skunk cabbage, and vine maple for pharmaceutical, technological, and ceremonial use (Moerman 1999; Suttles 1990).

The Revised Code of Washington, Chapter 27.44 protects Indian burial sites, cairns, petroglyph (incised in stone) and pictograph (painted) markings, and historic graves on public and private land. The chapter further stipulates that persons knowingly removing, destroying, or defacing these resources will be charged with a Class C felony. RCW Chapter 27.53 protects sites, objects, structures, artifacts, and locations of prehistoric or archaeological interest located in, on, or under the surface of any lands or waters owned or under the control of the state of Washington or its counties, cities, or political subdivisions. Disturbing archaeological resources without an archaeological excavation permit is punishable as a Class C felony.

Lummi Indian Nation

The shoreline at Cherry Point was the primary home of many Lummi villages and Traditional Cultural Properties (TCPs) within the traditional homeland of the Lummi. This area is an important component of the Lummi usual and accustomed grounds and stations used since time immemorial for hunting, fishing and gathering. The development of the Cherry Point shoreline by Euro-Americans since the 1950's has resulted in the elimination of fishing and gathering grounds and stations, village sites, landing sites, and locations where commerce was conducted. This development has also resulted in the filling of previously extensive and productive natural tidelands and has caused the contamination of previously pristine waters and sediments due to the operation of industrial and commercial facilities (Lummi Indian Nation, 2008). The existing piers and associated vessel traffic preclude and/or interfere with the ability of Lummi tribal members to exercise their treaty-protected fishing rights to fish.

The Lummi Indian Nation resides in an area ceded by the Lummi, Nooksack, and Samish Indians; these groups now comprise the Lummi Indian Nation. The Lummi are thought to have derived their name from *Lkungen,* the name that the North Straits-speaking Songish of Vancouver Island called themselves. The Lummi occupied coastal areas surrounding the mouth of the Nooksack River as well as several islands in Puget Sound. The Nooksack, meaning "mountain men," lived in the Nooksack River drainage. The Samish occupied additional islands in Puget Sound, including one that now bears their name as well as Guemes and Fidalgo islands (Ruby and Brown 1986; Suttles 1990; Swanton 1978).

The Lummi Indian Reservation is located south of Cherry Point. The Lummi Nation has a Department of Natural Resources, under which the Water Resources staff provide technical support for Lummi Indian Reservation Tidelands and Coastal Zone Management.

Nooksack Indian Tribe

For millennia before trappers, traders, lumbermen, gold seekers and homesteaders came to the Nooksack River valley, the Nooksack people resided in numerous villages at the banks of the Nooksack and Sumas.

Their fishing grounds extended from today's Bellingham Bay to British Columbia. They used nets and fish traps in the rivers to harvest various species of salmon. During the fish runs in the fall and spring, a number of families typically shared a smokehouse on the riverbanks next to the fish traps. The Nooksack also dug up clams, gathered meadow berries, stalked mountain goats for food and skins, and grew wild carrots (sbugmack

The Nooksack never signed a treaty with the U.S. that would have given them a reservation, because they had been overlooked. Thus they were vulnerable with no treaty to offer them any protection and lost their lands to white settlers. It was not until 1958 that, though landless, the Nooksacks won compensation for the loss of their lands, whose value was pegged at 1858 dollars.

In the mid-1930s, the Nooksack tribe voted to accept the provisions of the Indian Reorganization Act (1934), which had secured new rights for Native Americans, and began to work on a tribal constitution. Since they lacked a land base, they were denied federal recognition as a tribe. In 1971, however, the Nooksack Tribe won full federal recognition, and a reservation was founded on one acre at Deming. Since then, the tribe's holdings have expanded to 2,500 acres, which include 65 acres of trust land (www.u-s-history.com)

Euro-American History

Whatcom was named after a noisy waterfall, called “What-Coom” by the Lummi Indians, which means “noisy, rumbling water”. The first Europeans were Spanish Explorers in the late 1700s, followed by James Vancouver from England. Early land uses included fur trapping and trading, logging, lumber processing, farming, salmon packing, and mining coal. The first non-Indian residents settled including Hudson's Bay Company, which ran from 1825 to 1846. In the early 1850's, a high demand for timber in California led to scarce lumber supplies (Figure 22). Coal was discovered in the early 1800’s, and the lumber trend turned to mining. Bellingham Bay Coal Company became the area’s largest employer. In the mid 1800’s, a large influx of gold seekers entered the area on their way to the Fraser River to seek gold (Kyte, 1999). The County of Whatcom was created by territorial legislature on March 9, 1854 (Whatcom County website, 2007).

Northern Pacific Railroad expanded its infrastructure into Whatcom County in the late 1800’s, bringing further opportunities as Bellingham was linked to Vancouver, B.C., via Ferndale and Blaine, stimulating the lumber and salmon packing industries. The population increased by sixfold during this time, from approximately 3,000 to 18,000 (Kyte, et al. 1999). The national depression stopped the boom, and the railroad left. The population of the bay decreased, but by the turn of the century, Whatcom County was growing again. New lumber and shingle mills, salmon canneries, shipyards and agriculture brought stability to the area. Between 1890 and 1925, logging cleared thousands of acres for farmsteads. Development of commercial and residential areas increased, and major fish processing plants were constructed at Bellingham Bay. Between 1950 and 1990, coal mining had ceased, while sand and gravel mining grew in importance (Kyte, et al 1999).

Figure 22, postcard, mailed 1908 showing logging train heading to Bellingham

LOGGING TRAIN ON THE WAY TO BELLINGHAM'S MILLS.

Appendix D - Existing Encumbrances and Applications directly adjacent to the Aquatic Reserve

The following encumbrances have specific exceptions from the aquatic reserve in the original Commissioner of Public Lands withdrawal order and are therefore treated as leases adjacent to the aquatic reserve.

Birch Bay Water and Sewer District: DNR Aquatic Lease 51-082214 – Easement pertaining to the Birch Bay Water and Sewer District wastewater pipeline and diffuser.

A right of way measuring 2,300 feet in length and 100 feet in width comprising a total area of 5.28 acres of tidelands and bedlands was established in on March 23, 1975 as a lease (Lease 20-010521) and renewed as an easement on January 13, 2009.

British Petroleum: DNR Aquatic Lease 20-A09122 – Lease pertaining to BP/ARCO pier and outfalls

The BP Cherry Point Refinery is located at 4519 Grandview Road in Whatcom County, Washington. The refinery is situated on 849 acres of developed land 8 miles south of the U.S./Canada border and 20 miles northwest of Bellingham, Washington. BP owns an additional approximately 2000 acres of undeveloped land around the refinery, including approximately 1000 acres of marine riparian land between the Cherry Point Refinery Dock and Point Whitehorn. The refinery has been in operation since 1971 processing mainly Alaska North Slope (ANS) crude oil with an increasing percentage of oil from other parts of the world as ANS crude supplies decline over time. Refinery throughput averages approximately 200,000 barrels of crude oil per day, from which Cherry Point produces multiple grades of gasoline, jet fuel, low-sulfur and ultra low-sulfur diesel fuel, calcined coke, butane, propane and sulfur. The Cherry Point Refinery operates 24 hours a day, 365 days a year and has approximately 780 full-time BP employees; an additional approximately 1000 contractors also work on-site.

The Cherry Point Refinery Marine Terminal is located approximately 1.5 miles south of the refinery, extending 2,100 feet offshore into the Southeast Strait of Georgia in a “Y” configuration and terminating in two vessel berths - the North & South Dock Wings. The Cherry Point Dock is constructed of concrete on steel pilings and there is a minimum of 65’ of water alongside each dock wing at MLLW. The Cherry Point Dock can accommodate only one tanker or barge at a time on the seaward side of each dock wing (2 vessels max at any time). The maximum vessel length that can be accommodated is 1,100 feet.

Nearly 100% of all crude oil used by the refinery is delivered by tank vessel. Approximately 75 percent of the refined petroleum products are transported through the Olympic Pipeline to marketing terminals in western Washington and Oregon. The remaining products are transported by tanker, barge, or truck to other West Coast locations. In 2007, approximately 370 vessels transited to/from the Cherry Point Dock.

The refinery has approximately 50 crude oil and refined product storage tanks with a combined working capacity of over 7,500,000 barrels. The Cherry Point Refinery processes industrial

wastewater and stormwater through its on-site wastewater treatment plant and discharges an average 3,500,000 gallons of combined treated process wastewater and stormwater per day under NPDES Permit No. WA 002290-0 to the Strait of Georgia through a diffuser located below the North Dock. BP Cherry Point's NPDES permit requires daily effluent quality monitoring, effluent mixing and fish toxicity studies, groundwater studies, sediment quality studies, and the development and implementation of Pollution Prevention Plans.

Dock Operations at the BP Cherry Point Refinery are conducted in accordance with the BP Cherry Point Refinery's USCG- and Washington Department of Ecology-approved Oil Handling Facility Operations Manual, which describes personnel responsibilities, Dock operating procedures, and safe operating envelopes. The BP Cherry Point Refinery has a rigorous Dock inspection and maintenance program designed to protect the marine resources of the Cherry Point Aquatic Reserve and ensure the long-term operational integrity of the BP Cherry Point Dock.

The term for the BP lease, # 20-A09122, is April 1, 1999 – March 31, 2029

Ferndale Refinery operated by ConocoPhillips: DNR Lease 20-B11714 – Lease pertaining to ConocoPhillips/Tosco pier and outfalls

The ConocoPhillips (COP) Ferndale Refinery is located in Whatcom County on an 850 acre site, fronting on the Georgia Strait between Cherry Point and Sandy Point, five miles west-southwest of Ferndale, Washington. Originally built in 1954, the refinery has completed several upgrades and expansions since then and, as of January 2008, has a capacity to process approximately 105,000 bbl per day of crude oil. The main source of crude oil is from tankers delivering oil from Alaska's North Slope and Canadian crude via pipeline. The crude oil is processed to produce a range of fuels and products including: gasoline, diesel (low sulfur & ultra low sulfur), liquid petroleum gas, residual fuel oil, marine bunker fuel oil, and sulfur. The refinery currently employs about 280 people with an additional 150 contract employees. The indirect employment associated with the refinery is about 900 people. The refinery operates 24 hours per day and 365 days per year, except during turnaround periods which occur about once every two to three years.

As part of normal operation, the refinery has substantial water-dependent activities associated with the receipt of raw materials, shipping of products, vessel fueling and permitted Clean Water Act (CWA) discharges. In 2007, approximately 530 vessel transfers were conducted at the refinery dock. These vessels primarily consist of crude oil tankers and petroleum product barges. The scheduling of vessel and cargo activities at the marine terminal is coordinated by the refinery and is intended to meet raw material needs for the refinery and product distribution to the market.

All governmental regulations and ConocoPhillips' standards and procedures are strictly enforced throughout docking and loading/unloading operations. The refinery maintains and updates its Marine Terminal Safety & Operations Manual, which describes personnel responsibilities, operating procedures, and related data concerning the refinery dock and transfer operations, including the pre-booming of oil transfers in accordance with state requirements which came into effect in 2007. In compliance with federal and state regulations, the refinery also maintains and updates plans and programs, such as the Oil Spill Prevention Plan, the Oil Spill Response Plan, the Spill Prevention, Control, and Countermeasure Plan, the Integrated Contingency Plan, and Oil Handling Personnel Training. ConocoPhillips has an ongoing program for periodic inspection, maintenance, repair, and replacement activities required to ensure the longevity and reliability of operations at the dock and associated facilities; these activities may include above-water, on-water, and in-water work and are conducted in accordance with approvals received from federal, state, and local permitting agencies.

The refinery operates an NPDES AKART-permitted wastewater treatment plant. The NPDES outfall discharges into the Strait of Georgia approximately 1200 feet from the shoreline. The outfall line also periodically conveys treated wastewater from Tenaska, a cogeneration facility located adjacent to the refinery. The refinery NPDES permit requires monitoring, effluent mixing and toxicity studies, sediment sampling, and Stormwater Pollution Prevention Plan updates and implementation.

Intalco Aluminum Corporation – DNR Lease 20-A08488 – Lease pertaining to Intalco pier only (outfalls are managed using a separate lease instrument).

Intalco Aluminum Corporation (Intalco), a subsidiary of Alcoa Inc. (Alcoa), the world leader in the production and management of primary aluminum, fabricated aluminum and alumina combined, is located in Whatcom County approximately 100 miles north of Seattle, Washington and 50 miles south of Vancouver British Columbia. Intalco operates an aluminum smelter that occupies approximately 300 acres of a 1,500 acre tract fronting on the Georgia Strait between Cherry Point and Sandy Point near Ferndale Washington. Intalco has been part of the local community for more than 40 years and began operation in 1966 as a primary aluminum smelter, owned by Alumax, Pechiney and Howmet. In 1998, Alcoa acquired Alumax, resulting in Intalco becoming an Alcoa subsidiary.

Intalco produces aluminum metal utilizing the Hall-Heroult reduction process. This process utilizes electrical current to dissolve alumina in a cryolite bath inside large carbon-lined aluminum reduction cells. Once dissolved the molten aluminum separates from the solution and collects at the bottom of the reduction cell where it is removed and transported to natural gas fired furnaces. The molten aluminum is then cast into various sizes and forms to be utilized in casting or extrusion processes to make products such as window frames, wheels and ladders.

Intalco was originally designed and built to accommodate a paste plant, bake furnace, three operating potlines, and a casthouse. Each potline consists of 240 side worked, pre-bake aluminum reduction cells for a total of 720. While the smelter is currently permitted to produce 307,000 tons of aluminum metal per year, rising power costs in early 2001 caused the facility to operate in a curtailed mode since June of 2001. Since that time Intalco has been operating in a curtailed mode and as of March 2008 is operating at approximately 70% of capacity with a workforce of over 600 full time employees. Economic study has shown that every Intalco job in Washington creates an additional three jobs in the community.

Intalco's pier operations consist of permitted Clean Water Act (CWA) discharges and unloading activities as described in the current Aquatic Lands Lease between Intalco and the State of Washington (Department of Natural Resources). This lease currently allows for unloading alumina ore and liquefied petroleum gas. It also allows for the addition of future loading and unloading activities pending regulatory permit approvals.

There are numerous State and Federal regulations that apply to the activities throughout the facility including those activities associated with the loading/unloading operations at the facility's pier. These include, but are not limited to Spill Prevention, Control, and Countermeasure Plans, National Pollutant Discharge Elimination System permits, Title V Air Operating Permits, DNR Aquatic Lands Lease requirements, etc. Intalco takes all of these regulations seriously and is routinely inspected by State and Federal regulatory agencies to ensure compliance.

Gateway Pacific Terminals – DNR Lease 20-013265 – Application for a lease made by Gateway Pacific Terminals for a pier

Pacific International Terminals, Inc. (PIT) owns 1,092-acres of heavy-impact industrial zoned land at Cherry Point in Whatcom County, Washington. PIT is in the process of permitting and developing a deep-sea cargo shipping facility on the property known as Gateway Pacific Terminal (or proposed project). The proposed project includes a ~3000 x 105 foot wharf with three berths averaging approximately 80 feet of draft, a 1,250 foot access trestle connecting the wharf to the shore, and a series of on-shore cargo storage buildings, railroad track for transporting commodities, parking area, equipment storage, and administrative areas. The waterside trestle and wharf would be located on the shoreline at Cherry Point between the BP Cherry Point Refinery pier and the Alcoa-Intalco Works pier. The shoreward facility is on PIT's upland property bounded by Aldergrove Road on the north, the Straits of Georgia on the west, Kickerville Road on the east and Henry Road on the south. The proposed project's site is located 17 miles south of the United State and Canada boarder and 6 miles from Interstate 5 along Highway 548. The property has access to BNSF rail at the site boundary along with industrial water, natural gas, high voltage power and other heavy industry support utilities. The heavy impact industrial zoning, close proximity to deep water without dredging, supporting infrastructure, good geotechnical conditions and large number of acres at the site all lend themselves to a successful development of a marine shipping terminal.

In 1997, PIT received a Shoreline Substantial Development Permit from Whatcom County, Washington, to construct GPT. A consortium including Washington State Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), and a coalition of environmental groups appealed the permit to the State Shoreline Hearings Board on the basis that potential environmental impacts from the project were not satisfactorily addressed or mitigated. The appeal led to a Settlement Agreement (SA) among all the parties executed in 1999. Actions required of the Settlement Agreement included: baseline environmental studies and surveys; revisions and order-of-magnitude designs; financial studies; real estate acquisitions; contractual arrangements and the on going efforts to acquire the additional permits from the US Army Corps of Engineers (USACE) and Aquatic Lands Lease from the Washington State Department of Natural Resources (DNR).

Appendix E – Legal Description

Withdrawn Public Land Boundary Description

That porton of the tidelands and bedlans of navigable waters owned by the state of Washington, fronting and abutting Sectiosn 2, 11, 13, 14, and 24, Township 39 North, Range 1 West, Willamette Meridian and fronting and abutting Sections 19, 20, 29 and 32, Township 39 North, Range 1 East, Willamette Meridan described as follows:

Lying south of the south line of government lot 1, of said Section2, Township39 North, Range 1 West, W.M. being the south line of Birch Bay Sate Park; lying north of the south line of Township 39, Range 1 East; and extending waterward to a line which is 70 feet below mean lower low water OR 0.5 mile beyond extreme low tide, whichever line is further waterward;

EXCEPTING THEREFROM, the following Use Authorizations issued byt the Department of Natural Resources; lease application numbers 20-A09122, 20-A11714, 20-A08488, 20-013265 and 20-010521;

ALSO EXCEPTING THEREFROM, any second class tidelands previously sold byt the State of Washington.

Situated in Whatcom County, Washington

Appendix F – Cherry Point Workgroup Activities

The Common Aim

"Participants of the Cherry Point Collaborative Process will work together to create an agreement that contains a set of recommendations for action, to be jointly submitted to the appropriate entities, for the sustainable long-range management of the Cherry Point (Resource Area).

In the process of developing this agreement, the following objectives will be considered:

- protection and restoration of the Cherry Point water quality, aquatic ecosystem, and its valued species, including but not limited to, Cherry Point herring, Nooksack Chinook, and migratory waterfowl;
- public recognition of Cherry Point's unique ecological resources;
- determining whether there is an ongoing need for the Cherry Point Aquatic Reserve;
- respecting reserved treaty rights that protect cultural resources including the sustainable harvest of natural resources in usual and accustomed areas; and
- sustainable economic development, and the long-term viability of existing and pending leases as planned for by Whatcom County's current shoreline management program, and other activities at the site, in a way that is not detrimental or does not put resources or adjoining neighborhoods in jeopardy.

All of these objectives will be considered in a way that respects all interests in environmental protection and restoration, economic sustainability of water-dependent uses, and community goals. Although all of the above objectives will be considered in developing the agreement, there is no present commitment made to include any or all of them in the agreement. However, no party will consider entering the agreement unless it determines its interests have been met."

Coal Train Traffic Impact Study

NOVEMBER 2012

PRESENTATION

Parametrix

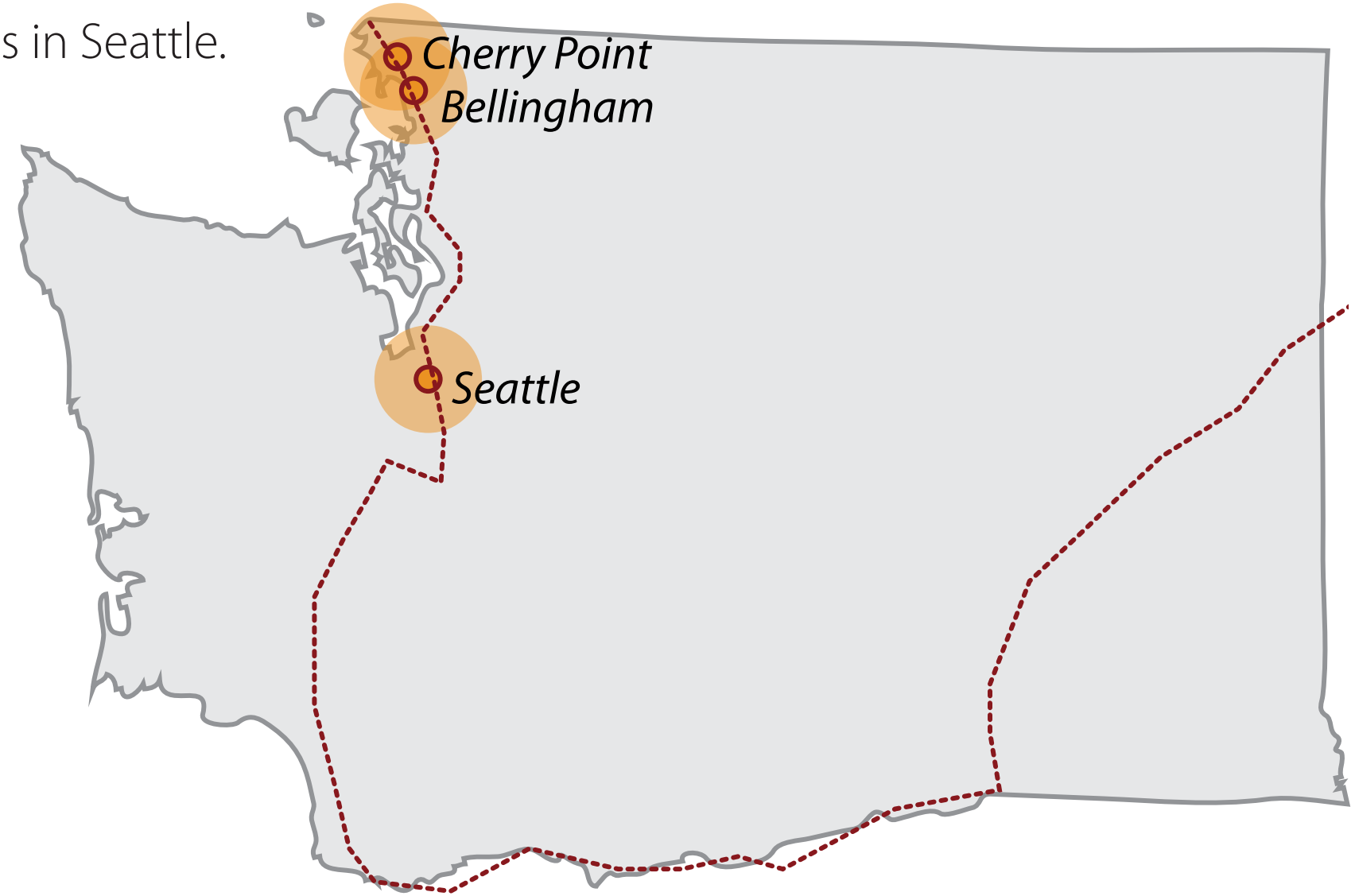
ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

Agenda

- Introduction
- Study Purpose
- North Waterfront and SODO Study Areas
- Existing Rail Operations
- Coal Train Assumptions
- Gate Down Times
- Collisions
- Emergency Vehicle Access
- Potential Crossing Improvements
- Summary

Study Purpose

Evaluate the impacts to local roads from potential coal train operations in Seattle.

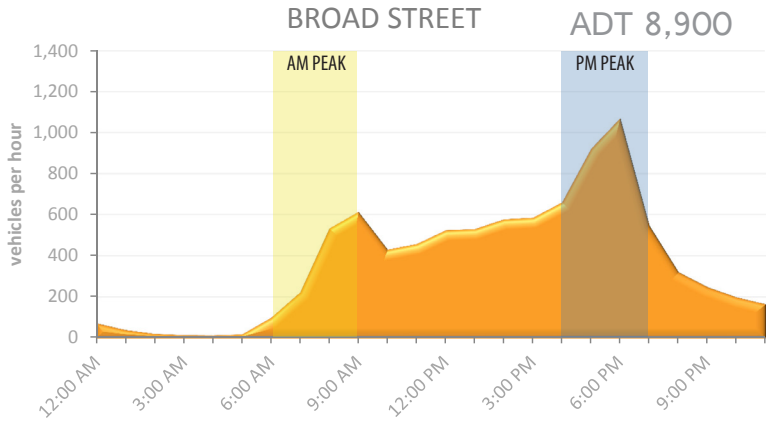


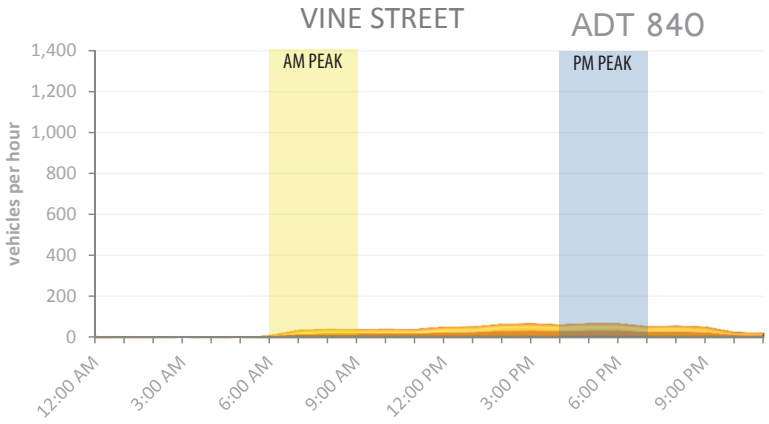
North Waterfront Study Area

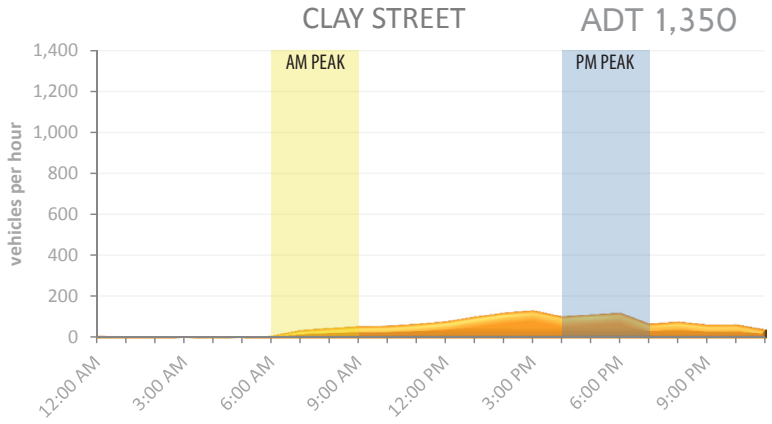
STAKEHOLDERS

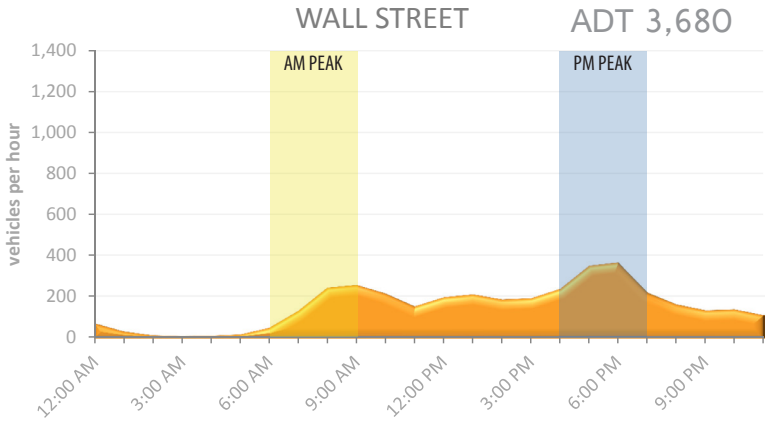
- Port of Seattle
- Cruise ships
- Olympic Sculpture Park
- Victoria Clipper
- Waterfront businesses
- Freight Community
- Area residents
- Edgewater Hotel
- Marriott Waterfront Hotel
- Washington State Ferries

Daily Vehicle Volumes at Railroad Crossings





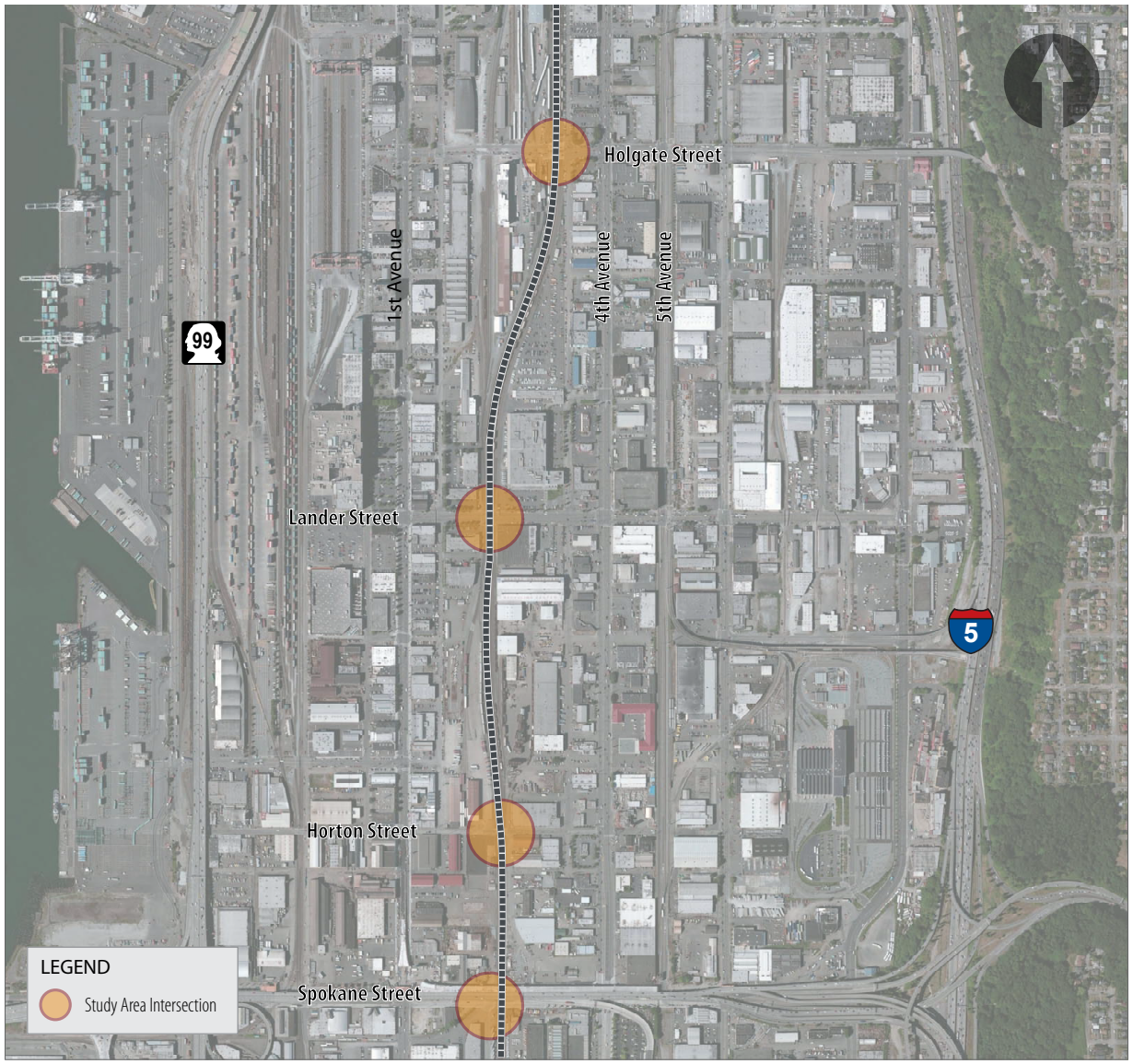




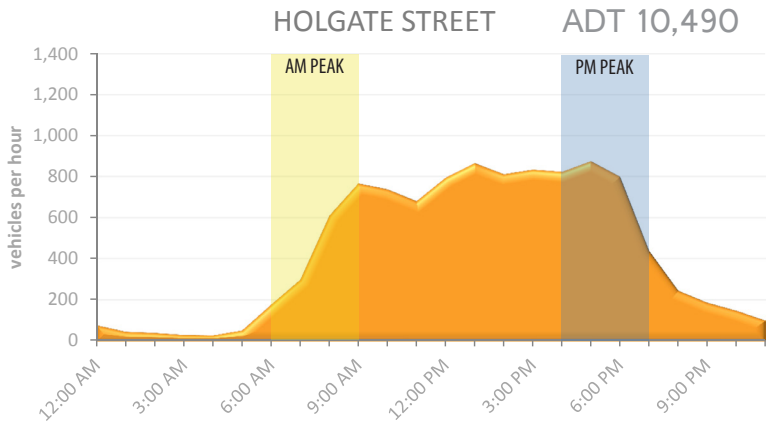
SODO

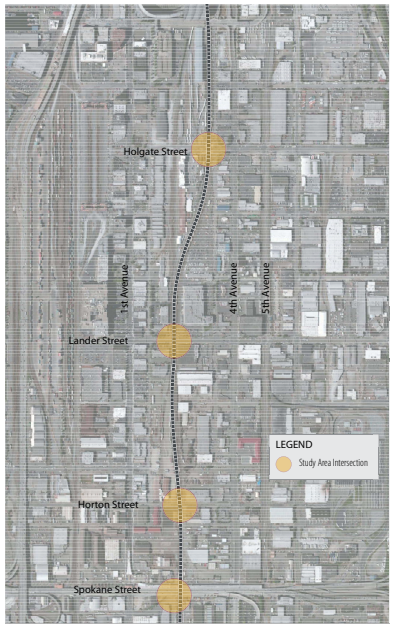
STAKEHOLDERS

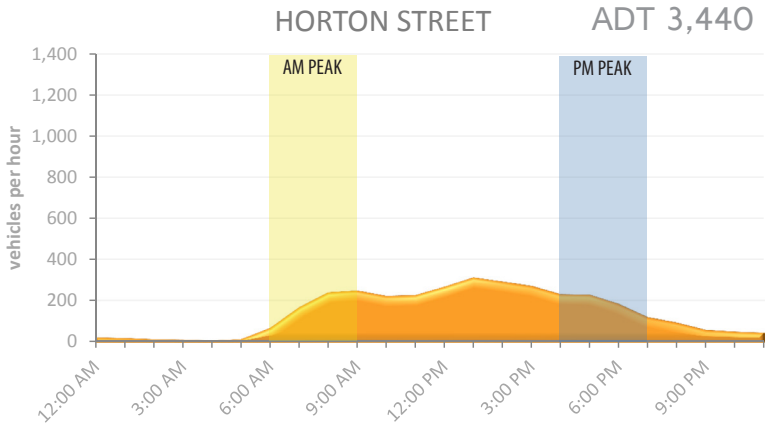
- SODO businesses
- Industries
- Stadiums
- Port of Seattle facilities
- Washington State Ferries

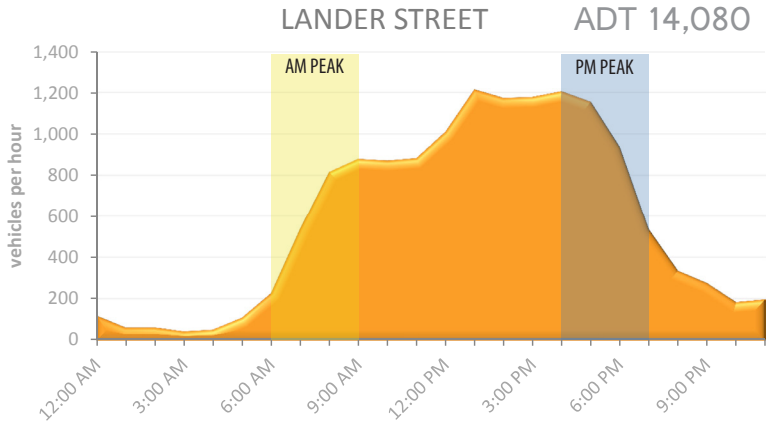


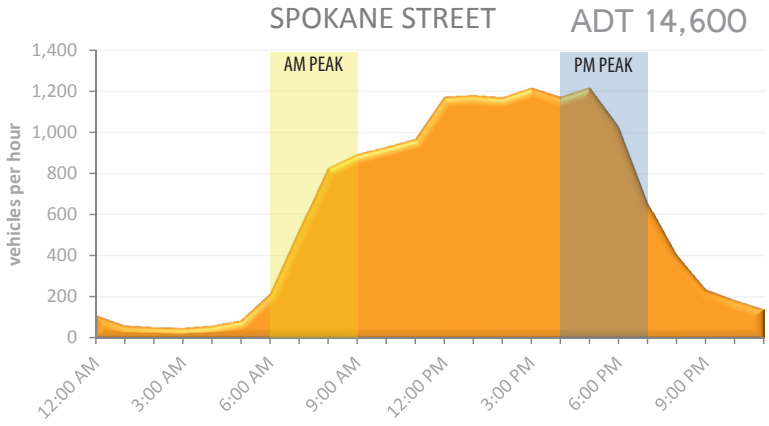
Daily Vehicle Volumes at Railroad Crossings











Existing Rail Operations

FREIGHT RAIL

- Approximately 30 freight trains (North Waterfront) and 65 to 85 freight trains (SODO) each day.
- Includes long-haul trains that are 1.6 miles long.
- Daily train volumes and schedules vary.

PASSENGER RAIL

- Sound Transit operates 4 Sounder trains north and 9 trains south.
- Amtrak operates 14 trains daily through Seattle.
- Sound Transit provides Link light rail service in the downtown transit tunnel.

OTHER RAIL

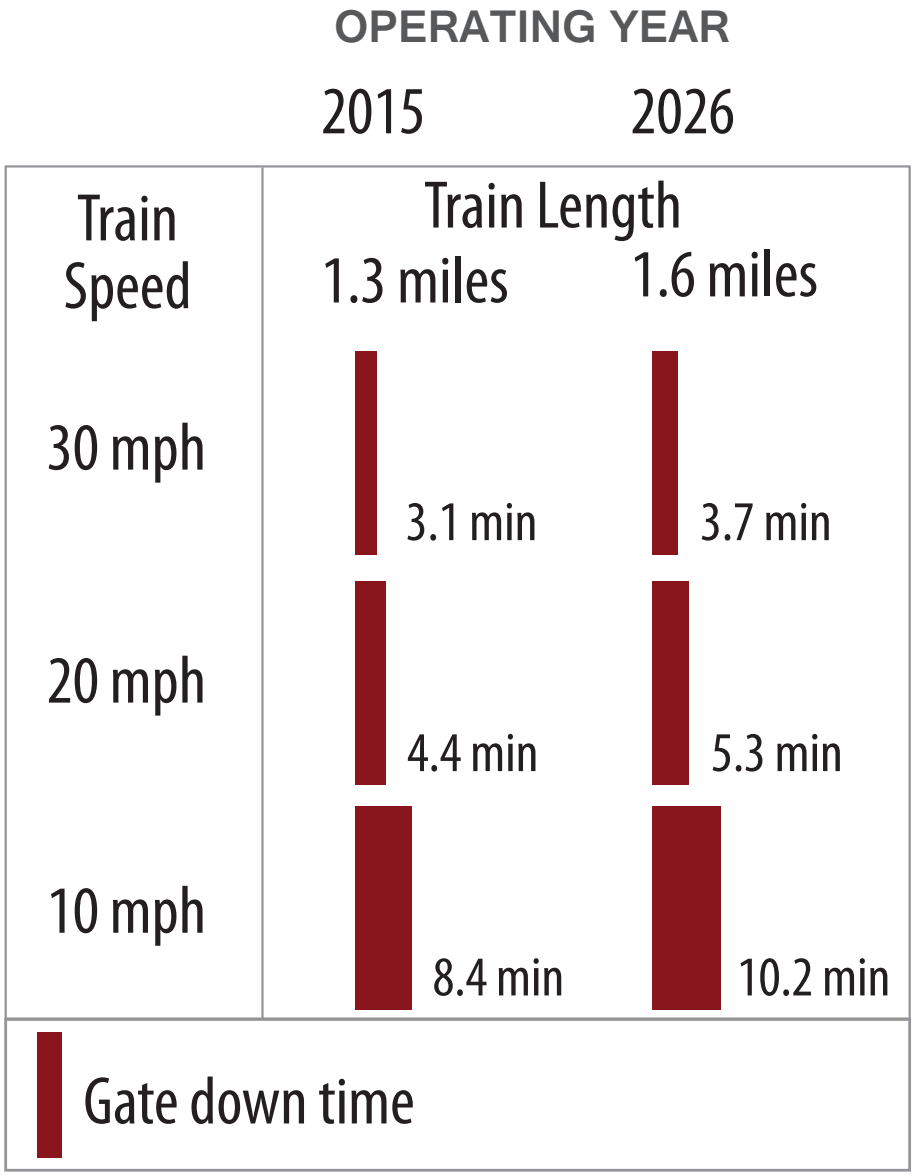
- BNSF operates rail tracks east of East Marginal Way South that serve its Seattle International Gateway (SIG) intermodal terminal.
- A number of spur tracks branch off the BNSF mainline between I-5 and Fourth Avenue.

Existing Rail Operations

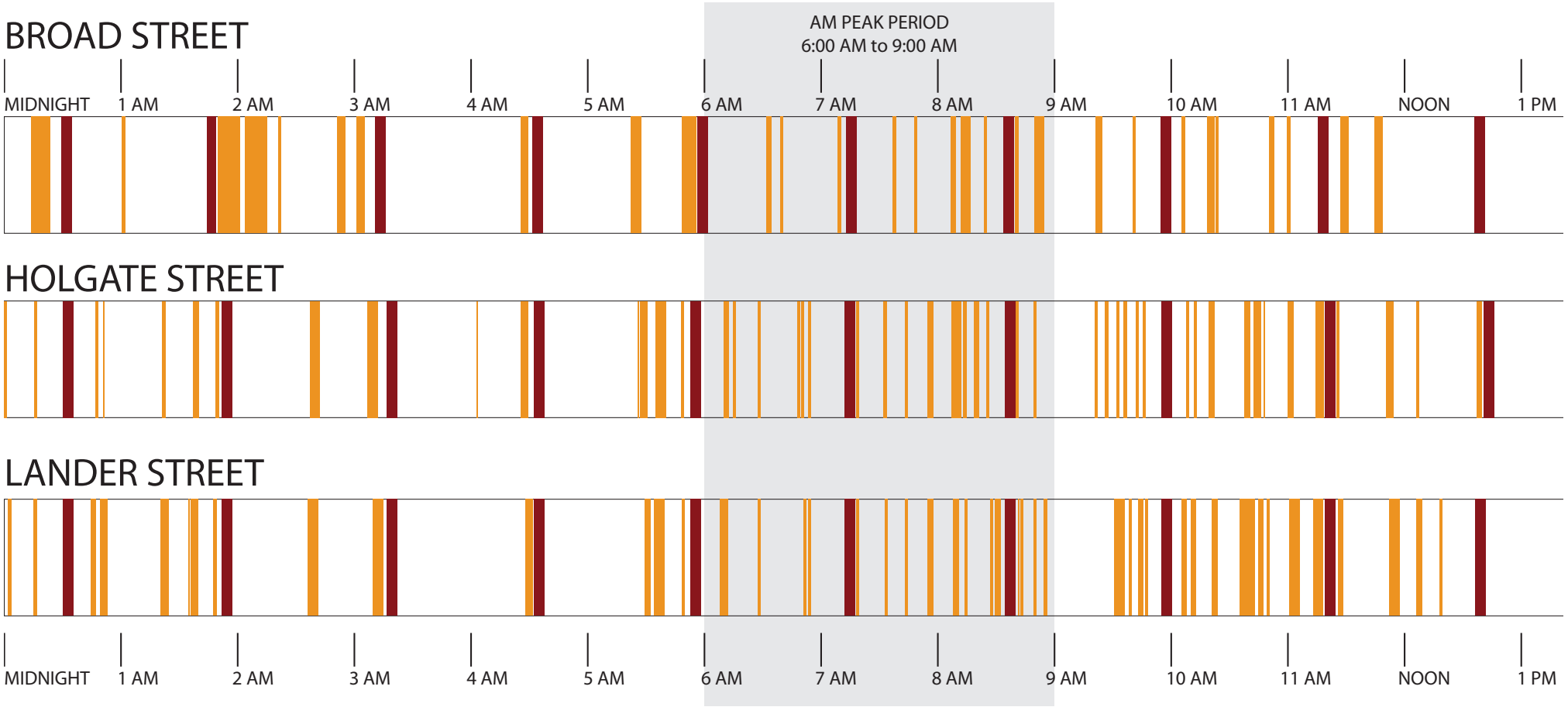
	Broad Street	Holgate Street	Lander Street
Number of Train Crossing Events	52	107	87
Total Gate Down Time (hours)	2.8	3.6	3.7
Average Gate Down Time (minutes)	3.3	2.0	2.5
Minimum/ Maximum Gate Down Time (minutes)	1.1 - 11.6	0.3 – 8.2	0.5 – 8.1
Average Train Speed (mph)	6.7	7.4	8.1
Minimum/Maximum Train Speed (mph)	0.3 – 22.7	0.4 – 24.6	0.5 – 22.9

Coal Train Assumptions

- From: www.coaltrainfacts.org/pid
- 2015: 10 daily 1.3 mile long trains
- 2026: 18 daily 1.6 mile long trains
- Operating speed based on existing track observation (24-hours)



Railroad Track Schedule with Coal Train (AM)

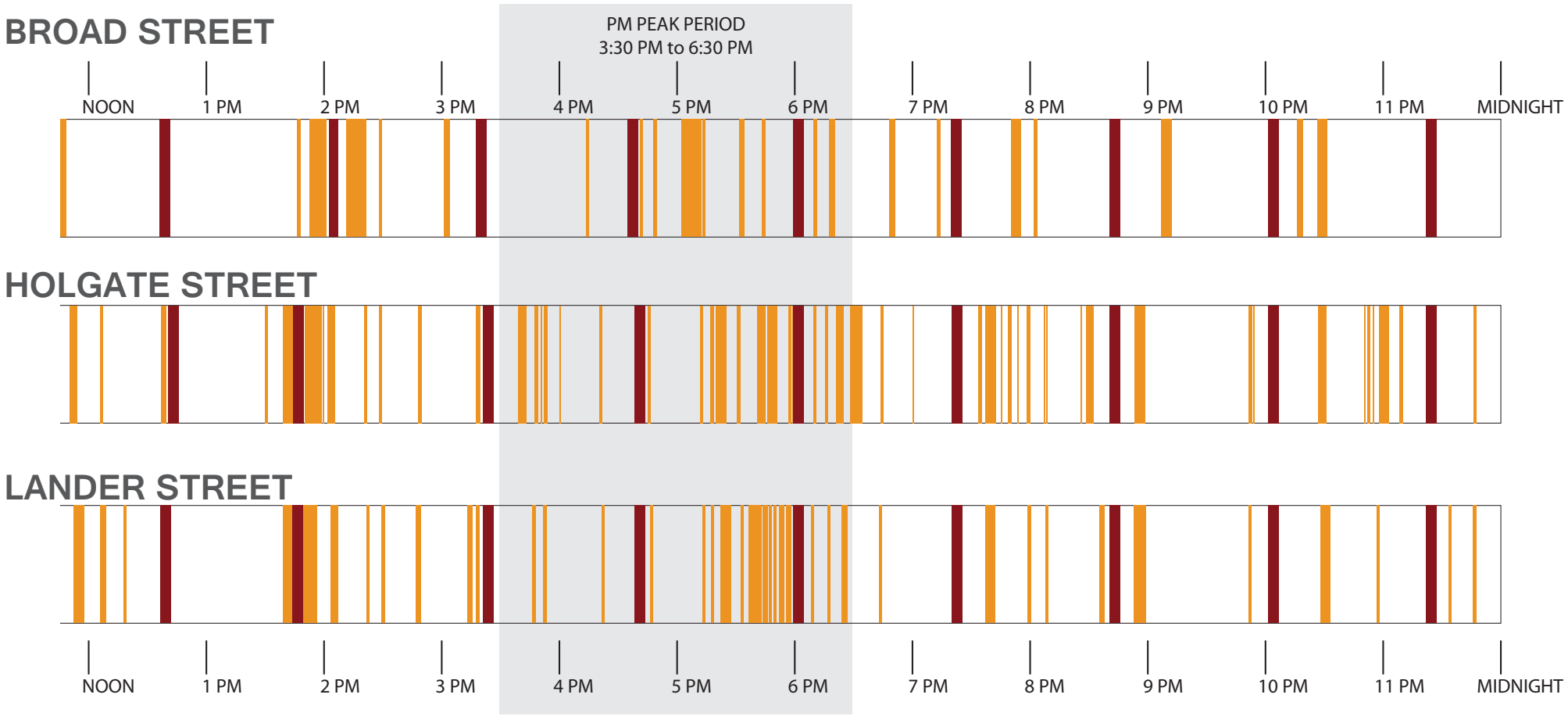


Legend

- Observed Gate Down Time
- Coal Train Gate Down Time

- One day of observed gate down times
- 18 total coal train trips equally distributed (2026)
- Coal trains assumed to be 1.6 miles long, operating at 20 mph

Railroad Track Schedule with Coal Train (PM)



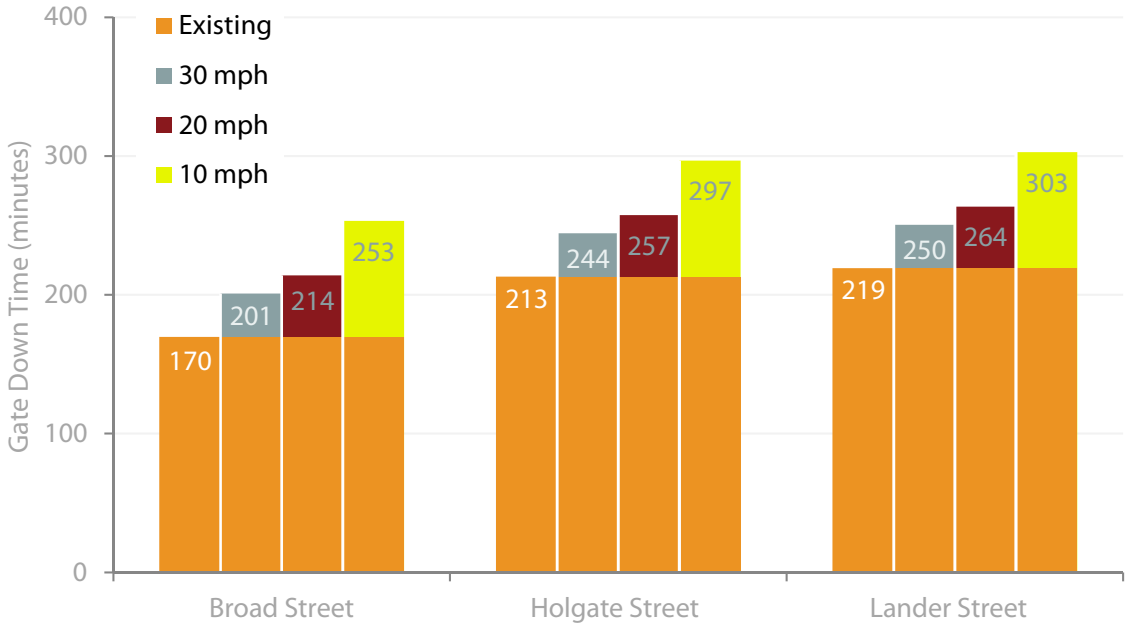
Legend

- Observed Gate Down Time
- Coal Train Gate Down Time

Anticipated Daily Gate Down Times

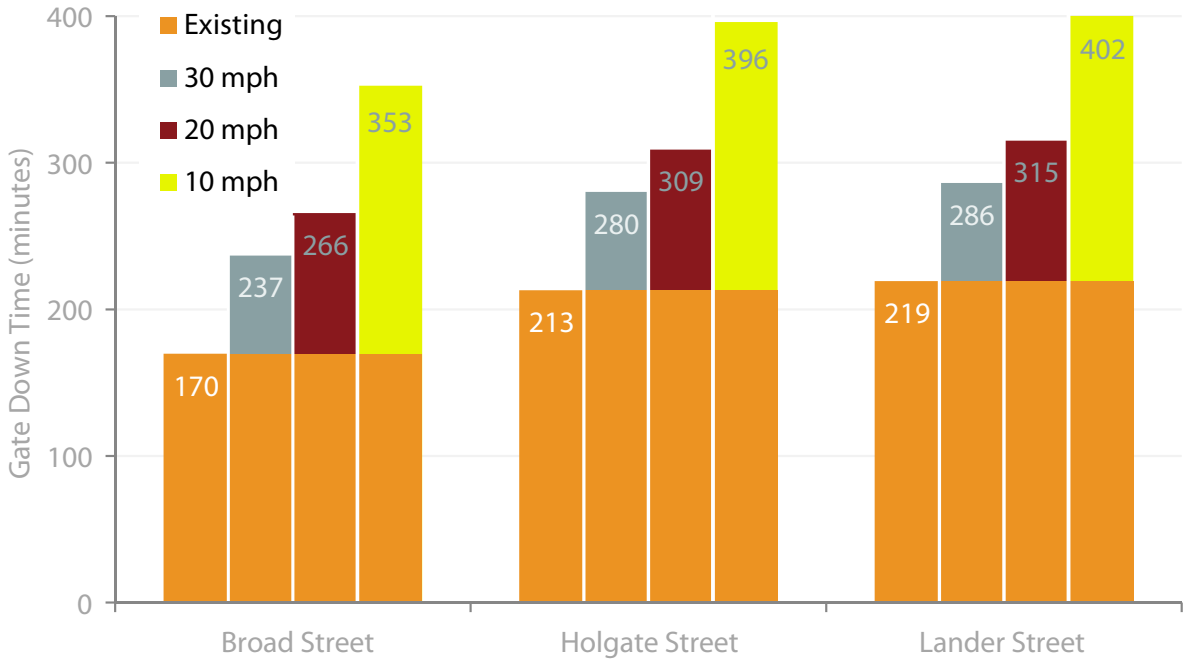
2015 DAILY GATE DOWN TIME

- 10 trains
- 1.3 miles long
- 20 mph



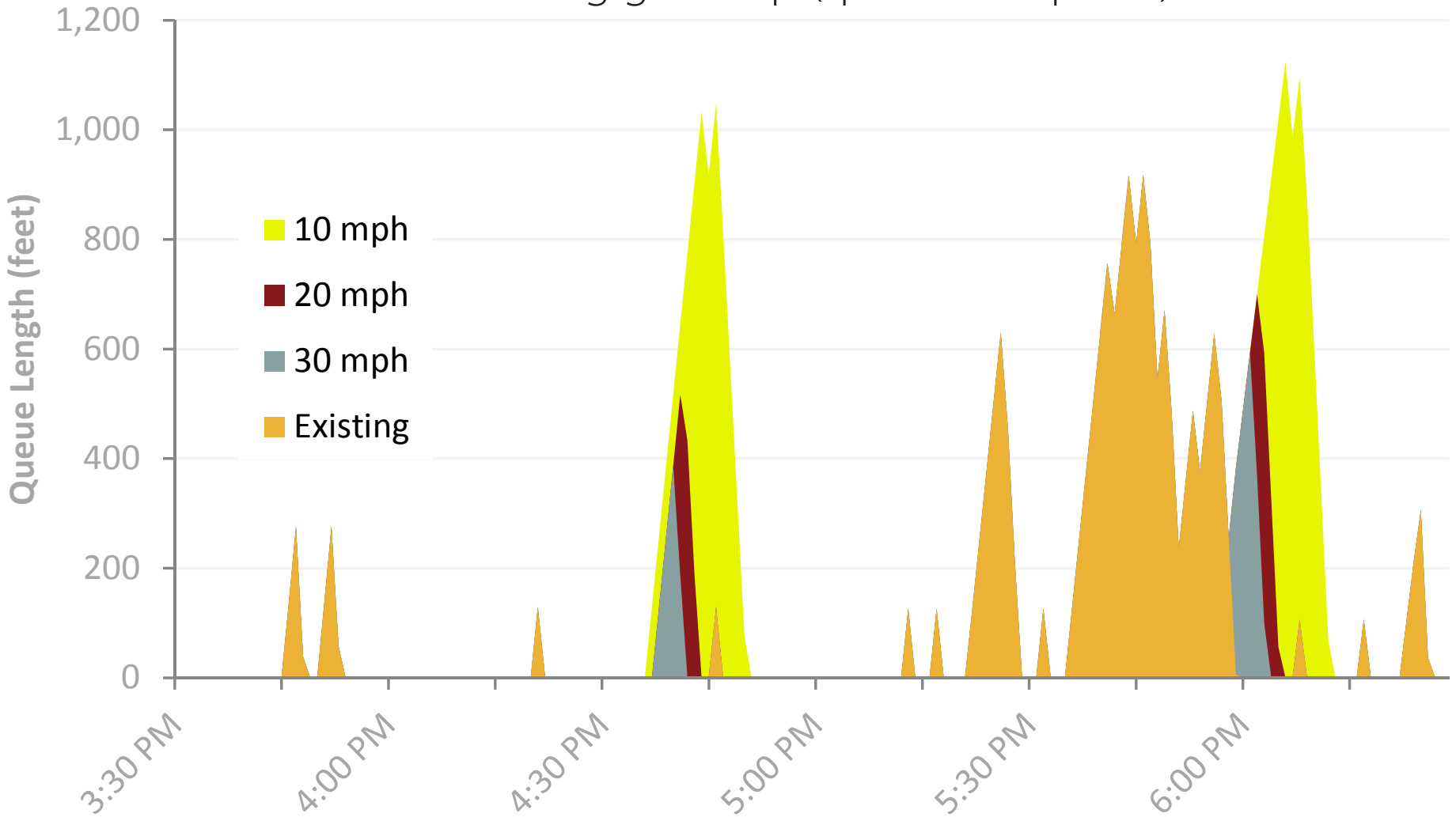
2026 DAILY GATE DOWN TIME

- 18 trains
- 1.6 miles long
- 20 mph



Lander Street Hourly Queues

- Slower coal train operating speed will have a greater impact on vehicles queues.
- Upward trends = Crossing gates down (queue builds)
- Downward trends = Crossing gates up (queue dissipates)



Collisions

- 4 train/vehicle collisions in the past 10 years.
- 127 improper crossings within a 24-hour period at Broad Street, South Holgate Street, and South Lander Street crossings.
- Saftey concerns increase with more trains.

Observed Improper Crossings 2012

	Bicycle	Pedestrian	Vehicle	Total
Broad Street	6	1	26	33
Lander Street	0	15	34	49
Holgate Street	0	0	45	45
Total	6	16	105	127

Emergency Vehicle Access

- Three fire stations directly impacted by rail delays in the SODO and North Waterfront districts.
  - Station 14 - 3224 4th Avenue South (Under Construction)
  - Station 5 - 925 Alaskan Way
  - Station 2 - 2320 4th Avenue
- Blockage from the proposed coal trains would impact emergency vehicle trips to/from the waterfront.
- Delays caused by the coal train affect local area responses and the ability to send emergency resources across the SODO district.

Potential Crossing Improvements

RECOMMENDATION FROM PREVIOUS REPORTS

- Grade separated overpasses at Broad Street and Lander Street
- Closure of Holgate Street
- Other possible improvements include:
  - Streetscape, such as fencing and plantings
  - Consolidating crossing gates
  - Raised medians
  - Pedestrian gates
  - Electronic message signs

Summary

- 10 total coal train trips (5 round trips) are expected each day or one train approximately every 2.4 hours.
- In 2026, the number of daily trains would increase to 18 total daily trips (9 round trips) or one train every 1.3 hours.
- Assumed coal train operating speed of 20 mph; slower speeds would create additional delay.
- In 2015, estimated additional daily gate down time for coal trains could be 31 to 83 minutes; increase of 15% to 49%
- In 2026, the estimated additional daily gate down time for coal trains could be approximately 67 to 183 minutes; increase of 31% to 108%

The Eastman Company
Real Estate Appraisers/Analysts/Consultants
925 N. 130th Street
Seattle, WA 98133
(206) 363-6611
Fax (206) 363-5507
appraisers@wavalue.com

October 30, 2012

Mr. Ross Macfarlane
Senior Advisor, Business Partnerships
Climate Solutions
1402 Third Avenue, Suite 1305
Seattle, WA 98101

RE: Increased Coal Train Traffic and Real Estate Values:
A study of the potential impact of increased coal train traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA
Eastman Company File No. 2036.1

Dear Mr. Mcfarlane:

As requested, I have completed my Valuation Consultation assignment that addresses and examines the impacts of increased coal train freight traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA, and my conclusions are summarized in this report. Generally, this project required the consultant to provide a document for use in assisting the client, Climate Solutions, in evaluating the impacts of this proposed new rail traffic on affected real estate. The depth of discussion contained in this report is specific to the needs of the client, and this report is for the intended use and users specifically stated on Page Two. The consultant is not responsible for unauthorized use of this report. The following summarizes my research and conclusions.

Client: Mr. Ross Macfarlane, on behalf of Climate Solutions

Consultant: Paul Zemtseff

Overview of Problem to be Considered: Pacific International Terminals, a subsidiary of SSA Marine, has proposed building a deep-water, multi-user, import and export marine terminal at Cherry Point, west of Ferndale in Whatcom County, WA. The proposed Gateway Pacific Terminal would eventually handle import and export of up to 54 million dry metric tons per year of bulk commodities – mostly exporting coal (48 million tons annually) to destinations in Asia. Coal mined in the Powder River Basin by Peabody Energy would be hauled by trains along the Burlington Northern and Santa Fe Railway Company (BNSF) rail lines. The proposed coal train transportation corridor route extends from mines in Montana and Wyoming through Sandpoint, Idaho to Spokane down through the Columbia River Gorge, then up along the Puget Sound coast, passing through the Washington state cities of Longview, Tacoma, Seattle, Edmonds, Everett, Marysville, Stanwood, Mount Vernon, Bellingham, Ferndale and all points in-between. It is understood that up to an additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) would

be expected to transport the coal along this the main line route, and the shipping terminal at Cherry Point would expect the addition of approximately 30 miles of coal trains daily along the BNSF rail line that runs along the Puget Sound coast. It is understood that nothing in the proposed project materials specifies a maximum; therefore, the 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future.

A wide variety of physical, environmental and other potential impacts have been anticipated from resultant unprecedented levels of regional rail usage. As segments of the Washington state rail system are already nearing or at practical capacity, the dramatic increase in rail traffic would likely constrain passenger rail and adversely affect the transport of freight other than coal. Negative impacts also associated with coal trains include concerns due to train length, weight, content, and polluting capacity.

This valuation consultation assignment was specifically undertaken primarily as an attempt to provide an opinion of the impact on property values and/or real estate tax revenues (if any) resulting from the influence of an additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) using the main line route expected to transport the coal to the terminal at Cherry Point[1]. This study and analysis is specifically intended to address BNSF's main rail line areas running through Whatcom, Skagit, Snohomish, King and Pierce Counties, which comprise the areas expected to be most adversely impacted as they are the most densely populated, intensely improved, and therefore, potentially the most affected metropolitan and urban areas along this route.

Purpose, Intended Use / User of the Consultation and Restrictions On Use: The purpose of this consultation is to provide my opinion of the range of diminution in property values for various affected property types resulting from the influence of an assumed additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) using BNSF's main line (running through Whatcom, Skagit, Snohomish, King and Pierce Counties in Washington state) to transport coal to the proposed Gateway Pacific Terminal at Cherry Point[2]. The intended use of this consultation to assist the client and other intended users in understanding and evaluating the impacts of this new rail traffic. The "broad brush" conclusions rendered within this report are intended to provide the user a framework to consider and address anticipated potential effects on property value resulting from a number of widely recognized value influencing factors that vary in impact due to their varying degrees of intensity and the unique attributes of different affected properties amongst a range

[1] **Note** that empty coal trains are expected to use a different route from Everett, returning easterly to pass through the Cascade Tunnel (not the Stampede Pass Tunnel); therefore the rail traffic north of Everett is greater than south of Everett.

[2] Ibid.

of differing property types. This consultation is intended for use by the Client (Climate Solutions), or persons specifically authorized by the Client for the indicated purpose and intended use. All others reading or relying on this report are unintended users.

Effective Date of Consulting Service: October 30, 2012

Scope of Work and Data Collection Process: The scope of this assignment was iterative with initial and possible future phases based upon what was found during the investigation and research process. The first phase was to determine if any loss in real estate value and/or real estate tax revenues would occur as a consequence of the new coal freight train traffic, assuming the levels of increased service previously described. The next phase was to determine if it was feasible to create a reliable model that could be used to quantify the dollar loss in value to various affected types of real estate, either on an individual property or some form of aggregate basis.

In preparing this report, I initially familiarized myself with the nature and extent of the proposed new coal train traffic and the rail corridors proposed for use in transporting coal to the Gateway Pacific Terminal (GPT) at Cherry Point. Numerous sources of public information were used to investigate and fully understand the background, scope, history and status of the project relative to the permitting process, the environmental impact statement (EIS), anticipated levels of use, and a variety of other meaningful parameters associated with the GPT project as proposed. I researched, assessed and reviewed fairly recent historical to the most current available data describing the status of the levels of service, capacities, anticipated increases and future projections for increased freight rail traffic along the previously defined subject areas of interest along BNSF's main line rail corridor and for Washington State as a whole. These documents included detailed analyses and recommendations along with detailed data regarding rail choke points, rail system needs, rail impacts and proposed mitigation measures and recent, anticipated and recommended rail corridor improvement projects. Studies and EIS's from other (non Washington State) rail corridor improvement projects were also reviewed and considered, as they address many of the same issues, elements and influences. I examined and reviewed various maps, online aerial mapping and other resources and exhibits to understand the rail route and property types within the areas of interest.

Access to a proprietary GIS based database identifying all tax parcels and various other information for properties located within 600 lineal feet of either side of BNSF main line route within the areas of interest was made available to me for possible use in this assignment. I familiarized myself with this tool, as well as with the transportation route corridor and the nature and type of surrounding properties. I visited many areas along the corridor to assess the nearby real estate as well as the nature and quality of crossings to obtain firsthand knowledge of existing conditions. I visited a representative sampling of the

various property types considered and addressed in this report (single family residential, multi-family, commercial and industrial properties) in all of the counties that abut the main rail line within the subject area of interest and/or that might be impacted by various adverse elements associated with the increased coal freight train traffic. (Note that while agricultural properties abut the area of interest, they were not specifically addressed or evaluated in this study). During this process, I was able to observe and experience coal trains traveling along this route. I reviewed recently conducted studies performed by Gibson Traffic Consultants, Inc. (GTC) that identify some of the possible rail impacts associated with transport of commodities to the proposed Cherry Point facility that affect the cities of Bellingham, Burlington, Mount Vernon, Stanwood, Marysville, Edmonds and Seattle and their access roads.

I was assisted by staff from the Appraisal Institute's Y.T. and Louise Lee Lum Library (which provides reference services in the subject area of real estate appraisal) and performed my own research, exploring numerous areas of interest associated with diminution in value issues involving rail and many other adverse influences. I found, read and/or reviewed numerous empirical research studies, statistical analyses utilizing hedonic models and regression analyses, professional research abstracts, and other publications that might provide support for my rail impact study and valuation analyses and conclusions. Although many of the studies reviewed did not specifically deal with rail impacts, they did function as proxy studies, demonstrating anecdotal evidence supporting the relative range of diminution in property values experienced in response to a variety of types of adverse influences. I surveyed a sample of a range of active, knowledgeable, real estate market participants and other experts for input as to their opinion of the extent of the influence of the proposed new coal train freight traffic on property values for the various property types. I performed extensive internet research on all of the above-referenced topics in order to maximize my understanding of the nature and extent of effects on real estate values due to a wide variety of adverse influence generating externalities including freight rail traffic.

All of the foregoing information gathered from these resources was considered from my personal experience perspective as a real estate appraiser/consultant, having been involved with numerous assignments and situations requiring the analysis of simple to complex real estate valuation problems for the purpose of rendering my opinion of diminution in value. Based upon the information and resources available to me for this assignment and my understanding of the wide variety of, and vastly differing types of, adverse influences associated with the increased coal train rail traffic, I concluded that the information and tools available would be insufficient to allow me to provide a reliable model that could be used to quantify the dollar loss in value to various affected types of real estate and/or real estate tax revenues, either on an individual property or some form of aggregate basis.

The as-described body of knowledge gathered, however, was deemed sufficient in its theoretical and functional application as background information to support and form the

basis for me to provide my opinion of a range of diminution in property value for the various property types considered, resulting from the range of adverse impacts associated with the increase in coal train freight rail traffic, as assumed. The final process required taking the perspective of an unbiased consultant and synthesizing this data in order to develop my conclusions. The nature of such real estate problems is often unique and involves a considerable degree of complexity; therefore, this consultation is seen as a means of bringing professional objectivity to, and market based support for, a framework that can generally be utilized to consider and address anticipated potential effects on property value resulting from the proposed additional coal freight train traffic assumed.

Subject Property: The subject property addressed in this study generally includes all properties with the potential to be adversely impacted by the proposed increase in coal train freight rail traffic along BNSF's main rail line areas running through Whatcom, Skagit, Snohomish, King and Pierce Counties. Although the nature of this assignment and scope of investigation required the consultant to visit a representative sampling of the different property types considered in these counties in order to acquire a good understanding (and a real sampling) of the range of potential situations to be considered, this assignment is not intended to address any specific subject properties or situations.

Elements of Adverse Influence Associated With Increased Coal Train Traffic: The literature reviewed generally identifies a number of categories of adverse influences associated with increased coal train freight rail traffic that have the potential to adversely influence real estate values. These elements and a summary of the perceived and potential impacts are briefly summarized as follows:

Access and Vehicular Traffic: The GTC traffic studies focus on six cities with a significant number of non-grade-separated (typically at grade/gate controlled) main line rail crossings, mostly in or near their central business districts in areas that experience substantial traffic, particularly during traditional "traffic times." The studies state language similar to the following (excerpted from their 6/21/12 Bellingham report) for each of the cities, but in some cases, the reports address somewhat different crossing conditions: "Each coal train will be up to 1.6 miles long, which at 50 mph would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour, it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35 mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Bellingham can be estimated to increase with an additional train every 1.3 hours, if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use sidings or speed restricted crossing. Assuming just a 5-minute average (consistent with the existing smaller coal trains traveling through Bellingham) would lead to every crossing on the track in Bellingham being closed for an

additional 90 minutes a day not including the additional clearance time for back ups to clear after a crossing arm lifts. Based on current data, the existing numbers of trains in the Bellingham area is averaging 15 trains a day. . . . The *Washington State 2010-2030 Freight Rail Plan* published by WSDOT in December 2009 identified that the rail line North from Everett in 2008 was already at its capacity of 18 trains per day. The State plan shows that it hopes to increase that capacity to 30 trains per day; however, the design and cost of the specific improvements needed to do that have not yet been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services."

The increased traffic and reduced quality of access not only have the potential to cause isolation and business interruption effects for properties in the immediate corridor area (say, within 800 feet of the track), but depending upon whether or not, and to what extent, alternative access potential exists, the area of adverse effect could, and in many cases does, cover a substantially larger area.

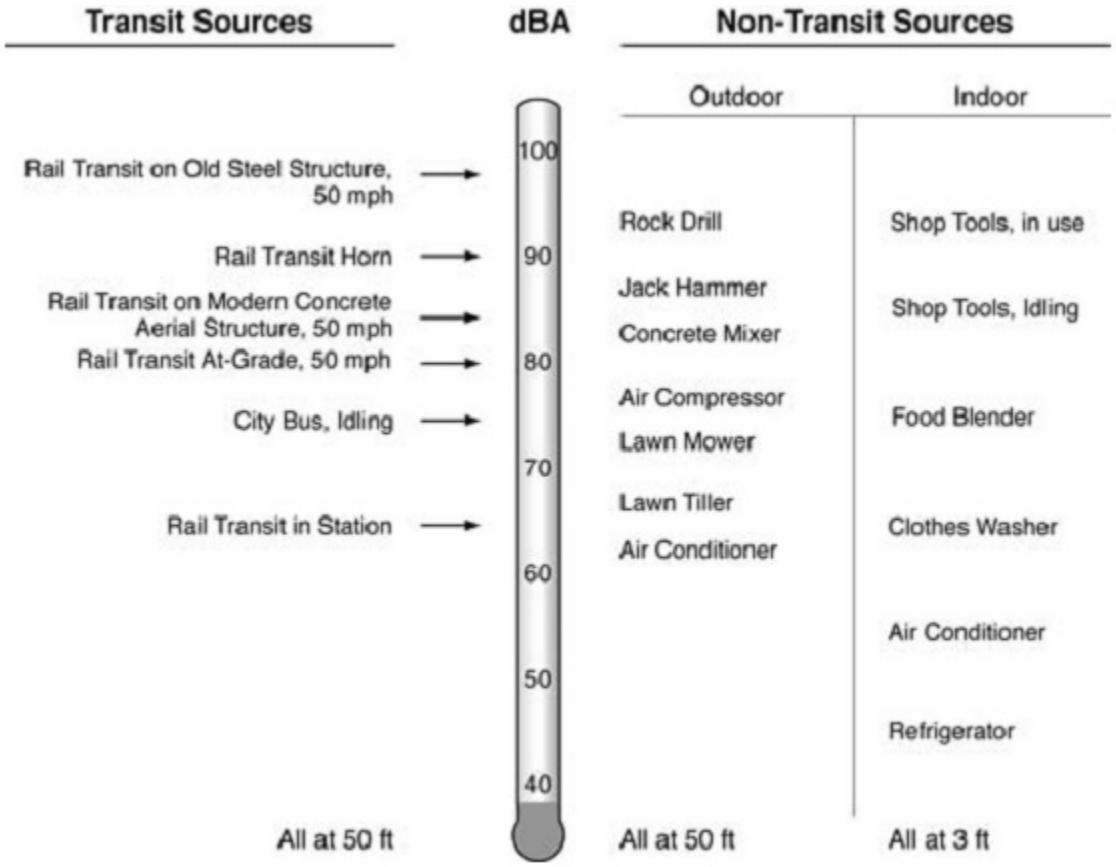
Life Safety Issues: Although infrequent, a potential problem associated with freight train traffic is that accidents occur at crossings and along the tracks, and fear of accidents is a perception that has the potential to affect nearby real estate values. Another duly noted life-safety consequence of the increased traffic identified for all of the GTC study areas is the potential for a first responder, such as an ambulance, police car, fire truck, aid car or utility provider, to suffer increased response times in reaching their destination at a critical time when emergency responses are needed.

Vibration: "Local and long-distance freight trains are similar in that they both are diesel-powered and have the same types of cars. They differ in their overall length, number and size of locomotives, and number of heavily loaded cars. Locomotives and rail cars with wheel flats are the sources of the highest vibration levels. Because locomotive suspensions are similar, the maximum vibration levels of local and long-distance freights are similar. It is not uncommon for freight trains to be the source of intrusive ground-borne vibration. Most railroad tracks used for freight lines were in existence for many years before the affected residential areas were developed. . . . . Vibration mitigation is very difficult to implement on tracks where trains with heavy axle loads will be operating. . . .

Although the perceptibility threshold is about 65 VdB, human response to vibration is not usually significant unless the vibration exceeds 70 VdB. Rapid transit or light rail systems typically generate vibration levels of 70 VdB or more near their tracks. On the other hand, buses and trucks rarely create vibration that exceeds 70 VdB unless there are bumps in the road. Because of the heavy locomotives on diesel commuter rail systems, the vibration levels

average about 5 to 10 decibels higher than rail transit vehicles. If there is unusually rough road or track, wheel flats, geologic conditions that promote efficient propagation of vibration, or vehicles with very stiff suspension systems, the vibration levels from any source can be 10 decibels higher than typical. Hence, at 50 feet, the upper range for rapid transit vibration is around 80 VdB and the high range for commuter rail vibration is 85 VdB. If the vibration level in a residence reaches 85 VdB, most people will be strongly annoyed by the vibration."[3]

Horn Noise: "In a large number of community attitudinal surveys, transportation noise has been ranked among the most significant causes of community dissatisfaction. . . . . The percentage of high annoyance is approximately 0 percent at 45 decibels, 10 percent around 60 decibels and increases quite rapidly to approximately 70 percent around 85 decibels." [4]



[3] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, May 2006.

[4] Ibid

The noise from a train is produced by a variety of sources and determined by numerous variables including the diesel locomotive noise, wheel noise (squeal, rolling noise), braking, signal horns and crossing gate bells, the type, quality and condition of the train, and the quality, condition and composition of the track and track bed.

Pollution: Sources of air and ground pollution include the exhaust from diesel locomotive engines, coal dust from open coal cars and other petrochemicals that typically fall from the train on to the tracks (such as lubricants). Concerns exist that adverse influences from coal dust due to open car transportation practices and from diesel exhaust that are expected to result from the increased coal train traffic may be sufficient to potentially cause negative human health effects. Even if studies are conducted that do not support these concerns, the public perception about them is sufficient to have an adverse effect on property values.

Stigma and Perception: Effects on real estate values are colored by the perception of the market participants (typically the buyer or seller) and not based on objective factors or parameters that can easily be measured or quantified. For example, fear of accidents is a subjective factor that can be quite variable in perception by different individuals. Some segments of the market are more sensitive to the preceding element items, and at the extreme, would not consider the possibility of owning property located nearby to, or significantly affected by, such freight rail influences, while others are less sensitive to these influences. Studies reviewed conclude that real estate values are increasingly adversely impacted as the level of dissemination of information to the public that concerns exist increases. Considering that the potential adverse effects of the additional coal train traffic have been very widely publicized, it is expected that the adverse effect on the market already exists to some extent. Anecdotally, more than one Realtor interviewed cited an example of property value or marketability being directly affected by the proposed increases in coal train traffic.

Property Types, Variables and Comments: The coal trains typically have two locomotive diesel engines at the front and two at the rear of the train. The distance of the real estate from the rail line traffic and/or crossing is a *most* significant variable in determining the extent of most of the aforementioned value-influencing elements. Other factors influencing the extent of adverse effect include the time of day (or night) that trains travel, and for noise and vibration effects, the duration, frequency of occurrence, noise frequency (i.e. hertz range), existing non-rail noise conditions, type of crossing (trestle, at grade or grade-separated), nature of the surrounding topography (relative elevation of tracks versus the real estate) and acoustical conditions, intervening property improvements, vegetation or other features that may exist between the rail line and the property to dampen or amplify the noise. Note that it is generally accepted that night noise is far more disturbing than daytime noise, and is therefore more heavily weighted as an adverse influence.

Differing property types are typically influenced to differing degrees by the aforementioned elements of adverse influence. **Single family residences** are generally acknowledged as the most sensitive property type to all of these elements, as the consequential impacts can be perceived as having the capacity to directly influence the quality of life of the occupant(s). In my opinion, all of the aforementioned elements have the potential to significantly impact the value of affected single family residential property. The train's signal horn, which is typically repeatedly blown prior to at grade crossings, is generally acknowledged as one of the loudest noises produced by freight trains, and is the primary negative externality generated by train traffic. The duration of the horn blast and time of day is a significant factor determining its grade on the nuisance scale. It has been found that residents living within 1,000 feet of the rail line were severely annoyed by train horns. During my survey, one Realtor who lives near the rail line noted that a "whistle happy" conductor blew the horn for 15 seconds at 4:30 to 5 AM the other morning. Hedonic price models and studies have shown that the loss in value for residences is amplified with each additional freight train trip.

Multi-family properties similarly have the potential to be strongly influenced by these elements. Multi-family properties observed near the rail line included a mixture of sizes, with many being larger mid-rise buildings containing many units, a number of which front Puget Sound. In many of these properties, due to the size of the buildings, some units face the rail line, while others face upland or toward the sound. In these cases, the units facing the tracks are more influenced by the noise, vibration and pollution factors, while those further away can be perceived as experiencing little or no adverse effects in this regard. Particularly in the case of multi-family properties located seaward of the tracks, with limited or no alternative access, the access and vehicular traffic elements tend to carry significant weight. Also of consideration for multi-family properties is the occupancy status - whereas apartment dwellers have the ability to be more transient and relocate if ambient conditions do not meet their preferences, condominium owners are more like single family residential owners to the extent that relocating represents a substantial barrier to changing their situation.

Commercial properties include restaurants, retail stores, offices and other similar uses. A number of the potentially most affected properties observed are located seaward of the tracks. Although noise and vibration are seen as influencing factors relative to the adverse influences of the increased coal freight train rail traffic, in my opinion, the access and vehicular traffic elements are considered to have the greatest potential to adversely influence property value for commercial properties. Also, depending upon proximity, the pollution factors also have potential to represent a substantial negative influence.

Industrial properties are the category of real estate considered to be least influenced by the increased rail traffic. By nature, these properties are typically in locations zoned to allow for a variety of vibration, noise and pollution influences. They are often sited near, and many specific properties benefit from or require, rail access or service. The access and vehicular

traffic elements are considered to have the greatest potential to adversely influence the value of industrial properties, particularly if they are located in areas where the presence of a train precludes vehicular and employee ingress and egress, as is typical for numerous facilities observed. Freight trains, unlike commuter trains, are often not on a specific or predictable schedule. This can create a substantial nuisance for companies with large workforces if access is blocked near the time employees need to arrive at or leave work. Often the industrial properties that are exposed to being landlocked by trains are marine dependent facilities that have no option to relocate to the other side of the tracks as they need to retain their waterfront location or proximity.

Conclusions: This assignment required the consultant to provide an opinion of a range of diminution in property value for the various property types considered resulting from the range of adverse impacts associated with the increase in coal train freight rail traffic, as described in this report. As discussed, the wide variety of elements of influence and their variations in intensity of impact which are dependent upon numerous variable factors and a wide variety of physical conditions and influences impacting a single property within a given property type result in an almost unlimited number of diminution in value situations. Based upon all of the research and study undertaken in performing this assignment, and because of this extreme variability, the concluded diminution in value has been expressed in a percentage range intended to capture the most probable effects on a given property type. Although the range is intended to reflect the "less" to the "most" affected diminution in value situations, it should be understood that in some specific instances, a specific property may be more affected than indicated by the range concluded; however, in my opinion, such cases are rare. At the low end are properties that suffer no adverse impact, which typically would be properties lying outside of the area of rail influence.

Most of the literature relied upon addressed studies of residential real estate, and they tend to specify the outer limit of rail traffic influence at a distance in the approximate 750 to 1,000 foot range from the tracks. Unfortunately, due to the unique nature of real estate and the variety of influencing factors determining the net intensity of adverse influence, there is no set distance that is certain to suffer influence. It is clear, however, that the closer the distance of the property to the rail line or crossing, the greater the influence. Because of this, in general, the upper end of the range of diminution in value concluded would be expected to strongly correlate with properties located closest to the rail line or crossing. At the opposite end of the spectrum, although property with the least net total intensity of adverse influence might be expected to experience a diminution in value of less than five percent, such minimal impacts are generally considered so slight as to be effectively immeasurable; therefore, five percent has been used at the lower end of the range.

As noted, empty coal trains are expected to use a different route from Everett, returning easterly to pass through the Cascade Tunnel (not the Stampede Pass Tunnel).

Property located north of Everett with 18 new train trips daily: Based upon all of the information and data gathered, in my opinion, the applicable range of diminition in value for **single family residences**, the property type expected to suffer the most severe impacts, has been concluded to range from **five to twenty percent** of market value. **Multi-family properties** as a whole, are considered to be less intensely impacted for reasons discussed in this report and would be expected to suffer a loss in market value ranging from **five to fifteen percent** of market value. It is anticipated that impacted **commercial properties** would experience loss in market value in the approximate **five to ten percent range**. Industrial properties, considered the least impacted of the property types overall, would be expected to suffer a **five to eight percent** range of loss in market value.

Property located south of Everett with 9 new train trips daily: Because the property south of Everett would experience half of the anticipated new rail traffic compared to property north of Everett, and because the nine trains south of Everett would all be fully loaded coal trains with no returning empty rail cars, the effects of pollution, coal dust and traffic would result in a decreased range of net overall impacts. In my opinion, the impacts for **all property types** considered would be approximately **three to five percent less** than the diminutions in value concluded for property located north of Everett, with a five percent threshold setting the lower end of the limit of measurable diminution in value for affected properties.

The suggested conclusions may not provide a reliable range of diminution in value for each and every property of a given property type in all possible situations that may be found, due to the fact that real estate is unique, and the variety of conditions that may be encountered are unlimited as they are "situation dependent." Therefore, the methodology and conclusions rendered in this report are intended to be viewed and used as general guidelines. Specific appraisals are suggested as the most effective means of providing defensible solutions to complex real estate problems. Solutions to complex valuation problems often rely upon subjective judgements based upon expertise that is primarily gained through familiarity and experience.

Although this report is not intended to be used to provide an aggregate loss in value for property that would be affected by the proposed increase in coal train freight rail traffic, it is felt that the total loss in value due to such influence would be substantial in terms of property market value and real estate tax revenues to taxing districts. The proprietary database provided and used in this assignment indicates a total of 21,548 tax parcels for properties identified as located within 600 feet of the BNSF main line railroad tracks in the subject area of interest, with a total aggregated assessed value of $26,556,663,168. If one were to assume these properties would suffer a loss in assessed value of one percent, the loss would be equal to approximately $265 million, which applied at a one percent millage rate is equivalent to an approximate $2,655,000 in annual tax revenue loss. In my opinion, the

effects and impacts of the additional freight rail traffic not only affect the properties within 600 feet of the main line, but also potentially affect property beyond this identified zone. At the very least, this information indicates that the aggregate losses to market value and tax revenues could be quite substantial.

This report is subject to the enclosed limiting conditions and has been prepared in conformity with, and subject to, the requirements of the Uniform Standards of Professional Appraisal Practice promulgated by the Appraisal Standards Board of the Appraisal Foundation. I hope this report addresses your needs and concerns. If you are in need of further assistance, please do not hesitate to contact me.

Respectfully Submitted,

Paul Zemtseff
Washington State Certified General
Real Estate Appraiser (1100208)

Partial List of Resources:

Gibson Traffic Consultants, Inc. "Memorandums Re: Cherry Point Commodity Export Facility Rail Operations for the Cities of Bellingham, Burlington, Mount Vernon, Stanwood, Marysville, Edmonds and Seattle" (August 15, 2011 through June 21, 2012).

Cascadia Center for Regional Development. *Seattle, WA - Vancouver, B.C. Cross Border Freight Rail Improvement Study Final Report #2010-CBRS-2*, June 30, 2011.

Washington State Department of Transportation. *Washington State Freight Rail Plan 2010-2030*, July 17, 2009.

Washington State Transportation Commission. *Statewide Rail Capacity and System Needs Study Final Report*, December 2006.

Wilbur Smith Associates. "Final Report: Cascade Gateway Rail Study", December 20, 2002.

The Working Group on Railroad Efficiency and Community Livability. "Transportation Futures: Rail Efficiency and Community Livability", A Report to the Western Governors' Association Task Force on Transportation Futures, August 1998.

Jaouhari, Abdellaziz El and Simons, Robert A. "The Effect of Freight Railroad Tracks and Train Activity on Residential Property Values", *The Appraisal Journal,* v. 72/3, Summer 2004, p. 223-233.

Federal Transit Administration Office of Planning and Environment. *Transit Noise and Vibration Impact Assessment,* FTA-VA-90-1003-06, May 2006.

You, Eun-chul. "Study on the Effects of Residential Environment Factors on the Prices of Apartment Household Units: Using a Computer Simulation and the Application of the Hedonic Pricing Model", Pan Pacific Congress of Real Estate Appraisers, Valuers and Counselors, Chicago IL, Appraisal Institute, 2006.

Hughes, William T., Jr. and Sirmans, C. F. "Adjusting House Prices for Intra-Neighborhood Traffic Differences", *The Appraisal Journal,* v. 61/4, October 1993, p. 533-538.

Futch, Michael. "Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles", November 11, 2011.

Julien, Benoit and Lanoie, Paul. "The Effect of Noise Barriers on the Market Value of Adjacent Residential Properties", *The Appraisal Journal,* v. 76/4, Fall 2008, p. 316-327.

Bell, Randall. "The Impact of Airport Noise on Residential Real Estate", *The Appraisal Journal,* v. 69/3, July 2001, p. 312-321.

Bell, Randall. "Airport Diminution in Value", A document submitted to the Orange County Board of Supervisors, January 9, 1997.

Frankel, Marvin. "Aircraft Noise and Residential Property Values: Results of a Survey Study", *The Appraisal Journal,* v. 59/1, January 1991, p. 96-110.

Booz-Allen and Hamilton. "The Effect of Airport Noise on Housing Values: A Summary Report, Prepared for the FAA's Office of Environment and Energy", September 15, 1994.

Crook, Eddie D., Cantrell, William F. and Pipkin, Lewis S. "Noise, We Have Heard It Before", *The Real Estate Appraiser and Analyst,* v. 49/3, Fall 1983, p. 51-56.

Hyde, James V., Jr. "The Appraiser's Approach to Noise Damage", *The Appraisal Journal,* v. 45/2*,* April 1977, p. 280-283.

Lewis, Harold J. "The Appraisal of Highway Noise Damages", *The Appraisal Journal,* v. 45/4, October 1977, p. 499-504.

Emerson, Frank C. "Valuation of Residential Amenities: An Econometric Approach", *The Appraisal Journal,* v. 40/2, April 1972, p. 268-278.

Theiss, William R. "The Appraisal Docket: Increased Noise as an Element of Condemnation Proceedings (Compensation, Schools and Homes)", *The Appraisal Journal,* v. 42/1, January 1974, p. 134-135.

Atherton, Edward B. "Appraising Noise Damages on Federal-Aid Highway Projects", *The Real Estate Appraiser*, v. 39/6, November/December 1973, p. 4-7.

Kern, Joe R. "Noise: Is it Compensable? How is it Measured?", *The Real Estate Appraiser,* v. 43/2, March/April 1977, p. 31-38.

Kennedy, John and Hill, Dennis. "Economic and Environmental Effects of One-Way Streets in Residential Areas", *The Appraisal Journal*, v. 39/4, October 1971, p. 562-567.

Nelson, Jon P. "Hedonic Property Value Studies of Transportation / Noise: Aircraft and Road Traffic", Pennsylvania State University Department of Economics, University Park, PA.

Barnes, William C. "Considerations in Value Findings for Avigation Easements", *The Appraisal Journal,* v. 42/3, July 1974, p. 441-447.

Nielsen, Donald A., Decker, Christopher S. and Sindt, Roger P. "Is Pollution a Homogeneous Determinant of Value?", *The Appraisal Journal*, v. 73/2, Spring 2005, p. 183-197.

Wilson, Albert R. "Emerging Approaches to Impaired Property Valuation", *The Appraisal Journal*, v. 64/2, April 1996, p. 155-170.

Sackman, Julius L. "Proximity Damages", *The Appraisal Journal,* v. 37/2, April 1969, p. 177-199.

Mundy, Bill. "Stigma and Value", *The Appraisal Journal*, v. 60/1, January 1992, p. 7-13.

CONSULTATION CERTIFICATION

I, Paul Zemtseff, certify that, to the best of my knowledge and belief:

The statements of fact contained in this report are true and correct.

The reported analyses, opinions, and conclusions are limited only by the reported assumptions and limiting conditions, and are my personal, impartial, and unbiased, professional analyses, opinions, conclusions and recommendations.

I have no present or prospective interest in the property that is the subject of this report, and I have no personal interest with respect to the parties involved.

I have performed prior appraisal services with regard to the property that is the subject of this report within the three year period immediately preceding acceptance of this assignment.

I have no bias with respect to any property that is the subject of this report or to the parties involved with this assignment.

My engagement in this assignment was not contingent upon developing or reporting predetermined results.

My compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this appraisal consulting assignment.

My analyses, opinions and conclusions were developed, and this report has been prepared, in conformity with the Uniform Standards of Professional Appraisal Practice.

I have made personal inspection of portions of the property that is the subject of this report.

No one provided significant real property appraisal or appraisal consulting assistance to the person signing this certification.

The reported analyses, opinions, and conclusions were developed, and this report has been prepared, in conformity with the Code of Professional Ethics and Standards of Professional Appraisal Practice of the Appraisal Institute

The use of this report is subject to the requirements of the Appraisal Institute relating to review by its duly authorized representatives.

As of the date of this report I have completed the Standards and Ethics Education Requirement of the Appraisal Institute for Associate Members.

I do not authorize the out-of-context quoting from, or partial or full reprinting of this consultation report.

Paul Zemtseff
Washington State Certified General
Real Estate Appraiser (1100208)

LIMITING CONDITIONS AND ASSUMPTIONS
APPRAISAL CONSULTING REPORT

1. This is an appraisal consulting report that is intended to comply with the reporting requirements set forth under Standard Rule 5 of the Uniform Standards of Professional Appraisal Practice. Report. The information contained in this report is specific to the needs of the client and for the intended use stated in this report. As such, it includes a summarized discussion of the data, reasoning, and analyses that were used in the appraisal process to develop the appraiser's opinion of value. The appraiser is not responsible for unauthorized use of this report.

2. LIMIT OF LIABILITY:
The liability of The Eastman Company and employees is limited to the client only and to the fee actually received by the appraiser. Further, there is no accountability, obligation or liability to any third party. If this report is placed in the hands of anyone other than the client, the client shall make such party aware of all limiting conditions and assumptions of the assignment and related discussions. The client agrees that in case of a lawsuit, any and all awards, settlements of any type in such suit, regardless of outcome, the client will hold appraiser completely harmless in any such action.

3. COPIES, PUBLICATION, DISTRIBUTION, USE OF REPORT:
Possession of this report or any copy thereof does not carry with it the right of publication, nor may it be used for other than its intended use.

The Bylaws and Regulations of the Appraisal Institute require each member and candidate to control the use and distribution of each appraisal report signed by such member or candidate; except as hereinafter provided, the client may distribute copies of this appraisal report in its entirety to such third parties as he may select; however, selected portions of this appraisal report shall not be given to third parties without the prior written consent of the signatories of this appraisal report. Neither all nor any part of this appraisal report shall be disseminated to the general public by the use of advertising media, public relations, news, sales or other media for public communication without the prior written consent of the appraiser.

Use of this appraisal by any party other than the party(ies) identified within this report, and for any other use or purpose(s) than the stated intended use, is expressly prohibited. The appraiser assumes no responsibility or liability for the use of this report, or any information contained herein, including the valuation conclusion, by any party not named as a user of this report.

4. CONFIDENTIALITY:
This appraisal is to be used only in its entirety, and no part is to be used without the whole report. All conclusions and opinions concerning the analysis as set forth in the report were prepared by the appraiser(s) whose signature appears on the appraisal report. No change of any item in the report shall be made by anyone other than the appraiser and/or officer of the firm. The appraiser and firm shall have no responsibility if any such unauthorized change is made.

The appraiser may not divulge the material (evaluation) contents of the report, analytical findings or conclusions, or give a copy of the report to anyone other than the client or his designee as specified in writing except as may be required by the Appraisal Institute as they may request in confidence for ethics enforcement, or by a court of law or body with the power of subpoena.

5. TRADE SECRETS:

This appraisal was obtained from The Eastman Company or related companies and/or its individuals or related independent contractors and consists of "trade secrets and commercial or financial information" which is privileged and confidential and exempted from disclosure under 5 U.S.C. 552 (b) (4). Notify the appraiser(s) signing the report of any request to reproduce this appraisal in whole or in part.

6. INFORMATION USED:

No responsibility is assumed for accuracy of information furnished by work of others, the client, his designee or public records. The data relied upon in this report has been thought reasonable; all are considered appropriate for inclusion to the best of our factual judgment and knowledge. An impractical and uneconomic expenditure of time would be required in attempting to furnish unimpeachable verification in all instances, particularly as to engineering and market-related information.

7. TESTIMONY, CONSULTATION, COMPLETION OF CONTRACT FOR APPRAISAL SERVICES:

The contract for appraisal, consultation or analytical service are fulfilled and the total fee payable upon completion of the report. The appraiser(s) or those assisting in the preparation of the report will not be asked or required to give testimony in court or hearing because of having made the appraisal, in full or in part, nor engage in post appraisal consultation with the client or third parties except under separate and special arrangement and at an additional fee. If testimony or deposition is required because of any subpoena, the client shall be responsible for any additional time, fees and charges regardless of issuing party.

8. CHANGES, MODIFICATIONS:

The appraisers and/or officers of The Eastman Company, reserve the right to alter statements, analysis, conclusion or any value estimate in the appraisal if there becomes known to us facts pertinent to the appraisal process which were unknown to us when the report was finished.

9. ACCEPTANCE OF, AND/OR USE OF, THIS APPRAISAL REPORT BY CLIENT OR ANY THIRD PARTY CONSTITUTES ACCEPTANCE OF THE ABOVE CONDITIONS. APPRAISER LIABILITY EXTENDS ONLY TO STATED CLIENT, NOT SUBSEQUENT PARTIES OR USERS, and it is limited to the amount of fee received by appraiser.

EDUCATION

Bachelors of Science Degree in Finance/Real Estate from the College of Commerce and Business Administration, University of Illinois at Urbana, Champaign, 1979.
Masters in Business Administration from DePaul University, Chicago, 1984.

Appraisal Institute (Including former American Institute of Real Estate Appraisers and Society of Real Estate Appraisers Courses):

- 101 – An Introduction To Appraising Real Property
- 1BA & B – Capitalization Theory and Techniques, Parts A & B
- 2-1 – Case Studies In Real Estate Valuation
- VII – Industrial Valuation
- SPP A & B – Standards of Professional Practice, Parts A & B
- 540 – Report Writing and Valuation Analysis

University of Illinois:

- Real Estate Principles
- Real Estate Finance
- Valuation Theory and Methods
- Urban and Regional Economics

Numerous additional ongoing, continuing-education courses – often related to various specialty aspects of right-of-way and partial interest appraisal.

EMPLOYMENT HISTORY

Appraiser and consultant with the Eastman Company from 1991 through the present (currently principal).
Self-employed real estate appraiser and consultant during 1986 through 1991 working for various clients – firms and individuals.
Staff appraiser for Real Estate Analysis Corporation, Chicago, from 1979 through 1986.

APPRAISAL EXPERIENCE

Property types appraised include commercial, industrial, vacant, special purpose, and multi-family and single family residential for assessment, mortgage, estate, purchase and condemnation (right-of-way and easement) purposes. Appraisal assignments have included apartments/duplex complexes (4-350 units), office and medical office buildings, shopping centers, grocery and retail stores, department stores, restaurants, hotels/motels, automobile dealerships, nursing homes, subdivisions, mobile home parks, service stations, bowling centers, manufacturing plants and factories, truck terminals and warehouses.

Approximately 20 years of right-of-way and acquisition appraisal experience (partial takes of all types), as well as in reviewing appraisals (both Eastman Company and outside appraisals). Specialty appraisal expertise in valuing acreage and properties with environmentally critical features and hazards, generally affected by environmentally critical area zoning ordinances. These difficult-to-develop properties have often consisted of steeply sloping sites, many of which have been improved with a wide variety of residential and/or commercial improvements.

COURT EXPERIENCE

Qualified as an expert witness and have testified in the Superior Court of the State of Washington.

CERTIFICATIONS

Washington State Certified General Real Estate Appraiser, License Number 1100208

PROFESSIONAL AFFILIATIONS

Associate Member of the Appraisal Institute
Listed as a Washington State Department of Transportation approved appraiser and reviewer

VALUATION CONSULTATION
INCREASED COAL TRAIN TRAFFIC AND REAL ESTATE VALUES ©

A study of the potential impact of increased coal train traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA

As of
October 30, 2012

For
Mr. Ross Macfarlane
Senior Advisor, Business Partnerships
Climate Solutions

By
Paul Zemtseff

THE EASTMAN COMPANY
925 North 130th Street
Seattle, Washington 98133
(206) 363-6611

File No. 2036.1

© 2012, Paul Zemtseff. No part of this document may be reproduced without written permission from the author.

Entrepreneur

The effect of freight railroad tracks and train activity on residential property values.

By Robert A. Simons & Abdellaziz El Jaouhari | Summer, 2004

Appraisal Journal

abstract

This study evaluates the impact of freight railroad tracks on housing markets. A hedonic price model is used to estimate reduction in the sale price of residential properties near freight railroad tracks in Cuyahoga County, Ohio for 1996 and 1999. The findings indicate an average loss in value between $3,800 and $5,800 (5%-7%) for houses under 1,250 square feet located within 750 feet from a railroad track. Larger houses showed mixed results. After substantial publicity about a freight train company merger, freight trip counts showed a negative and statistically significant impact on the sale price of smaller houses, and some larger houses, for each additional daily freight train trip.

****

The benefits of transportation in linking markets and generating positive externalities are well established in economic theory. Access to transportation links, such as highway interchanges, airport hubs, train stations, and boat landings, is a positive factor. However, being too close to transportation uses that are far away from access links can have a negative effect on property values due to the nuisance and potential problems of accidents. This is particularly true for railroads that crisscross the country carrying freight and have very few access points. For freight railroads, the access points are not directly used by residential property owners. In addition, there is train noise and whistle blowing as the trains pass by, the fear of accidents exists, and potential for other related nuisances. The main questions addressed by the research here are how much markets discount houses near railroad tracks and whether the discount decreases with distance from the track and less freight trip volume.

Variables Related to Railroad Freight Lines

Periodically, train companies merge and consolidate track activity; sometimes this can lead to changes in trip volumes on specific segments. Because proximity to train tracks is considered a nuisance, nearby property values can be affected. The effect could be related solely to proximity or to the volume of activity (e.g., freight train cars passing by the property). Effects may also be more pronounced on properties adjacent to where the freight lines cross streets. Also, if trip counts change due to rerouting, would there be any differential effect on property values? This study finds that rail traffic, as opposed to simply proximity to tracks, makes a difference in the sale price of residential properties. Further, publicity is found to increase public awareness of this issue.

In the Cleveland, Ohio area in the mid- to late-1990s, CSX Corporation (CSX) and Norfolk Southern Corporation (Norfolk Southern) decided to reorganize and acquire another railroad, Consolidated Rail Corporation (Conrail). An environmental impact statement (EIS) was done to determine track reconfiguration. Freight trip counts on various segments were scheduled to change. Beginning in 1997, there was a lot of publicity regarding the reconfiguration, and the railroad lines negotiated with various cities about the impacts of the train reconfiguration on property values. Cities received millions of dollars, but none of the money went toward property damage awards. By 1999, the EIS process had been completed and changes to track volumes had been implemented.

This study examines the "before" and "after" of the reconfiguration in freight railroads in Cuyahoga Count, Ohio, and comments on the inclusion of property damage awards in a process of this type. The study focuses on the effect of freight-carrying railroad tracks on single-family housing in Cuyahoga County, Ohio, which includes a total of 15 rail segments with over 50 miles of track. After a review of the extant literature, this article discusses the study area, data collection, and variables. Size-stratified hedonic regression models of the county residential real estate market are developed, and the proximity to railroad tracks is tested in various forms. The results are presented, as well as conclusions and implications for appraisers.

Overview and Literature Review

This study was inspired, in part, by a project done in a graduate urban planning class on the factors affecting the desirability of an urban neighborhood. A questionnaire was administered in person to 105 prospective homebuyers of inner-city homes on the near-west side of Cleveland, Ohio, during the summer of 2000. The questions mainly related to neighborhood characteristics that could have a positive or a negative effect on housing values. Residents were asked to weigh their willingness to live close to various urban factors (e.g., an auto junkyard, interstate, railroad tracks, city park) on a seven-point scale, where -3 was strongly negative and +3 was very desirable. The results of the questionnaire are shown in Table 1.

The least desirable site characteristics were junkyard (-2.81), leaking underground storage tank (LUST) (-2.71), and factory (-2.60). Living next to a train track had the next most negative score of -2.07, closely followed by proximity to a highway and main street (both about -1.9). Scores ranged up to +2.2 for lake views. (1)

Effects of Other Linear Urban Uses on Residential Property

Roads are a linear land use similar in some ways to railroad tracks. Hughes and Sirmans found a significant 1% negative change in residential property values for each 1,000 annual average daily traffic (AADT) in city areas, and a 0.5% change per 1,000 AADT in suburban areas in Baton Rouge, Louisiana. (2) A related study by the same authors showed an 11% decrease in value for houses on high traffic streets, compared with low traffic streets. (3) However, this study did not explicitly control for street design. This same research also showed an average reduction of 0.8% in property values per 1,000 AADT. (4) For a typical collector street with 5,000 to 10,000 more trip counts per day than a purely residential street, this would equate to a 5%-10% reduction in property values, holding all else constant.

Another linear and visible type of land use that is somewhat similar to railroad tracks is high-voltage overhead electrical transmission lines (HVOTL). Studies by Colwell, and Kinnard and Dickey showed a significant reduction of 5%-8% in residential property values within a few hundred feet of the transmission lines. (5) Another use similar to trains in its linearity is pipelines. In a study of the effect of a pipeline rupture on non-contaminated residential property on the pipeline easement in Fairfax County, Virginia, Simons estimated that single-family housing experienced a loss in value of 4%-5% after the rupture. (6)

Rail Impact Studies

Noise, especially from train horns, is the primary negative externality generated by train traffic. A study by Rapoza, Rickley, and Raslear (7) found that residents living within 1,000 feet of a railroad track were severely annoyed by train horns. Consistent with this unsurprising finding, many communities have enacted regulations to ban the use of train horns especially during nighttime hours to reduce the interference of train noise with the comfort of local residents. However, numerous studies funded by the Federal Railroad Administration (FRA) have proven that banning train horns increases fatalities and that the bans are costly to both residents and railroad companies. (8)

The FRA's numerous studies on the impact of noise on communities have also evaluated the effectiveness of warning systems, specifically the wayside train horn at crossing sections. A study conducted by the U.S. Department of Transportation and the FRA indicated that the use of railroad horns in addition to wayside horns could reduce accidents by 69%. The same study surveyed actions taken by residents to reduce the interference of noise with their daily activities. While most residents, as reported by the study, would stop talking or close windows, 14% considered moving. (9)

Most studies measure the frequency and level of noise to assess their impact on residents or property values. Few studies have examined the effect of proximity to a railroad track in terms of distance. Clark used distance from a railroad track to measure loss in property values for the mostly rural districts of Middletown and Niles in Ohio. (10) The findings indicate property values decreased by 2.1% in Middletown and 2.8% in Niles for every additional rail line within a buffer of 1/4 mile. The loss is

even higher for properties located near a crossing section where the use of train horns is more frequent. Another study in Oslo, Norway, looked at the relationship between tracks and residential sale price, based on pure proximity. Residential sale price decreased by up to 7%-10% within 100 meters (about 330 feet) of a railroad track. (11) These results were derived from both hedonic modeling and a type of contingent valuation analysis done by real estate salespeople.

To summarize, the benefits of railroad transportation in connecting markets are well established in economic theory but there is still a tension between the need for safety and the need to reduce the level of annoyance generated by railroad activities. Based on previous train studies and the negative effect on property values from other similar urban land uses, property value decreases in the single digits are expected from trains and train traffic.

Railroad Merger in Cleveland

Railroads sometimes merge and consolidate. As previously noted, in Cleveland this began in 1997 as CSX and Norfolk Southern sought to combine operations, acquire Conrail, and streamline and consolidate track utilization in Cuyahoga County. The negotiations were accompanied by an environmental impact statement that examined reconfiguring lines and train volumes. Trip counts on various segments ranged from 0-75 trips per day before the merge, with 15-30 trains per day being typical. The reconfiguration was finalized and operational by 1998. As a result, some lines experienced substantial reductions in traffic (e.g., from 50 per day down to 5 per day), some increased (10 to 45 per day), while other segments remained the same. (12)

COPYRIGHT 2004 The Appraisal Institute Reproduced with permission of the copyright holder. Further reproduction or distribution is prohibited without permission.

Copyright 2004, Gale Group. All rights reserved. Gale Group is a Thomson Corporation Company.

NOTE: All illustrations and photos have been removed from this article.

Copyright © 2010 Entrepreneur Media, Inc. All rights reserved. Privacy Policy

Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles

Michael Futch*

November 11, 2011

Abstract

This paper measures the impact of infrastructure expansion on local home values and examines the persistence of that impact over distance. Specifically, I exploit a natural experiment in which rail traffic from the Los Angeles seaport, one of the busiest in the country, was permanently redirected from several tracks to a central line, termed the Alameda Corridor. I link a rich, repeat-sale housing dataset to plausibly exogenous changes in local rail traffic to estimate these effects, controlling for local price trends using a Case-Shiller style housing index. Using the actual traffic changes the result is an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. The welfare impact of concentrating a negative externality on a smaller population should depend on the convexity of the cost function, but I find evidence that suggests the marginal cost is symmetric for winners and losers. Instead, the total welfare impact hinges on the efficiency gains achieved by relocating the traffic from circuitous routes to the more direct Alameda Corridor, thereby affecting fewer homeowners. While the net gains are minimal, the re-routing of traffic resulted in a transfer of housing wealth of approximately $200 million.

*Email: mfutch@ucsd.edu. I would like to thank Craig McIntosh, Gordon Dahl, Paul Niehaus, Mark Jacobsen, Josh Graff Zivin and UCSD seminar participants for their helpful comments.

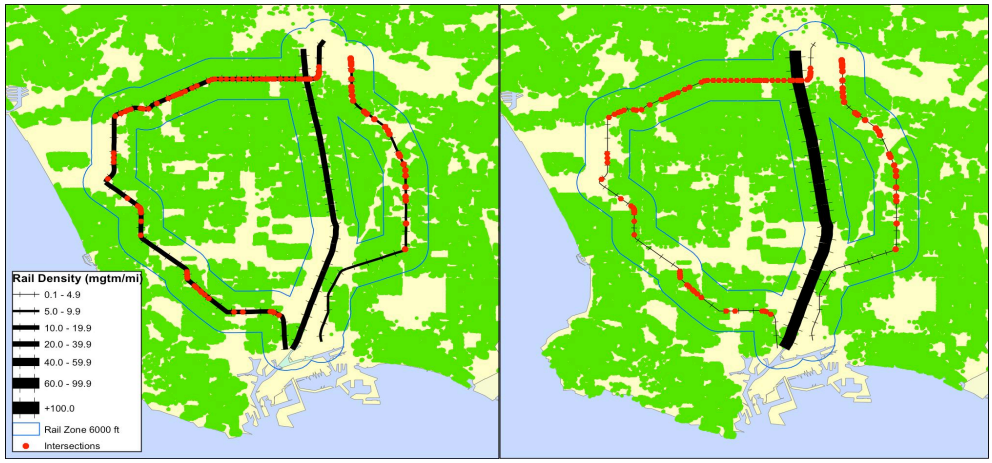
1 Introduction

Economic reforms often do not benefit everyone involved; instead, there are typically winners and losers. Identifying who wins and who loses and by how much is important when evaluating policy options especially because many of the groups affected often do not have representation at the negotiating table. This process is further complicated when policy actions impact groups or individuals external to the original intent of the policy.

This is particularly true of public infrastructure projects. Causal identification of public infrastructure impact is often challenging as the location is rarely random and may correlated with wealth and political clout. Using year to year changes in the intensity of an externality is also problematic as these changes are also likely to be correlated with local growth patterns. When concentrating a negative externality on a segment of the population it is important not just to measure the marginal effect at a point, but to understand the convexity of the cost imposed on individuals. If the marginal cost of the externality were increasing, this would suggest distributing the exposure to the externality among as many people as possible. If the marginal cost were decreasing, a case could be made for concentrating greater amounts of a negative externality on a smaller population.

This paper examines these issues in the context of urban rail in Los Angeles. This setting offers an attractive natural experiment, solving some of the identification issues discussed above by exploiting a shift in the way rail traffic travels through the city. The Alameda Corridor, an urban infrastructure project in Los Angeles, allowed for consolidation of most freight rail traffic into and out of the San Pedro port facilities from three geographically distinct tracks into one higher capacity line. Figure 1 depicts the level of rail traffic in the region before and after the opening of the Alameda Corridor. Rail traffic involves negative environmental spillovers onto local communities in the form of air and noise pollution, along with congestion effects caused by long waits at rail crossings. Because the rail traffic involved is freight and not transportation, there are fewer demand-side effects that could cause upward or downward pressure on housing values apart

Figure 1: Rail Traffic Density - Before and After



from the pollution and congestion caused by rail traffic alone. Most interestingly, the change in the flow of rail traffic was approximately zero-sum overall, providing a very straightforward window on the extent to which a redistribution generated net social gains or harm.

This setting allows me to directly measure the distribution of an externality using the cost inflicted on homeowners, exploiting substantial variation (both upwards and downwards) in the intensity of the externality. Many papers relate the existence of an externality to house prices, but most lack the data to clearly identify the costs actually induced by the environmental harm. I find that an increase in rail traffic by 10 million gross ton miles per mile (MGTM/mi) causes a 0.7 percentage point lower growth in home values within a 1/3 mile band around the tracks. Furthermore, under a stronger set of assumptions our results suggest that the response of property values is linear in the degree of damage in both positive and negative directions for an identical size change, indicating that a zero-sum redistribution of environmental damage has no overall effect on total welfare. Using the actual traffic changes this results in an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. Aggregating our estimates over the number of homes affected yields a net home value increase of $23 million - a negligible sum considering the total housing value for homes inside the one-mile zone was roughly $36 billion in 1997.

The rest of the paper is organized as follows: Section 2 discusses identification strategies and the data available, Section 3 outlines the estimation strategy and counterfactual selection, Section 4 presents the estimating equations, Section 5 discusses the results, and Section 6 concludes.

2 Identification Strategy and Data

2.1 Causal Identification Issues

While understanding the impacts of public infrastructure on local communities is of much interest, clean causal identification is typically difficult or impossible in many circumstances. The first hurdle to causal identification is due to the non-random nature in which locations are chosen for infrastructure. If the location for a project, say a new railroad track, is chosen based on unobservable factors that are related to the outcome of interest, OLS estimates of the treatment effect will be biased. There have been many papers that have taken this approach using cross-sectional data: Espey and Lopez (2000) and Cohen and Coughlin (2006) both look at the impact of airport proximity on housing values. Kim, Phipps, and Anselin (2001) use a cross section of home values and to measure the impact of air pollution on housing prices in South Korea. Chay and Greenstone (2005) look at air pollution and housing values, but circumvent this identification hurdle by instrumenting for air pollution using regulation changes triggered by county pollution levels.

If the housing data available spans several time periods, it could be tempting to use changes in pollution or changes in the external costs of public infrastructure (greater freeway or airport traffic) to identify the causal impact on house price changes. However, changes in infrastructure intensity or air pollution are likely to be correlated with other important variables that may drive the outcome measure. Greater freeway traffic may negatively impact nearby home values, but that increased traffic may be a result of higher employment in the city center which could drive up home prices. If causal effects are to be identified using changes in the externality, an argument

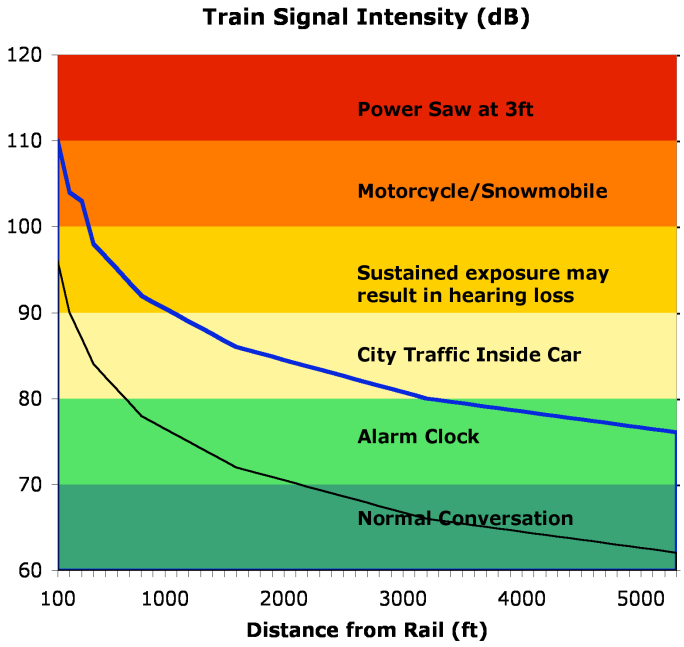
must be made for the exogeneity of the changes. If the changes are not exogenous, an instrumental variables or a natural experiment approach could be used if possible. Currie and Walker (2010) use a repeated cross section data set to exploit the creation of EZ-Pass toll lanes to find the impact of automobile congestion and poor birth outcomes. The main results of their paper are focused on health outcomes, but they do look for house price impacts and find none.

A housing data set that includes repeated sales of the same property is especially attractive once the exogeniety issues have been ironed out. Repeat sale data are useful because they allow better control of individual house idiosyncrasies. There have been several recent papers that utilize repeat sale data to estimate the impact of some spatially sourced event. Case et al. (2006) looks at the effect of water contamination on home prices. Cutter et al. (2009) follow a similar approach but look at the positive impact of open space preserves on home prices and raise the issue of finding the appropriate counterfactual. They craft an appropriate counterfactual using matching methods of Ho, Imai, King, and Stewart (2007). The data Case et al. use has a narrow time window before the sudden water contamination, so there is little opportunity to gauge the appropriateness of the counterfactual house trends.

2.2 Natural Experiment

This paper exploits a natural experiment to avoid the common identification pitfalls highlighted in the previous section. The setting for the natural experiment is freight rail traffic between the Los Angeles/Long Beach port complex and transfer facilities near downtown Los Angeles about 20 miles away. The Los Angeles and Long Beach seaports rank first and second in terms of container traffic into and out of the United States and combined comprise the fifth busiest port in the world. Until recently, much of that traffic passed through the city of Los Angeles on a collection of low speed rails to reach Union Pacific and BNSF transfer facilities. From there containers continue on to destinations throughout the United States. In April 2002, the Alameda Corridor opened,

Figure 2: Bounds on Rail Noise Decay



connecting the port facilities to the rail yards by a more direct and higher capacity track. Also installed were a series of bridges, trenches, and underpasses at intersections with the purpose of eliminating more than 200 street level crossings. The goal of the $2.2 billion Alameda Corridor project was to increase the speed at which cargo travels through the port and to reduce the noise and traffic congestion caused by slow freight trains at street level. The opening of the Alameda Corridor should have reduced air and noise pollution in neighborhoods near the tracks through reduced rail traffic and fewer idling automobiles at railroad crossings. Upper and lower bounds on the noise decay from train signals are plotted in Figure 2, illustrating the potential noise impact fading to conversation level after approximately one mile.

The shift in rail traffic induced by the Alameda Corridor was a structural redistribution that decreased traffic along two of the three main routes between the port and the transfer facilities increased traffic on the third line. This exogenous redistribution is used to identify the causal impact of pollution and congestion from freight traffic on local home prices. The spatial shift can be seen clearly in Figure 1 while the annual changes are plotted in Figure 4. The y-axis in

Figure 4 is the rail density code indicating the level of rail traffic as reported by the Federal Rail Administration and the year is on the x-axis. The west and east rails are the non-corridor rails where traffic decreased, while the center graph shows the sharp spike in traffic on the Alameda Corridor after the completion of the project.

2.3 Timing of Experiment and Perfect Foresight

Consolidation of the three rails into one higher speed track had been a topic of discussion in Los Angeles since the early 1980s, but did not become a reality until the late 1990s. Because the Alameda Corridor required nearly five years of construction before it opened in 2002 it is unlikely that homeowners near the corridor were taken by surprise when rail traffic skyrocketed after the opening. Due to the premeditated nature of this intervention, I am likely to see the impact begin to be capitalized into house prices before the actual opening of the corridor. The housing data available begin in 1995, before funding was secured or construction commenced, allowing capture of the full treatment period.

2.4 Housing Data

The housing data from DataQuick include all home sales in ZIP codes within 25 miles of the rails. The data set includes parcel number, address, sale price, sale date, lot size, bathrooms, bedrooms, and square feet. The data span the years 1995 to early 2009 and contain nearly 400,000 households that appear more than once - allowing for creation of a rich panel data set. The data is geolocated using the address and a streetline GIS file. After geocoding the housing data, a number of additional variables can be linked to each house including distance from rail lines, proximity to rail crossings, and Census block/tract.

Table 1 displays summary statistics for housing sales in the different rail zones. A house is considered to be in a rail zone if it is within one mile of the affected rail. This distance will be broken out into smaller increments in later analysis. Homes in the rail zones are on average smaller

Table 1: Home Sale Summary Statistics: 1995-2009

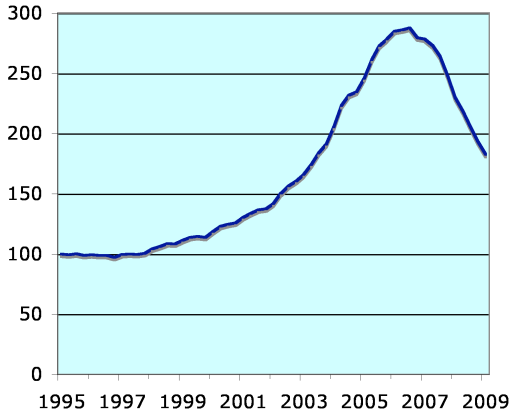
	Sales	Price	Sq. Feet	Beds	Baths
Corridor Zone	10,991	171,705	1,165	2.67	1.46
West Rail Zone	33,222	276,197	1,392	2.80	1.89
East Rail Zone	19,634	208,478	1,246	2.64	1.63
Greater LA	519,258	356,324	1,582	2.84	2.05

Table 2: Difference-in-Difference Estimates

One Mile Bands		Incremental Bands DID	
Log Price in Corridor Before	11.68	Corridor 0 - 1/3 mile	-0.033
Log Price in Corridor After	12.29		(0.015)**
Difference	0.61	Corridor 1/3 - 2/3 mile	-0.025
Difference-in-Difference w/ LA	-0.018		(0.013)**
Standard Error on DID	(0.008)**	Corridor 2/3 - 1 mile	-0.002
			(0.013)
Log Price in Non-Corridor Before	12.03	Non-Corridor 0 - 1/3 mile	0.034
Log Price in Non-Corridor After	12.67		(0.010)***
Difference	0.64	Non-Corridor 1/3 - 2/3 mile	0.002
Difference-in-Difference w/ LA	0.013		(0.009)
Standard Error on DID	(0.006)**	Non-Corridor 2/3 - 1 mile	0.012
			(0.009)
Log Price in LA Before	12.32		
Log Price in LA After	12.95		
Difference	0.627		
Standard Error on Difference	(0.002)***		

and less expensive compared to homes in the rest of the city. Among the rail zones, the homes around the Alameda Corridor tend to be the smallest and least expensive. The differences in value and size of the homes in different zones highlight the need for care in controlling for localized price trends. As motivation for further study of home price trends in the rail zones we provide a simple difference-in-difference in Table 2. This table shows that the prices for homes within a mile of the Alameda Corridor, where rail traffic increased considerably, grew about 1.8 percent slower than homes in the rest of Los Angeles. The negative effect was also stronger for homes closest to the rail as can be seen when the one mile zone is broken into increments. For homes nearest to the non-corridor rails, where traffic was decreased, home prices outpaced the rest of Los Angeles by 1.3 percent. Again, the effect is strongest for homes nearest to the rail. Using the rest of Los Angeles as the counterfactual may not be correct and this will be explored later, but the simple difference in difference result motivates further inquiry.

Figure 3: Los Angeles HPI (1995=100)



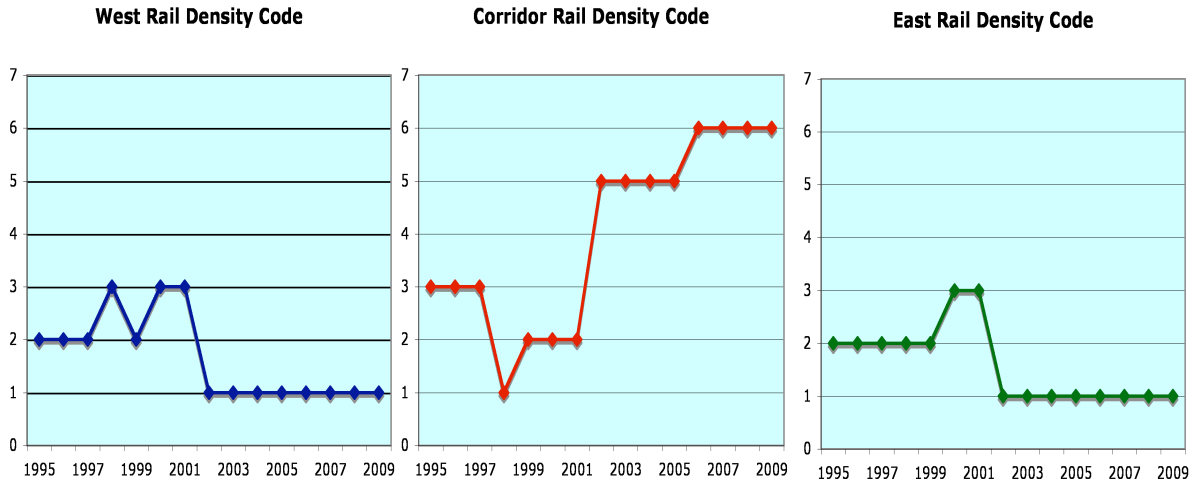
2.5 Housing Boom and Bust

The period under examination here contains the growth and subsequent popping of the house price bubble in the United States. Home prices in Los Angeles were not exempted from this phenomenon in the slightest. Figure 3 shows the rapid price growth witnessed in Los Angeles during the late 1990s and early 2000s and an equally rapid decline in prices when the bubble burst in 2006. The volatile nature of home prices during this period is even more reason to be careful when choosing a counterfactual set. Additionally, we want to be sure that our estimates are not being driven by the unusual events of the time period. We will report estimates that include the entire time period, boom and bust, and as a robustness check we restrict the sample to the period directly after the opening of the Alameda Corridor and drop transactions that occurred during the crash.

2.6 Rail Traffic Data

Rail traffic data are provided by the National Transportation Atlas published by the Bureau of Transportation Statistics. The data include a GIS map of the rail network along with a categorical measure of rail traffic density for each rail segment from 1995 to 2006. Rail density is a measure of the gross ton-miles of cargo traveled over a section of rail, divided by the length of the rail segment.

Figure 4: Annual Rail Traffic Density



For example, if a 100 mile track had only one gross ton of cargo traveling its length it would have a density of one gross ton mile per mile. A shorter track with the same number of gross ton miles would clearly have a much higher density. While not a perfect measure of the number of trains traveled, we believe it is an excellent proxy.

3 Estimation Strategy

3.1 Repeat Sale Framework

To estimate the causal impact of an increase in rail traffic on local home values we begin with the assumption that home prices follow a hedonic price function:

$$p_{i,t} = \alpha_i + \tau_t + \beta DEN_{i,t} * Proximity_i + \eta' x_i + u_{i,t} \tag{1}$$

where $p_{i,t}$ is the log price of home i at time t, τ_t is the local home price index at time t, $DEN_{i,t}$ is the rail density of the nearest rail interacted with some indicator for proximity to the rail, and x_i is a vector of home characteristics. Because our data contain repeated observations we can difference this equation with its previous sale, eliminating individual home idiosyncrasies and giving us the

following equation:

$$\Delta p_{i,t} = \Delta\tau_t + \beta\Delta DEN_{i,t} * Proximity_i + v_{i,t} \tag{2}$$

The term $\Delta\tau$ represents the change in the local house price index between time t and the period in which the home was last sold. In order to estimate β we will need to first identify the appropriate counterfactual group, then use the methods pioneered by Case and Shiller (1987) to estimate local house price trends and find fitted values $\widehat{\Delta\tau_t}$ for each home sale. If a home was sold in 1995Q2 and again in 1999Q4, the fitted value for $\Delta\tau$ for that home will yield the expected price change for a home that sold in those time periods if the rail traffic pattern had not changed. The x_i could contain time-varying characteristics capturing home remodels or additions, though our housing characteristic data are limited in this respect and do not vary over time.

3.2 House Price Index Calculation

To control for counterfactual price changes and to evaluate whether a set is an appropriate counterfactual we estimate Case-Shiller style house price indices. Standard repeat sale estimation begins with log home price as the dependent variable and an indicator for time period sold on the right hand side of the equation.

$$P_i = \gamma + \tau_1 T_{i,1} + ... + \tau_n T_{i,n} + u_i \tag{3}$$

We arrive at the estimating equation by taking a first difference:

$$\Delta P_i = \tau_1 \Delta T_{i,1} + ... + \tau_n \Delta T_{i,n} + v_i \tag{4}$$

so that a home sold first in period s and subsequently in period t would have a value of 1 for $\Delta T_{i,t}$ and a value of -1 for $\Delta T_{i,s}$. The predicted log price change would then be given by $\hat{\tau}_t - \hat{\tau}_s$

or, fitting with earlier notation, $\Delta\tau_t$. The τ coefficients are estimated using GLS, applying the standard heteroskedasticity correction for differing lengths of time between sales.

3.3 Selection of Counterfactual Set

Measuring the impact of rail traffic on housing prices requires an appropriate counterfactual to control for local price trends. House price trends are location specific, so the overall trend in a city or region may not be a good predictor of changes in a neighborhood. Other approaches have used matching methods to create a counterfactual group that resembled the affected homes in physical attributes. The approach taken here is to create a house price index (HPI) using homes that closely follow the pre-treatment trend in the rail zones, but are outside the one mile radius that we use to define the rail zone. The house price index can then be used to generate predicted values for the expected price change.

To find an appropriate counterfactual for homes in the affected rail zones we first compare the house price index for Los Angeles in general with the indices generated by homes in each zone. This is accomplished by running the standard repeat sale estimation equation and also interacting the housing index regressors with indicators for the relevant zone. If homes in each zone follow the same house price trend as the rest of the city, the difference in coefficients for each time period before the treatment should be insignificant. These differences are plotted for each zone in Figure 5. Panel (a) shows the difference between HPI coefficients for the west zone versus those for the rest of Los Angeles, panel (c) shows the same difference but for homes in the east zone, and finally panel (e) shows the differences for the corridor zone versus the rest of Los Angeles. Each of the three zones show statistically different house price index coefficients from Los Angeles as a whole. This is especially true for the east and corridor zones in panels (c) and (e). This indicates that using home prices for the rest of Los Angeles is not going to provide the correct counterfactual changes.

As an alternative to using city-wide trends as the counterfactual, we propose using homes in the "marginal" rail zone, homes one to two miles from each affected rail. To test the validity of this counterfactual group we follow the same method as before. The difference in coefficients for each zone and its marginal zone are plotted in panels (b), (d), and (f) of Figure 5. In each case the HPI coefficients are statistically indistinguishable from those for the accompanying marginal zone - confirming that the marginal zones are indeed providing the correct counterfactual changes. For the remainder of the paper, the marginal zones around each rail will be used to produce fitted values to control for counterfactual changes in the absence of the rail shift, though using the city of Los Angeles as the counterfactual instead does not fundamentally alter the results.

4 Estimation

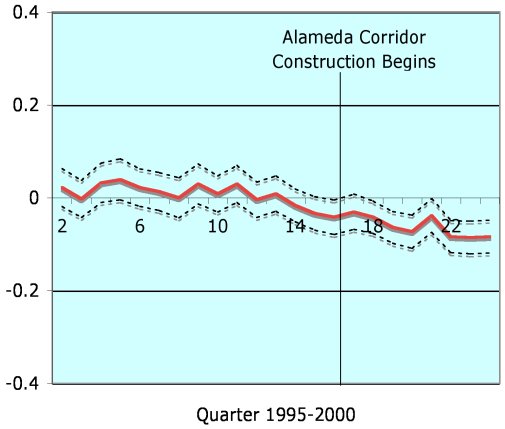
This section presents the basic estimation equations for measuring the impact of rail traffic density. While the rail traffic density decreased in the east and west zones and increased in the corridor zone, the coefficients on each density change regressor below are all expected to be negative reflecting the disamenity value of rail traffic in a neighborhood. The magnitude of the coefficients should be decreasing in absolute value as the distance from the rail increases, as homes further from the track are likely to experience lower noise, pollution, and congestion. In each specification below, the log price change for a home is regressed on the change in rail density, the predicted house price based on the relevant WRS index, and a vector of seasonal and neighborhood dummies. The method for choosing a predicted house price will be addressed in the following section.

4.1 Model 1 - Baseline

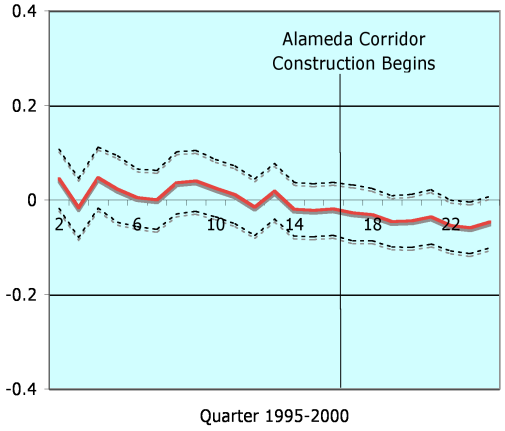
The first model examines the impact of the rail traffic changes in 1/3 mile-incremental bands around each affected rail without distinguishing between the Alameda Corridor and the other two rails. The assumption that all rail traffic affects home prices in the same way will be relaxed in later

Figure 5: HPI Coefficient Differences and 95% Confidence Bands on Point Estimates

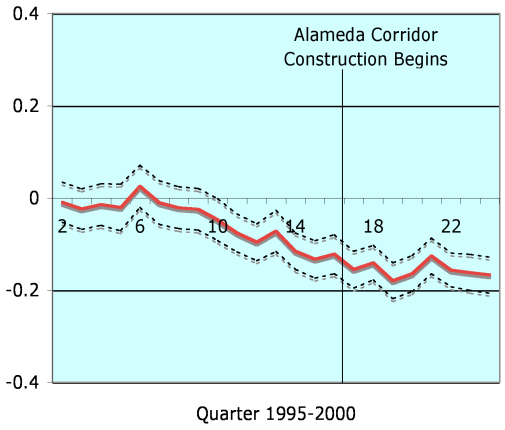
(a) West vs. LA



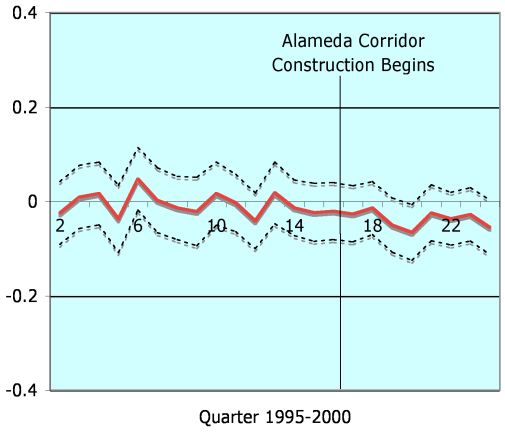
(b) West vs. Marginal West



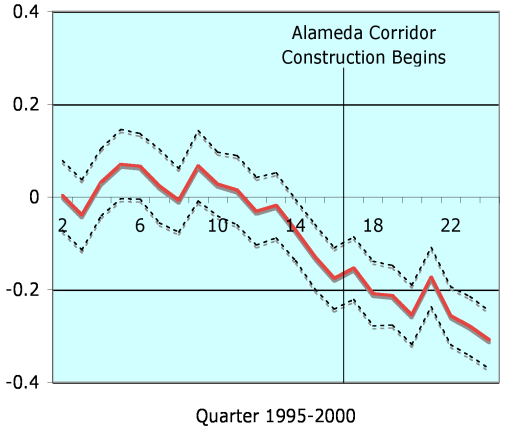
(c) East vs. LA



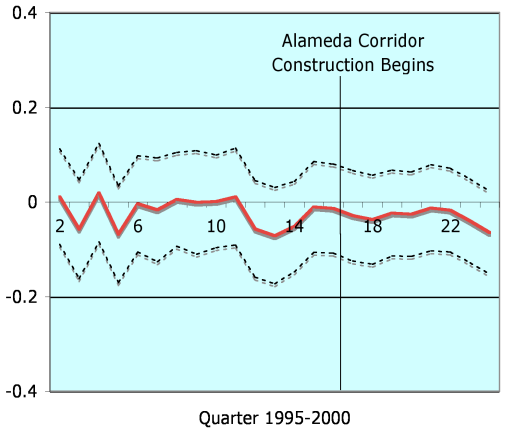
(d) East vs. Marginal East



(e) Corridor vs. LA



(f) Corridor vs. Marginal Corridor



analysis.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \beta' x_i + u_i$$

The format for regressors indicating the zone in which the house is located is as follows:

$$AnyRail_{1,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (0,\ .33) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{2,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.33,\ .67) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{3,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.67,1) \\ 0 & \text{otherwise} \end{cases}$$

4.2 Model 2 - Railroad Crossing Increments

The second specification includes an indicator for proximity to railroad crossings. Federal law requires trains to sound their horn when approaching street crossings, which is likely to augment the already negative impact of train traffic through a neighborhood. Train signals are required to be heard between 96 and 110 dB from a distance of 100 feet. Figure 2 displays lower and upper bounds on the sound decay of a train signal as you move further away from the track. Because the Alameda Corridor was constructed using a series of trenches and bridges, railroad crossings only exist on the east and west rail lines. This model divides the intersection zone into 500 foot increments to explore how the impact of rail density evolves with distance around these intersections. Each home in the intersection crossing zone will also be located in the zone closest to the rail, so the full effect of a density change for these houses will be the sum of ψ_1 and λ. As with the incremental zone variables, the impact of the traffic change at an intersection is expected to fade with increased distance.

$$\Delta P_i = \gamma\widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * (Crossing_{j,i} * AnyRail_{1,i}) + \beta' \bar{X}_i + u_i$$

4.3 Model 3 - Heterogeneous Rail Traffic Impacts

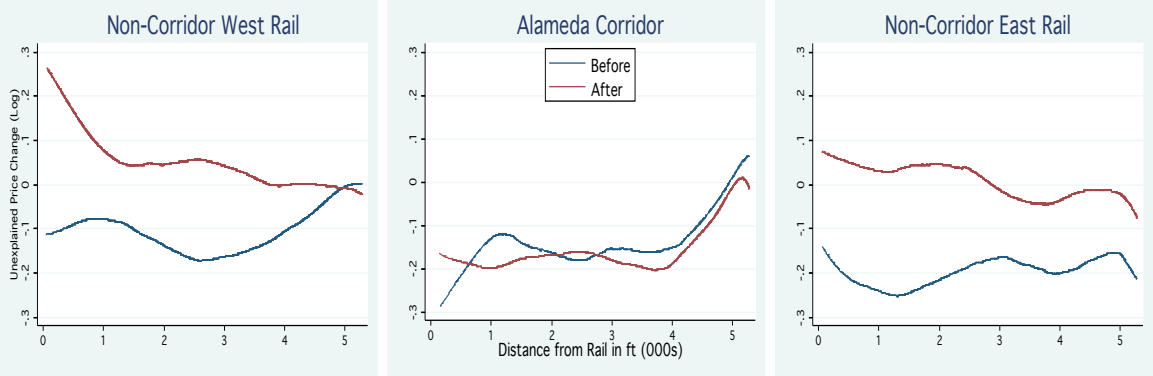
Part of the intent for the Alameda Corridor was to move containers through the city without the need for rail crossings. This was accomplished through a series of bridges, trenches and underpasses. To allow for heterogeneous impacts from rail traffic density, the previous two models are expanded to distinguish between corridor and non-corridor rail traffic. The non-corridor traffic will be further disaggregated by geography.

$$\Delta P_i = \gamma\widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * NonCorr_{j,i} + \sum_{j=1}^{3} \phi_j \Delta DEN_i * Corridor_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * Crossing_{j,i} + \beta' \bar{X}_i + u_i$$

5 Results

5.1 Locally Weighted Regressions

Before presenting the full regression results, inspection of Figure 6 helps to motivate the more detailed study. In each figure, the unexplained price change is non-parametrically regressed on the distance from the rail for home sale pairs both before and after the opening of the Alameda Corridor. The unexplained price change is found by taking the actual log price change less the predicted price change using the appropriate "marginal" rail zone discussed above. Panels (a) and (c) include homes within one mile of the rails where traffic was drastically reduced. Homes closest to the rail that were sold before the change in rail traffic grew in price about 10 percent less than expected, an effect that gradually fades toward zero as the distance increases, at least for the westernmost rail. The price-distance pattern is clearly different for the homes sold after the rail change. Homes close to the rail sold for more than expected and as the distance from the



(a) Non-Corridor West Rail (b) Alameda Corridor Zone (c) Non-Corridor East Rail

Figure 6: Locally Weighted Distance Regressions

rail increases the difference between the actual and expected price change falls toward zero. These patterns give evidence that the rail change was not anticipated by home buyers in the rail zone and that the redirection of traffic has given a noticeable boost to home prices close to the rail, eventually fading as you get further from the line.

The plot in panel (b) shows the same non-parametric regression but for the homes around the Alameda Corridor itself where rail traffic was significantly increased. Regardless of whether it was sold before or after the opening of the corridor, homes closer to the corridor sold for less than expected. The gap between sale price and expected sale price narrows for homes located further from the corridor both before and after the opening, which fits with the idea that the impact of the rail traffic should die off with distance. The similar price-distance pattern for homes sold before and after indicates that prices in the corridor area were negatively impacted before the corridor opened. With an infrastructure project of this scale, it is not surprising at all that prospective home buyers and sellers in the area were aware of the potential impact. The fact that the pattern persisted even after the opening suggests that the negative impact of the rail traffic was not completely capitalized into home prices beforehand.

5.2 Basic Model Results

The regression results for the first two models described earlier are summarized in Table 3. The units of the rail density measure in these regressions are hundred millions of gross ton miles per mile. In Panel A, the first column does not include zone or seasonal dummy variables or any housing characteristics, only the density change of the nearest rail interacted with the indicator for which zone in which the home is located. Column I shows a strong negative effect of an increase in the rail density for the homes within 1/3 of a mile of a rail. This indicates that for these homes, an increase in rail density of 100 million gross ton miles per mile will cause home prices in the area to fall by -0.6 percent. While this may seem small, the re-routing of traffic due to the Alameda Corridor increased traffic in the corridor zone by 50 to 90 million gross ton miles per mile. The negative effect of a density increase is lessened, but still statistically different from zero, for the next set of homes 1/3 to 2/3 of a mile from the rail. A one unit increase in rail density causes a -0.3 percent fall in the home price in this zone. Finally, for homes between 2/3 of a mile and one mile from the track the negative effect disappears. The coefficient for this last group is small and positive, but not significant. Column II includes zone indicators for all homes, seasonal dummies, and housing characteristics. All coefficients move towards zero and the standard errors are larger, but the overall pattern where the impact diminishes with distance remains.

Column III introduces indicators for proximity to a rail crossing interacted with the rail density change. The coefficient on density change for homes nearest an intersection (within 500 ft) is considerably more negative than for the rest of the zone but is not statistically significant. The period under study can be considered to be anomalous as the growth and subsequent popping of the real estate bubble characterizes the second half of the housing data. As a robustness check, Column IV restricts the data set to homes sold before the crash in housing prices. Truncation of the data pushes the coefficient on density change for homes nearest a crossing further negative. Since traffic was falling at these intersections we can interpret this result to mean the housing bubble

likely sapped some of the price boost felt by homes in this area.

Thus far it has been implicitly assumed that homebuyers and sellers are myopic about the impact of the Alameda Corridor on home values. This assumption is especially strong for homes near the corridor itself, as construction spanned several years and was by no means a minor project. Ideally it would be possible to use a timeline of the corridor's construction or news stories about the planning of the corridor as the points in time when agents became aware of the potential home price impacts. Unfortunately, the housing data available for this paper begin in 1995 and planning for the corridor began in the early 1980s. Instead I exclude homes that were sold during the construction period of the corridor and report the results in Panel B of Table 3. Despite the reduction in observations, the coefficients do not change much and are more precisely estimated.

5.3 Heterogeneous Effects

The regressions above were re-run to allow the coefficients on rail density to differ for corridor and non-corridor traffic. We see in Table 4 the pattern of negative impacts dissipating with distance persists, but the coefficients for corridor traffic are larger and more precisely estimated. For homes in the zone closest to the non-corridor rails, a 10 MGTM/mi increase in density causes a -0.5 percent decline in home prices. However, rail traffic in these areas fell so homes were appreciating at a faster pace than expected. The impact of a density change in the next zone around non-corridor rails is negative, but only statistically different from zero if the housing crash is excluded. In the corridor zone a 10 MGTM/mi increase in density causes a -0.8 percentage point lower growth than expected. This translates to a 4 percent lower home price growth when rail traffic increased by 50 MGTM/mi.

It should be noted that, while they are not statistically different, it is somewhat unexpected that the coefficient on corridor traffic is larger in absolute value. My expectation was that the coefficient would be smaller, capturing the concavity created by diminishing effect of greater amounts of traffic

Table 3: Impact of Rail Traffic on Home Prices

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Any	-0.062	-0.050	-0.032	-0.024	-0.062	-0.049	-0.016	-0.008
	(0.010)***	(0.022)**	(0.026)	(0.039)	(0.015)***	(0.018)***	(0.020)	(0.027)
1/3 - 2/3 mi. from Any	-0.035	-0.044	-0.051	-0.086	-0.039	-0.051	-0.063	-0.111
	(0.012)***	(0.020)**	(0.018)***	(0.019)***	(0.014)***	(0.020)**	(0.022)***	(0.027)***
2/3 - 1 mi. from Any	0.019	0.010	0.004	-0.020	0.025	0.018	0.006	-0.029
	(0.018)	(0.011)	(0.026)	(0.023)	(0.014)*	(0.015)	(0.014)	(0.020)
500 ft from Crossing			-0.248	-0.298			-0.286	-0.353
			(0.169)	(0.121)**			(0.105)***	(0.107)***
1000 ft from Crossing			-0.015	-0.010			-0.067	-0.076
			(0.059)	(0.071)			(0.066)	(0.074)
1500ft from Crossing			-0.040	-0.082			-0.079	-0.122
			(0.076)	(0.080)			(0.070)	(0.077)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	28586	28586	28586	20578	24833	24833	24833	17675
R-squared	0.8518	0.8536	0.8537	0.8283	0.8339	0.8358	0.8358	0.8058

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

- a hypothesis that will be tested later. One possible explanation is that homeowners and sellers surrounding the non-corridor rail were better informed as to the impact of the rails, they could have acted on this information prior to the redirection of traffic, dampening the total effect. Under this circumstance, excluding the construction period should bring the estimates for each zone closer together, which we can see in Panel B is the case.

Once construction period homes are excluded, we find that rail density changes have similar impacts for homes in the first two zones around corridor and non-corridor rails. While the impact of density changes for the first two zones are similar, the effect dies out faster for non-corridor homes. Homes located between 2/3 of a mile and one mile from the Alameda Corridor still felt a negative impact, falling -0.2 percent for each additional 10 MGTM/mi. However, homes that are the same distance from non-corridor rails do not experience a measurable impact from a rail change. Whether using Panel A or B, the strength of the density effect is greatly magnified for homes in the immediate vicinity of rail road crossings. Rail density in this area fell from about 30 MGTM/mi to 2.5 MGTM/mi meaning homes nearest the rail grew about 8.3 percent above the expected price.

When the non-corridor traffic is disaggregated even further (Table 5), separating the rail west of the corridor from the rail to the east, we find that the effect of the rail density change is concentrated around the railroad crossings and is stronger in the west. In fact, there is no effect for homes around the east railroad unless located near an intersection. The coefficient on density change for homes nearest to an east intersection should be disregarded as very few homes are located in this zone and even fewer (16) have sale pairs spanning a density change. These coefficients for rail crossing homes are negative, but only significant if we consider home sales before the housing bust, suggesting that any stronger growth felt in the area was given back when housing prices began falling. There are two possible explanations for the weaker results along the east rail. First, if container traffic from the port does not leave on rail, it leaves on trucks. Interstate 710 is the major truck route leaving

Table 4: Impact of Rail Traffic on Home Prices: Heterogeneous Impacts

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor	-0.050	-0.037	0.005	0.000	-0.068	-0.058	-0.006	-0.007
	(0.029)*	(0.023)	(0.030)	(0.046)	(0.027)**	(0.024)**	(0.036)	(0.045)
1/3 - 2/3 mi. from Non-Corridor	-0.023	-0.033	-0.032	-0.073	-0.042	-0.056	-0.056	-0.108
	(0.019)	(0.026)	(0.032)	(0.026)***	(0.028)	(0.027)**	(0.029)*	(0.038)***
2/3 - 1 mi. from Non-Corridor	0.032	0.022	0.022	-0.007	0.023	0.013	0.013	-0.025
	(0.017)*	(0.019)	(0.024)	(0.025)	(0.020)	(0.021)	(0.020)	(0.031)
0 - 1/3 mi. from Corridor	-0.080	-0.088	-0.088	-0.138	-0.071	-0.076	-0.076	-0.148
	(0.016)***	(0.013)***	(0.024)***	(0.036)***	(0.015)***	(0.022)***	(0.022)***	(0.030)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.056	-0.056	-0.056	-0.068	-0.063	-0.063	-0.059
	(0.014)***	(0.020)***	(0.018)***	(0.024)**	(0.014)***	(0.014)***	(0.022)***	(0.021)***
2/3 - 1 mi. from Corridor	-0.035	-0.033	-0.033	-0.062	-0.024	-0.027	-0.027	-0.040
	(0.013)***	(0.016)**	(0.016)**	(0.020)***	(0.013)*	(0.017)	(0.020)	(0.022)*
500 ft from Crossing			-0.276	-0.314			-0.290	-0.349
			(0.122)**	(0.183)*			(0.113)***	(0.111)***
1000 ft from Crossing			-0.044	-0.026			-0.072	-0.071
			(0.069)	(0.083)			(0.058)	(0.065)
1500 ft from Crossing			-0.069	-0.098			-0.084	-0.117
			(0.044)	(0.084)			(0.066)	(0.083)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	No
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	No
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	No
Observations	28586	28586	28586	20578	24833	24833	24833	24833
R-squared	0.8520	0.8537	0.8538	0.8283	0.8341	0.8359	0.8359	0.8059

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

the port and cuts directly through the east rail, so it is possible that rail traffic has been substituted for truck traffic in this area; something that could be explored further. Additionally, the homes in the most densely populated area of the east rail zone are also located adjacent to the rail yards where idling train have created a health risk for neighboring communities (ARB 2007). For the west rail, the coefficients are comparable to the earlier estimates, but the precision is reduced. If the construction period is excluded, we get the familiar pattern of a strong negative effect of rail density that diminishes as you move further from the rail.

5.4 Convexity of Costs

The nature of traffic shift that occurred due to the Alameda Corridor offers an opportunity to explore how homeowners react to differing levels of an externality. Homeowners along the corridor were faced with sharp increases in rail traffic near their homes, while homes in other areas experienced a sharp decline in traffic. This tandem upward and downward shift allows us to gain some insight into the marginal cost structure associated with the intensity of this externality. If the marginal cost of an increase in traffic is different in absolute value than the marginal cost of a decline in traffic the welfare implications of rail traffic will hinge on where these burdens are borne. Consider a situation where two equally populated neighborhoods each had a track running through. If the marginal cost of traffic were increasing total welfare would be largest with an equal distribution of traffic. However, if the marginal cost were diminishing an argument could be made that one of the neighborhoods should carry the traffic and could be compensated in some way by the other. If the marginal cost were constant, distribution of the traffic would be less important as it does not impact the magnitude of the welfare impact.

The test we perform to determine whether marginal costs are increasing or decreasing is to use a approximation to the marginal cost and compare the regression coefficients for a change in density in the corridor zone versus the non-corridor zone. Because the the areas have different

Table 5: Impact of Rail Traffic on Home Prices: Disaggregated Zones

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III		I	II	III	
Δ Rail Traffic :	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor West	-0.069	-0.063	-0.027	-0.030	-0.098	-0.088	-0.046	-0.050
	(0.039)*	(0.038)*	(0.045)	(0.060)	(0.040)**	(0.041)**	(0.064)	(0.066)
1/3 - 2/3 mi. from Non-Corridor West	-0.035	-0.051	-0.051	-0.102	-0.063	-0.079	-0.078	-0.155
	(0.030)	(0.029)*	(0.039)	(0.048)**	(0.032)**	(0.040)*	(0.033)**	(0.042)***
2/3 - 1 mi. from Non-Corridor West	0.022	0.014	0.015	0.000	0.016	0.012	0.012	-0.024
	(0.029)	(0.024)	(0.031)	(0.035)	(0.033)	(0.041)	(0.032)	(0.045)
0 - 1/3 mi. from Non-Corridor East	-0.012	0.009	0.034	0.021	-0.009	0.011	0.045	0.040
	(0.050)	(0.031)	(0.050)	(0.069)	(0.052)	(0.033)	(0.042)	(0.049)
1/3 - 2/3 mi. from Non-Corridor East	0.004	0.000	-0.000	-0.028	0.005	0.001	0.000	-0.019
	(0.038)	(0.037)	(0.047)	(0.037)	(0.059)	(0.042)	(0.043)	(0.040)
2/3 - 1 mi. from Non-Corridor East	0.051	0.035	0.035	-0.026	0.043	0.032	0.032	-0.020
	(0.036)	(0.036)	(0.039)	(0.024)	(0.044)	(0.031)	(0.035)	(0.050)
0 - 1/3 mi. from Corridor	-0.080	-0.087	-0.087	-0.139	-0.070	-0.071	-0.071	-0.147
	(0.015)***	(0.013)***	(0.025)***	(0.035)***	(0.017)***	(0.023)***	(0.022)***	(0.028)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.055	-0.055	-0.058	-0.067	-0.059	-0.059	-0.057
	(0.015)***	(0.019)***	(0.019)***	(0.026)**	(0.018)***	(0.016)***	(0.021)***	(0.022)**
2/3 - 1 mi. from Corridor	-0.035	-0.032	-0.032	-0.063	-0.022	-0.022	-0.022	-0.039
	(0.016)**	(0.017)*	(0.016)**	(0.020)***	(0.010)**	(0.018)	(0.019)	(0.023)*
500 ft from West Crossing			-0.275	-0.325			-0.275	-0.344
			(0.137)**	(0.228)			(0.143)*	(0.138)**
1000 ft from West Crossing			0.004	0.045			-0.015	0.009
			(0.090)	(0.096)			(0.066)	(0.088)
1500 ft from West Crossing			-0.050	-0.047			-0.055	-0.059
			(0.071)	(0.110)			(0.083)	(0.099)
500 ft from East Crossing			-0.120	0.123			-0.129	0.091
			(0.232)	(0.483)			(0.273)	(0.480)
1000ft from East Crossing			-0.124	-0.219			-0.151	-0.251
			(0.136)	(0.116)*			(0.168)	(0.144)*
1500 ft from East Crossing			-0.061	-0.184			-0.084	-0.197
			(0.085)	(0.064)***			(0.087)	(0.100)**
R-squared	0.8520	0.8537	0.8539	0.8283	0.8341	0.8359	0.8361	0.805
Observations	28586	28586	28586	20578	24833	24833	24833	17675

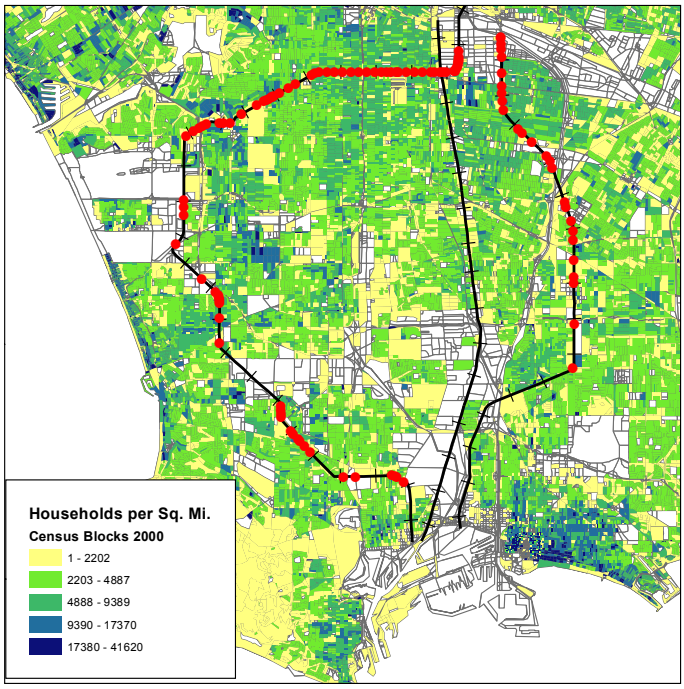
Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

home values we will need to incorporate this difference into the test in order to find the marginal dollar cost. Additionally, to test convexity of the cost structure some stronger assumptions have to be made. I am forced to assume that an increase in rail traffic in each area causes the same level of negative impact and that the difference in how it is capitalized into home prices is due to individuals preferences over these impacts. This may be a difficult assumption to accept as the Alameda Corridor was constructed such that trains would no longer cross streets at surface level. Removing traffic from surface level interactions is likely to reduce the impact that homeowners perceive, so our test is possibly biased towards accepting the hypothesis that marginal costs are diminishing. The hypothesis test is as follows:

$$\begin{aligned} H_0 &: \psi_1 AvgPrice_{NonCorridor1} = \theta_1 AvgPrice_{Corridor} \\ H_1 &: \psi_1 AvgPrice_{NonCorridor1} > \theta_1 AvgPrice_{Corridor} \end{aligned} \tag{5}$$

Using estimates from Table 4 we fail to reject the null hypothesis that marginal costs are constant. The coefficients on density change are similar or higher in the corridor zone, but the average home value is higher in the non-corridor zone. A change of 10 MGTM/mi in rail density causes a change in home value of \$1,180 in the western non-corridor zone, \$863 in east rail zone, and a \$832 change in home value in the corridor zone. The difference between these estimates is not statistically significant at any conventional level. While this test is imperfect due to the strong, and possibly invalid, assumptions required, it does still provide some evidence against diminishing marginal cost of the externality as the test is biased in the direction of finding diminishing marginal costs, but finds no evidence of this. Performing a joint test of the hypothesis that the marginal effects for each distance band are the same between corridor and non-corridor rails brings us to the same conclusion.

Figure 7: Household Density

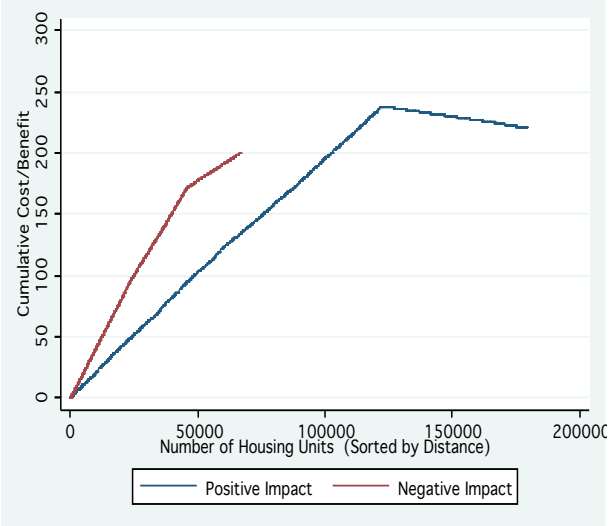


5.5 Aggregating Impact

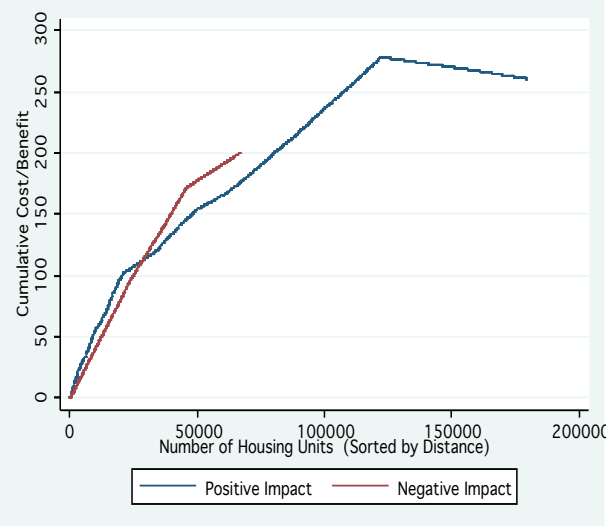
If the population density and distance of each affected line were identical we would only need the marginal effect and density change to determine whether the net effect capitalized into home prices was positive or negative. As can be seen in Figure 7, the population density is not constant along each line and, in fact, there are very few homes near the lower section of the central Alameda Corridor. In addition to changing population densities, the length of each line differs. To understand how this affects the overall impact of the rail shift, we must tabulate the number of homes and the average price in each zone. Using Census 2000 data we find the number of housing units in each Census block and using our housing data we find the average pre-treatment price. Using this information and the marginal effects calculated in the earlier regressions we can add up the total impact capitalized into home prices. Figure 8 displays number of housing units affected on the x-axis, sorted by distance to a rail, and the cumulative impact on the y-axis with the negative and positive impacts plotted separately. In panel (a) we use the regression coefficients from Panel B Column II of Table 5 to estimate the total effect on housing, finding the positive impact to be

Figure 8: Cumulative Impact of Rail Shift

(a) Disaggregated Impacts



(b) Intersections



roughly $23 million greater than the negative impact. It should be noted that line for the negative impact is more steeply sloped, not because of a difference in the marginal effect, but because the change in rail traffic was greater on the Alameda Corridor than on the individual non-corridor rails. Finally, when we use the most detailed specification including the effect on homes around the railroad crossings we see in panel (b) that the positive impact is now steeper initially due to the magnified effect around the rail crossings and that the gap between the positive impact and negative impact is wider. Considering the magnitude of the housing value in the one-mile zone around the rails totaled $36 billion in 1997, the small total positive impact is negligible. While the net impact may be negligible, there has been a significant transfer of housing value from the communities surrounding the Alameda Corridor, which tend to be predominantly minority and lower income, to higher income neighborhoods surrounding the non-corridor rails.

6 Conclusion

This paper exploited a natural experiment to measure the positive and negative impacts of rail traffic on neighboring homes. I find strong evidence negative spillovers from local rail traffic nega-

tively impact home values. Additionally, the case for concentration of a negative externality is not supported as I did not find evidence of concavity or convexity of the cost of rail traffic on homes. Therefore a zero-sum redistribution of traffic would be expected to have no impact. In this case, there was a small positive impact on housing values as a result of the more direct routing of traffic. Because the Alameda Corridor saw a larger increase in absolute value than the decrease on the other lines, the negative impact felt by a home along the Alameda Corridor was greater in absolute value than the positive impact received by a home along a rail where traffic was reduced. However, there were many more homes along the non-corridor rails leading to the small net positive effect. The positive gain was muted by the narrowly focused impact felt around the eastern non-corridor rail. Because of the confounding effect of the 710 interstate and nearby inter-modal railyards, the positive benefit was confined to the homes near rail crossings.

The rail traffic setting explored here is ideal for investigating the negative externality effects of infrastructure expansions with little interference from demand side effects. If the re-routing experiment had been for highway or airport traffic the negative impacts would have been more difficult to measure as the positive effects of proximity to airports or reduced commute times would have likely influenced home values. The use of freight rail traffic allowed for cleaner estimation of this impact. The most likely source of this type of demand side impact from freight rail would be from greater employment opportunities during construction, though the longer window of data available allows this issue to be circumvented.

Infrastructure expansions are often touted as local job creators, but there are also costs borne by the localities. Understanding the spatial dispersion of the costs and whether there are convexities is necessary when evaluating these projects. From this paper, the lack of evidence of diminishing marginal cost suggests that concentrating the negative impacts of an infrastructure project yield no reduction in the welfare costs. The fact that we uncover a relatively linear marginal damage curve for winners and losers from this infrastructural redistribution indicates that there are no complex

welfare dynamics at work, at least as revealed by home prices. This would indicate that planners considering future projects will maximize welfare simply by making transportation infrastructure as direct and efficient as possible when local impacts are unavoidable.

References

[1] Case, Colwell, Leishman, and Craig Watkins (2006), *The Impact of Environmental Contamination on Condo Prices: A Hybrid Repeat-Sale/Hedonic Approach*, Real Estate Economics, Vol. 34, 77-107.

[2] Case, Karl and Robert Shiller (1987), *Prices of Single Family Homes Since 1970: New Indexes for Four Cities*, New England Economic Review, September-October, 46-56.

[3] Chay, Kenneth Y. and Michael Greenstone (2005), *Does Air Quality Matter? Evidence from the Housing Market*, Journal of Political Economy, Vol. 113 No. 2, 376-424.

[4] Cohen, Jeffery P. and Cletus C. Coughlin (2008), *Spatial Hedonic Models of Airport Noise, Proximity, and Housing Prices*, Journal of Regional Science, Vol. 48 Issue 5, 859-878.

[5] Currie, Janet and Reed Walker (2010), *Traffic Congestion and Infant Health: Evidence from E-Z Pass*, American Economic Journal: Applied Economics, Vol. 3 No. 1 January 2011, 65-90.

[6] Cutter, Fernandez, Sharma, and Thomas Scott (2009), *Dynamic Analysis of Open Space Value Using a Repeat Sales/Hedonic Approach*, Working Paper.

[7] Espey, Molly and Hilary Lopez (2000), *The Impact of Airport Noise and Proximity on Residential Property Values*, Growth and Change, Vol. 31 Issue 3, 408-419.

[8] Ho, Imai, King and Elizabeth A. Stuart (2007), *Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference*, Political Analysis, Vol. 15 Issue 3, Summer, 199-236.

[9] Kim, Phipps, and Luc Anselin (2003), *Measuring the Benefits of Air Quality Improvement: A Spatial Hedonic Approach*, Journal of Environmental Economics and Management, Vol. 45 Issue 1, 24-39.

[10] Rosen, Sherwin (1974), *Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition*, Jounal of Political Economy, Vol. 82 No. 1, 34-55.

WORC

Western Organization of Resource Councils

Exporting Powder River Basin Coal: Risks and Costs

Updated September 2011

Summary

U.S. domestic coal production has encountered major uncertainties in recent years with proposals to regulate or abolish the destructive practice of mountain top removal and efforts to control greenhouse gas pollution. Proposals for new coal power plants have been put on hold or shelved. The economic downturn of 2008-2009 reduced demand for coal and electricity. New regulations and concerns about global warming have led to calls to retrofit or retire the oldest and dirtiest coal plants, and utilities are increasingly replacing coal-fired power plants with power from natural gas, wind and other sources. Meanwhile, demand for coal in other parts of the world is growing. The world's two most populous countries, China and India, are the world's fastest growing economies and major consumers of coal.

This combination of factors has the U.S. coal industry looking overseas at a more robust global export market, specifically in Asian-Pacific markets. Much of this export market would be met by opening new mines and expanding existing operations and infrastructure in the Powder River Basin of Montana and Wyoming, and exporting coal through Northwest ports.

For that to happen, the coal must be mined, railroads and ports must be upgraded or built new, and the communities along the way must face disruption from these changes. Coal mining already hurts the health and productivity of agricultural land in the West. Coal mining displaces farmers and ranchers who depend on the land to make a living by eliminating land used for crops or grazing. Coal seams also serve as aquifers in most of the West, and mining disrupts and degrades the water resources of the area, further damaging the long-term productivity of the land. Increasing coal mining would compound these problems.

The jury is still out on whether coal companies will meet reclamation standards for final bond release on most of the land disturbed by coal mining. Final bond release for coal mined land is the best measure of reclamation success, and only a tiny percentage of strip mined land has passed that test over 30 years after passage of the Surface Mining Control and Reclamation Act.

Expanded coal mining for export would have other impacts on western communities and the environment. New and expanded railroads would need to be built to accommodate increased coal shipments to the West Coast. New railroad lines would be built in pristine river valleys, across farms and ranches and prime hunting grounds, causing immeasurable harm to the beauty and economic value of this land.

Communities from Sheridan to Spokane and beyond would experience increased rail traffic. Up to 40 unit trains a day to and from the West Coast would be required to transport 110 million tons of coal a year, the amount in announced export plans of three major coal companies. In communities split by rail lines, this could significantly delay traffic and emergency vehicles, boost noise and air pollution and

220 S. 27th Street, Suite B, Billings, MT 59101
(406) 252-9672 FAX (406) 252-1092 billings@worc.org www.worc.org

increase the likelihood of train-auto collisions. Adverse impacts on residents and businesses and on restoration efforts in historic core neighborhoods of regional cities will be profound.

Increasing coal train traffic will also leave large amounts of coal dust in communities across the West. Each coal rail car could lose as much as 500 lbs of coal and coal dust per railcar–over 30 tons per unit train–during each trip. Coal dust can also have a detrimental effect on rail track beds, which could lead to an increased need for repair and more derailments. More coal train traffic will pollute air and water along the rail lines.

Exporting Powder River Basin coal from West Coast ports would mean rail and port capacity would not be available for other commodities. Coal export terminals would occupy valuable real estate at ports, limiting the choices coastal communities can make to use this real estate for their own economic prosperity. Increased coal trains could affect available capacity and quality of service for grain shipments and high value container traffic. Instead of addressing our trade deficit by promoting 21st century technology, such as wind and solar equipment manufacturing, we would be locking ourselves into exporting a dirty 19th century fuel.

Expanded coal mining and coal exports also subvert the goal of the United States and countries around the world to reduce global warming pollution. Whether coal is burned in the United States or abroad, it will have the same impact on global climate. While relatively low-sulfur coal from the Powder River Basin coal will produce less of some kinds of air pollution in China than burning high-sulfur Chinese coal, emissions of greenhouse gases are nearly identical from either Chinese or U.S. coal, and the global warming impacts of burning Powder River Basin coal will affect the U.S. no matter where the coal is burned.

Proposed coal exports from facilities in the Pacific Northwest shipping comparatively cheap Powder River Basin coal would undermine China's progress toward more efficient power generation and usage and renewable energy, thereby encouraging more coal burning in China and elsewhere in the Pacific Rim, according to an economic analysis released in July, 2011 by Dr. Thomas M. Power, past chair of the University of Montana Economics Department.

Powder River Basin Coal Resources

The Powder River Basin of Montana and Wyoming is the largest source of coal in the United States. Total production in the Powder River Basin was over 455 million short tons of coal in 2009.[1] Wyoming produces the most coal of any state in the nation, and Montana ranks fifth.[2] Both states would see an increase in production to meet export demands.

In addition to large levels of production, Montana and Wyoming lead the nation in estimated recoverable reserves of coal. Montana has over 74 billion tons of estimated recoverable reserves, the most in the U.S., and Wyoming has over 39 billion tons of estimated recoverable reserves, the second highest reserves in the U.S[3].

[1] Energy Information Administration- Coal Production and Number of Mines by State and Mine Type, 2009, 2008: http://www.eia.doe.gov/cneaf/coal/page/acr/table1.pdf

[2] Energy Information Administration, Coal Exports by Custom District: http://www.eia.doe.gov/cneaf/coal/quarterly/html/t13p01p1.pdf

[3] Montana has 74.81 billion tons of estimated recoverable reserves; Wyoming has 39.19 billion tons. The amount in each state that is economically recoverable is lower; how much lower depends on the current price of coal.

The 1990 amendments to the Clean Air Act drastically increased the domestic demand for low-sulfur Western coal. Western coal accounted for 54.5% of the total coal produced in the United States in 2009,[4] compared to just 32% in 1990.[5]

Over the past decade, coal production from the Powder River Basin has increased steadily, approaching record levels in 2008, followed by a drop in 2009, due to the economic downturn. In the 2nd quarter of 2011 severe flooding throughout the region and high water behind the dams resulted in disruptions to trains and to markets due to greater usage of hydroelectric power, both of which resulted in a reduction in coal usage compared to the 2nd quarter of 2010. Nevertheless, production in the Basin is on the rebound and in the 12 months prior to June 30, 2011, was up slightly from the previous 12 months.[6]

Current U.S. Exports from Powder River Basin

Today, close to 99% of the coal mined in the Powder River Basin is consumed in domestic U.S. coal markets.

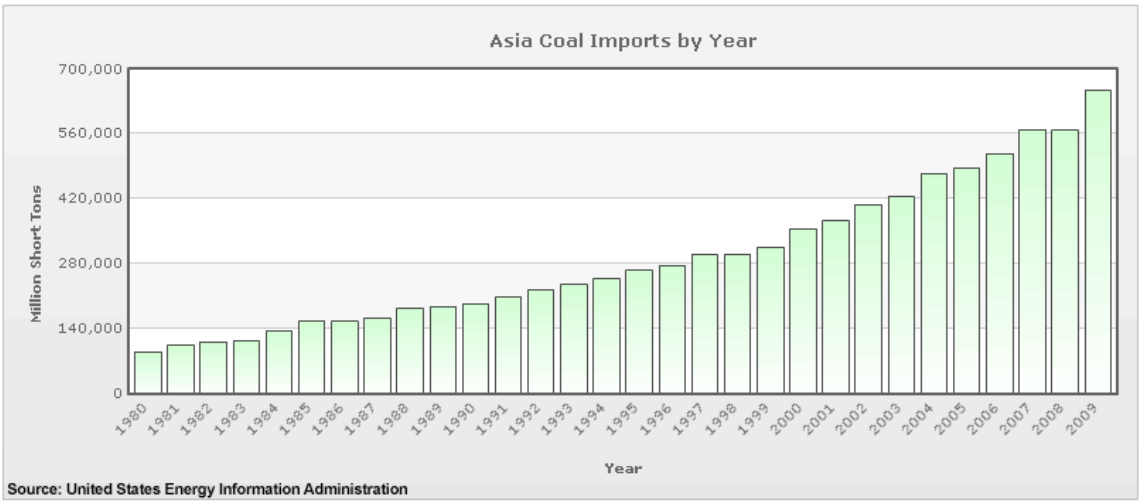
However, a depressed domestic market and increased foreign demand, especially from the Pacific Rim, has piqued the interest of the largest U.S. coal producers in potential export markets. Chris Ruppel, an energy analyst at Execution, a brokerage and research firm, recently predicted, "As U.S. coal demand is constrained because of increasing environmental regulation, coal production in the United States will increasingly go toward overseas buyers."[7]

According to the U.S. Energy Information Administration, total U.S. exports of coal to Asia grew 176% from 2009 to 2010 to 17.9 million short tons, 4.9 of which was steam coal as global supplies of thermal coal tightened.[8]
Unless strict limits on greenhouse gas emissions are put in place, growth in Asian coal demand is expected to increase world coal consumption by 2030. The U.S. Energy Information Administration predicts that nearly 90% of that increased consumption will be attributed to China.[9]

Investors are aware that China relies on coal for most of its energy needs, but is burning more than it can produce. According to the Beijing-based General Administration of Customs, China's 2009 coal imports more than tripled from the previous year's to 125.8 million tons.

[4] Energy Information Administration- Coal Production and Number of Mines by State and Mine Type: http://eia.gov/cneaf/coal/page/acr/table1.html
[5] Coal Industry Annual 1994, Energy Information Administration, accessed electronically 9/9/2010
[6] SNL Daily Coal Report, Sept. 6, 2011, "Top producing Powder River Basin mines in Q2'11" Dan Lowrey and Ashley Pipkin Jones
[7] Krauss, Clifford. "An Export is Solid Supply". *The New York Times.* March 19, 2008: http://www.nytimes.com/2008/03/19/business/19coal.html?pagewanted=2
[8] U.S. Energy Information Administration, "U.S. Coal Supply and Demand: 2010 Year in Review", William Watson, Nicholas Paduano, Tejasvi Raghuveer and Sundar Thapa, April 2011.
[9] Mining Companies Aim To Export to China Through Northwest Ports, *The Oregonian*, Wednesday, September 8, 2010. Scott Learn

Figure 1: Asia Coal Imports by Year



U.S. Coal Companies Signal Plans to Increase Exports

Western coal production and exports increased between 2009 and 2010,[10] despite the global recession, and the country's biggest coal companies have announced their intentions of continuing to expand the export market to their stakeholders and the public at large.

"The markets (for Powder River Basin coal) nationally are questionable, but it's unquestionable the demand that exists overseas – a wide variety of countries and into the foreseeable future," Bud Clinch, executive director of the Montana Coal Council, noted recently.[11]

Peabody Energy, the largest coal producer in the United States, and others in the coal industry are relying on this demand to continue.

In a presentation at an analyst and investor forum in early 2010, Rick Navarre, Peabody president and Chief Commercial Officer, estimated current Asia-Pacific market demand for imported coal to reach 140 million metric tons per year, and that annual demand in that region could increase to 220-260 million metric tons, by 2015.[12] Peabody plans to expand production throughout the world in order to bring coal to China, India, Japan and South Korea.

Mining Companies Move to Expand

Arch Coal has significantly consolidated and expanded its western operations over the past two years. In 2009, Arch acquired the Jacobs Ranch Mine in the southern Powder River Basin in Wyoming which, when integrated with the nearby Black Thunder Mine, created the largest coal mining complex in the world. In 2009, production from Arch's Black Thunder, Jacobs Ranch and the nearby Coal Creek mines added up to 120.1 million tons.[13] Arch also acquired the rights to 1.2 billion tons of coal on Otter Creek

[10] http://tonto.eia.doe.gov/FTPROOT/coal/058494.pdf
[11] Connelly, Joel, "Ultra-long coal trains on Seattle waterfront? Time for a long critical look", Seattle Post Intelligencer, July 31, 2011.
[12] Navarre, Rick. Peabody Energy. June 17, 2010 Expanding Markets and Peabody Growth Opportunities. 2010 Analyst and Investor Forum, Slide 42
[13] 29.3 million tons at Jacobs Ranch, 81.1 million tons at Black Thunder and 9.7 million tons at Coal Creek

in the Northern Powder River Basin in Montana. These actions increased the coal reserves under Arch's control by 25%.[14]

In 2006, Peabody expanded into Australia, currently the world's largest coal exporter, by acquiring Excel Coal Ltd. Peabody is also part of a consortium partnering with the government to develop high quality coal in Mongolia not far from growing Asian markets. In 2008, Peabody began sending coal from Wyoming to Europe, first by rail to the Mississippi River, then by vessel through the Gulf of Mexico. Now the company is shipping coal to Japan from the California coast. Further demonstrating its desires to increase production, Peabody has indicated that it could open the leased and permitted School Creek Mine just north of its North Antelope Rochelle Mine in Wyoming.[15] This mine was scheduled to open in 2008, but has not yet started operations due to economic conditions.

Cloud Peak Energy shipped 3.3 million tons for export in 2010 and was expected to ship 4 million tons in 2011. Signal Peak Mine north of Billings, Montana, has also sent coal to the West coast for export.

Port Expansions

In order to meet the export goals of Arch, Peabody, and other companies with western reserves, current railroad and port infrastructure in the United States would need to be significantly expanded and upgraded, as well.

"The real goal here is to see if we can't get large volumes of Powder River Basin coal to Asia,"[16] said Peabody Coal CEO Gregory Boyce, "obviously it's a longer-term project. Our goal is to get large volumes of Powder River Basin [western U.S. Powder River Basin] coal to the Pacific Rim. We know we can sell it in China and Korea." The challenge, he said, was to get the needed volumes into the marketplace through a custom-built port, although there was no time frame for such a project.[17]

Steven Leer, Arch Coal Chairman and CEO, described his company's second move in a week to acquire export terminals in January 2011, in a media statement: "This transaction is another important step in accomplishing our strategic objective of expanding Powder River Basin coal sales into the Asia-Pacific region."[18]

Industry analysts say Peabody's planned export expansions alone could mean an investment of as much as $500 million in new terminals.[19] Peabody is active in the Gateway Pacific Terminal proposal near Cherry Point, Washington, with plans to build first 24 million tons of coal capacity, and longer term plans to double that.

[14] Arch Coal 2009 Annual Investor Report, *The Power Within* accessed 8/29/2010 available online at http://investor.archcoal.com/phoenix.zhtml?c=107109&p=irol-irlhome
[15] http://gillettenewsrecord.com/articles/2010/08/02/news/yesterday/news08.txt
[16] http://www.bloomberg.com/news/2010-06-24/peabody-energy-sees-global-demand-at-the-beginning-of-a-super-cycle.html
[17] "Peabody Energy Still Looking At Australian, Mongolian Opportunities," Steve James, *Reuters,* Friday June 25, 2010
[18] http://news.archcoal.com/phoenix.zhtml?c=107109&p=irol-newsArticle&ID=1517028&highlight=
[19] Mining Companies Aim To Export to China Through Northwest Ports, *The Oregonian*, Wednesday, September 8, 2010. Scott Learn

Arch is moving aggressively to position itself to pursue exports of its PRB holdings. In 2011, Arch purchased a one-third share of the Tongue River Railroad which would connect its Otter Creek Montana holdings to the BNSF mainline and West Coast ports.

In 2010, Arch became a minority partner in the Millennium Bulk Terminal near Longview, Washington.[20] In November of 2010, Millennium received initial approval for the first U.S.-based West Coast terminal for coal exports with capacity to ship 5.7 million tons of coal per year. After being challenged by Earthjustice on behalf of Climate Solutions, Sierra Club, Washington Environmental Council and Columbia Riverkeeper, the application for a shoreline development permit for the facility was withdrawn.[21] The discovery of internal memoranda disclosing plans to expand the port to 60 million tons per year coal exports bolstered the case of port opponents who alleged that the Cowlitz County Commissioners did not fully consider the environmental impacts of the project before approving the permit. Apparently, hedging its port bets, in January, 2011, Arch announced an agreement to secure 2.5 million tons annual export capacity at Ridley Terminal in Prince Rupert, British Columbia[22] through 2015.

One hundred and ten million tons represents a conservative estimate of the Pacific Rim annual export market for Montana and Wyoming coal.

Rail Expansions

These moves and statements have not gone unnoticed in the railroad sector, which also sees opportunities for expansion.

In 2008, Matt Rose, CEO of Burlington Northern Santa Fe Corp (BNSF) said the company is talking to potential customers abroad about exporting Powder River Basin coal and looking at the logistical challenges of exporting large quantities. The mining companies are also talking to customers abroad, and both parties say they have enough capacity to handle increased demand.[23]

In the first six months of 2010, 3.5 million tons of coal was shipped from Powder River Basin Coal mines to Oregon and Washington for use in electrical generation and combined heat and power applications.[24] BNSF hauled 6 million short tons of Wyoming and Montana coal through Westshore terminal in British Columbia in 2010, compared with about 2 million in 2009 [25]

An export market of 110 million tons a year[26] would require about 40 unit trains[27] traveling to or from the West Coast and the Powder River Basin every day. For comparison, current volume

[20] Black, George. "Coal On A Roll: Plundering America to Power the Asian Boom", OnEarth, Fall 2011 p. 37.
[21] Learn, Scott. "Environmental groups appeal approval of Columbia River coal export terminal", The Oregonian, Monday, December 13, 2010: http://www.oregonlive.com/environment/index.ssf/2010/12/environmental_groups_appeal_ap.html
[22] Arch Coal, Inc. "Arch Coal Announces Agreement With Canada's Ridley Terminal For Pacific Coast Exports," January 18, 2011, http://news.archcoal.com/phoenix.zhtml?c=107109&p=irol-newsArticle&ID=1517028&highlight.
[23] http://www.mineweb.com/view/mineweb/en/page38?oid=54526&sn=Detail
[24] Energy Information Association- Monthly Nonutility Fuel Receipts and Fuel Quality Data, 2002-2007 http://www.eia.doe.gov/cneaf/electricity/page/eia423.html
[25] "Tripling of BNSF export coal volumes plays role in new US port moves" 12-3-10 Platts.
[26] This number is an estimate that combines the 60 million tons of capacity planned for Millennium Bulk Terminal at Longview, Washington with the 48 million tons of capacity planned for Gateway Pacific Terminal at Cherry Point near Bellingham, Washington with existing Powder River Basin exports of 2-6 million tons.
[27] Based on average of 15,000 tons per train, with approximately 130 car trains.

of traffic is no more than 5 unit trains[28] per day. Nearly all of the rail lines from the Powder River Basin to the West Coast would eventually need upgrades to carry additional weight or add additional tracks to accommodate an export market of this size.

Western Railroads

Union Pacific (UP) and BNSF are the two major Class I railways that operate in the Powder River Basin. Union Pacific is the largest railroad network in the U.S., with revenues at more than $13 billion, and employs 50,000 people. BNSF is owned by Berkshire Hathaway and has one of the largest freight railroad networks in North America, second only to UP, with revenues totaling more than $14 billion and employing nearly 40,000 people. UP ranks 153 on the 2011 Fortune 500 list, up from 164 in 2010. BNSF was ranked 167 in 2010 when it was acquired by Berkshire Hathaway, currently ranked number 7 on the Fortune list. The acquisition helped lift BH from number 11 in 2010.

Montana Rail Link is a Class II railroad that operates over 900 miles of line from just east of Billings, Montana to Sandpoint, Idaho. The black section of rail line on Figure 2 is owned by Montana Rail Link, an important section of rail to any export market.

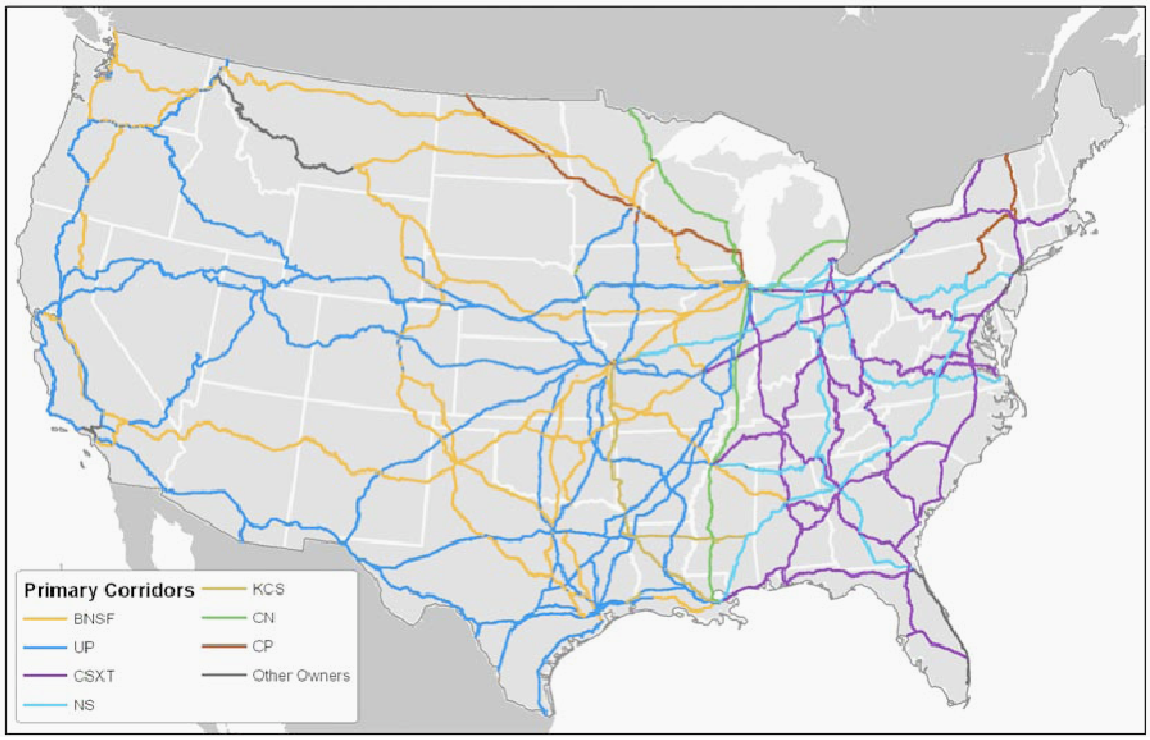
Only two railroads – the BNSF and Union Pacific – transport Powder River Basin coal westward. Coal trains vary from 100-150 cars to haul Powder River Basin coal to electric utilities, the vast majority of which are east and southeast out of the region. The rail cars haul coal only, and must return to the mines empty.

A relatively small amount of westbound coal from Powder River Basin mines in Wyoming and Montana today goes through Billings, Bozeman, Helena, and Missoula on Class I track, a portion of which is owned by Burlington Northern Santa Fe Railroad but leased and operated by Montana Rail Link.

The coal continues on through Sandpoint, Idaho and Spokane, Washington, where it heads south to follow the Columbia Gorge, avoiding the steep grades of coastal mountain ranges. The trains turn north through the heavily populated coastal communities of Washington, and proceed into Canada where coal is shipped from the Westshore Terminal in Vancouver, British Columbia. Coal shipments from Vancouver in 2009-2010 went primarily to South Korea and China.

[28] Based on 3.5 million tons for Oregon and Washington coal plants and 6 million tons exported in 2010.

Figure 2: Primary Rail Freight Corridors



Source: Cambridge Systematics, Inc.

Rail Capacity

Rail capacity is measured in the number of trains a segment of rail can handle in one day. The freight rail industry can suffer from capacity constraints that affect the entire system, and an increase in demand would worsen these constraints. According to the Congressional Budget Office, the "capacity" of a transportation sector describes a level of service and how it can be handled effectively by a facility or network in a given amount of time. Capacity can be constrained by a shortage of infrastructure somewhere along the route; because transportation industries are networks, capacity constraints at one corridor or junction can cause delays throughout the system.[29]

According to a study by Cambridge Systematics, Inc, determining capacity is "as much art as it is science."[30] Among the factors considered when determining capacity are the number of tracks, the frequency and length of sidings, the capacity of the yards and terminals along a corridor to receive the traffic, the type of control system, the terrain, the mix of train types, the power of the locomotives, track speed, and individual railroad operating practices.

As a result, measurements of railroad capacity are less often a solid number and more often a range. Even in capacity studies, the terminology is not completely consistent. Most often capacity is referred to as "practical capacity" or "theoretical capacity." On rail lines operating at practical capacity, minor disruptions can be absorbed with only temporary deterioration in performance. The system can

[29] Congressional Budget Office, Freight Rail Transportation: A Review of the 2004 Experience http://www.cbo.gov/doc.cfm?index=6350&type=0#pt1

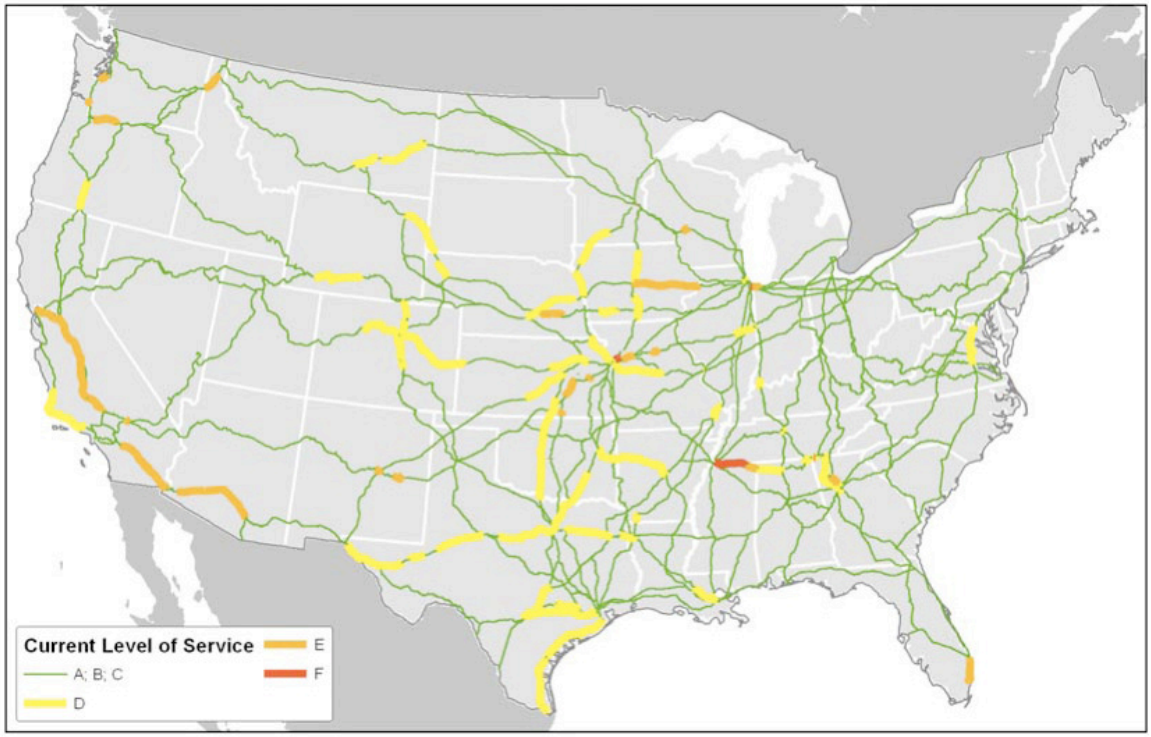
[30] HDR, Inc. Transit Safety Management. July, 2006. Statewide Capacity and System Needs Study. Prepared for Washington State Transportation Commission.

continue to operate at levels up to 80% of theoretical capacity, but any minor disruptions will result in severe disruptions system wide.

Through national aggregation, Cambridge Systematics determined the average capacity of a single track rail to be between 16 trains per day and 30 trains per day for multiple train types.[31] Each additional track does not add capacity in a linear fashion. For example, depending on the type of signaling, adding a track to go from one to two tracks could increase capacity from 16 trains per day to 28 trains per day or from 30 trains per day to 75 trains per day.

It is also important to note that railroads can operate for a short period above 100% of their theoretical capacity. Most studies say a rail is at capacity when it runs between 80 and 100% of theoretical capacity. As of 2007, less than 4% of the rail in the country is operating at or above capacity, and only an additional 9% is operating near capacity.[32] However, there are key segments of track between the Powder River Basin and West Coast ports that *are* operating at or near capacity.

Figure 3: Current Train Volumes Compared to Current Train Capacity



Source: Cambridge Systematics, Inc.

Key: Lines in green represent service with a volume less than 70% of capacity. Lines in yellow represent rail segments with volumes between 70% and 80% of capacity. Lines in orange represent rail segments with volumes between 80% and 100% of capacity. Lines in red represent rail segments with volumes over 100% of capacity.[33]

[31] National Rail Freight Infrastructure Capacity and Investment Study, September 2007, Prepared for Association of American Railroads by Cambridge Systematics, Inc. http://www.aar.org/~/media/aar/Files/natl_freight_capacity_study.ashx

[32] National Rail Freight Infrastructure Capacity and Investment Study, September 2007, Prepared for Association of American Railroads by Cambridge Systematics, Inc. http://www.aar.org/~/media/aar/Files/natl_freight_capacity_study.ashx

[33] National Rail Freight Infrastructure Capacity and Investment Study, September 2007, Prepared for Association of American Railroads by Cambridge Systematics, Inc.

Figure 3 shows the current level of service on the major rail lines in the United States.

Railroads are aware of the capacity constraints and are working to resolve them. Together, BNSF and UP invested more than $4 billion to increase capacity in recent years.[34] BNSF laid nearly 3,000 miles of track from 2007 to 2009. UP has been less aggressive with its expansion, adding less than 100 miles of track in 2009, but it did replace or surface nearly 16,000 miles of track.

To meet the coal industry's projected coal export demand of 110 million tons per year from Powder River Basin mines, railroads would need to build significant amounts of new rail in the coming years in the northwest.

Railroads Capacity Expansion Options

Railroads have several options for increasing capacity including: running more trains, running trains faster, running trains closer together, running trains with more cars and installing new and upgrading existing track. Track can be upgraded by adding double-track, straightening curves to allow for increased speed, replacing light-duty rail with heavier track, and expanding or building new rail yards and terminals.

Upgrading tracks would require approvals from various levels of government. The federal Surface Transportation Board has broad regulatory oversight over railroads.

Other regulations for upgrading capacity vary by state. State authority on rail permitting is most often housed in the state Departments of Transportation, which have varying construction requirements and rules for establishing right-of-ways to build rail lines. Rail impacts related to noise, pollution and public safety are regulated at various levels within states, often with a Public Service or Utilities Commission and local governments.

Since the passage of the Staggers Act in 1980 and subsequent laws deregulating railroads, the cost of much of the infrastructure needed to protect public safety has been borne by the federal government, with some matching funds coming from state and local taxpayers.[35] Through the Highway Safety Improvement Program, federal funds for grade crossing protection devices have been a feature of federal highway funding programs for decades, and distributed to states on a formula basis.

In an era of fiscal constraint and austerity inaugurated by sweeping recent and ongoing federal budget cuts, the cost of mitigating impacts from dramatic increases in coal train traffic would fall primarily on cities and towns, businesses, individual commuters and public safety agencies. Attempts to alleviate those impacts with major infrastructure investments in things like grade separated crossings and re-routed rail corridors could cost tens of millions of dollars that hard pressed state and local governments are unlikely to come up with.

---

[34] Four billion in investments was taken from the total capital expenditures that did not relate specifically to the acquisition of equipment such as freight cars or locomotives. Sourced from 2010 SEC-10K filings, page 20 BNSF http://bnsf.com/about-bnsf/financial-information/sec-filings/10-k-filings/, page 39 Union Pacific http://www.up.com/investors/secfiling/index.shtml.

[35] For example, the City of Billings, Montana, used tax increment financing of approximately $1.5 million to implement a new quiet zone and install the necessary safety equipment in the central core city rail corridor.

A recent ruling in the District of Columbia Court of Appeals provides some hope for local governments confronted with a wall of coal trains dividing their communities and disrupting traffic, established businesses, and threatening public safety. The Court ruled in support of the Village of Barrington, IL and the Surface Transportation Board, which required Canadian National Railroad to pick up most of the cost of two separated grade crossings outside Chicago[36] after the company re-routed the main volume of its long haul traffic out of the central city and through Barrington and other suburbs, vastly increasing traffic on an existing line.

Impacts of Increasing Coal Exports

Coal is the second largest producer of energy-related CO2 emissions in the country.[37] and the impacts of mining, processing, and transporting coal on the country's health, landscapes, and water are enormous. Ramping up exports of coal would subvert the nation's efforts to reduce reliance on coal, its impacts on global warming, and damages done by mining. Construction of new railroad lines and increased traffic on existing lines would have negative effects on the environment and communities along the route.

Greenhouse Gas Emissions

Combustion of coal from the Powder River Basin was the source of nearly 900 million tons of carbon dioxide (CO2) emissions in the United States in 2007, 13% of all U.S. emissions.

Exporting coal overseas subverts domestic efforts to reduce greenhouse gas emissions and weakens international efforts to combat global warming. A coal export facility with the capacity to ship 20-30 million tons per year of Peabody Powder River Basin coal would result in the export of 35-53 million tons of CO2 per year.[38] With each ton of coal contributing about two tons of CO2 to the atmosphere, a 110 million ton production increase in overseas exports to Asia would contribute an additional 220 million tons of CO2 annually.

Proposed coal export facilities in the Northwest will result in more coal consumption in Asia and undermine China's progress towards more efficient power generation and usage according to an economic analysis by Thomas Power released in July 2011 by Sightline[39]. Power found that lower coal prices afforded in Asia by using coal from the Powder River Basin would encourage greater investment in new coal burning facilities, which in turn would create a 30- to 50-year demand for coal. Lowering coal costs to China would undermine valuable energy efficiency efforts in an economy where energy usage per unit of Gross Domestic Product is almost four times that in the United States and eight times that in Japan, Power found.

Coal Mining

Exporting coal would require expanding existing mines and opening new mines in the Powder River Basin. Coal mining has many detrimental impacts on the people and environment where it is developed.

---

[36] Village of Barrington Illinois v. Surface Transportation Board, U.S. Court of Appeals, District of Columbia Circuit, March 15, 2011

[37] http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html

[38] *Science Daily,* Carbon Dioxide Emissions From Power Plants Rated Worldwide. Nov. 15, 2007 http://www.sciencedaily.com/releases/2007/11/071114163448.htm

[39] Power, Thomas M. "The Greenhouse Gas Impact of Exporting Coal from the West Coast: An Economic Analysis", July, 2011, published on-line by Sightline at: http://sightline.org/research/energy/coal/Coal-Power-White-Paper.pdf

Air Quality

Coal mining causes significant air pollution, mainly from fugitive emissions of particulate matter and gases including methane, sulfur dioxide and nitrogen oxides.[40] These emissions are largely created when blasting, drilling, collecting, hauling and moving heavy machinery.

These air pollutants can contribute to serious health problems. Of particular concern is the pollution of particulate matter, or dust, less than 2.5 microns in diameter (PM2.5). Respiratory problems including asthma and bronchitis have been linked to PM2.5. These respiratory problems, as well as increased likelihood of heart attacks and strokes caused by particulate inhalation, can lead to premature death.[41]

Additional mining will increase these air pollutants in the coal fields. New mines will put more communities at risk and expanded mines will make problems worse for those already experiencing air pollution caused by mining.

Several large coal mines in the Powder River Basin have already experienced air quality violations. In the summer of 2011, the Wyoming Department of Environmental Quality issued two notices of violation (NOV's) to two separate mines for air quality problems related to blasting which resulted in a noxious orange cloud that drifted miles off the mine site impacting livestock and residences. New mines and mine expansions will be in areas with more overburden per ton of coal mined. This will make the coal more difficult to mine, producing more particulates and emissions from mining equipment, and may result in more air pollution and air quality violations.

Land & Water Use

Exporting coal will mean the expansion of existing mines and development of new mines, requiring the industrialization of thousands of acres of agricultural land and wildlife habitat.

Coal mining can devastate farms, ranches and prime hunting grounds. Ranchers whose families have been grazing cattle on Bureau of Land Management (BLM) and state land for generations can lose pasture land, sometimes requiring them to ship cattle to non-contiguous pastures or reduce the size of their operations. This can have a serious impact on the ability of ranches to prosper. Loss of wildlife habitat will mean increased hunting and fishing pressure and reduced quality of hunting and other outdoor recreation in the West.

Coal mining also affects water. Coal seams in the Powder River Basin contain shallow aquifers; when the coal is strip mined, so is the water. These destroyed aquifers are not reconstructed by typical mine reclamation practices. Coal mining is already depleting and degrading the water in this region; more mines will compound this damage.

[40] Sharma, Partha Das, "Coal Mining Pollution and its control measures" http://www.docstoc.com/docs/6608086/Coal-Mining-Pollution

[41] California Environmental Protection Agency, Air Resources Board Facts about Particulate Matter Mortality: http://www.arb.ca.gov/research/health/pm-mort/pm-mort_fs.pdf

Table 1: Status of Bond Release by State in Acres [42]

The Surface Mining Control and Reclamation Act created a regulatory program to ensure that mining operations are reclaimed in an environmentally sound manner. The table summarizes the status of bond release in four of the WORC states, and contains data from the 2010 Evaluation Year reports for July 1, 2009, through June 30, 2010. The acreages in each column to the right of Phase I are subsets of the previous column.

State	Disturbed Acres	Phase I	Phase II	Phase III
Colorado	26,115	15,398 (59%)	11,966 (45%)	8,623 (32%)
Montana	37,484	15,218 (41%)	11,175 (30%)	3,181 (8%)[43]
North Dakota	66,075	16,163 (24%)	11,807 (18%)	11,742 (18%)
Wyoming	162,249	38,657 (24%)	5,791 (3.5%)	5,617 (3.5%)

When a coal company opens a mine, it is required to post a bond equivalent to the estimated cost of reclaiming the disturbed land. If the company goes out of business, the bond defaults to the state, which then has the means to reclaim the site. However, before the bond amount can finally be released, the mined area must be restored to its approximate original contours. Vegetation, wildlife habitat and water resources must all be in healthy condition. Reclamation is also supposed to be "as contemporaneous as possible"—an acre healed for an acre disturbed. However, the reclamation record for coal companies in the West is deplorable.

Using the best measure for reclamation success, final bond release, companies in the Powder River Basin have not been successful. According to the federal Office of Surface Mining, coal mining has disturbed more than 162,000 acres of land in Wyoming but only 4% of this land has gained final reclamation status. Montana mines have had even less success, reclaiming just 50 of the over 37,000 disturbed acres–0.1%–disturbed by coal mining sufficiently to attain final bond release.

New Rail Lines

Exporting coal would require construction of new rail lines that will sever prime farm or ranch land or take it out of production completely. Severing farm and ranch land with a rail line reduces productivity and property values. Ranching operations need to be able to move livestock from one side of the tracks to another, and even with proper construction of the rail this can be difficult. Access problems caused by severing ranches can also be a major problem when dealing with natural or train-caused fires.

New rail lines can also split wildlife habitats and interrupt migratory patterns. This disruption not only affects the species but also hunting in the region.

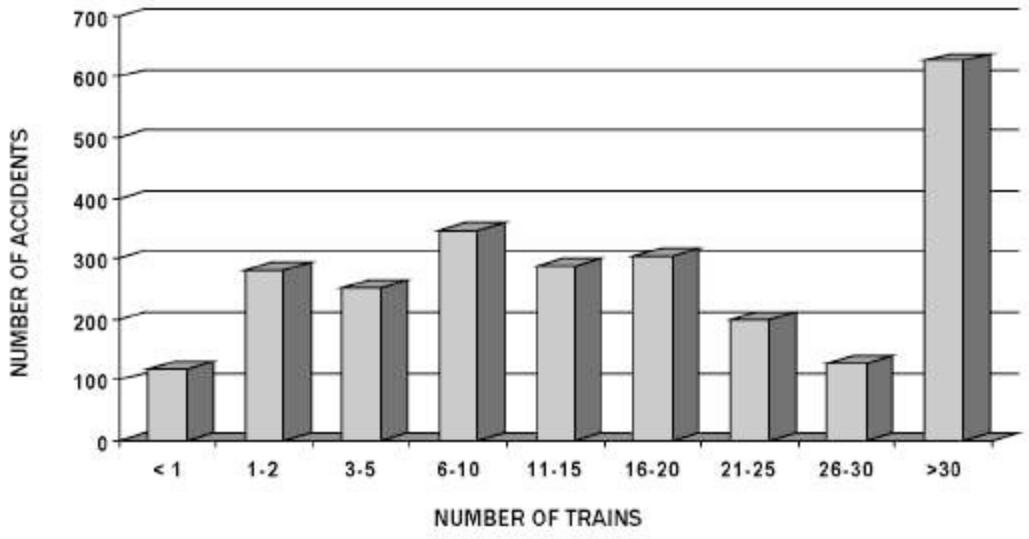
[42] All data from Office of Surface Mining regulatory reports EY 2010, http://www.osmre.gov/Reports/EvalInfo/EvalInfo.shtm.
[43] Montana adds a fourth phase of reclamation. Just 50 acres have achieved Phase IV, (final) bond release in Montana.

The spreading of noxious weeds is another impact of new rail lines. Railroads that cover great distances also can spread noxious weeds onto adjacent land. These weeds can harm farming or ranching operations in the area.

Public Safety

Almost 60 percent of coal in the United States is transported at least in part by train, with coal transportation accounting for 44 percent of rail freight ton-miles. Coal trains, some of which reach more than two miles in length, cause railroad-crossing collisions and pedestrian accidents. There are approximately 3,000 such collisions and 900 pedestrian accidents every year. Crossings with over 30 trains per day result in significant increases in collisions (see figure 4, below). Long coal trains interrupt traffic flow including disruption to emergency responders such as police, ambulance services, and fire departments.[44]

Figure 4: Number of Collisions by Number of Trains per Day per Crossing, 2004



Source: U.S. Department of Transportation Federal Highway Administration- Railroad-Highway Grade Crossing Handbook, revised second edition August 2007. http://safety.fhwa.dot.gov/xings/com_roaduser/07010/sec02.htm

Diesel Pollution

Transporting coal produces significant quantities of air pollution and other environmental problems. Diesel trucks, trains, and barges which transport coal all emit toxic chemicals, such as nitrogen oxide and particulates, which pose serious public health risks. According to a National Resources Defense Council study, railroad engines and trucks hauling coal together release more than 600,000 tons of nitrogen oxide and 50,000 tons of particulate matter into the air every year, mostly in diesel exhaust.[45]

Though small compared with the emissions from burning the coal itself, burning diesel to move coal also emits global warming pollution. According to an analysis by Earthworks, approximately 700,000 tons of

[44] Natural Resources Defense Council Issue Paper Coal in a Changing Climate, February 2007. http://www.nrdc.org/globalwarming/coal/coalclimate.pdf

[45] Natural Resources Defense Council Issue Paper Coal in a Changing Climate, February 2007. http://www.nrdc.org/globalwarming/coal/coalclimate.pdf

CO2 could be emitted every year if 20 or 30 million tons of coal was shipped to China from the Powder River Basin. A shorter trip to Japan would still result in emissions of up to 500,000 tons of CO2.

Coal Dust

Increasing coal shipments would increase the amount of coal dust lost from coal trains. BNSF estimates that a single loaded rail car can lose 500 pounds of coal, primarily from blowing off the top of the car[46]. Coal dust pollutes the communities that coal trains pass through. Coal dust can blow into rivers and streams. Coal dust has even caused fires in areas where coal dust blown from trains has built up near the tracks. [47]

Coal dust can also degrade track conditions. The dust can cause a weakened track structure leading to more derailments, inconveniencing all rail customers.

BNSF recently prevailed in a challenge by shippers against its attempts to establish a tariff and standards to reduce the dissemination of coal dust. If measures are taken to significantly control the dust from coal hoppers as they travel cross country, it will be an example of internalizing the true costs of coal shipping into the final price to the end user.

Impacts to Electricity Consumers

Increasing coal exports will require coal companies to mine coal that is increasingly dirty, dangerous, difficult and expensive to mine and reclaim. These increased costs will drive up domestic utility rates more quickly, decreasing the benefit of coal as a relatively cheap fuel source.

Impacts on other industries that ship commodities by rail

Rail carried 38 percent of the total freight shipped in the United States in 2005. Many commodities depend heavily on rail for transportation; among the most dependent are coal, domestically produced automobiles and grain.[48] An increased volume of coal shipping by rail would adversely affect these industries. For example, 110 million tons of coal shipped through Montana would double the volume of freight carried in and through the state in 2006.[49]

Grain growers are dependent on efficient, reliable, affordable service to get grain to market, and have fought to win fair service for smaller train service to grain elevators. Historically, grain growers have complained about the timeliness and reliability of service to elevators, and about rail rates for grain shipping. Greater rail traffic, and dominance of coal among major commodities served by the railroad, could lead to more problems for grain shippers and complaints about service.

---

[46] Eric DePlace, Sightline, "At Least the Website Is Clean" August 10, 2011 with a link to the BNSF FAQ preserved webpage on coal dust. http://daily.sightline.org/2011/08/10/at-least-the-website-is-clean/

[47] Burlington Northern Sante Fe website: http://www.bnsf.com/customers/what-can-i-ship/coal/coal-dust.html

[48] http://www.lrca.com/railroadstudy/Volume_1.pdf

[49] 2010 Montana State Rail Plan, Prepared for Montana Department of Transportation by Cambridge Systematics, December, 2010, p. ES-5

Conclusion

As the United States transitions away from dirty fuels, such as coal, to meet its electricity demand, the coal industry has begun to develop substitute markets by exporting coal, especially to China, India, and other countries on the Pacific Rim.

Coal extraction in the Powder River Basin harms the land, water, air and public health in the communities and people that live in and near coal production areas, and leaves behind a legacy of reduced productivity and waste.

Increasing coal exports would require significant additions and upgrades to rail lines in the West. These lines would cut through pristine areas, severing farms and ranches, reducing productivity and property values. Communities split by rail would face serious delays caused by over 40 trains a day needed to transport coal from the Powder River Basin to West Coast terminals and back.

These efforts to export coal coincide with the idea that the world is near "peak coal" – that is, the period of all-time high coal production, after which some geologists and economists predict that production will begin an irreversible decline. In a study published in the peer-reviewed journal *Energy, The International Journal*, two researchers say the world will hit peak coal production in 2011, or shortly thereafter[50].

Hitting "peak coal" production does not mean we are about to run out of coal entirely; instead, it means that we have mined all the coal that is easiest and cheapest to produce. Remaining deposits of coal are lower quality and becoming increasingly difficult, dangerous, environmentally destructive, and expensive to mine. Exporting coal will make domestic coal mining more dangerous, dirtier, more difficult, and increasingly more expensive to mine at a faster pace. Increasing coal exports will, among other things, accelerate the rate at which the cost of electricity produced from coal increases.

Exporting Powder River Basin coal to the Pacific Rim is fraught with unpaid costs. Powder River Basin coal cannot be economically exported to the Pacific Rim without imposing uncompensated costs on communities, businesses and individuals near the mines, along the railroad corridors, and at the ports. Local citizens, businesses and communities and the global climate must not be left to absorb the damages of coal exports while a handful of coal companies and railroads pockets the profits.

[50] Patzek, Tadeusz and Gregory D. Croft "A Global coal production forecast with multi-Hubbert cycle analysis", Energy, Volume 35, Issue 8, August 2010, Pages 3109-3122

EH-93-4 The Fire Below: Spontaneous Combustion in Coal

ENVIRONMENT SAFETY & HEALTH
BULLETIN

Assistant Secretary for
Environment, Safety & Health

U. S. Department of Energy
Washington, D.C. 20585

DOE/EH-0320 Issue No. 93-4 May 1993

THE FIRE BELOW: SPONTANEOUS COMBUSTION IN COAL

How Coal Self-Ignites

The coal's temperature begins to climb above ambient. At about 150-300 degrees F, it begins to give off minute, but measurable, quantities of gas--aerosols, hydrogen, and CO(2)--precursors of combustion. As the temperature increases further--at about 600-700 degrees F--relatively, large, visible particulates are emitted. Soon, as the heating rate increases in intensity to about 750-800 degrees F, incipient combustion, and ultimately self-ignition and flame, will occur.

At least a dozen coal fires occurred within the Department of Energy (DOE) over the last decade. Seven sites were involved, with two of the seven experiencing multiple incidents. Fortunately, none of the fires resulted in fatalities. However, damages from all but one ran into the thousands of dollars, and the most severe incident caused a minimum os $800,000 damage.

The risk from fire exists anywhere significant amounts of coal are in use or storage. Coal is a combustible material, making it susceptible to a variety of ignition scenarios. One of the most frequent and serious causes of coal fires in spontaneous combustion, which has been responsible for a number of incidents within the Department in recent years. Preventing spontaneous combustion coal fires involves attention to many different factors. Among the most critical are the type, age, and composition of coal, how it is stored, and how it is used. Given the right kind of coal, oxygen, and a certain temperature and moisture content, coal will burn by itself.

Spontaneous combustion has long been recognized as a fire hazard in stored coal. Spontaneous combustion fires usually begin as "hot spots" deep within the reserve of coal. The hot spots appear when coal absorbs oxygen from the air. Heat generated by the oxidation then initiated the fire.

Such fires can be very stubborn to extinguish because of the amount of coal involved (often hundreds of tons) and the difficulty of getting to the seat of the problem. Moreover, coal in either the smoldering of flaming stage may produce copious amounts of methane and carbon monoxide gases. In addition to their toxicity, these gases are highly explosive in certain concentrations, and can further complicate efforts to fight this type of coal fire.

Even the most universal firefighting substance, water, cannot be used indiscriminately. Because of the remote possibility of a steam explosion,

it is advisable that water be applied carefully and from a safe distance. Certain chemicals such as carbon dioxide or nitrogen may mitigate fire effects, but their use has had mixed success from a DOE perspective. The above information suggests that coal fires require awareness and prior planning to extinguish efficiently, completely, and safely.

Recent Coal Fire at DOE Site

In 1992, a DOE site experienced its most recent coal fire initiated by spontaneous combustion. Due to the nature of the fire and initial ineffectiveness of the means utilized to fight it, the fire required more than 28 hours to completely extinguish from the time a hot spot was first detected in the coal bunker. The initial strategy involved trying to remove coal from the bunker by feeding it more rapidly to the boiler and by using a drag chain to move more of it to the field. The drag chain failed in 30 minutes, however. Subsequent efforts to control the fire with carbon dioxide applied through inspection ports at the bottom of the bunker and from the tripper room high above the bunker were ineffective, and may have worsened the situation. The drag chain emptying coal from the bunker worked intermittently after being repaired, and finally stopped. Boiler plant personnel then began to remove burning coal by hand shovel.

Twenty-one hours after the fire was discovered, it had involved a large amount of the bunker. At one point, flames appeared at the tripped room windows, which are approximately 75 feet above the seat of the hot spots. A strong concern for a steam explosion delayed the application of water, but the decision was finally made to use water, which was applied without incident and eventually ended the fire.

Causes of Spontaneous Coal Fires

The incident related above serves as an excellent case study of a spontaneous combustion coal fire. It illustrated some major causes of such fires as well as the problems of fighting them effectively and safety. The following general factors have been mentioned as contributing causes:

- Coal handling procedures allowed for long-time retention of coal, which increases the possibility of heating.
- New coal added on top of old coal created segregation of particle sizes, which is a major cause of heating.
- Too few temperature probes installed in the coal bunker resulted in an excessive period of time before the fire was detected.
- Failure of equipment needed to fight the fire (drag chain conveyer).
- Ineffective capability and use of carbon dioxide fire suppression system.
- Delay in the application of water.
- Inadequate policies, procedures, and training of personnel prevented proper decision making, including the required knowledge to immediately attack the fire.

- Failure to learn lessons from two previous coal bunker fires at the same installation.

DOE Coal Fires in the Last Decade

Other coal fires caused by spontaneous combustion have occurred at DOE facilities in the last decade. In 1985 spontaneous combustion was responsible for starting two fires in a coal bunker at a DOE site. The fires were extinguished by injecting gaseous nitrogen into the bunker near the hot spots. The cause was determined to be the excessive storage time of the coal. In addition, excessive compaction caused by fines (finely crushed coal) contributed to the rate of ignition.

In 1991 at another DOE site, a smoldering fire was discovered in an unused coal bunker which had accumulated 2 cubic feet of coal dust from an overhead coal conveyer system. The fire was believed to have started spontaneously, through careless smoking was also listed as a possible cause. At still another site, coal stored too long in a silo ignited due to spontaneous combustion.

An unusual fire which occurred in 1991 illustrates the opportunistic nature of spontaneous combustion on coal. A backhoe had been sitting for 3 hours after the close of work. For the previous 2 days, the backhoe had been mucking out slag and coal collection ponds to remove coal fines. A security guard noticed a fire on the backhoe rear tire. Facility personnel believe the cause of the fire was spontaneous combustion of the coal fines which had adhered to the tire. Some of the thick coal mud in the ponds had not been exposed to oxygen until it was churned up by the tires of the backhoe. Personnel were instructed to wash equipment tires when leaving the ponds for the day.

Preventing Spontaneous Combustion in Stored Coal

Hugh quantities of coal are stored in bunkers, silos, hoppers and open air stockpiles. How susceptible such stocks of coal are to fire from spontaneous combustion depends on a number of factors, from how new the coal is to how it is piled.

Recommendations:

- Know your coal. Anthracite (sometimes called eastern coal) has a high carbon content and is much less combustible than low oxygen content bituminous (or western) coal. Freshly mined coal absorbs oxygen more quickly than coal mined at an earlier time, and is more likely to head spontaneously.

- Storing coal with a low sulphur content is helpful. Sulphur compounds in coal liberate considerable heat as they oxidize.

- Air circulating within a coal pile should be restricted as it contributes to heating; compacting helps seal air out.

- Moisture in coal contributes to spontaneous heating because it assists the oxidation process. Moisture content should be limited to 3 percent; sulphur content should be limited to 1 percent, "as mined." Coal having a high moisture content should be segregated

and used as quickly as possible. Efforts should be made to keep stored coal from being exposed to moisture.

- Following the "first in, first out" rule of using stock reduces the chance for hot spots by helping preclude heat buildup for portions
::
of stock which remain undisturbed for a long term. The design of coal storage bins is important in this regard.

- A high ambient temperature aids the spontaneous heating process.

- Use coal as quickly as practicable. The longer large coal piles are allowed to sit, the more time the spontaneous process has to work.

- The shape and composition of open stockpiles can help prevent fires. Dumping coal into a big pile with a trestle or grab bucket can lead to problems. Rather, coal should be packed in horizontal layers (opinions range from 1 1/2' to 3' high) which are then leveled by scraping and compacted by rolling (See Figure 1, not included in SPMS, see original Bulletin for Figure). This method helps distribute the coal evenly and thus avoids breakage and segregation of fine coal. Segregation of coal particles by size should be strenuously avoided, as it may allow more air to enter the pile and subsequent heating of finer sizes.

- The height of the coal pile is also important. Limit unlayered, uncompacted high grade coal to a height of 15' (10' for low grade coal); maximum height is 26' for layered and packed coal.

- Properly inspect, test and maintain installed fire protection equipment.

- Maintain an updated pre-fire plan and encourage regular visits to coal facilities by the site or local emergency response force.

Fig. 1 (Not included, see original Bulletin). Poor distribution of fine and coarse coal resulting from dumping from a high trestle or grab bucket without rolling (above), compared with good distribution and exclusion of air by roll-packing method. (Illustration courtesy of Factory Mutual Engineering Corp., 1975)

Pertinent Orders, Notices and Rules

DOE Order 5480.7A, Fire Protection, includes requirements for physical fire protection features, hazards analysis, fire prevention procedures, and periodic fire safety assessments.

29 CFR, Part 1910, Subpart L, Fire Protection, includes requirements for fire departments, such as pre-fire planning and training, as well as criteria for physical fire protection features.

Guidance

The DOE Fire Protection Resource Manual includes model fire prevention procedures, fire protection system testing and maintenance procedures, and model fire department operating procedures.

Factor Mutual, Coal and Charcoal Storage, Loss Prevention Date, #8-10, August 1975, provides guidance on prevention of coal fires.

A Lesson Learned from the Titanic

Deep-seated coal fires are not a new problem. J. Dilley, survivor of the sinking of the TITANIC, reported to following:

> The TITANIC sailed from Southhampton on Wednesday, April 10, 1912, at noon. I was assigned to the TITANIC from the OCEANIC, where I served as a fireman. From the day we sailed the TITANIC was on fire, and my sole duty, together with eleven other men, had been to fight that fire. We had made no headway against it.
>
> The fire started in bunker No. 6. There were hundreds of tons of coal stored there. The coal on top of the bunker was wet, as all the coal should have been, but down at the bottom of the bunker, the coal had been permitted to get dry.
>
> Two men from each watch of stokers were told off, sir, to fight that fire. The stokers, you know, sir, work four hours at a time, so twelve of us was fighting flames from the day we put out of Southhampton until we hit the iceberg.
>
> No sir, we didn't get that fire out, and among the stokers there was talk, sir, that we'd have to empty the big coal bunkers after we'd put our passengers off in New York and then call on the fireboats there to help us put out the fire. But we didn't need such help. It was right under bunker No. 6 that the iceberg tore the biggest hole in the TITANIC, and the floor of water that came through, sir, put out the fire that our tons and tons of water had not been able to get rid of.

This Bulletin is one in a series of publications issued by EH to share occupational safety information throughout the DOE complex. To be added to the Distribution List or to obtain copies of the publication, call (615)576-7548. For additional information regarding the publications, call Barbara Bowers, Safety Performance Indicator Division, Office of Environment, Safety and Health, U.S. Department of Energy, Washington, DC 20585, (301)903-3016.

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Mr. Ted Carlson
Title: City of Bellingham, Public Works Director
From: Edward Koltonowski
Subject: Cherry Point Commodity Export Facility Rail Operations-City of Bellingham; GTC #11-095
Date: June 21, 2012

This memorandum is to identify some of the possible rail impacts associated with transport of commodities to the proposed Cherry Point Facility affecting the City of Bellingham and its access roads. It identifies the potential impacts on the City's downtown waterfront, recreational and business area.

The purpose of this preliminary report is to provide City staff with information that may be useful as the City prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

1. Project Description and Expected Delays

We understand a terminal capable of exporting 54 million tons of commodities per year is proposed north of Bellingham. GTC understands that the probable route of the 48 million tons that would be coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run North-South directly along the west part of the City of Bellingham, Washington.

According to the applicant's *Project Information Document* (Feb. 2011), full build out of the export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day (16 for coal); however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. The current port proposal occupies 350 acres of a 1,000-acre site. Each coal train will be up to 1.6 miles long, which at 50 mph would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour, it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35 mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Bellingham can be estimated to increase with an additional train every *every 1.3 hours,* if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use sidings or speed restricted crossing. Assuming just a 5-minute average (consistent with the existing smaller coal trains traveling through Bellingham) would lead to every crossing on the track in Bellingham being closed for an additional 90 minutes a day not including the additional clearance time for back ups to clear after a crossing arm lifts. This doesn't take into account the potentially much greater impacts of a potential South Bellingham siding that are discussed further in this study.

2. Affected Crossings

The BNSF railway tracks bisect the western waterfront area of Bellingham (including the Ferry terminal and beaches) from the east side of Bellingham that includes the downtown business core and residential area. The City of Bellingham has a number of crossing connecting its downtown business core/residential areas to the waterfront area, most of which are directly affected by the proposed increase of rail traffic. The rail crossings that are at grade/gate controlled in the downtown area are:

- Harris Avenue
- 6th Street
- Bayview Road
- Cornwall Avenue
- Wharf Street
- Laurel Street
- Central Avenue
- C Street
- F Street

Due to these constraints, our preliminary review indicated that the additional trains from the Cherry Point operations could have a potential significant impact on the waterfront district and quality of life for the people who live and visit the City. Of primary concern are potential backups onto Holly from the proximity of the Central Avenue, F and C Street crossings, resulting in a likely drop in level of service on City streets and diminished emergency response times, thus affecting future development potential along the waterfront as well as existing businesses such as the Ferry Port and restaurants.

Equally if not more important to note for the Bellingham is that the 2008 WSDOT capacity study shows that the existing line in Bellingham is at capacity. Based on current data, the existing numbers of trains in the Bellingham area is averaging 15 trains a day. Therefore, the rail operators will need to implement improvements to add capacity along this stretch of rail line. Consistent with the WSDOT report, the South Bellingham siding appears to be the optimum location for adding capacity to the rail line but may have significant impacts to the street system. To accommodate 150-car coal trains the siding will be extended from near 6th Street to Central. This would mean permanent at-grade closures of Bayview Drive to Boulevard Park, Southbay Trail and Wharf Street access.

The additional or extension of a siding close to street crossings has a two impacts. The first impact is that with only the existing single track, the time between trains passing is more than enough to allow the queue of backed up traffic to dissipate before another long train arrives. However, with a local siding capable of having a full length coal train waiting nearby, the adjacent crossing can experience trains in such quick succession that either the existing queues that have built up do not have a chance to dissipate or the advanced warning timeframe is such that the crossing actually remains closed for the passage of two trains.

The second impact of having a siding near or at grade crossings is that unless the location of the train on the siding is a long distance from a crossing, the trains accelerating from a stop are traveling well below the maximum track speed as they enter or leave the siding. The closure of a crossing near a siding is therefore longer than the typical closure time at full track speed. Surveys of existing siding/closing location south of Bellingham shows that such combined crossing/siding location can have 10-12 minute closure times in a 15 minute interval.

3. Analysis of Potential Impacts

We have the following comments based on preliminary research:

1. The Rail Transportation Facilities and Services section of the City of Bellingham's Comprehensive Transportation Element identifies that "railroads do have significant impacts on the community. Industrial land use patterns in and near Bellingham are interrelated with rail lines in the City. Local rail service to the Port's industrial areas is an essential link in the transportation system".

   The Burlington Northern Santa Fe Railroad operates freight trains serving Bellingham. Amtrak operates passenger trains between Portland, Seattle, and Vancouver, B.C. The Amtrak station in south Bellingham is part of the Fairhaven Transportation Center and provides an important link with the Greyhound bus terminal, Amtrak Cascades rail service, the Alaska Marine Highway ferry service, privately operated commuter ferries to and from the San Juan Islands and WTA bus service. The location also provides easy access to state highways and Interstate 5.

   Railroad tracks can sometimes create a barrier to safe bicycle and pedestrian access to the waterfront and the City's trail system to and along the waterfront. Opportunities to develop grade-separated railroad crossing should be explored wherever feasible. The old Great Northern rail passenger station, at the foot of "D" Street, now owned by Burlington Northern Santa Fe, is one of several sites in Bellingham that has been listed on the National Register of Historic Places. As the Old Town and Central Waterfront areas are rezoned and redeveloped, this station could be refurbished and integrated into the revitalization of these neighborhoods. The December 2004 Waterfront Action Plan from the Waterfront Futures Group calls for improving waterfront access as follows:

   "Establish a comprehensive inventory of opportunities related to rail access and railroad facilities". The Waterfront Advisors group should establish priorities for action and designate lead and participant agencies.

   a. Explore options for moving or covering portions of the railroad tracks
   b. Explore future location of a multimodal rail station in the center of the city
   c. Evaluate options for improving railroad operation and safety
   d. Evaluate approaches to mitigate railroad impacts
   e. Preserve the revised railroad corridor for future

   The Bellingham Bicycle and Pedestrian Advisory Committee has identified several enhanced/new pedestrian connections in the central business district and waterfront area in the Transportation Element. A number of these would be impacted with additional train traffic. The impact on the adopted Bellingham non-motorized section of the Transportation Element should be assessed in any environmental evaluation of the Cherry Point permits.

2. Due to a speed restriction, approach warning signs and sidings, train travel along the waterfront means the barriers are down for approximately 4-6 minutes (over 300 seconds) for the larger (over one mile long) freight trains if there are no delays and they travel at their maximum allowable speed (20 mph for Central Avenue). This is the equivalent of 3-4 continuous red lights cycles in a row for a normal signal on such crossing as F Street, C Street, and Central Avenue. As stated earlier, with a siding the influence of combined trains may have a much longer crossing closing time of over 10 minutes in a 15-minute time period. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F. The City's standard for arterial roadway operation is LOS D, i.e. allowing only 55 seconds as the worst delay for normal conditions and LOS C for collectors (Dayton). The addition of 16-18 trains per day would call into question whether the City can maintain its adopted LOS D standard at these intersections. This, in combination with the impacts

on non-motorized transportation, may be central to future concurrency determinations by the City affecting future development projects.

3. With the increase in the number of long coal trains at the ferry/Coast Guard/Amtrak station area (Harris/6th Street) crossing, and because there are no alternative east-west grade separated crossings, the east-west route becomes degraded with the increased coal trains. This is a particular issue during summer peaks, with the beaches/Marine Park and ferry route subject to potential long and/or repeated closures. Mitigation could be a grade-separated crossing to the waterfront although site challenges may make that impractical.

4. There is a probable issue concerning emergency services response times, particularly to the ferry terminal/ship yard area that have no grade-separated crossing. Also, emergency access to the central waterfront area is severely hampered where the nearest emergency service station would need to do a significant roundabout detour when a train is blocking F Street, C Street, and Central Avenue (which would all occur at the same time with a coal train crossing). Adding 16-18 additional trains per day to service Cherry Point could tip the balance at a critical time when emergency responses are needed. There should be coordination between City emergency services and BNSF to see how this can be mitigated, particularly as just last January there was a freight train accident at the F Street crossing.

5. Already today the presence of a long freight train during the peak hours creates separation from the City's waterfront amenities and businesses. The City's annual counts show approximately 8,000 daily trips along Roeder Street, 2,600 daily trips near Wharf Street crossing with 5,600 ADT crossing the F Street crossing alone, and nearly 3,700 daily trips at the Harris Avenue crossing. With the additional coal trains that take 4-6 minutes to cross (if not delays/slowing for the siding) the cumulative additional delay to drivers is potentially significant not only in terms of delay at the crossing but also in terms of delay onto Holly. Holly Street is a major arterial for the City and carries approximately 9,000 daily trips in the vicinity and is a major emergency route for the City. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. One form of mitigation is to create grade-separation, with either a tunnel or a bridge.

6. Whatcom County communities and the State have recently invested heavily in improved passenger train (AMTRAK) services for Northwest Washington. Freight traffic on the single rail line north of Everett is expected to double with the Cherry Point proposal. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on-time reliability demands of passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to analyze the degree to which a doubling of freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand passenger rail. In 2001, the City participated in a state-sponsored study of the potential for passenger rail expansion, titled: *Pacific Northwest Rail Corridor: Everett to Blaine Commuter Rail Preliminary Feasibility Study*. On Page IV of the Executive Summary, the report concludes that there may be a viable market for commuter rail north of Everett by the year 2030. In 2004, the *North Sound Regional Study* conducted by Cascadia for Whatcom Council of Governments identified again the potential of significant rail capacity issues identified by BNSF. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies.

7. The City Comprehensive Transportation Element identifies the need for truck and rail access to its industrial areas. The State's 2006 Statewide *Rail Capacity and System Needs* study identifies a key issue affecting that access to local business as follows:

> "The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.

> Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market."

So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability of local rail spur business necessary to serve Bellingham businesses. These issues can be analyzed as part of the economic impact analysis we understand must be completed as part of the environmental review for the project.

The 2011 Cascadia study reported about Cherry Point train traffic impacts to local train users such as BP: "The entrance to the subdivision at Custer has the potential to create an operational bottleneck if the train frequencies expected by the Terminal materialize. Industry switch engines, slowly moving loaded coal trains and the resulting empties could result in volumes of traffic that would tax the mainline and small yard that is located at Custer. With the close proximity of the border to the Custer Intalco line, future congestion may result.

Other shippers in the Cherry Point area rely on schedule reliability to meet current market conditions. Mark Hinders, operations manager at Energy Logistics which transports petroleum products from the BP refinery indicated that they were actively pursuing new customers from Canada and the U.S. and would need more predictable rail service. Deliveries from BNSF Railway are sometimes random and my customers need predictability. Any infrastructure or operational improvement at the border or in Everett terminal would be welcome, said Hinders.

The Washington State *2010-2030 Freight Rail Plan* published by WSDOT in December 2009 identified that the rail line North from Everett in 2008 was already at its capacity of 18 trains per day (Exhibit 3-9). The State plan shows that it hopes to increase that capacity to 30 trains per day; however, the design and cost of the specific improvements needed to do that have not yet been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services. The 2011 Cascadia study also identified this issue in the "*The Bellingham Waterfront District"*

> "The future of rail service in Bellingham is also closely intertwined with plans for the Bellingham Waterfront District, through which the BNSF tracks will run, with or without the new coal trains, and within which the Fairhaven Transportation Center – the Amtrak station - is situated. The entire district is expected to take 30 to 40 years to build-out. Plans call for up to 6 million square feet of residential, commercial, marine-trades, hospitality and educational uses. Under the plan, advanced by the Port of Bellingham as lead agency, the public would gain new access to restored shorelines. The port would deed 33 acres of land to the city for waterfront parks and trails. The city has agreed to put in streets and utility infrastructure. The project will be developed in phases, so as to be gradually absorbed into the city's life as funding becomes available. The port plans to sell much of the land to developers so it can recoup its cleanup costs. Public investment by the port, city and state in cleanup, shoreline restoration, roads, utilities, parks and other infrastructure is estimated at well over $200 million, with half the funding coming from federal and state grants. This public sector investment is intended to attract the much larger private investment upon which the success of the project ultimately depends. Cost of the full build-out is estimated at $2 to $3 billion. Over the coming years, this public-private partnership will provide the community with an exciting urban waterfront with excellent public access that is pedestrian and bicycle-oriented. The district seen by its proponents as a neighborhood of the future will feature far

more than the average amount of open space for a development of this size, to say nothing of advanced energy-conservation features and compact urban design."

The economic impacts of the project on the area are significant. It is estimated that for every $1 million in construction costs, 13 direct jobs and 10 related services jobs would be created. Also, between 2,500 and 4,800 permanent jobs will be created by 2026, according to WWU's Center for Economic Research." It is clear that this sort of development does not envision an additional 18 trains over 1.5 miles long through the heart of the new waterfront development area.

8. The Cherry Point applicant and its advocates argue that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore there is no impact. In our judgment, this conclusion is not supportable, because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well as vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically as the Cascadia study identified that, since the 2008 drop in commerce, there has again been a steady rise in freight movement across the borders.

9. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. While grade separation is desirable, these improvements are typically multi-million dollar solutions based on the Bellingham multi-modal station study and waterfront plans. We recommend that the Cherry Point permitting agencies overseeing the environmental review provide local jurisdictions with detailed assessments of mitigation and funding necessary to alleviate the impacts that will results from the projected addition of up to 18 trains per day serving the Cherry Point export facility.

4. Conclusions

This analysis of possible rail line impacts associated with sidings and the increase of up to 18 trains per day serving the Cherry Point export facility is preliminary and is intended to illustrate some of the potential significant problems and areas deserving detailed study during the SEPA and NEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and planned waterfront redevelopment, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, and possible interference with local freight delivery systems important to the City's economic recovery.

MEMORANDUM

To: Mr. Chal Martin PE
Title: City of Burlington Public Works Director
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations-Burlington; GTC #11-036
Date: August 15, 2011

This memorandum is to identify some of the possible rail impacts associated with transport of coal to the proposed Cherry Point Facility in the City of Burlington and its access roads. It identifies the potential impacts on the City's downtown core area of Fairhaven as well as the approach roads to the city such as Pease Road to the south and Cook Road to the north.

We understand a terminal capable of exporting 48-54 million tons of coal per year is proposed north of Bellingham. GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north-south directly through the center of the City of Burlington, Washington. Burlington also has a number of spur lines/switching points and the major Sumas line that runs east that has been discussed before to take the Canadian bound trains to open up more capacity on the Burlington line.

According to the applicant's *Project Information Document* (Feb. 2011), full buildout of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day; however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. The current port proposal occupies 350 acres of a 1,000-acre site. Each train may be over 1.5 miles long, which at 50-60 miles per hour would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour it could take approximately 6-7 minutes to clear a crossing at switching or siding area crossings as they are typically rated for much slower traffic. Also, if trains are diverted to the Sumas track they are limited to 20 mph through town, which means signal warning light can restrict the crossing for up to 10 minutes for the longer trains. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Burlington can be estimated to increase with an additional train *every 1.3 hours*, if train trips were evenly spaced throughout the day and night at between 3-4 minutes or 6-7 minutes or up to 10 minutes depending on if they are having to use the siding/switching locations/Sumas route or not.

The BNSF mainline railway tracks bisect the eastern residential area of Burlington from the commercial west side of Burlington that includes the downtown business core and access to I-5. The City of Burlington has three major east-west roads connecting to the downtown business core areas of the City to the eastern residential area; Avon Street (SR-20), Fairhaven Street, and Greenleaf Street; all of the crossings are at grade/gate controlled. Additionally, the access roads of Pease Road and Cook Road to the south and north are both at grade crossings. As stated earlier, Burlington is also a major switching and connection point for not only the mainline Pacific Canada rail line but also has the Burlington Fidalgo line and Sumas Burlington line. Although the Fidalgo line is little used, the Sumas line has as many, if not more, trains per day than the Pacific Line. Also the Sumas line bisects the north side of the residential area from the south side. The line cuts Fairhaven Avenue, Pine Street, Anacortes Street, Regient Street, Skagit Street, Section Street, Gardner

Road and Peter Andersen Road. It is also this Sumas line that we understand may take any additional trains that cannot proceed north on the Pacific line if there are capacity constraints. Due to these constraints, our preliminary review indicated that the additional trains from the Cherry Point operations would have a potential significant impact on the commercial district and quality of life for the City of Burlington residents, as well as visitors to the commercial centers.

The purpose of this preliminary report is to provide City staff with information that may be useful as the City prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

We have the following comments based on preliminary research:

1. The City's comprehensive plan identifies several road segments that will be at capacity that are bisected by rail crossing such as Fairhaven Avenue and Avon Street. Additionally, some of the north-south routes are impacted because of the limited number of east-west crossings. People need to travel further parallel to the rail lines than would normally occur.
2. Due to speed restrictions for freight trains approach warning, train travel through downtown means the barriers are down for approximately 3-4 minutes (over 200 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 2-3 continuous red light cycles in a row for a normal signal on city streets. The Highway Capacity Manual identifies an average delay of over 80 seconds as level of service F. The City's standard for normal roadway operation is LOS C or LOS D depending on road classification, i.e. allowing only 45-60 seconds as the worst delay for normal conditions. The addition of 16-18 trains per day would call into question whether the City can maintain its adopted LOS standard.
3. With the increase in number of long coal trains through the City, there is no choice for east-west residential or commercial traffic. This is a particular issue during summer peaks, as both Fairhaven Avenue and Avon Street experience increased summer traffic volume as well as an increased mix of RV traffic.
4. There is a probable issue concerning emergency services response times, in a scenario where the 1.5 mile long trains block all the downtown east-west crossings at the same time for several minutes. Adding 16-18 additional trains per day to service Cherry Point could tip the balance at a critical time when emergency responses are needed.
5. Within the last 5 years there have been approximately 10 accidents at the City crossings, including two involving school buses. Nearly all were rear ends as gates closed or buses stopped to cross. Additionally there were four recorded accidents at the Cook Road crossing.
6. Already today the presence of a long freight train during the peak hours creates separation for both north-south and east-west travel in the City. The WSDOT and City count data bases identified that approximately 13,000 daily trips cross the Avon Street (SR-20) tracks on an average day and approximately 9,400 daily trips cross the Fairhaven Avenue tracks and recorded approximately 4,200 daily trips along Greenleaf Street. In addition Pease Road carries approximately 4,200 to the south and Cook Road nearly 13,000 daily trips to the north. Therefore, the main east-west at grade rail crossings in the city influence area have approximately 45,000 daily vehicle crossings. This does not account for the Sumas crossing, which would add close to another 20,000 daily trips. It also does not include the Fidalgo crossings that would not be impacted by the Cherry Point proposal. With the doubling of train traffic with coal trains that take 3-4 minutes to cross (if no delays/slowing) just on the Pacific line alone, the cumulative additional delay to drivers is potentially significant. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. One form of mitigation is to create grade-separation,

with either a tunnel or a bridge. The City may wish to request that mitigation is part of the environmental review process for Cherry Point.

7. Skagit County communities and the State have recently invested heavily in improved passenger train (AMTRAK) services for the north end. Freight traffic on the single rail line north of Everett is expected to double with the Cherry Point proposal. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on time reliability demands as passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to analyze the degree to which a doubling of freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand passenger rail. In 2001, the City participated in a state sponsored study of the potential for passenger rail expansion, titled: *Pacific Northwest Rail Corridor: Everett to Blaine Commuter Rail Preliminary Feasibility Study*. On Page IV of the Executive Summary, the report concludes that there may be a viable market for commuter rail north of Everett by the year 2030. In 2004 the North Sound Regional Study conducted by Cascadia for Whatcom Council of Governments identified again the potential of significant rail capacity issues identified by BNSF. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies.
8. The City does have a number of sidings for local industrial users and is one of the main residential/commercial areas east of other local train industrial users such as Twin Foods or the Oil refinery operations further west. Residents of the city or out-of-town employees from those facilities using the retail centers of Burlington may be impacted since local short-haul trains for local business could be impacted.

   The Washington State 2006 "statewide *Rail Capacity and System Needs* study" identifies the first issue as follows:

   > The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.
   >
   > Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market.

   So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability of local rail spur business necessary to serve Burlington and surrounding businesses. These issues can be analyzed as part of the economic impact analysis we understand must be completed as part of the environmental review for the project.

9. The Washington State 2010-2030 Freight Rail Plan published by WSDOT in December 2009 identified that the rail line in this area in 2008 was already at its capacity of 18 trains per day (Exhibit 3-9). The state plan shows that it hopes to increase that capacity to 30 trains per day; however the design and cost of the specific improvements needed to do that have not yet been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services. Additionally, the Cherry Point trains could create additional traffic on the Sumas tracks that could result in a significant capacity constraint on the movement of vehicles on the City street system.
10. The Cherry Point applicant and its advocates argue that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore it will have no impact. In our judgment, this conclusion is not supportable, because as soon as the

economic recovery really starts to take hold, those previous train activities will also pick up, as well vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically.

11. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. While grade separation is desirable particularly because of the already complicated movement of SR-20 through the City, these improvements are typically multi-million dollar solutions and funding is not yet planned. Estimates of this mitigation may be obtained by the City, in conjunction with estimates of similar improvements to be requested by other cities, counties, and WSDOT. It is our understanding, for example, that replacement of the Skagit River Bridge may be necessary to support the proposed heavy coal rail increases. The budget for design and construction of that improvement alone may be half a billion dollars. We recommend that local jurisdictions provide regulating authorities with detailed assessments of mitigation and funding necessary to alleviate the impacts that will result from the additional 16-18 trains per day serving the Cherry Point export facility.

This analysis of possible rail line impacts associated with the increase of 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to illustrate some of the potential problems and areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, and possible interference with local freight delivery systems important to the City's economic recovery.

ATTACHMENTS FOR CITY OF BURLINGTON RAIL CAPACITY PRESENTATION

- Rail Crossing Inventory
- Daily Traffic at Crossings
- Transportation Element Information
- Accident History Data
- State Report Information

Rail Crossing Inventory

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7301852

Home Crossing Forms/Publications Downloads Data Documents Policies Support

8.01 - Query by Location

Total Records: 30

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

Generate Repor | Show Paging | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**077833N**	WA	BNSF	Public	At Grade	Open	007322	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	N HILLS BLVD
☐	**084763T**	WA	BNSF	Public	At Grade	Open	007081	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	PEASE RD.
☐	**084764A**	WA	BNSF	Public	At Grade	Open	007193	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	GREENLEAF ST
☐	**084765G**	WA	BNSF	Public	At Grade	Open	007209	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FAIRHAVEN ST
☐	**084766N**	WA	BNSF	Public	At Grade	Open	007224	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	AVON STREET
☐	**084767V**	WA	BNSF	Public	At Grade	Open	007237	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	OAK ST.
☐	**084769J**	WA	BNSF	Public	At Grade	Open	007237	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	NO CHERRY ST
☐	**084771K**	WA	BNSF	Public	At Grade	Open	007238	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	PINE ST
☐	**084775M**	WA	BNSF	Public	At Grade	Open	007433	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	COOK RD.
☐	**084784L**	WA	BNSF	Public	At Grade	Open	007732	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	ERSHIG RD
☐	**084785T**	WA	BNSF	Public	At Grade	Open	007905	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	BOW HILL ROAD
☐	**084787G**	WA	BNSF	Public	At Grade	Open	008093	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	COLONY RD.
☐	**084788N**	WA	BNSF	Public	At Grade	Open	008121	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	S BLANCHARD RD
☐	**084789V**	WA	BNSF	Public	At Grade	Open	008141	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SO. LEGG ROAD
☐	**084791W**	WA	BNSF	Public	At Grade	Open	008183	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	NO. LEGG RD
☐	**092246A**	WA	BNSF	Public	At Grade	Open	001255	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	ANACORTES BR	AIRPORT WAY
☐	**092249V**	WA	BNSF	Public	At Grade	Open	001387	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	AVON-ALLEN RD.
☐	**092252D**	WA	BNSF	Public	At Grade	Open	001516	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	PULVER RD.
☐	**092253K**	WA	BNSF	Public	At Grade	Open	001589	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	PETERSON RD
☐	**092255Y**	WA	BNSF	Public	At Grade	Open	001627	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	SR 20 (GARL ST)
☐	**092259B**	WA	BNSF	Public	At Grade	Open	001645	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	WALNUT ST.
☐	**092260V**	WA	BNSF	Public	At Grade	Open	001653	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	SPRUCE ST
☐	**092261C**	WA	BNSF	Public	At Grade	Open	001667	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	FAIRHAVEN ST
☐	**092262J**	WA	BNSF	Public	At Grade	Open	001676	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N PINE ST
☐	**092263R**	WA	BNSF	Public	At Grade	Open	001684	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	ANACORTES ST
☐	**092264X**	WA	BNSF	Public	At Grade	Open	001699	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N REGENT ST
☐	**092265E**	WA	BNSF	Public	At Grade	Open	001713	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N SKAGIT ST
☐	**092266L**	WA	BNSF	Public	At Grade	Open	001741	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N. SECTION ST
☐	**092267T**	WA	BNSF	Public	At Grade	Open	001767	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	GARDNER ST
☐	**092269G**	WA	BNSF	Public	At Grade	Open	001796	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	PETER ANDERSON RD

Generate Repor | Show Paging | Reset

2

Daily Traffic at Crossings

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084775M*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near BURLINGTON***
Railroad Milepost:	***0074.33***	Street or Road Name:	***COOK RD.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO63000***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.5076771***
ENS Sign Installed:		Longitude:	***-122.3363723***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084775M*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* Specify:	
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Rural Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*007170*	AADT Year:	*1994*
Estimated Percent Trucks:	*12*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084766N*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In BURLINGTON***
Railroad Milepost:	***0072.24***	Street or Road Name:	***AVON STREET***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***SR 20***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4778234***
ENS Sign Installed:		Longitude:	***-122.3301341***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084766N*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*Yes*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other National Highway*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*011050*	AADT Year:	*1993*
Estimated Percent Trucks:	*06*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084765G*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In BURLINGTON***
Railroad Milepost:	***0072.09***	Street or Road Name:	***FAIRHAVEN ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4755319***
ENS Sign Installed:		Longitude:	***-122.3296502***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084765G*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*001229*	AADT Year:	*1993*
Estimated Percent Trucks:	*08*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084764A*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In BURLINGTON***
Railroad Milepost:	***0071.93***	Street or Road Name:	***GREENLEAF ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4732287***
ENS Sign Installed:		Longitude:	***-122.3291670***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***CONNECTING***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084764A*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*002091*	AADT Year:	*1993*
Estimated Percent Trucks:	*09*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084763T*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near BURLINGTON***
Railroad Milepost:	***0070.81***	Street or Road Name:	***PEASE RD.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO60350***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4571894***
ENS Sign Installed:		Longitude:	***-122.3257715***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***SIDING***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084763T*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*Yes*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Minor Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000400*	AADT Year:	*1994*
Estimated Percent Trucks:	*15*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***077833N*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near BURLINGTON***
Railroad Milepost:	***0073.22***	Street or Road Name:	***N HILLS BLVD***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	
Crossing Owner:		Latitude:	***48.4930790***
ENS Sign Installed:		Longitude:	***-122.3333420***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *077833N*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*		
Advanced Warning:	*Yes*	Hump Crossing Sign:			
Pavement Markings:	*RR Xing Symbols*	Other Signs:	*0*	Specify:	
			0		

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:			
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*		
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*		
Other Flashing Lights:	*0*	Specify Other Flashing Lights:			
Highway Traffic Signals:	*0*	Wigwags:	*0*	Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:			
Channelization:		Type of Train Detection:	*DC/AFO*		
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:			

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Rural Minor Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*001000*	AADT Year:	
Estimated Percent Trucks:	*02*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092263R*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SUMAS***	County:	***SKAGIT***
Branch or Line Name:	***SUMAS-BURLINGTN***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.84***	Street or Road Name:	***ANACORTES ST***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4766160***
ENS Sign Installed:		Longitude:	***-122.3247637***
Passenger Service:	***None***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***20*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***20*** mph Maximum Time Table Speed: ***20***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *092263R*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*001200*	AADT Year:	*1986*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092262J*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***05/04/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SUMAS***	County:	***SKAGIT***
Branch or Line Name:	***SUMAS-BURLINGTN***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.76***	Street or Road Name:	***N PINE ST***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4761137***
ENS Sign Installed:		Longitude:	***-122.3262702***
Passenger Service:		Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

	ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:				
State Use:				

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***20*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***20*** mph Maximum Time Table Speed: ***20***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *092262J*

Effective Begin-Date of Record: *05/04/10*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells: *0*	
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000550*	AADT Year:	*1986*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092261C*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***05/04/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Position: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SUMAS***	County:	***SKAGIT***
Branch or Line Name:	***SUMAS-BURLINGTN***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.67***	Street or Road Name:	***FAIRHAVEN ST***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4755114***
ENS Sign Installed:		Longitude:	***-122.3278011***
Passenger Service:		Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***20*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***10*** mph Maximum Time Table Speed: ***10***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *092261C*

Effective Begin-Date of Record: *05/04/10*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*3*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*009800*	AADT Year:	*1986*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092260V*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***05/04/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***ANACORTES SPUR***	County:	***SKAGIT***
Branch or Line Name:	***BURL-FIDALGO***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.53***	Street or Road Name:	***SPRUCE ST***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4743724***
ENS Sign Installed:		Longitude:	***-122.3307542***
Passenger Service:		Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***26*** Total Switching: ***6*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***10*** mph Maximum Time Table Speed: ***10***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***WYE LEG***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***092260V***

Effective Begin-Date of Record: ***05/04/10***
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	***2***	Highway Stop Signs:	***0***
Advanced Warning:	***Yes***	Hump Crossing Sign:	
Pavement Markings:	***No Markings***	Other Signs: ***0***	Specify:
		0	

Train Activated Devices:

Gates:	***0***	4 Quad or Full Barrier:	
Mast Mounted FL:	***0***	Total Number FL Pairs:	***0***
Cantilevered FL (Over):	***0***	Cantilevered FL (Not over):	***0***
Other Flashing Lights:	***0***	Specify Other Flashing Lights:	
Highway Traffic Signals:	***0***	Wigwags: ***0***	Bells: ***0***
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	***None***
Track Equipped with Train Signals?	***No***	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	***Commercial***	Smallest Crossing Angle:	***60 to 90 Degrees***
Number of Traffic Lanes Crossing Railroad:	***2***	Are Truck Pullout Lanes Present?	***No***
Is Highway Paved?	***Yes***		
Crossing Surface:	***Timber***	If Other:	
Nearby Intersecting Highway?	***Less than 75 feet***	Is it Signalized?	
Does Track Run Down a Street?	***No***	Is Crossing Illuminated?	
Is Commercial Power Available?	***Yes***		

Part V: Highway Information

Highway System:	***Non-Federal-aid***	Functional Classification of Road at Crossing:	***Urban Local***
Is Crossing on State Highway System:	***No***		
Annual Average Daily Traffic (AADT):	***001450***	AADT Year:	***1987***
Estimated Percent Trucks:	***10***	Avg. No of School Buses per Day:	***0***
Posted Highway Speed:	***0***		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092259B*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***ANACORTES SPUR***	County:	***SKAGIT***
Branch or Line Name:	***BURL-FIDALGO***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.45***	Street or Road Name:	***WALNUT ST.***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4741518***
ENS Sign Installed:		Longitude:	***-122.3322632***
Passenger Service:	***None***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***24*** Total Switching: ***4*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***10*** mph Maximum Time Table Speed: ***10***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***IND SPUR***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***092259B***

Effective Begin-Date of Record: ***08/17/06***

End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*No*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000450*	AADT Year:	*1987*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***092255Y*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***06/15/04***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***ANACORTES SPUR***	County:	***SKAGIT***
Branch or Line Name:	***BURL-FIDALGO***	City:	***In BURLINGTON***
Railroad Milepost:	***0016.27***	Street or Road Name:	***SR 20 (GARL ST)***
RailRoad I.D. No.:	***0409***	Highway Type & No.:	***SR 20***
Nearest RR Timetable Stn:	***ANACORTES***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3A***
Crossing Owner:		Latitude:	***48.4730250***
ENS Sign Installed:		Longitude:	***-122.3356710***
Passenger Service:		Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***22*** Total Switching: ***2*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***10*** mph Maximum Time Table Speed: ***10***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***092255Y***

Effective Begin-Date of Record: ***06/15/04***
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*3*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other National Highway*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*011800*	AADT Year:	*1988*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7301852

8.01 - Query by Location

Total Records: 30

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

Generate Repor | Show Paging | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**077833N**	WA	BNSF	Public	At Grade	Open	007322	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	N HILLS BLVD
☐	**084763T**	WA	BNSF	Public	At Grade	Open	007081	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	PEASE RD.
☐	**084764A**	WA	BNSF	Public	At Grade	Open	007193	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	GREENLEAF ST
☐	**084765G**	WA	BNSF	Public	At Grade	Open	007209	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FAIRHAVEN ST
☐	**084766N**	WA	BNSF	Public	At Grade	Open	007224	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	AVON STREET
☐	**084767V**	WA	BNSF	Public	At Grade	Open	007237	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	OAK ST.
☐	**084769J**	WA	BNSF	Public	At Grade	Open	007237	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	NO CHERRY ST
☐	**084771K**	WA	BNSF	Public	At Grade	Open	007238	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	POTATOE SPUR	PINE ST
☐	**084775M**	WA	BNSF	Public	At Grade	Open	007433	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	COOK RD.
☐	**084784L**	WA	BNSF	Public	At Grade	Open	007732	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	ERSHIG RD
☐	**084785T**	WA	BNSF	Public	At Grade	Open	007905	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	BOW HILL ROAD
☐	**084787G**	WA	BNSF	Public	At Grade	Open	008093	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	COLONY RD.
☐	**084788N**	WA	BNSF	Public	At Grade	Open	008121	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	S BLANCHARD RD
☐	**084789V**	WA	BNSF	Public	At Grade	Open	008141	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SO. LEGG ROAD
☐	**084791W**	WA	BNSF	Public	At Grade	Open	008183	SKAGIT	BURLINGTON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	NO. LEGG RD
☐	**092246A**	WA	BNSF	Public	At Grade	Open	001255	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	ANACORTES BR	AIRPORT WAY
☐	**092249V**	WA	BNSF	Public	At Grade	Open	001387	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	AVON-ALLEN RD.
☐	**092252D**	WA	BNSF	Public	At Grade	Open	001516	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	PULVER RD.
☐	**092253K**	WA	BNSF	Public	At Grade	Open	001589	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	PETERSON RD
☐	**092255Y**	WA	BNSF	Public	At Grade	Open	001627	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	SR 20 (GARL ST)
☐	**092259B**	WA	BNSF	Public	At Grade	Open	001645	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	WALNUT ST.
☐	**092260V**	WA	BNSF	Public	At Grade	Open	001653	SKAGIT	BURLINGTON	NORTHWEST	ANACORTES SPUR	BURL-FIDALGO	SPRUCE ST
☐	**092261C**	WA	BNSF	Public	At Grade	Open	001667	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	FAIRHAVEN ST
☐	**092262J**	WA	BNSF	Public	At Grade	Open	001676	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N PINE ST
☐	**092263R**	WA	BNSF	Public	At Grade	Open	001684	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	ANACORTES ST
☐	**092264X**	WA	BNSF	Public	At Grade	Open	001699	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N REGENT ST
☐	**092265E**	WA	BNSF	Public	At Grade	Open	001713	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N SKAGIT ST
☐	**092266L**	WA	BNSF	Public	At Grade	Open	001741	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	N. SECTION ST
☐	**092267T**	WA	BNSF	Public	At Grade	Open	001767	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	GARDNER ST
☐	**092269G**	WA	BNSF	Public	At Grade	Open	001796	SKAGIT	BURLINGTON	NORTHWEST	SUMAS	SUMAS-BURLINGTN	PETER ANDERSON RD

Generate Repor | Show Paging | Reset

28

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
ANNUAL TRAFFIC REPORT

STATE ROUTE	STATE ROUTE MILEPOST	LOCATION	COUPLET	FUNCT CLASS	TRUCK PERCENTAGES SNGL DBL TRIPLE TOTAL	AVERAGE DAILY TRAFFIC VOLUME 2007 UNITS	2008 UNITS	2009 UNITS	2010 UNITS
020	053.24	BEFORE JCT BAYVIEW*LACONNER RDS		1		31000*	30000	30000*	30000
020	053.26	AFTER JCT LACONNER-WHITNEY RD		1		29000*	28000	29000*	29000
020	054.87	BEFORE RAMP SR 536 EB		1		28000*	27000	28000*	28000
020	055.09	AFTER JCT SR 536 WB		1		18000*	18000*	19000*	19000
020	058.78	AFTER JCT PULVER RD WYE CONN		1		20000*	19000	21000*	21000
020	059.54	AT SR 5		1		21000*	21000	22000*	22000
020	059.85	BEFORE JCT S BURLINGTON*RIO VISTA		1		18000	17000	18000*	18000
020	059.85	AFTER JCT S BURLINGTON*RIO VISTA		1		21000	20000	21000*	22000
020	060.26	BEFORE JCT S BURLINGTON BLVD		1		18000*	18000	18000*	18000
020	060.28	AFTER JCT S BURLINGTON BLVD		1		14000*	13000	13000*	13000
020	063.33	BEFORE JCT STERLING RD WYE CONN		1		17000	16000	17000*	17000
020	063.36	AFTER JCT STERLING RD WYE CONN		1		18000	17000	17000*	17000
020	064.81	BEFORE JCT SR 9		2		13000*	13000*	13000	13000
020	064.81	AFTER JCT SR 9		2		15000*	15000*	16000	16000
020	064.98	AFTER JCT HARRISON ST		2		19000	20000*	20000	20000
020	065.71	BEFORE JCT REED ST		2			21000*	21000	21000
020	065.71	AFTER JCT REED ST		2			18000*	19000	19000
020	066.08	BEFORE JCT SR 9*TOWNSHIP ST		2		16000	16000*	18000*	18000
020	066.08	AFTER JCT SR 9*TOWNSHIP ST		2		10000	11000	12000*	12000
020	066.89	AFTER JCT FRUITDALE RD		2		9300	8900	9900*	10000
020	072.04	BEFORE JCT LYMAN HAMILTON WYE CONN		2		7800	7400	8400*	8500
020	072.06	AFTER JCT LYMAN HAMILTON WYE CONN		2		7200	6800	7700*	7700
020	078.43	BEFORE JCT OHARA RD		2				5600*	5600
020	078.65	BEFORE JCT LYMAN HAMILTON RD		2		5300	5000	5600*	5600
020	078.65	AFTER JCT LYMAN HAMILTON RD		2		5300	5000	5600*	5700
020	088.07	BEFORE JCT CONCRETE RD		2		5000	4700	5000*	5000
020	091.16	BEFORE JCT VAN HORN RD		2		2500	2400	2700*	2700
020	097.65	BEFORE JCT SR 530 WYE CONN		2		2000	1900	2100*	2100

* BASED ON ACTUAL COUNT
+ SOURCE OF TRUCK PERCENTAGES

29

Road #	Road Name	BMP	BMP Location	EMP	FFC	Average Daily Traffic	ADT Year
80070	CONWAY FRONTAGE ROAD	2.610	0.34 mi. North of KAYTONS SLOUGH	2.820	08	1189	2009
80070	CONWAY FRONTAGE ROAD	2.820	0.13 mi. North of KAYTONS SLOUGH	2.860	08	1189	2009
80070	CONWAY FRONTAGE ROAD	2.860	475 ft. North of KAYTONS SLOUGH	3.010	08	1189	2009
85050	CONWAY HILL LANE	0.000	at CONWAY HILL ROAD	0.252	09	30	1994
85000	CONWAY HILL ROAD	0.000	at STATE ROUTE 534	0.250	09	330	1994
85000	CONWAY HILL ROAD	0.250	at EAST CONWAY HILL LANE	0.830	09	90	2001
63000	COOK ROAD	0.000	at AVON ALLEN ROAD	0.130	07	2084	2009
63000	COOK ROAD	0.130	at ALLEN ELEMENTARY SCHOOL	0.440	07	2084	2009
63000	COOK ROAD	0.440	at STATE ROUTE 11	1.570	07	4902	2009
63000	COOK ROAD	1.570	0.18 mi. West of I-5 OVERPASS	1.750	07	4902	2009
63000	COOK ROAD	1.750	at I-5 OVERPASS	1.800	07	11979	2005
63000	COOK ROAD	1.800	264 ft. East of I-5 OVERPASS	1.860	07	16605	2009
63000	COOK ROAD	1.860	at OLD HWY 99 NORTH	1.890	07	12817	2009
63000	COOK ROAD	1.890	at BURLINGTON NORTHER RXR	1.950	07	12817	2009
63000	COOK ROAD	1.950	106 ft. West of GREEN ROAD	1.970	07	12817	2009
63000	COOK ROAD	1.970	at GREEN ROAD	2.191	07	11625	2009
63000	COOK ROAD	2.191	0.22 mi. East of GREEN ROAD	3.080	07	11625	2009
63000	COOK ROAD	3.080	0.14 mi. West of GARDNER ROAD	3.360	07	11625	2009
63000	COOK ROAD	3.360	0.14 mi. East of GARDNER ROAD	3.820	07	11625	2009
63000	COOK ROAD	3.820	0.15 mi. West of DISTRICT LINE ROAD	4.100	07	11625	2009
63000	COOK ROAD	4.100	0.13 mi. East of DISTRICT LINE ROAD	4.320	07	11625	2009
63000	COOK ROAD	4.320	422 ft. East of S.V. GRANGE HALL	4.600	07	11625	2009
63000	COOK ROAD	4.600	0.13 mi. East of COLLINS ROAD	4.880	07	11601	2009
63000	COOK ROAD	4.880	0.38 mi. West of GLENWOOD ACRES ROAD	5.000	07	11601	2009
63000	COOK ROAD	5.000	0.26 mi. West of GLENWOOD ACRES ROAD	5.080	07	11601	2009
63000	COOK ROAD	5.080	0.18 mi. West of GLENWOOD ACRES ROAD	5.260	07	11601	2009
63000	COOK ROAD	5.260	at GLENWOOD ACRES ROAD	5.320	07	11601	2009
63000	COOK ROAD	5.320	148 ft. West of ADRIAN LANE	5.390	07	11601	2009
63000	COOK ROAD	5.390	222 ft. East of ADRIAN LANE	5.470	07	11601	2009

Updated March 29, 2010

City of Burlington
Traffic Counts - AWDT
2000-2009 (No 2002)
2005 - 2009 - Tue. Thru Sat. All Other Years Tue. Thru Thur.

	LOCATION	2003 SPLIT		2003 TOTAL	2004 SPLIT		2004 TOTAL	2005 SPLIT		2005 TOTAL	2006 SPLIT		2006 TOTAL	2007 SPLIT		2007 TOTAL	2008 SPLIT		2008 TOTAL	2009 SPLIT		2009 TOTAL
1	Burlington Blvd. north of Avon Avenue (old #17)	(13,830) 6,221	NB SB	20,051 (Cook Rd Closure)	7,501 6,104	NB SB	13,605	7,476 6,108	NB SB	13,584	7,910 5,869	NB SB	13,779	7401 6131	NB SB	13,532	6423 5938	NB SB	12,261 N Blvd Construction	6,565 5,145	NB SB	11,710
2	Burlington Blvd. (SR-20) south of Avon Avenue (old #1)	11,284 9,839	NB SB	21,123	11,245 9,865	NB SB	21,110	11,796 10,374	NB SB	22,170	12,629 10,734	NB SB	23,363	12071 10594	NB SB	22,666	11,016 11,408	NB SB	22,424	11,223 9,952	NB SB	21,175
3	Burlington Blvd.(SR-20) north of Rio Vista Avenue (old #2)	13,089 10,438	NB SB	23,527	13,186 10,357	NB SB	23,543	13,335 11,220	NB SB	24,555	13,678 10,687	NB SB	24,366	13304 11298	NB SB	24,602	12,328 10,209	NB SB	22,536	13,340 11,604	NB SB	24,944
4	Burlington Blvd. South of Rio Vista (old #3)	11,740 12,108	NB SB	23,848	12,092 11,194	NB SB	23,286	13,168 12,236	NB SB	25,404	12,867 12,497	NB SB	25,792	13007 12281	NB SB	25,288	12,052 11,369	NB SB	23,422	11,657 11,990	NB SB	23,647
5	Burlington Blvd. South of Gilkey Road (old #4)	10,143 9,756	NB SB	19,899	11,385 10,523	NB SB	21,908	12,254 11,757	NB SB	24,011	12,805 13,486	NB SB	26,291	12796 12631	NB SB	25,426	12,162 11,098	NB SB	23,260	12,121 12,691	NB SB	24,812
6	Burlington Blvd. South of Pease Road (old #5)	10,948 11,542	NB SB	22,490	13,396 12,804	NB SB	26,200	14,354 14,598	NB SB	28,952	15,342 15768	NB SB	31,110	14952 15221	NB SB	30,173	14,916 14,193	NB SB	29,109	16,407 16,286	NB SB	32,693
7	Burlington Blvd. South of George Hopper (old #6)	NEW BRIDGE	NB SB	NEW BRIDGE	11,248 10,986	NB SB	22,234	12,703 12,607	NB SB	25,310	13,764 13,871	NB SB	27,635	14473 14185	NB SB	28,658	14,249 13,841	NB SB	28,090	13,598 13,541	NB SB	27,139
8	Peterson Road east of Pulver road (old #7)	2,284 2,446	WB EB	4,730		WB EB		2,523 2,723	WB EB	5,246		WB EB		2813 2635	WB EB	5,448		WB EB		2,482 2,767	WB EB	5,249
9	Peterson Road north of Norris Street (old #8)	3,454 3,527	NB SB	6,981		NB SB		4232 4551	NB SB	8,783		NB SB		4377 4441	NB SB	8,381		NB SB		2,698 2,505	NB SB	5,203 SR-20 Connect Removed
10	Pulver Road south of Peterson Road (old #9)	427 353	NB SB	780		NB SB		559 368	NB SB	927		NB SB		535 336	NB SB	870		NB SB		658 346	NB SB	1,003
11	Goldenrod Road south of SR-20 (old #10) (REMOVED)	5,701 11,790	NB SB	17,491		NB SB		5,934 11,157	NB SB	17,091		NB SB		6394 10915	NB SB	17,309		NB SB			NB SB	
12	Goldenrod Road north of Andis road (old #43)		NB SB		2,009 1,941	NB SB	3,950		NB SB		1,829 1832	NB SB	3,661				1,836 2,072	NB SB	3,908		NB SB	
13	Avon (SR-20) east of Burlington Blvd (old #19)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
14	Avon (SR-20) east of Anacortes Street (old #18)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
15	Fairhaven Avenue west of Burlington Blvd. (old #21)		WB EB		2,815 2,998	WB EB	5,813		WB EB		2,966 3,169	WB EB	6,136				2,979 3,103	WB EB	6,082		WB EB	
16	Fairhaven Avenue east of Walnut Street. (old #16)	5,342 4,779	WB EB	10,121		WB EB		4,546 4,554	WB EB	9,100		WB EB		4819 4319	WB EB	9,138		WB EB		4,520 4,856	WB EB	9,376
17	Fairhaven Avenue west of Pine Street. (old #22)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
18	Rio Vista east of Burlington Blvd (old #41)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
19	Rio Vista (SR-20) west of Burlington Blvd (old #23)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
20	Pease Road east of Burlington Blvd (e. of K-Mart e. Entrance) (old #29)	2,270 2,020	WB EB	4,290		WB EB		2,075 1,941	WB EB	4,016		WB EB		2213 2051	WB EB	4,264		WB EB		2,152 2,057	WB EB	4,210
21	George Hopper west of Burlington Blvd (old #46)		WB EB		7,643 7,985	WB EB	15,628		WB EB		8,634 8,922	WB EB	17,557				7,662 9,693	WB EB	17,359		WB EB	
22	George Hopper east of Bouslog (old #47)		WB EB		3,183 3,335	WB EB	6,518		WB EB		3,672 3,519	WB EB	7,191				3,547 3,332	WB EB	6,879		WB EB	
23	Whitmarsh Road west of Burlington Blvd. (old #45)		WB EB		1,485 1,407	WB EB	2,892		WB EB		1,808 1,983	WB EB	3,791				2,028 2,017	WB EB	4,045		WB EB	

City of Burlington
Traffic Counts - AWDT
2000-2009 (No 2002)
2005 - 2009 - Tue. Thru Sat. All Other Years Tue. Thru Thur.

	LOCATION	2003 SPLIT		2003 TOTAL	2004 SPLIT		2004 TOTAL	2005 SPLIT		2005 TOTAL	2006 SPLIT		2006 TOTAL	2007 SPLIT		2007 TOTAL	2008 SPLIT		2008 TOTAL	2009 SPLIT		2009 TOTAL
24	Whitmarsh Road south of Pease Road. (old #44)		NB SB		1,049 1,054	NB SB	2,103		NB SB		1,322 1,434	NB SB	2,756				1,489 1,331	NB SB	2,820		NB SB	
25	Old 99 south of County Shop Lane (old #42)		NB SB		2,879 2,643	NB SB	5,522		NB SB		3423 3,057	NB SB	6,479				2,975 3,377	NB SB	6,352		NB SB	
26	SR-11 (Chuckanut Dr) west of Old 99 (old #48)		NB SB		6,249 5,477	NB SB	11,726		NB SB		6,543 5,813	NB SB	11,290				5,395 4,645	NWB SEB	9739 N Blvd Construction		NWB SEB	
27	Spruce Street south of Fairhaven Avenue (old #11)	2,767 2,162	NB SB	4,929		NB SB		2,738 2,864	NB SB	5,602		NB SB		2964 2268	NB SB	5,232		NB SB		3,022 2,384	NB SB	5,406
28	Spruce Street south of SR-20 (old #27)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
29	Greenleaf east of Spruce Street (old #30)	1,987 3,954	WB EB	5,941		WB EB		2,092 2,027	WB EB	4,119		WB EB		2052 2043	WB EB	4,096		WB EB		2,004 2,043	WB EB	4,047
30	Skagit Street north of SR-20 (old #12)	671 654	NB SB	1,325		NB SB		753 722	NB SB	1,475		NB SB		892 1281	NB SB	2,173		NB SB		928 898	NB SB	1,826
31	Skagit Street south of SR-20 (old #13)	901 855	NB SB	1,756		NB SB		1,092 694	NB SB	1,786		NB SB		838 831	NB SB	1,669		NB SB		794 872	NB SB	1,666
32	Section Street south of SR-20 (old #14)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
33	Section Street south of Rio Vista (old #15)		NB SB		987 999	NB SB	1,986		NB SB		845 804	NB SB	1,649				810 701	NB SB	1,511		NB SB	
34	Norris Street east of Peterson Road (old #26)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
35	Old Cascade Hwy east of Anacortes Street (old #25)		WB EB		2,499 2,400	WB EB	4,899		WB EB		2,421 2,417	WB EB	4,838				2,388 2,563	NEB SWB	4,954		NEB SWB	
36	SR_20 east of Cascade Hwy (old #49)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
37	SR-20 @ Gardner (WEST LEG) (old #31)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
38	SR-20 @ Gardner (EAST LEG) (old #32)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
39	SR-20 @ Gardner (NORTH LEG) (old #33)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
40	SR-20 @ Gardner (SOUTH LEG) (old #34)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
41	SR-20 @ Peacock/Section (WEST LEG) SR-20 (old #35)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
42	SR-20 @ Peacock/Section (EAST LEG) SR-20 (old #36)		WB EB			WB EB			WB EB			WB EB						WB EB			WB EB	
43	SR-20 @ Peacock/Section (NORTH LEG) Peacock (old #37)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	
44	SR-20 @ Peacock/Section (SOUTH LEG) Section (old #38)		NB SB			NB SB			NB SB			NB SB						NB SB			NB SB	

City of Burlington
Traffic Counts - AWDT
2000-2009 (No 2002)
2005 - 2009 - Tue. Thru Sat. All Other Years Tue. Thru Thur.

	LOCATION	2003 SPLIT		2003 TOTAL	2004 SPLIT		2004 TOTAL	2005 SPLIT		2005 TOTAL	2006 SPLIT		2006 TOTAL	2007 SPLIT		2007 TOTAL	2008 SPLIT		2008 TOTAL	2009 SPLIT		2009 TOTAL
45	SR-20 east of Pulver Road (old #24)		WB EB			WB EB			WB EB			WB EB								WB EB				WB EB	
46	SR-20 east of Avon Allen Road (old #28)		WB EB			WB EB			WB EB			WB EB								WB EB				WB EB	
47	Pulver Road south of SR-20	805 507	NB SB	1,312		NB SB		370 870	NB SB	1,240		NB SB		353 921	NB SB	1,207		NB SB		343 749	NB SB	1,092
48	Goldernrod Road north of Fisher Land	667 623	NB SB	1,290		NB SB		753 824	NB SB	1,577	847 900	NB SB	1,747	861 902	NB SB	1,763	1,218 1,030	NB SB	2,248	1,073 3,265	NB SB	4,338
49	Gardner Road south of SR-20	921 632	NB SB	1,553		NB SB		870 370	NB SB	1,240		NB SB		731 593	NB SB	1,324		NB SB		832 604	NB SB	1,436
50	Rio Vista Avenue east of Anacortes	1,061 978	WB EB	2,039	1,108 1,904	WB EB	3,012	1,063 917	WB EB	1,980	1,456 1,045	WB EB	2,501	1039 1000	WB EB	2,040	1,053 942	WB EB	1,996	1,089 955	WB EB	2,044
51	George Hopper east of Burl. Blvd @ Napa	1,939 2,366	WB EB	4,305		WB EB		2606 2,802	WB EB	5,408		WB EB		3093 3093	WB EB	6,186		WB EB		3,449 3,583	WB EB	7,032
52	Gilkey Road east of Burl. Blvd.				3,259 2,754	WB EB	6,013		WB EB		3,387 2,861	WB EB	6,248				3,605 2,831	WB EB	6,437		WB EB	
53	Anacortes Street south of Gilkey Rd.				3,816 3,976	NB SB	7,792		NB SB		4,211 4,316	NB SB	8,527	4340 4526	NB SB	8,866	4,426 4,673	NB SB	9,100	4,584 4,906	NB SB	9,490
54	Skagit Street south of Rio Vista				1,242 1,300	NB SB	2,542		NB SB		1,265 1,354	NB SB	2,618				1,186 1,267	NB SB	2,453		NB SB	
55	West McCorquedale west of Lindamood Ln.				1,157 1,392	WB EB	2,549		WB EB		1,206 1,262	WB EB	2,468				1,341 1,390	WB EB	2,731		WB EB	
56	Anacortes Street north of Cascade Hwy.				328 244	NB SB	572		NB SB		303 259	NB SB	562				314 238	NB SB	551		NB SB	
57	Greenleaf west of Anacortes)																2,033 1,716	EB WB	3,749		EB WB	

Transportation Element Information

impacts, this increase of trip ends is relatively insignificant. The commercial trip estimates are estimated to be 3,375 and do not change between the two land use options.

ANALYSIS AND REVIEW

The analysis of future traffic volumes was based on a link segment volume-to-capacity (v/c) review. There are 39 separate link segments considered in the review. The assumed capacity of each segment was based on the functional classification of each segment. Table 8 identifies the capacity assumed for each link segment.

Table 9 identifies the V/C and LOS for each of the link segments. It is important to note that the differences between the two land use alternatives tested are minor, and there are 6 link segments where the LOS grade is one letter worse for Land Use Option B. Two of these link segments degrade from LOS D to E and one degrades from LOS E to F.

Some critical locations that are estimated to operate at LOS F are:

- SR 20 between Spruce St and Skagit St. Skagit St is the east limit of study area, and it is probably safe to assume the LOS F condition extends easterly.
- Fairhaven between Burlington Blvd and Cherry St.
- Spruce St between Rio Vista and Greenleaf Ave (Land Use Option B).
- Anacortes St between Rio Vista Ave and Greenleaf Ave.

Some critical locations that are estimated to operate at LOS E are:

- Burlington Blvd between Rio Vista and Washington St.
- Burlington Blvd between Fairhaven and Avon Ave.
- Spruce St between Rio Vista and Greenleaf Ave (Land Use Option A).
- Spruce St between Greenleaf Ave and Washington (Land Use Option B).
- Spruce St between Washington and Fairhaven (Land Use Option B).

CONCLUSIONS

The following conclusions have been made based on the analysis above. They are:

- The resulting PM peak hour trip end differences between Land Use Option A and B is approximately 360 trips. The increase in trips with Option B is approximately twice as many trips as Option A. However, accounting for all trips in the CBD defined area, this increase represents about a 9% increase in trips. Given all of the traffic in the surrounding area, this difference is relatively insignificant.

Table 8
Roadway Segment Capacity Estimates
(Existing Network)

ID	LINK SEGMENT	CROSS ST A	CROSS ST B	Functional Class	Number of Lanes	Left Turn Lane?	Thru Capacity	Total Capacity
1	Avon (SR 20)	Burlington Blvd	Spruce St	PRINCIPAL ARTERIAL	2	Y	1655	1955
2	Avon (SR 20)	Spruce St	Cascade Hwy Ext	PRINCIPAL ARTERIAL	2	N	1655	1655
3	Avon (SR 20)	Cascade Hwy Ext	Skagit St	PRINCIPAL ARTERIAL	2	Y	1655	1955
4	Fairhaven Ave	Burlington Blvd	Alder St	MAJOR COLLECTOR	2	Y	1200	1500
5	Fairhaven Ave	Alder St	Walnut St	MAJOR COLLECTOR	2	N	1200	1200
6	Fairhaven Ave	Walnut St	Spruce St	MAJOR COLLECTOR	2	N	1200	1200
7	Fairhaven Ave	Spruce St	Cherry St	MAJOR COLLECTOR	2	N	1200	1200
8	Fairhaven Ave	Cherry St	Pine St	MAJOR COLLECTOR	2	N	1200	1200
9	Fairhaven Ave	Pine St	Anacortes St	MAJOR COLLECTOR	2	N	1200	1200
10	Fairhaven Ave	Anacortes St	Regent St	MAJOR COLLECTOR	2	N	1200	1200
11	Fairhaven Ave	Regent St	Skagit St	MAJOR COLLECTOR	2	N	1200	1200
12	Washington Ave	Burlington Blvd	Alder St	COMMERCIAL LOCAL ACCESS	2	N	750	750
13	Washington Ave	Alder St	Walnut St	COMMERCIAL LOCAL ACCESS	2	N	750	750
14	Washington Ave	Walnut St	Spruce St	COMMERCIAL LOCAL ACCESS	2	N	750	750
15	Greenleaf Ave	Walnut St	Spruce St	RESIDENTIAL LOCAL ACCESS	2	N	500	500
16	Greenleaf Ave	Spruce St	Cherry St	MAJOR COLLECTOR	2	N	1200	1200
17	Greenleaf Ave	Cherry St	Anacortes St	MAJOR COLLECTOR	2	N	1200	1200
18	Rio Vista Ave	Burlington Blvd	Walnut St	MINOR ARTERIAL	2	Y	1458	1758
19	Rio Vista Ave	Walnut St	Spruce St	MINOR ARTERIAL	2	N	1458	1458
20	Rio Vista Ave	Anacortes St	Skagit St	MINOR ARTERIAL	2	N	1458	1458
21	Burlington Blvd	Rio Vista Ave	Washington Ave	PRINCIPAL ARTERIAL	4	Y	2718	3018
22	Burlington Blvd	Washington Ave	Fairhaven Ave	PRINCIPAL ARTERIAL	4	Y	2718	3018
23	Burlington Blvd	Fairhaven Ave	Avon (SR 20)	PRINCIPAL ARTERIAL	4	Y	2718	3018
24	Alder St	Washington Ave	Fairhaven Ave	RESIDENTIAL LOCAL ACCESS	2	N	500	500
25	Alder St	Fairhaven Ave	Avon (SR 20)	RESIDENTIAL LOCAL ACCESS	2	N	500	500
26	Walnut St	Rio Vista Ave	Washington Ave	COMMERCIAL LOCAL ACCESS	2	N	750	750
27	Walnut St	Washington Ave	Fairhaven Ave	COMMERCIAL LOCAL ACCESS	2	N	750	750
28	Walnut St	Fairhaven Ave	Avon (SR 20)	RESIDENTIAL LOCAL ACCESS	2	N	500	500
29	Spruce St	Rio Vista Ave	Greenleaf Ave	MAJOR COLLECTOR	2	N	1200	1200
30	Spruce St	Greenleaf Ave	Washington Ave	MAJOR COLLECTOR	2	N	1200	1200
31	Spruce St	Washington Ave	Fairhaven Ave	MAJOR COLLECTOR	2	N	1200	1200
32	Spruce St	Fairhaven Ave	Avon (SR 20)	MAJOR COLLECTOR	2	N	1200	1200
33	Anacortes St	Rio Vista Ave	Greenleaf Ave	MAJOR COLLECTOR	2	N	1200	1200
34	Anacortes St	Greenleaf Ave	Fairhaven Ave	MAJOR COLLECTOR	2	N	1200	1200
35	Anacortes St	Fairhaven Ave	Cascade Hwy Ext	MAJOR COLLECTOR	2	N	1200	1200
36	Skagit St	Rio Vista Ave	Fairhaven Ave	MAJOR COLLECTOR	2	N	1200	1200
37	Skagit St	Fairhaven Ave	Avon (SR 20)	MAJOR COLLECTOR	2	N	1200	1200
38	Cascade Hwy Ext	Cherry St	Anacortes St	MAJOR COLLECTOR	2	N	1200	1200
39	Cascade Hwy Ext	Anacortes St	Avon (SR 20)	MAJOR COLLECTOR	2	N	1200	1200

Table 9
Existing and Future Link Segment LOS Summaries

ID	LINK SEGMENT	CROSS ST A	CROSS ST B	2005 Network Capacity	2004/5 PM PK HR Count Based Volume	V/C	LOS	2025 Network Capacity	2025 PM PK HR OPT A LAND USE Volume	V/C	LOS	2025 PM PK HR OPT B LAND USE Volume	V/C	LOS
1	Avon (SR 20)	Burlington Blvd	Spruce St	1955	1200	0.61	B	1955	1720	0.88	D	1730	0.88	D
2	Avon (SR 20)	Spruce St	Cascade Hwy Ext	1655	1260	0.76	C	1655	1930	1.17	F	1930	1.17	F
3	Avon (SR 20)	Cascade Hwy Ext	Skagit St	1955	1680	0.86	D	1955	2530	1.29	F	2500	1.28	F
4	Fairhaven Ave	Burlington Blvd	Alder St	1500	900	0.60	B	1500	1600	1.07	F	1600	1.07	F
5	Fairhaven Ave	Alder St	Walnut St	1200	900	0.75	C	1200	1440	1.20	F	1440	1.20	F
6	Fairhaven Ave	Walnut St	Spruce St	1200	890	0.74	C	1200	1270	1.06	F	1290	1.08	F
7	Fairhaven Ave	Spruce St	Cherry St	1200	980	0.82	D	1200	1240	1.03	F	1310	1.09	F
8	Fairhaven Ave	Cherry St	Pine St	1200	620	0.52	A	1200	820	0.68	B	850	0.71	C
9	Fairhaven Ave	Pine St	Anacortes St	1200	680	0.57	A	1200	850	0.71	C	870	0.73	C
10	Fairhaven Ave	Anacortes St	Regent St	1200	550	0.46	A	1200	740	0.62	B	740	0.62	B
11	Fairhaven Ave	Regent St	Skagit St	1200	470	0.39	A	1200	640	0.53	A	650	0.54	A
12	Washington Ave	Burlington Blvd	Alder St	750	70	0.09	A	750	440	0.59	A	470	0.63	B
13	Washington Ave	Alder St	Walnut St	750	100	0.13	A	750	300	0.40	A	340	0.45	A
14	Washington Ave	Walnut St	Spruce St	750	120	0.16	A	750	190	0.25	A	170	0.23	A
15	Greenleaf Ave	Walnut St	Spruce St	500	10	0.02	A	500	10	0.02	A	40	0.08	A
16	Greenleaf Ave	Spruce St	Cherry St	1200	300	0.25	A	1200	300	0.25	A	300	0.25	A
17	Greenleaf Ave	Cherry St	Anacortes St	1200	240	0.20	A	1200	260	0.22	A	260	0.22	A
18	Rio Vista Ave	Burlington Blvd	Walnut St	1758	330	0.19	A	1758	380	0.22	A	430	0.24	A
19	Rio Vista Ave	Walnut St	Spruce St	1458	210	0.14	A	1458	370	0.25	A	410	0.28	A
20	Rio Vista Ave	Anacortes St	Skagit St	1458	400	0.27	A	1458	180	0.12	A	190	0.13	A
21	Burlington Blvd	Rio Vista Ave	Washington Ave	3018	1740	0.58	A	3018	2890	0.96	E	2910	0.96	E
22	Burlington Blvd	Washington Ave	Fairhaven Ave	3018	1670	0.55	A	3018	2570	0.85	D	2590	0.86	D
23	Burlington Blvd	Fairhaven Ave	Avon (SR 20)	3018	1720	0.57	A	3018	2820	0.93	E	2820	0.93	E
24	Alder St	Washington Ave	Fairhaven Ave	500	100	0.20	A	500	120	0.24	A	110	0.22	A
25	Alder St	Fairhaven Ave	Avon (SR 20)	500	100	0.20	A	500	330	0.66	B	350	0.70	C
26	Walnut St	Rio Vista Ave	Washington Ave	750	100	0.13	A	750	450	0.60	B	510	0.68	B
27	Walnut St	Washington Ave	Fairhaven Ave	750	100	0.13	A	750	190	0.25	A	220	0.29	A
28	Walnut St	Fairhaven Ave	Avon (SR 20)	500	100	0.20	A	500	100	0.20	A	100	0.20	A
29	Spruce St	Rio Vista Ave	Greenleaf Ave	1200	670	0.56	A	1200	1140	0.95	E	1230	1.03	F
30	Spruce St	Greenleaf Ave	Washington Ave	1200	460	0.38	A	1200	980	0.82	D	1090	0.91	E
31	Spruce St	Washington Ave	Fairhaven Ave	1200	470	0.39	A	1200	1030	0.86	D	1120	0.93	E
32	Spruce St	Fairhaven Ave	Avon (SR 20)	1200	170	0.14	A	1200	610	0.51	A	610	0.51	A
33	Anacortes St	Rio Vista Ave	Greenleaf Ave	1200	400	0.33	A	1200	1310	1.09	F	1300	1.08	F
34	Anacortes St	Greenleaf Ave	Fairhaven Ave	1200	430	0.36	A	1200	800	0.67	B	770	0.64	B
35	Anacortes St	Fairhaven Ave	Cascade Hwy Ext	1200	260	0.22	A	1200	470	0.39	A	450	0.38	A
36	Skagit St	Rio Vista Ave	Fairhaven Ave	1200	430	0.36	A	1200	800	0.67	B	770	0.64	B
37	Skagit St	Fairhaven Ave	Avon (SR 20)	1200	190	0.16	A	1200	300	0.25	A	290	0.24	A
38	Cascade Hwy Ext	Cherry St	Anacortes St	1200	250	0.21	A	1200	320	0.27	A	330	0.28	A
39	Cascade Hwy Ext	Anacortes St	Avon (SR 20)	1200	450	0.38	A	1200	700	0.58	A	700	0.58	A

- The commercial trip end estimate results in 3,375 weekday PM peak hour trips.

- The section of Fairhaven Ave between Burlington Blvd and Cherry St is estimated to operate at LOS F with either land use option. This section of roadway is defined as Major Collector and the capacity assumed was 1,200 vehicles per hour (total). With the angle parking along most of the section, it would be difficult to assume that the capacity of this segment could be much higher. If the roadway was channelized to include left turn pockets at intersections, the capacity could be increased and the LOS is estimated to improve to LOS E for most of the section.

- SR 20 (Avon Ave) is estimated to operate at LOS F from Spruce east. The section of SR 20 between Spruce and Burlington Blvd is estimated to operate at LOS D primarily because we have assumed an additional 300 vehicle capacity for the left turn pocket at SR 20 (Avon)/Burlington Blvd.

- The section of Spruce St between Rio Vista and Fairhaven Ave is estimated to operate at LOS F north to Greenleaf and E north to Fairhaven Ave for Land Use Option B. The LOS is E and D respectively for Option A. This section of roadway is defined as Major Collector and the capacity assumed was 1,200 vehicles per hour (total). Left turn and right turn lanes/pockets at intersections would increase the overall capacity assumptions thus it is estimated the LOS could improve to LOS D and C for Land Use Option B.

- The section of Anacortes St between Rio Vista and Greenleaf is estimated to operate at LOS F under either land use option. The functional classification of Anacortes St is a Major Collector. The PM peak hour volume is estimated at 1300 vehicles per hour whereas the capacity is assumed at 1,200 vph. This section would improve with left turn lanes at intersections.

APPENDIX E

- **TWENTY YEAR GROWTH AND DEVELOPMENT INFORMATION**

CITY OF Burlington
SKAGIT COUNTY, WASHINGTON INCORPORATED 1902

1989 – April 1, 2005 POPULATION INFORMATION

YEAR	**POPULATION*	+/-
1989	3830	0
1990	4349	+519
1991	4760	+411
1992	4690 **	-70
1993	4690	same
1994	5170	+480
1995	5385	+215
1996	5445	+60
1997	5445	same
1998	5525	+80
1999	5635	+110
2000	6757	+1122
2001	6995	+238
2002	7014 ***	+19
2002	7190	+176
2003	7315	+125
2004	7425	+110
2005	**7550 ******	+125
POPULATION INCREASE SINCE 1989		**3,720**
% OF POPULATION INCREASE SINCE 1989		**97 %**

* *Population inside city limits*

** *Correction in 1991 population by the Office of Financial Management*

*** *Based on 2000 Census data (updated November 30, 2001)*

**** *Population update by the Office of Financial Management – April 1, 2005*

Accident History Data

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
Skagit	Burlington	City Street		E FAIRHAVEN		CHERRY ST			
Skagit	Burlington	City Street		E FAIRHAVEN AVE		S CHERRY			
Skagit	Burlington	City Street		GARDNER RD	600	RR CROSSING			
Skagit	Burlington	City Street		PEASE RD		RAILROAD CROSSING			
Skagit	Burlington	City Street		S SPRUCE ST	200	RR XING			
Skagit	Burlington	State Route		20					
Skagit	Burlington	State Route		20					
Skagit	Burlington	State Route		20					
Skagit	Burlington	State Route		20					
Skagit	Burlington	State Route		20					
Skagit		County Road	COLONY RD	24000					
Skagit		County Road	FARM TO MARKET RD	31010		30900			
Skagit		County Road	COOK RD	63000		0			
Skagit		County Road	COOK RD	63000		50510			
Skagit		County Road	COOK RD	63000					
Skagit		County Road	COOK RD	63000					

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
					2889180	6/15/2007	9:41	No Injury	0	0	2		
					1672073	6/1/2005	12:16	No Injury	0	0	2		
					2889285	5/22/2008	19:37	No Injury	0	0	1		
					2879603	2/24/2009	15:00	No Injury	0	0	2		
					1834999	6/7/2005	23:15	Possible Injury	1	0	1		
			59.94		2889601	5/6/2008	12:40	No Injury	0	0	2		
			59.95		2463229	9/25/2007	14:55	No Injury	0	0	2		
			60.52		1367744	1/5/2005	18:12	Possible Injury	2	0	2		
			60.52		2879913	12/18/2009	1:48	No Injury	0	0	1		
			60.52		2463014	10/27/2006	15:35	Possible Injury	1	0	2		
			0.68		2520458	11/18/2006	18:00	No Injury	0	0	1		
			0.06		2351532	3/3/2006	7:18	Possible Injury	1	0	2		
			1.88		2520627	8/25/2006	22:17	No Injury	0	0	2		
			1.86		2911715	8/19/2009	10:44	Possible Injury	1	0	2		
			1.89		2723371	1/8/2010	9:03	No Injury	0	0	1		
			1.90		2520882	6/27/2008	10:45	Possible Injury	1	0	2		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Not Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	School Bus	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Wet	Dark-Street Lights On
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Not Related	Dry	Dark-Street Lights On
Passenger Car	School Bus	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Not Related	Dry	Dark-No Street Lights
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Dry	Dark-Street Lights On
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Wet	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	Intersection Related but Not at Intersection	Dry	Daylight

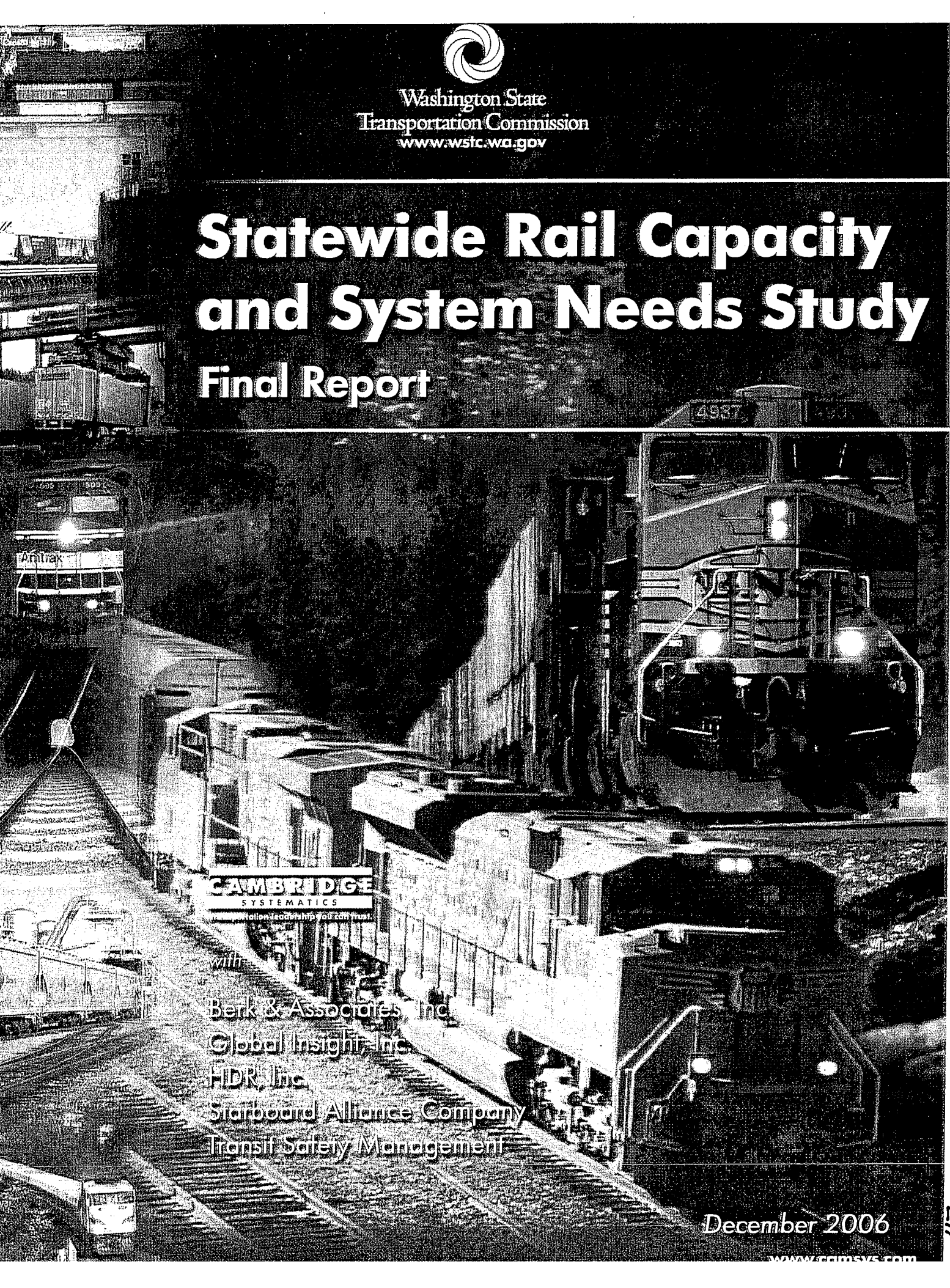
UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
From opposite direction - one left turn - one straight	Did Not Grant RW to Vehicle	None	West	Northeast	East	West
Entering at angle	Did Not Grant RW to Vehicle	None	South	North	East	West
Wood Sign Post	Under Influence of Alcohol		North	South		
From same direction - both going straight - one stopped - rear-end	Inattention	None	East	West	East	Vehicle Stopped
Vehicle struck moving train	Under Influence of Alcohol		South	North		
From same direction - both going straight - one stopped - rear-end	None	Inattention	North	Vehicle Stopped	North	South
From same direction - both going straight - one stopped - rear-end	Unknown Driver Distraction	None	North	South	North	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
Other Objects	Inattention		East	West		
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
Utility Pole	Unknown Driver Distraction		West	East		
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	North	South	North	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
All other non-collision	Other		East	West		
From same direction - both going straight - one stopped - rear-end	Driver Interacting with Passengers, Anim	None	East	West	East	Vehicle Stopped

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

State Report Information


Washington State
Transportation Commission
www.wstc.wa.gov
Statewide Rail Capacity
and System Needs Study
Final Report
4937
Amtrak
CAMBRIDGE
SYSTEMATICS
with
Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management
December 2006
www.camsys.com

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the State's passenger-rail program. The cost of resolving the rail choke points in the I-5 corridor to meet passenger service and ridership goals is increasing, potentially reducing the cost-effectiveness of the passenger rail program. Without capacity improvements, rail will not maintain its share of the Washington State freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the State's industrial and agricultural shippers.

The Rail Industry Is Expanding Capacity, But May Not Meet All the State's Needs

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines. They are operating longer trains and maximizing the number of containers packed on intermodal cars; consolidating pick-up and delivery of railcars at central terminals; and eliminating mainline switching wherever possible (i.e., minimizing the number of times trains are 'parked' on the mainline while picking up cars from individual shippers). These changes favor a hook-and-haul operations strategy, where the railroads pick up a full train in Seattle or Tacoma and haul it directly to Chicago, or pick up a full grain train in the Midwest and haul it directly to a Columbia River port. Hook-and-haul operations allow the railroads to achieve economies of scale that keep costs down and services profitable. However, capacity will remain constrained in Washington even with these changes.

The move toward wholesale rail service helps meet the needs of Washington State's ports, which handle high volumes of imported intermodal containers and exported grain. But it is problematic for Washington State's manufacturers and agricultural shippers. They need low-cost, shorter-haul carload service and do not generate the high volumes attractive to the railroads. In general, international intermodal container traffic has been outbidding domestic carload traffic for space on the rail system, and the railroads have been pricing out lower-volume, lower-profit shippers to meet the demands of higher-volume, higher-profit freight.

The shift toward high-volume, hook-and-haul operations is also problematic for Washington State's short line railroads. They provide a link between smaller shippers and the Class I railroads. If they cannot generate enough volume to get service

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to -
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic - most of which is associated with short- and medium-distance trips - on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 - Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

- Manufacturers, agricultural producers, and lumber and wood products producers generate 14 percent ($37 billion) of the State's $262 billion economic output value (gross state product) and 15.5 percent (425,700 jobs) of the State's employment.
- The Washington State ports generate between 200,000 and 300,000 direct, indirect, and trade-related jobs in the State. A portion of these jobs depend directly or indirectly on rail service.
- Sixteen percent of all freight tonnage moved in Washington State moves by rail.

Rail service is critical because it enables these Washington State industries to ship heavy or bulky commodities over long distances at low costs. Table 1 lists the top 10 outbound Washington State rail commodities by tonnage for 2004 and the forecast tonnages for 2015 and 2025. These are commodities that are shipped out of Washington State by rail. "Miscellaneous mixed shipments" are primarily merchandise and retail trade goods; many are moving in intermodal containers.

Table 1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025

STCC	Commodity	Rail Tonnage			Compound Annual Growth Rate		
		2004	2015	2025	2004-2015	2015-2026	2004-2025
46	Miscellaneous mixed shipments	6,516,304	11,309,371	19,060,968	5.1%	5.4%	5.2%
24	Lumber or wood products	4,506,679	4,072,939	4,183,956	-0.9%	0.3%	-0.4%
11	Coal	2,142,403	2,743,497	3,184,686	2.3%	1.5%	1.9%
40	Waste or scrap materials	1,543,296	2,377,099	3,260,635	4.0%	3.2%	3.6%
26	Pulp, paper, or allied products	1,231,469	1,556,870	1,752,517	2.2%	1.2%	1.7%
20	Food or kindred products	1,075,792	1,662,293	2,389,104	4.0%	3.7%	3.9%
37	Transportation equipment	826,102	2,090,719	4,523,959	8.8%	8.0%	8.4%
1	Farm products	700,653	997,648	1,385,204	3.3%	3.3%	3.3%
33	Primary metal products	606,415	677,274	597,161	1.0%	-1.3%	-0.1%
28	Chemicals or allied products	353,040	381,960	367,654	0.7%	-0.4%	0.2%

Source: Global Insight, Inc., 2006.

Figure 2 compares the 2004 tonnages to the forecast tonnages for 2015 and 2025. This figure includes commodities that are shipped into and out of Washington State; the previous figure showed only outbound commodities.

four trains that were supported financially by Washington State at that time, and about 637,000 on the entire *Cascades* service.[4] The State's passenger rail plans envision serving up to 3.0[5] million riders with 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) in 2023.

Sound Transit provides Sounder commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks. The *Cascades* service is operated by Amtrak; the Sounder commuter trains are operated by BNSF and maintained by Amtrak.

In the Puget Sound region, Sounder ridership is projected to grow from 1.2 million passenger trips in 2006 to 2.6 million passenger trips in 2011, a five-year increase of 117 percent.

Forecasts for both the Amtrak *Cascades* and the Sounder services are predicated on substantial investments to increase capacity and improve operations along the I-5 rail corridor. Full build out of the draft Long-Range Plan for the *Cascades* program calls for additional investments of $6.5 billion (in 2006 dollars) by 2023.

Rail Capacity *is calculated in a two-step process.*

First, a "theoretical capacity" is determined, assuming perfect conditions and operations.

Second, "practical capacity" is determined by considering factors, such as possible disruptions, signal needs, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand.

Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of "C." At higher percentages, rail congestion increases and service reliability deteriorates quickly.

3.4 Capacity of the Washington State Rail System and Implications for Rail Users

The Washington State rail system is nearing capacity; service quality is strained, and rates are going up.

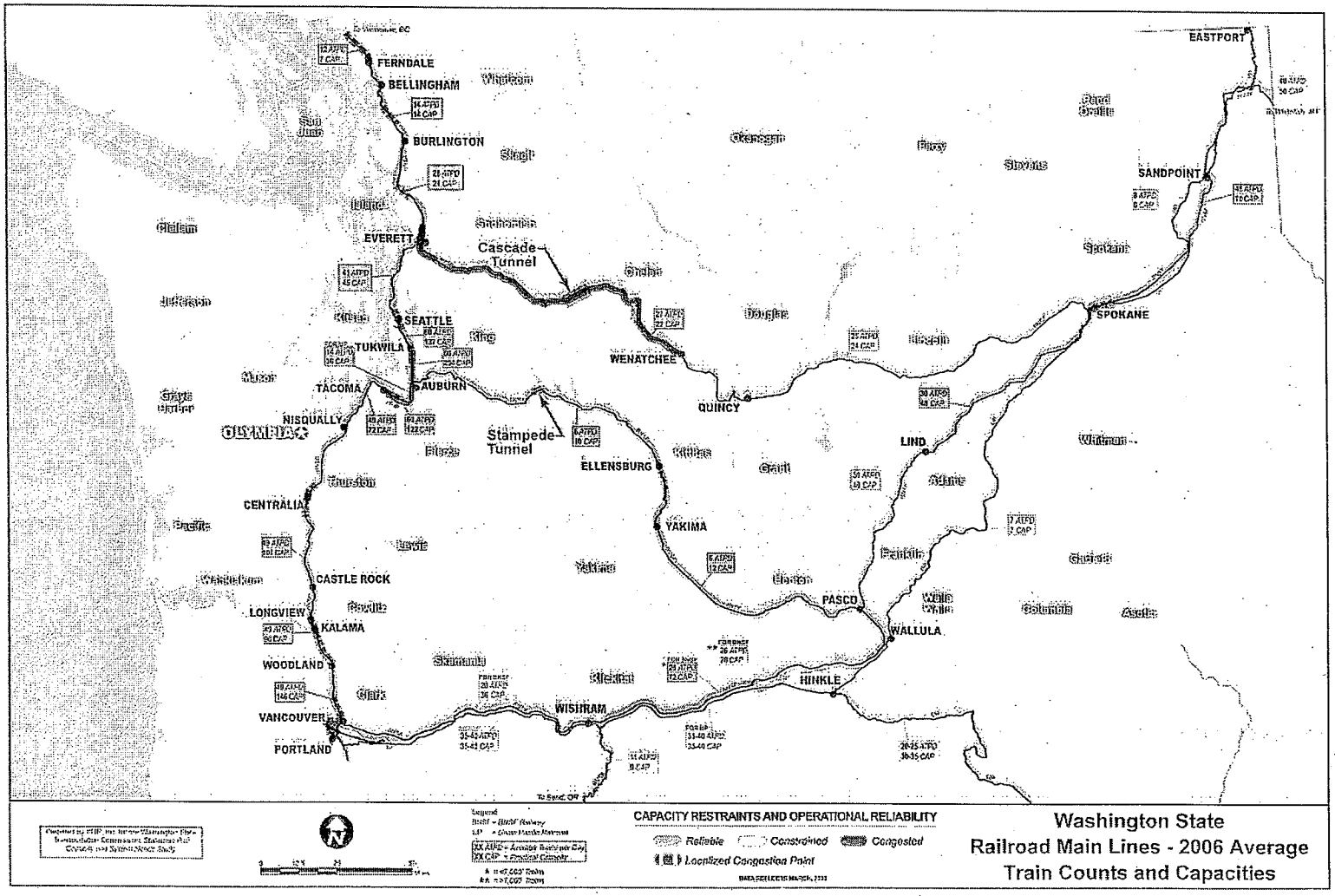
Figure 3 compares the average number of trains operated on each line to the practical capacity of the line.

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major transcontinental route for double-stack intermodal container trains. It is heavily used, operating today at about 123 percent of practical capacity.

[4] As of July 1, 2006, there are four round trips daily on the Seattle to Portland segment. Prior to this, there were only three round trips daily.

[5] A range of ridership projections were produced that varied based on fare structure and other variables. 3 million is a higher end projection.

Figure 3. Washington State Rail System: Mainline Capacities, 2006



The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UPRR freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver area, where the railroads' north-south and east-west routes intersect. Rail simulation studies of grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[6]

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, but the operational changes may not be sufficient to satisfy the future needs of Washington shippers. The short-term operating strategies being pursued by the railroads include the following:

- Operating longer 8,000-foot trains and maximizing the number of containers packed on intermodal flat cars;
- Marketing and operating single origin and destination unit trains for carload traffic;
- Consolidating pick-up and delivery of railcars at central terminals operated by third parties (examples include new rail-served industrial parks, logistics hubs, and transload centers);
- Eliminating mainline switching whenever possible (i.e., picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity); and
- Transferring responsibility for branch-line switching from the Class I railroads to local short lines, wherever possible.

These strategies will help meet the needs of the ports and intermodal shippers, but will likely complicate the problem of

[6] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

industrial carload shippers who cannot take advantage of longer and better packed intermodal trains. The Class I railroads are asking shippers, wherever possible, to reorganize and upgrade their tracks and track layouts to improve switching efficiency and be more compatible with the railroads' hook-and-haul operations. The more track space within the shipper's property and the longer the entrance and exit tracks, the faster and more efficiently the railroad can pick up or set out cars. This saves time and labor costs for the railroads and keeps high-volume mainlines open more hours of the day for through train movements. But for low-volume shippers, the costs of these site improvements are usually prohibitive. The same problems apply to consolidating rail pick-up and delivery of railcars at central terminals operated by third parties; unless the consolidation centers are well located, designed, and financed, the financial risks to shippers and operators may be very high.

Consolidation and outsourcing of terminal operations to third parties and transfer of branch-line switching from Class I to short line railroads can result in the replacement of union rail jobs with lower-paying nonunion jobs. Unless offset by future growth in Class I business that generates new union jobs, the loss of union jobs can mean a lower income and standard of living for some Washington State residents with jobs in the rail industry.

The new operating strategies also impact the State's agricultural shippers. Low-cost rail service keeps product costs competitive, but the increasing cost of rail service and the Class I railroads' focus on higher-profit, hook-and-haul intermodal traffic has made it more costly and more difficult for some agricultural shippers to get service at acceptable prices. The Class I railroads also have been asking Washington State grain and other bulk agricultural shippers to consolidate shipping points so that the railroads can operate more unit trains. Notable examples of this trend are the Ritzville grain-loading facility and the new Railex produce service at Wallula.[7]

While these new rail operating strategies have the potential to partially address future capacity needs, the analysis conducted for this study suggests that they may not be sufficient in the longer term. Table 2 lists the lines where mainline practical capacity will be exceeded within 20 years even with the additional capacity gained by operating longer trains and implementing better scheduling. The existing choke points will persist and worsen, some more quickly than others.

[7] http://www.wsdot.wa.gov/Projects/Rail/Freight/PortWallaWalla/.

5b

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[8]

Table 2. Rail Lines in Washington State Exceeding Practical Capacity, 2015 and 2025
Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains

2015	2025
Everett-Burlington	Everett-Burlington
Burlington-Ferndale	Burlington-Ferndale
Ferndale-New Westminster	Ferndale-New Westminster
Everett-Spokane, Washington (BNSF)	Everett-Spokane, Washington (BNSF)
Vancouver-Wishram	Vancouver-Wishram
Wishram-Roosevelt	Wishram-Roosevelt
Roosevelt-Pasco	Roosevelt-Pasco
	Pasco-Spokane, Washington (BNSF)
Pasco (Wallula)-Spokane, Washington (UP)	Pasco (Wallula)-Spokane, Washington (UP)
Spokane, Washington-Sandpoint, Idaho (UP)	Spokane, Washington-Sandpoint, Idaho (UP)
Auburn-Yakima	Auburn-Yakima
Yakima-Pasco	Yakima-Pasco

Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[8] See for example: AASHTO, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UPRR have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers. This is a painful change for all shippers, especially captive shippers, who are being forced to rethink their supply chains and markets.

The national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and Washington State. Continuing high levels of growth and the competition between the BNSF and the UPRR for the lucrative Southern California rail market have made Southern California the key focal point of investment for both railroads. This has shifted investment away from the Pacific Northwest and Washington State.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, Federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not

overtake and collide with slower-moving carload freight trains.[9] The freight railroads, who own the track, are focused on obtaining the maximum benefit from each available train slot and the revenue they receive for providing train slots to the passenger railroads is usually modest.

When the Amtrak *Cascades* program was initiated, the freight railroads were willing to sell slots to the State, especially in return for physical improvements to the rail lines that would benefit both the passenger and freight railroads. With capacity tightening and increasing shipper pressure to improve throughput and reliability, the freight railroads are less willing or able to accommodate expansion of the intercity rail program. As a result, passenger services are often asked to pay a premium when they purchase slots or contribute to mainline capacity improvements.

Amtrak *Cascades* ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases and the freight railroads give priority to freight trains. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. However, if congestion continues to build and the cost of improvements increases, on-time performance may deteriorate further, undermining ridership growth and reducing the cost-effectiveness of the program. Unless a coordinated solution is examined, the future cost of the Amtrak *Cascades* program may exceed the public benefits anticipated in the original plans, and the State may need to examine alternative strategies for the passenger rail program.

[9] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Mr. Phil Williams
Title: City of Edmonds, Public Works Director
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations-City of Edmonds; GTC #11-036
Date: May 22, 2012

This memorandum is to identify some of the possible rail impacts associated with transport of coal to the proposed Cherry Point Facility affecting the City of Edmonds and its access roads. It identifies the potential impacts on the City's downtown core area of Main Street, access to the WSDOT Ferry Terminal, as well as several key approach roads to the City, such as Dayton Street to the south.

The purpose of this preliminary report is to provide City leaders and interested stakeholders with information that may be useful as the City prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

1. Project Description and Expected Delays

We understand a terminal capable of exporting 48 million tons of coal per year is proposed north of Bellingham. GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north-south directly through the west part of the City of Edmonds, Washington.

According to the applicant's *Project Information Document* (Feb. 2011), full build out of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day; however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. Some return trains may return over the Stevens Pass route, bypassing Edmonds, but the railroad and project proponent have not provided details on anticipated traffic or routing. Each train may be over 1.5 miles long, which at 50 miles per hour would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Edmonds can be estimated to increase with an additional train every *every 1.3 hours,* if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use sidings or not. Also the proximity of siding for AMTRAK or Freight near a crossing can have a double impact. As a waiting train leaves the siding it has to accelerate up to speed taking longer to cross and still triggers the crossing arm for the nearby street crossing ahead. Thus it can mean the crossing arm is triggered before waiting queues are cleared from the last train and therefore have continual impact for over 10 minutes.

2. Affected Crossings

The BNSF rail way tracks bisect the western waterfront area of Edmonds (including the State Ferry terminal and beaches) from the east side of Edmonds that includes the downtown business core and residential area. The City of Edmonds only has two roads (Dayton Street and Main Street) connecting its downtown business core/residential areas to the waterfront area, both of which are directly affected by the proposed increase of rail traffic and both crossings are all at grade/gate controlled.. Due to these constraints, our preliminary review indicated that the additional trains from the Cherry Point operations could have a potential significant impact on the commercial district and quality of life for the City residence. Of primary concern are potential backups onto main street and likely drop in level of service on city streets and emergency response, thus affecting future development potential along the waterfront.

3. Analysis of Potential Impacts

We have the following comments based on preliminary research:

Due to a speed restriction approach warning, train travel through Edmonds downtown means the barriers are down for approximately 3-4 minutes (over 200 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 2-3 continuous red lights cycles in a row for a normal signal on Main or Dayton. Note: The proximity of siding for AMTRAK/commuter train or Freight near a crossing can have a double impact. As a waiting train leaves the siding it has to accelerate up to speed taking longer to cross and still triggers the crossing arm for a street crossing ahead. Thus it can mean the crossing arm is triggered before waiting queues are cleared from the last train and therefore have continual impact for over 10 minutes. With the long coal trains, increased use of sidings as train volume increases the impacts to the States Ferry service. This cumulative impact should be reviewed in any environmental impact review of the coal trains.

1. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F. The City's standard for arterial roadway operation is LOS D, i.e. allowing only 55 seconds as the worst delay for normal conditions and LOS C for collectors (Dayton). The addition of 16-18 trains per day would call into question whether the City can maintain its adopted LOS D standard and LOS C standard for these intersections. This may be central to future concurrency determinations by the City affecting future development projects.
2. The City's comprehensive plan chapter 4 identifies both Dayton and Main crossing as a walkway and bike lane crossing for the pedestrian and bike plans. The plan has identified a high priority of better connecting the downtown to the waterfront through increased pedestrian and bicycle access. The short, medium and long bike routes identified in the City's plan all run parallel to the rail line in the Main Street area. An additional crossing from non-motorized traffic has also been identified in the City plan. Unless this crossing is grade separated the 16-18 additional trains for the Cherry Point facility would make any such additional crossing more dangerous/complicated. A May pedestrian count recorded over 200 pedestrian movements in just an hour at the Main Street/Railway Avenue crossing intersection. A potential mitigation for the additional freight traffic may be to assist in the construction of a non motorized grade separated crossing for the downtown area. Given the geography and configuration of the Ferry Terminal, it would likely be very challenging to create a grade separated crossing at Main Street.
3. Railway Avenue is a major transit hub for the city with 7 different transit routes connecting with the waterfront and AMTRAC/Sounder station. Transit crosses Dayton and Main with all the routes. The impact to community transit by the 16-18 additional trains for the Cherry Point facility should be assessed and mitigated.
4. With the increase in number of long coal trains at the waterfront and ferry access crossing, there are no alternative east-west grade separated crossings as the east-west route becomes degraded with the increased coal trains. This is a particular issue during summer peaks, with the beaches and ferry route. Mitigation could be a grade separated crossing to the waterfront similar to many other jurisdictions, but it may require a complete relocation and rebuild of the Ferry Terminal, and would likely involve significant expense. Note the prior plans to relocate the Ferry Terminal have been put on hold indefinitely with 20-30 year timeframes being discussed. The 2005 Edmond Crossing FEIS

identified the need for relocation with projected train increases that did not even foresee the Coal train increase. Additionally the Cities plans to unify the downtown and waterfront could be significantly hampered without the relocation or grade separated crossings particularly with the projected increase in freight trains.

5. There is a probable issue concerning emergency services response times, in a scenario where the only reliable east-west crossing between the waterfront to the west and the services area to the east is Dayton and Main which are closed at the same time when a freight train crosses. Adding 16-18 additional trains per day to service Cherry Point could tip the balance at a critical time when emergency responses are needed. Given the fact that the Main Street crossing is the only egress from the Ferry Terminal, this will create additional concerns in the context of emergencies that occur either on the ferries or where ambulances utilize the ferry crossing. The increased residential and commercial plans along the waterfront as well as existing ferry and scuba diving activities will all increase further future emergency vehicle response needs to the other side of the tracks.
6. Within the last 5 years there have been 4 accidents at the Main Street crossings including two gate collisions.
7. Already today the presence of a long freight train during the peak hours creates separation from the Cities waterfront amenities and businesses. The Cities annual counts show over 6,000 daily trips crossing Main Street and US DOT federal crossing information shows over 8,500 daily trips cross the Dayton tracks on an average day know that summer peak volumes are considerably bigger. Therefore the rail crossings in the city have nearly 15,000 daily vehicles crossing a day. With the additional coal trains that will likely take a minimum of 3-4 minutes to cross (without accounting for delays or slower train speeds) the cumulative additional delay to drivers is potentially significant. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. One form of mitigation is to create grade-separation, with either a tunnel or a bridge. The City may wish to request that mitigation as part of the environmental review process for Cherry Point.
8. Puget Sound communities within the Sound Transit service area, the State, and the Federal Government have recently invested heavily in improved passenger train) services for the north end. Freight traffic on the rail line between Seattle and Everett (and transiting Edmonds) could increase from the approximately 40 a day (based on US DOT crossing inventory Information) to 50-55 with the Cherry Point proposal which would exceed their existing 45 trains per day capacity per the States 2009 report. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on-time reliability demands of passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to analyze the degree to which increasing freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand passenger rail particularly for the reverse commute that was originally analyzed for the Sounder commuter rail. With Sound Transit proposing the preferred alternative for the North Corridor transit EIS as the I-5 alignment instead of the SR-99 alignment it will become even more imperative to the City to preserve this existing rail corridor for passenger service. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies. It should also ensure that the public investments in passenger rail capacity in this corridor are being protected.

   Also the States 2006 "statewide *Rail Capacity and System Needs* study" identifies a key issue affecting that access to local business as follows:

   > The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.
   >
   > Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to

accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market.

So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability of local rail spur business necessary to local businesses such as Boeing and its suppliers. These issues should be analyzed as part of a comprehensive economic and environmental impact analysis that should be demanded conducted before this project goes forward.

9. The Washington State 2010-2030 Freight Rail Plan published by WSDOT in December 2009 identified that the rail line in this area in 2008 had a capacity of 60 trains per day (Exhibit 3-9). The existing use of the line is 40-45 trains per day based on the US DOT inventory reports that were accessed in 20011. The state plan shows that it hopes to increase that capacity to 80 trains per day; however, the design and cost of the specific improvements needed to do that were not available at the time of this report's completion. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for freight and expanded commuter services.
10. The Cherry Point applicant and its advocates argue that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore there is no impact. In our judgment, this conclusion is not supportable, because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well as vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically.
11. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. While grade separation is desirable, these improvements are typically multi-million dollar solutions. This is likely to be particularly true in Edmonds, based on a brief review of the multi-modal station plans. We recommend that local jurisdictions provide regulating authorities with detailed assessments of mitigation and funding necessary to alleviate the impacts that will results from the additional 16-18 trains per day serving the Cherry Point export facility.

4. Conclusions

This analysis of possible rail line impacts associated with the increase of up to 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to illustrate some of the potential problems and areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, waterfront/downtown unification plans, State Ferry route impacts and possible interference with local freight delivery systems important to the City's economic recovery.

ATTACHMENTS FOR CITY OF EDMONDS RAIL CAPACITY PRESENTATION

- Crossing Information
- Count Information
- Transportation Element & Transit Data
- Accident History Data
- State Information

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085445K*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***SNOHOMISH***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In EDMONDS***
Railroad Milepost:	***0017.66***	Street or Road Name:	***MAIN ST. (SR 104)***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***FAP104***
Nearest RR Timetable Stn:	***EDMONDS***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31-3H***
Crossing Owner:		Latitude:	***47.8125486***
ENS Sign Installed:		Longitude:	***-122.3826167***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***8***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

	ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:				
State Use:				

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***43*** Total Switching: ***0*** Day Thru: ***22***

Typical Speed Range Over Crossing: From ***1*** to ***60*** mph Maximum Time Table Speed: ***60***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085445K*

Effective Begin-Date of Record: *08/17/06*

End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *2*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*5*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other National Highway*	Functional Classification of Road at Crossing:	*Urban Other Principal*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*005200*	AADT Year:	*1995*
Estimated Percent Trucks:	*06*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085439G*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***SNOHOMISH***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In EDMONDS***
Railroad Milepost:	***0017.43***	Street or Road Name:	***DAYTON ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***EDMONDS***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31-3H***
Crossing Owner:		Latitude:	***47.8097953***
ENS Sign Installed:		Longitude:	***-122.3862232***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***8***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***41*** Total Switching: ***0*** Day Thru: ***21***

Typical Speed Range Over Crossing: From ***1*** to ***60*** mph Maximum Time Table Speed: ***60***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085439G*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*008520*	AADT Year:	*1993*
Estimated Percent Trucks:	*04*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

Count Information

Edward Koltonowski

From: Matt Palmer [mattp_gtc@earthlink.net]

Sent: Tuesday, September 06, 2011 2:55 PM

To: 'Edward Koltonowski'

Subject: City of Edmonds ADT data

Ed, Bertrand from the City of Edmonds called and these are the three ADT volumes he has in the vicinity of the railroad tracks from 2009-2011:

Dayton west of SR-104 - 6,650 ADT

Main St west of Railroad Ave - 5,800 ADT (likely ferry commuters)

Edmonds Way south of Dayton - 9,800 ADT

Matt

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7389810

Home Crossing Forms/Publications Downloads Data Documents Policies Support

8.01 - Query by Location

Total Records: 2

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

Generate Repor | Show All | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**085439G**	WA	BNSF	Public	At Grade	Open	001743	SNOHOMISH	EDMONDS	NORTHWEST	SCENIC	WENACHE-SEATTLE	DAYTON ST
☐	**085445K**	WA	BNSF	Public	At Grade	Open	001766	SNOHOMISH	EDMONDS	NORTHWEST	SCENIC	WENACHE-SEATTLE	MAIN ST. (SR 104)

Generate Repor | Show All | Reset

LM 9/6/2011 9:44
Bertrand Mauss
- counts from April 2008 @
Railroad Ave (Dayton St & Main St)
SR-104

Prepared for: **Jones & Stokes**

Traffic Count Consultants, Inc.

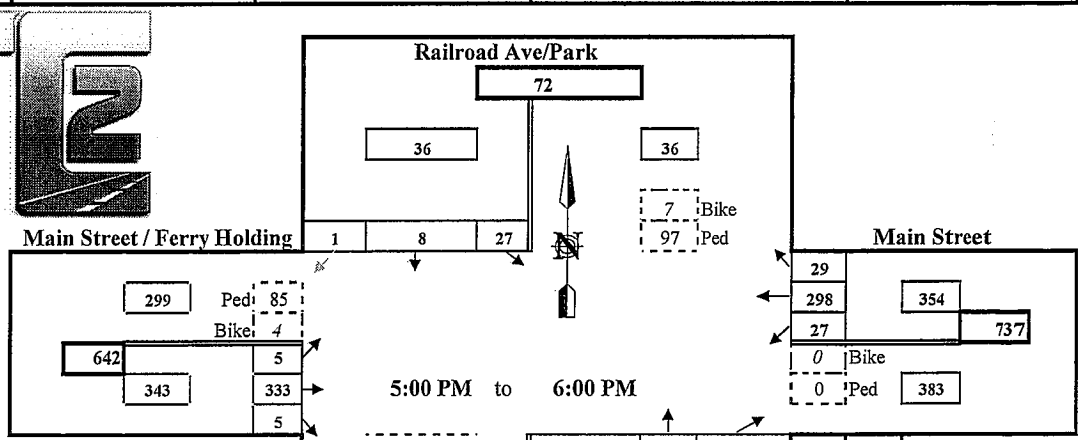
Phone: (425) 861-8866 FAX: (425) 861-8877 E-Mail: TC2inc@aol.com

WBE/DBE

Intersection: Railroad Ave @ Main St & Ferry Dock **Date of Count:** Thurs 5/29/08

Location: Edmonds **Checked By:** LBP

Time Interval Ending at	From North on (SB) Railroad Ave/Park				From South on (NB) Railroad Ave				From East on (WB) Main Street				From West on (EB) Main Street / Ferry Holding				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:45 P	0	5	1	0	0	0	2	4	9	7	98	6	0	0	0	0	123
5:00 P	0	1	2	0	0	0	1	6	6	9	0	5	0	0	0	1	25
5:15 P	0	10	0	0	0	0	2	10	5	5	0	10	8	2	183	3	225
5:30 P	0	9	2	0	0	0	0	2	13	8	223	10	3	0	31	0	285
5:45 P	0	6	3	0	0	0	0	3	6	7	75	8	0	0	0	0	102
6:00 P	0	2	3	1	0	0	0	8	9	7	0	1	9	3	119	2	146
6:15 P	0	4	0	0	0	0	0	4	9	12	103	2	0	0	74	0	199
6:30 P	0	7	0	0	0	0	1	4	7	11	38	6	0	0	0	0	67
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Survey	0	44	11	1	0	0	6	41	64	66	537	48	20	5	407	6	1172
Peak Hour: 5:00 PM to 6:00 PM																	
Total	0	27	8	1	0	0	2	23	33	27	298	29	20	5	333	5	758
Approach	36				25				354				343				758
%HV	n/a				n/a				9.3%				5.8%				7.0%
PHF	0.82				0.52				0.37				0.46				0.66



PEDs across:	N	S	E	W	
INT 01	18	11		20	49
INT 02	15	13		20	48
INT 03	18	65		25	108
INT 04	23	25		15	63
INT 05	33	24		20	77
INT 06	23	35		25	83
INT 07	25	10		26	61
INT 08	17	15		15	47
INT 09					0
INT 10					0
INT 11					0
INT 12					0
	172	198	0	166	536

Bicycles From:	N	S	E	W	
INT 01					0
INT 02					0
INT 03	5			1	6
INT 04	2			3	5
INT 05					0
INT 06					0
INT 07					0
INT 08					0
	7	0	0	4	11

1140 *1.0 PHF Peak Hour Volume*

		PHF	%HV
	EB	0.46	5.8%
Check	WB	0.37	9.3%
In: 758	NB	0.52	n/a
Out: 758	SB	0.82	n/a
	Intersection	0.66	7.0%

Special Notes:

Train gates closed: 4:57 - 59

5:12 - 14

5:16 - 17

5:28 - 31

5:30 - 36

6:02 - 6:03

Prepared for: **Jones & Stokes**

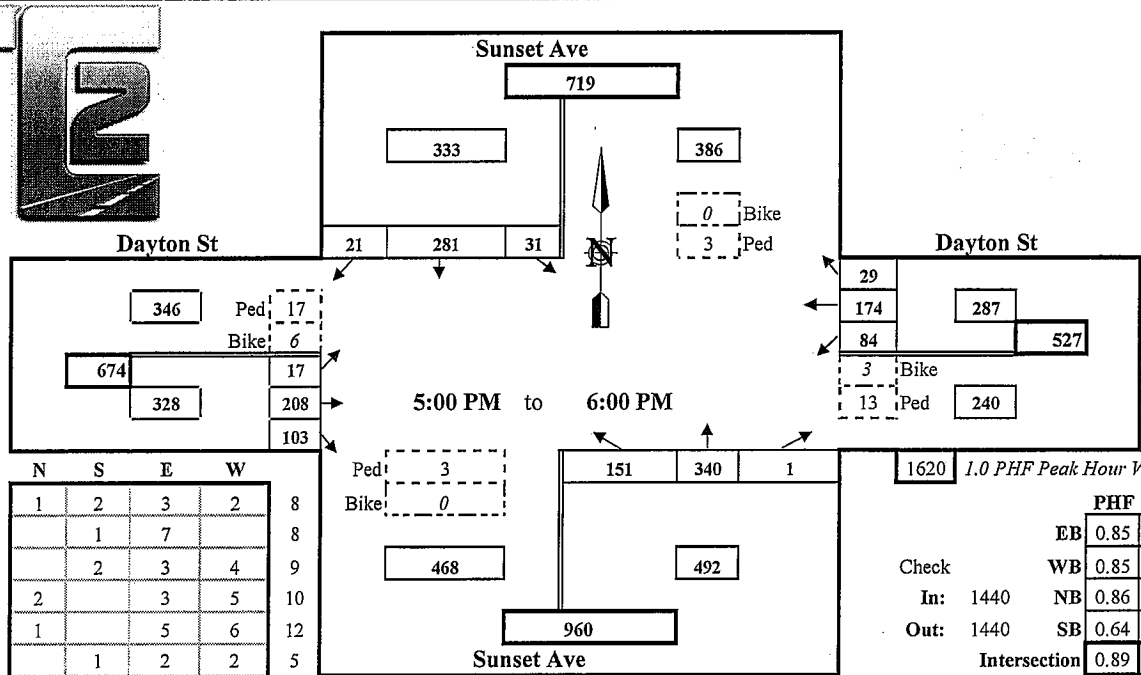
Traffic Count Consultants, Inc.

Phone: (425) 861-8866 FAX: (425) 861-8877 E-Mail: TC2inc@aol.com

WBE/DBE

Intersection: Dayton St @ Sunset Ave
Location: Edmonds
Date of Count: Thurs 5/29/08
Checked By: LBP

Time Interval Ending at	From North on (SB) Sunset Ave				From South on (NB) Sunset Ave				From East on (WB) Dayton St				From West on (EB) Dayton St				Interval Total
	T	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	
4:45 P	0	2	18	2	5	25	102	1	4	19	47	6	2	3	40	9	274
5:00 P	0	4	12	6	2	28	71	0	4	21	45	10	7	1	38	16	252
5:15 P	0	7	116	7	2	53	63	0	1	21	35	6	2	6	62	29	405
5:30 P	3	9	45	5	4	31	104	0	5	28	43	5	4	2	51	17	340
5:45 P	0	9	17	6	4	30	112	1	1	23	56	5	4	9	50	32	350
6:00 P	8	6	103	3	2	37	61	0	5	12	40	13	6	0	45	25	345
6:15 P	0	17	26	4	0	36	60	1	2	14	45	4	3	4	47	35	293
6:30 P	0	2	11	2	1	36	72	1	5	14	54	8	6	2	36	41	279
6:45 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:15 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:30 P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Survey	11	56	348	35	20	276	645	4	27	152	365	57	34	27	369	204	2538
Peak Hour: 5:00 PM to 6:00 PM																	
Total	11	31	281	21	12	151	340	1	12	84	174	29	16	17	208	103	1440
Approach	333				492				287				328				1440
%HV	3.3%				2.4%				4.2%				4.9%				3.5%
PHF	0.64				0.86				0.85				0.85				0.89



1620 *1.0 PHF Peak Hour Volume*

		PHF	%HV
	EB	0.85	4.9%
Check	WB	0.85	4.2%
In: 1440	NB	0.86	2.4%
Out: 1440	SB	0.64	3.3%
	Intersection	0.89	3.5%

PEDs across:

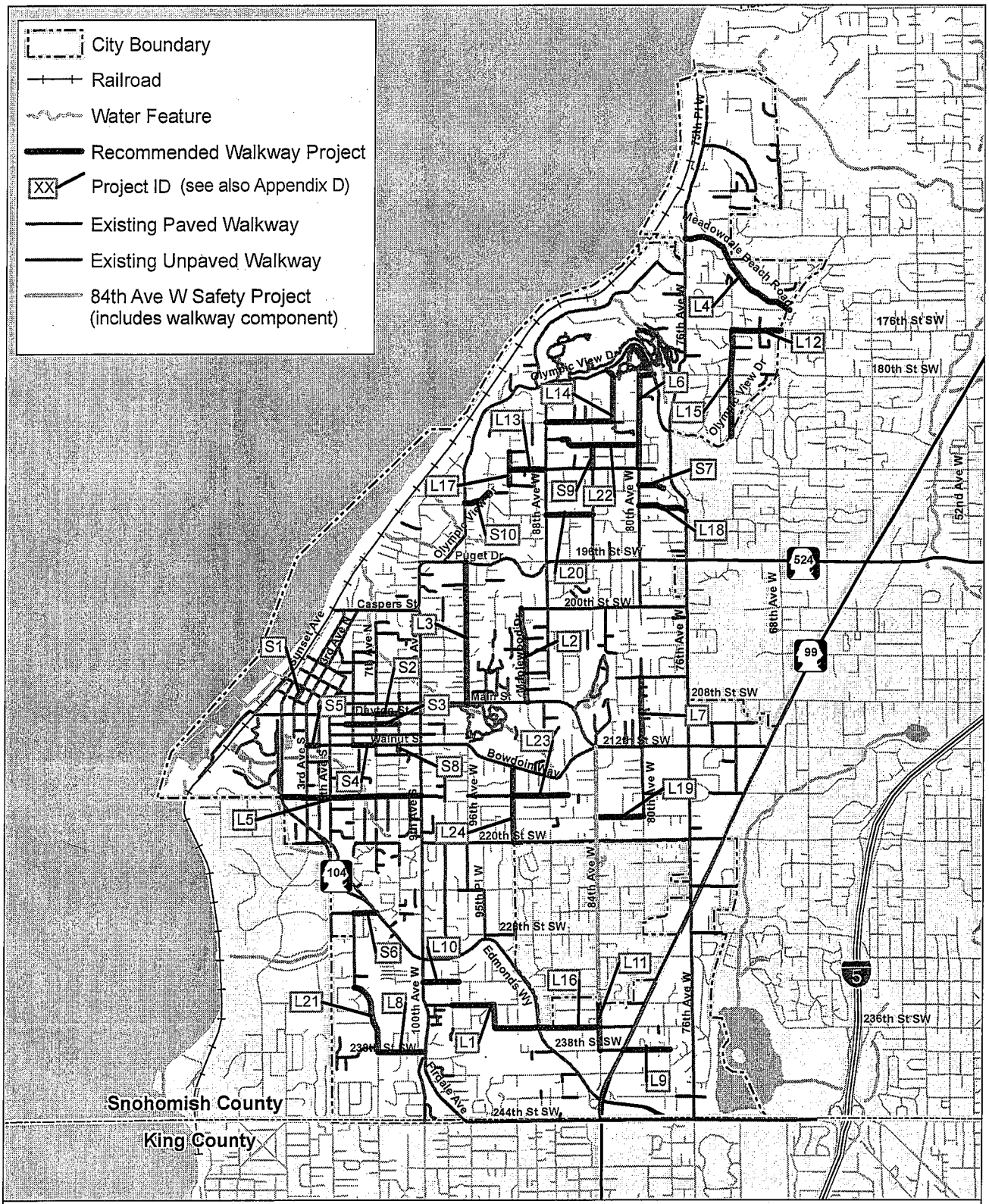
	N	S	E	W	
INT 01	1	2	3	2	8
INT 02		1	7		8
INT 03		2	3	4	9
INT 04	2		3	5	10
INT 05	1		5	6	12
INT 06		1	2	2	5
INT 07			2	4	6
INT 08			5	2	7
INT 09					0
INT 10					0
INT 11					0
INT 12					0
	4	6	30	25	65

Bicycles From:

	N	S	E	W	
INT 01					0
INT 02			1		1
INT 03			2	2	4
INT 04				2	2
INT 05				1	1
INT 06			1	1	2
INT 07					0
INT 08					0
	0	0	4	6	10

Special Notes:
The two right NB lanes n/o Dayton were ferry holding lanes

Transportation Element & Transit Data



Source: City of Edmonds (2008); WSDOT (2008); Snohomish County (2008)

0 0.5 1
Miles

Figure 4-3. Existing Walkways and Recommended Walkway Projects

City of Edmonds Comprehensive Transportation Plan
November 2009

Curb Ramp Upgrade Program

In an effort to upgrade the sidewalk ramps and meet ADA requirements, the City has developed a Curb Ramp Upgrade Program that prioritizes future sidewalk ramp improvements at sub-standard locations.

Citizen request for curb ramps should be addressed as they occur, and should be accommodated close to the time of the request unless there are circumstances which would cause them to be deferred, such as a pending construction project that would provide the ramps in a short time frame. Priorities for future sidewalk new ramp installations or ramp upgrades are determined based on the following priority order:

1. Downtown intersections receive priority over other locations;
2. Arterial streets receive priority over local access streets;
3. Intersections receive higher priority if they are near:
    a. Community centers, senior centers, or health facilities
    b. Transit stops, schools, or public buildings
    c. Commercial areas and parks.

Implementation of the curb ramp upgrade program will need to occur over time, due to the costs of those upgrades. As part of asphalt overlay projects, all ramps adjacent to the paving work must be upgraded to meet ADA standards and new ramps installed where none exist. Sidewalk ramps will also be installed as part of street reconstruction and sidewalk construction projects. Private redevelopment will also fund some ramp upgrades as part of required frontage improvements. Appendix C provides a complete list of the intersection locations and the prioritization criteria.

Bikeway Comprehensive Plan

The City updated its comprehensive Bikeway Plan in 2009. The Bikeway Plan outlines a list of improvement projects for the bikeway system; and prioritizes bikeway projects, bicycle parking, and bikeway signage. Before signing the routes, problem catch basin grates are replaced, sight distance problems are addressed, and potholes and other safety hazards are corrected. Additionally, the Bikeway Plan includes maintenance of bicycle facilities. Per RCW 35.75.060 and 36.82.145, all bicycle facilities must comply with Chapter 1020 of the WSDOT Design Manual (WSDOT 2009) which is consistent with the Guide for the Development of Bicycle Facilities (AASHTO 1999).

In addition to making project recommendations, the Bikeway Plan states several goals for the bicycle network in Edmonds. These goals are:

- **Goal 1**: To promote more bicycling.
- **Goal 2**: To provide safer streets and paths for those who bicycle in Edmonds.

- **Goal 3**: To provide better access to recreational opportunities for those who bicycle.
- **Goal 4**: To provide better access to schools for those who bicycle.
- **Goal 5**: To provide better access to businesses for those who bicycle.
- **Goal 6**: To provide better access to transit for those who bicycle.
- **Goal 7**: To provide access to bicycling opportunities in other jurisdictions.
- **Goal 8**: To consider bicycle facilities and program in all City transportation programs and funding.
- **Goal 9**: To provide enhanced parking facilities for those who bicycle, making the mode more convenient.
- **Goal 10**: To provide maintenance provisions for City bicycle facilities.

The following inventory and recommended bicycle network improvements may be considered as complements to the Bikeway Comprehensive Plan.

Bicycle Facility Inventory

Figure 4-4 shows existing bicycle facilities within the city, which include bicycle routes, bicycle lanes, trails, and bicycle parking facilities. Bicycle routes are designated along vehicle travel lanes that are shared between bicycles and motor vehicles with signing. Bicycle lanes are dedicated lanes within the traveled roadway that are reserved solely for bicyclists and distinguished through the use of pavement markings. Bicycle lanes may be located adjacent to the curbs or parking lanes. Trails are physically separated from vehicular traffic, and are shared with pedestrians and other non-motorized users.

The Interurban Trail, which links the cities of Seattle, Shoreline, Edmonds, Mountlake Terrace, Lynnwood, and Everett, runs through the southeastern portion of Edmonds. Upgrades to the trail are included in the City's capital improvement program. Trails are also located along the city's beaches and within city parks.

There are also easy connections for cyclists to ferries, Sound Transit's Sounder service, and Community Transit. Bicycles are allowed on all of these systems; WSF provides a reduced fare (relative to motorized vehicle fares) for bicycles, Sound Transit provides bike racks, and all Community Transit vehicles have bike racks.

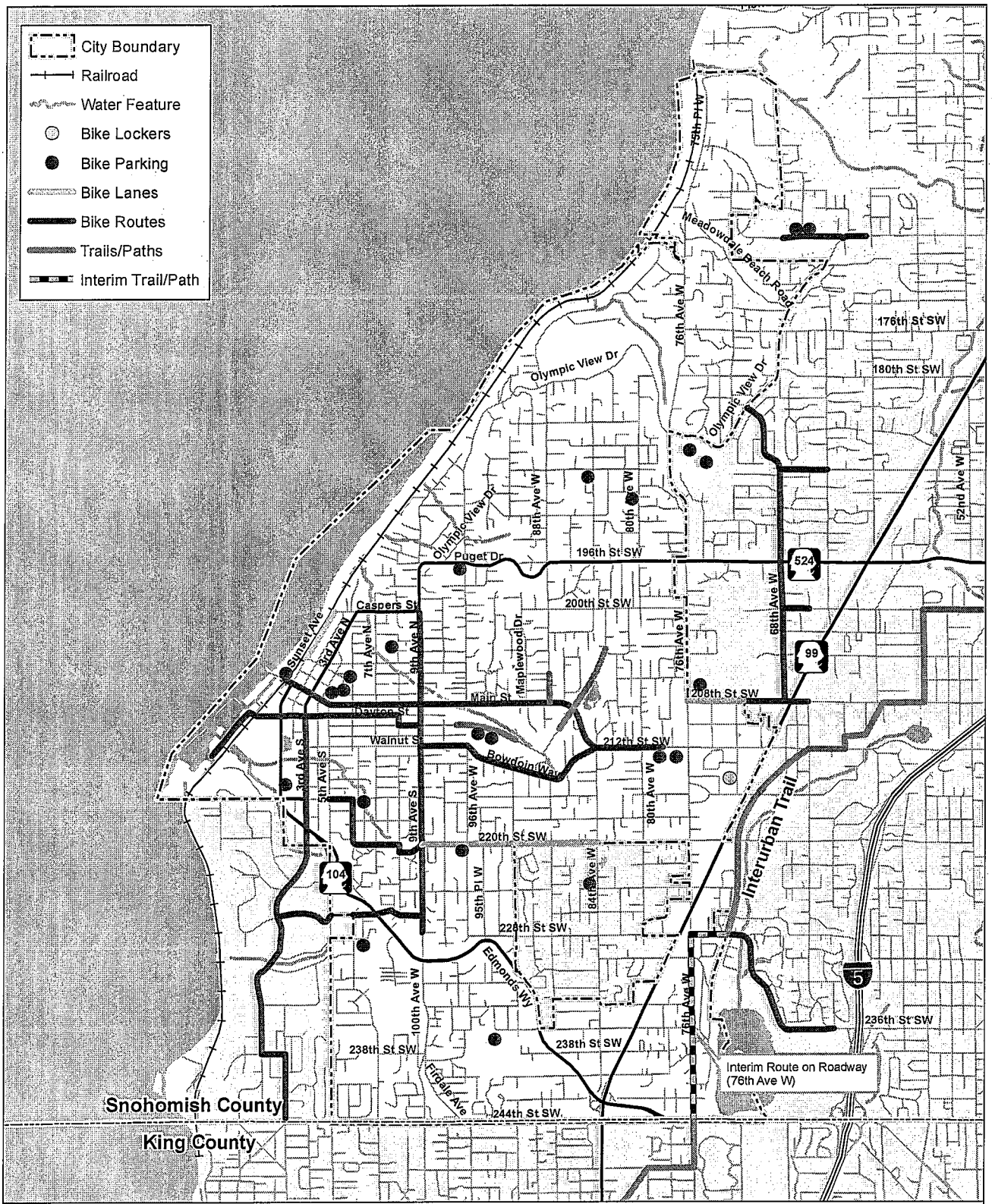


Figure 4-4. Existing Bicycle Facilities

City of Edmonds Comprehensive Transportation Plan

November 2009

Recommended Bikeway Improvements

The 2009 Bikeway Comprehensive Plan outlines a list of improvement projects for the bikeway system. The Bikeway Plan prioritizes bikeway projects, bicycle parking, and bikeway signage. The types of bikeway facilities that are recommended projects range from shared-use paths to bike lanes to bicycle parking. Shared-use or multiuse paths are physically separated from motorized vehicular traffic. They are designed and built primarily for use by bicycles, but are also used by pedestrians, joggers, skaters, wheelchair users (both non-motorized and motorized), equestrians, and other non-motorized users. The desirable width of a shared-use path is 12 feet; the minimum width is 10 feet.

Bike lanes are established along streets in corridors where there is current or anticipated bicycle demand and where it would be unsafe for bicyclists to ride in the travel lane. Bike lanes delineate the rights of way assigned to bicyclists and motorists and provide for movements that are more predictable by each. The minimum width for a bike lane is 4 feet. However, when parking is permitted along the bike lane, an additional width of 1 to 2 feet is recommended if parking is substantial or the turnover of parked cars is high. With curb, guardrail, or barrier, the minimum bike lane width is 5 feet.

Signed shared roadways are shared roadways that have been identified as preferred bike routes by posting bike route signs. A signed shared roadway bike route is established by placing the Bicycle Route signs or markers along the roadways according to guidelines set forth in the Manual of Uniform Traffic Control Devices. (FHWA 2001)

The Bikeway Plan categorizes bikeway projects into small bikeway projects and large bikeway projects. The distinction between these two categories is the funding sources. The small bikeway projects can be funded entirely through dedicated City funding; large bikeway projects will require grant funding and may be tied to a major roadway transportation project. Projected costs of the recommended bikeway projects are provided in Chapter 6 (Implementation and Financial Plan) of this Transportation Plan.

Small Bikeway Projects

Bicycle Loops

Figure 4-5 shows three bicycle loops of various difficulties and lengths that are recommended along roads that have low speeds and low vehicle volumes. The Edmonds Bike Group helped establish these three bicycle loops.

- The **short bicycle loop** has an easy level of difficulty and a distance of 5 miles.
- The **medium bicycle loop** is a medium level of difficulty route; it follows a similar route as the short bicycle loop, but has an additional 2 miles for a total length of 7 miles.

- The **long bicycle loop** is a scenic route designed for experienced cyclists. The total distance for the long bicycle loop is 20 miles with a portion located in the Town of Woodway.

Shared Use Lanes

Shared use lanes, or "sharrows," are commonly used to indicate where on the roadway a cyclist should ride, and also to remind motorists to share the lane with bicycles when present. Sharrows consist of a roadway striping treatment, with chevron arrows and a bicycle symbol placed on the outside portion of the travel lane. Approved by FHWA as an experimental treatment (Pedestrian and Bicycle Information Center 2009) and expected to be included in the next edition of the Manual of Uniform Traffic Control Devices, sharrows are a way for jurisdictions to create low-cost and safe bicycle facilities. The City intends to install sharrows as necessary as it completes roadway projects.

Bicycle Parking

In planning for bicycle parking, both public and private property needs must be considered. The recommended standard for new commercial developments is one bicycle rack for every 12 vehicle spaces provided. The City considers the following criteria when reviewing the suitability of new bicycle racks:

- The bicycle racks shall be as convenient as the majority of automobile parking spaces provided.
- All racks shall be securely anchored to the ground or building structures.
- Bicycle racks shall be in a visible location, close to the building entrances.
- Bicycle racks must be designed to accommodate U-shaped locks. (U-shaped locks are designed to allow the lock both wheels and the bicycle frame to a stationary object.)

Figure 4-6 shows the proposed bicycle parking locations identified in the City's Bikeway Plan.

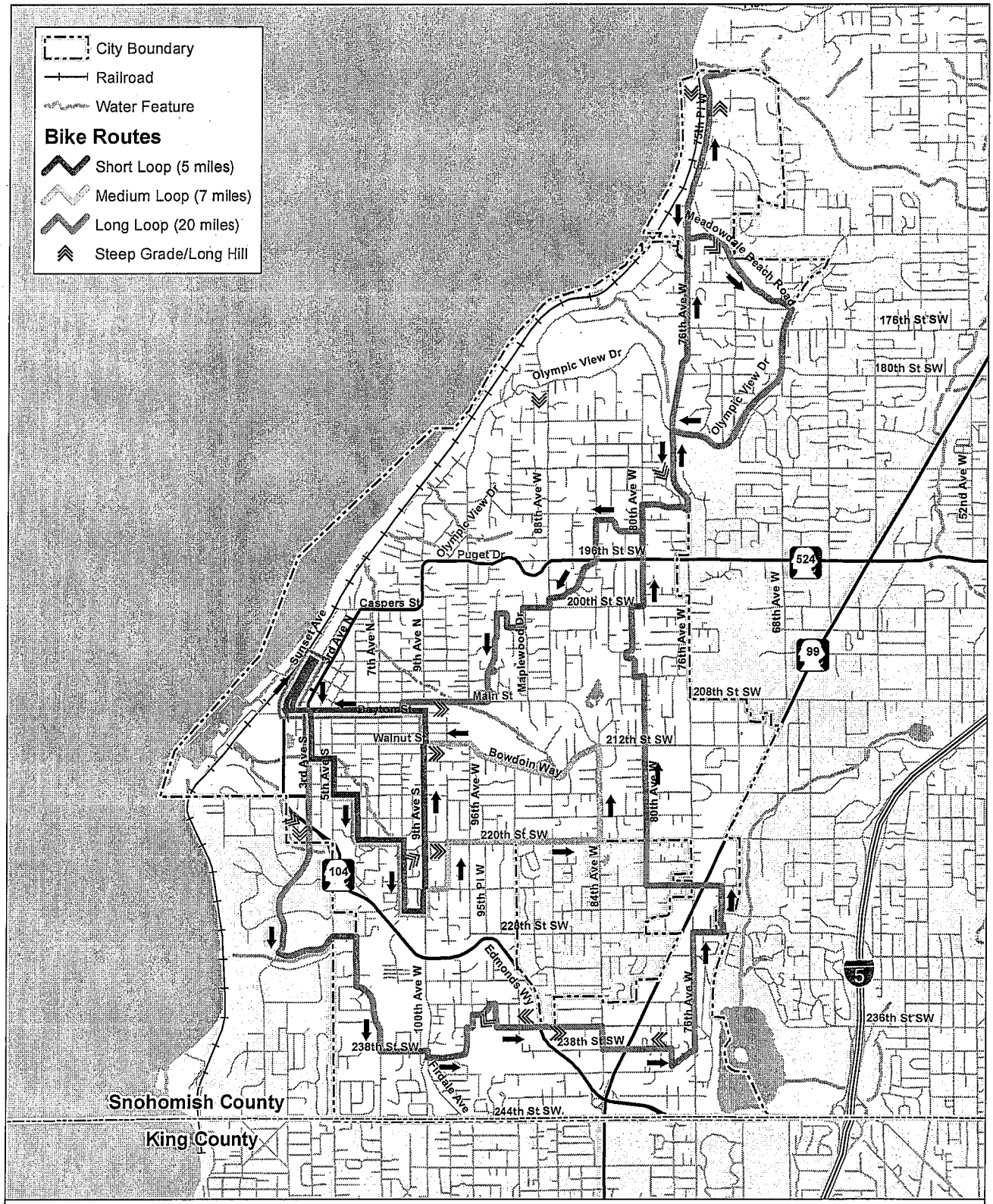


Figure 4-5. Recommended Signed Bicycle Loops

City of Edmonds Comprehensive Transportation Plan
November 2009

Large Bicycle Projects

Figure 4-6 shows the locations of the proposed bicycle routes and bicycle lanes. The large bikeway projects include bicycle lanes or bicycle routes that can be added as part of future roadway improvement projects. The large bikeway projects are concentrated around two major efforts: creating a north-south bicycle connection between downtown Edmonds and the Interurban Trail, and creating an east-west bicycle connection between the northern and southern portions of Edmonds.

The north-south bicycle projects include:

- 84th Avenue W, 238th Street SW - 212th Street SW
- 80th Avenue W, 220th Street SW - 206th Street SW
- 76th Avenue W, 224th Street SW - N Meadowdale Beach Drive

The east-west bicycle projects include:

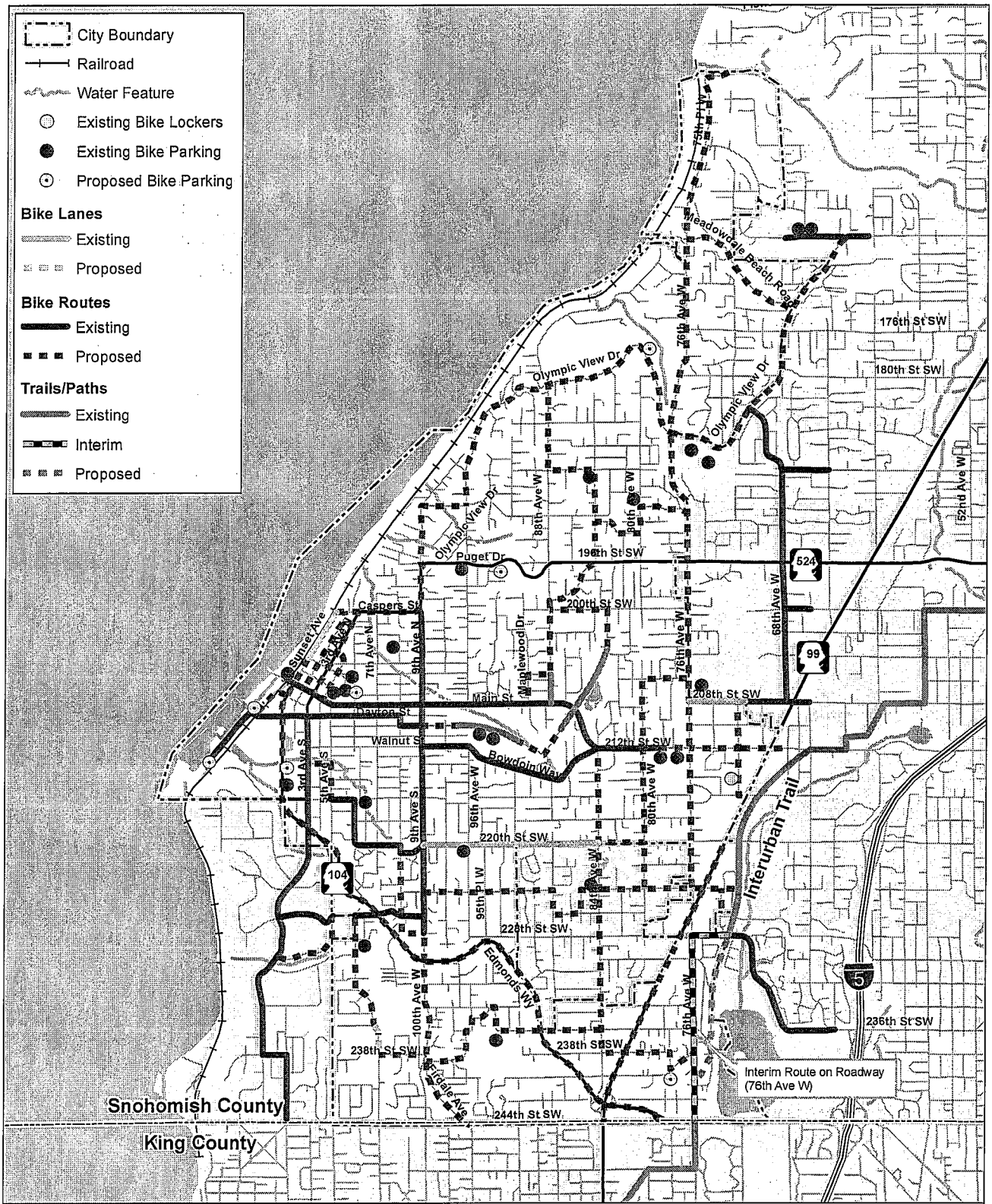
- Edmonds Way/Sunset Avenue, Edmonds Street - city limits
- 224th Street SW, 100th Avenue W - the Interurban Trail

Other large bikeway projects include:

- Olympic View Drive, Puget Drive - 76th Avenue W (less steep route)
- 3rd Avenue N, Main Street - Caspers Street
- Caspers Street, 3rd Avenue N - 9th Avenue N
- 9th Avenue N, Caspers Street - Puget Drive

Interurban Trail

The City is planning to complete the 1.4-mile link of the Interurban Trail between the cities of Shoreline and Mountlake Terrace. The planned alignment runs roughly parallel to 76th Avenue W, south of 228th Street SW. The "interurban corridor" is a former inter-city rail line, part of a nationwide system of similar lines that operated from the 1890's to the 1930's. This vital project is significant because it is the "missing link" north and beyond to Everett and south through the recently completed Shoreline Interurban Trail to Seattle and beyond. Locally and regionally this community supported trail will provide safe passage and a healthy alternative to connect homes, work, services, recreation sites and other modes of transportation. The trail lies along view corridors of Lake Ballinger with waterfront access and a respite stop with shelter and information kiosk at 76th Ave and McAleer Way. For consistency in style, the City's proposed design follows the lead of surrounding communities matching them in 12-foot width, design, historical elements, signage and landscaping. Shared road portions along busy 76th Avenue West and the quieter residential 74th Avenue West will be reconfigured and improved to add dedicated bicycle lanes. Traffic calming techniques will be installed at road crossings as well as appropriate signage.



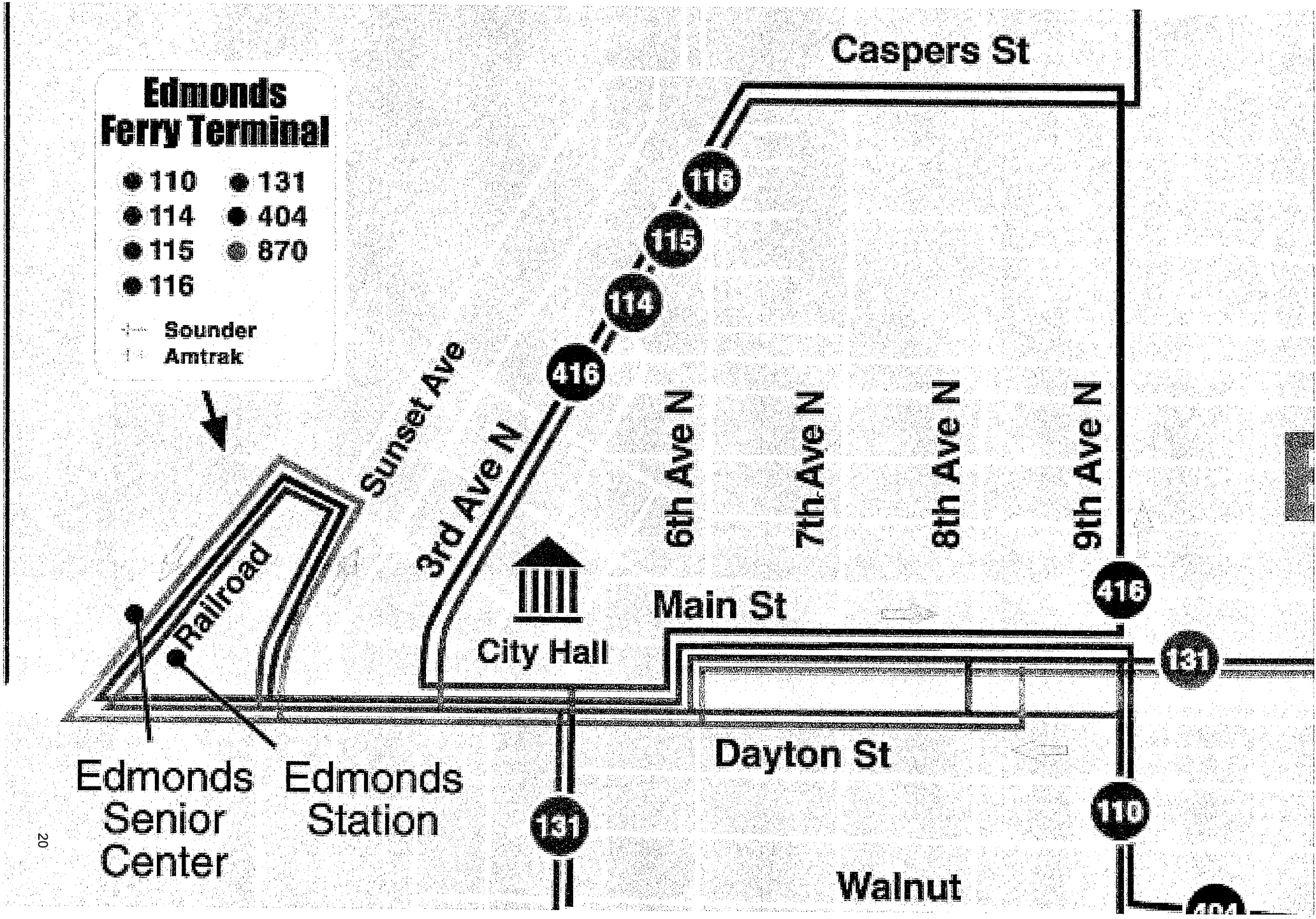
Source: City of Edmonds (2008); WSDOT (2008); Snohomish County (2008)

0 0.5 1

Miles

Figure 4-6. Recommended Bicycle Facilities

City of Edmonds Comprehensive Transportation Plan
November 2009


Edmonds Ferry Terminal
110
114
115
116
131
404
870
Sounder
Amtrak
Caspers St
Sunset Ave
3rd Ave N
6th Ave N
7th Ave N
8th Ave N
9th Ave N
Railroad
City Hall
Main St
Dayton St
Walnut
Edmonds Senior Center
Edmonds Station
116
115
114
416
131
110

Accident History Data

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7389810

Home Crossing Forms/Publications Downloads Data Documents Policies Support

8.01 - Query by Location

Total Records: 2

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

Generate Repor | Show All | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**085439G**	WA	BNSF	Public	At Grade	Open	001743	SNOHOMISH	EDMONDS	NORTHWEST	SCENIC	WENACHE-SEATTLE	DAYTON ST
☐	**085445K**	WA	BNSF	Public	At Grade	Open	001766	SNOHOMISH	EDMONDS	NORTHWEST	SCENIC	WENACHE-SEATTLE	MAIN ST. (SR 104)

Generate Repor | Show All | Reset

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0903200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0903200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085445K	09/07/03	03:10 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS	NORTHWEST	SNOHOMISH	53	WA

11. City *(if in a city)* EDMONDS — 12. Highway Name or No. MAIN ST. (SR 104) — ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 61 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
4	3	99	R. Recorded / E. Estimated 10 mph	E	1. North 2. South 3. East 4. West	3

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): 01 02

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach	Code	36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown	Code	37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown	Code
	1		1		1

38. Driver's Age	39. Driver's Gender — 1. Male, 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown	Code	41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)*	Code
		1		2		4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown	Code	43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed	Code
	2		8

Casualties to:	Killed	Injured	44. Driver was — 1. Killed 2. Injured 3. Uninjured	Code	45. Was Driver in the Vehicle? — 1. Yes 2. No	Code
				3		2
46. Highway-Rail Crossing Users			47. Highway Vehicle Property Damage *(est. dollar damage)*	$2,000	48. Total Number of Highway-Rail Crossing Users *(include driver)*	2
49. Railroad Employees			50. Total Number of People on Train *(include passengers and crew)*	3	51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No	2
52. Passengers on Train						

53a. Special Study Block — 53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57 * NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1201201
2. Other Railroad Involved in Train Accident/Incident		2a.	2b. NW1201201
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1201201

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085445K	12/18/01	11:40 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS	NORTHWEST	SNOHOMISH	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
EDMONDS	MAIN STREET	☑ Public ☐ Private

Highway User Involved

13. Type	Code
A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)*	A

14. Vehicle Speed *(est. mph at impact)*	15. Direction *(geographical)* 1. North 2. South 3. East 4. West	Code
1		1

16. Position	Code
1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped	3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither	Code
	4

Rail Equipment Involved

17. Equipment	Code
1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL	4

18. Position of Car Unit in Train
1

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user	Code
	1

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither	Code
	4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*	22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark	Code	23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow	Code
45 °F		2		3

24. Type of Equipment Consist *(single entry)* A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car	Code	25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry	Code	26. Track Number or Name
	9		1	MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated	Code	31. Time Table Direction 1. North 2. South 3. East 4. West	Code
4	0	1	5 mph	E		3

32. Type of Crossing Warning 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None	33. Signaled Crossing Warning	34. Whistle Ban 1. Yes 2. No 3. Unknown	Code
Code(s): 02	20 sec warn min (1);		2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach	Code	36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown	Code	37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown	Code
	1		3		2

38. Driver's Age	39. Driver's Gender 1. Male 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown	Code	41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*	Code
	1			2		3

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown	Code	43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed	Code
	3		8

Casualties to:	Killed	Injured	44. Driver was 1. Killed 2. Injured 3. Uninjured	Code	45. Was Driver in the Vehicle? 1. Yes 2. No	Code
				3		1
46. Highway-Rail Crossing Users	0	0	47. Highway Vehicle Property Damage *(est. dollar damage)*	$1	48. Total Number of Highway-Rail Crossing Users *(include driver)*	1
49. Railroad Employees	0	0	50. Total Number of People on Train *(include passengers and crew)*	2	51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No	Code
52. Passengers on Train	0	0				2

53a. Special Study Block	53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. PA0698203
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. PA0698203

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085445K	06/21/98	02:45 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS	PACIFIC	SNOHOMISH	53	WA

11. City *(if in a city)* | 12. Highway Name or No. MAIN STREET | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 1

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*: A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 60 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated	Code	31. Time Table Direction — 1. North 2. South 3. East 4. West	Code
3	5	38	40 mph	E	3	

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): 01

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age	39. Driver's Gender — 1. Male 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown	Code	41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)*	Code
42	1			2		4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $500

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. PA0407
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. PA0407

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085439G	09/11/96	11:10 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS		SNOHOMISH	53	WA

11. City *(if in a city)*: EDMONDS
12. Highway Name or No.: DAYTON STREET
☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code:

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 56 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN TRACK

27. FRA Track Class: 4

28. Number of Locomotive Units: 2

29. Number of Cars: 32

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 40 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 4

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 01 05 08

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code:

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age:

39. Driver's Gender — 1. Male 2. Female — Code:

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $1,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*:

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Burlington Northern RR Co. [BN]	1a. BN	1b. PA0053
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Burlington Northern RR Co. [BN]	3a. BN	3b. PA0053

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085439G	02/01/96	05:40 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS		SNOHOMISH	53	WA

11. City *(if in a city)* EDMONDS — 12. Highway Name or No. DAYTON STREET — ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: F

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code:

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 27 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment — Consist *(single entry)*: 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN TRACK

27. FRA Track Class: 4

28. Number of Locomotive Units: 3

29. Number of Cars: 56

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 30 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 4

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s): 01, 06, 07

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code:

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 1

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age:

39. Driver's Gender — 1. Male, 2. Female — Code:

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $30,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*:

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 1

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Burlington Northern RR Co. [BN]	1a. BN	1b. CA0464
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Burlington Northern RR Co. [BN]	3a. BN	3b. CA0464

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085439G	12/01/93	06:10 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS		SNOHOMISH	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
EDMONDS	DAYTON ST	☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code:

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 45 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 3

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN TRACK

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
2	3	28	R. Recorded E. Estimated 25 mph	E	1. North 2. South 3. East 4. West	4

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 01 03 08

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code:

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age:

39. Driver's Gender — 1. Male 2. Female — Code:

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 3

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $1,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*:

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Burlington Northern RR Co. [BN]	1a. BN	1b. PA2419
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Burlington Northern RR Co. [BN]	3a. BN	3b. PA2419

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085439G	12/31/89	07:45 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EDMONDS		SNOHOMISH	53	WA

11. City *(if in a city)*

12. Highway Name or No. DAYTON AVE ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code:

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 42 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 3

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN TRACK

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
3	3	12	R. Recorded E. Estimated 20 mph	E	1. North 2. South 3. East 4. West	3

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s): 01

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code:

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age:

39. Driver's Gender — 1. Male, 2. Female — Code:

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 1

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $6,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
Snohomish	Edmonds	City Street		T AVE N	100		50	F	S
Snohomish	Edmonds	State Route		104					
Snohomish	Edmonds	State Route		104					
Snohomish	Edmonds	State Route		104					

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL	VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)
BELL ST					2489203	1/8/2007	8:45	No Injury	0	0	1			Pickup,Panel Truck or Vanette under 10,000 lb
			24.46		2489251	7/7/2006	20:18	No Injury	0	0	1			Pickup,Panel Truck or Vanette under 10,000 lb
			24.46		E056457	6/18/2010	13:20	No Injury	0	0	2			Passenger Car
			24.47		2489285	9/26/2006	15:05	No Injury	0	0	2			Passenger Car

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS	FIRST COLLISION TYPE / OBJECT STRUCK
	Not at Intersection and Not Related	Dry	Daylight	Railway Crossing Gate
	At Intersection and Related	Dry	Daylight	Railway Crossing Gate
Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight	From same direction - one left turn - one straight
Bus or Motor Stage	At Intersection and Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

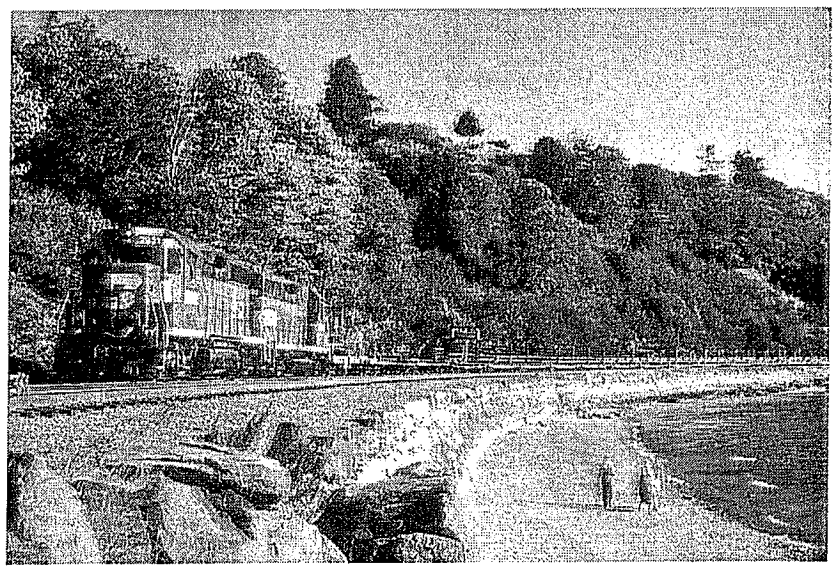
MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
Other		North	South		
Other		Northwest	Vehicle Stopped		
Follow Too Closely	None	East	South	East	Vehicle Stopped
Follow Too Closely	None	Southeast	Northwest	Southeast	Vehicle Stopped

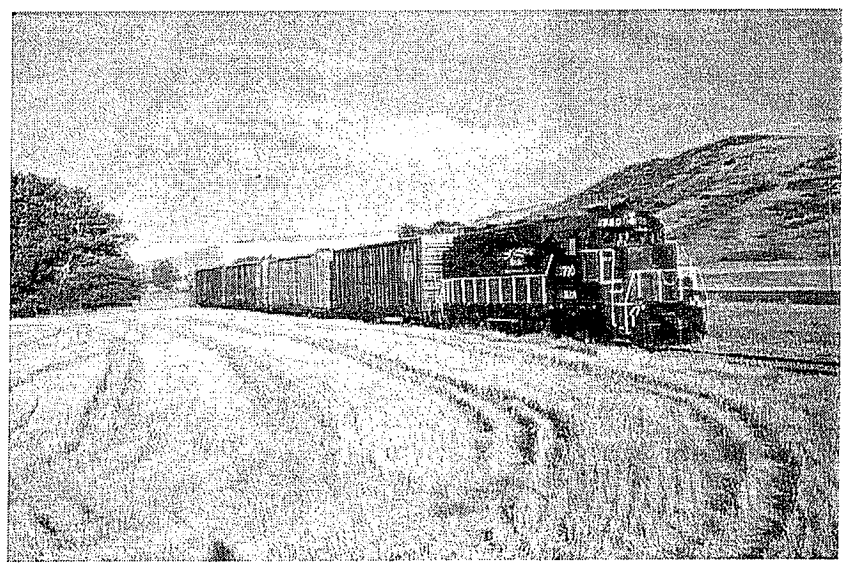
UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

State Information

Washington State

2010-2030 Freight Rail Plan

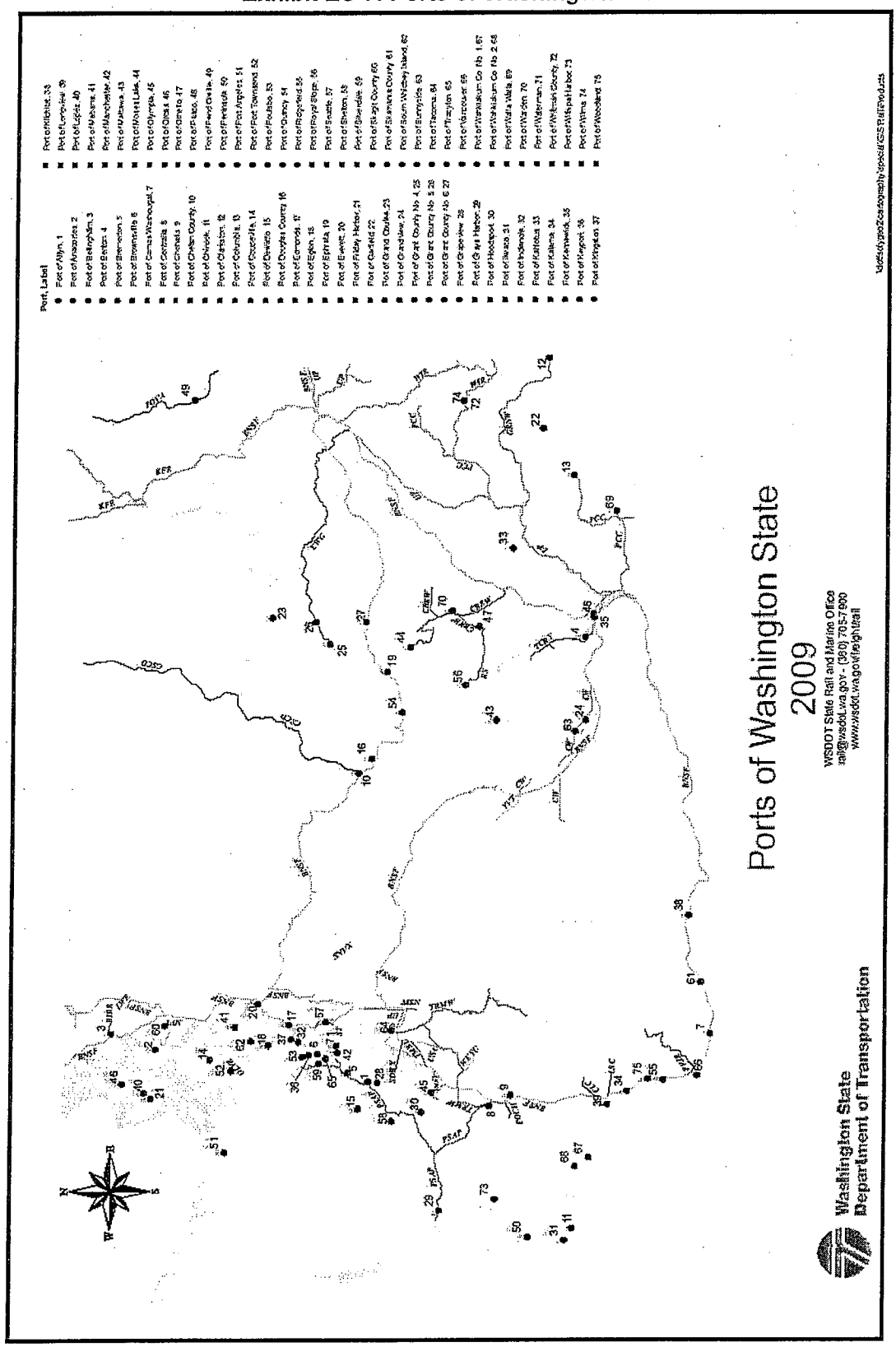




December 2009

Washington State
Department of Transportation

Exhibit ES-7: Ports of Washington State



Freight Rail Service Corridors

The state currently has ten major rail corridors and 12 low-density corridors. These corridors are defined and operated by BNSF and UP. Exhibit 3-6 lists all the corridors. Appendix 3-B has a description of each rail service corridor. While these rail corridors are defined by private railroads, the state has an interest in defining rail corridors in terms of public benefits. The Freight Mobility Strategic Investment Board is authorized to define strategic rail corridors and update them periodically. Some short-line routes are critical to the economic viability of local communities and certain industries. The state needs to develop criteria to define rail corridors in terms of their impacts on the state's economic and societal needs, as discussed in Chapter 5.

Exhibit 3-6: Rail Service Corridors in Washington State

Railroads	Major Corridors	Low-Density Corridors
BNSF	Seattle-Spokane	Tukwila-Snohomish
	Seattle-Portland, Oregon (OR)	Woodinville-Redmond
	Portland, OR-Pasco	Burlington-Sumas
	Auburn-Pasco	Sumas-Lynden
	Pasco-Spokane	Burlington-Anacortes
	Spokane-Sandpoint, Idaho (ID)	Intalco-Cherry Point
	Everett-Vancouver, British Columbia (B.C.)	Marysville-Arlington
		Lakeview-Roy
		Spokane-Chewelah
UP	Hinkle, OR-Spokane	Spokane-Plummer, ID; Manito-Fairfield
	Spokane-Eastport, ID	Ayer Junction-Riparia
	Tacoma-Seattle	Wallula-Kennewick

Source: *Statewide Rail Capacity and System Needs Study* (2006)

Railroad Profiles

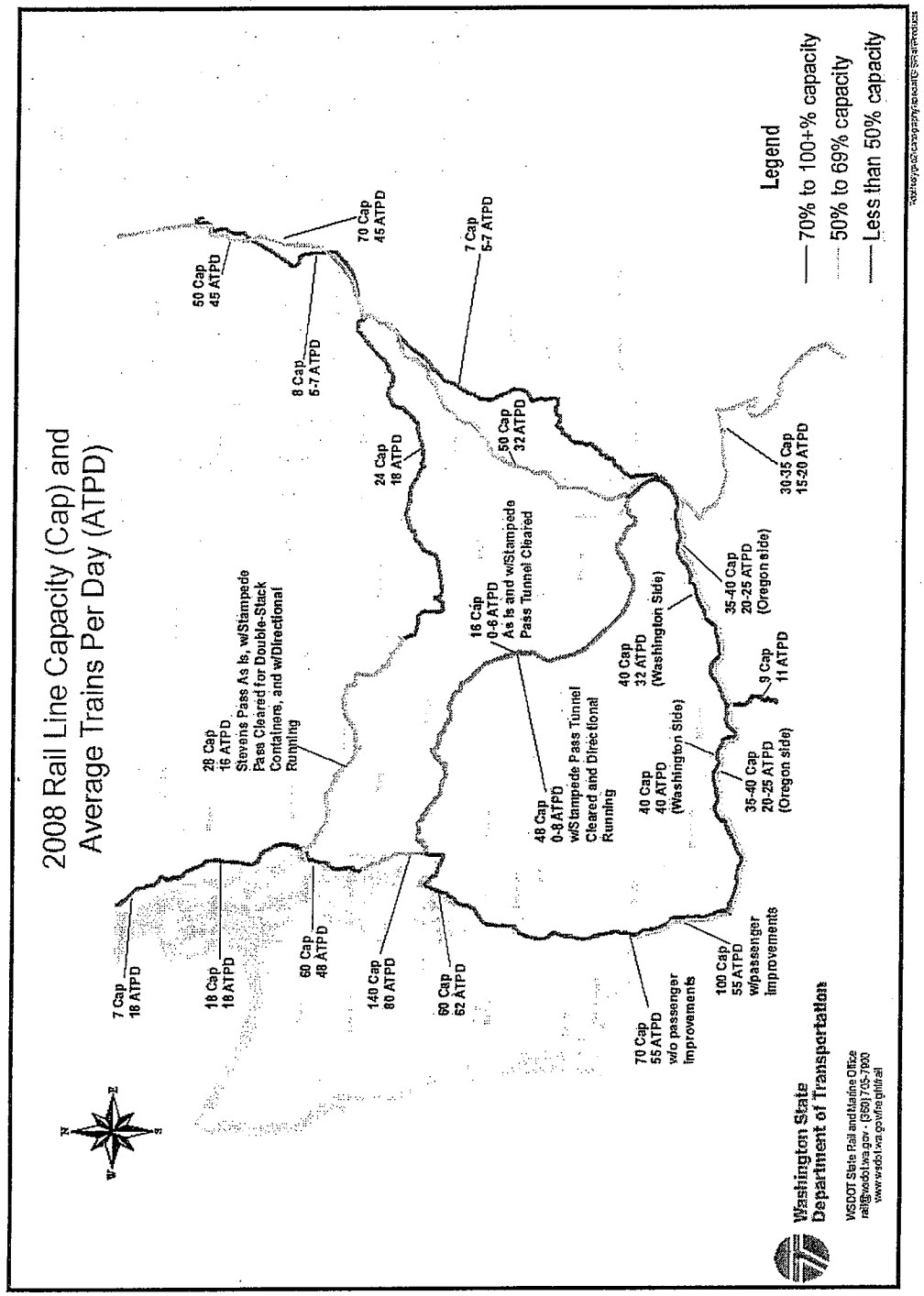
Appendix 3-B also contains more information about the freight rail carriers in the state including descriptions, maps, revenue, and history.

Class I Railroads

BNSF Railway

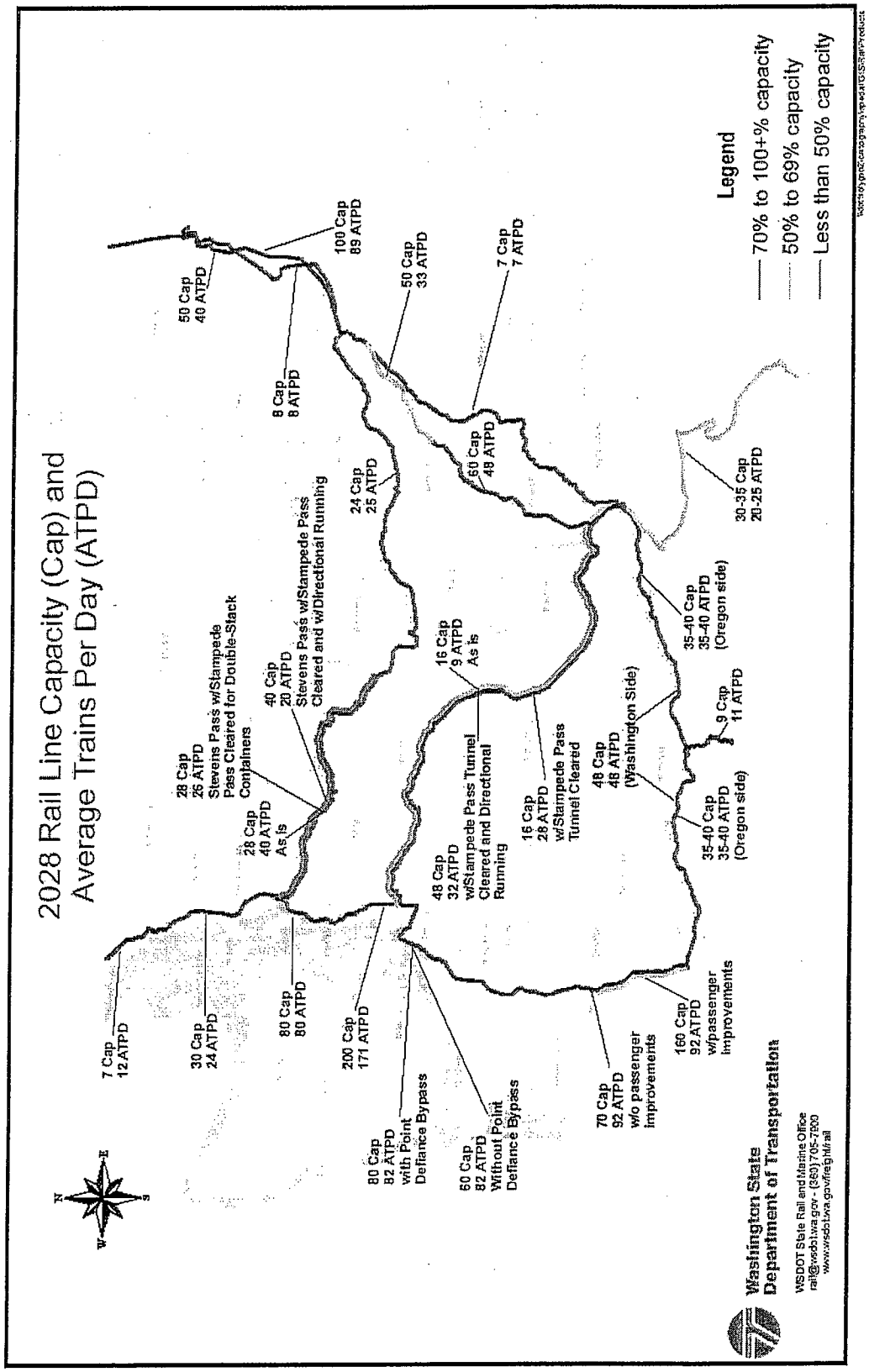
BNSF, one of the four largest U.S. railroads, owns and operates track over seven major corridors and nine low-density corridors in the state. BNSF

Exhibit 3-9: 2008 Rail Line Capacity[17]



[17] Train volumes (average trains per day) reflect business activities that are fluctuated sharply and sensitive to economic climate. Although the long-term trend is upward, the short-term trend could drop significantly. The information in this map reflects the long-term forecast results. These numbers were derived based on the best knowledge of the researchers and information available at the time of the research. The recent recession impacts may not be captured by this map.

Exhibit 3-10: 2028 Rail Line Capacity



Bottleneck	Type of Bottleneck
Tacoma (BNSF)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Tacoma (Tacoma Rail)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Fife (UP)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Argo (UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Port of Seattle (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
SIG/Stacy (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Interbay (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Everett (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Wishram (BNSF)	Yard Infrastructure
Arco (Cherry Point; BNSF)	Yard Infrastructure
Longview Jct. (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems
Pasco (BNSF)	Yard Infrastructure
Centralia (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation
Spokane (BNSF)	Yard Infrastructure

Source: Washington State Transportation Commission (WSTC) *Statewide Rail System and Capacity Study*, 2006

Montana Rail Link (MRL) system; the MRL has operating rights over BNSF into Spokane.

The Funnel was part of the original Northern Pacific mainline, completed to Spokane in 1881. After the 1970 Burlington Northern merger, the Northern Pacific route was selected over the parallel ex-Great Northern route as the primary mainline from the east into Spokane, a function that it retains today for BNSF. Portions of the original Great Northern route continue under operation as segments of the Pend Oreille Valley Railroad and BNSF's Kettle Falls Subdivision, but abandonments have rendered that line no longer viable as a through route.

As the corridor experienced substantial growth in recent years, BNSF began to increase capacity by adding a second main track. As of April 2005, only 20 miles remained under single-track operation. Except for a short stretch in Spokane, the entire line is controlled by CTC. Annual freight traffic consists of intermodal, forest and agricultural products, coal, chemicals, and finished automobiles.

Everett-Vancouver, British Columbia Mainline

The 152-mile corridor spanning the Bellingham and New Westminster Subdivisions is the only remaining mainline link between the Washington State rail network and Canada (low-volume connections are served by BNSF at Sumas and KFR at Columbia Gardens, B.C.). An average of 23 freight trains operates on the line daily, with approximately 12 running through to Vancouver, B.C. Four daily Amtrak *Cascades* trains run between Everett and Vancouver, B.C.

This stretch of U.S. and Canadian railroad was completed by the Great Northern in 1891. From Blanchard to Bellingham, the line closely follows the shores of Samish and Bellingham Bays, a condition that limits both train speed and the ability to increase capacity without incurring great expenses. Additional delays are encountered while passing through Customs at the Blaine/White Rock border crossing. BNSF also operates a 2-mile stretch of former Milwaukee Road trackage in Bellingham that is owned by the Bellingham International Railroad (BIRR); the BIRR was formed for the purpose of preventing an industry from losing service on a line that BNSF intended to abandon.

The corridor is single-track CTC from Everett to New Westminster, with the exception of a few short stretches of Automatic Block Signaling/ Occupancy Control System (ABS/OCS). From New Westminster to Vancouver, the line is double-track CTC. Maximum train speeds are:

- Everett to Delta Junction: Talgo[22] 50 mph, passenger 35 mph, freight 15 mph.
- Delta Junction to Blaine: Talgo 79 mph, passenger 79 mph, freight 60 mph.
- Blaine to Vancouver, B.C.: Talgo 60 mph, passenger 60 mph, freight 40 mph.

Freight traffic includes intermodal, forest and agricultural products, refuse, chemicals, and finished automobiles.

Tukwila-Snohomish Branch Line

BNSF's 51-mile Woodinville Subdivision traverses the east side of the Seattle metropolitan area, connecting Tukwila, Renton, Bellevue, Woodinville, and Snohomish. BNSF operates one round-trip local on weekdays that serves industrial customers along the line, including delivery of 737 fuselages to Boeing's assembly plant in Renton.

The Woodinville Subdivision is a remnant of the former Northern Pacific (NP) mainline from Seattle to Sumas. The line to Sumas and a connection with the Canadian Pacific Railroad was completed by the Seattle, Lake Shore, & Eastern Railroad (SLS&E) in 1891; the SLS&E was subsequently absorbed into the NP in 1901. In the wake of the 1970 Burlington Northern merger, the Sumas line from Snohomish Junction to Sedro-Woolley was abandoned. In 2006 a study was conducted on the segment from Tukwila to Snohomish to consider potential future uses, including a parallel bicycle/pedestrian trail, mass transit, and as an emergency bypass route for freight traffic normally operating via Interbay, Edmonds, and Everett.

Traffic on the Woodinville Subdivision operates via TWC. Maximum permitted train speeds are 30 mph for passenger and 25 mph for freight. Railcar weights up to 143 tons can be operated from Snohomish Junction to Woodinville, while the remainder of the line is restricted to 134 tons. Tukwila-Woodinville freight corridor traffic consists of aircraft fuselages, forest products, and chemicals.

[22] Talgo, Inc. manufactures high-speed articulated trains. These operate as a set, with adjacent cars sharing axles and wheels and functioning as a single unit. This technology increases stability and improves safety and the smoothness of the ride. Talgo trains were initially allowed into the United States on a temporary basis and were leased for use in the Pacific Northwest from 1994 through 1998. Today, five trains built by Talgo operate in the Pacific Northwest and British Columbia as the Amtrak *Cascades* service.

segment of a former Great Northern branch that connected Anacortes and Rockport.

The line is operated as an industrial track with a speed limit of 10 mph, and railcars up to 134 tons are permitted. Traffic includes petrochemicals.

Intalco-Cherry Point Branch Line

BNSF's Cherry Point Subdivision splits off the Bellingham Subdivision at Intalco, near the town of Custer, and runs southwest to serve a collection of industries at Cherry Point. BNSF operates two daily round trips on the line.

The Cherry Point Subdivision is operated by TWC, with a speed limit of 25 mph and a maximum railcar weight of 143 tons. The line was built in 1965 to serve the Intalco aluminum smelter, and later a series of petroleum-related industries were constructed on the line. Traffic includes metals and petrochemicals.

Marysville-Arlington Branch Line

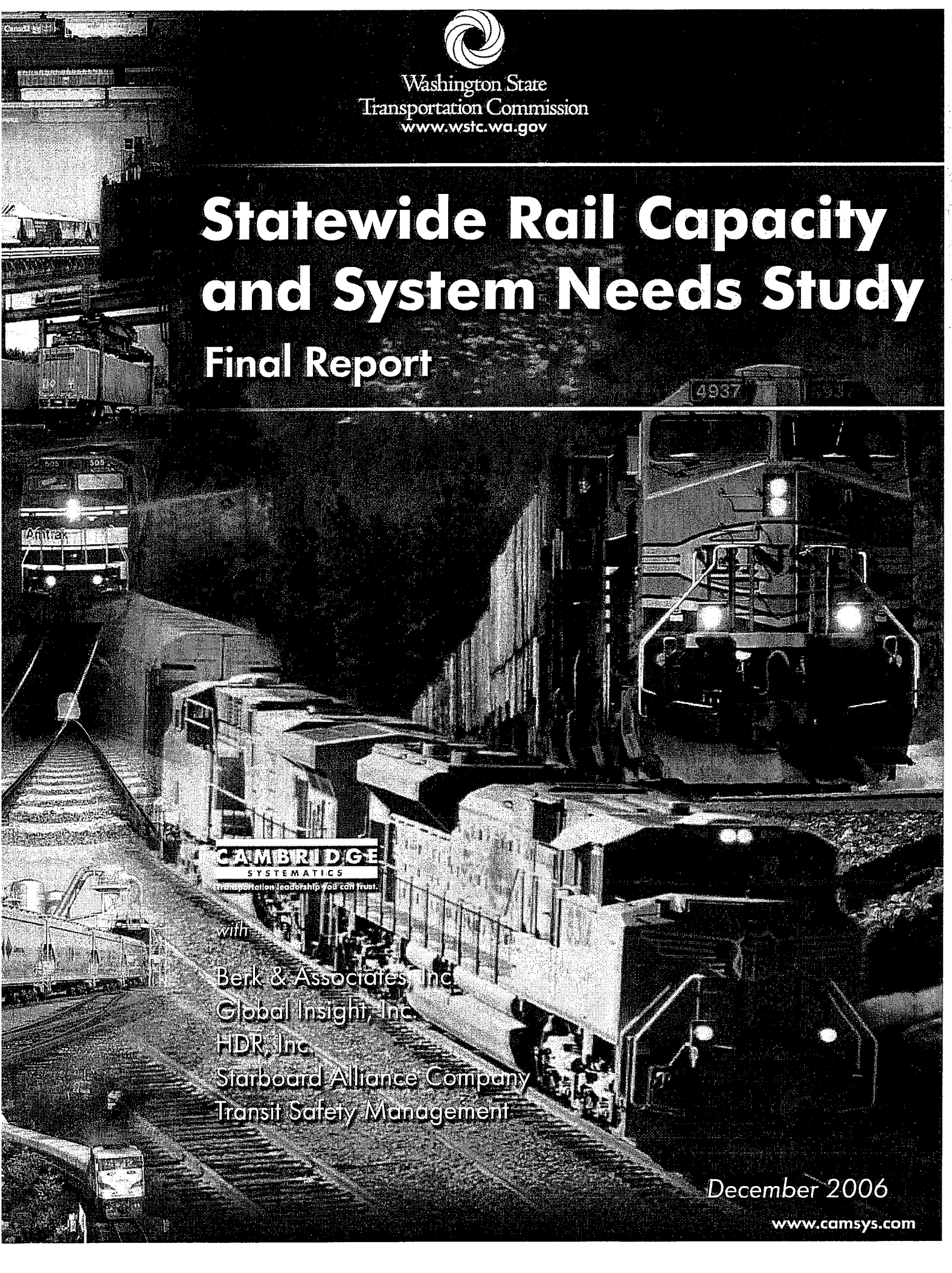
Breaking off the Bellingham Subdivision at Kruse Junction, BNSF's Arlington Spur connects Arlington to the national rail network, and is classified by BNSF as an industrial spur. The line is served twice weekly by a road switcher based in Everett. Track speed on the line is 10 mph, and 143-ton railcars are permitted.

Lakeview-Roy Branch Line

Although BNSF sold freight rights on the north end of its Lakeview Subdivision and the entire length of the connecting Lakeview Spur to Tacoma Rail in 2004, it retained the remainder of the Lakeview Subdivision from Lakeview to Roy. The customers on the line are the U.S. Army's Fort Lewis, which occasionally ships or receives military equipment, and Wilcox Farms, which receives feed at Roy twice a week. Track speed on the line is 10 mph, and 143-ton railcars are permitted; however, as of spring 2006, the only connection to the rest of the BNSF network, via the Lakeview Spur and Nisqually, is restricted to 134-ton railcars.

Spokane-Chewelah Branch Line

BNSF's Kettle Falls Subdivision was constructed in 1889 by the Spokane Falls and Northern Railway, and came under control of James Hill's Great Northern in 1898. In late 2004, BNSF sold the Kettle Falls and San Poil Subdivisions north of Kettle Falls to OmniTRAX's Kettle Falls International Railway (KFR), and leased the Kettle Falls-Chewelah segment to the KFR; the two railroads interchange daily at the latter



Washington State
Transportation Commission
www.wstc.wa.gov

Statewide Rail Capacity and System Needs Study

Final Report

CAMBRIDGE SYSTEMATICS
transportation leadership you can trust.

with

Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management

December 2006

www.camsys.com

1.0 Executive Summary

The Washington Rail Capacity and System Needs Study was requested by the Washington State Legislature to:

- Assess rail needs in the State;
- Determine the State's interest in the rail system;
- Develop policies to govern the State's participation in the rail system; and
- Develop a plan for managing the rail lines, railcars, and service rights owned by the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity rail service. In the last decade, it also has provided emergency relief to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature for this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The Economic Vitality of Washington State Requires a Robust Rail System

The economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. For example:

- Manufacturers, lumber and wood products producers, and central and eastern Washington agriculture and food products businesses rely on rail transportation to move heavy, bulky products to market cost effectively. These businesses generate 14 percent of the State's gross state product and 15.5 percent of its employment. If rail service deteriorates, these businesses may shift their freight to trucks, but this will increase their transportation costs and may increase the cost to state and

local government of maintaining roads. In some cases, the loss of rail service could drive businesses to relocate or close.

- The State's ports and international trade industry depend on rail to export grain and other agricultural products and to import intermodal containers of consumer goods. The ports generate more than 200,000 jobs directly and indirectly, and over $500 million in state and local tax revenues. If the rail system cannot deliver high-quality transportation services, especially for intermodal cargo that is not destined for Washington State, shippers will quickly shift to other ports. This could result in lower growth at Washington ports and a loss of port-related jobs. In addition, export trade plays a major role in the Washington economy, ranking it first among states in export value per capita. Without good rail connections to support both import and export trade, the Washington ports will become less attractive to ocean carriers, and ultimately, the State will become a less attractive location for export businesses.

- A high-quality intercity passenger rail service offers an alternative to automobile and air travel that can help reduce congestion, energy use, and environmental impacts of highways. If the rail system cannot accommodate frequent and reliable intercity passenger rail service, the State risks losing the benefits of passenger rail as an alternative to highway and air travel.

The System Is Nearing Capacity

The benefits that Washington State can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. For example:

- The Everett-Spokane line over Stevens Pass is the Burlington Northern Santa Fe Railway's (BNSF) major transcontinental route for double-stack intermodal trains. It operates today at about 123 percent of practical capacity.[1]

[1] Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is the point at which the system ceases to operate freely and reliably and begins to suffer slowdowns and congestion. At higher percentages, rail congestion increases and service reliability deteriorates quickly. For more information about how rail capacity is determined, see Technical Memorandum #3, *Rail Capacity Needs and Constraints.*

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic - most of which is associated with short- and medium-distance trips - on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 - Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Kevin Nielsen
Title: Marysville Public Works Director
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations; GTC #11-036
Date: June 15, 2011

This memorandum is to identify some of the possible Rail Impacts associated with transport of coal to the proposed Cherry Point Facility on the City of Marysville WA. We understand a terminal capable of exporting 54 million tons of coal per year is proposed north of Bellingham.

GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north south directly through the heart of the business district of the City of Marysville Washington. According to the applicant's *Project Information Document* (Feb. 2011), full buildout of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day, however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. Each train may be over 1.5 miles long, which at 30 miles per hour would mean approximately 6-7 minutes between train approach warming/gate closure and ultimate gate opening or at 5 miles per hour could take approximately 14-18 minutes to clear a crossing. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic.

The BNSF rail way tracks bisect all of the major arterial roads that connect the City business and residential areas with I-5. Preliminary review indicated that the additional trains from the Cherry Point operations would have a significant impact on the commercial district and quality of life for the City of Marysville. We have the following comments based on preliminary research:

1. The City is finalizing its downtown vision plan. A downtown bisected by 16-18 coal train trips per day rumbling through its "green downtown" for several hours a day is not part of that vision.
2. The City's downtown access plan has identified major east west improvement needs (i.e. additional lanes on SR-528) under the I-5 structure and an extension east of 1st Street alternative corridor south of the mall. Both these future critical links have at-grade crossing that the traffic modeling by HDR shows are significantly impacted by the train movements. This would result in their 1st Street and I-5/SR-528 improvements would be negated when a train crosses in the peak hour.
3. Due to speed restriction approach warning, trains through Marysville downtown means the barriers are down for approximately 6-8 minutes (over 400 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 3-4 continuous red lights cycles in a row for a normal signal on 4th Street. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F - the city's standard for normal roadway operation is LOS D i.e. allowing only 60 seconds as the worst delay for normal conditions.
4. With the increase in number of long coal trains, the nightmare scenario for the city is having all its I-5 entrances blocked at the same time, i.e. SR-528, 88th and 116th. The recent capacity improvement on 116th Street completed by the city would be negated by the increased coal train activity.

2802 Wetmore Avenue · Suite 220 · Everett WA, 98201
Tel: 425-339-8266 · Fax: 425-258-2922 · E-mail: info gibsontraffic.com

5. Marysville is one of the largest cities with the highest traffic volume j that does not have at least one grade-separated crossing for its major access. For example look at Everett to the south; it's last major at grade rail crossing (Pacific Avenue) was grade separated over a decade ago and it carries less traffic than SR-528 or 88th Street.
6. A single long train will close the gates from 1st North to 88th Street at the same time the rail crossing between 88th Street and 1st Street carry approximately 7,000 PM peak hour trips or over 80,000 daily trips. The rail crossing to the north at 116th Street also carries approximately 20,000 daily trips. The addition of just 16 train trips will block the Marysville main lifeline to I-5 for an additional 2-3 hours a day.
7. Within the last 5 years there have been approximately 30 accidents at rail crossings in the City of Marysville, nearly half involving the actual rail gates and one with a vehicle struck by a train in December 2008 causing serous injury to two people at the 88th Street crossing. The remainder was mainly rear ends of vehicles stopping for the gate closures (based on the State's accident data base).
8. Already today the presence of a long freight train during the peak hours creates back ups from the I-5 ramps onto the mainline. The Puget Sound Regional Council (PSRC), the City of Marysville and Tulalip Tribes have identified capacity improvement needs at both the 88th Street and 116th Street interchanges due to existing congestion at these ramps. WSDOT over the last few years has already maximized the queuing capacity of the ramps through deviations to standards to restripe shoulders to accommodate the queuing created when trains block access from I-5 to the City. Adding 18 trains per day to existing levels will likely exacerbate this problem by a significant factor. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects.
9. The City of Marysville, John McCoy (State Representative), and Tulalip Tribes have long envisioned a passenger train station on the Marysville line (Policy Point T-9c.1 of the Marysville Adopted Transportation Element). The increased coal train activity hampers that plan.
10. The Cherry Point applicant argues that the coal train activity will only bring train activity back up to the level it was before the economic crash, and therefore there is no impact. This is misleading because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well vehicular traffic on the roads. At that point, even greater impacts will begin.
11. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. The City's transportation element Policy T-1E.6 identifies a priority in needing to minimize the number of at grade-crossings. While grade separation is desired in the City plan, these improvements are typically multi-million dollar solutions and funding is not yet planned.

This analysis of possible rail line impacts associated with the increase of 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to illustrate some of the potential problems and areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents.

CC: Jon Nehring, Mayor
Gloria Hirashima, City of Marysville

Rail Crossing Inventory

Cross Stree	RR MP	DOT #	Permit No	Use	Signal W/Ir	PreSignal
1st	38.48	084630B		Public at Grade		
4th	38.68	084640G		Public at Grade	YES	
8th	38.95	084644J		Public at Grade		
Grove	39.32	084646X		Public at Grade		
80th	39.8	084647E		Public at Grade	YES	
Private	40.02	084648L		Residential		
Private	40.11	084649T		Residential		
88th	40.34	084650M		Public at Grade	YES	YES
Private (92	40.6	084651U		Residential		
Private	40.8	084652B	CX93-16124	Residential		
104th	41.2	084653H		Public at Grade		
116th	42.04	084654P		Public at Grade	YES	YES
122nd	42.45	084657K		Public at Grade		
124th (Priv	42.55	084658S		Industrial		
128th (Priv	42.82	084660T		Industrial	YES	YES
Private	43.1	084661A		Industrial		
136th	43.35	084664V		Public at Grade	YES	
Private	45.5	084668X		Farm		
172nd	45.9	084669E		Public at Grade		
Smoky Poir	0.16	092077P		Public at Grade		
128th	0.63	092080X		Public at Grade		
136th	1.23	092081L		Public at Grade		
152nd	1.36	092083T		Public at Grade		
51st	1.8	092082L		Public at Grade		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 6/20/2011

Crossing No.: ***084630B*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***02/26/07***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SNOHOMISH***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MARYSVILLE***
Railroad Milepost:	***0038.49***	Street or Road Name:	***1ST ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***FAM2692***
Nearest RR Timetable Stn:	***MARYSVILLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31 3C***
Crossing Owner:		Latitude:	***48.0490984***
ENS Sign Installed:		Longitude:	***-122.1804926***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***19*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***084630B***

Effective Begin-Date of Record: ***02/26/07***
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	***2***	Highway Stop Signs:	***2***		
Advanced Warning:	***Yes***	Hump Crossing Sign:			
Pavement Markings:	***No Markings***	Other Signs:	***0***	Specify:	
			0		

Train Activated Devices:

Gates:	***2***	4 Quad or Full Barrier:			
Mast Mounted FL:	***0***	Total Number FL Pairs:	***4***		
Cantilevered FL (Over):	***2***	Cantilevered FL (Not over):	***0***		
Other Flashing Lights:	***0***	Specify Other Flashing Lights:			
Highway Traffic Signals:	***0***	Wigwags:	***0***	Bells:	***1***
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:			
Channelization:		Type of Train Detection:	***Constant Warning Time***		
Track Equipped with Train Signals?	***Yes***	Traffic Light Interconnection/Preemption:			

Part IV: Physical Characteristics

Type of Development:	***Commercial***	Smallest Crossing Angle:	***60 to 90 Degrees***
Number of Traffic Lanes Crossing Railroad:	***2***	Are Truck Pullout Lanes Present?	***No***
Is Highway Paved?	***Yes***		
Crossing Surface:	***Asphalt***	If Other:	
Nearby Intersecting Highway?	***Less than 75 feet***	Is it Signalized?	
Does Track Run Down a Street?	***No***	Is Crossing Illuminated?	
Is Commercial Power Available?	***Yes***		

Part V: Highway Information

Highway System:	***Other FA Highway - Not NHS***	Functional Classification of Road at Crossing:	***Urban Collector***
Is Crossing on State Highway System:	***No***		
Annual Average Daily Traffic (AADT):	***002790***	AADT Year:	***1993***
Estimated Percent Trucks:	***11***	Avg. No of School Buses per Day:	***0***
Posted Highway Speed:	***0***		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 6/20/2011

Crossing No.: ***084650M*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Position: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SNOHOMISH***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MARYSVILLE***
Railroad Milepost:	***0040.34***	Street or Road Name:	***88TH ST.N.E.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO67240***
Nearest RR Timetable Stn:	***MARYSVILLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31-3A***
Crossing Owner:		Latitude:	***48.0755967***
ENS Sign Installed:		Longitude:	***-122.1763071***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***19*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***084650M*** Effective Begin-Date of Record: ***08/17/06***
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*0*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	***Stop Lines and RR Xing Symbols***	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	***Constant Warning Time***
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	***Simultaneous Preemption***

Part IV: Physical Characteristics

Type of Development:	***Residential***	Smallest Crossing Angle:	***60 to 90 Degrees***
Number of Traffic Lanes Crossing Railroad:	*3*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Asphalt*	If Other:	
Nearby Intersecting Highway?	***Less than 75 feet***	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	***Non-Federal-aid***	Functional Classification of Road at Crossing:	***Rural Local***
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*002122*	AADT Year:	*1993*
Estimated Percent Trucks:	*06*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 6/20/2011

Crossing No.: ***084654P*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SNOHOMISH***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MARYSVILLE***
Railroad Milepost:	***0042.04***	Street or Road Name:	***116TH ST. N.E.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO68400***
Nearest RR Timetable Stn:	***KRUSE JCT***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31-3A***
Crossing Owner:		Latitude:	***48.0999926***
ENS Sign Installed:		Longitude:	***-122.1755875***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***19*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084654P*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*1*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*012880*	AADT Year:	*1993*
Estimated Percent Trucks:	*03*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 6/20/2011

Crossing No.: ***084640G*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***02/26/07***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SNOHOMISH***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MARYSVILLE***
Railroad Milepost:	***0038.68***	Street or Road Name:	***SR 528 (4TH ST)***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***SR 528***
Nearest RR Timetable Stn:	***MARYSVILLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***31-3C***
Crossing Owner:		Latitude:	***48.0518478***
ENS Sign Installed:		Longitude:	***-122.1800427***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***19*** Total Switching: ***0*** Day Thru: ***10***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084640G*

Effective Begin-Date of Record: *02/26/07*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*4*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*Constant Warning Time*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*4*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Other Principal*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*023550*	AADT Year:	*1993*
Estimated Percent Trucks:	*08*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

Counts at Crossings

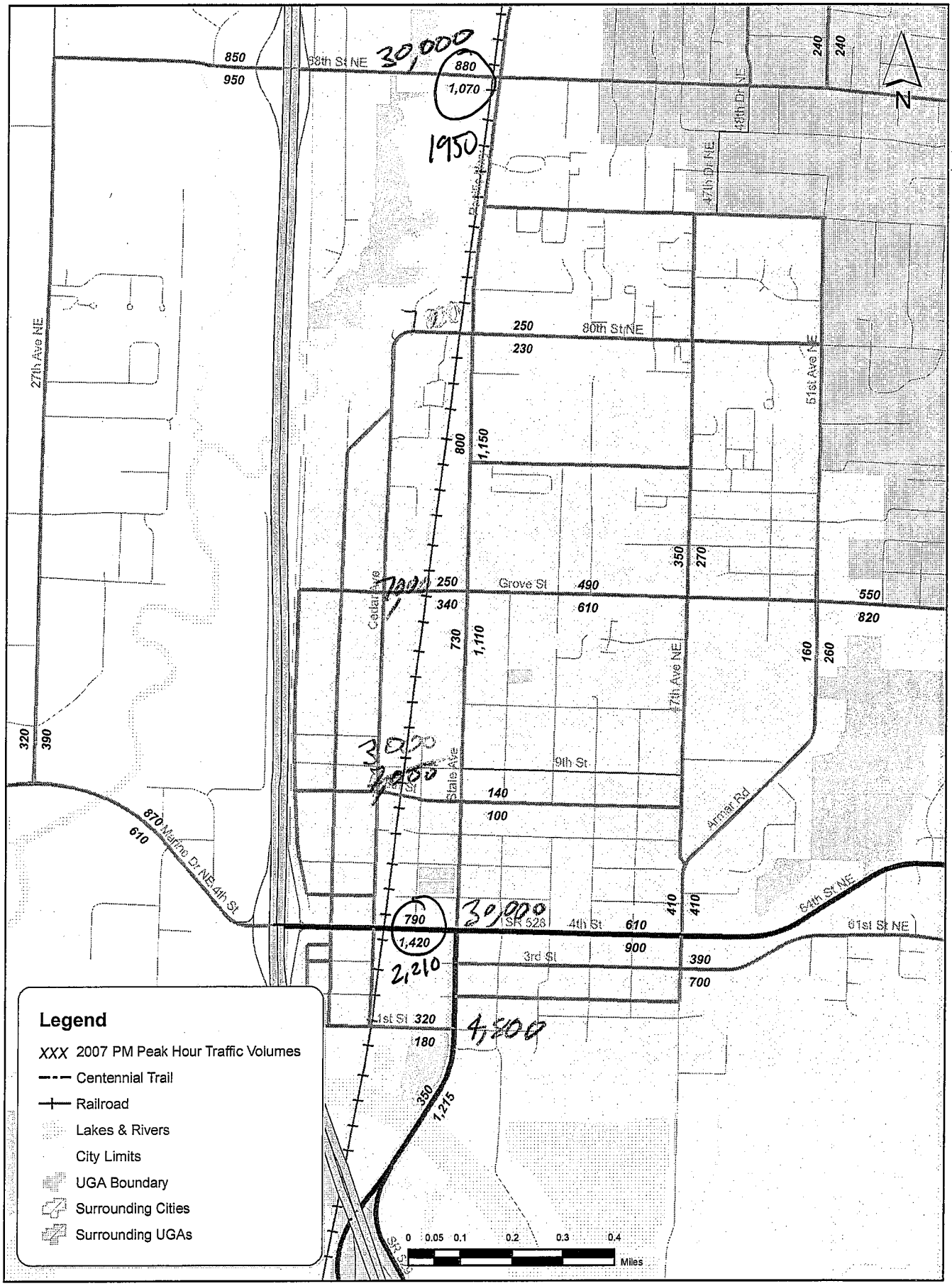


Figure 3
2007 PM Peak Hour Directional Traffic Volumes - Downtown Area

City of Marysville Transportation Element 2008

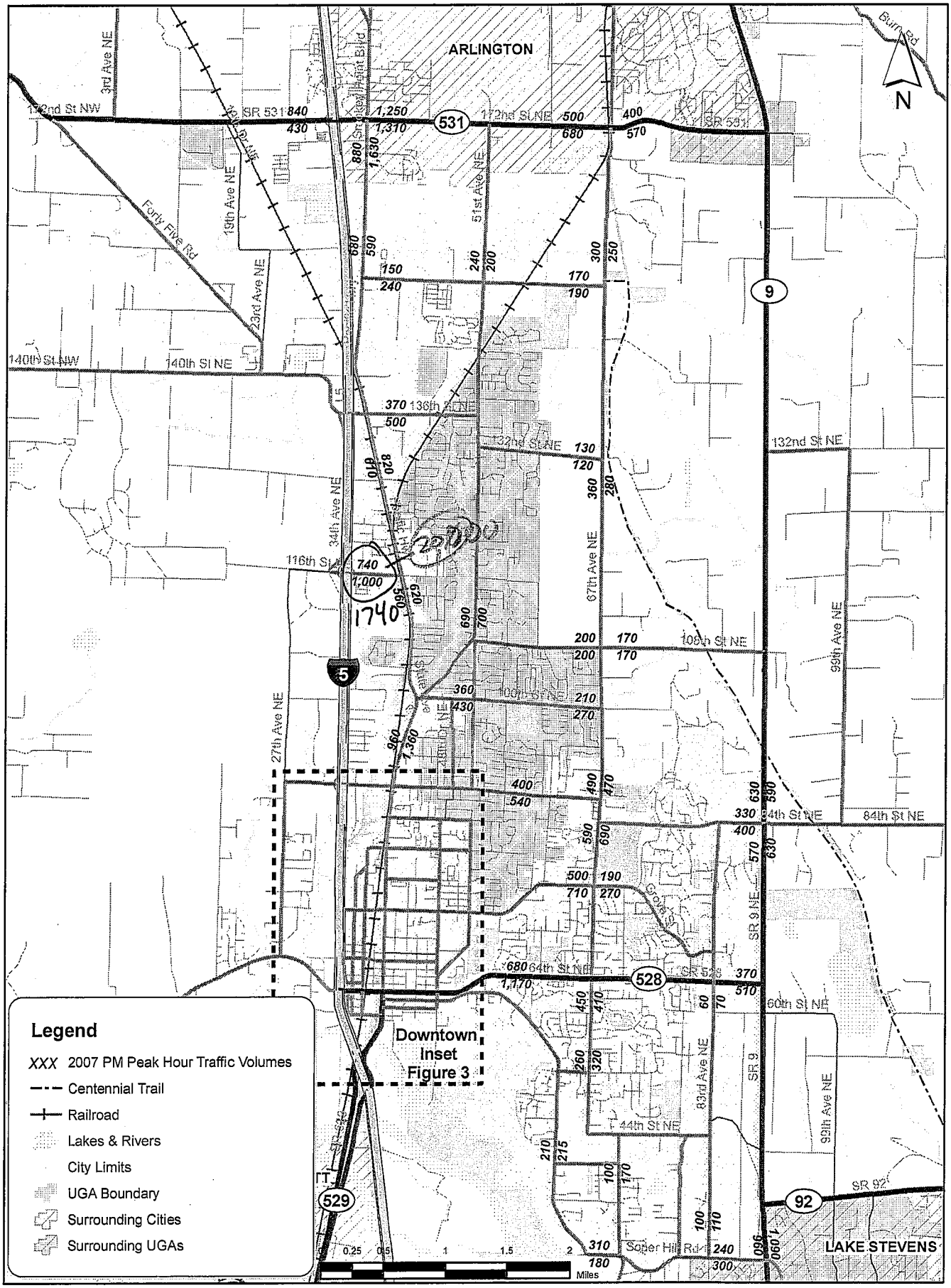


Figure 2
2007 PM Peak Hour Directional Traffic Volumes

City of Marysville Transportation Element 2008

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/5/2010
Tuesday

Daily Volume, per Channel
Channel: W/B

Interval Begin			Interval Begin		
12:00 AM	20	68	12:00 PM	212	954
12:15 AM	22		12:15 PM	231	
12:30 AM	12		12:30 PM	252	
12:45 AM	14		12:45 PM	259	
1:00 AM	7	43	1:00 PM	223	963
1:15 AM	15		1:15 PM	251	
1:30 AM	10		1:30 PM	237	
1:45 AM	11		1:45 PM	252	
2:00 AM	12	68	2:00 PM	224	943
2:15 AM	19		2:15 PM	231	
2:30 AM	14		2:30 PM	236	
2:45 AM	23		2:45 PM	252	
3:00 AM	19	108	3:00 PM	219	869
3:15 AM	24		3:15 PM	198	
3:30 AM	29		3:30 PM	217	
3:45 AM	36		3:45 PM	235	
4:00 AM	43	339	4:00 PM	239	927
4:15 AM	76		4:15 PM	244	
4:30 AM	108		4:30 PM	236	
4:45 AM	112		4:45 PM	208	
5:00 AM	125	633	5:00 PM	237	999
5:15 AM	176		5:15 PM	266	
5:30 AM	175		5:30 PM	244	
5:45 AM	157		5:45 PM	252	
6:00 AM	219	898	6:00 PM	249	868
6:15 AM	215		6:15 PM	218	
6:30 AM	231		6:30 PM	195	
6:45 AM	233		6:45 PM	206	
7:00 AM	236	1074	7:00 PM	190	622
7:15 AM	271		7:15 PM	175	
7:30 AM	303		7:30 PM	146	
7:45 AM	264		7:45 PM	111	
8:00 AM	233	863	8:00 PM	108	441
8:15 AM	220		8:15 PM	137	
8:30 AM	176		8:30 PM	121	
8:45 AM	234		8:45 PM	75	
9:00 AM	230	864	9:00 PM	109	364
9:15 AM	209		9:15 PM	95	
9:30 AM	245		9:30 PM	92	
9:45 AM	180		9:45 PM	68	
10:00 AM	206	851	10:00 PM	56	203
10:15 AM	220		10:15 PM	59	
10:30 AM	227		10:30 PM	39	
10:45 AM	198		10:45 PM	49	
11:00 AM	184	897	11:00 PM	27	105
11:15 AM	229		11:15 PM	27	
11:30 AM	239		11:30 PM	26	
11:45 AM	245		11:45 PM	25	

	W/B
24 Hour Volume	14964

12:00 AM - 12:00 PM	W/B
Count	6706
Peak Hour	7:00 AM
Volume	1074
Factor	0.89

12:00 PM - 12:00 AM	W/B
	8258
	5:15 PM
	1011
	0.95

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/6/2010
Wednesday

Daily Volume, per Channel
Channel: W/B

Interval Begin			Interval Begin		
12:00 AM	32	71	12:00 PM	209	865
12:15 AM	18		12:15 PM	204	
12:30 AM	10		12:30 PM	201	
12:45 AM	11		12:45 PM	251	
1:00 AM	15	61	1:00 PM	233	971
1:15 AM	20		1:15 PM	259	
1:30 AM	13		1:30 PM	243	
1:45 AM	13		1:45 PM	236	
2:00 AM	14	73	2:00 PM	214	897
2:15 AM	21		2:15 PM	236	
2:30 AM	14		2:30 PM	209	
2:45 AM	24		2:45 PM	238	
3:00 AM	12	94	3:00 PM	223	884
3:15 AM	24		3:15 PM	214	
3:30 AM	32		3:30 PM	226	
3:45 AM	26		3:45 PM	221	
4:00 AM	39	335	4:00 PM	230	880
4:15 AM	72		4:15 PM	228	
4:30 AM	115		4:30 PM	190	
4:45 AM	109		4:45 PM	232	
5:00 AM	131	662	5:00 PM	249	959
5:15 AM	147		5:15 PM	235	
5:30 AM	193		5:30 PM	235	
5:45 AM	191		5:45 PM	240	
6:00 AM	209	888	6:00 PM	214	861
6:15 AM	208		6:15 PM	223	
6:30 AM	224		6:30 PM	243	
6:45 AM	247		6:45 PM	181	
7:00 AM	233	1089	7:00 PM	149	567
7:15 AM	285		7:15 PM	151	
7:30 AM	280		7:30 PM	144	
7:45 AM	291		7:45 PM	123	
8:00 AM	234	849	8:00 PM	122	471
8:15 AM	196		8:15 PM	109	
8:30 AM	223		8:30 PM	137	
8:45 AM	196		8:45 PM	103	
9:00 AM	212	883	9:00 PM	109	375
9:15 AM	238		9:15 PM	105	
9:30 AM	251		9:30 PM	91	
9:45 AM	182		9:45 PM	70	
10:00 AM	202	795	10:00 PM	61	176
10:15 AM	199		10:15 PM	48	
10:30 AM	199		10:30 PM	43	
10:45 AM	195		10:45 PM	24	
11:00 AM	210	923	11:00 PM	27	126
11:15 AM	249		11:15 PM	30	
11:30 AM	248		11:30 PM	42	
11:45 AM	216		11:45 PM	27	

	W/B
24 Hour Volume	14755

12:00 AM - 12:00 PM	W/B
Count	6723
Peak Hour	7:15 AM
Volume	1090
Factor	0.94

12:00 PM - 12:00 AM	W/B
	8032
	12:45 PM
	986
	0.95

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/7/2010
Thursday

Daily Volume, per Channel
Channel: W/B

Interval Begin			Interval Begin		
12:00 AM	22	90	12:00 PM	222	932
12:15 AM	22		12:15 PM	233	
12:30 AM	24		12:30 PM	220	
12:45 AM	22		12:45 PM	257	
1:00 AM	11	68	1:00 PM	232	874
1:15 AM	15		1:15 PM	226	
1:30 AM	15		1:30 PM	234	
1:45 AM	27		1:45 PM	182	
2:00 AM	19	64	2:00 PM	201	935
2:15 AM	8		2:15 PM	255	
2:30 AM	20		2:30 PM	220	
2:45 AM	17		2:45 PM	259	
3:00 AM	22	115	3:00 PM	216	896
3:15 AM	23		3:15 PM	209	
3:30 AM	34		3:30 PM	232	
3:45 AM	36		3:45 PM	239	
4:00 AM	42	328	4:00 PM	226	928
4:15 AM	75		4:15 PM	214	
4:30 AM	110		4:30 PM	257	
4:45 AM	101		4:45 PM	231	
5:00 AM	135	668	5:00 PM	225	979
5:15 AM	152		5:15 PM	266	
5:30 AM	197		5:30 PM	267	
5:45 AM	184		5:45 PM	221	
6:00 AM	204	894	6:00 PM	250	830
6:15 AM	232		6:15 PM	203	
6:30 AM	233		6:30 PM	220	
6:45 AM	225		6:45 PM	157	
7:00 AM	251	1048	7:00 PM	187	601
7:15 AM	245		7:15 PM	152	
7:30 AM	282		7:30 PM	129	
7:45 AM	270		7:45 PM	133	
8:00 AM	195	845	8:00 PM	113	428
8:15 AM	222		8:15 PM	114	
8:30 AM	211		8:30 PM	90	
8:45 AM	217		8:45 PM	111	
9:00 AM	226	891	9:00 PM	124	403
9:15 AM	234		9:15 PM	104	
9:30 AM	231		9:30 PM	94	
9:45 AM	200		9:45 PM	81	
10:00 AM	198	833	10:00 PM	65	192
10:15 AM	186		10:15 PM	59	
10:30 AM	218		10:30 PM	39	
10:45 AM	231		10:45 PM	29	
11:00 AM	206	856	11:00 PM	36	137
11:15 AM	230		11:15 PM	37	
11:30 AM	196		11:30 PM	35	
11:45 AM	224		11:45 PM	29	

	W/B
24 Hour Volume	14835

12:00 AM - 12:00 PM	W/B	**12:00 PM - 12:00 AM**	W/B
Count	6700		8135
Peak Hour	7:00 AM		5:15 PM
Volume	1048		1004
Factor	0.93		0.94

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/5/2010
Tuesday

Daily Volume, per Channel
Channel: E/B

Interval Begin			Interval Begin		
12:00 AM	45	142	12:00 PM	249	927
12:15 AM	47		12:15 PM	232	
12:30 AM	25		12:30 PM	243	
12:45 AM	25		12:45 PM	203	
1:00 AM	25	92	1:00 PM	266	998
1:15 AM	36		1:15 PM	220	
1:30 AM	14		1:30 PM	238	
1:45 AM	17		1:45 PM	274	
2:00 AM	21	84	2:00 PM	301	1221
2:15 AM	22		2:15 PM	301	
2:30 AM	19		2:30 PM	320	
2:45 AM	22		2:45 PM	299	
3:00 AM	17	49	3:00 PM	338	1368
3:15 AM	16		3:15 PM	355	
3:30 AM	8		3:30 PM	344	
3:45 AM	8		3:45 PM	331	
4:00 AM	14	68	4:00 PM	344	1478
4:15 AM	6		4:15 PM	329	
4:30 AM	19		4:30 PM	414	
4:45 AM	29		4:45 PM	391	
5:00 AM	18	134	5:00 PM	349	1361
5:15 AM	21		5:15 PM	339	
5:30 AM	43		5:30 PM	373	
5:45 AM	52		5:45 PM	300	
6:00 AM	56	325	6:00 PM	305	1132
6:15 AM	74		6:15 PM	281	
6:30 AM	77		6:30 PM	294	
6:45 AM	118		6:45 PM	252	
7:00 AM	110	551	7:00 PM	256	870
7:15 AM	109		7:15 PM	219	
7:30 AM	156		7:30 PM	215	
7:45 AM	176		7:45 PM	180	
8:00 AM	119	578	8:00 PM	140	564
8:15 AM	135		8:15 PM	170	
8:30 AM	142		8:30 PM	138	
8:45 AM	182		8:45 PM	116	
9:00 AM	150	653	9:00 PM	142	516
9:15 AM	189		9:15 PM	135	
9:30 AM	158		9:30 PM	128	
9:45 AM	156		9:45 PM	111	
10:00 AM	166	701	10:00 PM	109	350
10:15 AM	192		10:15 PM	76	
10:30 AM	149		10:30 PM	83	
10:45 AM	194		10:45 PM	82	
11:00 AM	187	826	11:00 PM	69	256
11:15 AM	186		11:15 PM	75	
11:30 AM	226		11:30 PM	62	
11:45 AM	227		11:45 PM	50	

	E/B
24 Hour Volume	15244

12:00 AM - 12:00 PM	E/B	**12:00 PM - 12:00 AM**	E/B
Count	4203		11041
Peak Hour	11:00 AM		4:30 PM
Volume	826		1493
Factor	0.91		0.90

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/6/2010
Wednesday

Daily Volume, per Channel
Channel: E/B

Interval Begin			Interval Begin		
12:00 AM	50	157	12:00 PM	240	943
12:15 AM	39		12:15 PM	206	
12:30 AM	45		12:30 PM	264	
12:45 AM	23		12:45 PM	233	
1:00 AM	27	97	1:00 PM	243	982
1:15 AM	24		1:15 PM	242	
1:30 AM	23		1:30 PM	236	
1:45 AM	23		1:45 PM	261	
2:00 AM	22	92	2:00 PM	268	1125
2:15 AM	27		2:15 PM	263	
2:30 AM	19		2:30 PM	309	
2:45 AM	24		2:45 PM	285	
3:00 AM	13	41	3:00 PM	281	1182
3:15 AM	5		3:15 PM	303	
3:30 AM	9		3:30 PM	308	
3:45 AM	14		3:45 PM	290	
4:00 AM	11	59	4:00 PM	306	1232
4:15 AM	6		4:15 PM	298	
4:30 AM	17		4:30 PM	251	
4:45 AM	25		4:45 PM	377	
5:00 AM	24	143	5:00 PM	325	1283
5:15 AM	32		5:15 PM	310	
5:30 AM	32		5:30 PM	312	
5:45 AM	55		5:45 PM	336	
6:00 AM	68	352	6:00 PM	298	1099
6:15 AM	73		6:15 PM	287	
6:30 AM	89		6:30 PM	266	
6:45 AM	122		6:45 PM	248	
7:00 AM	97	541	7:00 PM	257	856
7:15 AM	122		7:15 PM	220	
7:30 AM	150		7:30 PM	197	
7:45 AM	172		7:45 PM	182	
8:00 AM	145	607	8:00 PM	195	628
8:15 AM	150		8:15 PM	175	
8:30 AM	128		8:30 PM	128	
8:45 AM	184		8:45 PM	130	
9:00 AM	178	695	9:00 PM	139	512
9:15 AM	207		9:15 PM	129	
9:30 AM	155		9:30 PM	106	
9:45 AM	155		9:45 PM	138	
10:00 AM	166	682	10:00 PM	131	412
10:15 AM	176		10:15 PM	109	
10:30 AM	138		10:30 PM	77	
10:45 AM	202		10:45 PM	95	
11:00 AM	195	787	11:00 PM	97	285
11:15 AM	201		11:15 PM	73	
11:30 AM	194		11:30 PM	57	
11:45 AM	197		11:45 PM	58	

	E/B
24 Hour Volume	14792

12:00 AM - 12:00 PM	E/B	**12:00 PM - 12:00 AM**	E/B
Count	4253		10539
Peak Hour	10:45 AM		4:45 PM
Volume	792		1324
Factor	0.98		0.88

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/7/2010
Thursday

Daily Volume, per Channel

Channel: E/B

Interval Begin			Interval Begin		
12:00 AM	50	184	12:00 PM	237	933
12:15 AM	55		12:15 PM	246	
12:30 AM	48		12:30 PM	240	
12:45 AM	31		12:45 PM	210	
1:00 AM	26	109	1:00 PM	262	962
1:15 AM	33		1:15 PM	222	
1:30 AM	27		1:30 PM	245	
1:45 AM	23		1:45 PM	233	
2:00 AM	21	92	2:00 PM	309	1200
2:15 AM	26		2:15 PM	272	
2:30 AM	19		2:30 PM	296	
2:45 AM	26		2:45 PM	323	
3:00 AM	16	64	3:00 PM	296	1249
3:15 AM	13		3:15 PM	302	
3:30 AM	14		3:30 PM	298	
3:45 AM	21		3:45 PM	353	
4:00 AM	12	66	4:00 PM	333	1264
4:15 AM	15		4:15 PM	312	
4:30 AM	23		4:30 PM	280	
4:45 AM	16		4:45 PM	339	
5:00 AM	22	127	5:00 PM	252	1272
5:15 AM	24		5:15 PM	321	
5:30 AM	29		5:30 PM	338	
5:45 AM	52		5:45 PM	361	
6:00 AM	51	317	6:00 PM	297	1120
6:15 AM	72		6:15 PM	277	
6:30 AM	75		6:30 PM	292	
6:45 AM	119		6:45 PM	254	
7:00 AM	118	554	7:00 PM	224	721
7:15 AM	141		7:15 PM	172	
7:30 AM	140		7:30 PM	180	
7:45 AM	155		7:45 PM	145	
8:00 AM	149	583	8:00 PM	165	666
8:15 AM	149		8:15 PM	188	
8:30 AM	120		8:30 PM	163	
8:45 AM	165		8:45 PM	150	
9:00 AM	139	668	9:00 PM	140	562
9:15 AM	205		9:15 PM	153	
9:30 AM	154		9:30 PM	140	
9:45 AM	170		9:45 PM	129	
10:00 AM	181	693	10:00 PM	112	355
10:15 AM	171		10:15 PM	102	
10:30 AM	148		10:30 PM	70	
10:45 AM	193		10:45 PM	71	
11:00 AM	193	810	11:00 PM	76	279
11:15 AM	215		11:15 PM	97	
11:30 AM	190		11:30 PM	51	
11:45 AM	212		11:45 PM	55	

	E/B
24 Hour Volume	14850

12:00 AM - 12:00 PM	E/B
Count	4267
Peak Hour	11:00 AM
Volume	810
Factor	0.94

12:00 PM - 12:00 AM	E/B
	10583
	5:15 PM
	1317
	0.91

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/5/2010
Tuesday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	62	1	0	3	14	17	17	6	3	1	0	0	0	0
1:00 AM	34	0	0	0	5	14	9	4	1	0	0	0	0	1
2:00 AM	45	0	0	0	7	14	14	8	1	0	1	0	0	0
3:00 AM	73	1	0	3	12	18	23	10	5	1	0	0	0	0
4:00 AM	122	0	1	3	15	31	48	18	6	0	0	0	0	0
5:00 AM	127	0	0	2	25	39	38	14	5	2	0	0	0	2
6:00 AM	88	0	0	5	14	28	28	10	2	1	0	0	0	0
7:00 AM	60	2	3	0	7	24	17	4	3	0	0	0	0	0
8:00 AM	82	1	0	3	15	21	25	16	1	0	0	0	0	0
9:00 AM	89	1	1	4	15	33	23	9	0	1	1	0	0	1
10:00 AM	92	1	3	10	24	31	19	2	2	0	0	0	0	0
11:00 AM	70	1	1	5	15	27	14	4	2	1	0	0	0	0
12:00 PM	49	0	3	3	10	19	12	2	0	0	0	0	0	0
1:00 PM	64	0	2	3	9	22	24	3	1	0	0	0	0	0
2:00 PM	50	0	1	7	9	10	16	6	1	0	0	0	0	0
3:00 PM	50	0	2	1	14	17	10	3	2	1	0	0	0	0
4:00 PM	62	1	2	4	10	22	17	5	1	0	0	0	0	0
5:00 PM	50	0	1	7	11	15	10	5	1	0	0	0	0	0
6:00 PM	61	0	0	3	11	22	19	5	0	1	0	0	0	0
7:00 PM	81	0	0	5	18	31	20	4	3	0	0	0	0	0
8:00 PM	107	0	2	3	23	38	28	11	2	0	0	0	0	0
9:00 PM	112	1	0	1	26	38	35	8	2	1	0	0	0	0
10:00 PM	108	0	0	5	23	30	35	12	2	1	0	0	0	0
11:00 PM	69	0	0	6	2	30	26	5	0	0	0	0	0	0
Total	1807	10	22	86	334	591	527	174	46	11	2	0	0	4
%		0.6	1.2	4.8	18.5	32.7	29.2	9.6	2.5	0.6	0.1	0.0	0.0	0.2

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	26.6	27.9	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1173 (64.9 %)

Average 34.0 mph
Minimum 4.9 mph
Maximum 93.1 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	3.5 %	0.3 %	0.2 %
Count	63	6	4

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/6/2010
Wednesday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	47	1	0	0	10	16	15	5	0	0	0	0	0	0
1:00 AM	45	0	0	1	8	26	8	1	1	0	0	0	0	0
2:00 AM	49	0	0	1	11	17	13	5	2	0	0	0	0	0
3:00 AM	74	0	1	2	11	24	24	8	4	0	0	0	0	0
4:00 AM	123	0	1	4	9	37	49	18	4	1	0	0	0	0
5:00 AM	124	0	0	2	21	32	41	19	8	1	0	0	0	0
6:00 AM	99	0	0	4	17	34	35	6	2	0	1	0	0	0
7:00 AM	54	2	0	6	9	17	15	3	2	0	0	0	0	0
8:00 AM	105	0	4	2	21	25	30	20	3	0	0	0	0	0
9:00 AM	89	0	1	2	26	24	31	3	2	0	0	0	0	0
10:00 AM	64	0	0	5	19	19	14	6	1	0	0	0	0	0
11:00 AM	68	1	1	5	12	20	22	6	1	0	0	0	0	0
12:00 PM	70	0	0	4	21	23	14	6	2	0	0	0	0	0
1:00 PM	50	0	3	2	11	21	12	0	1	0	0	0	0	0
2:00 PM	56	0	2	2	16	21	10	2	1	1	0	0	0	1
3:00 PM	66	0	0	2	13	25	17	5	3	0	1	0	0	0
4:00 PM	59	0	1	2	13	24	11	7	0	0	1	0	0	0
5:00 PM	58	0	2	3	10	20	19	3	0	1	0	0	0	0
6:00 PM	71	0	1	6	20	25	16	3	0	0	0	0	0	0
7:00 PM	96	0	1	5	24	30	29	3	4	0	0	0	0	0
8:00 PM	92	0	2	5	22	37	18	5	3	0	0	0	0	0
9:00 PM	98	0	1	4	18	35	28	8	3	0	0	0	1	0
10:00 PM	100	0	2	5	11	34	31	11	4	1	1	0	0	0
11:00 PM	54	0	1	4	9	13	19	6	2	0	0	0	0	0
Total	1811	4	24	78	362	599	521	159	53	5	4	0	1	1
%		0.2	1.3	4.3	20.0	33.1	28.8	8.8	2.9	0.3	0.2	0.0	0.1	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	26.2	27.9	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1161 (64.1 %)

Average 34.0 mph
Minimum 11.5 mph
Maximum 88.2 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	3.5 %	0.3 %	0.1 %
Count	64	6	2

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE WB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/7/2010
Thursday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	58	0	0	2	17	17	18	3	1	0	0	0	0	0
1:00 AM	45	0	0	3	6	13	17	5	0	1	0	0	0	0
2:00 AM	45	0	1	1	10	14	13	5	1	0	0	0	0	0
3:00 AM	63	0	0	2	15	14	22	7	1	1	0	0	0	1
4:00 AM	120	0	1	4	16	33	37	14	10	5	0	0	0	0
5:00 AM	122	0	0	6	14	27	49	18	4	2	0	1	1	0
6:00 AM	92	0	1	6	14	32	28	6	5	0	0	0	0	0
7:00 AM	71	0	2	2	16	19	17	12	3	0	0	0	0	0
8:00 AM	91	1	1	1	14	28	30	15	0	1	0	0	0	0
9:00 AM	88	0	1	1	20	29	30	6	1	0	0	0	0	0
10:00 AM	81	0	0	4	14	37	23	3	0	0	0	0	0	0
11:00 AM	75	1	1	6	17	26	17	4	2	0	1	0	0	0
12:00 PM	70	0	1	8	19	30	8	3	1	0	0	0	0	0
1:00 PM	79	0	2	9	15	20	30	3	0	0	0	0	0	0
2:00 PM	67	2	0	4	15	24	18	3	1	0	0	0	0	0
3:00 PM	63	0	1	5	10	28	14	5	0	0	0	0	0	0
4:00 PM	61	0	3	5	15	20	14	3	0	0	1	0	0	0
5:00 PM	60	2	0	3	15	21	15	3	0	1	0	0	0	0
6:00 PM	58	0	1	3	13	24	15	2	0	0	0	0	0	0
7:00 PM	103	0	1	6	20	37	28	9	2	0	0	0	0	0
8:00 PM	98	0	0	6	19	31	35	6	0	1	0	0	0	0
9:00 PM	107	0	0	5	12	39	38	8	3	1	0	0	1	0
10:00 PM	99	0	0	3	17	42	25	8	4	0	0	0	0	0
11:00 PM	70	1	0	5	15	29	16	2	1	0	1	0	0	0
Total	1886	7	17	100	358	634	557	153	40	13	3	1	2	1
%		0.4	0.9	5.3	19.0	33.6	29.5	8.1	2.1	0.7	0.2	0.1	0.1	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	26.2	27.9	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1236 (65.5 %)

Average 33.9 mph
Minimum 8.2 mph
Maximum 72.9 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	3.2 %	0.4 %	0.2 %
Count	60	7	3

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/5/2010
Tuesday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	79	0	1	3	13	24	32	3	2	1	0	0	0	0
1:00 AM	60	0	0	1	9	29	17	2	1	1	0	0	0	0
2:00 AM	55	0	0	2	7	21	16	4	3	1	1	0	0	0
3:00 AM	30	1	0	1	7	9	8	4	0	0	0	0	0	0
4:00 AM	50	0	1	1	8	13	19	8	0	0	0	0	0	0
5:00 AM	80	0	2	2	14	26	24	8	4	0	0	0	0	0
6:00 AM	95	0	0	0	17	33	29	13	3	0	0	0	0	0
7:00 AM	85	0	0	3	16	20	30	15	1	0	0	0	0	0
8:00 AM	85	2	1	2	17	25	22	12	3	1	0	0	0	0
9:00 AM	94	0	1	5	15	29	30	12	2	0	0	0	0	0
10:00 AM	105	0	1	5	25	35	26	11	2	0	0	0	0	0
11:00 AM	98	0	0	6	13	29	34	13	2	1	0	0	0	0
12:00 PM	88	0	1	8	17	24	29	7	2	0	0	0	0	0
1:00 PM	69	0	0	3	17	22	16	8	2	0	0	1	0	0
2:00 PM	55	2	5	8	11	15	9	4	0	0	0	0	0	1
3:00 PM	24	5	6	4	5	1	3	0	0	0	0	0	0	0
4:00 PM	21	5	7	4	1	1	3	0	0	0	0	0	0	0
5:00 PM	25	6	6	2	6	1	3	1	0	0	0	0	0	0
6:00 PM	73	1	2	6	18	18	19	5	3	1	0	0	0	0
7:00 PM	112	0	1	6	17	46	28	12	1	1	0	0	0	0
8:00 PM	126	0	2	4	27	41	40	10	1	0	0	1	0	0
9:00 PM	121	0	0	7	23	44	39	7	1	0	0	0	0	0
10:00 PM	130	0	1	6	15	42	47	15	3	0	0	1	0	0
11:00 PM	113	0	0	1	16	45	38	9	1	1	0	1	1	0
Total	1873	22	38	90	334	593	561	183	37	8	1	4	1	1
%		1.2	2.0	4.8	17.8	31.7	30.0	9.8	2.0	0.4	0.1	0.2	0.1	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	25.8	27.5	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1205 (64.3 %)

Average 33.7 mph
Minimum 3.4 mph
Maximum 76.2 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	2.8 %	0.4 %	0.1 %
Count	52	7	2

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/6/2010
Wednesday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	90	0	0	3	18	28	33	8	0	0	0	0	0	0
1:00 AM	70	0	0	0	14	28	24	4	0	0	0	0	0	0
2:00 AM	68	0	0	2	10	21	28	7	0	0	0	0	0	0
3:00 AM	33	0	0	0	4	17	8	4	0	0	0	0	0	0
4:00 AM	33	0	1	2	2	13	11	4	0	0	0	0	0	0
5:00 AM	74	0	1	1	6	34	20	7	5	0	0	0	0	0
6:00 AM	97	1	0	3	17	22	35	16	3	0	0	0	0	0
7:00 AM	103	1	0	2	12	31	35	19	3	0	0	0	0	0
8:00 AM	107	0	2	6	20	30	31	15	1	1	0	0	0	1
9:00 AM	91	1	0	5	15	23	33	10	4	0	0	0	0	0
10:00 AM	100	1	2	4	20	30	32	9	2	0	0	0	0	0
11:00 AM	83	0	1	1	19	32	20	4	5	1	0	0	0	0
12:00 PM	73	0	3	2	16	16	23	8	2	2	1	0	0	0
1:00 PM	83	1	2	7	15	26	20	9	1	2	0	0	0	0
2:00 PM	69	3	2	2	16	17	23	3	3	0	0	0	0	0
3:00 PM	65	3	2	7	17	16	14	5	0	0	1	0	0	0
4:00 PM	47	3	4	3	17	13	5	1	0	0	1	0	0	0
5:00 PM	52	5	11	7	10	19	0	0	0	0	0	0	0	0
6:00 PM	73	0	0	6	15	23	20	6	3	0	0	0	0	0
7:00 PM	114	0	0	13	18	38	32	11	1	1	0	0	0	0
8:00 PM	108	0	1	5	19	45	28	8	2	0	0	0	0	0
9:00 PM	130	0	0	3	19	48	44	11	4	1	0	0	0	0
10:00 PM	131	0	2	7	19	41	46	11	3	1	1	0	0	0
11:00 PM	121	0	0	4	22	41	39	12	1	2	0	0	0	0
Total	2015	19	34	95	360	652	604	192	43	11	4	0	0	1
%		0.9	1.7	4.7	17.9	32.4	30.0	9.5	2.1	0.5	0.2	0.0	0.0	0.0

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	25.8	27.5	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1292 (64.1 %)

Average 33.8 mph
Minimum 5.7 mph
Maximum 98.6 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	2.9 %	0.2 %	0.0 %
Count	59	5	1

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett WA 98201

LOCATION: 88 ST NE EB E/O 36 AVE NE
WEATHER: 3 MIXED
CLIENT: INT

Site: MARYSVILLE
Date: 10/7/2010
Thursday

24 Hour Speed
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	95	1	0	3	19	38	23	10	1	0	0	0	0	0
1:00 AM	76	0	0	1	14	29	21	9	0	1	1	0	0	0
2:00 AM	70	0	2	1	11	21	29	6	0	0	0	0	0	0
3:00 AM	44	1	1	3	11	12	13	1	2	0	0	0	0	0
4:00 AM	43	0	1	1	8	17	11	3	2	0	0	0	0	0
5:00 AM	74	1	2	4	19	24	17	7	0	0	0	0	0	0
6:00 AM	102	1	1	3	20	30	36	9	2	0	0	0	0	0
7:00 AM	101	2	0	1	16	26	33	16	5	1	0	0	0	1
8:00 AM	97	0	0	9	17	23	28	17	2	0	0	0	1	0
9:00 AM	99	0	2	5	21	27	33	8	2	0	0	0	1	0
10:00 AM	110	3	3	8	17	33	31	12	3	0	0	0	0	0
11:00 AM	99	0	0	4	16	29	31	17	2	0	0	0	0	0
12:00 PM	76	0	0	4	22	21	23	3	3	0	0	0	0	0
1:00 PM	90	0	1	9	15	21	22	17	4	1	0	0	0	0
2:00 PM	71	2	3	5	15	24	17	4	1	0	0	0	0	0
3:00 PM	65	3	3	4	11	26	14	3	1	0	0	0	0	0
4:00 PM	46	2	3	16	9	7	6	2	0	0	1	0	0	0
5:00 PM	25	7	3	2	8	3	1	0	1	0	0	0	0	0
6:00 PM	81	2	6	8	14	25	16	7	3	0	0	0	0	0
7:00 PM	114	0	2	6	23	36	31	12	2	1	0	0	0	1
8:00 PM	124	2	0	6	15	47	41	10	2	1	0	0	0	0
9:00 PM	116	0	0	5	15	39	42	12	3	0	0	0	0	0
10:00 PM	122	0	1	6	32	37	34	8	3	0	0	1	0	0
11:00 PM	131	0	2	5	20	40	49	9	4	0	0	1	0	1
Total	2071	27	36	119	388	635	602	202	48	5	2	2	2	3
%		1.3	1.7	5.7	18.7	30.7	29.1	9.8	2.3	0.2	0.1	0.1	0.1	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	25.4	27.0	34.2	39.9	40.9

10 mph Pace Speed 29.9 - 39.9
Number in Pace 1299 (62.7 %)

Average 33.6 mph
Minimum 1.5 mph
Maximum 119.7 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	3.0 %	0.4 %	0.2 %
Count	62	9	5

A - 27

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE WB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/27/2007
Tuesday

AM/PM Volume (1 channel/pg., 15 Min.)

Channel: W/B

Interval Begin			Interval Begin		
00:00	14	45	12:00	112	439
00:15	11		12:15	110	
00:30	12		12:30	95	
00:45	8		12:45	122	
01:00	5	28	13:00	135	466
01:15	4		13:15	127	
01:30	8		13:30	122	
01:45	11		13:45	82	
02:00	8	24	14:00	153	539
02:15	5		14:15	124	
02:30	4		14:30	132	
02:45	7		14:45	130	
03:00	9	47	15:00	143	541
03:15	9		15:15	118	
03:30	14		15:30	148	
03:45	15		15:45	132	
04:00	19	150	16:00	170	563
04:15	26		16:15	148	
04:30	57		16:30	132	
04:45	48		16:45	113	
05:00	87	363	17:00	115	492
05:15	82		17:15	147	
05:30	108		17:30	120	
05:45	86		17:45	110	
06:00	89	397	18:00	130	435
06:15	106		18:15	102	
06:30	102		18:30	110	
06:45	100		18:45	93	
07:00	111	418	19:00	102	294
07:15	95		19:15	63	
07:30	113		19:30	66	
07:45	99		19:45	63	
08:00	92	395	20:00	67	235
08:15	88		20:15	65	
08:30	109		20:30	59	
08:45	106		20:45	44	
09:00	100	353	21:00	56	192
09:15	80		21:15	37	
09:30	87		21:30	56	
09:45	86		21:45	43	
10:00	89	376	22:00	43	121
10:15	82		22:15	26	
10:30	85		22:30	27	
10:45	120		22:45	25	
11:00	134	488	23:00	17	69
11:15	102		23:15	24	
11:30	144		23:30	12	
11:45	108		23:45	16	
Totals					
12 Hours	3084			4386	
24 Hours	7470				
Peak Hours					
AM	10:45		PM	15:30	
Volume	500			598	
Factor	0.87			0.88	

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE WB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/28/2007
Wednesday

AM/PM Volume (1 channel/pg., 15 Min.)

Channel: W/B

Interval Begin			Interval Begin		
00:00	9	52	12:00	125	507
00:15	19		12:15	117	
00:30	17		12:30	134	
00:45	7		12:45	131	
01:00	3	30	13:00	126	444
01:15	10		13:15	92	
01:30	8		13:30	108	
01:45	9		13:45	118	
02:00	13	42	14:00	121	548
02:15	11		14:15	131	
02:30	6		14:30	138	
02:45	12		14:45	158	
03:00	8	46	15:00	141	606
03:15	10		15:15	163	
03:30	13		15:30	153	
03:45	15		15:45	149	
04:00	31	139	16:00	142	565
04:15	24		16:15	147	
04:30	38		16:30	139	
04:45	46		16:45	137	
05:00	73	355	17:00	132	524
05:15	81		17:15	159	
05:30	111		17:30	122	
05:45	90		17:45	111	
06:00	87	379	18:00	118	473
06:15	88		18:15	116	
06:30	88		18:30	121	
06:45	116		18:45	118	
07:00	115	432	19:00	96	336
07:15	106		19:15	81	
07:30	110		19:30	94	
07:45	101		19:45	65	
08:00	99	397	20:00	95	272
08:15	97		20:15	67	
08:30	96		20:30	55	
08:45	105		20:45	55	
09:00	95	333	21:00	43	160
09:15	72		21:15	38	
09:30	87		21:30	41	
09:45	79		21:45	38	
10:00	95	368	22:00	44	114
10:15	77		22:15	26	
10:30	103		22:30	26	
10:45	93		22:45	18	
11:00	106	495	23:00	28	78
11:15	131		23:15	18	
11:30	140		23:30	18	
11:45	118		23:45	14	
Totals					
12 Hours	3068			4627	
24 Hours	7695				
Peak Hours					
AM	11:00		PM	14:45	
Volume	495			615	
Factor	0.88			0.94	

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE EB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/27/2007
Tuesday

AM/PM Volume (1 channel/pg., 15 Min.)

Channel: E/B

Interval Begin			Interval Begin		
00:00	17	54	12:00	125	587
00:15	10		12:15	147	
00:30	16		12:30	170	
00:45	11		12:45	145	
01:00	19	74	13:00	120	538
01:15	21		13:15	131	
01:30	11		13:30	140	
01:45	23		13:45	147	
02:00	5	38	14:00	168	675
02:15	12		14:15	167	
02:30	6		14:30	163	
02:45	15		14:45	177	
03:00	4	43	15:00	162	763
03:15	12		15:15	195	
03:30	7		15:30	215	
03:45	20		15:45	191	
04:00	21	98	16:00	221	876
04:15	15		16:15	216	
04:30	23		16:30	216	
04:45	39		16:45	223	
05:00	35	219	17:00	207	882
05:15	35		17:15	228	
05:30	65		17:30	215	
05:45	84		17:45	232	
06:00	72	396	18:00	173	583
06:15	77		18:15	140	
06:30	105		18:30	153	
06:45	142		18:45	117	
07:00	93	418	19:00	118	415
07:15	86		19:15	113	
07:30	108		19:30	93	
07:45	131		19:45	91	
08:00	92	405	20:00	94	343
08:15	82		20:15	90	
08:30	93		20:30	91	
08:45	138		20:45	68	
09:00	100	426	21:00	76	264
09:15	111		21:15	71	
09:30	114		21:30	56	
09:45	101		21:45	61	
10:00	96	517	22:00	54	169
10:15	137		22:15	39	
10:30	139		22:30	31	
10:45	145		22:45	45	
11:00	110	493	23:00	31	98
11:15	123		23:15	34	
11:30	148		23:30	16	
11:45	112		23:45	17	
Totals					
12 Hours	3181			6193	
24 Hours	9374				
Peak Hours					
AM	10:15		PM	17:00	
Volume	531			882	
Factor	0.92			0.95	

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location	: 116 ST NE EB E/O I-5 NB RAMPS	Site:	MARYSVILLE
Weather	: 2 MIXED	Date:	3/28/2007
Client	: SCREENLINE		Wednesday

AM/PM Volume (1 channel/pg., 15 Min.)

Channel: E/B

Interval Begin			Interval Begin		
00:00	22	71	12:00	128	547
00:15	13		12:15	133	
00:30	18		12:30	149	
00:45	18		12:45	137	
01:00	12	52	13:00	160	604
01:15	14		13:15	146	
01:30	12		13:30	149	
01:45	14		13:45	149	
02:00	9	41	14:00	136	633
02:15	10		14:15	168	
02:30	7		14:30	164	
02:45	15		14:45	165	
03:00	9	43	15:00	188	819
03:15	9		15:15	199	
03:30	11		15:30	204	
03:45	14		15:45	228	
04:00	13	79	16:00	187	853
04:15	14		16:15	228	
04:30	18		16:30	209	
04:45	34		16:45	229	
05:00	29	211	17:00	214	827
05:15	38		17:15	238	
05:30	53		17:30	183	
05:45	91		17:45	192	
06:00	53	367	18:00	178	644
06:15	67		18:15	186	
06:30	113		18:30	150	
06:45	134		18:45	130	
07:00	81	429	19:00	137	443
07:15	100		19:15	103	
07:30	137		19:30	102	
07:45	111		19:45	101	
08:00	81	375	20:00	84	356
08:15	91		20:15	99	
08:30	100		20:30	79	
08:45	103		20:45	94	
09:00	91	378	21:00	76	291
09:15	88		21:15	72	
09:30	92		21:30	85	
09:45	107		21:45	58	
10:00	107	464	22:00	47	176
10:15	122		22:15	45	
10:30	120		22:30	38	
10:45	115		22:45	46	
11:00	113	466	23:00	25	93
11:15	93		23:15	28	
11:30	142		23:30	18	
11:45	118		23:45	22	
Totals					
12 Hours	2976			6286	
24 Hours	9262				
Peak Hours					
AM	10:15		PM	16:30	
Volume	470			890	
Factor	0.96			0.93	

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE WB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/27/2007
Tuesday

24 Hour Speed (60 Min.)
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
00:00	36	0	1	3	13	10	6	2	1	0	0	0	0	0
01:00	25	0	3	1	8	6	4	2	1	0	0	0	0	0
02:00	19	0	1	0	4	6	5	2	1	0	0	0	0	0
03:00	41	0	2	4	7	8	8	6	5	0	1	0	0	0
04:00	86	3	3	8	17	13	18	15	6	2	0	0	1	0
05:00	133	7	15	22	27	21	16	17	5	3	0	0	0	0
06:00	134	10	13	13	26	23	29	15	4	1	0	0	0	0
07:00	118	13	11	15	18	21	27	12	1	0	0	0	0	0
08:00	113	7	13	23	17	18	19	14	1	0	0	0	1	0
09:00	148	17	16	27	29	25	22	9	3	0	0	0	0	0
10:00	103	8	19	25	15	18	13	4	1	0	0	0	0	0
11:00	111	18	12	16	33	15	12	3	1	0	0	0	0	1
12:00	117	15	17	25	32	13	7	5	1	1	0	0	0	1
13:00	104	18	12	18	23	19	8	5	0	1	0	0	0	0
14:00	94	9	25	16	22	9	10	1	0	0	0	0	1	1
15:00	113	14	27	22	26	13	4	5	1	0	0	0	0	1
16:00	106	24	21	24	18	12	2	3	1	0	0	0	0	1
17:00	103	11	22	19	24	14	8	4	1	0	0	0	0	0
18:00	93	11	6	17	21	19	10	6	1	0	0	0	0	2
19:00	92	14	19	27	20	6	4	2	0	0	0	0	0	0
20:00	118	13	17	35	24	16	11	1	1	0	0	0	0	0
21:00	112	4	19	28	25	20	12	4	0	0	0	0	0	0
22:00	92	3	13	13	27	17	13	3	1	2	0	0	0	0
23:00	59	1	3	13	16	11	10	4	1	0	0	0	0	0
Total	2270	220	310	414	492	353	278	144	38	10	1	0	3	7
%		9.7	13.7	18.2	21.7	15.6	12.2	6.3	1.7	0.4	0.0	0.0	0.1	0.3

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	15.2	17.1	26.6	36.8	39.4

10 mph Pace Speed 19.5 - 29.5
Number in pace 925 (40.7 %)

Average 27.3 mph
Minimum 0.2 mph
Maximum 157.4 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	2.6 %	0.5 %	0.4 %
Count	59	11	10

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE WB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/28/2007
Wednesday

24 Hour Speed (60 Min.)
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
00:00	43	2	4	2	11	11	12	1	0	0	0	0	0	0
01:00	21	0	2	4	5	5	4	1	0	0	0	0	0	0
02:00	27	0	0	5	7	7	3	4	0	1	0	0	0	0
03:00	42	0	0	2	10	13	8	8	0	0	1	0	0	0
04:00	94	1	4	6	18	18	24	15	4	4	0	0	0	0
05:00	146	7	15	21	30	20	24	22	6	1	0	0	0	0
06:00	132	11	13	16	26	27	22	13	4	0	0	0	0	0
07:00	132	14	10	18	21	22	18	16	10	1	0	0	2	0
08:00	112	23	13	19	22	11	11	11	2	0	0	0	0	0
09:00	139	13	13	18	30	20	29	12	3	1	0	0	0	0
10:00	93	7	13	22	19	9	14	8	0	0	0	0	0	1
11:00	111	12	16	22	28	17	12	4	0	0	0	0	0	0
12:00	93	10	17	24	19	13	3	4	1	1	0	0	0	1
13:00	114	11	18	20	24	14	12	12	1	0	0	0	0	2
14:00	94	16	9	19	28	13	4	1	1	2	0	0	0	1
15:00	81	15	17	20	12	8	2	3	0	0	0	0	0	4
16:00	99	18	9	24	24	6	8	5	1	0	0	0	0	4
17:00	82	16	14	14	15	6	11	4	1	0	0	0	1	0
18:00	93	23	11	16	18	15	4	4	1	0	0	0	0	1
19:00	117	17	25	34	22	14	2	3	0	0	0	0	0	0
20:00	113	16	13	31	28	20	4	0	1	0	0	0	0	0
21:00	101	5	12	32	21	19	6	6	0	0	0	0	0	0
22:00	76	0	6	11	17	16	18	7	1	0	0	0	0	0
23:00	61	0	5	11	12	14	13	4	2	0	0	0	0	0
Total	2216	237	259	411	467	338	268	168	39	11	1	0	3	14
%		10.7	11.7	18.5	21.1	15.3	12.1	7.6	1.8	0.5	0.0	0.0	0.1	0.6

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	14.6	17.1	27.1	38.5	40.3

10 mph Pace Speed 19.5 - 29.5
Number in pace 897 (40.5 %)

Average 27.8 mph
Minimum 0.2 mph
Maximum 157.4 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	3.1 %	0.8 %	0.8 %
Count	68	18	17

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE EB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/27/2007
Tuesday

24 Hour Speed (60 Min.)
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
00:00	46	1	5	8	12	12	4	3	1	0	0	0	0	0
01:00	61	2	8	12	23	7	5	4	0	0	0	0	0	0
02:00	23	0	0	7	7	3	5	1	0	0	0	0	0	0
03:00	30	3	1	7	9	7	1	2	0	0	0	0	0	0
04:00	66	2	4	11	29	9	7	4	0	0	0	0	0	0
05:00	98	0	9	15	36	26	4	6	1	0	0	1	0	0
06:00	129	3	13	27	59	19	6	1	1	0	0	0	0	0
07:00	116	3	8	29	49	14	9	4	0	0	0	0	0	0
08:00	114	3	12	24	49	14	9	3	0	0	0	0	0	0
09:00	118	3	12	33	39	16	12	2	0	0	1	0	0	0
10:00	126	4	13	42	41	19	6	0	1	0	0	0	0	0
11:00	120	4	8	29	42	27	3	5	2	0	0	0	0	0
12:00	114	7	6	25	33	27	12	3	1	0	0	0	0	0
13:00	120	2	13	32	38	24	9	2	0	0	0	0	0	0
14:00	120	3	7	36	42	20	7	3	1	0	0	0	1	0
15:00	101	0	11	25	44	13	6	2	0	0	0	0	0	0
16:00	113	2	8	29	45	18	8	3	0	0	0	0	0	0
17:00	92	1	6	14	38	25	6	1	0	0	1	0	0	0
18:00	118	1	8	23	49	24	5	5	1	0	0	2	0	0
19:00	129	2	10	30	48	27	4	6	1	0	0	0	1	0
20:00	126	0	7	31	50	25	11	0	2	0	0	0	0	0
21:00	147	2	7	21	58	34	17	7	0	0	0	0	1	0
22:00	103	1	2	20	38	16	24	1	1	0	0	0	0	0
23:00	78	0	7	22	28	13	6	1	1	0	0	0	0	0
Total	2408	49	185	552	906	439	186	69	14	0	2	3	3	0
%		2.0	7.7	22.9	37.6	18.2	7.7	2.9	0.6	0.0	0.1	0.1	0.1	0.0

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	20.1	21.6	27.5	33.3	35.3

10 mph Pace Speed 22.2 - 32.2
Number in pace 1563 (64.9 %)

Average 27.6 mph
Minimum 8.3 mph
Maximum 66.6 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	0.9 %	0.3 %	0.1 %
Count	22	8	3

A - 34

Snohomish County Traffic Analysis & Design

3000 Rockefeller Ave. ADM-W-5
Everett WA. 98201

Location : 116 ST NE EB E/O I-5 NB RAMPS
Weather : 2 MIXED
Client : SCREENLINE

Site: MARYSVILLE
Date: 3/28/2007
Wednesday

24 Hour Speed (60 Min.)
Channel: A Tube

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
00:00	63	0	4	17	25	13	3	1	0	0	0	0	0	0
01:00	43	2	2	9	16	6	6	2	0	0	0	0	0	0
02:00	36	1	3	6	10	10	3	3	0	0	0	0	0	0
03:00	33	0	2	4	13	8	4	2	0	0	0	0	0	0
04:00	63	2	5	10	21	16	6	2	0	1	0	0	0	0
05:00	107	2	8	17	41	27	7	4	1	0	0	0	0	0
06:00	114	0	16	19	42	19	13	4	1	0	0	0	0	0
07:00	130	1	10	21	53	31	10	3	1	0	0	0	0	0
08:00	133	2	10	27	52	25	11	6	0	0	0	0	0	0
09:00	124	6	14	22	45	20	8	8	0	0	0	1	0	0
10:00	135	4	13	31	44	24	13	6	0	0	0	0	0	0
11:00	121	7	6	31	39	27	11	0	0	0	0	0	0	0
12:00	119	9	7	32	36	24	8	2	0	1	0	0	0	0
13:00	128	1	8	33	47	26	9	4	0	0	0	0	0	0
14:00	124	2	13	32	49	19	8	1	0	0	0	0	0	0
15:00	83	1	6	26	26	13	7	3	1	0	0	0	0	0
16:00	76	0	8	18	28	12	8	2	0	0	0	0	0	0
17:00	92	0	6	16	47	14	8	0	0	0	0	1	0	0
18:00	127	0	9	30	49	21	17	1	0	0	0	0	0	0
19:00	138	0	5	23	56	36	13	2	2	1	0	0	0	0
20:00	127	1	2	36	43	33	8	2	1	1	0	0	0	0
21:00	134	1	5	27	58	30	8	4	1	0	0	0	0	0
22:00	115	1	10	25	39	28	10	2	0	0	0	0	0	0
23:00	78	0	3	15	32	24	3	1	0	0	0	0	0	0
Total	2443	43	175	527	911	506	202	65	8	4	0	2	0	0
%		1.8	7.2	21.6	37.3	20.7	8.3	2.7	0.3	0.2	0.0	0.1	0.0	0.0

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	20.6	21.9	27.5	34.0	36.1

10 mph Pace Speed 22.8 - 32.8
Number in pace 1572 (64.3 %)

Average 27.9 mph
Minimum 7.9 mph
Maximum 64.1 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	0.6 %	0.1 %	0.0 %
Count	14	2	0

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

Date Printed: 02-Apr-09

1st St
Geddes
Site Code:

EB WB

Start Time	17-Mar-09 Tue	Channel 1	Channel 2	Total
12:00 AM		*	*	*
01:00		*	*	*
02:00		*	*	*
03:00		*	*	*
04:00		*	*	*
05:00		*	*	*
06:00		*	*	*
07:00		*	*	*
08:00		*	*	*
09:00		*	*	*
10:00		*	*	*
11:00		*	*	*
12:00 PM		*	*	*
01:00		*	*	*
02:00		**205**	253	458
03:00		172	**319**	**491**
04:00		132	263	395
05:00		84	189	273
06:00		42	107	149
07:00		39	60	99
08:00		29	39	68
09:00		17	25	42
10:00		17	7	24
11:00		4	9	13
Total		741	1271	2012
Percent		36.8%	63.2%	
AM Peak				
Vol.				
PM Peak		14:00	15:00	15:00
Vol.		205	319	491

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	18-Mar-09 Wed	Channel 1	Channel 2	Total
12:00 AM		8	13	21
01:00		3	6	9
02:00		5	6	11
03:00		10	6	16
04:00		26	27	53
05:00		32	56	88
06:00		82	110	192
07:00		46	77	123
08:00		63	110	173
09:00		73	112	185
10:00		103	144	247
11:00		**122**	**182**	**304**
12:00 PM		101	196	297
01:00		133	209	342
02:00		**185**	**280**	**465**
03:00		153	277	430
04:00		137	272	409
05:00		92	166	258
06:00		67	87	154
07:00		40	72	112
08:00		25	41	66
09:00		14	27	41
10:00		9	18	27
11:00		5	9	14
Total		1534	2503	4037
Percent		38.0%	62.0%	
AM Peak		11:00	11:00	11:00
Vol.		122	182	304
PM Peak		14:00	14:00	14:00
Vol.		185	280	465

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	19-Mar-09 Thu	Channel 1	Channel 2	Total
12:00 AM		7	4	11
01:00		9	3	12
02:00		3	4	7
03:00		9	5	14
04:00		83	18	101
05:00		**345**	60	405
06:00		292	132	**424**
07:00		47	98	145
08:00		76	118	194
09:00		83	121	204
10:00		95	154	249
11:00		122	**203**	325
12:00 PM		104	190	294
01:00		157	197	354
02:00		**187**	271	458
03:00		163	**307**	**470**
04:00		109	245	354
05:00		80	152	232
06:00		51	106	157
07:00		46	57	103
08:00		19	36	55
09:00		15	18	33
10:00		7	12	19
11:00		12	14	26
Total		2121	2525	4646
Percent		45.7%	54.3%	
AM Peak		05:00	11:00	06:00
Vol.		345	203	424
PM Peak		14:00	15:00	15:00
Vol.		187	307	470

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	20-Mar-09 Fri	Channel 1	Channel 2	Total
12:00 AM		8	5	13
01:00		3	4	7
02:00		5	3	8
03:00		9	9	18
04:00		32	27	59
05:00		30	44	74
06:00		72	99	171
07:00		52	91	143
08:00		76	114	190
09:00		80	137	217
10:00		88	158	246
11:00		**136**	**204**	**340**
12:00 PM		122	215	337
01:00		128	266	394
02:00		232	366	598
03:00		**252**	**392**	**644**
04:00		126	363	489
05:00		75	295	370
06:00		52	147	199
07:00		34	80	114
08:00		36	59	95
09:00		17	39	56
10:00		21	25	46
11:00		8	18	26
Total		1694	3160	4854
Percent		34.9%	65.1%	
AM Peak		11:00	11:00	11:00
Vol.		136	204	340
PM Peak		15:00	15:00	15:00
Vol.		252	392	644

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

Date Printed: 02-Apr-09

1st St
Geddes
Site Code:

Start Time	21-Mar-09 Sat	Channel 1	Channel 2	Total
12:00 AM		8	24	32
01:00		12	6	18
02:00		2	3	5
03:00		6	3	9
04:00		6	11	17
05:00		9	9	18
06:00		17	25	42
07:00		31	47	78
08:00		43	88	131
09:00		81	117	198
10:00		103	169	272
11:00		**118**	**215**	**333**
12:00 PM		82	**173**	255
01:00		**92**	169	**261**
02:00		80	145	225
03:00		80	135	215
04:00		61	150	211
05:00		68	118	186
06:00		48	94	142
07:00		36	53	89
08:00		25	42	67
09:00		22	28	50
10:00		16	20	36
11:00		12	12	24
Total		1058	1856	2914
Percent		36.3%	63.7%	
AM Peak		11:00	11:00	11:00
Vol.		118	215	333
PM Peak		13:00	12:00	13:00
Vol.		92	173	261

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	22-Mar-09 Sun	Channel 1	Channel 2	Total
12:00 AM		5	5	10
01:00		10	6	16
02:00		4	5	9
03:00		3	2	5
04:00		4	5	9
05:00		3	6	9
06:00		5	19	24
07:00		22	36	58
08:00		34	64	98
09:00		33	74	107
10:00		50	108	158
11:00		**77**	**122**	**199**
12:00 PM		69	**140**	**209**
01:00		69	131	200
02:00		**80**	118	198
03:00		46	110	156
04:00		65	122	187
05:00		71	103	174
06:00		33	69	102
07:00		25	35	60
08:00		20	28	48
09:00		18	24	42
10:00		9	7	16
11:00		3	11	14
Total		758	1350	2108
Percent		36.0%	64.0%	
AM Peak		11:00	11:00	11:00
Vol.		77	122	199
PM Peak		14:00	12:00	12:00
Vol.		80	140	209

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

Date Printed: 02-Apr-09

1st St
Geddes
Site Code:

Start Time	23-Mar-09 Mon	Channel 1	Channel 2	Total
12:00 AM		3	2	5
01:00		2	2	4
02:00		2	2	4
03:00		4	4	8
04:00		30	26	56
05:00		32	53	85
06:00		89	100	189
07:00		55	108	163
08:00		72	110	182
09:00		74	123	197
10:00		115	169	284
11:00		**121**	**200**	**321**
12:00 PM		107	207	314
01:00		120	196	316
02:00		**157**	253	410
03:00		145	**326**	**471**
04:00		123	296	419
05:00		80	129	209
06:00		30	69	99
07:00		23	58	81
08:00		12	35	47
09:00		11	24	35
10:00		7	18	25
11:00		3	6	9
Total		1417	2516	3933
Percent		36.0%	64.0%	
AM Peak		11:00	11:00	11:00
Vol.		121	200	321
PM Peak		14:00	15:00	15:00
Vol.		157	326	471

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	24-Mar-09 Tue	Channel 1	Channel 2	Total
12:00 AM		6	3	9
01:00		3	5	8
02:00		5	1	6
03:00		7	3	10
04:00		24	25	49
05:00		33	57	90
06:00		91	111	202
07:00		56	99	155
08:00		64	108	172
09:00		69	166	235
10:00		100	147	247
11:00		**122**	**201**	**323**
12:00 PM		129	202	331
01:00		135	201	336
02:00		**157**	234	391
03:00		152	**314**	**466**
04:00		109	309	418
05:00		82	154	236
06:00		45	88	133
07:00		30	63	93
08:00		18	39	57
09:00		13	22	35
10:00		9	18	27
11:00		10	12	22
Total		1469	2582	4051
Percent		36.3%	63.7%	
AM Peak		11:00	11:00	11:00
Vol.		122	201	323
PM Peak		14:00	15:00	15:00
Vol.		157	314	466

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	25-Mar-09 Wed	Channel 1	Channel 2	Total
12:00 AM		7	5	12
01:00		3	4	7
02:00		6	6	12
03:00		4	3	7
04:00		25	30	55
05:00		39	54	93
06:00		89	112	201
07:00		66	106	172
08:00		74	111	185
09:00		79	124	203
10:00		87	141	228
11:00		**102**	**188**	**290**
12:00 PM		119	184	303
01:00		147	208	355
02:00		**173**	215	388
03:00		164	**314**	**478**
04:00		117	264	381
05:00		91	174	265
06:00		46	104	150
07:00		40	74	114
08:00		20	51	71
09:00		12	32	44
10:00		8	14	22
11:00		5	9	14
Total		1523	2527	4050
Percent		37.6%	62.4%	
AM Peak		11:00	11:00	11:00
Vol.		102	188	290
PM Peak		14:00	15:00	15:00
Vol.		173	314	478

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	26-Mar-09 Thu	Channel 1	Channel 2	Total
12:00 AM		3	4	7
01:00		3	2	5
02:00		4	8	12
03:00		8	7	15
04:00		25	25	50
05:00		36	48	84
06:00		80	102	182
07:00		51	104	155
08:00		60	94	154
09:00		86	95	181
10:00		**112**	**193**	**305**
11:00		112	184	296
12:00 PM		120	174	294
01:00		127	210	337
02:00		**187**	244	431
03:00		187	**326**	**513**
04:00		125	315	440
05:00		79	219	298
06:00		51	100	151
07:00		26	58	84
08:00		23	44	67
09:00		12	16	28
10:00		13	19	32
11:00		7	8	15
Total		1537	2599	4136
Percent		37.2%	62.8%	
AM Peak		10:00	10:00	10:00
Vol.		112	193	305
PM Peak		14:00	15:00	15:00
Vol.		187	326	513

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	27-Mar-09 Fri	Channel 1	Channel 2	Total
12:00 AM		9	8	17
01:00		6	10	16
02:00		3	7	10
03:00		7	9	16
04:00		37	42	79
05:00		46	48	94
06:00		105	113	218
07:00		78	99	177
08:00		98	102	200
09:00		89	122	211
10:00		135	178	313
11:00		**142**	**237**	**379**
12:00 PM		142	217	359
01:00		141	218	359
02:00		151	272	423
03:00		**167**	306	**473**
04:00		107	**330**	437
05:00		101	190	291
06:00		58	129	187
07:00		46	81	127
08:00		22	44	66
09:00		23	39	62
10:00		17	27	44
11:00		14	7	21
Total		1744	2835	4579
Percent		38.1%	61.9%	
AM Peak		11:00	11:00	11:00
Vol.		142	237	379
PM Peak		15:00	16:00	15:00
Vol.		167	330	473

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	28-Mar-09 Sat	Channel 1	Channel 2	Total
12:00 AM		8	16	24
01:00		8	5	13
02:00		3	4	7
03:00		4	9	13
04:00		2	16	18
05:00		10	21	31
06:00		23	41	64
07:00		37	78	115
08:00		55	129	184
09:00		58	165	223
10:00		**78**	249	**327**
11:00		71	**255**	326
12:00 PM		95	**289**	**384**
01:00		**112**	255	367
02:00		81	235	316
03:00		78	179	257
04:00		59	231	290
05:00		59	158	217
06:00		58	146	204
07:00		22	85	107
08:00		16	60	76
09:00		10	61	71
10:00		17	36	53
11:00		10	19	29
Total		974	2742	3716
Percent		26.2%	73.8%	
AM Peak		10:00	11:00	10:00
Vol.		78	255	327
PM Peak		13:00	12:00	12:00
Vol.		112	289	384

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	29-Mar-09 Sun	Channel 1	Channel 2	Total
12:00 AM		5	15	20
01:00		4	6	10
02:00		8	0	8
03:00		3	5	8
04:00		4	12	16
05:00		4	14	18
06:00		6	26	32
07:00		16	60	76
08:00		31	116	147
09:00		62	107	169
10:00		63	103	166
11:00		**70**	**139**	**209**
12:00 PM		72	132	204
01:00		75	133	208
02:00		**84**	**138**	**222**
03:00		58	120	178
04:00		62	82	144
05:00		58	118	176
06:00		26	69	95
07:00		33	49	82
08:00		18	30	48
09:00		19	30	49
10:00		7	8	15
11:00		7	10	17
Total		795	1522	2317
Percent		34.3%	65.7%	
AM Peak		11:00	11:00	11:00
Vol.		70	139	209
PM Peak		14:00	14:00	14:00
Vol.		84	138	222

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	30-Mar-09 Mon	Channel 1	Channel 2	Total
12:00 AM		3	5	8
01:00		0	3	3
02:00		3	2	5
03:00		2	5	7
04:00		18	21	39
05:00		34	50	84
06:00		67	92	159
07:00		52	52	104
08:00		72	102	174
09:00		79	127	206
10:00		106	171	277
11:00		**127**	**176**	**303**
12:00 PM		113	200	313
01:00		122	203	325
02:00		135	255	390
03:00		**137**	**311**	**448**
04:00		130	305	435
05:00		73	168	241
06:00		31	87	118
07:00		26	72	98
08:00		14	43	57
09:00		19	22	41
10:00		9	14	23
11:00		8	7	15
Total		1380	2493	3873
Percent		35.6%	64.4%	
AM Peak		11:00	11:00	11:00
Vol.		127	176	303
PM Peak		15:00	15:00	15:00
Vol.		137	311	448

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	31-Mar-09 Tue	Channel 1	Channel 2	Total
12:00 AM		3	3	6
01:00		1	1	2
02:00		4	4	8
03:00		3	4	7
04:00		20	29	49
05:00		35	56	91
06:00		69	93	162
07:00		45	110	155
08:00		80	123	203
09:00		96	123	219
10:00		**118**	198	316
11:00		118	**209**	**327**
12:00 PM		132	207	339
01:00		147	221	368
02:00		**184**	230	414
03:00		177	**321**	**498**
04:00		160	265	425
05:00		110	187	297
06:00		65	89	154
07:00		46	62	108
08:00		38	45	83
09:00		15	30	45
10:00		5	8	13
11:00		3	5	8
Total		1674	2623	4297
Percent		39.0%	61.0%	
AM Peak		10:00	11:00	11:00
Vol.		118	209	327
PM Peak		14:00	15:00	15:00
Vol.		184	321	498

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	01-Apr-09 Wed	Channel 1	Channel 2	Total
12:00 AM		7	5	12
01:00		3	7	10
02:00		3	5	8
03:00		8	8	16
04:00		23	22	45
05:00		38	56	94
06:00		63	82	145
07:00		62	85	147
08:00		59	89	148
09:00		72	135	207
10:00		115	170	285
11:00		**117**	**183**	**300**
12:00 PM		113	234	347
01:00		127	216	343
02:00		132	258	390
03:00		**155**	310	**465**
04:00		124	**317**	441
05:00		68	151	219
06:00		47	113	160
07:00		49	71	120
08:00		27	57	84
09:00		15	27	42
10:00		11	20	31
11:00		10	7	17
Total		1448	2628	4076
Percent		35.5%	64.5%	
AM Peak		11:00	11:00	11:00
Vol.		117	183	300
PM Peak		15:00	16:00	15:00
Vol.		155	317	465

City of Marysville

80 Columbia Avenue
Marysville, WA 98270
360-363-8100

1st St
Geddes
Site Code:

Start Time	02-Apr-09 Thu	Channel 1	Channel 2	Total
12:00 AM		6	9	15
01:00		3	9	12
02:00		4	2	6
03:00		4	4	8
04:00		23	21	44
05:00		40	56	96
06:00		70	**105**	175
07:00		**109**	72	**181**
08:00		60	96	156
09:00		*	*	*
10:00		*	*	*
11:00		*	*	*
12:00 PM		*	*	*
01:00		*	*	*
02:00		*	*	*
03:00		*	*	*
04:00		*	*	*
05:00		*	*	*
06:00		*	*	*
07:00		*	*	*
08:00		*	*	*
09:00		*	*	*
10:00		*	*	*
11:00		*	*	*
Total		319	374	693
Percent		46.0%	54.0%	
AM Peak		07:00	06:00	07:00
Vol.		109	105	181
PM Peak				
Vol.				
Grand Total		22186	38106	60292
Percent		36.8%	63.2%	
ADT		ADT 3,818	AADT 3,818	

Washington State Department of Transportation

Diamond Traffic Counter

RU

Interval ☐ 60 min.	☒ 15 min.
☐ Binned(CL/SP)	☒ Count(volume)
Lane No ☐ 1 ☐ 2	

Counter No. 152292 Count ID HPMS

SR 528 RRT/RRQ _____ MP 0.36

Leg 1 Direction See 1,2 OSID _____

Direction Channel 1 EB

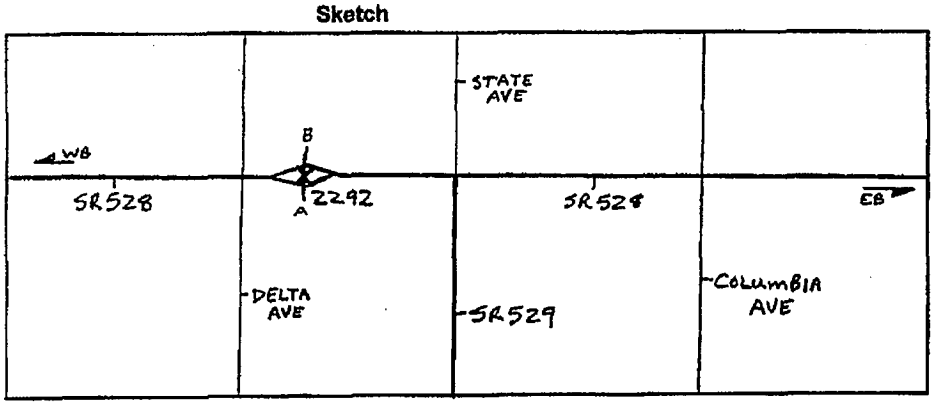
Direction Channel 2 WB

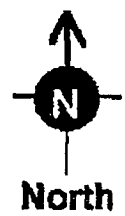
Data Hog # _____

Station Description _ ON SR 528 W/O SR 529 / STATE AVE

Date	Day	Time	Comments
4/6/09	2	10:51	Manual (1) 13 (2) 10 Counter (1) 13 (2) 10 CNTR SET OK CJ/JDM 6.5V
4/7/09	3	11:07	Manual (1) 40 (2) 50 Counter (1) 46 (2) 50 AC=6 ON A-TUBE CNTR CHECK OK CJ/JDM 7.1V
4/8/09	4	7:16	Manual (1) 20 (2) 50 Counter (1) 20 (2) 50 CNTR CHECK OK CJ/JDM 6.4V
4/9/09	5	7:26	Manual (1) 34 (2) 54 Counter (1) 36 (2) 54 AC=2 ON A-TUBE CNTR CHECK OK CJ/JDM 6.4V
4/10/09	6	7:06	Manual (1) 1 (2) 1 Counter (1) 1 (2) 1 CNTR C.P.U. OK CJ/JDM 6.4V

Sketch





North

CJ/JDM

Field Person

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 103

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC WESTBOUND LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/06/09 MONDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15												195	231	226	212	183	196	213	174	160	131	137	84	40	
15-30												181	200	209	212	181	178	195	155	129	118	78	56	34	
30-45												197	203	210	188	205	201	180	172	143	105	107	69	36	
45-00												220	198	191	191	194	185	141	157	137	107	72	44	27	
HOUR TOT												793	832	836	803	763	760	729	658	569	461	394	253	137	7988

AM PEAK HOUR 1100 TO 1200 VOLUME 793
PM PEAK HOUR 1245 TO 0145 VOLUME 843

AM TOTAL 793
PM TOTAL 7195

04/07/09 TUESDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	22	8	13	20	46	163	186	231	210	225	186	132	206	198	202	205	199	185	174	164	124	112	69	34	
15-30	21	12	13	25	73	164	234	258	197	179	182	199	202	212	234	199	162	163	172	131	116	95	59	28	
30-45	21	14	17	32	106	207	255	257	221	230	164	208	215	202	203	189	204	225	168	141	106	107	45	37	
45-00	17	9	26	33	117	202	257	267	235	175	184	202	207	217	188	193	177	182	172	155	117	77	46	18	
HOUR TOT	81	43	69	110	342	736	932	1013	863	809	716	741	830	829	827	786	742	755	686	591	463	391	219	117	13691

AM PEAK HOUR 0700 TO 0800 VOLUME 1013
PM PEAK HOUR 0145 TO 0245 VOLUME 856

AM TOTAL 6455
PM TOTAL 7236

04/08/09 WEDNESDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	21	19	8	14	49	141	191	243	211	191	222	205	191	218	208	208	190	177	197	163	155	107	96	38	
15-30	20	15	10	29	76	164	226	260	207	197	182	206	222	208	201	183	188	178	201	151	145	114	62	42	
30-45	13	11	16	32	120	200	234	246	226	223	172	231	218	210	203	187	151	203	184	133	133	117	41	38	
45-00	12	5	17	38	122	199	256	243	227	171	193	197	224	183	204	181	213	212	181	120	113	85	44	28	
HOUR TOT	66	50	51	113	367	704	907	992	871	782	769	839	855	819	816	759	742	770	763	567	546	423	243	146	13960

AM PEAK HOUR 0645 TO 0745 VOLUME 1005
PM PEAK HOUR 1215 TO 0115 VOLUME 882

AM TOTAL 6511
PM TOTAL 7449

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 104

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC WESTBOUND LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/09/09 THURSDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	17	11	49	13	40	150	197	228	193	215	162	183	210	197	206	166	195	218	188	154	136	121	91	45	
15-30	18	17	14	21	90	141	230	266	209	179	191	167	211	237	205	190	203	188	199	150	156	119	62	42	
30-45	16	22	22	36	128	188	241	259	221	201	187	181	221	215	218	222	192	223	203	141	133	103	63	39	
45-00	21	14	12	32	118	202	272	270	222	147	174	235	218	211	186	197	206	179	177	130	117	104	59	33	
HOUR																									
TOT	72	64	97	102	376	681	940	1023	845	742	714	766	860	860	815	775	796	808	767	575	542	447	275	159	14101

AM PEAK HOUR 0645 TO 0745 VOLUME 1025
PM PEAK HOUR 1230 TO 0130 VOLUME 873

AM TOTAL 6422
PM TOTAL 7679

04/10/09 FRIDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	29	11	8	20	44	119	166																		
15-30	20	24	14	29	77	149	187																		
30-45	20	18	23	29	107	169	225																		
45-00	18	17	19	18	100	196	225																		
HOUR																									
TOT	87	70	64	96	328	633	803																		2081

AM PEAK HOUR 0600 TO 0700 VOLUME 803
PM PEAK HOUR 0000 TO 0000 VOLUME 0

AM TOTAL 2081
PM TOTAL 0

04/06/09 THRU 04/10/09
TOTAL HOURS FOR COUNT 91

3 DAYS FACTOR GROUP GR-02 FACTOR GROUP GR-A2
AVG WEEKDAY VOL 13917 X SEASONAL ADJ. FACTOR 0.9200 = 12804 X AXLE CORR FACTOR 0.9461 = ESTIMATED AVG DAILY TRAFFIC 12114

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 105

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC EASTBOUND LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/06/09 MONDAY

	AM HOURS											--|--	PM HOURS											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15												155	231	226	232	307	309	338	246	165	153	143	102	85	
15-30												192	195	217	283	301	331	290	286	186	141	155	82	102	
30-45												168	178	203	276	300	321	298	241	186	140	114	84	63	
45-00												162	200	241	279	320	315	282	230	184	143	119	84	49	
HOUR																									
TOT												677	804	887	1070	1228	1276	1208	1003	721	577	531	352	299	10633

AM PEAK HOUR 1100 TO 1200 VOLUME 677
PM PEAK HOUR 0415 TO 0515 VOLUME 1305

AM TOTAL 677
PM TOTAL 9956

04/07/09 TUESDAY

	AM HOURS											--|--	PM HOURS											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15	59	27	23	19	13	32	57	86	127	172	162	162	211	192	267	299	312	351	255	219	165	139	133	80	
15-30	34	25	27	9	10	23	80	108	129	124	146	208	226	228	280	294	256	323	233	196	165	132	101	104	
30-45	35	20	18	10	13	44	90	132	118	166	140	182	192	215	291	328	314	310	255	200	132	129	86	47	
45-00	25	26	25	12	24	62	94	138	155	129	162	190	216	262	302	340	368	262	246	190	137	112	90	46	
HOUR																									
TOT	153	98	93	50	60	161	321	464	529	591	610	742	845	897	1140	1261	1250	1246	989	805	599	512	410	277	14103

AM PEAK HOUR 1100 TO 1200 VOLUME 742
PM PEAK HOUR 0430 TO 0530 VOLUME 1356

AM TOTAL 3872
PM TOTAL 10231

04/08/09 WEDNESDAY

	AM HOURS											--|--	PM HOURS											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15	57	24	18	10	12	28	62	87	109	162	164	150	182	224	238	304	329	292	268	209	161	159	103	74	
15-30	56	23	25	8	19	25	74	129	151	145	156	182	213	237	300	290	314	288	201	201	195	154	103	92	
30-45	27	23	27	17	14	37	68	149	126	140	151	144	199	218	265	326	219	330	214	176	189	124	91	71	
45-00	45	27	27	15	21	51	111	151	181	126	143	176	204	236	276	302	365	298	279	188	185	126	95	58	
HOUR																									
TOT	185	97	97	50	66	141	315	516	567	573	614	652	798	915	1079	1222	1227	1208	962	774	730	563	392	295	14038

AM PEAK HOUR 1100 TO 1200 VOLUME 652
PM PEAK HOUR 0445 TO 0545 VOLUME 1275

AM TOTAL 3873
PM TOTAL 10165

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 106

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC EASTBOUND LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/09/09 THURSDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	60	27	18	8	23	22	51	110	94	162	145	154	204	213	235	206	292	315	308	218	184	175	126	80	
15-30	51	24	19	12	11	31	74	148	140	112	147	200	216	236	292	307	297	318	272	238	173	173	96	99	
30-45	36	25	19	10	20	38	91	115	142	133	159	173	220	198	292	279	297	323	240	186	215	150	98	57	
45-00	39	20	28	17	27	47	84	181	138	140	178	196	184	233	303	284	320	260	244	207	188	131	87	65	
HOUR																									
TOT	186	96	84	47	81	138	300	554	514	547	629	723	824	880	1122	1076	1206	1216	1064	849	760	629	407	301	14233

AM PEAK HOUR 1100 TO 1200 VOLUME 723
PM PEAK HOUR 0445 TO 0545 VOLUME 1276

AM TOTAL 3899
PM TOTAL 10334

04/10/09 FRIDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
00-15	48	37	22	21	10	22	56																		
15-30	44	31	19	11	10	25	72																		
30-45	40	37	23	14	23	37	76																		
45-00	44	39	29	15	29	53	114																		
HOUR																									
TOT	176	144	93	61	72	137	318																		1001

AM PEAK HOUR 0600 TO 0700 VOLUME 318
PM PEAK HOUR 0000 TO 0000 VOLUME 0

AM TOTAL 1001
PM TOTAL 0

04/06/09 THRU 04/10/09
TOTAL HOURS FOR COUNT 91

3 DAYS FACTOR GROUP GR-02 FACTOR GROUP GR-A2
AVG WEEKDAY VOL 14125 X SEASONAL ADJ. FACTOR 0.9200 = 12995 X AXLE CORR FACTOR 0.9461 = ESTIMATED AVG DAILY TRAFFIC 12295

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 107

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC BOTH WAYS LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/06/09 MONDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15												350	462	452	444	490	505	551	420	325	284	280	186	125	
15-30												373	395	426	495	482	509	485	441	315	259	233	138	136	
30-45												365	381	413	464	505	522	478	413	329	245	221	153	99	
45-00												382	398	432	470	514	500	423	387	321	250	191	128	76	
HOUR	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	------
TOT												1470	1636	1723	1873	1991	2036	1937	1661	1290	1038	925	605	436	18621

AM PEAK HOUR 1100 TO 1200 VOLUME 1470
PM PEAK HOUR 0415 TO 0515 VOLUME 2082

AM TOTAL 1470
PM TOTAL 17151

04/07/09 TUESDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15	81	35	36	39	59	195	243	317	337	397	348	294	417	390	469	504	511	536	429	383	289	251	202	114	
15-30	55	37	40	34	83	187	314	366	326	303	328	407	428	440	514	493	418	486	405	327	281	227	160	132	
30-45	56	34	35	42	119	251	345	389	339	396	304	390	407	417	494	517	518	535	423	341	238	236	131	84	
45-00	42	35	51	45	141	264	351	405	390	304	346	392	423	479	490	533	545	444	418	345	254	189	136	64	
HOUR	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	------
TOT	234	141	162	160	402	897	1253	1477	1392	1400	1326	1483	1675	1726	1967	2047	1992	2001	1675	1396	1062	903	629	394	27794

AM PEAK HOUR 0715 TO 0815 VOLUME 1497
PM PEAK HOUR 0445 TO 0545 VOLUME 2102

AM TOTAL 10327
PM TOTAL 17467

04/08/09 WEDNESDAY

	AM HOURS												PM HOURS												
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	DAILY
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
00-15	78	43	26	24	61	169	253	330	320	353	386	355	373	442	446	512	519	469	465	372	316	266	199	112	
15-30	76	38	35	37	95	189	300	389	358	342	338	388	435	445	501	473	502	466	402	352	340	268	165	134	
30-45	40	34	43	49	134	237	302	395	352	363	323	375	417	428	468	513	370	533	398	309	322	241	132	109	
45-00	57	32	44	53	143	250	367	394	408	297	336	373	428	419	480	483	578	510	460	308	298	211	139	86	
HOUR	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	------
TOT	251	147	148	163	433	845	1222	1508	1438	1355	1383	1491	1653	1734	1895	1981	1969	1978	1725	1341	1276	986	635	441	27998

AM PEAK HOUR 0700 TO 0800 VOLUME 1508
PM PEAK HOUR 0445 TO 0545 VOLUME 2046

AM TOTAL 10384
PM TOTAL 17614

DOT-RNB515A-B

STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION
T R I P S S Y S T E M
15 MINUTE TRAFFIC COUNT SUMMARY

DATE 07/10/09
TIME 06:43:55
PAGE 108

SR 528 MP 000.36 OFF SYSTEM ID. LEG 1 DIRECTION OF TRAFFIC BOTH WAYS LANE ALL OF

COUNT IDENTIFIER HPMS COUNTER NUMBER 152292 DESCRIPTION: ON SR 528 W/O SR 529/STATE AVE

04/09/09 THURSDAY

	AM HOURS												PM HOURS											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
00-15	77	38	67	21	63	172	248	338	287	377	307	337	414	410	441	372	487	533	496	372	320	296	217	125
15-30	69	41	33	33	101	172	304	414	349	291	338	367	427	473	497	497	500	506	471	388	329	292	158	141
30-45	52	47	41	46	148	226	332	374	363	334	346	354	441	413	510	501	489	546	443	327	348	253	161	96
45-00	60	34	40	49	145	249	356	451	360	287	352	431	402	444	489	481	526	439	421	337	305	235	146	98
HOUR TOT	258	160	181	149	457	819	1240	1577	1359	1289	1343	1489	1684	1740	1937	1851	2002	2024	1831	1424	1302	1076	682	460

DAILY TOTAL 28334

AM PEAK HOUR 0700 TO 0800 VOLUME 1577
PM PEAK HOUR 0445 TO 0545 VOLUME 2111

AM TOTAL 10321
PM TOTAL 18013

04/10/09 FRIDAY

	AM HOURS												PM HOURS											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
00-15	77	48	30	41	54	141	222																	
15-30	64	55	33	40	87	174	259																	
30-45	60	55	46	43	130	206	301																	
45-00	62	56	48	33	129	249	339																	
HOUR TOT	263	214	157	157	400	770	1121																	

3082

AM PEAK HOUR 0600 TO 0700 VOLUME 1121
PM PEAK HOUR 0000 TO 0000 VOLUME 0

AM TOTAL 3082
PM TOTAL 0

04/06/09 THRU 04/10/09
TOTAL HOURS FOR COUNT 91

3 DAYS FACTOR GROUP GR-02 FACTOR GROUP GR-A2
AVG WEEKDAY VOL 28042 X SEASONAL ADJ. FACTOR 0.9200 = 25799 X AXLE CORR FACTOR 0.9461 = ESTIMATED AVG DAILY TRAFFIC 24408

PEAK HOUR PERCENTAGES: K = 7.53 D = 60.45
PEAK HOUR LOCATION : VOLUME = 2111 DATE: 04/09/09 TIME: 04:45 PM

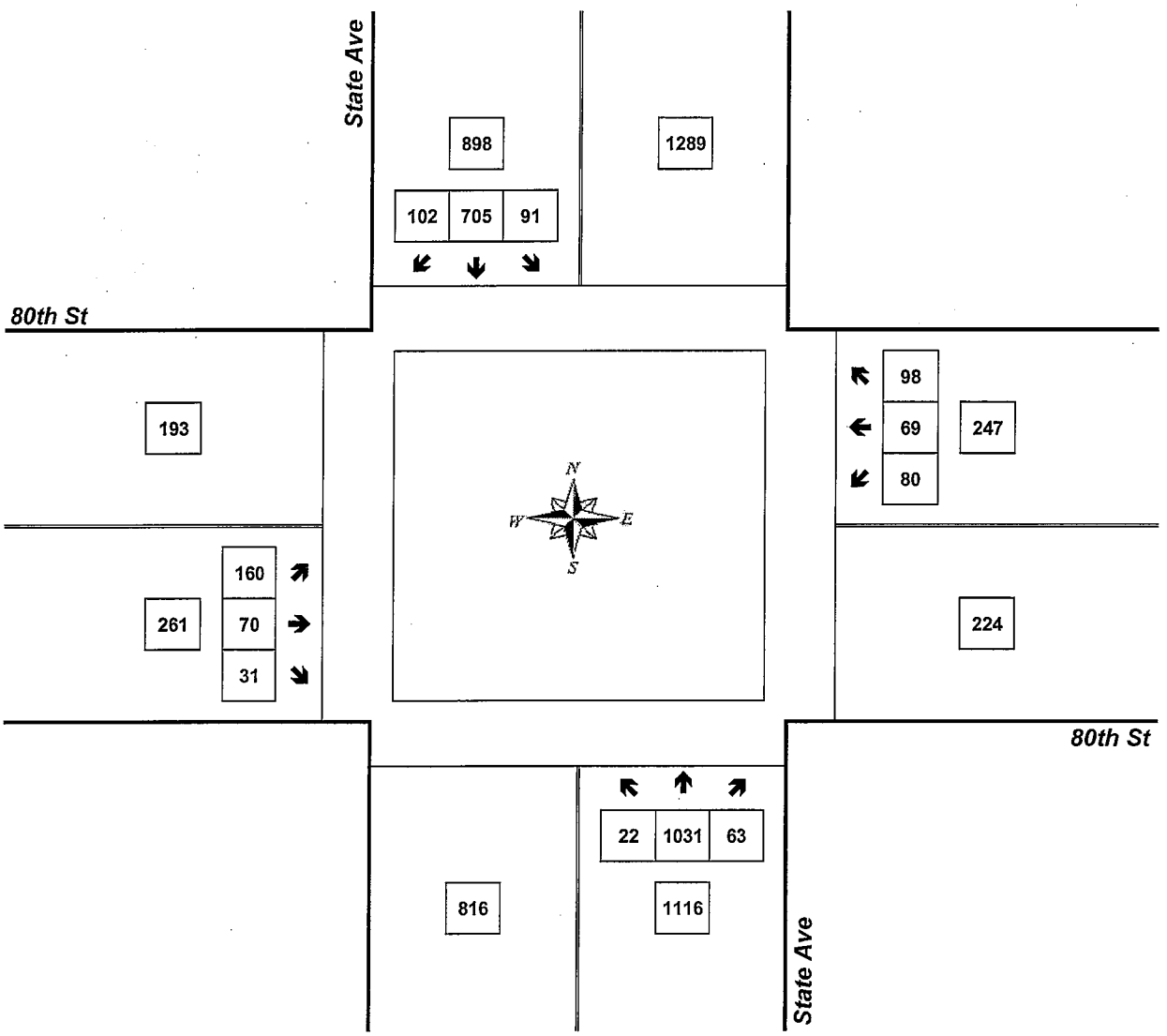
Peak Hour Summary

All Traffic Data Services Inc.

Mark Skaggs
(206) 251-0300

State Ave & 80th St

4:00 PM to 5:00 PM
Tuesday, November 06, 2007

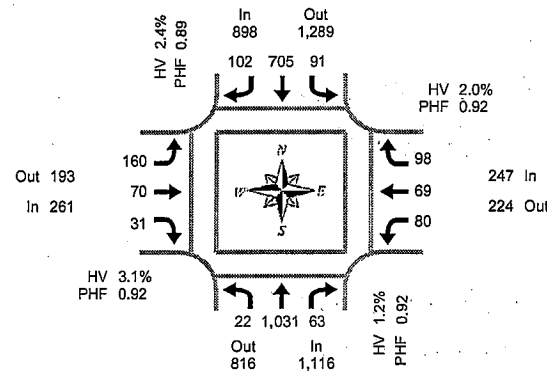


Approach	PHF	HV%	Volume
EB	0.92	3.1%	261
WB	0.92	2.0%	247
NB	0.92	1.2%	1,116
SB	0.89	2.4%	898
Intersection	0.93	1.9%	2,522

Count Period: 4:00 PM to 6:00 PM

Total Vehicle Summary

All Traffic Data Services Inc.
Mark Skaggs
(206) 251-0300



State Ave & 80th St

Tuesday, November 06, 2007
4:00 PM to 6:00 PM

Peak Hour Summary
4:00 PM to 5:00 PM

15-Minute Interval Summary
4:00 PM to 6:00 PM

Interval Start Time	Northbound State Ave				Southbound State Ave				Eastbound 80th St				Westbound 80th St				Interval Total
	L	T	R	HV	L	T	R	HV	L	T	R	HV	L	T	R	HV	
4:00 PM	7	273	23	3	33	187	21	8	39	21	8	3	22	19	26	0	679
4:15 PM	2	269	16	2	23	197	32	5	35	9	10	0	13	9	28	2	643
4:30 PM	5	248	10	6	20	149	25	5	40	24	4	4	26	17	22	1	590
4:45 PM	8	241	14	2	15	172	24	4	46	16	9	1	19	24	22	2	610
5:00 PM	4	289	18	3	18	173	20	2	31	10	3	0	18	9	28	0	621
5:15 PM	6	256	13	0	14	165	20	4	29	15	0	0	12	5	13	1	548
5:30 PM	4	279	16	2	18	170	20	4	34	13	3	1	7	10	12	0	586
5:45 PM	3	242	14	1	17	164	19	0	34	16	1	1	9	7	17	0	543
Total Survey	39	2,097	124	19	158	1,377	181	32	288	124	38	10	126	100	168	6	4,820

Peak Hour Summary
4:00 PM to 5:00 PM

By Approach	Northbound State Ave				Southbound State Ave				Eastbound 80th St				Westbound 80th St				Total
	In	Out	Total	HV	In	Out	Total	HV	In	Out	Total	HV	In	Out	Total	HV	
Volume	1,116	816	1,932	13	898	1,289	2,187	22	261	193	454	8	247	224	471	5	2,522
%HV	1.2%				2.4%				3.1%				2.0%				1.9%
PHF	0.92				0.89				0.92				0.92				0.93

By Movement	Northbound State Ave				Southbound State Ave				Eastbound 80th St				Westbound 80th St				Total
	L	T	R	Total	L	T	R	Total	L	T	R	Total	L	T	R	Total	
Volume	22	1,031	63	1,116	91	705	102	898	160	70	31	261	80	69	98	247	2,522
PHF	0.69	0.94	0.68	0.92	0.69	0.89	0.80	0.89	0.87	0.73	0.78	0.92	0.77	0.72	0.88	0.92	0.93

Rolling Hour Summary
4:00 PM to 6:00 PM

Interval Start Time	Northbound State Ave				Southbound State Ave				Eastbound 80th St				Westbound 80th St				Interval Total
	L	T	R	HV	L	T	R	HV	L	T	R	HV	L	T	R	HV	
4:00 PM	22	1,031	63	13	91	705	102	22	160	70	31	8	80	69	98	5	2,522
4:15 PM	19	1,047	58	13	76	691	101	16	152	59	26	5	76	59	100	5	2,464
4:30 PM	23	1,034	55	11	67	659	89	15	146	65	16	5	75	55	85	4	2,369
4:45 PM	22	1,065	61	7	65	680	84	14	140	54	15	2	56	48	75	3	2,365
5:00 PM	17	1,066	61	6	67	672	79	10	128	54	7	2	46	31	70	1	2,298

	Northbound				Southbound				
Start Time	Left	Thru	Right	Ped	Left	Thru	Right	Ped	Left
15:45	93	103	14		11	81	94	0	28
16:00	80	105	8		6	66	75		22
16:15	86	104	9	1	20	79	69		22
16:30	79	100	10	2	6	63	72	2	12
16:45	64	68	16		5	52	71	0	15
17:00	88	76	9	0	5	7	63		15
17:15	76	97	13		10	50	56		13
17:30	87	84	13		6	67	72		17
Max Hour	338	412	41	3	43	289	310	2	84

Westbound				Eastbound				Total	
Thru	Right	Ped	Left	Thru	Right	Ped			
25	14		98	56	86	1		704	
32	5		105	40	97	1		642	
23	15	1	100	48	107	1		685	
22	14		92	42	84			600	2631
25	17	0	112	68	106			619	2546
31	11		97	44	79	0		525	2429
27	10	0	116	32	103	1		604	2348
22	16	0	86	45	94	1		610	2358
102	48	1	395	186	374	3			2631

Estimate of 116th ADT 17050

Accident Data

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 110513
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084650M	12/15/08	09:40 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MOUNT VERNON	PAC	SNOHOMISH	53	WA

11. City *(if in a city)*: MARYSVILLE
12. Highway Name or No.: CO67240; 88TH ST.N.E
☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer, F. Bus, J. Other Motor Vehicle; A. Auto, D. Pick-up truck, G. School Bus, K. Pedestrian; B. Truck, E. Van, H. Motorcycle, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 25

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 25 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 2

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN TRACK

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
3	1	13	R. Recorded / E. Estimated 50 mph	R	1. North 2. South 3. East 4. West	2

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None
Code(s): 01 | 02 | 06

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach	Code	36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown	Code	37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown	Code
	1		1		2

38. Driver's Age	39. Driver's Gender — 1. Male, 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown	Code	41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)*	Code
		1		2		1

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown	Code	43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed	Code
	2		8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured	Code	45. Was Driver in the Vehicle? — 1. Yes 2. No	Code
	2		1
47. Highway Vehicle Property Damage *(est. dollar damage)*	$3,000	48. Total Number of Highway-Rail Crossing Users *(include driver)*	1
50. Total Number of People on Train *(include passengers and crew)*	100	51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No	Code: 2

53a. Special Study Block
53b. Special Study Block

54. Narrative Description

TRAIN 513 OPERATING WITH LOCOMOTIVE E/466 AND 13 CARS STRUCK AN AUTOMOBILE AT MP 40.34, 88TH STREET NE CROSSING

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 099353
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX
4. U.S. DOT-AAR Grade Crossing ID No. 084654P	5. Date of Accident/Incident 12/29/05	6. Time of Accident/Incident 11:22 AM	

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EVERETT	PAC	SNOHOMISH	53	WA

11. City *(if in a city)* | 12. Highway Name or No. CO68400; 116TH ST. N | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 10

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 2

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 44 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 2

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN

27. FRA Track Class: 4

28. Number of Locomotive Units: 1

29. Number of Cars: 13

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 79 mph — Code: R

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 01

33. Signaled Crossing Warning: Allgd. warn > 60 sec (2);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 1

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age: 10

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 1

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 2

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $6,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 130

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 1

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

TRAIN NO.#513 OPERATING WITH ENGINE 467 AND 13 CARS, WAS STRUCK BY AN AUTOMOBILE AT MP42.04, 116TH STREET CROSSING.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57 * NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0404203
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0404203

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084640G	04/30/04	12:20 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MARYSVILLE	NORTHWEST	SNOHOMISH	53	WA

11. City *(if in a city)*: MARYSVILLE
12. Highway Name or No.: SR528/4TH STREET
☑ Public ☐ Private

Highway User Involved

13. Type — Code: A
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*:
15. Direction *(geographical)* — Code: 4
1. North 2. South 3. East 4. West

16. Position — Code: 4
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 2
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 68 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 1
A. Spec. MoW Equip
1. Freight train 4. Work train 7. Yard/Switching
2. Passenger train 5. Single car 8. Light loco(s)
3. Commuter train 6. Cut of cars 9. Main./inspect. car

25. Track Type Used by Rail Equipment Involved — Code: 1
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: SINGLE MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* — Code	31. Time Table Direction — Code
2	2	77	R. Recorded E. Estimated 10 mph — R	1. North 2. South 3. East 4. West — 2

32. Type of Crossing Warning — Code(s): 01, 02
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew
2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)*
3. Standard FLS 6. Audible 9. Watchman 12. None

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — Code: 2
1. Yes
2. No
3. Unknown

35. Location of Warning — Code	36. Crossing Warning Interconnected with Highway Signals — Code	37. Crossing Illuminated by Street Lights or Special Lights — Code
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — 1	1. Yes 2. No 3. Unknown — 3	1. Yes 2. No 3. Unknown — 1

38. Driver's Age	39. Driver's Gender — Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code	41. Driver — Code
34	1. Male 2. Female — 1	1. Yes 2. No 3. Unknown — 2	1. Drove around or thru the gate 4. Stopped on crossing 2. Stopped and then proceeded 5. Other *(specify)* 3. Did not stop — 4

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)*
2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users		
49. Railroad Employees		
52. Passengers on Train		

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT	REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
Snohomish	Marysville	City Street		116		STATE AVE									1972417	3/9/2005	14:13	Unknown	0	0	1		
Snohomish	Marysville	City Street		116 ST		RR CROSSING									1918857	1/29/2005	11:25	No Injury	0	0	1		
Snohomish	Marysville	City Street		116 ST		SMOKEY PT BLVD									2445734	7/27/2006	11:18	No Injury	0	0	1		
Snohomish	Marysville	City Street		116 ST		STATE AVE									2095437	11/11/2005	10:45	No Injury	0	0	2		
Snohomish	Marysville	City Street		116 ST NE		STATE AV									3182809	4/30/2009	17:42	No Injury	0	0	2		
Snohomish	Marysville	City Street		136 AV		STATE AV									2095296	8/23/2005	17:24	No Injury	0	0	1		
Snohomish	Marysville	City Street		136 ST		36 DR									2445844	6/4/2007	12:00	No Injury	0	0	2		
Snohomish	Marysville	City Street		136 ST		RR TRACKS					STATE AV	36 DR NE			2095441	11/16/2005	7:23	No Injury	0	0	2		
Snohomish	Marysville	City Street		136 ST NE		RR CROSSING				STATE AVE					2813415	7/27/2007	20:18	Possible Injury	1	0	2		
Snohomish	Marysville	City Street		136 ST NE		STATE AV									2641312	11/2/2006	13:45	No Injury	0	0	2		
Snohomish	Marysville	City Street		80 ST	3900	RR CROSSING									2268092	6/27/2006	15:13	No Injury	0	0	1		
Snohomish	Marysville	City Street		88 ST	3800	RR CROSSING				STATE AV					2891576	11/17/2007	19:56	Unknown	0	0	1		
Snohomish	Marysville	City Street		88 ST		RR CROSSING					STATE AVE	40 DR NE			2813379	2/19/2007	10:59	No Injury	0	0	1		
Snohomish	Marysville	City Street		88 ST	3900	RR XING									2445776	9/24/2006	9:42	No Injury	0	0	1		
Snohomish	Marysville	City Street		88 ST		STATE AV									2445850	8/1/2007	9:17	No Injury	0	0	1		
Snohomish	Marysville	City Street		88 ST NE		STATE AVE									3182152	11/4/2008	11:47	No Injury	0	0	2		
Snohomish	Marysville	City Street		88 ST NE		STATE AVE									3148429	8/24/2008	14:18	No Injury	0	0	3		
Snohomish	Marysville	City Street		88 ST NE		STATE AVE									E065556	8/31/2010	8:33	No Injury	0	0	1		
Snohomish	Marysville	City Street		GROVE	1400	BNRR XING									2813265	5/23/2007	7:14	No Injury	0	0	1		
Snohomish	Marysville	City Street		GROVE ST		R AND R CROSSING WEST OF STATE AVE									2955147	11/2/2008	15:13	No Injury	0	0	2		
Snohomish	Marysville	City Street		GROVE ST	1400	RR TRACKS									2445608	6/1/2007	11:08	Possible Injury	1	0	3		
Snohomish	Marysville	City Street		GROVE ST	1400	RR XING									1972604	3/26/2005	11:34	No Injury	0	0	1		
Snohomish	Marysville	City Street		GROVE ST	1300										978683	5/23/2006	13:07	Evident Injury	1	0	1		1
Snohomish	Marysville	City Street		SMOKEY PT BLVD		136 ST									928667	3/14/2005	14:38	No Injury	0	0	2		
Snohomish	Marysville	City Street		STATE AV		116 ST NE									3150669	12/17/2008	9:31	Unknown	0	0	1		
Snohomish	Marysville	City Street		STATE AVE		116 TH ST									1360261	2/5/2005	16:28	No Injury	0	0	2		
Snohomish	Marysville	City Street		STATE AVE		88 ST									2813180	5/12/2007	13:29	No Injury	0	0	2		
Snohomish	Marysville	City Street		STATE AVE		88 ST									2813507	12/15/2008	9:44	Serious Injury	2	0	2		
Snohomish	Marysville	City Street		STATE AVE	12100	BURLINGTON RR XING									2095604	6/24/2005	11:17	Serious Injury	1	0			1

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS	FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
Truck Tractor		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✓	None		North	West		
Passenger Car		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✔	Other		West	East		
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight	Signal Pole	Driver Distractions Outside Vehicle		West	South		
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Daylight	Same direction -- both turning right -- one stopped -- rear end	Follow Too Closely	None	North	West	North	Vehicle Stopped
Passenger Car	Truck (Flatbad,Van,etc)	At Intersection and Related	Dry	Daylight	Same direction -- both turning left -- both moving -- sideswipe	Improper Turn	None	West	North	West	North
Passenger Car		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✔	Inattention		West	East		
Truck (Flatbad,Van,etc)	Passenger Car	At Intersection and Related	Dry	Daylight	From same direction - all others	Improper Backing	None	West	Vehicle Backing	West	Vehicle Stopped
Passenger Car	Bus or Motor Stage	At Intersection and Related	Wet	Daylight	From same direction - both going straight - one stopped - rear-end	Exceeding Reas. Safe Speed	None	East	West	East	Vehicle Stopped
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end	Under Influence of Alcohol	None	West	East	West	Vehicle Stopped
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Daylight	From same direction - all others	Improper Backing	None		Vehicle Backing		Vehicle Stopped
Passenger Car		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✔	Other		West	East		
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Dark-Street Lights On	Railway Crossing Gate ✔	Other		East	West		
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Daylight	Railway Crossing Gate ✔	Other		West	Vehicle Backing		
Passenger Car		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✔	Improper Backing		West	Vehicle Backing		
Truck (Flatbad,Van,etc)		At Intersection and Related	Dry	Daylight	Tree or Stump (stationary)	Disregard Stop Sign - Flashing Red		West	East		
Passenger Car	Bus or Motor Stage	At Intersection and Related	Wet	Daylight	From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Daylight	Entering at angle	Exceeding Reas. Safe Speed	None	South	West	West	Vehicle Stopped
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Daylight	All other non-collision	Other		West	Vehicle Stopped		
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight	Railway Crossing Gate ✔	Other		East	West		
Passenger Car	School Bus	At Intersection and Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
Passenger Car	Passenger Car	At Intersection and Not Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end	Inattention	None	East	West	East	Vehicle Stopped
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Daylight	Railway Crossing Gate ✔	Other		West	East		
Not Stated		At Intersection and Not Related	Wet	Daylight	Vehicle - Pedalcyclist	Other		East	West		
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Not Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
Not Stated		At Intersection and Related	Snow/Slush	Daylight	Railway Crossing Gate ✔	Other		North	West		
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Dry	Daylight	From same direction - both going straight - one stopped - rear-end	Inattention	None	North	South	North	Vehicle Stopped
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Dry	Daylight	Same direction -- both turning right -- both moving -- rear end	Follow Too Closely	None	North	West	North	West
Passenger Car		At Intersection and Related	Dry	Daylight	Train struck moving vehicle ✔	Improper Turn		North	West		
		At Intersection and Related	Dry	Daylight	Vehicle - Pedalcyclist						

total 29
11 - Railway Crossing Gate
or
Train Struck moving Veh

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Mr. Esco Bell PE
Title: City of Mt Vernon Public Works Director
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations-Mount Vernon; GTC #11-036
Date: September 1, 2011

This memorandum is to identify some of the possible rail impacts associated with transport of coal to the proposed Cherry Point Facility affecting the City of Mount Vernon and its access roads. It identifies the potential impacts on the City's downtown core area of Kincaid Street as well as the approach roads to the City, such as Blackburn Road to the south and College Way and Hoag Road to the north.

The purpose of this preliminary report is to provide City staff with information that may be useful as the City prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

1. Project Description and Expected Delays

We understand a terminal capable of exporting 48-54 million tons of coal per year is proposed north of Bellingham. GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north-south directly through the center of the City of Mount Vernon, Washington.

According to the applicant's *Project Information Document* (Feb. 2011), full buildout of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day; however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. The current port proposal occupies 350 acres of a 1,000-acre site. Each train may be over 1.5 miles long, which at 50 miles per hour would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At -35 miles per hour it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Mt Vernon can be estimated to increase with an additional train every *every 1.3 hours*, if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use the siding or not.

2. Affected Crossings

The BNSF rail way tracks bisect the eastern residential area of Mt Vernon (including the high school and hospitals) from the west side of Mt Vernon that includes the downtown business core. The City of Mt Vernon has four roads connecting its downtown business core to areas of the City to the eastern residential/School/hospital are, three of which are directly affected by the proposed increase of rail traffic

while 4th Street has a grade separated crossing. However, SR-536/Kincaid, Fir Street, and College Way crossings are all at grade/gate controlled. SR-536/Kincaid and SR-538/College are also the major access to I-5 for the central city area and residential area east respectively. Due to these constraints, our preliminary review indicated that the additional trains from the Cherry Point operations would have a potential significant impact on the commercial district and quality of life for the City of Mt Vernon residence. Of primary concern are potential backups onto I-5 and the likely drop in level of service on city streets and emergency response, thus affecting future development potential in the City.

3. Analysis of Potential Impacts

We have the following comments based on preliminary research:

1. The City's comprehensive plan identifies several road segments that will be at capacity that are bisected by rail crossing such as College Way and Kincaid. This analysis identified the need for additional routes between the residential area to the east and the commercial area. The potential to obtain improved or additional rail crossings in the future would likely be complicated by the 16-18 additional trains for the Cherry Point facility.
2. Due to a speed restriction approach warning, train travel through Mt Vernon downtown means the barriers are down for approximately 3-4 minutes (over 200 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 2-3 continuous red lights cycles in a row for a normal signal on Kincaid or Collage. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F. The City's standard for normal roadway operation is LOS D, i.e. allowing only 60 seconds as the worst delay for normal conditions. The addition of 16-18 trains per day would call into question whether the City can maintain its adopted LOS D standard. This may be central to future concurrency determinations by the City affecting future development projects.
3. With the increase in number of long coal trains at the Fir, Kincaid or College crossing, the only alternative east-west for local traffic is the regional the 4th Street grade separated crossing as the "local" east west route becomes degraded with the increased coal trains. This is a particular issue during summer peaks, as Kincaid and College already approach capacity limits.
4. There is a probable issue concerning emergency services response times, in a scenario where the only reliable east-west crossing between the business district to the west and the residential area to the east is 4th Street. Adding 16-18 additional trains per day to service Cherry Point could tip the balance at a critical time when emergency responses are needed.
5. Within the last 5 years there have been approximately 25 accidents at the MT Vernon crossings including a death when a passenger vehicle hit a signal pole. Approximately half were rear ends as gates closed with also several gate collisions. In addition there were four train-road vehicle accidents recorded at the Mt Vernon crossing in the last five-year reporting period.
6. Already today the presence of a long freight train during the peak hours creates separation in the downtown core. The WSDOT 2010 annual count data base identified that approximately 17,000 daily trips cross the Kincaid tracks on an average day and approximately 24,000 daily trips cross the College way tracks. The City's 2008 comprehensive plan recorded approximately 10,000 daily trips along Hoag Road, 7,000 daily trips along Fire and nearly 18,000 trips along Riverside at the crossing. The future 2025 projections showed significant growth at all the crossings. We also know that summer peak volumes are considerably bigger. Therefore the main at grade rail crossing in the city have over 75,000 daily vehicles crossing a day. With the doubling of train traffic with coal trains that take 3-4 minutes to cross (if not delays/slowing) the cumulative additional delay to drivers is potentially significant. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. One form of mitigation is to create grade-separation, with either a tunnel or a bridge. The City may wish to request that mitigation as part of the environmental review process for Cherry Point.

7. Skagit County communities and the State have recently invested heavily in improved passenger train (AMTRAK) services for the north end. Freight traffic on the single rail line north of Everett is expected to double with the Cherry Point proposal. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on-time reliability demands of passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to analyze the degree to which a doubling of freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand passenger rail. In 2001, the City participated in a state-sponsored study of the potential for passenger rail expansion, titled: *Pacific Northwest Rail Corridor: Everett to Blaine Commuter Rail Preliminary Feasibility Study*. On Page IV of the Executive Summary, the report concludes that there may be a viable market for commuter rail north of Everett by the year 2030. In 2004 the North Sound Regional Study conducted by Cascadia for Whatcom Council of Governments identified again the potential of significant rail capacity issues identified by BNSF. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies.

   The City 2008 Comprehensive Transportation Element identifies in policies such as Goal 4 Objective T-41 the need for truck and rail access to its industrial area. The States 2006 "statewide *Rail Capacity and System Needs* study" identifies a key issue affecting that access to local business as follows:

   > The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.
   >
   > Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market.

   So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability of local rail spur business necessary to serve Mount Vernon businesses. These issues can be analyzed as part of the economic impact analysis we understand must be completed as part of the environmental review for the project.

8. The Washington State 2010-2030 Freight Rail Plan published by WSDOT in December 2009 identified that the rail line in this area in 2008 was already at its capacity of 18 trains per day (Exhibit 3-9). The state plan shows that it hopes to increase that capacity to 30 trains per day; however the design and cost of the specific improvements needed to do that have not yet been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services.
9. The Cherry Point applicant and its advocates argue that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore there is no impact. In our judgment, this conclusion is not supportable, because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically.

10. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. While grade separation is desirable particularly because of the already complicated I-5 interchanges intersections and the Mount Vernon transit center, these improvements are typically multi-million dollar solutions and funding is not yet planned. Estimates of this mitigation may be obtained by the City, in conjunction with estimates of similar improvements to be requested by other cities, counties and WSDOT. It is our understanding, for example, that replacement of the Skagit River Bridge may be necessary to support the proposed heavy coal rail increases. The budget for design and construction of that improvement alone may be half a billion dollars. We recommend that local jurisdictions provide regulating authorities with detailed assessments of mitigation and funding necessary to alleviate the impacts that will results from the additional 16-18 trains per day serving the Cherry Point export facility.

4. Conclusions

This analysis of possible rail line impacts associated with the increase of 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to illustrate some of the potential problems and areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, and possible interference with local freight delivery systems important to the City's economic recovery.

ATTACHMENTS FOR CITY OF MT. VERNON RAIL CAPACITY PRESENTATION

- Rail Crossing Inventory
- Daily Traffic at Crossings
- Transportation Element Information
- Accident History Data
- State Report Information

Rail Crossing Inventory

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7301846

Home Crossing Forms/Publications Downloads Data Documents Policies Support

8.01 - Query by Location

Total Records: 18

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

Generate Repor | Show Paging | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**084727X**	WA	BNSF	Public	At Grade	Open	006028	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	MILLTOWN
☐	**084733B**	WA	BNSF	Public	At Grade	Open	006250	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SPRUCE ST.
☐	**084734H**	WA	BNSF	Public	At Grade	Open	006256	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FIR ISLAND RD.
☐	**084735P**	WA	BNSF	Public	At Grade	Open	006358	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	JOHNSON RD
☐	**084736W**	WA	BNSF	Public	At Grade	Open	006458	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	STACK POLE RD
☐	**084737D**	WA	BNSF	Public	At Grade	Open	006560	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	HICKOK RD
☐	**084739S**	WA	BNSF	Public	At Grade	Open	006712	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	BLACKBURN & PAC.
☐	**084741T**	WA	BNSF	Public	At Grade	Open	006762	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SECTION ST
☐	**084744N**	WA	BNSF	Public	At Grade	Open	006786	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	KINCAID ST
☐	**084746C**	WA	BNSF	Public	At Grade	Open	006798	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	EVERETT-BLAINIE	MONTGOMERY ST.
☐	**084749X**	WA	BNSF	Public	At Grade	Open	006870	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	CARNATION SPUR	3RD ST & WAY
☐	**084751Y**	WA	BNSF	Public	At Grade	Open	006870	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	CARNATION SPUR	NO 1ST ST
☐	**084753M**	WA	BNSF	Public	At Grade	Open	006867	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FIR STREET
☐	**084754U**	WA	BNSF	Public	At Grade	Open	006879	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	WSTRN FRMRS SPR	N 4TH ST/RVRSD DR
☐	**084758W**	WA	BNSF	Public	At Grade	Open	006883	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	4TH ST N/RVRSD DR
☐	**084759D**	WA	BNSF	Public	At Grade	Open	006928	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	KINCAID ST
☐	**084760X**	WA	BNSF	Public	At Grade	Open	006983	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	HOAG RD
☐	**916334R**	WA	MVT	Public	At Grade	Open	000020	SKAGIT	MOUNT VERNON				FIR ST. (CAMERON)

Generate Repor | Show Paging | Reset

2

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084746C*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***02/27/09***
Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:
Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***EVERETT-BLAINIE***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0067.98***	Street or Road Name:	***MONTGOMERY ST.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	
Nearest RR Timetable Stn:		HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4206243***
ENS Sign Installed:		Longitude:	***-122.3352454***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Neither***
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:	***No***		

Private Crossing Information:

Category: Public Access: ***Unknown***

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use: ***2B67.98***

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***6***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084746C*

Effective Begin-Date of Record: *02/27/09*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:			*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:			*Yes*
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs:	*2*	Specify:	*R8-8*
			1		*R10-6*

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:			*No*
Mast Mounted FL:	*3*	Total Number FL Pairs:			*10*
Cantilevered FL (Over):	*1*	Cantilevered FL (Not over):			*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:			
Highway Traffic Signals:	*1*	Wigwags:	*0*	Bells:	*2*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:			
Channelization:		Type of Train Detection:			*Constant Warning Time*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:			*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*3*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*76 to 200 feet*	Is it Signalized?	*Yes*
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	*No*
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000900*	AADT Year:	*2003*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*25*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084760X*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0069.83***	Street or Road Name:	***HOAG RD***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4430084***
ENS Sign Installed:		Longitude:	***-122.3253127***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084760X*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*005990*	AADT Year:	*1994*
Estimated Percent Trucks:	*03*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084759D*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Position: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0069.28***	Street or Road Name:	***KINCAID ST*** Peabody
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***SR 538*** 538
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4357969***
ENS Sign Installed:		Longitude:	***-122.3300747***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084759D*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Collector*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*026000*	AADT Year:	*1995*
Estimated Percent Trucks:	*07*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084758W*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency: ***Railroad*** Type and Position: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0068.83***	Street or Road Name:	***4TH ST N/RVRSD DR***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4302986***
ENS Sign Installed:		Longitude:	***-122.3352959***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084758W*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*4*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Asphalt*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Other Principal*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*016640*	AADT Year:	*1994*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084744N*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Position: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0067.86***	Street or Road Name:	~~KINCAID ST~~ extra
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***SR 536*** / 538
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4187985***
ENS Sign Installed:		Longitude:	***-122.3351911***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084744N*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	*Simultaneous Preemption*

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other National Highway*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*Yes*		
Annual Average Daily Traffic (AADT):	*017000*	AADT Year:	*1995*
Estimated Percent Trucks:	*04*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084741T*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0067.62***	Street or Road Name:	***SECTION ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4138790***
ENS Sign Installed:		Longitude:	***-122.3352992***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084741T*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*002441*	AADT Year:	*1994*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084739S*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***10/19/05***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0067.12***	Street or Road Name:	***BLACKBURN & PAC.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***FAM 740***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4066334***
ENS Sign Installed:		Longitude:	***-122.3360075***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***SIDING***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084739S*

Effective Begin-Date of Record: *10/19/05*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*4*	4 Quad or Full Barrier:	
Mast Mounted FL:	*4*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*4*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*4*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*004148*	AADT Year:	*1994*
Estimated Percent Trucks:	*03*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084737D*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0065.60***	Street or Road Name:	***HICKOK RD***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO70000***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.3848243***
ENS Sign Installed:		Longitude:	***-122.3381392***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084737D*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Minor Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000391*	AADT Year:	*1994*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084736W*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0064.58***	Street or Road Name:	***STACK POLE RD***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO89000***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.3703285***
ENS Sign Installed:		Longitude:	***-122.3395642***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084736W*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000120*	AADT Year:	*1994*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084735P*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0063.58***	Street or Road Name:	***JOHNSON RD***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO86000***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.3558982***
ENS Sign Installed:		Longitude:	***-122.3409721***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084735P*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000070*	AADT Year:	*1994*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084734H*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0062.56***	Street or Road Name:	***FIR ISLAND RD.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO40200***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.3412251***
ENS Sign Installed:		Longitude:	***-122.3423981***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084734H*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*0*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Residential*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Rural Major Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*005100*	AADT Year:	*1994*
Estimated Percent Trucks:	*15*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084733B*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0062.50***	Street or Road Name:	***SPRUCE ST.***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO80240***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.3404709***
ENS Sign Installed:		Longitude:	***-122.3424775***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***IND SPUR***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084733B*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*0*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000825*	AADT Year:	*1994*
Estimated Percent Trucks:	*20*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084727X*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***Near MOUNT VERNON***
Railroad Milepost:	***0060.28***	Street or Road Name:	***MILLTOWN***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CO***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3***
Crossing Owner:		Latitude:	***48.3085264***
ENS Sign Installed:		Longitude:	***-122.3486490***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***79*** mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: ***1*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084727X*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*1*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*No*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000020*	AADT Year:	*1994*
Estimated Percent Trucks:	*00*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***084753M*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***BELLINGHAM***	County:	***SKAGIT***
Branch or Line Name:	***PA J-US CAN BDR***	City:	***In MOUNT VERNON***
Railroad Milepost:	***0068.67***	Street or Road Name:	***FIR STREET***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***STANWOOD***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***29-3B***
Crossing Owner:		Latitude:	***48.4284118***
ENS Sign Installed:		Longitude:	***-122.3370837***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***13*** Total Switching: ***0*** Day Thru: ***7***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***1*** Other ***1*** Specify: ***CONNECTING***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084753M*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* Specify:	
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0* Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*007166*	AADT Year:	*1994*
Estimated Percent Trucks:	*08*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: ***916334R*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***01/11/07***

Railroad: ***MVT Mount Vernon Term. Rwy, Inc. [MVT]*** End-Date of Record:

Initiating Agency ***State*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:		State:	*WA*
Subdivision:		County:	*SKAGIT*
Branch or Line Name:		City:	*In MOUNT VERNON*
Railroad Milepost:	*0000.20*	Street or Road Name:	*FIR ST. (CAMERON)*
RailRoad I.D. No.:	*916 334 R*	Highway Type & No.:	
Nearest RR Timetable Stn:	*MT VER-BURLIN*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	
Crossing Owner:		Latitude:	*48.4284000*
ENS Sign Installed:		Longitude:	*-122.3374000*
Passenger Service:		Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*0*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: Railroad Contact: State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: *1* Total Switching: *1* Day Thru: *0*

Typical Speed Range Over Crossing: From *1* to *10* mph Maximum Time Table Speed: *10*

Type and Number of Tracks: Main: *1* Other *1* Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***No***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *916334R*

Effective Begin-Date of Record: *01/11/07*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*No*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*008000*	AADT Year:	
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

Daily Traffic at Crossings

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7301846

8.01 - Query by Location

out of city (OOC)

Total Records: 18

Report Type: ◉ Inventory ○ Accident ○ Contact Sheet

Inventory: ◉ Current ○ History

Generate Repor | Show Paging | Reset

2005 ADT

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street	
☐	084727X	WA	BNSF	Public	At Grade	Open	006028	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	MILLTOWN OOC	✓
☐	084733B	WA	BNSF	Public	At Grade	Open	006250	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SPRUCE ST.	✓
☐	084734H	WA	BNSF	Public	At Grade	Open	006256	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FIR ISLAND RD. 7,200	✓
☐	084735P	WA	BNSF	Public	At Grade	Open	006358	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	JOHNSON RD OOC	✓
☐	084736W	WA	BNSF	Public	At Grade	Open	006458	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	STACK POLE RD	✓
☐	084737D	WA	BNSF	Public	At Grade	Open	006560	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	HICKOK RD 200	✓
☐	084739S	WA	BNSF	Public	At Grade	Open	006712	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	BLACKBURN & PAC. 7,700	✓
☐	084741T	WA	BNSF	Public	At Grade	Open	006762	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SECTION ST 1,800	✓
☐	084744N	WA	BNSF	Public	At Grade	Open	006786	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	KINCAID ST 18,400	✓2010
☐	084746C	WA	BNSF	Public	At Grade	Open	006798	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	EVERETT-BLAINIE	MONTGOMERY ST. Station	✓
☐	084749X	WA	BNSF	Public	At Grade	Open	006870	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	CARNATION SPUR	3RD ST & WAY	
☐	084751Y	WA	BNSF	Public	At Grade	Open	006870	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	CARNATION SPUR	NO 1ST ST	
☐	084753M	WA	BNSF	Public	At Grade	Open	006867	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	FIR STREET 7,400	✓
☐	084754U	WA	BNSF	Public	At Grade	Open	006879	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	WSTRN FRMRS SPR	N 4TH ST/RVRSD DR 17,800	
☐	084758W	WA	BNSF	Public	At Grade	Open	006883	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	4TH ST N/RVRSD DR 17,800	✓
☐	084759D	WA	BNSF	Public	At Grade	Open	006928	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	KINCAID ST 24000 18,400	✓2010
☐	084760X	WA	BNSF	Public	At Grade	Open	006983	SKAGIT	MOUNT VERNON	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	HOAG RD 9,900	✓
☐	916334R	WA	MVT	Public	At Grade	Open	000020	SKAGIT	MOUNT VERNON				FIR ST. (CAMERON)	

Generate Repor | Show Paging | Reset

PM

ADT

	2005 PM PEAK VOLUMES (TWO-WAY) WITH 2005 NETWORK											
				PM Peak Hour (Two-way)								
ID	LINKSEG	CROSSSTA	CROSSSTB	Vol	# of Lns	Lefts?	Capacity	V/C	LOS	Avg	Daily Vol	Roadway Classification
1001	I-5 NB	SR 530/534	Mt Vernon Rd/Old SR 99	2490	3	N	6000	0.42	A	51	27,700	FREEWAY
1002	I-5 NB	Mt Vernon Rd	Anderson Rd	2360	2	N	4000	0.59	A	39	26,200	FREEWAY
1003	I-5 NB	Anderson Rd	Kincaid St	2700	2	N	4000	0.68	B	37	30,000	FREEWAY
1004	I-5 NB	Kincaid St	College Way	3210	2	N	4000	0.80	D	35	35,700	FREEWAY
1005	I-5 NB	College Way	George Hopper	3830	2	N	4000	0.96	E	24	42,600	FREEWAY
1006	I-5 SB	George Hopper	College Way	3400	2	N	4000	0.85	D	28	37,800	FREEWAY
1007	I-5 SB	College Way	Kincaid St	2960	2	N	4000	0.74	C	32	32,900	FREEWAY
1008	I-5 SB	Kincaid St	Anderson Rd	2670	2	N	4000	0.67	B	38	29,700	FREEWAY
1009	I-5 SB	Anderson Rd	Mt Vernon Rd	2450	2	N	4000	0.61	B	37	27,200	FREEWAY
1010	I-5 SB	Mt Vernon Rd/Old SR 99	SR 530/534	2700	3	N	6000	0.45	A	50	30,000	FREEWAY
2001	Division St	Freeway Dr	Ball St	1950	2	N	2100	0.93	E	19	21,700	2 LANE HIGHWAY
2002	Division St	Ball St	Wall St	1950	2	Y	2400	0.81	D	19	21,700	2 LANE HIGHWAY
2003	Division St	Wall St	Moores Garden	1340	2	Y	2400	0.56	A	35	14,900	2 LANE HIGHWAY
2004	Division St	Moores Garden	west model boundary	1190	2	N	2100	0.57	A	32	13,200	2 LANE HIGHWAY
2005	SR 9	SR 538	Mt Vernon Big Lake Rd	640	2	N	2100	0.30	A	43	7,100	2 LANE HIGHWAY
2006	SR 9	Mt Vernon Big Lake Rd	Lakeview Dr	230	2	N	2100	0.11	A	45	2,600	2 LANE HIGHWAY
3001	Mt Vernon Rd	Cedardale Rd	I-5 NB off ramp	130	2	N	1656	0.08	A	32	1,400	PRINCIPAL ARTERIAL
3002	Mt Vernon Rd	I-5 NB off ramp	I-5 SB on-ramp	140	2	N	1656	0.08	A	23	1,600	PRINCIPAL ARTERIAL
3003	Mt Vernon Rd	I-5 SB on-ramp	Old SR 99/Hickox Rd	180	2	N	1656	0.11	A	30	2,000	PRINCIPAL ARTERIAL
3004	Old SR 99	Hickox Rd	Anderson Rd	870	2	N	1656	0.53	A	49	9,700	PRINCIPAL ARTERIAL
3005	Old SR 99	Anderson Rd	Blackburn Rd	690	2	Y	1956	0.35	A	41	7,700	PRINCIPAL ARTERIAL
3006	2nd St	Blackburn Rd	3rd St	690	2	Y	1956	0.35	A	21	7,700	PRINCIPAL ARTERIAL
3007	2nd St	3rd St	Hazel St	780	2	Y	1956	0.40	A	21	8,700	PRINCIPAL ARTERIAL
3008	2nd St	Hazel St	Section St	1030	2	N	1656	0.62	B	24	11,400	PRINCIPAL ARTERIAL
3009	2nd St	Section St	Kincaid St	930	2	Y	1677	0.55	A	22	10,300	PRINCIPAL ARTERIAL
3010	2nd St	Kincaid St	Myrtle	750	2	Y	1587	0.47	A	14	8,300	PRINCIPAL ARTERIAL
3011	2nd St	Myrtle	Gates	380	2	Y	1587	0.24	A	12	4,200	PRINCIPAL ARTERIAL
3012	2nd St	Gates	Montgomery	810	2	Y	1587	0.51	A	17	9,000	PRINCIPAL ARTERIAL
3013	2nd St	Montgomery	Fulton St	950	2	Y	1677	0.57	A	21	10,600	PRINCIPAL ARTERIAL
3014	4th St	Fulton St	Fir St	1020	2	Y	1587	0.64	B	19	11,300	PRINCIPAL ARTERIAL
3015	Riverside Dr	Fir St	Roosevelt Ave	1600	4	Y	2649	0.60	B	25	17,800	PRINCIPAL ARTERIAL
3016	Riverside Dr	Roosevelt Ave	College Way	1560	4	Y	2649	0.59	A	19	17,300	PRINCIPAL ARTERIAL
3017	Riverside Dr	College Way	Commercial St	1650	4	Y	2649	0.62	B	19	18,300	PRINCIPAL ARTERIAL
3018	Riverside Dr	Commercial St	Pacific Pl	1580	4	Y	2649	0.60	A	15	17,600	PRINCIPAL ARTERIAL
3019	Riverside Dr	Pacific Pl	Hoag Rd overxing	1990	6	Y	4638	0.43	A	17	22,100	PRINCIPAL ARTERIAL
3020	Riverside Dr	Hoag Rd overxing	Whitmarsh Rd	2570	4	Y	3639	0.71	C	20	28,600	PRINCIPAL ARTERIAL
3021	College Way	Freeway Dr	I-5 SB on/off ramp	1160	2	Y	1371	0.85	D	8	12,900	PRINCIPAL ARTERIAL
3022	College Way	I-5 SB on/off ramp	I-5 NB on/off ramp	1600	2	Y	1371	1.17	F	11	17,800	PRINCIPAL ARTERIAL

3023	College Way	I-5 NB on/off ramp	Market St	2230	4	Y	2649	0.84	D	10	24,800	PRINCIPAL ARTERIAL
3024	College Way	Market St	Riverside Dr	1830	4	Y	2649	0.69	B	12	20,300	PRINCIPAL ARTERIAL
3025	College Way	Riverside Dr	Urban Ave	2060	4	Y	2649	0.78	C	26	22,900	PRINCIPAL ARTERIAL
3026	College Way	Urban Ave	Leigh Way	2260	4	Y	3018	0.75	C	22	25,100	PRINCIPAL ARTERIAL
3027	College Way	Leigh Way	Continental P	2230	4	Y	3153	0.71	C	20	24,800	PRINCIPAL ARTERIAL
3028	College Way	Continental P	18th St	1970	4	Y	3153	0.62	B	22	21,900	PRINCIPAL ARTERIAL
3029	College Way	18th St	Laventure Rd	1720	4	Y	3153	0.55	A	21	19,100	PRINCIPAL ARTERIAL
3030	College Way	Laventure Rd	30th St	1270	4	Y	3153	0.40	A	27	14,100	PRINCIPAL ARTERIAL
3031	College Way	30th St	Waugh Rd	960	4	Y	3639	0.26	A	35	10,700	PRINCIPAL ARTERIAL
3032	College Way	Waugh Rd	Skagit Highlands spine rd	880	2	Y	1956	0.45	A	41	9,800	PRINCIPAL ARTERIAL
3033	College Way	Skagit Highlands spine rd	SR 9	590	2	Y	1956	0.30	A	41	6,600	PRINCIPAL ARTERIAL
3034	Kincaid St	2nd St	3rd St	700	4	N	2718	0.26	A	12	~~7,800~~	PRINCIPAL ARTERIAL
3035	Kincaid St	3rd St	I-5 SB on/off ramps	1660	4	Y	3018	0.55	A	13	18,400	PRINCIPAL ARTERIAL
3036	Kincaid St	I-5 SB on/off ramps	I-5 NB on/off ramps	1530	4	Y	3018	0.51	A	11	17,000	PRINCIPAL ARTERIAL
3037	3rd St	Kincaid St	Myrtle	860	2	N	1656	0.52	A	17	9,600	PRINCIPAL ARTERIAL
3038	3rd St	Myrtle	Gates	1060	2	N	1656	0.64	B	24	11,800	PRINCIPAL ARTERIAL
3039	3rd St	Gates	Montgomery	1090	2	N	1656	0.66	B	24	12,100	PRINCIPAL ARTERIAL
3040	3rd St	Montgomery	Freeway Dr	760	2	Y	1677	0.45	A	18	8,400	PRINCIPAL ARTERIAL
3041	Anderson Rd	Old SR 99	Henson Rd	380	2	Y	1677	0.23	A	23	4,200	PRINCIPAL ARTERIAL
3042	Anderson Rd	Henson Rd	I-5 SB on/off ramps	550	2	N	1656	0.33	A	36	6,100	PRINCIPAL ARTERIAL
3043	Anderson Rd	I-5 SB on/off ramps	I-5 NB on/off ramps	560	2	N	1656	0.34	A	34	6,200	PRINCIPAL ARTERIAL
3044	Anderson Rd	I-5 NB on/off ramps	Cedardale Rd	650	2	N	1656	0.39	A	40	7,200	PRINCIPAL ARTERIAL
3045	Anderson Rd	Cedardale Rd	Blodgett	160	2	N	1656	0.10	A	32	1,800	PRINCIPAL ARTERIAL
3046	Anderson Rd	Blodgett	Laventure Rd extension	0	0	0	#N/A	#N/A	#N/A	32	-	#N/A
3047	Laventure Rd	Laventure Rd extension	Blackburn Rd	0	0	0	#N/A	#N/A	#N/A	30	-	#N/A
3048	Laventure Rd	Blackburn Rd	Section St	0	0	0	#N/A	#N/A	#N/A	28	-	#N/A
3049	Laventure Rd	Section St	E Division St	440	2	Y	1677	0.26	A	24	4,900	PRINCIPAL ARTERIAL
3050	Laventure Rd	E Division St	Fir St	760	2	Y	1677	0.45	A	23	8,400	PRINCIPAL ARTERIAL
3051	Laventure Rd	Fir St	Roosevelt Ave	760	2	Y	1677	0.45	A	23	8,400	PRINCIPAL ARTERIAL
3052	Laventure Rd	Roosevelt Ave	College Way	1060	2	Y	1677	0.63	B	18	11,800	PRINCIPAL ARTERIAL
3053	Laventure Rd	College Way	Hoag Rd	900	2	Y	1677	0.54	A	19	10,000	PRINCIPAL ARTERIAL
3054	blank	blank	blank		0	0	#N/A					#N/A
4001	Freeway Dr	SR 536/Division St	Cameron Way	1090	2	Y	1479	0.74	C	17	12,100	MINOR ARTERIAL
4002	Freeway Dr	Cameron Way	College Way	840	2	Y	1479	0.57	A	25	9,300	MINOR ARTERIAL
4003	Freeway Dr	College Way	Commercial St	760	2	Y	1479	0.51	A	21	8,400	MINOR ARTERIAL
4004	Freeway Dr	Commercial St	Stewart Rd	340	2	Y	1479	0.23	A	21	3,800	MINOR ARTERIAL
4005	Stewart Rd	Freeway Dr	Market St	380	2	N	1179	0.32	A	25	4,200	MINOR ARTERIAL
4006	Stewart Rd	Market St	Riverside off	510	2	N	1179	0.43	A	25	5,700	MINOR ARTERIAL
4007	Stewart Rd	Riverside off	Riverside on	180	2	N	1179	0.15	A	26	2,000	MINOR ARTERIAL
4008	Hoag Rd	Riverside on	Urban Ave	710	2	Y	1479	0.48	A	25	7,900	MINOR ARTERIAL
4009	Hoag Rd	Urban Ave	Continental Pl	890	2	Y	1758	0.51	A	24	9,900	MINOR ARTERIAL
4010	Hoag Rd	Continental Pl	Laventure Rd	850	2	Y	1758	0.48	A	23	~~9,400~~	MINOR ARTERIAL

4011	E Martin Rd	Laventure Rd	30th St	350	2	N	1458	0.24	A	23	3,900	MINOR ARTERIAL
4012	E Martin Rd	30th St	E Martin Rd	80	2	N	1458	0.05	A	24	900	MINOR ARTERIAL
4013	Cameron Way	Freeway Dr	Market St extension	580	2	Y	1479	0.39	A	16	~~6,400~~	MINOR ARTERIAL
4014	Fir St	Market St extension	N 4th St	670	2	Y	1479	0.45	A	18	7,400	MINOR ARTERIAL
4015	Fir St	N 4th St	6th St	830	2	Y	1479	0.56	A	19	~~9,200~~	MINOR ARTERIAL
4016	Fir St	6th St	15th St	930	2	Y	1758	0.53	A	24	10,300	MINOR ARTERIAL
4017	Fir St	15th St	18th St	690	2	Y	1758	0.39	A	22	7,700	MINOR ARTERIAL
4018	Fir St	18th St	Laventure Rd	600	2	Y	1479	0.41	A	22	6,700	MINOR ARTERIAL
4019	Fir St	Laventure Rd	30th St	420	2	Y	1758	0.24	A	23	4,700	MINOR ARTERIAL
4020	Fir St	30th St	Waugh Rd	370	2	N	1458	0.25	A	24	4,100	MINOR ARTERIAL
4021	Fulton St	N 4th St	6th St	540	2	Y	1479	0.37	A	19	6,000	MINOR ARTERIAL
4022	6th St	Fulton St	E Division St	450	2	N	1458	0.31	A	19	5,000	MINOR ARTERIAL
4023	E Division St	6th St	15th St	670	2	N	1458	0.46	A	23	7,400	MINOR ARTERIAL
4024	E Division St	15th St	18th St	950	2	Y	1479	0.64	B	22	10,600	MINOR ARTERIAL
4025	E Division St	18th St	Laventure Rd	930	2	Y	1479	0.63	B	22	10,300	MINOR ARTERIAL
4026	E Division St	Laventure Rd	30th St	720	2	Y	1479	0.49	A	23	8,000	MINOR ARTERIAL
4027	E Division St	30th St	Digby Rd	460	2	Y	1758	0.26	A	25	5,100	MINOR ARTERIAL
4028	E Division St	Digby Rd	Waugh Rd	360	2	N	1458	0.25	A	25	4,000	MINOR ARTERIAL
4029	E Division St	Waugh Rd	Burlingame Rd	250	2	N	1458	0.17	A	25	2,800	MINOR ARTERIAL
4030	Mt Vernon Big Lake Rd	Burlingame Rd	Mountain View Rd	160	2	N	1458	0.11	A	25	1,800	MINOR ARTERIAL
4031	Mt Vernon Big Lake Rd	Mountain View Rd	SR 9	30	2	N	1458	0.02	A	24	300	MINOR ARTERIAL
4032	Broad St	I-5 NB on/off-ramp	Blodgett	1390	4	N	2952	0.47	A	17	15,400	MINOR ARTERIAL
4033	Broad St	9th St	15th St	790	2	N	1458	0.54	A	17	8,800	MINOR ARTERIAL
4034	Section St	15th St	18th St	300	2	N	1458	0.21	A	22	3,300	MINOR ARTERIAL
4035	Section St	18th St	Laventure Rd	610	2	N	1179	0.00	A	0	6,800	MINOR ARTERIAL
4036	Section St	Laventure Rd	30th St	530	2	N	1179	0.45	A	23	5,900	MINOR ARTERIAL
4037	Section St	30th St	Digby Rd	70	2	N	1458	0.05	A	25	800	MINOR ARTERIAL
4038	Blackburn Rd	Old SR 99	Henson Rd	560	2	N	1458	0.38	A	21	6,200	MINOR ARTERIAL
4039	Blackburn Rd	Henson Rd	Cedardale Rd	470	2	N	1458	0.32	A	25	~~5,200~~	MINOR ARTERIAL
4040	Blackburn Rd	Cedardale Rd	15th St	800	2	N	1458	0.55	A	24	8,900	MINOR ARTERIAL
4041	Blackburn Rd	15th St	18th St	670	2	N	1458	0.46	A	25	7,400	MINOR ARTERIAL
4042	Blackburn Rd	18th St	Laventure Rd	280	2	N	1458	0.19	A	35	3,100	MINOR ARTERIAL
4043	Blackburn Rd	Laventure Rd	Little Mtn Rd/30th St	100	2	N	1458	0.07	A	33	1,100	MINOR ARTERIAL
4044	Blackburn Rd extension	Little Mtn Rd/30th St	Waugh Rd extension	0	0	0	#N/A	#N/A	#N/A	32	-	#N/A
4045	Waugh Rd	Division St	Broadway	130	2	N	1458	0.09	A	24	1,400	MINOR ARTERIAL
4046	Waugh Rd	Division St	Fir St	300	2	N	1458	0.21	A	24	3,300	MINOR ARTERIAL
4047	Waugh Rd	Fir St	College Way	320	2	N	1458	0.22	A	22	3,600	MINOR ARTERIAL
4048	E Martin Rd (n-s section)	College Way	E Martin Rd (e-w	150	2	N	1458	0.10	A	24	1,700	MINOR ARTERIAL
4049	Wall St	SR 536 (Memorial Hwy)	McLean Rd	370	2	Y	1758	0.21	A	14	4,100	MINOR ARTERIAL
4050	Conway Rd	Hickox RdOld SR 99	West Stackpole	490	2	N	1458	0.34	A	48	5,400	MINOR ARTERIAL
4051	Conway Rd	West Stackpole	Peter Johnson	490	2	N	1458	0.34	A	50	5,400	MINOR ARTERIAL
4052	Conway Rd	Peter Johnson	Fir Island Rd	480	2	N	1458	0.33	A	48	5,300	MINOR ARTERIAL

4053	Fir Island Rd	Dike Rd	SR 530 (Pioneer Hwy)	650	2	N	1458	0.45	A	25	7,200	MINOR ARTERIAL
4054	SR 530 (Pioneer Hwy)	Fir Island Rd	I-5 SB on/off-ramps	760	2	Y	1758	0.43	A	21	8,400	MINOR ARTERIAL
4055	SR 530 / SR 534	I-5 SB on/off-ramps	I-5 NB on/off-ramps	770	2	Y	1758	0.44	A	24	8,600	MINOR ARTERIAL
4056	SR 534	I-5 NB on/off-ramps	Cedardale Rd	690	2	Y	1758	0.39	A	25	7,700	MINOR ARTERIAL
4057	SR 534	Cedardale Rd	Conway Hill Rd	600	2	N	1458	0.41	A	24	6,700	MINOR ARTERIAL
4058	Section/9th St	Broad St	15th St	120	0	0	#N/A	#N/A	#N/A	9	1,300	#N/A
4059	Broad St	Blodgett	9th St	1300	2	N	1458	0.89	D	20	14,400	MINOR ARTERIAL
4060	McLean	Wall St	west growth boundary	330	2	N	1458	0.23	A	29	3,700	MINOR ARTERIAL
4061	Broadway	Digby Rd	Waugh Rd	60	2	N	1458	0.04	A	24	700	MINOR ARTERIAL
4062	Digby Rd	Section St	Division St	40	2	N	1458	0.03	A	24	400	MINOR ARTERIAL
4063	Waugh Rd extension	Broadway	Blackburn Rd extension	150	0	0	#N/A	#N/A	#N/A	24	1,700	#N/A
5001	Blackburn Rd	Old SR 99	Britt Rd	160	2	N	999	0.16	A	24	1,800	COLLECTOR
5002	Britt Rd	Blackburn Rd	N to Hazel Rd	160	2	N	999	0.16	A	25	1,800	COLLECTOR
5003	Hazel St / Rd / 1st St	Britt Rd	2nd St	390	2	N	999	0.39	A	23	4,300	COLLECTOR
5004	Hazel St	2nd St	3rd St	170	2	N	999	0.17	A	13	1,900	COLLECTOR
5005	Section St	Cleveland	2nd St	110	2	N	999	0.11	A	13	1,200	COLLECTOR
5006	Section St	2nd St	3rd St	70	2	N	999	0.07	A	17	800	COLLECTOR
5007	Section St	3rd St	6th St	160	2	N	999	0.16	A	20	1,800	COLLECTOR
5008	3rd St	Section St	Kincaid St	320	2	Y	1299	0.25	A	19	3,600	COLLECTOR
5009	Cleveland	Section St	Kincaid St	480	2	N	999	0.48	A	23	5,300	COLLECTOR
5010	Kincaid St	Cleveland	2nd St	640	2	Y	1299	0.49	A	14	7,100	COLLECTOR
5011	1st St	Kincaid St	Myrtle	440	2	N	819	0.54	A	20	4,900	COLLECTOR
5012	1st St	Myrtle	Gates	470	2	N	819	0.57	A	19	5,200	COLLECTOR
5013	1st St	Gates	Montgomery	420	2	N	819	0.51	A	20	4,700	COLLECTOR
5014	1st St	Montgomery	SR 536/Division St	600	2	Y	1119	0.54	A	17	6,700	COLLECTOR
5015	N Wall St	SR 536/Division St	N to Dunbar Rd	360	2	N	999	0.36	A	12	4,000	COLLECTOR
5016	Market St	College Way	Commercial St	660	2	Y	1067	0.62	B	16	7,300	COLLECTOR
5017	Market St	Commercial St	Pacific Pl	460	2	Y	1299	0.35	A	0	5,100	COLLECTOR
5018	Market St	Pacific Pl	Stewart Rd	360	2	N	819	0.44	A	0	4,000	COLLECTOR
5019	Pacific Pl	Market St	Riverside Dr	260	2	Y	1119	0.23	A	0	2,900	COLLECTOR
5020	Pacific Pl	Riverside Dr	Urban Ave	310	2	Y	1119	0.28	A	0	3,400	COLLECTOR
5021	Commercial St	Market St	Riverside Dr	160	2	Y	1119	0.14	A	12	1,800	COLLECTOR
5022	Commercial St	Riverside Dr	Urban Ave	210	2	Y	1299	0.16	A	11	2,300	COLLECTOR
5023	Commercial St	Urban Ave	Continental Pl	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5024	Urban Ave	Roosevelt Ave	College Way	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5025	Urban Ave	College Way	Commercial St	300	2	N	999	0.30	A	10	3,300	COLLECTOR
5026	Urban Ave	Commercial St	Pacific Pl	120	2	N	999	0.12	A	0	1,300	COLLECTOR
5027	Urban Ave	Pacific Pl	Hoag Rd	570	2	Y	1299	0.44	A	0	6,300	COLLECTOR
5028	Leigh Way	Roosevelt Ave	College Way	170	2	Y	1119	0.15	A	0	1,900	COLLECTOR
5029	Continental Pl	Roosevelt Ave	College Way	310	2	Y	1119	0.28	A	13	3,400	COLLECTOR
5030	Continental Pl	College Way	Commercial St	270	2	Y	1119	0.24	A	12	3,000	COLLECTOR
5031	Continental Pl	Commercial St	Hoag Rd	220	2	Y	1119	0.20	A	14	2,400	COLLECTOR

5032	Roosevelt Ave	Riverside Dr	Urban Ave	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5033	Roosevelt Ave	Urban Ave	Leigh Way	440	2	Y	1299	0.34	A	14	4,900	COLLECTOR
5034	Roosevelt Ave	Leigh Way	Continental P	270	2	Y	1299	0.21	A	25	3,000	COLLECTOR
5035	Roosevelt Ave	Continental P	18th St	300	2	Y	1299	0.23	A	20	3,300	COLLECTOR
5036	Roosevelt Ave	18th St	Laventure Rd	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5037	15th St	Blackburn Rd	Section St	40	2	N	819	0.05	A	12	400	COLLECTOR
5038	15th St	Section St	Broad St	470	2	N	819	0.57	A	18	5,200	COLLECTOR
5039	15th St	Broad St	E Division St	570	2	Y	1119	0.51	A	20	6,300	COLLECTOR
5040	15th St	E Division St	Fir St	250	2	N	819	0.31	A	21	2,800	COLLECTOR
5041	18th St	Blackburn Rd	Section St	690	2	N	999	0.69	B	19	7,700	COLLECTOR
5042	18th St	Section St	E Division St	440	2	Y	1299	0.34	A	19	4,900	COLLECTOR
5043	18th St	E Division St	Fir St	580	2	Y	1119	0.52	A	18	6,400	COLLECTOR
5044	18th St	Fir St	Roosevelt Ave	660	2	N	999	0.66	B	23	7,300	COLLECTOR
5045	18th St	Roosevelt Ave	College Way	630	2	Y	1119	0.56	A	19	7,000	COLLECTOR
5046	N Laventure Rd	Hoag Rd	30th St extension	660	2	Y	1299	0.51	A	25	7,300	COLLECTOR
5047	30th St	Blackburn Rd	Section St	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5048	30th St	Section St	Division St	60	2	N	999	0.06	A	14	700	COLLECTOR
5049	30th St	Division St	Fir St	160	2	N	999	0.16	A	18	1,800	COLLECTOR
5050	30th St	Fir St	College Way	300	2	N	999	0.30	A	18	3,300	COLLECTOR
5051	30th St	College Way	Martin Rd	50	0	0	#N/A	#N/A	#N/A	12	600	#N/A
5052	30th St	Martin Rd	Francis Rd	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5053	Francis Rd	30th St	Swan Rd	120	2	N	999	0.12	A	29	1,300	COLLECTOR
5054	Little Mtn Rd	West Big Lk R	Andal Rd extension	60	2	N	999	0.06	A	29	700	COLLECTOR
5055	Little Mtn Rd	Andal Rd extension	E Hickox Rd Ext	100	2	N	999	0.10	A	30	1,100	COLLECTOR
5056	Little Mtn Rd	E Hickox Rd Ext	Blackburn Rd	100	2	N	999	0.10	A	29	1,100	COLLECTOR
5057	Mountain View	Andal Rd	Mt Vernon Big Lake Rd	80	2	N	999	0.08	A	30	900	COLLECTOR
5058	Cedardale Rd	Mt Vernon Rd	Hickox Rd	60	2	N	999	0.06	A	45	700	COLLECTOR
5059	Cedardale Rd	Hickox Rd	Anderson Rd	120	2	N	999	0.12	A	35	1,300	COLLECTOR
5060	Cedardale Rd	Anderson Rd	Blodgett	400	2	N	999	0.40	A	32	4,400	COLLECTOR
5061	E Hickox Rd	Cedardale Rd	Burkland Rd	90	2	N	999	0.09	A	34	1,000	COLLECTOR
5062	E Hickox Rd	Burkland Rd	Blodgett	40	2	N	999	0.04	A	32	400	COLLECTOR
5063	E Hickox Rd	Blodgett	East Stackpole	20	2	N	999	0.02	A	34	200	COLLECTOR
5064	E Hickox Rd Ext	East Stackpole	Little Mtn Rd	0	0	0	#N/A	#N/A	#N/A	5	-	#N/A
5065	Blodgett	E Hickox Rd	Anderson Rd	100	2	N	999	0.10	A	34	1,100	COLLECTOR
5066	Blodgett	Anderson Rd	Cedardale Rd	160	2	N	999	0.16	A	14	1,800	COLLECTOR
5067	Hickox Rd	Dike Rd	Old SR 99	20	2	N	999	0.02	A	32	200	COLLECTOR
5068	West Stackpol	Dike Rd	Conway Rd	10	2	N	999	0.01	A	33	100	COLLECTOR
5069	Peter Johnson	Dike Rd	Conway Rd	10	2	N	999	0.01	A	33	100	COLLECTOR
5070	East Stackpol	Cedardale Rd	Burkland Rd	0	2	N	999	0.00	A	33	-	COLLECTOR
5071	East Johnson	Cedardale Rd	Burkland Rd	40	2	N	999	0.04	A	33	400	COLLECTOR
5072	Dike Rd	Britt Rd (north end)	Hickox Rd	40	2	N	999	0.04	A	33	400	COLLECTOR
5073	Dike Rd	Hickox Rd	West Stackpole	10	2	N	999	0.01	A	33	100	COLLECTOR

5074	Dike Rd	West Stackpole	Peter Johnson	10	2	N	999	0.01	A	33	100	COLLECTOR
5075	Cedardale Rd	Mt Vernon Rd	East Stackpole	30	2	N	999	0.03	A	33	300	COLLECTOR
5076	Cedardale Rd	East Stackpole	East Johnson	30	2	N	999	0.03	A	33	300	COLLECTOR
5077	Cedardale Rd	East Johnson	SR 534	60	2	N	999	0.06	A	33	700	COLLECTOR
5078	Blodgett	Cedardale Rd	Blackburn Rd	400	2	N	999	0.40	A	33	4,400	COLLECTOR
5079	Roosevelt Ave	Riverside Dr	new frontage rd	400	0	0	#N/A	#N/A	#N/A	33	4,400	#N/A
5080	new frontage rd	Roosevelt Ave	Cameron Way	0	0	0	#N/A	#N/A	#N/A	33	-	#N/A
5081	South Andal Rd	Mountain View Rd	Little Mtn Rd	40	0	0	#N/A	#N/A	#N/A	33	400	#N/A
5082	Skagit Highlands Spine Rd	Burlingame & Division	College Way	0	0	0	#N/A	#N/A	#N/A	33	-	#N/A
5083	Dike Rd	Peter Johnson Rd	Fir Island Rd	20	2	N	999	0.02	A	33	200	COLLECTOR

4011	E Martin Rd	Laventure Rd	30th St	350	2	N	1458	0.24	A	23	3,900	MINOR ARTERIAL
4012	E Martin Rd	30th St	E Martin Rd	80	2	N	1458	0.05	A	24	900	MINOR ARTERIAL
4013	Cameron Way	Freeway Dr	Market St extension	580	2	Y	1479	0.39	A	16	6,400	MINOR ARTERIAL
4014	Fir St	Market St extension	N 4th St	670	2	Y	1479	0.45	A	18	7,400	MINOR ARTERIAL
4015	Fir St	N 4th St	6th St	830	2	Y	1479	0.56	A	19	9,200	MINOR ARTERIAL
4016	Fir St	6th St	15th St	930	2	Y	1758	0.53	A	24	10,300	MINOR ARTERIAL
4017	Fir St	15th St	18th St	690	2	Y	1758	0.39	A	22	7,700	MINOR ARTERIAL
4018	Fir St	18th St	Laventure Rd	600	2	Y	1479	0.41	A	22	6,700	MINOR ARTERIAL
4019	Fir St	Laventure Rd	30th St	420	2	Y	1758	0.24	A	23	4,700	MINOR ARTERIAL
4020	Fir St	30th St	Waugh Rd	370	2	N	1458	0.25	A	24	4,100	MINOR ARTERIAL
4021	Fulton St	N 4th St	6th St	540	2	Y	1479	0.37	A	19	6,000	MINOR ARTERIAL
4022	6th St	Fulton St	E Division St	450	2	N	1458	0.31	A	19	5,000	MINOR ARTERIAL
4023	E Division St	6th St	15th St	670	2	N	1458	0.46	A	23	7,400	MINOR ARTERIAL
4024	E Division St	15th St	18th St	950	2	Y	1479	0.64	B	22	10,600	MINOR ARTERIAL
4025	E Division St	18th St	Laventure Rd	930	2	Y	1479	0.63	B	22	10,300	MINOR ARTERIAL
4026	E Division St	Laventure Rd	30th St	720	2	Y	1479	0.49	A	23	8,000	MINOR ARTERIAL
4027	E Division St	30th St	Digby Rd	460	2	Y	1758	0.26	A	25	5,100	MINOR ARTERIAL
4028	E Division St	Digby Rd	Waugh Rd	360	2	N	1458	0.25	A	25	4,000	MINOR ARTERIAL
4029	E Division St	Waugh Rd	Burlingame Rd	250	2	N	1458	0.17	A	25	2,800	MINOR ARTERIAL
4030	Mt Vernon Big Lake Rd	Burlingame Rd	Mountain View Rd	160	2	N	1458	0.11	A	25	1,800	MINOR ARTERIAL
4031	Mt Vernon Big Lake Rd	Mountain View Rd	SR 9	30	2	N	1458	0.02	A	24	300	MINOR ARTERIAL
4032	Broad St	I-5 NB on/off-ramp	Blodgett	1390	4	N	2952	0.47	A	17	15,400	MINOR ARTERIAL
4033	Broad St	9th St	15th St	790	2	N	1458	0.54	A	17	8,800	MINOR ARTERIAL
4034	Section St	15th St	18th St	300	2	N	1458	0.21	A	22	3,300	MINOR ARTERIAL
4035	Section St	18th St	Laventure Rd	610	2	N	1179	0.00	A	0	6,800	MINOR ARTERIAL
4036	Section St	Laventure Rd	30th St	530	2	N	1179	0.45	A	23	5,900	MINOR ARTERIAL
4037	Section St	30th St	Digby Rd	70	2	N	1458	0.05	A	25	800	MINOR ARTERIAL
4038	Blackburn Rd	Old SR 99	Henson Rd	560	2	N	1458	0.38	A	21	6,200	MINOR ARTERIAL
4039	Blackburn Rd	Henson Rd	Cedardale Rd	470	2	N	1458	0.32	A	25	5,200	MINOR ARTERIAL
4040	Blackburn Rd	Cedardale Rd	15th St	800	2	N	1458	0.55	A	24	8,900	MINOR ARTERIAL
4041	Blackburn Rd	15th St	18th St	670	2	N	1458	0.46	A	25	7,400	MINOR ARTERIAL
4042	Blackburn Rd	18th St	Laventure Rd	280	2	N	1458	0.19	A	35	3,100	MINOR ARTERIAL
4043	Blackburn Rd	Laventure Rd	Little Mtn Rd/30th St	100	2	N	1458	0.07	A	33	1,100	MINOR ARTERIAL
4044	Blackburn Rd extension	Little Mtn Rd/30th St	Waugh Rd extension	0	0	0	#N/A	#N/A	#N/A	32	-	#N/A
4045	Waugh Rd	Division St	Broadway	130	2	N	1458	0.09	A	24	1,400	MINOR ARTERIAL
4046	Waugh Rd	Division St	Fir St	300	2	N	1458	0.21	A	24	3,300	MINOR ARTERIAL
4047	Waugh Rd	Fir St	College Way	320	2	N	1458	0.22	A	22	3,600	MINOR ARTERIAL
4048	E Martin Rd (n-s section)	College Way	E Martin Rd (e-w	150	2	N	1458	0.10	A	24	1,700	MINOR ARTERIAL
4049	Wall St	SR 536 (Memorial Hwy)	McLean Rd	370	2	Y	1758	0.21	A	14	4,100	MINOR ARTERIAL
4050	Conway Rd	Hickox RdOld SR 99	West Stackpole	490	2	N	1458	0.34	A	48	5,400	MINOR ARTERIAL
4051	Conway Rd	West Stackpole	Peter Johnson	490	2	N	1458	0.34	A	50	5,400	MINOR ARTERIAL
4052	Conway Rd	Peter Johnson	Fir Island Rd	480	2	N	1458	0.33	A	48	5,300	MINOR ARTERIAL

4053	Fir Island Rd	Dike Rd	SR 530 (Pioneer Hwy)	650	2	N	1458	0.45	A	25	7,200	MINOR ARTERIAL
4054	SR 530 (Pioneer Hwy)	Fir Island Rd	I-5 SB on/off-ramps	760	2	Y	1758	0.43	A	21	8,400	MINOR ARTERIAL
4055	SR 530 / SR 534	I-5 SB on/off-ramps	I-5 NB on/off-ramps	770	2	Y	1758	0.44	A	24	8,600	MINOR ARTERIAL
4056	SR 534	I-5 NB on/off-ramps	Cedardale Rd	690	2	Y	1758	0.39	A	25	7,700	MINOR ARTERIAL
4057	SR 534	Cedardale Rd	Conway Hill Rd	600	2	N	1458	0.41	A	24	6,700	MINOR ARTERIAL
4058	Section/9th St	Broad St	15th St	120	0	0	#N/A	#N/A	#N/A	9	1,300	#N/A
4059	Broad St	Blodgett	9th St	1300	2	N	1458	0.89	D	20	14,400	MINOR ARTERIAL
4060	McLean	Wall St	west growth boundary	330	2	N	1458	0.23	A	29	3,700	MINOR ARTERIAL
4061	Broadway	Digby Rd	Waugh Rd	60	2	N	1458	0.04	A	24	700	MINOR ARTERIAL
4062	Digby Rd	Section St	Division St	40	2	N	1458	0.03	A	24	400	MINOR ARTERIAL
4063	Waugh Rd extension	Broadway	Blackburn Rd extension	150	0	0	#N/A	#N/A	#N/A	24	1,700	#N/A
5001	Blackburn Rd	Old SR 99	Britt Rd	160	2	N	999	0.16	A	24	1,800	COLLECTOR
5002	Britt Rd	Blackburn Rd	N to Hazel Rd	160	2	N	999	0.16	A	25	1,800	COLLECTOR
5003	Hazel St / Rd / 1st St	Britt Rd	2nd St	390	2	N	999	0.39	A	23	4,300	COLLECTOR
5004	Hazel St	2nd St	3rd St	170	2	N	999	0.17	A	13	1,900	COLLECTOR
5005	Section St	Cleveland	2nd St	110	2	N	999	0.11	A	13	1,200	COLLECTOR
5006	Section St	2nd St	3rd St	70	2	N	999	0.07	A	17	800	COLLECTOR
5007	Section St	3rd St	6th St	160	2	N	999	0.16	A	20	1,800	COLLECTOR
5008	3rd St	Section St	Kincaid St	320	2	Y	1299	0.25	A	19	3,600	COLLECTOR
5009	Cleveland	Section St	Kincaid St	480	2	N	999	0.48	A	23	5,300	COLLECTOR
5010	Kincaid St	Cleveland	2nd St	640	2	Y	1299	0.49	A	14	7,100	COLLECTOR
5011	1st St	Kincaid St	Myrtle	440	2	N	819	0.54	A	20	4,900	COLLECTOR
5012	1st St	Myrtle	Gates	470	2	N	819	0.57	A	19	5,200	COLLECTOR
5013	1st St	Gates	Montgomery	420	2	N	819	0.51	A	20	4,700	COLLECTOR
5014	1st St	Montgomery	SR 536/Division St	600	2	Y	1119	0.54	A	17	6,700	COLLECTOR
5015	N Wall St	SR 536/Division St	N to Dunbar Rd	360	2	N	999	0.36	A	12	4,000	COLLECTOR
5016	Market St	College Way	Commercial St	660	2	Y	1067	0.62	B	16	7,300	COLLECTOR
5017	Market St	Commercial St	Pacific Pl	460	2	Y	1299	0.35	A	0	5,100	COLLECTOR
5018	Market St	Pacific Pl	Stewart Rd	360	2	N	819	0.44	A	0	4,000	COLLECTOR
5019	Pacific Pl	Market St	Riverside Dr	260	2	Y	1119	0.23	A	0	2,900	COLLECTOR
5020	Pacific Pl	Riverside Dr	Urban Ave	310	2	Y	1119	0.28	A	0	3,400	COLLECTOR
5021	Commercial St	Market St	Riverside Dr	160	2	Y	1119	0.14	A	12	1,800	COLLECTOR
5022	Commercial St	Riverside Dr	Urban Ave	210	2	Y	1299	0.16	A	11	2,300	COLLECTOR
5023	Commercial St	Urban Ave	Continental Pl	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5024	Urban Ave	Roosevelt Ave	College Way	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5025	Urban Ave	College Way	Commercial St	300	2	N	999	0.30	A	10	3,300	COLLECTOR
5026	Urban Ave	Commercial St	Pacific Pl	120	2	N	999	0.12	A	0	1,300	COLLECTOR
5027	Urban Ave	Pacific Pl	Hoag Rd	570	2	Y	1299	0.44	A	0	6,300	COLLECTOR
5028	Leigh Way	Roosevelt Ave	College Way	170	2	Y	1119	0.15	A	0	1,900	COLLECTOR
5029	Continental Pl	Roosevelt Ave	College Way	310	2	Y	1119	0.28	A	13	3,400	COLLECTOR
5030	Continental Pl	College Way	Commercial St	270	2	Y	1119	0.24	A	12	3,000	COLLECTOR
5031	Continental Pl	Commercial St	Hoag Rd	220	2	Y	1119	0.20	A	14	2,400	COLLECTOR

5032	Roosevelt Ave	Riverside Dr	Urban Ave	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5033	Roosevelt Ave	Urban Ave	Leigh Way	440	2	Y	1299	0.34	A	14	4,900	COLLECTOR
5034	Roosevelt Ave	Leigh Way	Continental P	270	2	Y	1299	0.21	A	25	3,000	COLLECTOR
5035	Roosevelt Ave	Continental P	18th St	300	2	Y	1299	0.23	A	20	3,300	COLLECTOR
5036	Roosevelt Ave	18th St	Laventure Rd	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5037	15th St	Blackburn Rd	Section St	40	2	N	819	0.05	A	12	400	COLLECTOR
5038	15th St	Section St	Broad St	470	2	N	819	0.57	A	18	5,200	COLLECTOR
5039	15th St	Broad St	E Division St	570	2	Y	1119	0.51	A	20	6,300	COLLECTOR
5040	15th St	E Division St	Fir St	250	2	N	819	0.31	A	21	2,800	COLLECTOR
5041	18th St	Blackburn Rd	Section St	690	2	N	999	0.69	B	19	7,700	COLLECTOR
5042	18th St	Section St	E Division St	440	2	Y	1299	0.34	A	19	4,900	COLLECTOR
5043	18th St	E Division St	Fir St	580	2	Y	1119	0.52	A	18	6,400	COLLECTOR
5044	18th St	Fir St	Roosevelt Ave	660	2	N	999	0.66	B	23	7,300	COLLECTOR
5045	18th St	Roosevelt Ave	College Way	630	2	Y	1119	0.56	A	19	7,000	COLLECTOR
5046	N Laventure Rd	Hoag Rd	30th St extension	660	2	Y	1299	0.51	A	25	7,300	COLLECTOR
5047	30th St	Blackburn Rd	Section St	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5048	30th St	Section St	Division St	60	2	N	999	0.06	A	14	700	COLLECTOR
5049	30th St	Division St	Fir St	160	2	N	999	0.16	A	18	1,800	COLLECTOR
5050	30th St	Fir St	College Way	300	2	N	999	0.30	A	18	3,300	COLLECTOR
5051	30th St	College Way	Martin Rd	50	0	0	#N/A	#N/A	#N/A	12	600	#N/A
5052	30th St	Martin Rd	Francis Rd	0	0	0	#N/A	#N/A	#N/A	1	-	#N/A
5053	Francis Rd	30th St	Swan Rd	120	2	N	999	0.12	A	29	1,300	COLLECTOR
5054	Little Mtn Rd	West Big Lk R	Andal Rd extension	60	2	N	999	0.06	A	29	700	COLLECTOR
5055	Little Mtn Rd	Andal Rd extension	E Hickox Rd Ext	100	2	N	999	0.10	A	30	1,100	COLLECTOR
5056	Little Mtn Rd	E Hickox Rd Ext	Blackburn Rd	100	2	N	999	0.10	A	29	1,100	COLLECTOR
5057	Mountain View	Andal Rd	Mt Vernon Big Lake Rd	80	2	N	999	0.08	A	30	900	COLLECTOR
5058	Cedardale Rd	Mt Vernon Rd	Hickox Rd	60	2	N	999	0.06	A	45	700	COLLECTOR
5059	Cedardale Rd	Hickox Rd	Anderson Rd	120	2	N	999	0.12	A	35	1,300	COLLECTOR
5060	Cedardale Rd	Anderson Rd	Blodgett	400	2	N	999	0.40	A	32	4,400	COLLECTOR
5061	E Hickox Rd	Cedardale Rd	Burkland Rd	90	2	N	999	0.09	A	34	1,000	COLLECTOR
5062	E Hickox Rd	Burkland Rd	Blodgett	40	2	N	999	0.04	A	32	400	COLLECTOR
5063	E Hickox Rd	Blodgett	East Stackpole	20	2	N	999	0.02	A	34	200	COLLECTOR
5064	E Hickox Rd Ext	East Stackpole	Little Mtn Rd	0	0	0	#N/A	#N/A	#N/A	5	-	#N/A
5065	Blodgett	E Hickox Rd	Anderson Rd	100	2	N	999	0.10	A	34	1,100	COLLECTOR
5066	Blodgett	Anderson Rd	Cedardale Rd	160	2	N	999	0.16	A	14	1,800	COLLECTOR
5067	Hickox Rd	Dike Rd	Old SR 99	20	2	N	999	0.02	A	32	200	COLLECTOR
5068	West Stackpol	Dike Rd	Conway Rd	10	2	N	999	0.01	A	33	100	COLLECTOR
5069	Peter Johnson	Dike Rd	Conway Rd	10	2	N	999	0.01	A	33	100	COLLECTOR
5070	East Stackpol	Cedardale Rd	Burkland Rd	0	2	N	999	0.00	A	33	-	COLLECTOR
5071	East Johnson	Cedardale Rd	Burkland Rd	40	2	N	999	0.04	A	33	400	COLLECTOR
5072	Dike Rd	Britt Rd (north end)	Hickox Rd	40	2	N	999	0.04	A	33	400	COLLECTOR
5073	Dike Rd	Hickox Rd	West Stackpole	10	2	N	999	0.01	A	33	100	COLLECTOR

5074	Dike Rd	West Stackpole	Peter Johnson	10	2	N	999	0.01	A	33	100	COLLECTOR
5075	Cedardale Rd	Mt Vernon Rd	East Stackpole	30	2	N	999	0.03	A	33	300	COLLECTOR
5076	Cedardale Rd	East Stackpole	East Johnson	30	2	N	999	0.03	A	33	300	COLLECTOR
5077	Cedardale Rd	East Johnson	SR 534	60	2	N	999	0.06	A	33	700	COLLECTOR
5078	Blodgett	Cedardale Rd	Blackburn Rd	400	2	N	999	0.40	A	33	4,400	COLLECTOR
5079	Roosevelt Ave	Riverside Dr	new frontage rd	400	0	0	#N/A	#N/A	#N/A	33	4,400	#N/A
5080	new frontage rd	Roosevelt Ave	Cameron Way	0	0	0	#N/A	#N/A	#N/A	33	-	#N/A
5081	South Andal Rd	Mountain View Rd	Little Mtn Rd	40	0	0	#N/A	#N/A	#N/A	33	400	#N/A
5082	Skagit Highlands Spine Rd	Burlingame & Division	College Way	0	0	0	#N/A	#N/A	#N/A	33	-	#N/A
5083	Dike Rd	Peter Johnson Rd	Fir Island Rd	20	2	N	999	0.02	A	33	200	COLLECTOR

Transportation Element Information

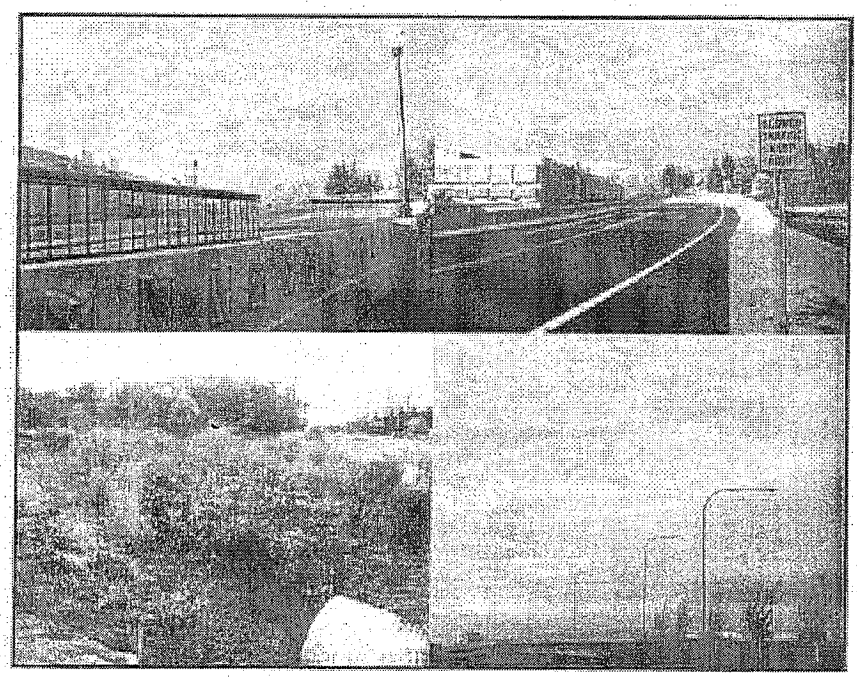
The City of Mount Vernon

Transportation Element Comprehensive Plan

MAYOR Bud Norris

COUNCIL Glenn Ash, Kathy Combs, Joe Lindquist, Robert Fiedler, John Cheney, Dale Ragan, Scott McMullan

PUBLIC WORKS DIRECTOR Esco Bell



Prepared by:

City of Mount Vernon
1024 Cleveland
P.O. Box 809
Mount Vernon, WA 98273

Updated January 2008

Policy T-2.1.1 Land use patterns should support transit and non-motorized modes of travel by encouraging higher density in selected residential and employment areas.

Policy T-2.1.2 Consultation with Skagit Transit is encouraged in order to evaluate the need for and location of new transit stops in large scale developments.

Policy T-2.1.4 The City should take an active role in working with the regional transit agencies in planning and locating public transit facilities.

Goal 3: Maintain, enhance, and increase pedestrian and bicycle travel by providing safe and convenient routes for the commuting and recreating public.

Objective T-3.1 Provide a non-motorized transportation system which effectively serves the needs of pedestrian and bicycle users and encourages non-motorized travel and provides a continuous network of attractive sidewalks, footpaths, bike routes, pathways, and trails throughout the City.

Policy T-3.1.1 Encourage pedestrian and bicycle connections between residential developments, neighborhood commercial centers, recreation areas. Use incentives or regulations to encourage new construction to promote pedestrian and bicycle connections to schools, parks, community centers, public transit services and facilities, neighborhoods and other services.

Policy T-3.1.3 Establish a network of bicycle routes within the City to connect those land uses likely to produce significant concentrations of bicycle usage. Work with interested parties in the planning of such a network.

Policy T-3.1.4 Improve the safety of crossings for pedestrians and bicycles where streets intersect with rail facilities, trails, paths and all areas where pedestrians and/or bicycle movements are encouraged.

Policy T-3.1.5 Whenever practical, provide safe access for pedestrians and bicyclists to transit stops.

Policy T-3.1.6 Seek to develop a comprehensive pedestrian and bicycle signage program that provides directional information, identification of on/off street routes, and a printed non-motorized facilities map.

Goal 4: Maintain and improve truck and freight rail access to industrial areas.

Objective T-4.1 Provide adequate infrastructure to facilitate the movement of freight to and from designated commercial and industrial areas.

Policy T-4.1.1 Promote freight mobility projects in and around the Mount Vernon UGA that facilitate the development of economically viable and environmentally sustainable commercial and industrial areas.

Goal 5: Develop a funding and implementation program for needed transportation improvements that supports adopted land use policies and appropriately distributes transportation costs between public agencies and private development.

Objective T-5.1 Effectively pursue adequate funding for transportation improvements from all potential sources.

Policy T-5.1.1 Consider creating funding mechanisms that can be applied across boundaries to address the impact of growth outside the city limits on the City's transportation system.

Objective T-5.2 Prepare a transportation financing plan that optimizes the use of City funds and leverages other funding sources.

Policy T-5.2.1 Aggressively seek available Federal, State and local government funding opportunities for projects that meet the City's transportation objectives.

Policy T-5.2.2 When appropriate, require new and expanded developments to construct, or participate in the funding to upgrade, roadways to City standards.

Policy T-5.2.3 Allow for funding of growth-related traffic improvements proportionately by impact fees or other mechanisms that apportion costs in relation to impact charged to new development.

Goal 6: Develop and maintain relationships between the City and other agencies and local jurisdictions for cooperative planning of common transportation improvements, and discussion of transportation-related interests.

Objective 6.1 Proactively work with the state and neighboring jurisdictions to provide capacity on regional transportation systems and to reduce regional traffic on local streets.

Policy T-6.1.1 Establish a mechanism to provide multi-jurisdictional cooperation to fund transportation improvements, participate in joint ventures and promote improvement of inter-jurisdictional transportation systems to mitigate transportation impacts that occur beyond the permitting jurisdiction.

Policy T-6.1.2 Continue active participation and leadership in the Regional Transportation Planning Organization (RTPO) and the Metropolitan Planning Organization (MPO).

CHAPTER 2. ARTERIAL STREET PLAN

The basis for the arterial street plan for the City of Mount Vernon is maximizing the use of the existing system and providing facilities to serve the forecasted population and employment growth over the next 20 years. This chapter provides a description of the arterial street plan. This chapter also describes the transportation model, which was a principle tool used to analyze the future travel needs based on forecasted land use, population, and employment conditions. The area analyzed was the urban growth boundary, coordinated with the Skagit County regional transportation systems. A number of elements constitute the arterial street plan:

- Functional classification of arterial streets
- Standard street sections
- Existing road evaluation
- Future improvements (discussed further in Chapter 4)

The arterial street system in the City of Mount Vernon is substantially impacted by the Washington State highway system. In order to effectively evaluate the future needs of the City's facilities, assumptions have been made with respect to the improvements that will be needed on the Washington State highways. The following factors have been used in evaluating needs and determining improvements within the City:

1. The interchanges serving the City at Kincaid Street and College Way will be improved to provide the capacity needed to serve the local arterial streets.

2. The other highways, SR 536 and SR 538 will be improved jointly with the State. On these routes, the City is responsible for network improvements and the State is responsible for pavement preservation. This will require close schedule coordination between the agencies.

3. The I-5 corridor through the City will be widened to 3 continuous general purpose lanes in each direction by the year 2025. This assumption improves the functionality of the City street network.

2.1 ARTERIAL STREET SYSTEM

The backbone of the City's transportation system is the arterial street plan. Based on the anticipated future travel needs, this system has been defined and is shown in Figures 2.1 and 2.2. The streets are classified based on the function that the street provides. The functional classification system is a uniform method used by the State of Washington and the Federal Highway Administration to describe the street's function.

2.1.1 Functional Classification

Table 2.1 shows the functional classification of the City's transportation system's arterials. Figures 2.1 and 2.2 show the functional classification of the arterial street system in the City of Mount Vernon.

Accident History Data

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0906201
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0906201

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084758W	09/06/06	10:20 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
STANWOOD	NORTHWEST	SKAGIT	53	WA

11. City *(if in a city)* MOUNT VERNON — 12. Highway Name or No. 4TH ST N/RVRSD DR — ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 5

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 1

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 75 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 1

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN

27. FRA Track Class: 4

28. Number of Locomotive Units: 3

29. Number of Cars: 100

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 31 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 01 02

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age: 67

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 1

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users		1
49. Railroad Employees		
52. Passengers on Train		

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 2

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 102853
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084741T	11/27/06	08:18 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MOUNT VERNON,	PAC	SKAGIT	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
MOUNT VERNON	CITY ST; SECTION ST	☑ Public ☐ Private

Highway User Involved

13. Type — Code: A
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — Code: 4
1. North 2. South 3. East 4. West

16. Position — Code: 1
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*	22. Visibility *(single entry)*	Code	23. Weather *(single entry)*	Code
20 °F	1. Dawn 2. Day 3. Dusk 4. Dark	4	1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow	6

24. Type of Equipment Consist *(single entry)*	Code	25. Track Type Used by Rail Equipment Involved	Code	26. Track Number or Name
A. Spec. MoW Equip 1. Freight train 4. Work train 7. Yard/Switching 2. Passenger train 5. Single car 8. Light loco(s) 3. Commuter train 6. Cut of cars 9. Main./inspect. car	2	1. Main 2. Yard 3. Siding 4. Industry	1	MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
4	2	13	R. Recorded E. Estimated 79 mph	R	1. North 2. South 3. East 4. West	1

32. Type of Crossing Warning	Code(s)	33. Signaled Crossing Warning	34. Whistle Ban	Code
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew 2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)* 3. Standard FLS 6. Audible 9. Watchman 12. None	01 02	20 sec warn min (1);	1. Yes 2. No 3. Unknown	2

35. Location of Warning	Code	36. Crossing Warning Interconnected with Highway Signals	Code	37. Crossing Illuminated by Street Lights or Special Lights	Code
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach	1	1. Yes 2. No 3. Unknown	3	1. Yes 2. No 3. Unknown	1

38. Driver's Age	39. Driver's Gender	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train	Code	41. Driver	Code
	1. Male 2. Female		1. Yes 2. No 3. Unknown	2	1. Drove around or thru the gate 4. Stopped on crossing 2. Stopped and then proceeded 5. Other *(specify)* 3. Did not stop	4

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown	Code	43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)* 2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed	Code
	2		8

Casualties to:	Killed	Injured	44. Driver was 1. Killed 2. Injured 3. Uninjured	Code	45. Was Driver in the Vehicle? 1. Yes 2. No	Code
				3		2
46. Highway-Rail Crossing Users	0	0	47. Highway Vehicle Property Damage *(est. dollar damage)*	$8,000	48. Total Number of Highway-Rail Crossing Users *(include driver)*	0
49. Railroad Employees	0	0	50. Total Number of People on Train *(include passengers and crew)*	137	51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No	Code 2
52. Passengers on Train	0	0				

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

TRAIN NO.#516 OPERATING WITH LOCOMOTIVE E/25, 13 CARS, AND LOCOMOTIVE 89 TRAILING, STRUCK AN UNOCCUPIED VEHICLE AT MP67.6, SECTION ST CROSSING.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 103259
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084733B	01/15/07	08:03 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MOUNT VERNON	PAC	SKAGIT	53	WA

11. City *(if in a city)* | 12. Highway Name or No. CO80240; SPRUCE ST. | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* (1. North 2. South 3. East 4. West) — Code: 2

16. Position (1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped) — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? (1. Highway User 2. Rail Equipment 3. Both 4. Neither) — Code: 4

Rail Equipment Involved

17. Equipment (1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL) — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance (1. Rail equipment struck highway user 2. Rail equipment struck by highway user) — Code: 1

20b. Was there a hazardous materials release by (1. Highway User 2. Rail Equipment 3. Both 4. Neither) — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 37 °F

22. Visibility *(single entry)* (1. Dawn 2. Day 3. Dusk 4. Dark) — Code: 4

23. Weather *(single entry)* (1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow) — Code: 1

24. Type of Equipment Consist *(single entry)* (1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching A. Spec. MoW Equip 8. Light loco(s) 9. Main./inspect. car) — Code: 2

25. Track Type Used by Rail Equipment Involved (1. Main 2. Yard 3. Siding 4. Industry) — Code: 1

26. Track Number or Name: MAIN TRACK

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction (1. North 2. South 3. East 4. West)	Code
4	2	13	R. Recorded E. Estimated 79 mph	R	1	1

32. Type of Crossing Warning (1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None)

Code(s): 01 | 03 | 07

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban (1. Yes 2. No 3. Unknown) — Code: 2

35. Location of Warning (1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach) — Code: 1

36. Crossing Warning Interconnected with Highway Signals (1. Yes 2. No 3. Unknown) — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights (1. Yes 2. No 3. Unknown) — Code: 2

38. Driver's Age: 51

39. Driver's Gender (1. Male 2. Female) — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train (1. Yes 2. No 3. Unknown) — Code: 2

41. Driver (1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*) — Code: 4

42. Driver Passed Standing Highway Vehicle (1. Yes 2. No 3. Unknown) — Code: 3

43. View of Track Obscured by *(primary obstruction)* (1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed) — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was (1. Killed 2. Injured 3. Uninjured) — Code: 3

45. Was Driver in the Vehicle? (1. Yes 2. No) — Code: 2

47. Highway Vehicle Property Damage *(est. dollar damage)*: $10,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*: 126

51. Is a Rail Equipment Accident / Incident Report Being Filed (1. Yes 2. No) — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

TRAIN NO.#516 OPERATING WITH LOCOMOTIVE E/465, 13 CARS, AND LOCOMOTIVE E/469 IN THE REAR STRUCK AN AUTOMOBILE THAT STALLED ON THE TRACKS AT MP62.5, SPRUCE ST CROSSING.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1110203
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1110203

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084746C	11/19/10	01:47 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MT VERNON	NORTHWEST	SKAGIT	53	WA

11. City *(if in a city)*: MOUNT VERNON
12. Highway Name or No.: MONTGOMERY STREET
☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer, F. Bus, J. Other Motor Vehicle; A. Auto, D. Pick-up truck, G. School Bus, K. Pedestrian; B. Truck, E. Van, H. Motorcycle, M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 3
15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 4

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 50 °F
22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2
23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip, 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car — Code: 9
25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1
26. Track Number or Name: SINGLE MAIN

27. FRA Track Class: 4
28. Number of Locomotive Units: 0
29. Number of Cars: 1
30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 10 mph — Code: E
31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None
Code(s): 01 02
33. Signaled Crossing Warning: Conf. no warn (7); Insulated Rail Car (A)
34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1
36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2
37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age
39. Driver's Gender — 1. Male, 2. Female — Code: 2
40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2
41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2
43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 1

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3
45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1
47. Highway Vehicle Property Damage *(est. dollar damage)*: $1,000
48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1
50. Total Number of People on Train *(include passengers and crew)*: 1
51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block
53b. Special Study Block

54. Narrative Description

DRIVER AGE UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1210202
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1210202

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084759D	12/29/10	09:10 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MT VERNON	NORTHEWST	SKAGIT	53	WA

11. City *(if in a city)*: MOUNT VERNON
12. Highway Name or No.: E COLLEGE WAY
☑ Public ☐ Private

Highway User Involved

13. Type — Code: C
A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — Code: 3
1. North 2. South 3. East 4. West

16. Position — Code: 1
1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 2
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user 2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 32 °F

22. Visibility *(single entry)* — Code: 4
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 1
A. Spec. MoW Equip
1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car

25. Track Type Used by Rail Equipment Involved — Code: 1
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: SINGLE MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
4	2	104	R. Recorded E. Estimated 10 mph	E	1. North 2. South 3. East 4. West	1

32. Type of Crossing Warning — Code(s): 01, 02
1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — Code: 2
1. Yes 2. No 3. Unknown

35. Location of Warning — Code: 1
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 2
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 1
1. Yes 2. No 3. Unknown

38. Driver's Age	39. Driver's Gender	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train	Code	41. Driver	Code
46	1. Male 2. Female	1	1. Yes 2. No 3. Unknown	2	1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*	5

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $2,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 1
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

TRAIN STRUCK TRAILER PORTION OF SEMI 41: TRAILER FOULING XING

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
Skagit	Mount Vernon	City Street		BLACKBURN		S 2			
Skagit	Mount Vernon	City Street		RIVERSIDE DR		ALDER LN			
Skagit	Mount Vernon	City Street		RIVERSIDE DR	1000	BNRR			
Skagit	Mount Vernon	City Street		RIVERSIDE DR		RAILROAD TRACKS			
Skagit	Mount Vernon	City Street		RIVERSIDE DR	1100	RR CROSSING			
Skagit	Mount Vernon	City Street		RIVERSIDE DR	1000	RR TRACKS			
Skagit	Mount Vernon	City Street		RIVERSIDE DR	1022				
Skagit	Mount Vernon	City Street		S 2 ST		BLACKBURN RD			
Skagit	Mount Vernon	City Street		S 2ND		BLACKBURN			
Skagit	Mount Vernon	City Street		S 4 ST		SECTION ST			
Skagit	Mount Vernon	City Street		SECTION		RR XING			
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		536					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					
Skagit	Mount Vernon	State Route		538					

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
					3042725	8/4/2007	9:50	Evident Injury	1	0	2		
					2494453	9/9/2006	15:59	Possible Injury	2	0	3		
					2494490	1/26/2007	9:36	Unknown	0	0	1		
					3042427	12/30/2006	23:31	Possible Injury	3	0	2		
					2494439	9/6/2006	10:22	Possible Injury	1	0	2		
					1834011	10/19/2005	22:28	Unknown	0	0	1		
					E049692	4/16/2010	11:22	No Injury	0	0	1		
					2943518	12/20/2008	9:56	Possible Injury	1	0	2		
					1833527	10/12/2005	11:01	Died in Hospital	0	1	1		
					3027357	6/23/2007	18:33	No Injury	0	0	1		
					2527295	11/27/2006	20:22	No Injury	0	0	1		
			4.92		2494365	8/3/2006	12:35	No Injury	0	0	2		
			5.28		2494637	10/11/2006	14:21	No Injury	0	0	2		
			5.28		E070115	9/30/2010	17:08	Unknown	0	0	1		
			5.28		2494434	8/31/2006	9:14	No Injury	0	0	1		
			5.28		2246830	6/9/2006	6:40	No Injury	0	0	1		
			5.28		E037352	12/23/2009	9:56	Unknown	0	0	1		
			0.51		2943560	1/27/2009	12:29	No Injury	0	0	2		
			0.51		1847153	4/19/2005	15:26	No Injury	0	0	3		
			0.51		1672394	2/15/2005	11:44	No Injury	0	0	2		
			0.51		E058066	7/2/2010	9:15	No Injury	0	0	2		
			0.51		2943558	11/7/2008	17:26	No Injury	0	0	2		
			0.51		3043106	8/2/2007	16:33	Possible Injury	2	0	2		
			0.51		2246686	4/28/2006	6:49	No Injury	0	0	1		
			0.52		3232831	1/17/2009	13:57	Evident Injury	1	0	1		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Not Stated		At Intersection and Related	Dry	Daylight
Taxi	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Dark-Street Lights On
Passenger Car		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Wet	Dark-No Street Lights
Truck Tractor & Semi-Trailer		At Driveway within Major Intersection	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Snow/Slush	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck & Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Wet	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Wet	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Bus or Motor Stage	At Intersection and Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Not Related	Wet	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Motorcycle		Not at Intersection and Not Related	Dry	Daylight

89

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

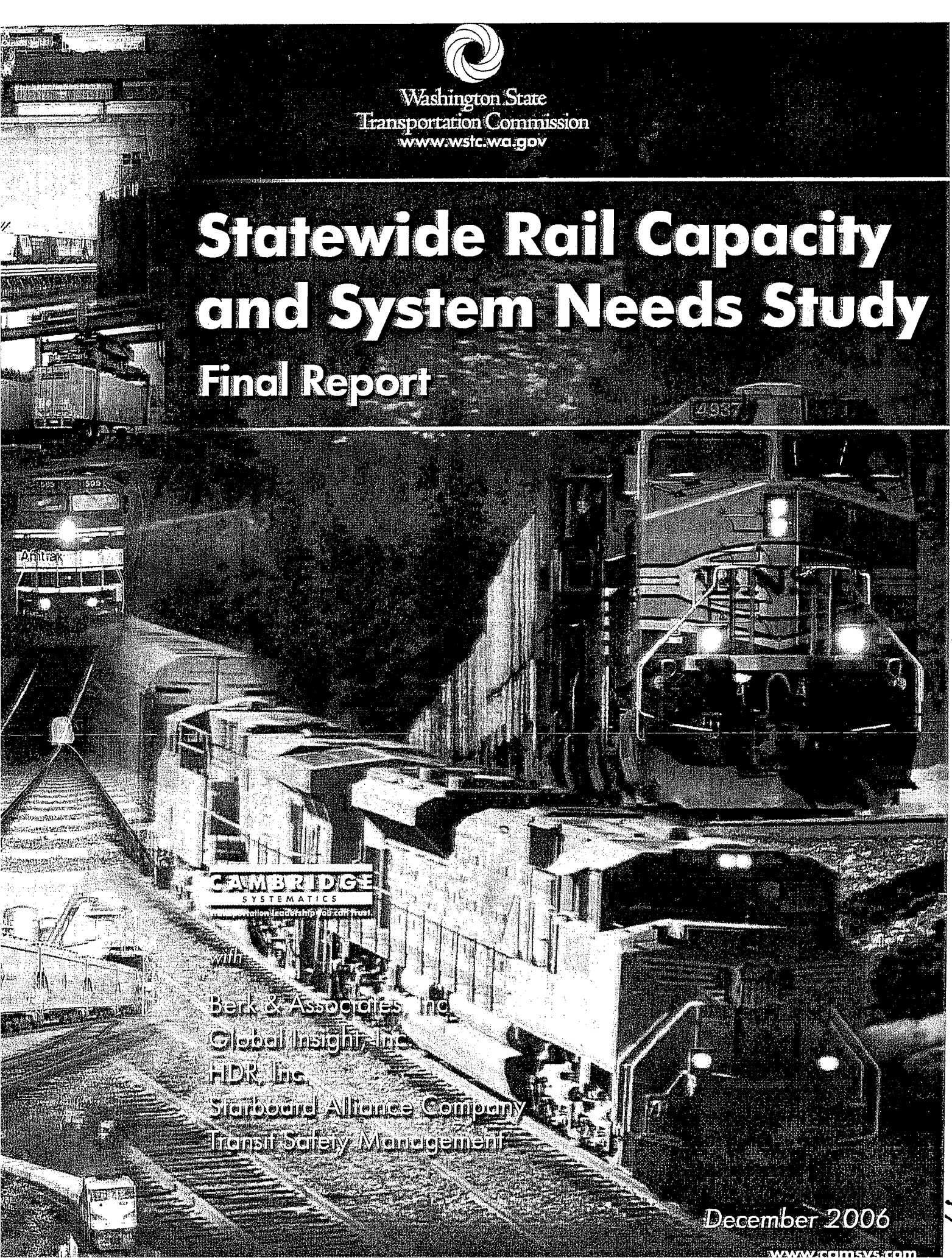
REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
From opposite direction - one left turn - one straight	Did Not Grant RW to Vehicle	None	Northwest	East	Southeast	Northwest
Entering at angle	Exceeding Stated Speed Limit	None	North	South	West	North
Railway Crossing Gate	Other		South	North		
From same direction - both going straight - both moving - rear-end	Other Driver Distractions Inside Vehicle	None	North	South	North	South
Railway Crossing Gate	Other		South	North		
Other Objects	Improper Turn		North	East		
Railway Signal Pole	Inattention		East	North		
From opposite direction - one left turn - one straight	Did Not Grant RW to Vehicle	None	North	East	South	North
Railway Signal Pole	Exceeding Stated Speed Limit		Northwest	Southeast		
Curb, Raised Traffic Island or Raised Median Curb	Under Influence of Alcohol		North	South		
Train struck stopped or stalled vehicle	Other		West	Vehicle Stopped		
From same direction - both going straight - one stopped - rear-end	Inattention	None	West	East	West	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
Railway Crossing Gate	Other		West	East		
Railway Crossing Gate	Inattention		East	Vehicle Stopped		
Railway Crossing Gate	Other		East	West		
All other non-collision	Inattention		West	East		
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
From same direction - both going straight - one stopped - sideswipe	Inattention	None	West	East	West	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	East	West	East	Vehicle Stopped
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	West	East	West	Vehicle Stopped
Railway Crossing Gate	Other		East	West		
Vehicle overturned	Other		West	East		

59

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

State Report Information



Washington State
Transportation Commission
www.wstc.wa.gov

Statewide Rail Capacity and System Needs Study

Final Report

CAMBRIDGE SYSTEMATICS

with

Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management

December 2006

www.camsys.com

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the State's passenger-rail program. The cost of resolving the rail choke points in the I-5 corridor to meet passenger service and ridership goals is increasing, potentially reducing the cost-effectiveness of the passenger rail program. Without capacity improvements, rail will not maintain its share of the Washington State freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the State's industrial and agricultural shippers.

The Rail Industry Is Expanding Capacity, But May Not Meet All the State's Needs

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines. They are operating longer trains and maximizing the number of containers packed on intermodal cars; consolidating pick-up and delivery of railcars at central terminals; and eliminating mainline switching wherever possible (i.e., minimizing the number of times trains are 'parked' on the mainline while picking up cars from individual shippers). These changes favor a hook-and-haul operations strategy, where the railroads pick up a full train in Seattle or Tacoma and haul it directly to Chicago, or pick up a full grain train in the Midwest and haul it directly to a Columbia River port. Hook-and-haul operations allow the railroads to achieve economies of scale that keep costs down and services profitable. However, capacity will remain constrained in Washington even with these changes.

The move toward wholesale rail service helps meet the needs of Washington State's ports, which handle high volumes of imported intermodal containers and exported grain. But it is problematic for Washington State's manufacturers and agricultural shippers. They need low-cost, shorter-haul carload service and do not generate the high volumes attractive to the railroads. In general, international intermodal container traffic has been outbidding domestic carload traffic for space on the rail system, and the railroads have been pricing out lower-volume, lower-profit shippers to meet the demands of higher-volume, higher-profit freight.

The shift toward high-volume, hook-and-haul operations is also problematic for Washington State's short line railroads. They provide a link between smaller shippers and the Class I railroads. If they cannot generate enough volume to get service

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic - most of which is associated with short- and medium-distance trips - on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 - Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

- Manufacturers, agricultural producers, and lumber and wood products producers generate 14 percent ($37 billion) of the State's $262 billion economic output value (gross state product) and 15.5 percent (425,700 jobs) of the State's employment.
- The Washington State ports generate between 200,000 and 300,000 direct, indirect, and trade-related jobs in the State. A portion of these jobs depend directly or indirectly on rail service.
- Sixteen percent of all freight tonnage moved in Washington State moves by rail.

Rail service is critical because it enables these Washington State industries to ship heavy or bulky commodities over long distances at low costs. Table 1 lists the top 10 outbound Washington State rail commodities by tonnage for 2004 and the forecast tonnages for 2015 and 2025. These are commodities that are shipped out of Washington State by rail. "Miscellaneous mixed shipments" are primarily merchandise and retail trade goods; many are moving in intermodal containers.

Table 1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025

STCC	Commodity	Rail Tonnage			Compound Annual Growth Rate		
		2004	2015	2025	2004-2015	2015-2026	2004-2025
46	Miscellaneous mixed shipments	6,516,304	11,309,371	19,060,968	5.1%	5.4%	5.2%
24	Lumber or wood products	4,506,679	4,072,939	4,183,956	-0.9%	0.3%	-0.4%
11	Coal	2,142,403	2,743,497	3,184,686	2.3%	1.5%	1.9%
40	Waste or scrap materials	1,543,296	2,377,099	3,260,635	4.0%	3.2%	3.6%
26	Pulp, paper, or allied products	1,231,469	1,556,870	1,752,517	2.2%	1.2%	1.7%
20	Food or kindred products	1,075,792	1,662,293	2,389,104	4.0%	3.7%	3.9%
37	Transportation equipment	826,102	2,090,719	4,523,959	8.8%	8.0%	8.4%
1	Farm products	700,653	997,648	1,385,204	3.3%	3.3%	3.3%
33	Primary metal products	606,415	677,274	597,161	1.0%	-1.3%	-0.1%
28	Chemicals or allied products	353,040	381,960	367,654	0.7%	-0.4%	0.2%

Source: Global Insight, Inc., 2006.

Figure 2 compares the 2004 tonnages to the forecast tonnages for 2015 and 2025. This figure includes commodities that are shipped into and out of Washington State; the previous figure showed only outbound commodities.

four trains that were supported financially by Washington State at that time, and about 637,000 on the entire *Cascades* service.[4] The State's passenger rail plans envision serving up to 3.0[5] million riders with 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) in 2023.

Sound Transit provides Sounder commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks. The *Cascades* service is operated by Amtrak; the Sounder commuter trains are operated by BNSF and maintained by Amtrak.

In the Puget Sound region, Sounder ridership is projected to grow from 1.2 million passenger trips in 2006 to 2.6 million passenger trips in 2011, a five-year increase of 117 percent.

Forecasts for both the Amtrak *Cascades* and the Sounder services are predicated on substantial investments to increase capacity and improve operations along the I-5 rail corridor. Full build out of the draft Long-Range Plan for the *Cascades* program calls for additional investments of $6.5 billion (in 2006 dollars) by 2023.

Rail Capacity *is calculated in a two-step process.*

First, a "theoretical capacity" is determined, assuming perfect conditions and operations.

Second, "practical capacity" is determined by considering factors, such as possible disruptions, signal needs, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand.

Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of "C." At higher percentages, rail congestion increases and service reliability deteriorates quickly.

3.4 Capacity of the Washington State Rail System and Implications for Rail Users

The Washington State rail system is nearing capacity; service quality is strained, and rates are going up.

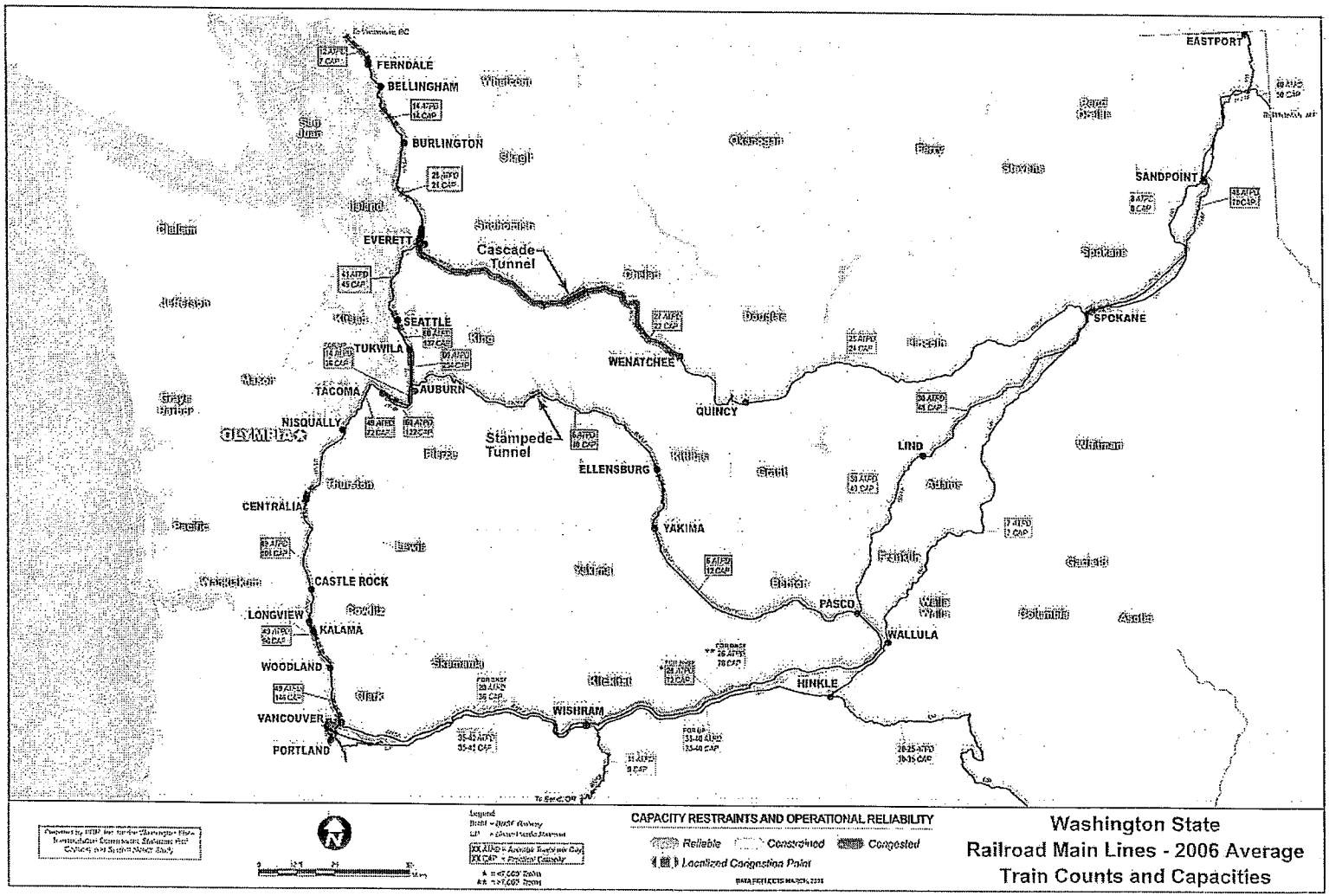
Figure 3 compares the average number of trains operated on each line to the practical capacity of the line.

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major transcontinental route for double-stack intermodal container trains. It is heavily used, operating today at about 123 percent of practical capacity.

[4] As of July 1, 2006, there are four round trips daily on the Seattle to Portland segment. Prior to this, there were only three round trips daily.

[5] A range of ridership projections were produced that varied based on fare structure and other variables. 3 million is a higher end projection.

Figure 3. Washington State Rail System: Mainline Capacities, 2006



The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UPRR freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver area, where the railroads' north-south and east-west routes intersect. Rail simulation studies of grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[6]

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, but the operational changes may not be sufficient to satisfy the future needs of Washington shippers. The short-term operating strategies being pursued by the railroads include the following:

- Operating longer 8,000-foot trains and maximizing the number of containers packed on intermodal flat cars;
- Marketing and operating single origin and destination unit trains for carload traffic;
- Consolidating pick-up and delivery of railcars at central terminals operated by third parties (examples include new rail-served industrial parks, logistics hubs, and transload centers);
- Eliminating mainline switching whenever possible (i.e., picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity); and
- Transferring responsibility for branch-line switching from the Class I railroads to local short lines, wherever possible.

These strategies will help meet the needs of the ports and intermodal shippers, but will likely complicate the problem of

[6] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

industrial carload shippers who cannot take advantage of longer and better packed intermodal trains. The Class I railroads are asking shippers, wherever possible, to reorganize and upgrade their tracks and track layouts to improve switching efficiency and be more compatible with the railroads' hook-and-haul operations. The more track space within the shipper's property and the longer the entrance and exit tracks, the faster and more efficiently the railroad can pick up or set out cars. This saves time and labor costs for the railroads and keeps high-volume mainlines open more hours of the day for through train movements. But for low-volume shippers, the costs of these site improvements are usually prohibitive. The same problems apply to consolidating rail pick-up and delivery of railcars at central terminals operated by third parties; unless the consolidation centers are well located, designed, and financed, the financial risks to shippers and operators may be very high.

Consolidation and outsourcing of terminal operations to third parties and transfer of branch-line switching from Class I to short line railroads can result in the replacement of union rail jobs with lower-paying nonunion jobs. Unless offset by future growth in Class I business that generates new union jobs, the loss of union jobs can mean a lower income and standard of living for some Washington State residents with jobs in the rail industry.

The new operating strategies also impact the State's agricultural shippers. Low-cost rail service keeps product costs competitive, but the increasing cost of rail service and the Class I railroads' focus on higher-profit, hook-and-haul intermodal traffic has made it more costly and more difficult for some agricultural shippers to get service at acceptable prices. The Class I railroads also have been asking Washington State grain and other bulk agricultural shippers to consolidate shipping points so that the railroads can operate more unit trains. Notable examples of this trend are the Ritzville grain-loading facility and the new Railex produce service at Wallula.[7]

While these new rail operating strategies have the potential to partially address future capacity needs, the analysis conducted for this study suggests that they may not be sufficient in the longer term. Table 2 lists the lines where mainline practical capacity will be exceeded within 20 years even with the additional capacity gained by operating longer trains and implementing better scheduling. The existing choke points will persist and worsen, some more quickly than others.

[7] http://www.wsdot.wa.gov/Projects/Rail/Freight/PortWallaWalla/.

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[8]

Table 2. Rail Lines in Washington State Exceeding Practical Capacity, 2015 and 2025
Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains

2015	2025
Everett-Burlington	Everett-Burlington
Burlington-Ferndale	Burlington-Ferndale
Ferndale-New Westminster	Ferndale-New Westminster
Everett-Spokane, Washington (BNSF)	Everett-Spokane, Washington (BNSF)
Vancouver-Wishram	Vancouver-Wishram
Wishram-Roosevelt	Wishram-Roosevelt
Roosevelt-Pasco	Roosevelt-Pasco
	Pasco-Spokane, Washington (BNSF)
Pasco (Wallula)-Spokane, Washington (UP)	Pasco (Wallula)-Spokane, Washington (UP)
Spokane, Washington-Sandpoint, Idaho (UP)	Spokane, Washington-Sandpoint, Idaho (UP)
Auburn-Yakima	Auburn-Yakima
Yakima-Pasco	Yakima-Pasco

Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[8] See for example: AASHTO, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UPRR have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers. This is a painful change for all shippers, especially captive shippers, who are being forced to rethink their supply chains and markets.

The national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and Washington State. Continuing high levels of growth and the competition between the BNSF and the UPRR for the lucrative Southern California rail market have made Southern California the key focal point of investment for both railroads. This has shifted investment away from the Pacific Northwest and Washington State.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, Federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not

overtake and collide with slower-moving carload freight trains.[9] The freight railroads, who own the track, are focused on obtaining the maximum benefit from each available train slot and the revenue they receive for providing train slots to the passenger railroads is usually modest.

When the Amtrak *Cascades* program was initiated, the freight railroads were willing to sell slots to the State, especially in return for physical improvements to the rail lines that would benefit both the passenger and freight railroads. With capacity tightening and increasing shipper pressure to improve throughput and reliability, the freight railroads are less willing or able to accommodate expansion of the intercity rail program. As a result, passenger services are often asked to pay a premium when they purchase slots or contribute to mainline capacity improvements.

Amtrak *Cascades* ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases and the freight railroads give priority to freight trains. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. However, if congestion continues to build and the cost of improvements increases, on-time performance may deteriorate further, undermining ridership growth and reducing the cost-effectiveness of the program. Unless a coordinated solution is examined, the future cost of the Amtrak *Cascades* program may exceed the public benefits anticipated in the original plans, and the State may need to examine alternative strategies for the passenger rail program.

[9] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Mr. Peter Hahn
Title: City of Seattle, Director Seattle Department of Transportation
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations-City of Seattle – Preliminary Report; GTC #11-036
Date: February 13, 2012

This memorandum identifies some of the possible rail impacts associated with transport of coal to the proposed Cherry Point Facility affecting the City of Seattle and its access roads. It preliminarily identifies the potential impacts on the City's Sodo and waterfront area where surface traffic intersects with the main line.

The purpose of this preliminary report is to provide City staff with information that may be useful as the City evaluates its position on the proposed project and prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand that the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

1. Project Description and Expected Delays

We understand that Pacific International Terminal, a wholly owned subsidiary of SSA Marine, is proposing to develop the Gateway Pacific Terminal at Cherry Point, Washington. This terminal would be capable of exporting 48-54 million tons of coal per year is proposed north of Bellingham. GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north-south directly through the west part of the City of Seattle, Washington.

According to the applicant's *Project Information Document* (Feb. 2011), full build out of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day; however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. The current port proposal occupies 350 acres of a 1,000-acre site. Each train may be over 1.5 miles long, which at 50 miles per hour would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Seattle can be estimated to increase with an additional train every *every 1.3 hours*, if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use sidings or not.

2. Affected Crossings

The BNSF rail way tracks bisect the western waterfront area of Seattle (including the terminals in the Broad Street area and stadiums) from the east side of Seattle that includes the downtown business core and residential area. The federal inventory of crossing identifies nearly 200 rail and spur crossing in the Seattle limits. The significant crossing that would be directly impacted by additional trains is probably on the Wenatchee-Seattle and Seattle Vancouver lines. These include the following crossings

- Spokane St
- Lander St
- Holgate ST
- Broad St
- Clay St
- Vine St
- Wall St

The City and Sate has already heavily invested in improved crossing and grade separation. However due to the city street system layout, grades and the waterfront the high traffic volumes in Seattle will still be impacted with increased train traffic and additional grade crossing or mitigation may be needed with a significant increase in train traffic.

3. Analysis of Potential Impacts

We have the following comments based on preliminary research:

1. The City's Transportation Element and Freight Mobility Strategic Action plan identified the importance of local freight access for its business vitality and also the importance of partnership investment in it key crossing to pursue additional grade separation. A potential mitigation for the additional freight traffic may be to assist in the construction of additional grade separated crossing for the City such as Lander St.
2. The City's Transportation Element strongly supports increased non motorized transportation such as bike trails. There are several miles of bike trail and waterfront park areas however that are not easily accessed due the rail lines. Additional grade separated crossing front non motorized transport in that area such as the sculptor Park Eliot Bay; Interbay Golden Gardens etc should be investigated and proposed. .
3. Due to a speed restriction approach warning, train travel through the downtown means the barriers are down for approximately 3-4 minutes (over 200 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 2-3 continuous red lights cycles in a row for a normal signal on Broad or Lander. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F. The City's standard for arterial roadway operation is LOS D for SEPA impact review, i.e. allowing only 55 seconds as the worst delay for normal conditions. The addition of 16-18 trains per day would trigger potential SEPA review for the city.
4. With the increase in number of long coal trains at the Belltown waterfront area and cruise ship terminal access crossing, steep grade there are no alternative east-west grade separated in the area north of downtown once the trains come out of the tunnel. This will create particular challenges during summer peaks, with the waterfront parks, tourist traffic, cruise ship passengers, visitors to the SAM Sculpture Garden and other uses. Mitigation could hypothetically include a grade separated crossing to the waterfront such as Broad Street, although the topography and local improvements will likely make this difficult.
5. Within the last 5 years there have been 27 collisions involving trains at public crossings including a fatality at the Holgate crossing this January. In total, the State accident base has recorded

approximately 100 accidents at train crossings in the last 5 year reporting period in the City of Seattle.

6. Already today the presence of a long freight train during the peak hours creates separation from the some of the City's waterfront amenities and businesses. The City's annual counts show over 9,000 daily trips at the Broad Street crossing and over 15,000 daily trips on S. Lander just west of 6th Avenue while S. Holgate carries over 6,000 daily trips in that vicinity. With the additional coal trains that will take a minimum of 3-4 minutes to cross (without accounting for significant train delays or slowing at the crossings) the cumulative additional delay to drivers is potentially significant. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. It should also evaluate the costs to businesses from delays in shipping, employee availability and other factors. The City may wish to request that the GPT EIS to include mitigation such as funding for planned grade separated crossings.
7. Sound Transit communities and the State have recently invested heavily in improved passenger train services for the north end. Freight traffic on the rail line between Seattle and Everett could increase from the current baseline of approximately 40 a day (based on US DOT crossing inventory Information) to 50-55 with the Cherry Point proposal. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on-time reliability demands of passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to ensure that the EIS analyzes the degree to which increasing freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand future passenger rail. Since Sound Transit's North Corridor transit EIS identified the preferred alternative as the I-5 alignment (instead of the SR-99 alignment) it becomes even more imperative to the City to preserve this existing rail corridor for passenger service to the neighborhoods closer to Puget Sound to the north. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies.
8. The 2006 "Washington State Rail Capacity & System Needs Study " identifies a key issue affecting local business and Port access to rail shipments for their products. The report states:

> The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.
>
> Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market.

[Page 49 of attachments]. So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability rail shipment to local rail spur business such as tenants of the Port of Seattle. These issues should be analyzed as part of the economic impact analysis we understand must be completed as part of the environmental review for the project.

9. The Washington State 2010-2030 Freight Rail Plan published by WSDOT in December 2009 identified that the rail line north of the city to Everett in 2008 as having a capacity of 60 trains per day (Exhibit 3-9). The existing use of the line is 40-45 based on the US DOT inventory reports that were accesses in 2011. The state plan shows that it hopes to increase that capacity to 80 trains per day; however, the design, cost and funding of the specific improvements needed to do that were not available at the time of this reports completion. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system,

sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for freight on this critical corridor to such businesses as the Port of Seattle, the Everett Boeing plant, and local businesses, as well as expanded commuter services.10. The Cherry Point applicant and its advocates argue that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore there is no impact. In our judgment, this conclusion is not supportable, because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well as vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically.

11. Train delays at crossings and the separation of non motorized traffic from city waterfront amenities can sometimes be eliminated by constructing grade separation, which allows traffic or pedestrians/bikes to pass over or under railroad tracks. While grade separation can be a desirable solution, these improvements typically multi-million dollar projects and involve substantial amounts of public funding. We recommend that local jurisdictions provide the regulating authorities with detailed assessments of mitigation and funding necessary to alleviate the impacts that will results from the addition of up to 18 trains per day serving the Cherry Point export facility.

4. Conclusions

This analysis of possible rail line impacts associated with the increase of up to 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to investigate some of the potential d areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, and possible interference with local freight delivery systems important to the City's economic recovery. Based on the results of this preliminary analysis, we recommend that the City conduct or request a more detailed evaluation of the specific impacts on specific crossings and intersections. Gibson Traffic Consultants has conducted preliminary evaluations of traffic impacts from the Cherry Point proposal for the communities of Burlington, Marysville, Mt. Vernon, and Stanwood. The results of these analyses can be found here: http://www.coaltrainfacts.org/gtc-traffic-study-burlington-marysville-mt-vernon-and-stanwood-wa. In many cases, these evaluations show severe degradation in level of service for key arterials that cross the tracks. Please feel free to contact us should you have any questions regarding this preliminary analysis.

ATTACHMENTS FOR CITY OF SEATTLE RAIL CAPACITY PRESENTATION

- Rail Crossing Inventory
- Daily Traffic at Crossings
- Transportation Element Information
- Accident History Data
- State Report Information

Rail Crossing Inventory

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7390271

8.01 - Query by Location

Total Records: 199

Report Type: Inventory Accident Contact Sheet

Inventory: Current History

Generate Repor Show Paging Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	085410J	WA	BNSF	Public	At Grade	Open	000151	KING	SEATTLE	NORTHWEST	SCENIC	WENACHE-SEATTLE	WALL ST
☐	085411R	WA	BNSF	Public	At Grade	Open	000157	KING	SEATTLE	NORTHWEST	SCENIC	WENACHE-SEATTLE	VINE ST
☐	085413E	WA	BNSF	Public	At Grade	Open	000168	KING	SEATTLE	NORTHWEST	SCENIC	WENACHE-SEATTLE	CLAY ST
☐	085414L	WA	BNSF	Public	At Grade	Open	000177	KING	SEATTLE	NORTHWEST	SCENIC	WENACHE-SEATTLE	BROAD STREET
☐	085416A	WA	BNSF	Public	At Grade	Open	000326	KING	SEATTLE	NORTHWEST	SCENIC	WENACHE-SEATTLE	W GALER ST
☐	085583Y	WA	BNSF	Public	At Grade	Open	000084	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE-VANC WA	HOLGATE ST
☐	085584F	WA	BNSF	Public	At Grade	Open	000128	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE-VANC WA	LANDER ST
☐	085585M	WA	BNSF	Public	At Grade	Open	000165	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE-VANC WA	HORTON ST
☐	085586U	WA	BNSF	Public	At Grade	Open	000185	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE-VANC WA	WB SPOKANE ST
☐	085587B	WA	BNSF	Public	At Grade	Open	000186	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE-VANC WA	EB SPOKANE ST
☐	095988D	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SPOKANE ST WYE	SPOKANE ST W.BD
☐	095995N	WA	BNSF	Public	At Grade	Open	000153	KING	SEATTLE	NORTHWEST	COLORADO AVE L	STCY ST. YD	HORTON ST
☐	096168J	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. MARGINAL	PRT OF SEA ACCESS
☐	096179W	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. MARGINAL	W EDMUNDS ST
☐	096186G	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. MARGINAL	S.W. IDAHO ST
☐	096187N	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. MARGINAL	S.W. IDAHO ST
☐	096190W	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	W. MARGINAL	SW DAKOTA ST
☐	096195F	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	FRASER BROILER	W. MARGINAL WY SW
☐	096202N	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	W. SEA. SPUR	CHELAN AVE. SW.
☐	096409V	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. SEA. SPUR	TERMINAL 5
☐	096415Y	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	W. SEA. SPUR	S W FLORIDA ST
☐	096439M	WA	BNSF	Public	At Grade	Open	000179	KING	SEATTLE	NORTHWEST	SEATTLE	SEA PAC SPUR	2ND AT SPKNE (E)
☐	096442V	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SPOKANE ST. LD	SPOKANE ST E.BD.
☐	096445R	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SPOKANE ST LD.	E.MARGINAL WAY
☐	096446X	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SPOKANE ST. LD.	E.MARGNLWY 1WY-NO
☐	096451U	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SPOKANE ST. LD	KLICKITAT ST SW.
☐	096452B	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	16TH AVE SPUR	KLICKITAT ST. SW
☐	096454P	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	16TH AVE SPUR	13AV SW&KLICKATIT
☐	096462G	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	FSHR MLS MID-TK	16TH AVE. SW
☐	096463N	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	FSHR ML TRK#5&6	16TH AVE SW
☐	096464V	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	FSHR MLLS TRK#7	16TH AVE SW
☐	096470Y	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	16TH AVE SPUR	HANFORD ST
☐	096480E	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	TEXACO SPUR	16TH AVE SW.
☐	096481L	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	SEAFAB-TXCO SPR	S.W. LANDER ST
☐	096486V	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	NO.TEXACO SPUR	16TH AVE SW.
☐	096488J	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	ALNTC RCHFLD SP	SO.BO.16TH AVE SW
☐	096490K	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	SEATTLE	TODD SHIPYARD	SO.BO.16TH AVE SW
☐	096491S	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	TODD MID TRKS	FLORIDA ST
☐	096498P	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	NO LEG WYE	2ND AVE SO.

☐	096502C	WA	BNSF	Public	At Grade	Open	000251	KING	SEATTLE	NORTHWEST	SEATTLE	SEATTLE STEEL	PUBLIC XING
☐	096504R	WA	BNSF	Public	At Grade	Open	000179	KING	SEATTLE	NORTHWEST	SEATTLE	SEA-PAC SPUR	2ND AT SPKNE (W)
☐	099007Y	WA	BNSF	Public	At Grade	Open	000180	KING	SEATTLE	NORTHWEST	COLORADO AVE L	STCY ST. YD	SPOKANE ST E.BD
☐	099009M	WA	BNSF	Public	At Grade	Open	000180	KING	SEATTLE	NORTHWEST	COLORADO AVE L	STCY ST. YD	SPOKANE ST W.BD
☐	101002T	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	7TH AVE LEAD	6TH AVE. SO.
☐	101003A	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	7TH AVE LEAD	FOREST ST
☐	101005N	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	INDSTRL TRF.SPR	7TH AVE. SO.
☐	101006V	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	7TH AVE LEAD	STACY ST
☐	101007C	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	KING ST STATIO	7TH AVE LD&SPRS	HOLGATE ST.
☐	101010K	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	8TH AVE SO LEAD	8TH AVE SO.ALLEY
☐	101011S	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	8TH AVE LEAD	LANDER ST
☐	101012Y	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	8TH AVE LEAD	8TH AVE SO.
☐	101014M	WA	BNSF	Public	At Grade	Open	000300	KING	SEATTLE	NORTHWEST	SEATTLE	RAINR. BREW SPR	8TH AVE SO.
☐	101031D	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	STCY ST TM TRK	HINDS ST
☐	101032K	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	STACY ST TM TRK	HORTEN ST
☐	101033S	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	STACY ST TM TRK	HANFORD ST
☐	101034Y	WA	BNSF	Public	At Grade	Open	000146	KING	SEATTLE	NORTHWEST	COLORADO AVE L	STCY ST YARD	HANFORD ST.
☐	101039H	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	STACY ST YARD	STCY ST. YD	ATLANTIC ST
☐	101051P	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY LEAD	COLUMBIA ST
☐	101052W	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY LEAD	MARION ST.
☐	101053D	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY MAIN	MADISON ST
☐	101055S	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY MAIN	SPRING ST
☐	101056Y	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY MAIN	SENECA ST
☐	101058M	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WY MAIN	UNIVERSITY ST
☐	101059U	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WAY MN	UNION ST.
☐	101060N	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			OLD NP ALASKAN	ALASKAN WAY VIADC
☐	101061V	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WAY MN	PIKE ST.
☐	101064R	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WAY MN	PINE ST
☐	101065X	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WAY MN	VIRGINIA ST
☐	101069A	WA	SNCT	Public	At Grade	Open	NONE00	KING	SEATTLE			ALASKAN WAY MN	BLANCHARD ST.
☐	101103E	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	KING ST STATIO	OCCIDENTAL ST	OCCIDENTAL AVE S.
☐	101128A	WA	BNSF	Public	At Grade	Open	000000	KING	SEATTLE	NORTHWEST	KING ST STATIO	OCCDT. ST. SPUR	ROYAL BROUGHAM
☐	101140G	WA	BNSF	Public	At Grade	Open	000453	KING	SEATTLE	NORTHWEST	INTERBAY-WOODI	TERRY AVE LINE	13TH AVE NW
☐	101206E	WA	BNSF	Public	At Grade	Open	000053	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	SEAVIEW AVE N.W.
☐	101207L	WA	BDTL	Public	At Grade	Open	000075	KING	SEATTLE				NW 57TH/SEAVIEW
☐	101208T	WA	BDTL	Public	At Grade	Open	000080	KING	SEATTLE				MARKET ST/300BLK
☐	101211B	WA	BDTL	Public	At Grade	Open	000730	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	32ND ST NW.
☐	101212H	WA	BDTL	Public	At Grade	Open	00NONE	KING	SEATTLE	SEATTLE	TERM'L PAC-2	BALLARD	30TH AVE NW GOV
☐	101213P	WA	BDTL	Public	At Grade	Open	000730	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	28TH AVE N.W.
☐	101217S	WA	BDTL	Public	At Grade	Open	000730	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	26TH AVE N.W.
☐	101221G	WA	BDTL	Public	At Grade	Open	000730	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	24TH AVE N.W.
☐	101246C	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	W 46 ST
☐	101247J	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	BALLARD WAY
☐	101251Y	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	14 AV NW&NW 49 ST
☐	101252F	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	N.W. 50TH ST.
☐	101253M	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	N.W. 51 ST
☐	101254U	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	14TH AVE SPUR	N.W. 52ND ST.
☐	101258W	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	OLYMPIC STN SPR	N.W. 46TH ST.
☐	101259D	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	OLYMPIC STN SPR	BALLARD WAY
☐	101260X	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	OLYMPIC STN SPR	LEARY WAY
☐	101262L	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	11TH AVE N.W.

☐	101263T	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	N.W. 45TH AT 9TH
☐	101264A	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	PIONEER SUPPLY	N.W. 45TH
☐	101265G	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	8TH AVE N.W.
☐	101267V	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	7TH AVE N.W.
☐	101268C	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	N.W. 42ND ST.
☐	101269J	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	N W 41ST ST.
☐	101270D	WA	BDTL	Public	At Grade	Open	000734	KING	SEATTLE	NORTHWEST	SCENIC	BALLARD	6TH AVE NW
☐	101272S	WA	BDTL	Public	At Grade	Open	000733	KING	SEATTLE	PACIFIC	SCENIC	BALLARD	NW. 40TH ST.
☐	101380N	WA	BNSF	Public	At Grade	Open	000222	KING	SEATTLE	NORTHWEST	WEST SEATTLE Y	W. MARGINAL	W MARGINAL WAY
☐	399748N	WA	UP	Public	At Grade	Open	092000	KING	SEATTLE	COAST	5	WATERFRONT LINE	IDAHO ST
☐	399749V	WA	UP	Public	At Grade	Open	095000	KING	SEATTLE	COAST	5	WATERFRONT LINE	E MARGINAL WAY
☐	399750P	WA	UP	Public	At Grade	Open	072000	KING	SEATTLE	COAST	5	SPUR	E MARGINAL WAY
☐	399751W	WA	UP	Public	At Grade	Open	004200	KING	SEATTLE	COAST	5	WATERFRONT LINE	E MARGINAL WAY
☐	399752D	WA	UP	Public	At Grade	Open	002442	KING	SEATTLE	COAST	5	WATERFRONT LINE	
☐	399753K	WA	UP	Public	At Grade	Open	074500	KING	SEATTLE	COAST	5	WATERFRONT LINE	SPOKANE ST (EB)
☐	399754S	WA	UP	Public	At Grade	Open	084500	KING	SEATTLE	COAST	5	WATERFRONT LINE	SPOKANE ST
☐	399755Y	WA	UP	Public	At Grade	Open	060000	KING	SEATTLE	COAST	5	WATERFRONT LINE	HINDS ST
☐	399756F	WA	UP	Public	At Grade	Open	082500	KING	SEATTLE	COAST	5	WATERFRONT LINE	HORTON ST
☐	399757M	WA	UP	Public	At Grade	Open	027500	KING	SEATTLE	COAST	5	WATERFRONT LINE	HANFORD ST
☐	399758U	WA	UP	Public	At Grade	Open	017800	KING	SEATTLE	COAST	5	WATERFRONT LINE	E MARGINAL WAY
☐	399760V	WA	UP	Public	At Grade	Open	070000	KING	SEATTLE	COAST	5	WATERFRONT LINE	E MARGINAL WAY
☐	399761C	WA	UP	Public	At Grade	Open	078000	KING	SEATTLE	COAST	5	WATERFRONT LINE	ATLANTIC ST
☐	399762J	WA	UP	Public	At Grade	Open	055500	KING	SEATTLE	COAST	5	WATERFRONT LINE	SR-519 MP 0.48
☐	399763R	WA	UP	Public	At Grade	Open	005400	KING	SEATTLE	COAST	5	WATERFRONT LINE	DEARBORN ST
☐	399764X	WA	UP	Public	At Grade	Open	021700	KING	SEATTLE	COAST	5	WATERFRONT LINE	KING ST
☐	399765E	WA	UP	Public	At Grade	Open	006000	KING	SEATTLE	COAST	5	WATERFRONT LINE	JACKSON ST
☐	399766L	WA	UP	Public	At Grade	Open	035900	KING	SEATTLE	COAST	5	WATERFRONT LINE	MAIN ST
☐	399767T	WA	UP	Public	At Grade	Open	066300	KING	SEATTLE	COAST	5	WATERFRONT LINE	WASHINGTON ST
☐	399771H	WA	UP	Public	At Grade	Open	066700	KING	SEATTLE	COAST	5	SEARS ROEBUCK	OREGON ST
☐	399772P	WA	UP	Public	At Grade	Open	041700	KING	SEATTLE	COAST	5	COLORADO LINE	SPOKANE ST (EB)
☐	399773W	WA	UP	Public	At Grade	Open	056700	KING	SEATTLE	COAST	5	COLORADO LINE	SPOKANE ST (WB)
☐	399775K	WA	BNSF	Public	At Grade	Open	000117	KING	SEATTLE	COAST	5	COLORADO AVE LD	HORTON ST
☐	399776S	WA	UP	Public	At Grade	Open	010000	KING	SEATTLE	COAST	5	SPURS	COLORADO AVE
☐	399778F	WA	BNSF	Public	At Grade	Open	000107	KING	SEATTLE	COAST	5	COLORADO AVE LD	HANFORD ST
☐	399780G	WA	UP	Public	At Grade	Open	030000	KING	SEATTLE	COAST	5	SPUR	COLORADO AVE
☐	399783C	WA	UP	Public	At Grade	Open	075000	KING	SEATTLE	COAST	5	SPUR	UTAH AVE
☐	399784J	WA	UP	Public	At Grade	Open	015000	KING	SEATTLE	COAST	5	SPURS	UTAH AVE
☐	399786X	WA	UP	Public	At Grade	Open	036000	KING	SEATTLE	COAST	5	SPUR	UTAH AVE
☐	399787E	WA	UP	Public	At Grade	Open	061000	KING	SEATTLE	COAST	5	FREIGHT HOUSE	MASSACHUSETTS ST
☐	809500M	WA	UP	Public	At Grade	Open	018101	KING	SEATTLE	N. WEST	ORE.	ML SEA.	INDUSTRIAL WAY SO
☐	809501U	WA	UP	Public	At Grade	Open	018128	KING	SEATTLE	N. WEST	ORE.	SEA. ML	SPOKANE ST. SO.
☐	809503H	WA	UP	Public	At Grade	Open	018180	KING	SEATTLE	N. WEST.	ORE.	ML SEA.	LANDER ST. SO.
☐	809504P	WA	UP	Public	At Grade	Open	018230	KING	SEATTLE	N. WEST	ORE.	SEA. M.L.	HOLGATE STREET SO
☐	809513N	WA	UP	Public	At Grade	Open	000014	KING	SEATTLE	N WEST	ORE	8TH AVE LEAD	LUCILE ST.
☐	809514V	WA	UP	Public	At Grade	Open	000020	KING	SEATTLE	N WEST	ORE	8TH AVE LD TRK.	FINDLEY ST.
☐	809515C	WA	UP	Public	At Grade	Open	000029	KING	SEATTLE	N. WEST	ORE	8TH AVE. LEAD	CORSON STREET
☐	809516J	WA	UP	Public	At Grade	Open	000032	KING	SEATTLE	N. WEST	ORE	8TH AVE LEAD	CARSTENS PL. SO.
☐	809517R	WA	UP	Public	At Grade	Open	000036	KING	SEATTLE	N. WEST	ORE	8TH AVE LEAD	HOMER STREET
☐	809518X	WA	UP	Public	At Grade	Open	000042	KING	SEATTLE	N WEST	ORE	8TH AVE LEAD	DORIS STREET SO.
☐	809521F	WA	UP	Public	At Grade	Open	000015	KING	SEATTLE	N.WEST	ORE	7TH AVE LEAD	6THAVESO.&BENNETT
☐	809522M	WA	UP	Public	At Grade	Open	000019	KING	SEATTLE	N.WEST	ORE	7TH AVE. LEAD	DENVER AVE. SO.
☐	809525H	WA	UP	Public	At Grade	Open	000026	KING	SEATTLE	N.WEST	ORE	7TH AVE.LEAD	DENVER AVE
☐	809526P	WA	UP	Public	At Grade	Open	000029	KING	SEATTLE	N.WEST	ORE	7TH AVE.LEAD	LUCILLE ST.&7TH
☐	809527W	WA	UP	Public	At Grade	Open	000030	KING	SEATTLE	N.WEST	ORE	7TH AVE LEAD	DENVERAVE-7THAVE.

☐	**809528D**	WA	UP	Public	At Grade	Open	000034	KING	SEATTLE	N.WEST	ORE	7TH AVE LEAD	S.FINDLAY&7TH
☐	**809529K**	WA	UP	Public	At Grade	Open	000040	KING	SEATTLE	N.WEST	ORE	7TH AVE.LEAD	7TH & HOMER ST.
☐	**809530E**	WA	UP	Public	At Grade	Open	000046	KING	SEATTLE	N.WEST	ORE.	7TH AVE.LEAD	7TH&ORCAS STREET
☐	**809531L**	WA	UP	Public	At Grade	Open	000052	KING	SEATTLE	N.WESY	ORE	7TH AVE LEAD	7TH FIDALGO
☐	**809532T**	WA	UP	Public	At Grade	Open	000059	KING	SEATTLE	N.WEST	ORE	7TH AVE LEAD	ALLEY
☐	**809533A**	WA	UP	Public	At Grade	Open	000054	KING	SEATTLE	N.WEST	ORE	7TH AVE LEAD	7TH ST.&FIDALGOST
☐	**809534G**	WA	UP	Public	At Grade	Open	000062	KING	SEATTLE	N WEST	ORE	7TH AVE.LEAD	6TH AVE SO.
☐	**809535N**	WA	UP	Public	At Grade	Open	000062	KING	SEATTLE	N WEST	ORE	7TH AVE LEAD	6TH AVE SO.
☐	**809541S**	WA	UP	Public	At Grade	Open	000023	KING	SEATTLE	N WEST	ORE	UTAH LEAD	UTAH ST. & ALASKA
☐	**809548P**	WA	UP	Public	At Grade	Open	000001	KING	SEATTLE	N. WEST	ORE	E. MARG WAY	COLORADO ST.
☐	**809552E**	WA	UP	Public	At Grade	Open	000004	KING	SEATTLE	N WEST	ORE	E.MARGINAL WAY	DIAGONAL AVE
☐	**809554T**	WA	UP	Public	At Grade	Open	000011	KING	SEATTLE	N. WEST	ORE.	E MARG WAY LD	DIAGONAL AVE.
☐	**809556G**	WA	UP	Public	At Grade	Open	000014	KING	SEATTLE	N. WEST	ORE	E. MARGINAL WAY	SR099 MP 28.26
☐	**809557N**	WA	UP	Public	At Grade	Open	000007	KING	SEATTLE	N.WEST	ORE	MARGINAL WAY LD	DIAGONAL AVE
☐	**809564Y**	WA	UP	Public	At Grade	Open	000054	KING	SEATTLE	N. WEST	ORE	E. MARGINAL WAY	DAWSON ST.
☐	**809566M**	WA	UP	Public	At Grade	Open	000005	KING	SEATTLE	N. WEST	ORE.	OHIO AVE LEAD	SR099 MP 27.81
☐	**809568B**	WA	UP	Public	At Grade	Open	000069	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	BRANDON ST.
☐	**809569H**	WA	UP	Public	At Grade	Open	000070	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	BRANDON ST.
☐	**809570C**	WA	UP	Public	At Grade	Open	000073	KING	SEATTLE	N. WEST.	ORE.	E. MARGINAL LD	OHIO ST. SO.
☐	**809577A**	WA	UP	Public	At Grade	Open	000103	KING	SEATTLE	N WEST	ORE	E. MARGINAL LD	FIDALGO ST. SO.
☐	**809582W**	WA	UP	Public	At Grade	Open	000133	KING	SEATTLE	N. WEST	ORE.	E. MARGINAL LD	1ST AVE SO.&FRONT
☐	**809583D**	WA	UP	Public	At Grade	Open	000136	KING	SEATTLE	N. WEST.	ORE.	E. MARGINAL LD	1ST AVE. SO.
☐	**809584K**	WA	UP	Public	At Grade	Open	000137	KING	SEATTLE	N. WEST	ORE.	E. MARGINAL LD	1ST AVE. SO.
☐	**809637G**	WA	UP	Public	At Grade	Open	017893	KING	SEATTLE	PORTLAND	SEATTLE SUB		1ST AVE SOUTH
☐	**809638N**	WA	UP	Public	At Grade	Open	000152	KING	SEATTLE	N. WEST.	ORE	E. MARGINAL LD	OCCIDENTAL & RVR
☐	**809640P**	WA	UP	Public	At Grade	Open	000158	KING	SEATTLE	N.WEST	ORE.	E.MARGINAL LEAD	SO. RIVER ST
☐	**809641W**	WA	UP	Public	At Grade	Open	000157	KING	SEATTLE	N.WEST	ORE.	E.MARGINAL LEAD	RIVER ST
☐	**809643K**	WA	UP	Public	At Grade	Open	000191	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	SO. BRIGHTON ST.
☐	**809645Y**	WA	UP	Public	At Grade	Open	000198	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	WILLOW ST.
☐	**809648U**	WA	UP	Public	At Grade	Open	000211	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	8TH AVE S
☐	**809649B**	WA	UP	Public	At Grade	Open	000213	KING	SEATTLE	N. WEST	ORE	E. MARGINAL W.	SO. MYRTLE ST.
☐	**809651C**	WA	UP	Public	At Grade	Open	000220	KING	SEATTLE	COLUMBIA RIVER		E.MARG.WAY S.	E. MARG.WAY&ELLIS
☐	**809658A**	WA	UP	Public	At Grade	Open	000255	KING	SEATTLE	N. WEST	ORE.	E. MARGINAL LD	WEBSTER ST.
☐	**809659G**	WA	UP	Public	At Grade	Open	000259	KING	SEATTLE	N. WEST	ORE.	E. MARGINAL LD	SO. 14TH AVE
☐	**809660B**	WA	UP	Public	At Grade	Open	000269	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	16TH AVE SO.
☐	**809690T**	WA	UP	Public	At Grade	Open	000009	KING	SEATTLE	N.WEST	ORE	OHIO AVE	
☐	**809692G**	WA	UP	Public	At Grade	Open	000015	KING	SEATTLE	N.WEST	ORE	E.MARGINAL LEAD	8TH AVE.SO.&GARDN
☐	**809698X**	WA	UP	Public	At Grade	Open	000045	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	7TH& MYRTLE
☐	**809700W**	WA	UP	Public	At Grade	Open	000038	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	FOX AVE. & MYRTLE
☐	**809703S**	WA	UP	Public	At Grade	Open	000016	KING	SEATTLE	N. WEST	ORE	E MARGINAL LEAD	FOX AVE&WILLOW ST
☐	**809709H**	WA	UP	Public	At Grade	Open	000026	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	FOX AVE. SO.
☐	**809710C**	WA	UP	Public	At Grade	Open	000022	KING	SEATTLE	N. WEST	ORE	E. MARGINAL LD	FOX AVE S&BRIGHTN
☐	**809711J**	WA	UP	Public	At Grade	Open	000009	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	DUWAMISH AVE SO
☐	**809712R**	WA	UP	Public	At Grade	Open	000011	KING	SEATTLE	N WEST	ORE	HAR ISL LEAD	E MARGINAL WAY SO
☐	**809715L**	WA	UP	Public	At Grade	Open	000025	KING	SEATTLE	N WEST	ORE	HAR ISL LEAD	DUWAMISH AVE SO
☐	**809720H**	WA	UP	Public	At Grade	Open	000065	KING	SEATTLE	COL. RIVER	SEATTLE	HARBOR ISL.LEAD	W. SPOKANE ST
☐	**809721P**	WA	UP	Public	At Grade	Open	000074	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	11TH AVE
☐	**809726Y**	WA	UP	Public	At Grade	Open	000094	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	11TH AVE(HANFORD)
☐	**809729U**	WA	UP	Public	At Grade	Open	000131	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	11TH AVE. NO.
☐	**809733J**	WA	UP	Public	At Grade	Open	000158	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	FLORIDA ST
☐	**809734R**	WA	UP	Public	At Grade	Open	000175	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	W MASSACHUSETTS
☐	**809791E**	WA	UP	Public	At Grade	Open	000100	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	11TH AVE. SO.
☐	**809796N**	WA	UP	Public	At Grade	Open	000054	KING	SEATTLE	N.WEST	ORE	E.MARGINAL LEAD	E.MARG.&DUWAMISH
☐	**809798C**	WA	UP	Public	At Grade	Open	000020	KING	SEATTLE	N.WEST	ORE	E.MARGINAL LEAD	IDAHO ST.

☐	**809804D**	WA	UP	Public	At Grade	Open	000075	KING	SEATTLE	N WEST	ORE	HARBOR ISL LEAD	11TH AVE SO

Generate Repor | Show Paging | Reset

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085414L*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***12/07/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***KING***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In SEATTLE***
Railroad Milepost:	***0001.77***	Street or Road Name:	***BROAD STREET***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***SEATTLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.6145757***
ENS Sign Installed:		Longitude:	***-122.3538231***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***24 hr***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access: ***Unknown***

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***55*** Total Switching: ***0*** Day Thru: ***28***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***2*** Other ***1*** Specify: ***TROLLEY***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***085414L*** Effective Begin-Date of Record: ***12/07/10***
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	***2***	Highway Stop Signs:	***0***
Advanced Warning:	***Yes***	Hump Crossing Sign:	
Pavement Markings:	***Stop Lines and RR Xing Symbols***	Other Signs: ***2*** ***0***	Specify:

Train Activated Devices:

Gates:	***2***	4 Quad or Full Barrier:	
Mast Mounted FL:	***2***	Total Number FL Pairs:	***0***
Cantilevered FL (Over):	***2***	Cantilevered FL (Not over):	***0***
Other Flashing Lights:	***0***	Specify Other Flashing Lights:	
Highway Traffic Signals:	***0***	Wigwags: ***0***	Bells: ***1***
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	***DC/AFO***
Track Equipped with Train Signals?	***Yes***	Traffic Light Interconnection/Preemption:	***Simultaneous Preemption***

Part IV: Physical Characteristics

Type of Development:	***Industrial***	Smallest Crossing Angle:	***60 to 90 Degrees***
Number of Traffic Lanes Crossing Railroad:	***4***	Are Truck Pullout Lanes Present?	***No***
Is Highway Paved?	***Yes***		
Crossing Surface:	***Rubber***	If Other:	
Nearby Intersecting Highway?	***Less than 75 feet***	Is it Signalized?	
Does Track Run Down a Street?	***No***	Is Crossing Illuminated?	
Is Commercial Power Available?	***Yes***		

Part V: Highway Information

Highway System:	***Other FA Highway - Not NHS***	Functional Classification of Road at Crossing:	***Urban Local***
Is Crossing on State Highway System:	***No***		
Annual Average Daily Traffic (AADT):	***008649***	AADT Year:	***1993***
Estimated Percent Trucks:	***07***	Avg. No of School Buses per Day:	***0***
Posted Highway Speed:	***0***		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085413E*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***12/07/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***KING***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In SEATTLE***
Railroad Milepost:	***0001.68***	Street or Road Name:	***CLAY ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***SEATTLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.6134653***
ENS Sign Installed:		Longitude:	***-122.3519477***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***24 hr***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access: ***Unknown***

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***55*** Total Switching: ***0*** Day Thru: ***28***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***2*** Other ***1*** Specify: ***TROLLEY***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***085413E***

Effective Begin-Date of Record: ***12/07/10***

End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	***2***	Highway Stop Signs:	***0***
Advanced Warning:	***No***	Hump Crossing Sign:	
Pavement Markings:	***Stop Lines***	Other Signs: ***0***	Specify:
		0	

Train Activated Devices:

Gates:	***2***	4 Quad or Full Barrier:	
Mast Mounted FL:	***2***	Total Number FL Pairs:	***0***
Cantilevered FL (Over):	***1***	Cantilevered FL (Not over):	***0***
Other Flashing Lights:	***0***	Specify Other Flashing Lights:	
Highway Traffic Signals:	***0***	Wigwags: ***0***	Bells: ***1***
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	***DC/AFO***
Track Equipped with Train Signals?	***Yes***	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	***Industrial***	Smallest Crossing Angle:	***60 to 90 Degrees***
Number of Traffic Lanes Crossing Railroad:	***4***	Are Truck Pullout Lanes Present?	***No***
Is Highway Paved?	***Yes***		
Crossing Surface:	***Asphalt***	If Other:	
Nearby Intersecting Highway?	***Less than 75 feet***	Is it Signalized?	
Does Track Run Down a Street?	***No***	Is Crossing Illuminated?	
Is Commercial Power Available?	***Yes***		

Part V: Highway Information

Highway System:	***Non-Federal-aid***	Functional Classification of Road at Crossing:	***Urban Local***
Is Crossing on State Highway System:	***No***		
Annual Average Daily Traffic (AADT):	***001440***	AADT Year:	***1993***
Estimated Percent Trucks:	***01***	Avg. No of School Buses per Day:	***0***
Posted Highway Speed:	***0***		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085411R*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***12/07/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***KING***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In SEATTLE***
Railroad Milepost:	***0001.57***	Street or Road Name:	***VINE ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***SEATTLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.6129353***
ENS Sign Installed:		Longitude:	***-122.3510103***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***24 hr***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access: ***Unknown***

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***55*** Total Switching: ***0*** Day Thru: ***28***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***2*** Other ***1*** Specify: ***TROLLEY***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085411R*

Effective Begin-Date of Record: *12/07/10*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*1*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Asphalt*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000866*	AADT Year:	*1993*
Estimated Percent Trucks:	*27*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085410J*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***12/07/10***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SCENIC***	County:	***KING***
Branch or Line Name:	***WENACHE-SEATTLE***	City:	***In SEATTLE***
Railroad Milepost:	***0001.51***	Street or Road Name:	***WALL ST***
RailRoad I.D. No.:	***0050***	Highway Type & No.:	***CITY ST***
Nearest RR Timetable Stn:	***SEATTLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.6116900***
ENS Sign Installed:		Longitude:	***-122.3486709***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***24 hr***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access: ***Unknown***

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***55*** Total Switching: ***0*** Day Thru: ***28***

Typical Speed Range Over Crossing: From ***1*** to ***30*** mph Maximum Time Table Speed: ***30***

Type and Number of Tracks: Main: ***2*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085410J*

Effective Begin-Date of Record: *12/07/10*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*4*	4 Quad or Full Barrier:	*Yes*
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*1*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Asphalt*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*003477*	AADT Year:	*1993*
Estimated Percent Trucks:	*03*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 101039H Update Reason: Changed Crossing Effective Begin-Date of Record: 08/17/06
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	STACY ST YARD	County:	KING
Branch or Line Name:	STCY ST. YD	City:	In SEATTLE
Railroad Milepost:	0000.00	Street or Road Name:	ATLANTIC ST
RailRoad I.D. No.:	0623	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2
Crossing Owner:		Latitude:	47.3037990
ENS Sign Installed:		Longitude:	-122.2266010
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 32 Total Switching: 32 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 5 Specify: YARD & IND

Does Another RR Operate a Separate Track at Crossing? Yes: UP
Does Another RR Operate Over Your Track at Crossing? Yes: UP

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 101039H

Effective Begin-Date of Record: 08/17/06
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	1	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	None
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	4	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Timber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Local
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	000010	AADT Year:	1988
Estimated Percent Trucks:	01	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 399761C Update Reason: New Crossing Effective Begin-Date of Record: 01/01/70
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency State Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COAST	State:	WA
Subdivision:	5	County:	KING
Branch or Line Name:	WATERFRONT LINE	City:	In SEATTLE
Railroad Milepost:	0780.00	Street or Road Name:	ATLANTIC ST
RailRoad I.D. No.:	TRK W2	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	SHT 7OF13
Crossing Owner:		Latitude:	47.3037990
ENS Sign Installed:		Longitude:	-122.2266010
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 4 Total Switching: 4 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 2 Specify: LEADS

Does Another RR Operate a Separate Track at Crossing? Yes: UP BN PRTD
Does Another RR Operate Over Your Track at Crossing? Yes: UP BN

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 399761C

Effective Begin-Date of Record: 01/01/70
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	None
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Local
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	000010	AADT Year:	1970
Estimated Percent Trucks:	01	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085583Y*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***07/01/08***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SEATTLE***	County:	***KING***
Branch or Line Name:	***SEATTLE-VANC WA***	City:	***In SEATTLE***
Railroad Milepost:	***0000.84***	Street or Road Name:	***HOLGATE ST***
RailRoad I.D. No.:	***0051***	Highway Type & No.:	
Nearest RR Timetable Stn:	***SEATTLE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.5861009***
ENS Sign Installed:		Longitude:	***-122.3320137***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***67*** Total Switching: ***0*** Day Thru: ***34***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***2*** Other ***4*** Specify: ***YARD TRKS***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085583Y*

Effective Begin-Date of Record: *07/01/08*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*3*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *2* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *2*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*Constant Warning Time*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*4*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*005900*	AADT Year:	*1993*
Estimated Percent Trucks:	*09*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 101007C Update Reason: Changed Crossing Effective Begin-Date of Record: 12/14/09
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	KING ST STATIO	County:	KING
Branch or Line Name:	7TH AVE LD&SPRS	City:	In SEATTLE
Railroad Milepost:	0003.00	Street or Road Name:	HOLGATE ST.
RailRoad I.D. No.:	0622	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SPOKANE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2
Crossing Owner:		Latitude:	47.5866010
ENS Sign Installed:		Longitude:	-122.3193970
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 8 Total Switching: 8 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 2 Specify: YARD

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 101007C

Effective Begin-Date of Record: 12/14/09
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 2	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	2	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Commercial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	5	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Other Principal
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	010900	AADT Year:	1988
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 809504P Update Reason: Changed Crossing Effective Begin-Date of Record: 12/27/88
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	N. WEST	State:	WA
Subdivision:	ORE.	County:	KING
Branch or Line Name:	SEA. M.L.	City:	In SEATTLE
Railroad Milepost:	0182.30	Street or Road Name:	HOLGATE STREET SO
RailRoad I.D. No.:		Highway Type & No.:	FAM9011
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2&8OF13
Crossing Owner:		Latitude:	47.5863000
ENS Sign Installed:		Longitude:	-122.3261030
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 2 Total Switching: 2 Day Thru: 0
Typical Speed Range Over Crossing: From 10 to 15 mph Maximum Time Table Speed: 15
Type and Number of Tracks: Main: 2 Other 1 Specify: SPURS

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 809504P

Effective Begin-Date of Record: 12/27/88
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 4	Specify: 6 TRACKS
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	4	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 2
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Commercial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	4	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Collector
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	009100	AADT Year:	1988
Estimated Percent Trucks:	10	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085584F*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***07/01/08***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SEATTLE***	County:	***KING***
Branch or Line Name:	***SEATTLE-VANC WA***	City:	***In SEATTLE***
Railroad Milepost:	***0001.28***	Street or Road Name:	***LANDER ST***
RailRoad I.D. No.:	***0051***	Highway Type & No.:	
Nearest RR Timetable Stn:	***SPOKANE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17 2 11***
Crossing Owner:		Latitude:	***47.5798105***
ENS Sign Installed:		Longitude:	***-122.3320193***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***67*** Total Switching: ***0*** Day Thru: ***34***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***2*** Other ***2*** Specify: ***YARD TRKS***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing ***085584F***

Effective Begin-Date of Record: ***07/01/08***

End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*0*	Highway Stop Signs:	*0*		
Advanced Warning:	*No*	Hump Crossing Sign:			
Pavement Markings:	*No Markings*	Other Signs:	*2*	Specify:	*4-TRKS*
			0		

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:			
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*		
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*		
Other Flashing Lights:	*0*	Specify Other Flashing Lights:			
Highway Traffic Signals:	*0*	Wigwags:	*0*	Bells:	*2*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:			
Channelization:		Type of Train Detection:	*DC/AFO*		
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:			

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*5*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Other Principal*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*013280*	AADT Year:	*1993*
Estimated Percent Trucks:	*15*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 096481L Update Reason: Changed Crossing Effective Begin-Date of Record: 02/27/09
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	SEATTLE	County:	KING
Branch or Line Name:	SEAFAB-TXCO SPR	City:	In SEATTLE
Railroad Milepost:	0002.22	Street or Road Name:	S.W. LANDER ST
RailRoad I.D. No.:	0051	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SPOKANE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2
Crossing Owner:		Latitude:	47.5798190
ENS Sign Installed:		Longitude:	-122.3548370
Passenger Service:		Lat/Long Source:	Fed. Derived
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 3 Total Switching: 3 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 50 mph Maximum Time Table Speed: 50
Type and Number of Tracks: Main: 0 Other 4 Specify: IND. SPURS

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 096481L

Effective Begin-Date of Record: 02/27/09
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	None
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	30 to 59 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Local
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	000010	AADT Year:	1988
Estimated Percent Trucks:	01	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 101011S Update Reason: Changed Crossing Effective Begin-Date of Record: 08/17/06
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Position: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	SEATTLE	County:	KING
Branch or Line Name:	8TH AVE LEAD	City:	In SEATTLE
Railroad Milepost:	0003.00	Street or Road Name:	LANDER ST
RailRoad I.D. No.:	0051	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SPOKANE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2
Crossing Owner:		Latitude:	47.5798000
ENS Sign Installed:		Longitude:	-122.3365020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 4 Total Switching: 4 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 79 mph Maximum Time Table Speed: 79
Type and Number of Tracks: Main: 0 Other 3 Specify: IND LEAD

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 101011S

Effective Begin-Date of Record: 08/17/06
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	None
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Commercial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	5	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	Yes	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Other Principal
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	012100	AADT Year:	1988
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 809503H Update Reason: Changed Crossing Effective Begin-Date of Record: 12/27/88
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	N. WEST.	State:	WA
Subdivision:	ORE.	County:	KING
Branch or Line Name:	ML SEA.	City:	Near SEATTLE
Railroad Milepost:	0181.80	Street or Road Name:	LANDER ST, SO.
RailRoad I.D. No.:		Highway Type & No.:	FAM9008
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2&8OF13
Crossing Owner:		Latitude:	47.5798000
ENS Sign Installed:		Longitude:	-122.3262020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 2 Total Switching: 2 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 15
Type and Number of Tracks: Main: 2 Other 1 Specify: SPUR

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 809503H

Effective Begin-Date of Record: 12/27/88
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 2 0	Specify: 4 TRACKS

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	4	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 2
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Commercial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	4	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Other Principal
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	011800	AADT Year:	1988
Estimated Percent Trucks:	10	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***095988D*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***02/27/09***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SEATTLE***	County:	***KING***
Branch or Line Name:	***SPOKANE ST WYE***	City:	***In SEATTLE***
Railroad Milepost:	***0002.22***	Street or Road Name:	***SPOKANE ST W.BD***
RailRoad I.D. No.:	***0051***	Highway Type & No.:	
Nearest RR Timetable Stn:	***SPOKANE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	
Crossing Owner:		Latitude:	***47.5719990***
ENS Sign Installed:		Longitude:	***-122.3263020***
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	***0***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***27*** Total Switching: ***27*** Day Thru: ***0***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***0*** Other ***3*** Specify: ***IND SPUR***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: UP***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *095988D*

Effective Begin-Date of Record: *02/27/09*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*0*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*No*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Industrial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Urban Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*010000*	AADT Year:	*1990*
Estimated Percent Trucks:	*07*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085587B*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***07/01/08***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SEATTLE***	County:	***KING***
Branch or Line Name:	***SEATTLE-VANC WA***	City:	***In SEATTLE***
Railroad Milepost:	***0001.86***	Street or Road Name:	***EB SPOKANE ST***
RailRoad I.D. No.:	***0051***	Highway Type & No.:	
Nearest RR Timetable Stn:	***SPOKANE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.5714049***
ENS Sign Installed:		Longitude:	***-122.3317176***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***67*** Total Switching: ***0*** Day Thru: ***34***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***2*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085587B*

Effective Begin-Date of Record: *07/01/08*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*1*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*017350*	AADT Year:	*1993*
Estimated Percent Trucks:	*12*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: ***085586U*** Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***07/01/08***

Railroad: ***BNSF BNSF Rwy Co. [BNSF]*** End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	***NORTHWEST***	State:	***WA***
Subdivision:	***SEATTLE***	County:	***KING***
Branch or Line Name:	***SEATTLE-VANC WA***	City:	***In SEATTLE***
Railroad Milepost:	***0001.85***	Street or Road Name:	***WB SPOKANE ST***
RailRoad I.D. No.:	***0051***	Highway Type & No.:	
Nearest RR Timetable Stn:	***SPOKANE***	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	***17-2***
Crossing Owner:		Latitude:	***47.5715939***
ENS Sign Installed:		Longitude:	***-122.3317173***
Passenger Service:	***AMTRAK***	Lat/Long Source:	***Actual***
Avg Passenger Train Count:	***1***	Quiet Zone:	***No***
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: ***67*** Total Switching: ***0*** Day Thru: ***34***

Typical Speed Range Over Crossing: From ***1*** to ***50*** mph Maximum Time Table Speed: ***50***

Type and Number of Tracks: Main: ***2*** Other ***0*** Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *085586U*

Effective Begin-Date of Record: *07/01/08*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*0*
Advanced Warning:	*No*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*1*	4 Quad or Full Barrier:	
Mast Mounted FL:	*1*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*1*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Concrete*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Urban Minor Arterial*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*008348*	AADT Year:	*1994*
Estimated Percent Trucks:	*12*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 096442V Update Reason: Changed Crossing Effective Begin-Date of Record: 02/27/09
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	SEATTLE	County:	KING
Branch or Line Name:	SPOKANE ST. LD	City:	In SEATTLE
Railroad Milepost:	0002.22	Street or Road Name:	SPOKANE ST E.BD.
RailRoad I.D. No.:	0051	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SPOKANE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2
Crossing Owner:		Latitude:	47.5658990
ENS Sign Installed:		Longitude:	-122.3383030
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 6 Total Switching: 6 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 50 mph Maximum Time Table Speed: 50
Type and Number of Tracks: Main: 0 Other 3 Specify: LEAD

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 096442V

Effective Begin-Date of Record: 02/27/09
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 1
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	30 to 59 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	003700	AADT Year:	1988
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 099009M Update Reason: Changed Crossing Effective Begin-Date of Record: 04/29/08
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	COLORADO AVE L	County:	KING
Branch or Line Name:	STCY ST. YD	City:	In SEATTLE
Railroad Milepost:	0001.80	Street or Road Name:	SPOKANE ST W:BD
RailRoad I.D. No.:	0430	Highway Type & No.:	
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	
Crossing Owner:		Latitude:	47.5719990
ENS Sign Installed:		Longitude:	-122.3263020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 50 Total Switching: 50 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 3 Specify: IND SPUR

Does Another RR Operate a Separate Track at Crossing? Yes: UP
Does Another RR Operate Over Your Track at Crossing? Yes: UP

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 099009M

Effective Begin-Date of Record: 04/29/08
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 1
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Local
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	010000	AADT Year:	1990
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 099007Y Update Reason: Changed Crossing Effective Begin-Date of Record: 04/29/08
Railroad: BNSF BNSF Rwy Co. [BNSF] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	NORTHWEST	State:	WA
Subdivision:	COLORADO AVE L	County:	KING
Branch or Line Name:	STCY ST. YD	City:	In SEATTLE
Railroad Milepost:	0001.80	Street or Road Name:	SPOKANE ST E.BD
RailRoad I.D. No.:	0430	Highway Type & No.:	
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	
Crossing Owner:		Latitude:	47.5719990
ENS Sign Installed:		Longitude:	-122.3263020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)832-5452 Railroad Contact: (913)551-4540 State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 50 Total Switching: 50 Day Thru: 0
Typical Speed Range Over Crossing: From 1 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 3 Specify: IND SPUR

Does Another RR Operate a Separate Track at Crossing? Yes: UP
Does Another RR Operate Over Your Track at Crossing? Yes: UP

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 099007Y

Effective Begin-Date of Record: 04/29/08
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 1
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Local
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	010000	AADT Year:	1990
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 399753K Update Reason: New Crossing Effective Begin-Date of Record: 01/01/70
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency State Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COAST	State:	WA
Subdivision:	5	County:	KING
Branch or Line Name:	WATERFRONT LINE	City:	In SEATTLE
Railroad Milepost:	0745.00	Street or Road Name:	SPOKANE ST (EB)
RailRoad I.D. No.:	TRK W2	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	SHT 7OF17
Crossing Owner:		Latitude:	47.5719990
ENS Sign Installed:		Longitude:	-122.3263020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 2 Total Switching: 2 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 1 Specify: LEAD

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? Yes: UP BN

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 399753K

Effective Begin-Date of Record: 01/01/70
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	1	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	1	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	None
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	003700	AADT Year:	1970
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 399754S Update Reason: New Crossing Effective Begin-Date of Record: 01/01/70
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency State Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COAST	State:	WA
Subdivision:	5	County:	KING
Branch or Line Name:	WATERFRONT LINE	City:	In SEATTLE
Railroad Milepost:	0845.00	Street or Road Name:	SPOKANE ST
RailRoad I.D. No.:	TRK W2	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	SHT 7OF13
Crossing Owner:		Latitude:	47.5719990
ENS Sign Installed:		Longitude:	-122.3263020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 2 Total Switching: 2 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 1 Specify: LEAD

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? Yes: UP BN

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 399754S

Effective Begin-Date of Record: 01/01/70
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	1	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0	Specify:
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	1	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	006150	AADT Year:	1970
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 399773W Update Reason: New Crossing Effective Begin-Date of Record: 01/01/70
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency State Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COAST	State:	WA
Subdivision:	5	County:	KING
Branch or Line Name:	COLORADO LINE	City:	In SEATTLE
Railroad Milepost:	0567.00	Street or Road Name:	SPOKANE ST (WB)
RailRoad I.D. No.:	TRK S15	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	SHT 7OF13
Crossing Owner:		Latitude:	47.5716020
ENS Sign Installed:		Longitude:	-122.3360980
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 12 Total Switching: 12 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 1 Specify: LEAD

Does Another RR Operate a Separate Track at Crossing? Yes: BN
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 399773W

Effective Begin-Date of Record: 01/01/70
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	2	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 1	Specify: 4 TRK
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0	Bells: 0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	003700	AADT Year:	1970
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 399772P Update Reason: New Crossing Effective Begin-Date of Record: 01/01/70
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency State Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COAST	State:	WA
Subdivision:	5	County:	KING
Branch or Line Name:	COLORADO LINE	City:	In SEATTLE
Railroad Milepost:	0417.00	Street or Road Name:	SPOKANE ST (EB)
RailRoad I.D. No.:	TRK S15	Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	SHT 7OF13
Crossing Owner:		Latitude:	47.5716020
ENS Sign Installed:		Longitude:	-122.3360980
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 12 Total Switching: 12 Day Thru: 0
Typical Speed Range Over Crossing: From 5 to 10 mph Maximum Time Table Speed: 10
Type and Number of Tracks: Main: 0 Other 1 Specify: LEAD

Does Another RR Operate a Separate Track at Crossing? Yes: BN
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 399772P

Effective Begin-Date of Record: 01/01/70
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	2	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 1 Specify:	4 TRK
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0 Bells:	0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Asphalt	If Other:	
Nearby Intersecting Highway?	N/A	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	003700	AADT Year:	1970
Estimated Percent Trucks:	07	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 809501U Update Reason: Changed Crossing Effective Begin-Date of Record: 12/27/88
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	N. WEST	State:	WA
Subdivision:	ORE.	County:	KING
Branch or Line Name:	SEA. ML	City:	In SEATTLE
Railroad Milepost:	0181.28	Street or Road Name:	SPOKANE ST. SO.
RailRoad I.D. No.:		Highway Type & No.:	EAM9097
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2&8OF13
Crossing Owner:		Latitude:	47.5713190
ENS Sign Installed:		Longitude:	-122.3277100
Passenger Service:		Lat/Long Source:	Actual
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 2 Total Switching: 2 Day Thru: 0
Typical Speed Range Over Crossing: From 10 to 15 mph Maximum Time Table Speed: 15
Type and Number of Tracks: Main: 2 Other 0 Specify:

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? No

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 809501U

Effective Begin-Date of Record: 12/27/88
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 2 Specify: 2TRACK	
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	4	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags: 0 Bells: 2	
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	No	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Commercial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	4	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Minor Arterial
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	003800	AADT Year:	1988
Estimated Percent Trucks:	10	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 9/2/2011

Crossing No.: 809720H Update Reason: Changed Crossing Effective Begin-Date of Record: 01/14/92
Railroad: UP Union Pacific RR Co. [UP] End-Date of Record:
Initiating Agency Railroad Type and Positiion: Public At Grade

Part I Location and Classification of Crossing

Division:	COL. RIVER	State:	WA
Subdivision:	SEATTLE	County:	KING
Branch or Line Name:	HARBOR ISL.LEAD	City:	In SEATTLE
Railroad Milepost:	0000.65	Street or Road Name:	W. SPOKANE ST
RailRoad I.D. No.:		Highway Type & No.:	CITY ST
Nearest RR Timetable Stn:	SEATTLE	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	17-2&7OF13
Crossing Owner:		Latitude:	47.5719990
ENS Sign Installed:		Longitude:	-122.3263020
Passenger Service:		Lat/Long Source:	
Avg Passenger Train Count:	0	Quiet Zone:	No
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: (800)848-8715 Railroad Contact: State Contact: (360)664-1262

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 6 Total Switching: 3 Day Thru: 2
Typical Speed Range Over Crossing: From 2 to 5 mph Maximum Time Table Speed: 15
Type and Number of Tracks: Main: 1 Other 0 Specify:

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? Yes: BN

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 809720H

Effective Begin-Date of Record: 01/14/92
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	No	Hump Crossing Sign:	
Pavement Markings:	No Markings	Other Signs: 0 Specify:	
		0	

Train Activated Devices:

Gates:	0	4 Quad or Full Barrier:	
Mast Mounted FL:	0	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	2	Wigwags: 0 Bells:	0
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	DC/AFO
Track Equipped with Train Signals?	Yes	Traffic Light Interconnection/Preemption:	Simultaneous Preemption

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	30 to 59 Degrees
Number of Traffic Lanes Crossing Railroad:	1	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Rubber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Other FA Highway - Not NHS	Functional Classification of Road at Crossing:	Urban Other Principal
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	000010	AADT Year:	1988
Estimated Percent Trucks:	01	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

Daily Traffic at Crossings

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 302544	S HOLGATE BR, E/O S HOLGATE ST; W FLOW;(AGG) TUBE; 12Apr2011 10:30 4/12/11 10:30 am THRU 4/19/11 10:30 am		
COUNTER: 020	CHAN: A TUBE	FLOW: W	LANE CODE: STANDARD

INTERVAL	17-Apr-2011 SUN	18-Apr-2011 MON	12-Apr-2011 TUE	13-Apr-2011 WED	14-Apr-2011 THU	15-Apr-2011 FRI	16-Apr-2011 SAT
1:00	28	16	13	17	12	23	21
2:00	33	19	8	12	10	11	17
3:00	19	4	7	6	7	6	15
4:00	14	17	19	16	13	19	17
5:00	19	45	39	42	46	42	16
6:00	30	71	75	78	88	80	40
7:00	37	167	165	168	182	161	64
8:00	64	255	262	265	287	258	79
9:00	97	259	285	278	307	264	121
10:00	110	209	224	239	246	273	201
11:00	200	215	183	201	204	233	224
12:00	171	232	238	232	212	247	239
13:00	197	239	227	228	233	271	235
14:00	226	251	215	214	240	259	238
15:00	169	267	243	239	237	236	195
16:00	183	254	254	204	217	265	226
17:00	166	234	213	249	241	244	190
18:00	98	234	218	213	222	201	173
19:00	91	158	159	133	136	129	122
20:00	68	109	101	107	105	130	108
21:00	47	68	71	77	61	93	74
22:00	32	45	54	43	64	67	50
23:00	23	36	31	34	37	50	82
24:00	17	21	24	31	24	33	47
Daily Total	2,139	3,425	3,328	3,326	3,431	3,595	2,794
AM Peak Vol	200	289	313	302	330	287	245
AM Peak Hr	10:00 - 11:00	07:45 - 08:45	07:45 - 08:45	07:30 - 08:30	07:30 - 08:30	08:30 - 09:30	10:45 - 11:45
AM Peak Fac	0.794	0.794	0.921	0.858	0.868	0.920	0.806
AM 15min Hi	10:45	08:00	08:00	08:00	08:00	09:00	11:45
PM Peak Vol	226	272	254	253	253	274	244
PM Peak Hr	13:00 - 14:00	13:45 - 14:45	15:00 - 16:00	15:45 - 16:45	15:45 - 16:45	12:45 - 13:45	12:30 - 13:30
PM Peak Fac	0.883	0.861	0.847	0.866	0.930	0.846	0.897
PM 15min Hi	13:15	14:30	15:45	16:45	16:15	13:00	12:45
Max8 Vol	1,422	2,004	1,968	1,958	2,021	2,099	1,722
Max8 %/DT	0.665	0.585	0.591	0.589	0.589	0.584	0.616

Average Daily Traffic (ADT)	=	3,148	based on 7 days
Average Weekday Traffic (AWDT)	=	3,421	based on 5 weekdays
AWDT Max8 Volume	=	2,010	(58.8% of AWDT)
AWDT AM Peak Hour Volume	=	304	based on 5 weekdays
AWDT PM Peak Hour Volume	=	261	based on 5 weekdays

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 302543	S HOLGATE BR, E/O S HOLGATE ST; E FLOW; CHA TUBE; 12Apr2011 10:30 4/12/11 10:30 am THRU 4/19/11 10:30 am		
COUNTER: 020	CHAN: A TUBE	FLOW: E	LANE CODE: STANDARD

INTERVAL	17-Apr-2011 SUN	18-Apr-2011 MON	12-Apr-2011 TUE	13-Apr-2011 WED	14-Apr-2011 THU	15-Apr-2011 FRI	16-Apr-2011 SAT
1:00	47	11	31	32	24	26	52
2:00	58	14	15	18	20	20	26
3:00	54	9	15	15	19	17	36
4:00	29	7	10	9	7	12	20
5:00	14	13	13	13	12	12	12
6:00	12	15	18	19	24	18	12
7:00	21	44	38	45	47	48	25
8:00	27	119	120	113	98	116	37
9:00	38	139	138	140	158	127	55
10:00	59	145	128	149	165	162	101
11:00	96	172	143	153	168	130	172
12:00	123	171	213	196	197	207	163
13:00	143	250	230	234	212	233	183
14:00	167	226	173	217	213	246	217
15:00	171	243	247	264	273	275	222
16:00	209	305	311	265	311	320	233
17:00	201	342	342	381	341	373	239
18:00	141	384	378	373	387	359	199
19:00	130	232	253	209	247	208	202
20:00	87	112	142	151	162	145	119
21:00	69	110	104	115	91	111	93
22:00	59	94	117	72	80	87	84
23:00	52	72	66	57	71	68	123
24:00	26	55	60	35	44	57	103
Daily Total	2,033	3,284	3,305	3,275	3,371	3,377	2,728
AM Peak Vol	123	172	213	196	200	207	176
AM Peak Hr	11:00 - 12:00	09:30 - 10:30	11:00 - 12:00	11:00 - 12:00	10:45 - 11:45	11:00 - 12:00	10:45 - 11:45
AM Peak Fac	0.750	0.754	0.795	0.961	0.746	0.892	0.815
AM 15min Hi	11:15	10:15	11:45	12:00	11:15	11:30	11:45
PM Peak Vol	209	385	378	405	397	386	248
PM Peak Hr	15:00 - 16:00	16:30 - 17:30	16:45 - 17:45	16:45 - 17:45	16:30 - 17:30	16:45 - 17:45	15:45 - 16:45
PM Peak Fac	0.871	0.917	0.859	0.955	0.848	0.919	0.849
PM 15min Hi	15:15	16:45	17:45	17:45	17:30	17:00	16:00
Max8 Vol	1,230	2,112	2,132	2,103	2,181	2,160	1,595
Max8 %/DT	0.605	0.643	0.645	0.642	0.647	0.640	0.585

Average Daily Traffic (ADT)	=	**3,053**	**based on 7 days**
Average Weekday Traffic (AWDT)	=	**3,322**	**based on 5 weekdays**
AWDT Max8 Volume	=	**2,138**	**(64.3% of AWDT)**
AWDT AM Peak Hour Volume	=	**198**	**based on 5 weekdays**
AWDT PM Peak Hour Volume	=	**390**	**based on 5 weekdays**

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 303801	S LANDER ST, W/O 6TH AVE S; W FLOW; CHA TUBE; 11Aug2011 10:30 8/11/11 10:30 am THRU 8/18/11 10:30 am		
COUNTER: **005**	CHAN: **A TUBE**	FLOW: **W**	LANE CODE: **STANDARD**

INTERVAL	14-Aug-2011 **SUN**	15-Aug-2011 **MON**	16-Aug-2011 **TUE**	17-Aug-2011 **WED**	11-Aug-2011 **THU**	12-Aug-2011 **FRI**	13-Aug-2011 **SAT**
1:00	97	36	40	288	301	53	74
2:00	61	23	41	170	210	39	63
3:00	37	29	37	135	132	33	53
4:00	39	72	51	125	115	54	50
5:00	29	138	119	227	151	96	62
6:00	73	377	366	424	388	362	102
7:00	128	647	666	683	723	673	168
8:00	110	743	731	779	769	781	217
9:00	150	746	739	764	816	842	240
10:00	233	679	745	699	726	705	408
11:00	461	634	662	720	678	757	445
12:00	797	756	763	781	803	804	703
13:00	971	744	730	735	705	766	817
14:00	471	649	683	660	752	682	551
15:00	259	640	658	632	592	631	444
16:00	268	663	703	643	703	767	497
17:00	326	627	690	672	665	796	497
18:00	174	617	699	607	579	798	582
19:00	136	508	561	517	343	593	533
20:00	104	223	259	248	246	287	199
21:00	101	150	179	176	178	216	143
22:00	88	101	176	158	106	179	131
23:00	82	101	188	160	100	203	199
24:00	40	75	317	267	73	133	113
Daily Total	**5,235**	**9,978**	**10,803**	**11,270**	**10,854**	**11,250**	**7,291**
AM Peak Vol	797	756	765	849	818	889	703
AM Peak Hr	11:00 - 12:00	11:00 - 12:00	08:15 - 09:15	07:15 - 08:15	07:45 - 08:45	07:30 - 08:30	11:00 - 12:00
AM Peak Fac	0.807	0.909	0.861	0.852	0.951	0.875	0.806
AM 15min Hi	11:45	12:00	09:15	08:15	08:00	08:30	11:45
PM Peak Vol	971	744	733	735	752	846	817
PM Peak Hr	12:00 - 13:00	12:00 - 13:00	14:45 - 15:45	12:00 - 13:00	13:00 - 14:00	16:30 - 17:30	12:00 - 13:00
PM Peak Fac	0.930	0.873	0.970	0.875	0.931	0.936	0.884
PM 15min Hi	12:15	12:30	15:15	12:15	13:30	16:45	12:15
Max8 Vol	3,729	5,729	5,869	5,902	6,009	6,315	4,634
Max8 %/DT	0.712	0.574	0.543	0.524	0.554	0.561	0.636

Average Daily Traffic (ADT)	=	**9,526**	**based on 7 days**
Average Weekday Traffic (AWDT)	=	**10,831**	**based on 5 weekdays**
AWDT Max8 Volume	=	**5,965**	**(55.1% of AWDT)**
AWDT AM Peak Hour Volume	=	**815**	**based on 5 weekdays**
AWDT PM Peak Hour Volume	=	**762**	**based on 5 weekdays**

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 303800	S LANDER ST, W/O 6TH AVE S; E FLOW; CHB TUBE; 11Aug2011 10:45 8/11/11 10:45 am THRU 8/18/11 10:45 am		
COUNTER: 046	CHAN: B TUBE	FLOW: E	LANE CODE: STANDARD

INTERVAL	14-Aug-2011 SUN	15-Aug-2011 MON	16-Aug-2011 TUE	17-Aug-2011 WED	11-Aug-2011 THU	12-Aug-2011 FRI	13-Aug-2011 SAT
1:00	58	26	14	25	44	38	63
2:00	46	27	24	26	38	36	90
3:00	37	15	18	17	25	41	40
4:00	25	14	21	21	18	28	38
5:00	12	34	57	42	36	40	16
6:00	26	76	76	80	85	84	27
7:00	27	150	161	166	175	177	59
8:00	27	260	274	269	266	278	56
9:00	49	269	323	300	323	286	102
10:00	60	304	284	306	346	293	153
11:00	73	331	333	340	344	348	195
12:00	126	459	439	446	421	464	194
13:00	161	465	451	474	495	482	247
14:00	156	449	464	473	500	485	206
15:00	179	473	438	461	457	480	246
16:00	591	501	627	541	550	592	514
17:00	535	515	536	502	623	486	239
18:00	128	451	601	435	493	411	216
19:00	121	294	397	309	329	294	201
20:00	61	157	190	176	158	159	116
21:00	42	122	168	138	127	132	78
22:00	46	196	172	220	94	177	205
23:00	37	343	312	230	56	235	630
24:00	21	47	61	43	45	54	286
Daily Total	2,644	5,978	6,441	6,040	6,048	6,100	4,217
AM Peak Vol	126	459	439	446	421	464	215
AM Peak Hr	11:00 - 12:00	11:00 - 12:00	11:00 - 12:00	11:00 - 12:00	11:00 - 12:00	11:00 - 12:00	10:45 - 11:45
AM Peak Fac	0.808	0.844	0.838	0.851	0.907	0.823	0.827
AM 15min Hi	11:30	12:00	12:00	12:00	12:00	12:00	11:00
PM Peak Vol	736	544	634	541	623	592	682
PM Peak Hr	15:30 - 16:30	16:30 - 17:30	16:45 - 17:45	15:00 - 16:00	16:00 - 17:00	15:00 - 16:00	22:15 - 23:15
PM Peak Fac	0.780	0.925	0.852	0.896	0.933	0.937	0.782
PM 15min Hi	16:00	16:45	17:15	15:15	16:45	16:00	22:45
Max8 Vol	1,961	3,481	3,719	3,648	3,748	3,708	2,619
Max8 %/DT	0.742	0.582	0.577	0.604	0.620	0.608	0.621

Average Daily Traffic (ADT)	=	5,353	based on 7 days
Average Weekday Traffic (AWDT)	=	6,121	based on 5 weekdays
AWDT Max8 Volume	=	3,661	(59.8% of AWDT)
AWDT AM Peak Hour Volume	=	446	based on 5 weekdays
AWDT PM Peak Hour Volume	=	587	based on 5 weekdays

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 215717	BROAD ST, SW/O ELLIOTT AVE; NE FLOW; CH1; 14JAN2009 11:00+ 1/14/09 11:00 am THRU 1/21/09 10:30 am		
COUNTER: **204**	CHAN: **1**	FLOW: **NE**	LANE CODE: **STANDARD**

INTERVAL	18-Jan-2009 **SUN**	19-Jan-2009 **MON** HOLIDAY	20-Jan-2009 **TUE**	14-Jan-2009 **WED**	15-Jan-2009 **THU**	16-Jan-2009 **FRI**	17-Jan-2009 **SAT**
1:00	104	34	26	27	23	37	98
2:00	78	11	9	16	12	21	59
3:00	31	13	7	4	8	13	36
4:00	11	4	10	6	11	14	25
5:00	20	2	4	6	5	25	36
6:00	22	39	39	44	63	70	13
7:00	35	107	117	110	117	92	33
8:00	64	178	314	309	306	313	83
9:00	56	219	323	348	396	341	102
10:00	108	192	196	277	264	232	111
11:00	145	238	249	263	249	266	173
12:00	237	242	272	298	312	308	214
13:00	310	372	258	354	300	310	257
14:00	375	369	271	312	334	391	386
15:00	428	378	290	315	337	368	397
16:00	458	413	293	351	321	412	439
17:00	458	446	451	469	478	518	450
18:00	315	485	532	633	848	679	360
19:00	245	254	325	415	415	394	287
20:00	168	214	168	189	192	247	256
21:00	187	155	145	173	174	164	192
22:00	159	111	118	133	119	152	192
23:00	104	80	102	97	108	148	226
24:00	69	33	39	48	51	85	142
Daily Total	4,187	4,589	4,558	5,197	5,443	5,600	4,567
AM Peak Vol	237	276	375	380	435	392	214
AM Peak Hr	11:00 - 12:00	09:30 - 10:30	07:30 - 08:30	07:45 - 08:45	07:45 - 08:45	07:45 - 08:45	11:00 - 12:00
AM Peak Fac	0.898	0.704	0.884	0.812	0.843	0.852	0.836
AM 15min Hi	11:15	09:45	08:00	08:00	08:45	08:00	11:15
PM Peak Vol	503	525	532	641	848	681	455
PM Peak Hr	15:30 - 16:30	16:30 - 17:30	17:00 - 18:00	17:15 - 18:15	17:00 - 18:00	16:45 - 17:45	14:45 - 15:45
PM Peak Fac	0.791	0.777	0.751	0.712	0.869	0.839	0.932
PM 15min Hi	15:45	17:30	17:30	17:30	17:30	17:30	15:45
Max8 Vol	2,826	2,984	2,692	3,147	3,345	3,385	2,832
Max8 %/DT	0.675	0.650	0.591	0.606	0.615	0.604	0.620

Average Daily Traffic (ADT)	=	**4,965**	**based on 6 days**
Average Weekday Traffic (AWDT)	=	**5,200**	**based on 4 weekdays**
AWDT Max8 Volume	=	**3,142**	**(60.4% of AWDT)**
AWDT AM Peak Hour Volume	=	**396**	**based on 4 weekdays**
AWDT PM Peak Hour Volume	=	**676**	**based on 4 weekdays**

9,143 Total AWDT

AUTOMATIC TRAFFIC COUNT - 1 Hour Detail Report

Seattle Department of Transportation

STUDY 215718	BROAD ST, SW/O ELLIOTT AVE; SW FLOW; CH2; 14JAN2009 11:00 1/14/09 11:00 am THRU 1/21/09 11:00 am		
COUNTER: 183	CHAN: 2	FLOW: SW	LANE CODE: STANDARD

INTERVAL	18-Jan-2009 SUN	19-Jan-2009 MON HOLIDAY	20-Jan-2009 TUE	14-Jan-2009 WED	15-Jan-2009 THU	16-Jan-2009 FRI	17-Jan-2009 SAT
1:00	35	12	5	10	10	20	32
2:00	19	7	7	10	5	13	12
3:00	16	8	5	6	3	7	13
4:00	8	0	8	3	4	5	4
5:00	14	5	11	7	13	12	14
6:00	23	24	73	50	54	43	28
7:00	41	91	134	127	108	110	55
8:00	54	169	287	290	271	232	77
9:00	63	181	294	320	322	329	86
10:00	118	184	202	212	198	196	93
11:00	164	204	221	200	200	202	160
12:00	227	235	237	246	240	234	212
13:00	259	271	188	200	186	214	241
14:00	239	289	190	233	207	293	277
15:00	317	268	194	267	229	284	239
16:00	311	284	247	312	313	357	329
17:00	295	350	444	478	457	515	301
18:00	227	278	424	485	526	461	240
19:00	145	136	214	182	206	197	215
20:00	79	134	107	89	115	151	201
21:00	93	80	72	81	87	114	99
22:00	55	52	69	68	73	100	102
23:00	41	39	37	65	63	87	116
24:00	31	15	13	22	18	42	55
Daily Total	2,874	3,316	3,683	3,963	3,908	4,218	3,201
AM Peak Vol	227	238	329	351	334	333	212
AM Peak Hr	11:00 - 12:00	10:30 - 11:30	07:30 - 08:30	07:30 - 08:30	07:45 - 08:45	07:45 - 08:45	11:00 - 12:00
AM Peak Fac	0.946	0.815	0.875	0.895	0.928	0.895	0.869
AM 15min Hi	11:30	11:15	08:00	08:00	08:30	08:15	12:00
PM Peak Vol	317	350	520	553	563	544	330
PM Peak Hr	14:00 - 15:00	16:15 - 17:15	16:45 - 17:45	16:45 - 17:45	16:45 - 17:45	16:30 - 17:30	15:15 - 16:15
PM Peak Fac	0.932	0.866	0.769	0.875	0.932	0.840	0.771
PM 15min Hi	14:15	17:00	17:30	17:00	17:45	17:30	15:30
Max8 Vol	2,046	2,179	2,155	2,432	2,388	2,569	2,067
Max8 %/DT	0.712	0.657	0.585	0.614	0.611	0.609	0.646

Average Daily Traffic (ADT)	=	**3,684**	**based on 6 days**
Average Weekday Traffic (AWDT)	=	**3,943**	**based on 4 weekdays**
AWDT Max8 Volume	=	**2,386**	**(60.5% of AWDT)**
AWDT AM Peak Hour Volume	=	**337**	**based on 4 weekdays**
AWDT PM Peak Hour Volume	=	**545**	**based on 4 weekdays**

Transportation Element Information

T48 Recognize the importance of the freight network to the city's economic health when making decisions that affect Major Truck streets as well as other parts of the region's roadway system.

T49 Support efficient and safe movement of goods by rail where appropriate. Promote continued operation of freight rail lines and intermodal yards that serve industrial properties and the transport of goods. Improve the safety and operational conditions for freight rail transport at the rail track crossings within city streets.

T50 Promote an intermodal freight transportation strategy, including rail, truck, air and water transport and advocate for improved freight and goods movement. Work toward improved multi-modal connections among rail yards, industrial areas, airports, and regional roadways.

T51 Consider the needs for local delivery and collection of goods at businesses by truck when making street operational decisions and when developing and implementing projects and programs for highways, streets and bridges.

E Improving the Environment

discussion

The development pattern promoted by the urban village strategy is supported by transportation policies that encourage walking, biking, and transit. Streets that support travel by all modes and that are well designed and maintained and that include landscaping and street trees contribute to a healthy urban environment. Over-reliance on motor vehicles degrades environmental quality in the form of deteriorating air quality, increasing water pollution through street and stormwater runoff, and causing higher levels of noise pollution. Excessive reliance on motor vehicles also negatively affects the quality of life in the city by increasing congestion and travel time.

goals

TG21 Promote healthy neighborhoods with a transportation system that protects and Improves environmental quality.

TG22 Reduce or mitigate air, water, and noise pollution from motor vehicles.

TG23 Promote energy-efficient transportation.

policies

T52 Design and operate streets to promote healthy urban environments while keeping safety, accessibility and aesthetics in balance.

T53 Implement an environmental management system to develop, operate and maintain a safe and reliable transportation system in a manner that reduces the environmental impacts of City operations and services.

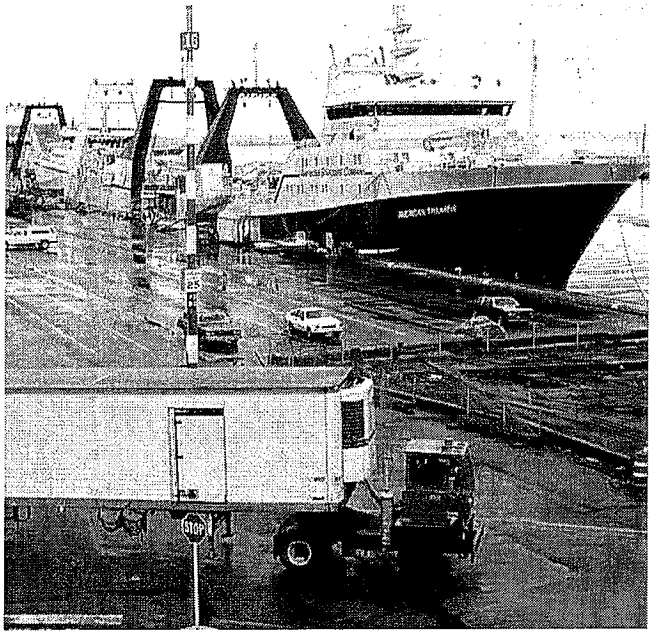
Freight Mobility Strategic Action Plan

June 2005

SDOT

Seattle Department of Transportation

Freight Mobility Strategic Action Plan
2005 Update — Executive Summary



The City of Seattle is investing in improvements to move goods efficiently, create jobs, support businesses and grow the economy.

Strengthening the Voice Of Industry: The Freight Community Partnership

In October 2002, the Seattle Freight Mobility Advisory Committee, co-sponsored by SDOT and the Seattle industrial community, was created. This forum offers regular communication with city staff and other agencies and advises on freight needs. The Committee makes sure we know freight's interests on projects as small as speed bumps to as large as the Alaskan Way Viaduct.

SDOT presents the committee's recommendations to project sponsors and decision makers, reflecting the interests of constituents both in north and south Seattle to encourage attendance and participation.

SEATTLE TAKES ACTION - 2004 RESULTS

Highlights of SDOT's implementation of the *2004 Freight Mobility Strategic Action Plan* and the *Manufacturing and Maritime Action Plan* include:

IMPROVING OUR STREETS

1) Finished design for the SR 519 Alaskan Way Truck and Rail Improvements to increase access to the Central Waterfront, the Port's Terminal 46 and the BNSF intermodal rail yard;

2) Completed the Leary Way Street Improvements in Ballard and upgraded signals along seven industrial and maritime corridors. As a result delays were reduced by 40 percent and travel times improved 10 to 25 percent in these areas;

3) Solicited freight input on the Alaskan Way Viaduct and Seawall Replacement project on issues such as travel times, grades, and combustible materials. These needs were considered when determining the preferred tunnel alternative.

IMPROVING RAIL CAPACITY & SPEEDS

Coordinated with the BNSF Railroad on mainline rail crossing improvements to add a third mainline track south of downtown.

SUPPORTING MARINE OPERATIONS

Upgraded the Lower Spokane Swing Bridge mechanical components, thereby ensuring their long term operability and keeping the Duwamish River open for marine traffic.

SDOT
Seattle Department of Transportation

For further information please contact Ron Borowski, Freight Mobility Program Manager, at (206) 684-8370 or by email at: ron.borowski@seattle.gov

Accident History Data

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0111202
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0111202

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085583Y	01/30/11	02:10 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: HOLGATE ST
☑ Public ☐ Private

Highway User Involved

13. Type — Code: K
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*:
15. Direction *(geographical)* — Code:
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 42 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 1
A. Spec. MoW Equip
1. Freight train 4. Work train 7. Yard/Switching
2. Passenger train 5. Single car 8. Light loco(s)
3. Commuter train 6. Cut of cars 9. Main./inspect. car

25. Track Type Used by Rail Equipment Involved — Code: 1
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: MAIN 3 DBL

27. FRA Track Class: 4

28. Number of Locomotive Units: 4

29. Number of Cars: 125

30. Consist Speed *(Recorded if available)* — Code: E
R. Recorded
E. Estimated 30 mph

31. Time Table Direction — Code: 4
1. North 2. South 3. East 4. West

32. Type of Crossing Warning — Code(s): 01 03
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew
2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)*
3. Standard FLS 6. Audible 9. Watchman 12. None

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — Code: 2
1. Yes
2. No
3. Unknown

35. Location of Warning — Code: 1
1. Both Sides
2. Side of Vehicle Approach
3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 1
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 1
1. Yes 2. No 3. Unknown

38. Driver's Age: 57

39. Driver's Gender — Code: 1
1. Male
2. Female

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code:
1. Yes 2. No 3. Unknown

41. Driver — Code:
1. Drove around or thru the gate 4. Stopped on crossing
2. Stopped and then proceeded 5. Other *(specify)*
3. Did not stop

42. Driver Passed Standing Highway Vehicle — Code:
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)*
2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	1	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code:
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code:
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $0

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

QUESTION 15: PEDESTRIAN DIRECTION UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1110201
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1110201

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101034Y	11/12/10	09:30 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. HANFORD ST | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 46 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 1031

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated	Code	31. Time Table Direction — 1. North 2. South 3. East 4. West	Code
1	1	35	3 mph	E		4

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): 01 02

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach	Code	36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown	Code	37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown	Code
	1		2		1

38. Driver's Age	39. Driver's Gender — 1. Male, 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown	Code	41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)*	Code
	1	1		2		5

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 4

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

DRIVER AGE UNKNOWN STRUCK SEMI TRAILER FOULING TRACK, NO INJURY.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1010200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1010200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096445R	10/06/10	12:40 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. EAST MARGINAL WAY | ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 10

15. Direction *(geographical)* 1. North 2. South 3. East 4. West — Code: 2

16. Position 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 63 °F

22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 1700

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 16

30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated: 5 mph — Code: R

31. Time Table Direction 1. North 2. South 3. East 4. West — Code: 4

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 28

39. Driver's Gender 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown — Code: 2

41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	2
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was 1. Killed 2. Injured 3. Uninjured — Code: 2

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $2,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 2

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0910204
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0910204

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101033S	09/30/10	04:45 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
SEATTLE	HANFORD ST	☑ Public ☐ Private

Highway User Involved

13. Type (A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)*)	Code
	A

14. Vehicle Speed *(est. mph at impact)*	15. Direction *(geographical)* (1. North 2. South 3. East 4. West)	Code
0		4

16. Position (1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped)	Code
	2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? (1. Highway User 2. Rail Equipment 3. Both 4. Neither)	Code
	4

Rail Equipment Involved

17. Equipment (1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL)	Code
	2

18. Position of Car Unit in Train
1

19. Circumstance (1. Rail equipment struck highway user, 2. Rail equipment struck by highway user)	Code
	1

20b. Was there a hazardous materials release by (1. Highway User 2. Rail Equipment 3. Both 4. Neither)	Code
	4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*	22. Visibility *(single entry)* (1. Dawn 2. Day 3. Dusk 4. Dark)	Code	23. Weather *(single entry)* (1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow)	Code
54 °F		4		2

24. Type of Equipment Consist *(single entry)* (1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip)	Code	25. Track Type Used by Rail Equipment Involved (1. Main 2. Yard 3. Siding 4. Industry)	Code	26. Track Number or Name
	7		2	1602

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated	Code	31. Time Table Direction (1. North 2. South 3. East 4. West)	Code
1	1	10	5 mph	E		2

32. Type of Crossing Warning (1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None)								33. Signaled Crossing Warning	34. Whistle Ban (1. Yes 2. No 3. Unknown)	Code
Code(s)	10									2

35. Location of Warning (1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach)	Code	36. Crossing Warning Interconnected with Highway Signals (1. Yes 2. No 3. Unknown)	Code	37. Crossing Illuminated by Street Lights or Special Lights (1. Yes 2. No 3. Unknown)	Code
	1		2		1

38. Driver's Age	39. Driver's Gender (1. Male 2. Female)	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train (1. Yes 2. No 3. Unknown)	Code	41. Driver (1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)*)	Code
58		2		2		4

42. Driver Passed Standing Highway Vehicle (1. Yes 2. No 3. Unknown)	Code	43. View of Track Obscured by *(primary obstruction)* (1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed)	Code
	2		8

Casualties to:	Killed	Injured	44. Driver was (1. Killed 2. Injured 3. Uninjured)	Code	45. Was Driver in the Vehicle? (1. Yes 2. No)	Code
				3		1
46. Highway-Rail Crossing Users	0	0	47. Highway Vehicle Property Damage *(est. dollar damage)*	$2,000	48. Total Number of Highway-Rail Crossing Users *(include driver)*	1
49. Railroad Employees	0	0	50. Total Number of People on Train *(include passengers and crew)*	3	51. Is a Rail Equipment Accident / Incident Report Being Filed (1. Yes 2. No)	Code 2
52. Passengers on Train	0	0				

53a. Special Study Block	53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0910PD003
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0910PD003

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809692G	09/09/10	10:09 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND SU	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. 8TH AVE SOUTH & GARD | ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 30

15. Direction *(geographical)* 1. North 2. South 3. East 4. West — Code: 1

16. Position 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 2

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 65 °F

22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 1

25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry — Code: 4

26. Track Number or Name: INDUSTRY

27. FRA Track Class: 1

28. Number of Locomotive Units: 2

29. Number of Cars: 3

30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated: 5 mph — Code: E

31. Time Table Direction 1. North 2. South 3. East 4. West — Code: 3

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 2

36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown — Code:

37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age: 37

39. Driver's Gender 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown — Code: 2

41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 1

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $2,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1109200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1109200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101380N	11/10/09	10:30 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
SEATTLE	W MARGINAL WAY	☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 2

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 48 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 3

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 2098

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 10

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 5 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): 03 07

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code:

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 61

39. Driver's Gender — 1. Male, 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 5

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

41: CNT FOULING XING

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0609200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0609200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101039H	06/05/09	11:45 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: ATLANTIC STRET
☑ Public ☐ Private

Highway User Involved

13. Type — Code: A
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 5

15. Direction *(geographical)* — Code: 4
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

21. Temperature *(specify if minus)*: 70 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

24. Type of Equipment Consist *(single entry)* — Code: 7
1. Freight train 4. Work train 7. Yard/Switching
2. Passenger train 5. Single car 8. Light loco(s)
3. Commuter train 6. Cut of cars 9. Main./inspect. car
A. Spec. MoW Equip

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 19

32. Type of Crossing Warning — Code(s): 07
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew
2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)*
3. Standard FLS 6. Audible 9. Watchman 12. None

35. Location of Warning — Code: 1
1. Both Sides
2. Side of Vehicle Approach
3. Opposite Side of Vehicle Approach

38. Driver's Age

39. Driver's Gender — Code: 1
1. Male
2. Female

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

Rail Equipment Involved

17. Equipment — Code: 2
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

23. Weather *(single entry)* — Code: 1
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

25. Track Type Used by Rail Equipment Involved — Code: 2
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: 2694

30. Consist Speed *(Recorded if available)* — Code: E
R. Recorded
E. Estimated 5 mph

31. Time Table Direction — Code: 2
1. North 2. South 3. East 4. West

33. Signaled Crossing Warning

34. Whistle Ban — Code: 2
1. Yes
2. No
3. Unknown

36. Crossing Warning Interconnected with Highway Signals — Code:
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 2
1. Yes 2. No 3. Unknown

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code: 2
1. Yes 2. No 3. Unknown

41. Driver — Code: 3
1. Drove around or thru the gate 4. Stopped on crossing
2. Stopped and then proceeded 5. Other *(specify)*
3. Did not stop

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)*
2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $2,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0409200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0409200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096445R	04/01/09	08:46 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. E. MARGINAL WAY | ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: D

14. Vehicle Speed *(est. mph at impact)*: 4

15. Direction *(geographical)* 1. North 2. South 3. East 4. West — Code: 1

16. Position 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 2

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 45 °F

22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 3

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: LEAD

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 4

30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated: 5 mph — Code: E

31. Time Table Direction 1. North 2. South 3. East 4. West — Code: 3

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 30

39. Driver's Gender 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown — Code: 2

41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 1008PD007
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 1008PD007

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809712R	10/16/08	01:15 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND SU	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: EAST MARGINAL WAY SO — ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 57 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: YARD

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 6

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 5 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 1

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 08 07

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age: 54

39. Driver's Gender — 1. Male 2. Female — Code: 2

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $200

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0908PD011
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0908PD011

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809556G	09/17/08	03:40 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND SU	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: EAST MARGINAL WAY
☑ Public ☐ Private

Highway User Involved

13. Type — Code: C
A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 3
15. Direction *(geographical)* — Code: 3
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user 2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 75 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 7
1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip

25. Track Type Used by Rail Equipment Involved — Code: 4
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: INDUSTRIAL LEAD

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 15

30. Consist Speed *(Recorded if available)* — Code: R
R. Recorded E. Estimated: 4 mph

31. Time Table Direction — Code: 1
1. North 2. South 3. East 4. West

32. Type of Crossing Warning — Code(s): 03 05 06 07
1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — Code: 2
1. Yes 2. No 3. Unknown

35. Location of Warning — Code: 2
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 1
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 2
1. Yes 2. No 3. Unknown

38. Driver's Age: 29

39. Driver's Gender — Code: 1
1. Male 2. Female

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code: 2
1. Yes 2. No 3. Unknown

41. Driver — Code: 2
1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $1,800

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0508200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0508200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096470Y	05/22/08	04:46 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. HANFORD ST | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: **E**

14. Vehicle Speed *(est. mph at impact)*: 1

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: **B**

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 40 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car, A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 1602

27. FRA Track Class: 1

28. Number of Locomotive Units: 3

29. Number of Cars: 5

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 4 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): 01 | 02 | 03 | 06 | 07

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age: 39

39. Driver's Gender — 1. Male, 2. Female — Code: 2

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 1

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

VEHICLE OPERATOR WAS APPARENTLY OBLIVIOUS TO WARNING DEVICES.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0308PD015
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0308PD015

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809692G	03/18/08	10:20 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. 8TH AVE. SO. | ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 15

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 6

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*	22. Visibility *(single entry)*	Code	23. Weather *(single entry)*	Code
48 °F	1. Dawn 2. Day 3. Dusk 4. Dark	2	1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow	2

24. Type of Equipment Consist *(single entry)*	Code	25. Track Type Used by Rail Equipment Involved	Code	26. Track Number or Name
A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car	8	1. Main 2. Yard 3. Siding 4. Industry	4	INDUSTRY

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
1	1	0	R. Recorded E. Estimated 1 mph	E	1. North 2. South 3. East 4. West	4

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 12

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach	Code	36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown	Code: 2	37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown	Code: 1

38. Driver's Age	39. Driver's Gender — 1. Male 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown	Code: 2	41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*	Code: 3
30	1					

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train		

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $800

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW1007200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW1007200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
099007Y	10/10/07	04:45 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: SPOKANE ST E. BD
☑ Public ☐ Private

Highway User Involved

13. Type — Code: C
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 1

15. Direction *(geographical)* — Code: 3
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 59 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 1
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 7
1. Freight train 4. Work train 7. Yard/Switching
2. Passenger train 5. Single car 8. Light loco(s)
3. Commuter train 6. Cut of cars 9. Main./inspect. car
A. Spec. MoW Equip

25. Track Type Used by Rail Equipment Involved — Code: 2
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: 1099

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 18

30. Consist Speed *(Recorded if available)* — Code: E
R. Recorded
E. Estimated: 7 mph

31. Time Table Direction — Code: 1
1. North 2. South 3. East 4. West

32. Type of Crossing Warning — Code(s): 03, 06
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew
2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)*
3. Standard FLS 6. Audible 9. Watchman 12. None

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — Code: 2
1. Yes
2. No
3. Unknown

35. Location of Warning — Code: 1
1. Both Sides
2. Side of Vehicle Approach
3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 1
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 1
1. Yes 2. No 3. Unknown

38. Driver's Age: 36

39. Driver's Gender — Code: 1
1. Male
2. Female

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code: 2
1. Yes 2. No 3. Unknown

41. Driver — Code: 3
1. Drove around or thru the gate 4. Stopped on crossing
2. Stopped and then proceeded 5. Other *(specify)*
3. Did not stop

42. Driver Passed Standing Highway Vehicle — Code: 3
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)*
2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $70,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0807204
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0807204

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096445R	08/27/07	12:15 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: E. MARGINAL WAY ☑ Public ☐ Private

Highway User Involved

13. Type — Code: C
A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 1
15. Direction *(geographical)* — Code: 1
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: A
1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user 2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 75 °F

22. Visibility *(single entry)* — Code: 2
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 1
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 7
1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip

25. Track Type Used by Rail Equipment Involved — Code: 2
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: 1700

27. FRA Track Class: 1

28. Number of Locomotive Units: 2

29. Number of Cars: 1

30. Consist Speed *(Recorded if available)* — Code: E
R. Recorded E. Estimated: 5 mph

31. Time Table Direction — Code: 4
1. North 2. South 3. East 4. West

32. Type of Crossing Warning — Code(s): 07
1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

33. Signaled Crossing Warning

34. Whistle Ban — Code: 2
1. Yes 2. No 3. Unknown

35. Location of Warning — Code: 1
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 3
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 2
1. Yes 2. No 3. Unknown

38. Driver's Age

39. Driver's Gender — Code: 1
1. Male 2. Female

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code: 2
1. Yes 2. No 3. Unknown

41. Driver — Code: 3
1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 1
1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $10,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0607201
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0607201

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096202N	06/25/07	11:00 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE — 12. Highway Name or No. CHELAN AVE. SW. — ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 2

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 60 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip, 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 2021

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 15

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 4 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 4

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s): 03, 07

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes, 2. No, 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code:

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 41

39. Driver's Gender — 1. Male, 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $100,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0507201
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0507201

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101128A	05/15/07	10:15 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. ROYAL BROUGHAM | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 1

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 2

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 62 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 1031

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 36

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 6 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 1

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 12

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code:

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age

39. Driver's Gender — 1. Male 2. Female: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $10,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0207PD033
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0207PD033

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809548P	02/22/07	04:30 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
SEATTLE	COLORADO STREET	☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: **C**

14. Vehicle Speed *(est. mph at impact)*: **13**

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: **4**

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: **3**

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: **4**

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: **A**

18. Position of Car Unit in Train: **1**

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: **2**

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: **4**

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: **50** °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: **2**

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: **1**

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip, 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car — Code: **7**

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: **2**

26. Track Number or Name: **YARD**

27. FRA Track Class: **1**

28. Number of Locomotive Units: **1**

29. Number of Cars: **12**

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: **5** mph — Code: **E**

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: **3**

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None

Code(s): **07**

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: **2**

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: **1**

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: **2**

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: **1**

38. Driver's Age: **43**

39. Driver's Gender — 1. Male, 2. Female — Code: **1**

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: **2**

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: **2**

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: **2**

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: **8**

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: **3**

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: **1**

47. Highway Vehicle Property Damage *(est. dollar damage)*: **$5,000**

48. Total Number of Highway-Rail Crossing Users *(include driver)*: **1**

50. Total Number of People on Train *(include passengers and crew)*: **2**

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: **2**

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0107205
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0107205

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101007C	01/27/07	02:10 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: HOLGATE ST.
☑ Public ☐ Private

Highway User Involved

13. Type — Code: A
A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 35

15. Direction *(geographical)* — Code: 3
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 6
1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL

18. Position of Car Unit in Train: 1

19. Circumstance — Code: 1
1. Rail equipment struck highway user 2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 42 °F

22. Visibility *(single entry)* — Code: 4
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 8
1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip

25. Track Type Used by Rail Equipment Involved — Code: 4
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: 1491

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* — Code: E	31. Time Table Direction — Code: 4
1	1	0	R. Recorded E. Estimated 2 mph	1. North 2. South 3. East 4. West

32. Type of Crossing Warning — Code(s): 07 10
1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

33. Signaled Crossing Warning

34. Whistle Ban — Code: 2
1. Yes 2. No 3. Unknown

35. Location of Warning — Code: 1
1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 3
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 3
1. Yes 2. No 3. Unknown

38. Driver's Age

39. Driver's Gender — Code: 1
1. Male 2. Female

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code: 2
1. Yes 2. No 3. Unknown

41. Driver — Code: 3
1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code: 3
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 1
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

AGE OF DRIVER UNKNOWN

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0906PD031
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0906PD031

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809513N	09/27/06	09:45 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
ARGO	PORTLAND	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: LUCILLE & 8TH
☑ Public ☐ Private

Highway User Involved

13. Type: A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)* — Code: E

14. Vehicle Speed *(est. mph at impact)*: 5

15. Direction *(geographical)*: 1. North 2. South 3. East 4. West — Code: 4

16. Position: 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment: 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance: 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 2

20b. Was there a hazardous materials release by: 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 71 °F

22. Visibility *(single entry)*: 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)*: 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)*: 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved: 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: YARD

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 12

30. Consist Speed *(Recorded if available)*: R. Recorded E. Estimated 2 mph — Code: E

31. Time Table Direction: 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning: 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None
Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban: 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning: 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals: 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights: 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 59

39. Driver's Gender: 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train: 1. Yes 2. No 3. Unknown — Code: 2

41. Driver: 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 2

42. Driver Passed Standing Highway Vehicle: 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)*: 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users		
49. Railroad Employees		
52. Passengers on Train		

44. Driver was: 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $2,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed: 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0706PD013
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0706PD013

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809568B	07/19/06	04:45 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. BRANDON STREET | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 5

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* — A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 70 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 4

26. Track Number or Name: INDUSTRY

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 17

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 5 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 1

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 58

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $3,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

*NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0606PD042
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0606PD042

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809648U	06/30/06	01:30 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: 8TH AVE SOUTH — ☑ Public ☐ Private

Highway User Involved

13. Type: C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)*: 1. North 2. South 3. East 4. West — Code: 3

16. Position: 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment: 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance: 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by: 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 79 °F

22. Visibility *(single entry)*: 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)*: 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)*: 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 7

25. Track Type Used by Rail Equipment Involved: 1. Main 2. Yard 3. Siding 4. Industry — Code: 4

26. Track Number or Name: INDUSTRY

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* Code	31. Time Table Direction Code
1	1	12	R. Recorded E. Estimated 10 mph E	1. North 2. South 3. East 4. West 1

32. Type of Crossing Warning: 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None
Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban: 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning: 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals: 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights: 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 45

39. Driver's Gender: 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train: 1. Yes 2. No 3. Unknown — Code: 2

41. Driver: 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 4

42. Driver Passed Standing Highway Vehicle: 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)*: 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was: 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed: 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 101190
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
085587B	06/25/06	04:05 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PAC	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: CITY ST: SPOKANE ST
☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: K

14. Vehicle Speed *(est. mph at impact)*:

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 2

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 75 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 2

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN NO.#2

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
3	2	13	R. Recorded E. Estimated 19 mph	R	1. North 2. South 3. East 4. West	1

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 01 02 05 06

33. Signaled Crossing Warning: Allgd. warn > 60 sec (2);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age: 40

39. Driver's Gender — 1. Male 2. Female — Code: 2

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code:

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code:

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code:

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 3

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code:

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code:

47. Highway Vehicle Property Damage *(est. dollar damage)*: $0

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 225

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

TRAIN NO.#506 STRUCK A PEDESTRIAN AT MP1.86, SPOKANE ST CROSSING.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0606PD016
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0606PD016

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809513N	06/11/06	02:40 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)* SEATTLE — 12. Highway Name or No. LUCILLE ST. & 8TH — ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 35

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 3

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 2

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 50 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: YARD

27. FRA Track Class: 1

28. Number of Locomotive Units: 2

29. Number of Cars: 32

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 4 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 30

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $25,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0606PD010
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0606PD010

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809648U	06/05/06	04:30 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
SEATTLE	8TH AVENUE SOUTH	☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: A

14. Vehicle Speed *(est. mph at impact)*: 0

15. Direction *(geographical)* 1. North 2. South 3. East 4. West — Code: 3

16. Position 1. Stalled on crossing 3. Moving over crossing 2. Stopped on Crossing 4. Trapped — Code: 2

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: B

18. Position of Car Unit in Train: 5

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 52 °F

22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: YARD

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* R. Recorded E. Estimated	Code	31. Time Table Direction 1. North 2. South 3. East 4. West	Code
1	1	4	4 mph	E		1

32. Type of Crossing Warning 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age	39. Driver's Gender 1. Male 2. Female	Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown	Code	41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)*	Code
35	2	2		2		4

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $1,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Union Pacific RR Co. [UP]	1a. UP	1b. 0306PD051
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co. [UP]	3a. UP	3b. 0306PD051

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
809513N	03/31/06	10:00 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	PORTLAND	KING	53	WA

11. City *(if in a city)* SEATTLE | 12. Highway Name or No. LUCILLE STREET & 8TH | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 10

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*: A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 50 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip, 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: YARD

27. FRA Track Class: 1

28. Number of Locomotive Units: 1

29. Number of Cars: 24

30. Consist Speed *(Recorded if available)* — R. Recorded, E. Estimated: 7 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 2

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 1

38. Driver's Age: 22

39. Driver's Gender — 1. Male, 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: 5

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $10,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 2

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

BOX 41. FAILED TO YIELD

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0206200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0206200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
096445R	02/01/06	01:15 PM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
SEATTLE	E MARGINAL WAY	☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: **B**

14. Vehicle Speed *(est. mph at impact)*: **1**

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: **1**

16. Position — 1. Stalled on crossing, 2. Stopped on Crossing, 3. Moving over crossing, 4. Trapped — Code: **3**

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: **2**

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code: **A**

18. Position of Car Unit in Train: **1**

19. Circumstance — 1. Rail equipment struck highway user, 2. Rail equipment struck by highway user — Code: **2**

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: **4**

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: **48** °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: **2**

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: **2**

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip, 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/Switching, 8. Light loco(s), 9. Main./inspect. car — Code: **7**

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: **2**

26. Track Number or Name: **2010**

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
4	1	31	R. Recorded E. Estimated 5 mph	E	1. North 2. South 3. East 4. West	3

32. Type of Crossing Warning — 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s): **07**

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: **2**

35. Location of Warning — 1. Both Sides, 2. Side of Vehicle Approach, 3. Opposite Side of Vehicle Approach — Code: **1**

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: **3**

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: **2**

38. Driver's Age: **36**

39. Driver's Gender — 1. Male, 2. Female — Code: **1**

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: **2**

41. Driver — 1. Drove around or thru the gate, 2. Stopped and then proceeded, 3. Did not stop, 4. Stopped on crossing, 5. Other *(specify)* — Code: **3**

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: **1**

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure, 2. Standing railroad equipment, 3. Passing Train, 4. Topography, 5. Vegetation, 6. Highway Vehicles, 7. Other *(specify)*, 8. Not Obstructed — Code: **8**

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users		
49. Railroad Employees		
52. Passengers on Train		

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: **3**

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: **1**

47. Highway Vehicle Property Damage *(est. dollar damage)*: **$5,000**

48. Total Number of Highway-Rail Crossing Users *(include driver)*: **1**

50. Total Number of People on Train *(include passengers and crew)*: **2**

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: **2**

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0106205
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0106205

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
101039H	01/13/06	11:15 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
SEATTLE	NORTHWEST	KING	53	WA

11. City *(if in a city)*: SEATTLE
12. Highway Name or No.: ATLANTIC ST
☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School Bus, H. Motorcycle, J. Other Motor Vehicle, K. Pedestrian, M. Other *(specify)* — Code: C

14. Vehicle Speed *(est. mph at impact)*: 1

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 3

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: A

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 50 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 3

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 7

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 2

26. Track Number or Name: 1001

27. FRA Track Class: 2

28. Number of Locomotive Units: 1

29. Number of Cars: 12

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 5 mph — Code: E

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 1

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None — Code(s): 07

33. Signaled Crossing Warning

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 2

38. Driver's Age: 47

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code: 2

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 3

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code: 3

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $5,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
King	Seattle	City Street		14 AV S		E MARGINAL WY S			
King	Seattle	City Street		2 AVE S	4200	R AND R CROSSING			
King	Seattle	City Street		7 AVE		WESTLAKE AVE			
King	Seattle	City Street		8 AVE		S GARDEN			
King	Seattle	City Street		AIRPORT WY S	5800	R R CROSSING			
King	Seattle	City Street		AIRPORT WY S	5300	S LUCILE ST			
King	Seattle	City Street		AIRPORT WY S		S LUCILE ST			
King	Seattle	City Street		ALASKA WY	900	MARION ST			
King	Seattle	City Street		ALASKAN WY	1200	SENECA ST			
King	Seattle	City Street		ALASKAN WY S	1500	RR CROSSING			
King	Seattle	City Street		BROAD ST		RR TRACK			
King	Seattle	City Street		CHELAN AVE SW		RR CROSSING			
King	Seattle	City Street		COLORADO AV S		DENVER AV S			
King	Seattle	City Street		DELRIDGE WY SW		RR XING			
King	Seattle	City Street		DUWAMISH AV S	3600	BNSF TRACKS			
King	Seattle	City Street		E MARGINAL WAY	4735				
King	Seattle	City Street		E MARGINAL WAY S		RAILROAD CROSSING			
King	Seattle	City Street		E MARGINAL WAY S		RAILROAD CROSSING			
King	Seattle	City Street		E MARGINAL WAY S		RR CROSSING			
King	Seattle	City Street		E MARGINAL WAY S		RR CROSSING S OF S SPOKANE ST			
King	Seattle	City Street		E MARGINAL WAY S	3600				
King	Seattle	City Street		E MARGINAL WY	3600	RR XING			
King	Seattle	City Street		E MARGINAL WY S		8 AVE S			
King	Seattle	City Street		E MARGINAL WY S		RR XING			
King	Seattle	City Street		E MARGINAL WY S		RR XING			
King	Seattle	City Street		E MARGINAL WY S		S SPOKANE ST			
King	Seattle	City Street		E3 BUSWAY		R AND R CROSSING			
King	Seattle	City Street		FOX AV S		RR CROSSING			
King	Seattle	City Street		M L KING JR WAY S	9400	S MERTON ST			
King	Seattle	City Street		MARION ST		RR XING			
King	Seattle	City Street		MARTIN LUTHER KING JR WAY S	3400	S DAWSON ST			
King	Seattle	City Street		MARTIN LUTHER KING WY S		S GRAHAM ST			
King	Seattle	City Street		MERCER ST		TERRY AV			
King	Seattle	City Street		MERCER ST		TERRY AV N			
King	Seattle	City Street		MLK JR WY S		MERTON WY S			
King	Seattle	City Street		MLK JR WY S		S DAWSON ST			
King	Seattle	City Street		MLK JR WY S		S DAWSON ST			
King	Seattle	City Street		MLK JR WY S		S KENYON ST			
King	Seattle	City Street		MLK JR WY S	7800	S KENYON ST			
King	Seattle	City Street		MLK JR WY S		S NORFOLK ST			
King	Seattle	City Street		MLK JR WY S		S OTHELLO ST			
King	Seattle	City Street		MLK JR WY S		S OTHELLO ST			
King	Seattle	City Street		MLK JR WY S	7100	S OTHELLO ST			
King	Seattle	City Street		MLK JR WY S AND RR XING		S MYRTLE ST			

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
					2895587	5/23/2008	9:46	Evident Injury	1	0	1		
					3383963	4/1/2010	5:00	No Injury	0	0	2		
					3282655	11/10/2009	19:41	No Injury	0	0	1		
					3325721	7/9/2010	10:30	No Injury	0	0	2		
					2191792	5/7/2006	2:16	Unknown	0	0	1		
					2625426	9/27/2006	9:23	No Injury	0	0	1		
					2060431	3/31/2006	9:49	No Injury	0	0	2		
					1933355	6/10/2005	16:10	No Injury	0	0	1		
					1069323	11/17/2005	18:16	No Injury	0	0	1		
					2898433	10/22/2007	8:06	Evident Injury	2	0	3		
ALASKAN WAY					2024129	8/21/2005	1:49	No Injury	0	0	1		
					3288505	11/10/2009	11:03	No Injury	0	0	1		
					2625250	2/22/2007	16:32	No Injury	0	0	1		
					2060740	12/5/2005	11:04	No Injury	0	0	1		
					2060603	11/21/2005	12:42	Serious Injury	1	0	1	1	
					2793167	4/4/2007	13:41	No Injury	0	0	1		
SPOKANE ST					1076847	2/1/2006	13:33	No Injury	0	0	1		
SPOKANE ST					2039748	2/1/2006	13:34	No Injury	0	0	2		
					2826130	7/30/2007	17:12	No Injury	0	0	2		
					3280024	4/1/2009	21:17	No Injury	0	0	1		
					1076944	9/12/2005	17:41	Evident Injury	1	0	1		
					1326672	6/11/2005	22:15	No Injury	0	0	3		
					2072146	6/5/2006	16:40	Unknown	0	0	1		
	S SPOKANE ST	DUWAMISH AVE S			3281829	11/12/2008	16:05	Possible Injury	2	0	2		
	S SPOKANE ST	DUWAMISH AV S			2827475	8/27/2007	12:15	No Injury	0	0	1		
					1795464	1/25/2005	6:45	No Injury	0	0	1		
					2611589	11/10/2006	6:25	Evident Injury	1	0	1		
S BRIGHTON ST					3282196	4/29/2009	11:27	Possible Injury	1	0	1		
					3335928	1/24/2010	18:02	No Injury	0	0	2		
					1783645	7/9/2005	14:35	Possible Injury	1	0	1		
					2786268	4/15/2009	17:08	Possible Injury	1	0	1		
					2997626	9/25/2010	16:39	Serious Injury	1	0	1	1	
					2791282	12/19/2007	7:28	No Injury	0	0	1		
					3346353	5/22/2010	21:39	No Injury	0	0	2		
					2551611	8/1/2010	10:40	No Injury	0	0	2		
					3387902	8/3/2010	11:48	No Injury	0	0	2		
					3285118	9/15/2009	13:39	No Injury	0	0	1		
					2543218	9/26/2009	15:23	Possible Injury	2	0	1		
					2997803	3/10/2010	15:25	Possible Injury	1	0	2		
					2786560	9/15/2010	11:30	No Injury	0	0	2		
					2842484	4/2/2010	16:20	Evident Injury	1	0	2		
					3374051	9/9/2010	10:35	Possible Injury	2	0	2		
					3384015	4/23/2010	15:43	Evident Injury	1	0	1	1	
					3210959	6/29/2009	17:10	Possible Injury	1	0	1		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Motorcycle		At Intersection and Related	Wet	Daylight
Passenger Car	Railway Vehicle	At Intersection and Related	Dry	Dark-Street Lights On
Passenger Car		At Intersection and Related	Wet	Dark-Street Lights On
Truck & Trailer	Railway Vehicle	At Intersection and Related	Oil	Daylight
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Truck (Flatbad,Van,etc)		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Not Related	Wet	Daylight
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Truck Tractor & Semi-Trailer		At Intersection and Related	Wet	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Dark-Street Lights On
Passenger Car		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Passenger Car		At Driveway within Major Intersection	Dry	Daylight
Truck (Flatbad,Van,etc)		At Intersection and Related	Wet	Daylight
Truck (Flatbad,Van,etc)	Truck Tractor & Semi-Trailer	At Intersection and Related	Wet	Daylight
Motorcycle	Passenger Car	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Dark-Street Lights On
Passenger Car		At Intersection and Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Dark-Street Lights On
Passenger Car		At Intersection and Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Wet	Dusk
Truck - Double Trailer Combinations		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Dark-Street Lights On
Motorcycle		At Intersection and Related	Wet	Dark-No Street Lights
Passenger Car		At Driveway within Major Intersection	Dry	Daylight
Passenger Car	Railway Vehicle	At Intersection and Related	Wet	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Railway Vehicle		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Dawn
Passenger Car	Railway Vehicle	At Intersection and Related	Wet	Dark-Street Lights On
Not Stated	Railway Vehicle	At Driveway within Major Intersection	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Railway Vehicle	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight
Passenger Car	Railway Vehicle	At Intersection and Related	Dry	Daylight
Other	Railway Vehicle	At Driveway within Major Intersection	Dry	Daylight
Passenger Car	Railway Vehicle	At Intersection and Related	Wet	Daylight
Passenger Car	Railway Vehicle	At Intersection and Related	Dry	Daylight
Railway Vehicle		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
Vehicle overturned	Inattention		North	West		
Train struck moving vehicle	Disregard Stop Sign - Flashing Red	None	North	South	East	West
Train struck moving vehicle	Other		North	South		
Train struck moving vehicle	Inattention	None	South	North	West	East
All other non-collision	Other					
Train struck stopped or stalled vehicle	Inattention		South	West		
Train struck moving vehicle	Did Not Grant RW to Vehicle		North	West		
Train struck moving vehicle	Did Not Grant RW to Vehicle		South	East		
Vehicle struck moving train	Did Not Grant RW to Vehicle		North	East		
From same direction - both going straight - both moving - rear-end	Follow Too Closely	None	South	North	South	North
All other non-collision	Inattention		West	North		
Train struck stopped or stalled vehicle	Other		North	Vehicle Stopped		
Train struck moving vehicle	Inattention		South	North		
Train struck stopped or stalled vehicle	Inattention		Southeast	Northwest		
Train struck moving vehicle	Other		Northwest	Southeast		
Train struck moving vehicle	Other		West	East		
Vehicle struck moving train	Inattention		South	North		
From same direction - all others	Inattention	None	South	North	South	Vehicle Stopped
From same direction - both going straight - one stopped - sideswipe	Improper Passing	None	South	North	South	Vehicle Stopped
Vehicle struck moving train	Did Not Grant RW to Vehicle		South	North		
Train struck moving vehicle	Other		North	South		
From same direction - both going straight - one stopped - sideswipe	Exceeding Reas. Safe Speed	None	North	South	North	Vehicle Stopped
Train struck moving vehicle	Did Not Grant RW to Vehicle		West	East		
From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None	North	South	North	Vehicle Stopped
Train struck moving vehicle	Inattention		South	North		
Train struck moving vehicle	Other		South	North		
All other non-collision	Other		South	North		
Train struck stopped or stalled vehicle	Operating Defective Equipment		North	Vehicle Stopped		
Vehicle struck moving train	Disregard Stop and Go Light	None	South	South	South	North
Train struck stopped or stalled vehicle	Inattention		South	East		
Train struck moving vehicle	Did Not Grant RW to Vehicle		South	West		
Vehicle going straight hits pedestrian	None		North	South		
Train struck moving vehicle	Disregard Stop and Go Light		West	East		
Train struck moving vehicle	Driver Distractions Outside Vehicle	None	West	East	South	North
Train struck stopped or stalled vehicle	Improper Turn	None	North	East	North	South
Train struck moving vehicle	Improper Turn	None	South	North		
Vehicle struck moving train	Improper Turn		South	West		
Train struck stopped or stalled vehicle	Improper Turn		West	Vehicle Stopped		
Vehicle struck moving train	Improper Turn	None	North	East	North	South
Curb, Raised Traffic Island or Raised Median Curb	Improper Backing	None	West	Vehicle Backing	South	North
Train struck moving vehicle	Disregard Stop and Go Light	None	South	West	South	North
Train struck moving vehicle	Disregard Stop and Go Light	None	South	West	South	North
Vehicle going straight hits pedestrian	None		South	North		
Train struck moving vehicle	Disregard Stop and Go Light		North	East		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
King	Seattle	City Street		MLK WY S		S WALDEN ST			
King	Seattle	City Street		S ATLANTIC ST	1200	ALASKAN WY S			
King	Seattle	City Street		S ATLANTIC ST		ALASKAN WY S			
King	Seattle	City Street		S ATLANTIC ST		ALASKAN WY S			
King	Seattle	City Street		S ATLANTIC ST		BNSF RR CROSSING			
King	Seattle	City Street		S ATLANTIC ST	40				
King	Seattle	City Street		S HANFORD ST	44	RR CROSSING			
King	Seattle	City Street		S HANFORD ST		UPRR			
King	Seattle	City Street		S HOLGATE		RR CROSSING			
King	Seattle	City Street		S HOLGATE	200	RR CROSSING			
King	Seattle	City Street		S HOLGATE ST		3 AV S			
King	Seattle	City Street		S HOLGATE ST	184	BNSF RR			
King	Seattle	City Street		S HOLGATE ST	300	RR CROSSING			
King	Seattle	City Street		S HOLGATE ST	500	RR TRACKS			
King	Seattle	City Street		S HOLGATE ST	200	RR XING			
King	Seattle	City Street		S HOMER ST		RR CROSSING			
King	Seattle	City Street		S HORTON ST		2 AVE S			
King	Seattle	City Street		S HORTON ST		2 AVE S			
King	Seattle	City Street		S LANDER ST	400	RR CROSSING			
King	Seattle	City Street		S LANDER ST	400	RR TRACKS			
King	Seattle	City Street		S LUCILLE ST	709	AIRPORT WY S			
King	Seattle	City Street		S MYRTLE ST		E MARGINAL WY S			
King	Seattle	City Street		S OTHELLO ST		MLK JR WY S			
King	Seattle	City Street		S RIVER ST	300				
King	Seattle	City Street		S SPOKANE ST		2 AVE S			
King	Seattle	City Street		S SPOKANE ST		COLORADO ST			
King	Seattle	City Street		S SPOKANE ST	400	RAILROAD CROSSING			
King	Seattle	City Street		S SPOKANE ST		RR CROSSING			
King	Seattle	City Street		S SPOKANE ST	3600	RR XING			
King	Seattle	City Street		SW SPOKANE ST		CHELAN AVE SW			
King	Seattle	City Street		VALLEY ST	1010	RR CROSSING			
King	Seattle	City Street		VALLEY ST		TERRY AV N			
King	Seattle	City Street		VALLEY ST	1100		40	F	W
King	Seattle	City Street		W MARGINAL WY S		BNSF RAILROAD TRACKS			
King	Seattle	City Street		W MARGINAL WY SW	3800	SW ANDOVER ST			
King	Seattle	City Street		W MARGINAL WY SW		SW ANDOVER ST			
King	Seattle	City Street		W MARGINAL WY SW	5900				
King	Seattle	City Street		WALL		ALASKAN WAY			
King	Seattle	City Street		WALL ST	50	AUBURN WAY			
King	Seattle	City Street		WESTLAKE AV		DENNY WY			
King	Seattle	State Route		99					
King	Seattle	State Route		99					
King	Seattle	State Route		99					
King	Seattle	State Route		99					

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
					3206896	9/27/2009	1:50	No Injury	0	0	1		
					2898361	12/11/2007	11:58	Possible Injury	1	0	2		
					2792913	7/10/2007	15:54	No Injury	0	0	1		
					2826336	11/21/2007	7:30	No Injury	0	0	2		
					3200384	6/5/2009	11:50	No Injury	0	0	1		
					1932819	8/13/2005	11:59	No Injury	0	0	1		
					3346105	9/30/2010	4:35	No Injury	0	0	2		
					2894645	8/8/2008	11:37	No Injury	0	0	2		
					3274470	6/24/2009	8:00	No Injury	0	0	1		
					2796964	1/30/2008	17:35	No Injury	0	0	1		
					2826124	6/21/2007	22:07	Evident Injury	1	0	2		
					3326897	7/30/2010	14:01	No Injury	0	0	1		
4 AVE S					2825983	7/14/2007	21:58	No Injury	0	0	2		
					2608784	6/17/2006	0:01	No Injury	0	0	2		
					2805773	8/13/2007	8:26	No Injury	0	0	2		
					3326132	10/13/2009	10:40	No Injury	0	0	1		
					3211133	1/14/2010	21:54	No Injury	0	0	2		
					1482553	2/11/2005	15:23	No Injury	0	0	3		
					3384311	5/13/2010	17:00	No Injury	0	0	2		
					1785130	2/23/2005	9:33	Evident Injury	2	0	3		
					2191798	6/11/2006	2:49	No Injury	0	0	1		
					1197868	9/27/2005	13:23	No Injury	0	0	1		
					3296251	12/31/2008	23:46	No Injury	0	0	1		
	3 AV S	2 AV S			2792778	12/28/2007	13:14	No Injury	0	0	3		
					2616614	8/20/2009	11:45	No Injury	0	0	2		
					1198141	2/2/2005	5:55	No Injury	0	0	2		
					3279431	7/22/2008	5:35	No Injury	0	0	1		
2 AV S					2827162	8/28/2007	16:36	Unknown	0	0	1		
	E MARGINAL WY	COLORADO AV S			2620299	10/10/2007	16:40	No Injury	0	0	3		
					2827089	6/25/2007	11:33	Possible Injury	1	0	1		
BOREN AVE N					2908153	4/17/2008	14:14	No Injury	0	0	1		
					2899686	10/1/2008	11:38	Possible Injury	1	0	2		
FAIRVIEW AV N					2907299	4/17/2009	1:56	No Injury	0	0	1		
					3374306	10/6/2010	12:25	Evident Injury	2	0	2		
TERMINAL 103 S ACCESS					2618931	7/14/2006	16:47	No Injury	0	0	1		
					3295978	2/26/2009	11:49	No Injury	0	0	1		
					2060662	12/13/2005	11:50	Possible Injury	1	0	1		
					C690379	8/7/2007	11:30	No Injury	0	0	1		
					3208722	7/31/2009	13:43	Evident Injury	3	0	2		
					2618357	1/29/2008	12:02	No Injury	0	0	1		
			27.40		2619034	11/9/2006	17:12	No Injury	0	0	1		
			27.69		3279745	9/17/2008	15:54	No Injury	0	0	1		
			27.69		2619001	7/19/2006	16:52	No Injury	0	0	1		
			28.26		3280112	10/22/2008	15:54	Possible Injury	1	0	1		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Truck Tractor & Semi-Trailer	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer	Passenger Car	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Railway Vehicle	At Intersection and Related	Dry	Dark-Street Lights On
Truck (Flatbad,Van,etc)	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Not Related	Wet	Dark-No Street Lights
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Dry	Dark-Street Lights On
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Passenger Car	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Unknown
Pickup,Panel Truck or Vanette under 10,000 lb	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Wet	Dark-Street Lights On
Truck Tractor & Semi-Trailer	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Not Stated	Passenger Car	At Intersection and Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Truck & Trailer		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Wet	Dark-Street Lights On
Truck Tractor & Semi-Trailer	Passenger Car	At Intersection and Not Related	Wet	Daylight
Truck Tractor	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Not Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Not Related	Dry	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Dawn
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Driveway within Major Intersection	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Other	At Intersection and Related	Dry	Daylight
Passenger Car		Not at Intersection and Not Related	Standing Water	Dark-Street Lights On
Passenger Car	Railway Vehicle	At Intersection and Related	Dry	Daylight
Truck & Trailer		At Driveway within Major Intersection	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Driveway within Major Intersection	Snow/Slush	Daylight
Passenger Car		At Intersection and Related	Wet	Daylight
Truck (Flatbad,Van,etc)		At Intersection and Not Related	Dry	Daylight
Bus or Motor Stage	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights Off
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Motorcycle		At Intersection and Related	Dry	Daylight

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
Train struck moving vehicle	Disregard Stop and Go Light		North	East		
Entering at angle	Other	Other	North	East	East	South
Train struck moving vehicle	Did Not Grant RW to Vehicle		East	South		
From same direction - all others	Improper Backing	None	East	Vehicle Backing	East	Vehicle Stopped
Train struck moving vehicle	Inattention		East	West		
Train struck stopped or stalled vehicle	Inattention		East	Vehicle Stopped		
Train struck stopped or stalled vehicle	Other	None	East	West	North	South
From same direction - all others	Improper Backing	None	West	Vehicle Backing	West	Vehicle Stopped
Railway Crossing Gate	Other		East	West		
All other non-collision	Other		West	East		
Entering at angle	Did Not Grant RW to Vehicle	None	North	South	West	East
Railway Crossing Gate	None		East	West		
From same direction - both going straight - one stopped - rear-end	Driver Reading or Writing	None	West	East	West	Vehicle Stopped
From same direction - both going straight - both moving - rear-end	Follow Too Closely	None	West	East	West	East
From same direction - all others	Other	Other				
Train struck moving vehicle	Other		West	East		
From same direction - all others	Improper Backing	None	East	Vehicle Backing	East	Vehicle Stopped
From same direction - all others	Improper Backing	None	East	Vehicle Backing	East	Vehicle Stopped
From same direction - both going straight - one stopped - sideswipe	None	Improper Passing	East	Vehicle Stopped	East	West
From same direction - both going straight - one stopped - rear-end	Inattention	None	West	East	West	Vehicle Stopped
Train struck moving vehicle	Under Influence of Alcohol		West	East		
Train struck stopped or stalled vehicle	Other		West	Vehicle Stopped		
Street Light Pole or Base	Inattention		West	North		
Train struck stopped or stalled vehicle	Improper Parking Location					
From same direction - both going straight - one stopped - sideswipe	Inattention	None	East	West	East	Vehicle Stopped
From same direction - all others	Other	None	East	Vehicle Backing	East	Vehicle Stopped
All other non-collision	None		West	East		
Railway Crossing Gate	Other		West	East		
Train struck moving vehicle	Disregard Stop and Go Light		West	East		
Train struck stopped or stalled vehicle	Other		Northwest	Vehicle Stopped		
Train struck moving vehicle	Disregard Stop Sign - Flashing Red		North	South		
Vehicle struck moving train	Disregard Stop and Go Light	None	West	East	South	North
Railway Signal Pole	Exceeding Reas. Safe Speed		Northeast	West		
Train struck moving vehicle	None	Other	North	South	East	West
Train struck moving vehicle	Did Not Grant RW to Vehicle		East	North		
Train struck moving vehicle	Inattention		East	West		
Vehicle struck moving train	Did Not Grant RW to Vehicle		West	East		
Railway Signal Pole			South	Vehicle Backing		
From same direction - both going straight - one stopped - rear-end	Inattention	None	East	West	East	Vehicle Stopped
Train struck moving vehicle	None		South	East		
Train struck moving vehicle	Other		West	South		
Train struck stopped or stalled vehicle	Other		West	Vehicle Stopped		
Train struck moving vehicle	Did Not Grant RW to Vehicle		West	South		
Vehicle overturned	Other		North	South		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
King	Seattle	State Route		99					
King	Seattle	State Route		99					
King	Seattle	State Route		99					
King	Seattle	State Route		99					
King	Seattle	State Route		519					
King	Seattle	State Route		519					
King	Seattle	State Route		519					
King	Seattle	State Route		519TBORGBEG					
King	Seattle	State Route		519TBORGBEG					
King	Seattle	State Route		519TBORGBEG					
King	Seattle	State Route		519TBORGBEG					
King	Seattle	State Route		519TBORGBEG					
King	Seattle	State Route		519TBORGBEG					

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
			28.26		3281703	10/30/2008	4:11	No Injury	0	0	1		
			28.26		2127915	5/19/2006	12:41	No Injury	0	0	1		
			28.26		2609498	1/18/2008	12:08	Possible Injury	1	0	1		
			28.26		2060389	10/17/2005	15:35	No Injury	0	0	1		
			0.49		2825512	5/15/2007	9:57	No Injury	0	0	1		
			1.14		C651729	6/9/2005	12:10	No Injury	0	0	1		
			1.14		1932807	6/9/2005	12:10	Possible Injury	5	0	2		
			0.19		2899769	7/26/2008	14:12	No Injury	0	0	2		
			0.20		2898850	9/29/2008	7:54	No Injury	0	0	2		
			0.20		2804580	9/21/2007	12:27	Evident Injury	1	0	1		
			0.20		2616776	4/15/2007	12:46	No Injury	0	0	1		
			0.20		3345105	10/3/2009	7:37	No Injury	0	0	2		
			0.21		3286491	8/25/2008	17:39	No Injury	0	0	1		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Moped		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck Tractor & Semi-Trailer		At Intersection and Related	Dry	Daylight
Truck (Flatbad,Van,etc)		At Intersection and Related	Dry	Daylight
Truck (Flatbad,Van,etc)	Other	At Intersection and Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Truck (Flatbad,Van,etc)	Pickup,Panel Truck or Vanette under 10,000 lb	At Intersection and Related	Dry	Daylight
Passenger Car		At Intersection and Related	Dry	Daylight
Bus or Motor Stage		At Intersection and Related	Dry	Daylight
Passenger Car	Passenger Car	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Wet	Daylight

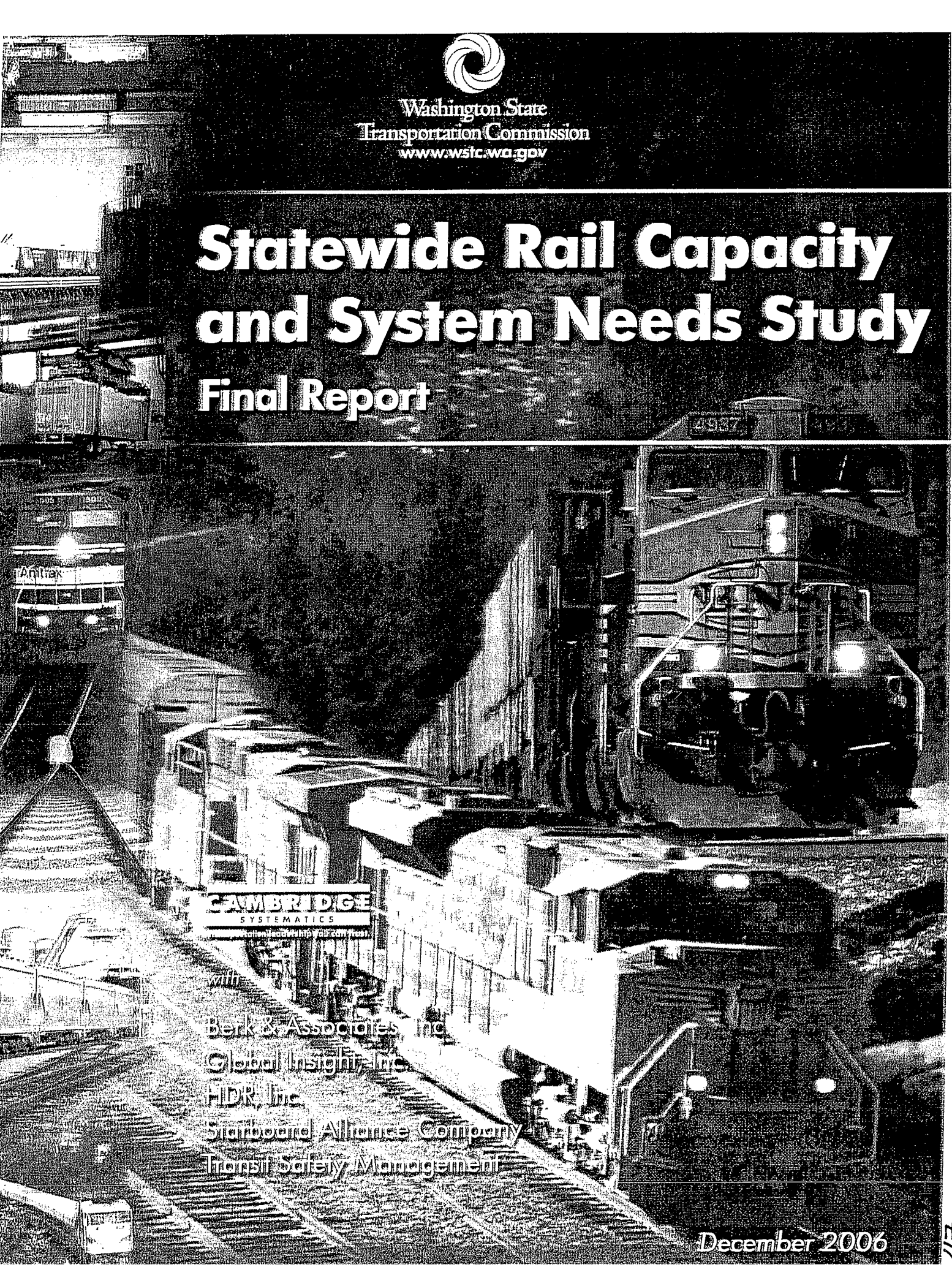
UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
Vehicle struck stopped train	Other		North	South		
Train struck moving vehicle	Did Not Grant RW to Vehicle		North	East		
All other non-collision	None		North	South		
Train struck moving vehicle	Inattention		South	North		
Train struck moving vehicle	Did Not Grant RW to Vehicle		East	West		
Train struck moving vehicle			South	East		
Train struck moving vehicle	Did Not Grant RW to Vehicle	None	South	East	South	North
From same direction - one left turn - one straight	Inattention	None	East	South	East	Vehicle Stopped
From same direction - both going straight - both moving - rear-end	Other	Other	East	West	East	West
Train struck moving vehicle	Other		East	West		
All other non-collision	None		West	East		
From same direction - both going straight - one stopped - rear-end	Improper Backing	None	East	Vehicle Backing	East	Vehicle Stopped
Railway Crossing Gate	Disregard Stop and Go Light		West	East		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

State Report Information


Washington State
Transportation Commission
www.wstc.wa.gov
Statewide Rail Capacity
and System Needs Study
Final Report
Amtrak
CAMBRIDGE
SYSTEMATICS
with
Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management
December 2006

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the State's passenger-rail program. The cost of resolving the rail choke points in the I-5 corridor to meet passenger service and ridership goals is increasing, potentially reducing the cost-effectiveness of the passenger rail program. Without capacity improvements, rail will not maintain its share of the Washington State freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the State's industrial and agricultural shippers.

The Rail Industry Is Expanding Capacity, But May Not Meet All the State's Needs

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines. They are operating longer trains and maximizing the number of containers packed on intermodal cars; consolidating pick-up and delivery of railcars at central terminals; and eliminating mainline switching wherever possible (i.e., minimizing the number of times trains are 'parked' on the mainline while picking up cars from individual shippers). These changes favor a hook-and-haul operations strategy, where the railroads pick up a full train in Seattle or Tacoma and haul it directly to Chicago, or pick up a full grain train in the Midwest and haul it directly to a Columbia River port. Hook-and-haul operations allow the railroads to achieve economies of scale that keep costs down and services profitable. However, capacity will remain constrained in Washington even with these changes.

The move toward wholesale rail service helps meet the needs of Washington State's ports, which handle high volumes of imported intermodal containers and exported grain. But it is problematic for Washington State's manufacturers and agricultural shippers. They need low-cost, shorter-haul carload service and do not generate the high volumes attractive to the railroads. In general, international intermodal container traffic has been outbidding domestic carload traffic for space on the rail system, and the railroads have been pricing out lower-volume, lower-profit shippers to meet the demands of higher-volume, higher-profit freight.

The shift toward high-volume, hook-and-haul operations is also problematic for Washington State's short line railroads. They provide a link between smaller shippers and the Class I railroads. If they cannot generate enough volume to get service

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic – most of which is associated with short- and medium-distance trips – on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- Chapter 3.0 – Washington State Rail System, Rail Users, Capacity, and Issues describes the rail system, identifies the

- Manufacturers, agricultural producers, and lumber and wood products producers generate 14 percent ($37 billion) of the State's $262 billion economic output value (gross state product) and 15.5 percent (425,700 jobs) of the State's employment.
- The Washington State ports generate between 200,000 and 300,000 direct, indirect, and trade-related jobs in the State. A portion of these jobs depend directly or indirectly on rail service.
- Sixteen percent of all freight tonnage moved in Washington State moves by rail.

Rail service is critical because it enables these Washington State industries to ship heavy or bulky commodities over long distances at low costs. Table 1 lists the top 10 outbound Washington State rail commodities by tonnage for 2004 and the forecast tonnages for 2015 and 2025. These are commodities that are shipped out of Washington State by rail. "Miscellaneous mixed shipments" are primarily merchandise and retail trade goods; many are moving in intermodal containers.

Table 1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025

		Rail Tonnage			Compound Annual Growth Rate		
STCC	Commodity	2004	2015	2025	2004-2015	2015-2026	2004-2025
46	Miscellaneous mixed shipments	6,516,304	11,309,371	19,060,968	5.1%	5.4%	5.2%
24	Lumber or wood products	4,506,679	4,072,939	4,183,956	-0.9%	0.3%	-0.4%
11	Coal	2,142,403	2,743,497	3,184,686	2.3%	1.5%	1.9%
40	Waste or scrap materials	1,543,296	2,377,099	3,260,635	4.0%	3.2%	3.6%
26	Pulp, paper, or allied products	1,231,469	1,556,870	1,752,517	2.2%	1.2%	1.7%
20	Food or kindred products	1,075,792	1,662,293	2,389,104	4.0%	3.7%	3.9%
37	Transportation equipment	826,102	2,090,719	4,523,959	8.8%	8.0%	8.4%
1	Farm products	700,653	997,648	1,385,204	3.3%	3.3%	3.3%
33	Primary metal products	606,415	677,274	597,161	1.0%	-1.3%	-0.1%
28	Chemicals or allied products	353,040	381,960	367,654	0.7%	-0.4%	0.2%

Source: Global Insight, Inc., 2006.

Figure 2 compares the 2004 tonnages to the forecast tonnages for 2015 and 2025. This figure includes commodities that are shipped into and out of Washington State; the previous figure showed only outbound commodities.

four trains that were supported financially by Washington State at that time, and about 637,000 on the entire *Cascades* service.[4] The State's passenger rail plans envision serving up to 3.0[5] million riders with 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) in 2023.

Sound Transit provides Sounder commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks. The *Cascades* service is operated by Amtrak; the Sounder commuter trains are operated by BNSF and maintained by Amtrak.

In the Puget Sound region, Sounder ridership is projected to grow from 1.2 million passenger trips in 2006 to 2.6 million passenger trips in 2011, a five-year increase of 117 percent.

Forecasts for both the Amtrak *Cascades* and the Sounder services are predicated on substantial investments to increase capacity and improve operations along the I-5 rail corridor. Full build out of the draft Long-Range Plan for the *Cascades* program calls for additional investments of $6.5 billion (in 2006 dollars) by 2023.

Rail Capacity *is calculated in a two-step process.*

First, a "theoretical capacity" is determined, assuming perfect conditions and operations.

Second, "practical capacity" is determined by considering factors, such as possible disruptions, signal needs, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand.

Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of "C." At higher percentages, rail congestion increases and service reliability deteriorates quickly.

3.4 Capacity of the Washington State Rail System and Implications for Rail Users

The Washington State rail system is nearing capacity; service quality is strained, and rates are going up.

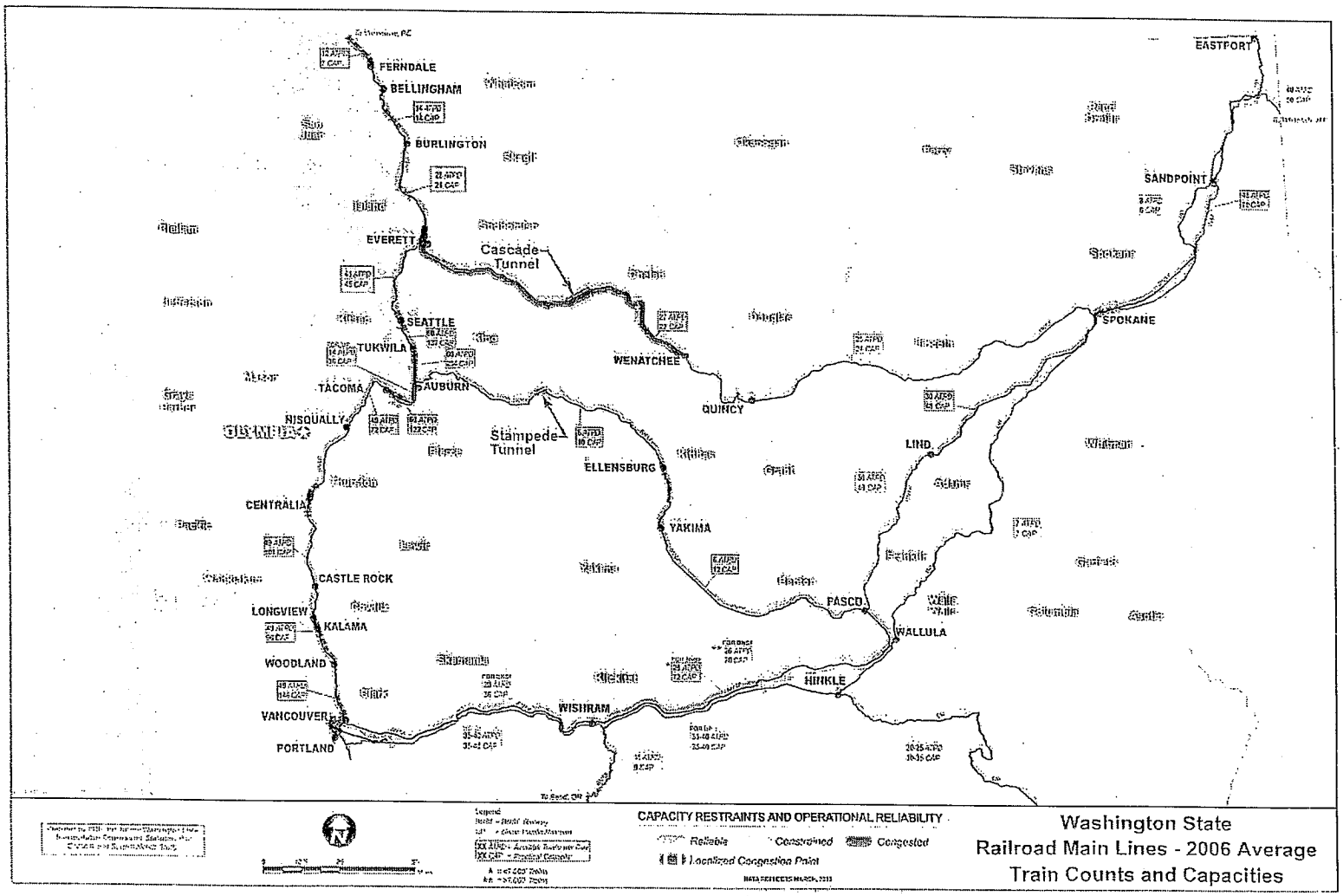
Figure 3 compares the average number of trains operated on each line to the practical capacity of the line.

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major transcontinental route for double-stack intermodal container trains. It is heavily used, operating today at about 123 percent of practical capacity.

[4] As of July 1, 2006, there are four round trips daily on the Seattle to Portland segment. Prior to this, there were only three round trips daily.

[5] A range of ridership projections were produced that varied based on fare structure and other variables. 3 million is a higher end projection.

Figure 3. Washington State Rail System: Mainline Capacities, 2006



The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UPRR freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver area, where the railroads' north-south and east-west routes intersect. Rail simulation studies of grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[6]

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, but the operational changes may not be sufficient to satisfy the future needs of Washington shippers. The short-term operating strategies being pursued by the railroads include the following:

- Operating longer 8,000-foot trains and maximizing the number of containers packed on intermodal flat cars;
- Marketing and operating single origin and destination unit trains for carload traffic;
- Consolidating pick-up and delivery of railcars at central terminals operated by third parties (examples include new rail-served industrial parks, logistics hubs, and transload centers);
- Eliminating mainline switching whenever possible (i.e., picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity); and
- Transferring responsibility for branch-line switching from the Class I railroads to local short lines, wherever possible.

These strategies will help meet the needs of the ports and intermodal shippers, but will likely complicate the problem of

[6] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

industrial carload shippers who cannot take advantage of longer and better packed intermodal trains. The Class I railroads are asking shippers, wherever possible, to reorganize and upgrade their tracks and track layouts to improve switching efficiency and be more compatible with the railroads' hook-and-haul operations. The more track space within the shipper's property and the longer the entrance and exit tracks, the faster and more efficiently the railroad can pick up or set out cars. This saves time and labor costs for the railroads and keeps high-volume mainlines open more hours of the day for through train movements. But for low-volume shippers, the costs of these site improvements are usually prohibitive. The same problems apply to consolidating rail pick-up and delivery of railcars at central terminals operated by third parties; unless the consolidation centers are well located, designed, and financed, the financial risks to shippers and operators may be very high.

Consolidation and outsourcing of terminal operations to third parties and transfer of branch-line switching from Class I to short line railroads can result in the replacement of union rail jobs with lower-paying nonunion jobs. Unless offset by future growth in Class I business that generates new union jobs, the loss of union jobs can mean a lower income and standard of living for some Washington State residents with jobs in the rail industry.

The new operating strategies also impact the State's agricultural shippers. Low-cost rail service keeps product costs competitive, but the increasing cost of rail service and the Class I railroads' focus on higher-profit, hook-and-haul intermodal traffic has made it more costly and more difficult for some agricultural shippers to get service at acceptable prices. The Class I railroads also have been asking Washington State grain and other bulk agricultural shippers to consolidate shipping points so that the railroads can operate more unit trains. Notable examples of this trend are the Ritzville grain-loading facility and the new Railex produce service at Wallula.[7]

While these new rail operating strategies have the potential to partially address future capacity needs, the analysis conducted for this study suggests that they may not be sufficient in the longer term. Table 2 lists the lines where mainline practical capacity will be exceeded within 20 years even with the additional capacity gained by operating longer trains and implementing better scheduling. The existing choke points will persist and worsen, some more quickly than others.

[7] http://www.wsdot.wa.gov/Projects/Rail/Freight/PortWallaWalla/.

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[8]

Table 2. Rail Lines in Washington State Exceeding Practical Capacity, 2015 and 2025
Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains

2015	2025
Everett-Burlington	Everett-Burlington
Burlington-Ferndale	Burlington-Ferndale
Ferndale-New Westminster	Ferndale-New Westminster
Everett-Spokane, Washington (BNSF)	Everett-Spokane, Washington (BNSF)
Vancouver-Wishram	Vancouver-Wishram
Wishram-Roosevelt	Wishram-Roosevelt
Roosevelt-Pasco	Roosevelt-Pasco
	Pasco-Spokane, Washington (BNSF)
Pasco (Wallula)-Spokane, Washington (UP)	Pasco (Wallula)-Spokane, Washington (UP)
Spokane, Washington-Sandpoint, Idaho (UP)	Spokane, Washington-Sandpoint, Idaho (UP)
Auburn-Yakima	Auburn-Yakima
Yakima-Pasco	Yakima-Pasco

Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[8] See for example: AASHTO, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UPRR have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers. This is a painful change for all shippers, especially captive shippers, who are being forced to rethink their supply chains and markets.

The national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and Washington State. Continuing high levels of growth and the competition between the BNSF and the UPRR for the lucrative Southern California rail market have made Southern California the key focal point of investment for both railroads. This has shifted investment away from the Pacific Northwest and Washington State.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, Federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not

overtake and collide with slower-moving carload freight trains.[9] The freight railroads, who own the track, are focused on obtaining the maximum benefit from each available train slot and the revenue they receive for providing train slots to the passenger railroads is usually modest.

When the Amtrak *Cascades* program was initiated, the freight railroads were willing to sell slots to the State, especially in return for physical improvements to the rail lines that would benefit both the passenger and freight railroads. With capacity tightening and increasing shipper pressure to improve throughput and reliability, the freight railroads are less willing or able to accommodate expansion of the intercity rail program. As a result, passenger services are often asked to pay a premium when they purchase slots or contribute to mainline capacity improvements.

Amtrak *Cascades* ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases and the freight railroads give priority to freight trains. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. However, if congestion continues to build and the cost of improvements increases, on-time performance may deteriorate further, undermining ridership growth and reducing the cost-effectiveness of the program. Unless a coordinated solution is examined, the future cost of the Amtrak *Cascades* program may exceed the public benefits anticipated in the original plans, and the State may need to examine alternative strategies for the passenger rail program.

[9] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

GTC Gibson Traffic Consultants, Inc.
Transportation Planners and Traffic Engineers

MEMORANDUM

To: Dianne White
Title: City of Stanwood Mayor
From: Edward Koltonowski
Subject: Cherry Point Coal Export Facility Rail Operations-Stanwood; GTC #11-036
Date: August 8, 2011

This memorandum is to identify some of the possible rail impacts associated with transport of coal to the proposed Cherry Point Facility on the City of Stanwood Washington. It identifies the potential impacts on the City's downtown core area, including 271st Street with its only local access to the Cedarhomes area east of the City, as well potential impacts on local employers such as Twin City foods that use bulk railway services for movement of local product.

We understand a terminal capable of exporting 54 million tons of coal per year is proposed north of Bellingham. GTC understands that the probable route of the coal delivery trains for Cherry Point would be from Wyoming/Montana, through Spokane, along the Columbia River and then up from the south from Seattle north to Bellingham and then to Cherry Point, along the Burlington Northern Santa Fe mainline. The route follows the rail tracks that run north south directly through the heart of the business district of the City of Stanwood Washington.

According to the applicant's *Project Information Document* (Feb. 2011), full buildout of the coal export facility would result in 9 full northbound trains along this line a day, which equates to 18 train trips a day, however, nothing in the project materials specifies a maximum. The 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future. The current port proposal occupies 350 acres of a 1,000-acre site. Each train may be over 1.5 miles long, which at 60 miles per hour would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 10-35 miles per hour it could take approximately 6-10 minutes to clear a crossing as the siding near this area is rated for 10 mph to be improved to 35mph based on the WSDOT 2006 Stanwood station report. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Stanwood can be estimated to increase with an additional train every *every 1.3 hours,* if train trips were evenly spaced throughout the day and night at between 3-4 minutes and 6-10 minutes depending on if they are having to use the siding or not.

The BNSF rail way tracks bisect the eastern residential home area of Cedarhomes and the high school from the west side of the Stanwood that includes the downtown business core. The City of Stanwood has only two east west roads connecting its downtown business core to areas of the City to the east: in this area; SR-532 that does have a grade separated crossing and 271st-Cedar Home Drive crossing which is at grade/gate controlled. Due to these constraints, our preliminary review indicated that the additional trains from the Cherry Point operations would have a potential significant impact on the commercial district and quality of life for the City of Stanwood.

The purpose of this preliminary report is to provide City staff with information that may be useful as the City prepares comments on the scope of the Cherry Point Environmental Impact Statement. We understand the City may wish to conduct additional data collection and modeling and hope that this preliminary research provides some baseline data to help understand possible impacts and the issues involved in assessing any proposed mitigation.

2802 Wetmore Avenue · Suite 220 · Everett WA, 98201
Tel: 425-339-8266 · Fax: 425-258-2922 · E-mail: info@gibsontraffic.com

We have the following comments based on preliminary research:

1. The City 2008 Comprehensive Transportation Element identifies in policies such as Policy 8.1 and 8.9 the goals of connecting east and west communities and "developing a sense of community and reviving downtown." A downtown bisected by an additional 16-18 coal train trips per day through its downtown for several hours a day at up to 60 mph raises questions about the City's ability to implement that vision and adopted planning policies.
2. The City's comprehensive plan includes an "analysis of needed capacity improvements." This analysis identified the need for additional routes between the "residential area" on the hill and the low lying commercial area, and identifies the need for improvement to Cedar Home drive. The likelihood of obtaining additional rail crossings in the future would likely be complicated by the 16-18 additional trains for the Cherry Point facility.
3. Due to a speed restriction approach warning, train travel through Stanwood downtown means the barriers are down for approximately 3-4 minutes (over 200 seconds) for the larger (over one mile long) freight trains. This is the equivalent of 2-3 continuous red lights cycles in a row for a normal signal on 271st NW. The Institute of Traffic Engineers identifies an average delay of over 80 seconds as level of service F - the City's standard for normal roadway operation is LOS D, i.e. allowing only 60 seconds as the worst delay for normal conditions. The addition of 16-18 trains per day would call into question whether the City can maintain its adopted LOS D standard.
4. With the increase in number of long coal trains across 271st grade crossing, the only alternative east-west for local traffic is the regional SR-532 grade separated crossing as the "local" east west route becomes degraded with the increase coal trains. This is a particular issue during summer peaks as SR-532 already reaches capacity limits.
5. There is a probable issue concerning emergency services response times, in a scenario where SR-532 is closed due to an accident/obstruction or peak summer traffic and the only east-west crossing between the business district to the west and the residential area to the east is dependent on the Cedar Home/271st crossing being unobstructed. In the event a mile and a half long train is stopped or moving slowly past this point, emergency response times could be delayed until the crossing is cleared. Adding 16-18 additional trains per day to service Cherry Point could tip the balance at a critical time when emergency responses are needed.
6. Within the last 5 years there have been 3 accidents at the Cedar Home drive/271st crossing two of which included an injury. Two included other motor vehicles at the crossing, not actual trains, but one included a train striking and injuring a pedestrian crossing the tracks. Additionally within the approach roads to Stanwood there were three accidents recorded at the Old Pacific Highway crossing just to the north that included collisions with the guard rail. To the south, the minor 48th Avenue crossing in the County recorded two accidents both of which involved trains and crossing vehicles.
7. Already today the presence of a long freight train during the peak hours creates separation in the downtown core. The City's comprehensive plan identified that 271st St NW in the downtown core carried approximately 16,000 vehicles a day and states that growth is going to come from the increased in City residential development. This means those areas primarily east of the tracks thus even greater future demands on 271st can be anticipated. Any environmental review of rail line impacts should study this current condition and likely increased impact, including costs to mitigate the effects. One form of mitigation is to create grade-separation, with either a tunnel or a bridge. The City may wish to request that mitigation as part of the environmental review process for Cherry Point.
8. It should also be recognized that the rail tracks also cross the City's primary access to the north from the west side for the City (Old Pacific Highway). Old Pacific highway north of the City carries over 5,000 daily trips near the crossing point.

9. The City of Stanwood and state have recently invested heavily in establishing the Stanwood station and improved passenger train (AMTRAK) services for the north end. Freight traffic on the single rail line north of Everett is expected to double with the Cherry Point proposal. Under BNSF's policy, it is our understanding that freight deliveries are not scheduled to the same on time reliability demands of passenger trains but can still take precedence over passenger rail under certain circumstances. The City may wish to analyze the degree to which a doubling of freight traffic is expected to adversely affect the reliability of existing passenger rail schedules and also whether it will diminish opportunities to expand passenger rail. In 2001, the City participated in a state-sponsored study of the potential for passenger rail expansion, titled: *Pacific Northwest Rail Corridor: Everett to Blaine Commuter Rail Preliminary Feasibility Study.* On Page IV of the Executive Summary, the report concludes that there may be a viable market for commuter rail north of Everett by the year 2030. In 2004 the North Sound Regional Study conducted by Cascadia for Whatcom Council of Governments identified again the potential of significant rail capacity issues identified by BNSF. The City may wish to comment on whether the Cherry Point proposal affects the conclusions in those studies.
10. The States 2006 "statewide *Rail Capacity and System Needs* study" identifies the 1st issue as follows:

    > The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services.
    >
    > Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market.

    So a key question may be whether this interstate traffic from the coal trains will have the impact of reducing the availability of local rail spur business necessary to serve Stanwood businesses such as Twin City Foods. These issues can be analyzed as part of the economic impact analysis we understand must be completed as part of the environmental review for the project.

11. The Washington State 2010-2030 Freight Rail Plan published by WSDOT in December 2009 identified that the rail line through Stanwood in 2008 capacity was already at its capacity of 18 trains per day (Exhibit 3-9). The state plan shows that it hopes to increase that capacity to 30 trains per day; however the design and cost of the specific improvements needed to do that have not been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services.
12. The Cherry Point applicant argues that the coal train activity will only bring train activity back up to the level it was before the economic recession of 2007/2008, and therefore there is no impact. In our judgment, this conclusion is not supportable, because as soon as the economic recovery really starts to take hold, those previous train activities will also pick up, as well vehicular traffic on the roads. At that point, even greater impacts will begin to accumulate. Additional work is needed to obtain reliable information concerning pre-recession and historic train levels, the length of trains and delay times. Reliable projections of train and road traffic during economic recovery are critical to obtaining realistic estimates of delays and impacts. Assumptions from the past should be regarded critically.
13. Train delays at crossings are often eliminated by constructing grade separation, which allows traffic to pass over or under railroad tracks. While grade separation is desirable particularly because of the already complicated Pioneer/Cedar Drive intersections and the new Stanwood AMTRAK station,

these improvements are typically multi-million dollar solutions and funding is not yet planned. Estimates of this mitigation may be obtained by the City, in conjunction with estimates of similar improvements to be requested by other cities, counties and WSDOT. It is our understanding, for example, that replacement of the Skagit River Bridge may be necessary to support the proposed heavy coal rail increases. The budget for design and construction of that improvement alone may be half a billion dollars.

This analysis of possible rail line impacts associated with the increase of 18 trains per day serving the Cherry Point Coal export facility is preliminary and is intended to illustrate some of the potential problems and areas deserving detailed study during the SEPA review for the facility. This preliminary analysis suggests potentially severe consequences for the City's transportation plan and improvements, with increases in risk of accidents, impacts to the City's levels of service, ability to provide effective emergency response times, and possible interference with local freight delivery systems important to the City's economic recovery.

Attachments for City of Stanwood Rail Capacity Presentation

Crossing Information

Federal Railroad Administration
Office of Safety Analysis

You are Visitor# 7301838

8.01 - Query by Location

Total Records: 11

Report Type: (•) Inventory ( ) Accident ( ) Contact Sheet

Inventory: (•) Current ( ) History

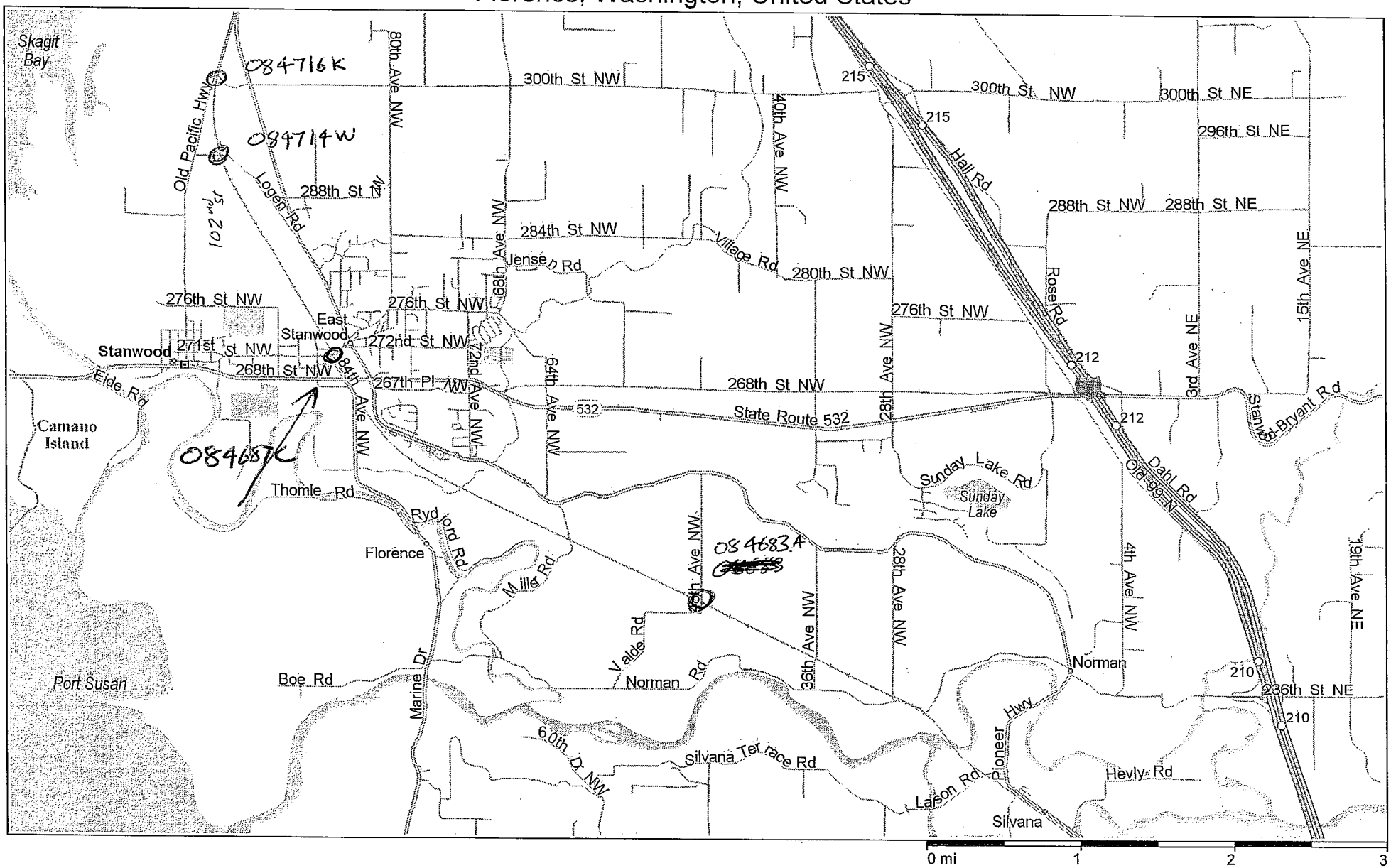
Generate Repor | Show All | Reset

	Crossing#	State	Rr	Type	Position	Status	Milepost	County	City	Division	SubDivision	Branch	Street
☐	**084676P**	WA	BNSF	Public	At Grade	Open	004995	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	SATHER RD
☐	**084677W**	WA	BNSF	Public	At Grade	Open	005017	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	227TH ST.N.W.
☐	**084680E**	WA	BNSF	Public	At Grade	Open	005101	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	28TH AVE. N.W.
☐	**084683A**	WA	BNSF	Public	At Grade	Open	005241	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	48TH N.W.
☐	**084685N**	WA	BNSF	Public	At Grade	Open	005336	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	MILLER RD
☐	**084687C**	WA	BNSF	Public	At Grade	Open	005540	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	271ST ST NW
☐	**084694M**	WA	BNSF	Public	At Grade	Open	000088	SNOHOMISH	STANWOOD	NORTHWEST	TWIN CITY FOOD	TWIN CTY FDS SP	102ND NW
☐	**084695U**	WA	BNSF	Public	At Grade	Open	000096	SNOHOMISH	STANWOOD	NORTHWEST	TWIN CITY FOOD	TWIN CTY FDS SP	276TH ST
☐	**084699W**	WA	BNSF	Public	At Grade	Open	005570	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	TWIN CTY FDS SP	SARATOGA DRIVE
☐	**084714W**	WA	BNSF	Public	At Grade	Open	005742	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	300TH ST.
☐	**084716K**	WA	BNSF	Public	At Grade	Open	005793	SNOHOMISH	STANWOOD	NORTHWEST	BELLINGHAM	PA J-US CAN BDR	102ND ST

Generate Repor | Show All | Reset

CROSS INC #

Florence, Washington, United States



Copyright © and (P) 1988–2009 Microsoft Corporation and/or its suppliers. All rights reserved. http://www.microsoft.com/streets/
Certain mapping and direction data © 2009 NAVTEQ. All rights reserved. The Data for areas of Canada includes information taken with permission from Canadian authorities, including: © Her Majesty the Queen in Right of Canada, © Queen's Printer for Ontario. NAVTEQ and NAVTEQ ON BOARD are trademarks of NAVTEQ. © 2009 Tele Atlas North America, Inc. All rights reserved. Tele Atlas and Tele Atlas North America are trademarks of Tele Atlas, Inc. © 2009 by Applied Geographic Systems. All rights reserved.

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: *084687C* Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: *BNSF BNSF Rwy Co. [BNSF]* End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	*NORTHWEST*	State:	*WA*
Subdivision:	*BELLINGHAM*	County:	*SNOHOMISH*
Branch or Line Name:	*PA J-US CAN BDR*	City:	*Near STANWOOD*
Railroad Milepost:	*0055.40*	Street or Road Name:	*271ST ST NW*
RailRoad I.D. No.:	*0050*	Highway Type & No.:	*CITY ST*
Nearest RR Timetable Stn:	*STANWOOD*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	*31-3*
Crossing Owner:		Latitude:	*48.2422255*
ENS Sign Installed:		Longitude:	*-122.3496090*
Passenger Service:	*AMTRAK*	Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*1*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements:

Total Trains: *19* Total Switching: *0* Less Than One Movement Per Day: ***No***

Day Thru: ***10***

Typical Speed Range Over Crossing: From *1* to *79* mph Maximum Time Table Speed: ***79***

Type and Number of Tracks: Main: *1* Other *2* Specify: ***SIDE & IND***

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084687C*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*3*	Highway Stop Signs:	*0*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Commercial*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Rubber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Minor Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*006902*	AADT Year:	*1993*
Estimated Percent Trucks:	*05*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: *084683A* Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: *BNSF BNSF Rwy Co. [BNSF]* End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	*NORTHWEST*	State:	*WA*
Subdivision:	*BELLINGHAM*	County:	*SNOHOMISH*
Branch or Line Name:	*PA J-US CAN BDR*	City:	*Near STANWOOD*
Railroad Milepost:	*0052.41*	Street or Road Name:	*48TH N.W.*
RailRoad I.D. No.:	*0050*	Highway Type & No.:	*CO70450*
Nearest RR Timetable Stn:	*STANWOOD*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	*31-3*
Crossing Owner:		Latitude:	*48.2185301*
ENS Sign Installed:		Longitude:	*-122.2971902*
Passenger Service:	*AMTRAK*	Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*1*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements:

Total Trains: *19* Total Switching: *0*

Typical Speed Range Over Crossing: From *1* to *79* mph

Type and Number of Tracks: Main: *1* Other *0*

Less Than One Movement Per Day: ***No***

Day Thru: ***10***

Maximum Time Table Speed: ***79***

Specify:

Does Another RR Operate a Separate Track at Crossing? ***No***

Does Another RR Operate Over Your Track at Crossing? ***Yes: ATK***

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084683A*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*No Markings*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*0*	4 Quad or Full Barrier:	
Mast Mounted FL:	*0*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *0*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*None*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*N/A*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000100*	AADT Year:	*1987*
Estimated Percent Trucks:	*12*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: *084716K* Update Reason: *Changed Crossing* Effective Begin-Date of Record: *08/17/06*

Railroad: *BNSF BNSF Rwy Co. [BNSF]* End-Date of Record:

Initiating Agency *Railroad* Type and Positiion: *Public At Grade*

Part I Location and Classification of Crossing

Division:	*NORTHWEST*	State:	*WA*
Subdivision:	*BELLINGHAM*	County:	*SNOHOMISH*
Branch or Line Name:	*PA J-US CAN BDR*	City:	*Near STANWOOD*
Railroad Milepost:	*0057.93*	Street or Road Name:	*102ND ST*
RailRoad I.D. No.:	*0050*	Highway Type & No.:	*CO97885*
Nearest RR Timetable Stn:	*STANWOOD*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	*31-3*
Crossing Owner:		Latitude:	*48.2757928*
ENS Sign Installed:		Longitude:	*-122.3632049*
Passenger Service:	*AMTRAK*	Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*1*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

← Old Pacific

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:			
State Use:			

Narrative:

Emergency Contact: *(800)832-5452* Railroad Contact: *(913)551-4540* State Contact: *(360)664-1262*

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: *No*

Total Trains: *13* Total Switching: *0* Day Thru: *7*

Typical Speed Range Over Crossing: From *1* to *79* mph Maximum Time Table Speed: *79*

Type and Number of Tracks: Main: *1* Other *0* Specify:

Does Another RR Operate a Separate Track at Crossing? *No*

Does Another RR Operate Over Your Track at Crossing? *Yes: ATK*

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084716K*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*		
Advanced Warning:	*Yes*	Hump Crossing Sign:			
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs:	*0*	Specify:	
			0		

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:			
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*		
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*		
Other Flashing Lights:	*0*	Specify Other Flashing Lights:			
Highway Traffic Signals:	*0*	Wigwags:	*0*	Bells:	*1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:			
Channelization:		Type of Train Detection:	*DC/AFO*		
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:			

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*30 to 59 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Other FA Highway - Not NHS*	Functional Classification of Road at Crossing:	*Rural Major Collector*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*002000*	AADT Year:	*1993*
Estimated Percent Trucks:	*03*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: *084714W* Update Reason: *Changed Crossing* Effective Begin-Date of Record: *08/17/06*

Railroad: *BNSF BNSF Rwy Co. [BNSF]* End-Date of Record:

Initiating Agency *Railroad* Type and Positiion: *Public At Grade*

Part I Location and Classification of Crossing

Division:	*NORTHWEST*	State:	*WA*
Subdivision:	*BELLINGHAM*	County:	*SNOHOMISH*
Branch or Line Name:	*PA J-US CAN BDR*	City:	*Near STANWOOD*
Railroad Milepost:	*0057.42*	Street or Road Name:	*300TH ST.*
RailRoad I.D. No.:	*0050*	Highway Type & No.:	*CO73600*
Nearest RR Timetable Stn:	*STANWOOD*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	*31-3*
Crossing Owner:		Latitude:	*48.2693425*
ENS Sign Installed:		Longitude:	*-122.3659966*
Passenger Service:	*AMTRAK*	Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*1*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: *(800)832-5452* Railroad Contact: *(913)551-4540* State Contact: *(360)664-1262*

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: *No*

Total Trains: *13* Total Switching: *0* Day Thru: *7*

Typical Speed Range Over Crossing: From *1* to *79* mph Maximum Time Table Speed: *79*

Type and Number of Tracks: Main: *1* Other *0* Specify:

Does Another RR Operate a Separate Track at Crossing? *No*

Does Another RR Operate Over Your Track at Crossing? *Yes: ATK*

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084714W*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines and RR Xing Symbols*	Other Signs: *0* *0*	Specify:

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*2*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000075*	AADT Year:	*1993*
Estimated Percent Trucks:	*10*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 8/1/2011

Crossing No.: *084680E* Update Reason: ***Changed Crossing*** Effective Begin-Date of Record: ***08/17/06***

Railroad: *BNSF BNSF Rwy Co. [BNSF]* End-Date of Record:

Initiating Agency ***Railroad*** Type and Positiion: ***Public At Grade***

Part I Location and Classification of Crossing

Division:	*NORTHWEST*	State:	*WA*
Subdivision:	*BELLINGHAM*	County:	*SNOHOMISH*
Branch or Line Name:	*PA J-US CAN BDR*	City:	*Near STANWOOD*
Railroad Milepost:	*0051.01*	Street or Road Name:	*28TH AVE. N.W.*
RailRoad I.D. No.:	*0050*	Highway Type & No.:	*CO70750*
Nearest RR Timetable Stn:	*STANWOOD*	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	*31-3*
Crossing Owner:		Latitude:	*48.2097553*
ENS Sign Installed:		Longitude:	*-122.2699478*
Passenger Service:	*AMTRAK*	Lat/Long Source:	*Actual*
Avg Passenger Train Count:	*1*	Quiet Zone:	*No*
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:

Specify Signs: Specify Signals:

ST/RR A ST/RR B ST/RR C ST/RR D

Railroad Use:

State Use:

Narrative:

Emergency Contact: ***(800)832-5452*** Railroad Contact: ***(913)551-4540*** State Contact: ***(360)664-1262***

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: ***No***

Total Trains: *19* Total Switching: *0* Day Thru: *10*

Typical Speed Range Over Crossing: From *1* to *79* mph Maximum Time Table Speed: *79*

Type and Number of Tracks: Main: *1* Other *0* Specify:

Does Another RR Operate a Separate Track at Crossing? *No*

Does Another RR Operate Over Your Track at Crossing? *Yes: ATK*

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing *084680E*

Effective Begin-Date of Record: *08/17/06*
End-Date of Record:

Part III: Traffic Control Device Information

Signs:

Crossbucks:	*2*	Highway Stop Signs:	*2*
Advanced Warning:	*Yes*	Hump Crossing Sign:	
Pavement Markings:	*Stop Lines*	Other Signs: *0*	Specify:
		0	

Train Activated Devices:

Gates:	*2*	4 Quad or Full Barrier:	
Mast Mounted FL:	*2*	Total Number FL Pairs:	*0*
Cantilevered FL (Over):	*0*	Cantilevered FL (Not over):	*0*
Other Flashing Lights:	*0*	Specify Other Flashing Lights:	
Highway Traffic Signals:	*0*	Wigwags: *0*	Bells: *1*
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	*DC/AFO*
Track Equipped with Train Signals?	*Yes*	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	*Open Space*	Smallest Crossing Angle:	*60 to 90 Degrees*
Number of Traffic Lanes Crossing Railroad:	*2*	Are Truck Pullout Lanes Present?	*No*
Is Highway Paved?	*Yes*		
Crossing Surface:	*Timber*	If Other:	
Nearby Intersecting Highway?	*Less than 75 feet*	Is it Signalized?	
Does Track Run Down a Street?	*No*	Is Crossing Illuminated?	
Is Commercial Power Available?	*Yes*		

Part V: Highway Information

Highway System:	*Non-Federal-aid*	Functional Classification of Road at Crossing:	*Rural Local*
Is Crossing on State Highway System:	*No*		
Annual Average Daily Traffic (AADT):	*000045*	AADT Year:	*1993*
Estimated Percent Trucks:	*20*	Avg. No of School Buses per Day:	*0*
Posted Highway Speed:	*0*		

Count Information

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

A - 26

24 Hour Volume

Begin	N/B		S/B		Combined	
12:00 AM	0	4	5	22	5	26
12:15 AM	1		6		7	
12:30 AM	2		6		8	
12:45 AM	1		5		6	
1:00 AM	1	4	3	7	4	11
1:15 AM	1		1		2	
1:30 AM	1		1		2	
1:45 AM	1		2		3	
2:00 AM	0	4	0	4	0	8
2:15 AM	0		0		0	
2:30 AM	1		1		2	
2:45 AM	3		3		6	
3:00 AM	1	7	1	18	2	25
3:15 AM	2		2		4	
3:30 AM	1		6		7	
3:45 AM	3		9		12	
4:00 AM	1	24	5	13	6	37
4:15 AM	5		3		8	
4:30 AM	5		4		9	
4:45 AM	13		1		14	
5:00 AM	15	78	2	44	17	122
5:15 AM	13		11		24	
5:30 AM	21		13		34	
5:45 AM	29		18		47	
6:00 AM	24	128	7	62	31	190
6:15 AM	28		7		35	
6:30 AM	41		19		60	
6:45 AM	35		29		64	
7:00 AM	39	199	15	73	54	272
7:15 AM	57		12		69	
7:30 AM	61		19		80	
7:45 AM	42		27		69	
8:00 AM	37	192	33	107	70	299
8:15 AM	48		22		70	
8:30 AM	57		23		80	
8:45 AM	50		29		79	
9:00 AM	49	189	25	117	74	306
9:15 AM	43		31		74	
9:30 AM	54		34		88	
9:45 AM	43		27		70	
10:00 AM	47	171	28	113	75	284
10:15 AM	38		30		68	
10:30 AM	36		32		68	
10:45 AM	50		23		73	
11:00 AM	35	156	23	110	58	266
11:15 AM	47		25		72	
11:30 AM	37		22		59	
11:45 AM	37		40		77	

Begin	N/B		S/B		Combined	
12:00 PM	49	179	33	145	82	324
12:15 PM	52		32		84	
12:30 PM	44		42		86	
12:45 PM	34		38		72	
1:00 PM	47	177	33	181	80	358
1:15 PM	36		49		85	
1:30 PM	46		49		95	
1:45 PM	48		50		98	
2:00 PM	54	202	40	159	94	361
2:15 PM	54		39		93	
2:30 PM	51		34		85	
2:45 PM	43		46		89	
3:00 PM	40	165	51	222	91	387
3:15 PM	49		56		105	
3:30 PM	38		61		99	
3:45 PM	38		54		92	
4:00 PM	40	170	50	232	90	402
4:15 PM	52		56		108	
4:30 PM	45		57		102	
4:45 PM	33		69		102	
5:00 PM	30	151	72	269	102	420
5:15 PM	35		76		111	
5:30 PM	45		64		109	
5:45 PM	41		57		98	
6:00 PM	19	104	60	233	79	337
6:15 PM	32		69		101	
6:30 PM	31		60		91	
6:45 PM	22		44		66	
7:00 PM	19	68	31	109	50	177
7:15 PM	19		30		49	
7:30 PM	21		24		45	
7:45 PM	9		24		33	
8:00 PM	12	59	42	116	54	175
8:15 PM	18		17		35	
8:30 PM	9		30		39	
8:45 PM	20		27		47	
9:00 PM	11	33	18	90	29	123
9:15 PM	6		24		30	
9:30 PM	10		28		38	
9:45 PM	6		20		26	
10:00 PM	7	41	9	49	16	90
10:15 PM	15		14		29	
10:30 PM	14		11		25	
10:45 PM	5		15		20	
11:00 PM	6	16	5	22	11	38
11:15 PM	2		7		9	
11:30 PM	3		5		8	
11:45 PM	5		5		10	

	N/B	S/B	Combined
24 Hour Volume	2521 (50.0%)	2517 (50.0%)	5038

	12:00 AM - 12:00 PM			12:00 PM - 12:00 AM		
	N/B	S/B	Combined	N/B	S/B	Combined
Count	1156	690	1846	1365	1827	3192
	62.6 %	37.4 %		42.8 %	57.2 %	
Peak Hour	8:15 AM	9:15 AM	8:45 AM	1:45 PM	4:45 PM	4:45 PM
Volume	204	120	315	207	281	424
Factor	0.89	0.88	0.89	0.96	0.92	0.95

PREPARED BY SNOHOMISH COUNTY

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

A - 27

24 Hour Volume

Begin	N/B		S/B		Combined	
12:00 AM	3	4	8	16	11	20
12:15 AM	1		2		3	
12:30 AM	0		2		2	
12:45 AM	0		4		4	
1:00 AM	1	6	3	13	4	19
1:15 AM	1		3		4	
1:30 AM	2		5		7	
1:45 AM	2		2		4	
2:00 AM	0	3	1	5	1	8
2:15 AM	1		2		3	
2:30 AM	1		1		2	
2:45 AM	1		1		2	
3:00 AM	1	6	0	5	1	11
3:15 AM	3		1		4	
3:30 AM	1		1		2	
3:45 AM	1		3		4	
4:00 AM	2	31	2	19	4	50
4:15 AM	6		10		16	
4:30 AM	10		4		14	
4:45 AM	13		3		16	
5:00 AM	14	66	1	32	15	98
5:15 AM	15		9		24	
5:30 AM	23		10		33	
5:45 AM	14		12		26	
6:00 AM	32	154	9	67	41	221
6:15 AM	37		14		51	
6:30 AM	52		15		67	
6:45 AM	33		29		62	
7:00 AM	47	204	15	88	62	292
7:15 AM	54		23		77	
7:30 AM	62		25		87	
7:45 AM	41		25		66	
8:00 AM	45	164	30	122	75	286
8:15 AM	49		29		78	
8:30 AM	43		25		68	
8:45 AM	27		38		65	
9:00 AM	36	181	23	102	59	283
9:15 AM	40		28		68	
9:30 AM	55		21		76	
9:45 AM	50		30		80	
10:00 AM	43	206	24	106	67	312
10:15 AM	48		34		82	
10:30 AM	60		20		80	
10:45 AM	55		28		83	
11:00 AM	31	157	35	142	66	299
11:15 AM	42		36		78	
11:30 AM	40		41		81	
11:45 AM	44		30		74	

Begin	N/B		S/B		Combined	
12:00 PM	43	172	37	158	80	330
12:15 PM	40		39		79	
12:30 PM	56		46		102	
12:45 PM	33		36		69	
1:00 PM	49	181	29	156	78	337
1:15 PM	46		47		93	
1:30 PM	52		33		85	
1:45 PM	34		47		81	
2:00 PM	48	181	36	155	84	336
2:15 PM	47		33		80	
2:30 PM	47		35		82	
2:45 PM	39		51		90	
3:00 PM	44	163	38	196	82	359
3:15 PM	40		36		76	
3:30 PM	51		58		109	
3:45 PM	28		64		92	
4:00 PM	33	145	59	251	92	396
4:15 PM	30		53		83	
4:30 PM	32		75		107	
4:45 PM	50		64		114	
5:00 PM	37	160	62	245	99	405
5:15 PM	49		74		123	
5:30 PM	41		52		93	
5:45 PM	33		57		90	
6:00 PM	29	125	47	188	76	313
6:15 PM	27		61		88	
6:30 PM	31		42		73	
6:45 PM	38		38		76	
7:00 PM	25	87	44	126	69	213
7:15 PM	27		29		56	
7:30 PM	19		25		44	
7:45 PM	16		28		44	
8:00 PM	13	64	29	118	42	182
8:15 PM	16		19		35	
8:30 PM	16		26		42	
8:45 PM	19		44		63	
9:00 PM	11	43	21	96	32	139
9:15 PM	11		42		53	
9:30 PM	15		17		32	
9:45 PM	6		16		22	
10:00 PM	10	37	21	56	31	93
10:15 PM	9		13		22	
10:30 PM	11		17		28	
10:45 PM	7		5		12	
11:00 PM	2	7	7	33	9	40
11:15 PM	2		11		13	
11:30 PM	3		7		10	
11:45 PM	0		8		8	

	N/B	S/B	Combined
24 Hour Volume	2547 (50.5%)	2495 (49.5%)	5042

	12:00 AM - 12:00 PM			12:00 PM - 12:00 AM		
	N/B	S/B	Combined	N/B	S/B	Combined
Count	1182	717	1899	1365	1778	3143
	62.2 %	37.8 %		43.4 %	56.6 %	
Peak Hour	10:00 AM	11:00 AM	10:00 AM	12:30 PM	4:30 PM	4:30 PM
Volume	206	142	312	184	275	443
Factor	0.86	0.87	0.94	0.82	0.92	0.90

PREPARED BY SNOHOMISH COUNTY

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

A - 22

24 Hour Vehicle Classification
Channel: N/B

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	4	0	3	1	0	0	0	0	0	0	0	0	0	0
1:00 AM	4	0	3	1	0	0	0	0	0	0	0	0	0	0
2:00 AM	4	0	2	1	0	1	0	0	0	0	0	0	0	0
3:00 AM	7	0	7	0	0	0	0	0	0	0	0	0	0	0
4:00 AM	24	1	19	3	0	1	0	0	0	0	0	0	0	0
5:00 AM	78	1	62	9	1	5	0	0	0	0	0	0	0	0
6:00 AM	128	0	101	22	0	4	0	0	1	0	0	0	0	0
7:00 AM	199	1	158	26	0	13	1	0	0	0	0	0	0	0
8:00 AM	192	0	142	34	1	11	1	0	2	1	0	0	0	0
9:00 AM	189	0	145	28	1	11	0	0	2	0	0	2	0	0
10:00 AM	171	4	134	23	4	4	0	0	1	0	0	1	0	0
11:00 AM	156	1	112	27	1	14	0	0	0	1	0	0	0	0
12:00 PM	179	2	132	34	0	9	1	0	0	1	0	0	0	0
1:00 PM	177	3	121	33	1	14	1	0	3	0	0	1	0	0
2:00 PM	202	5	147	32	0	15	0	0	0	0	0	2	0	1
3:00 PM	165	1	111	34	0	13	0	0	2	0	0	2	0	2
4:00 PM	170	3	102	41	3	13	0	0	3	0	0	5	0	0
5:00 PM	151	5	95	35	3	8	0	0	1	0	0	2	0	2
6:00 PM	104	3	68	20	1	7	2	0	1	0	0	2	0	0
7:00 PM	68	0	55	10	0	3	0	0	0	0	0	0	0	0
8:00 PM	59	1	50	4	1	3	0	0	0	0	0	0	0	0
9:00 PM	33	1	25	7	0	0	0	0	0	0	0	0	0	0
10:00 PM	41	0	37	4	0	0	0	0	0	0	0	0	0	0
11:00 PM	16	0	14	1	0	0	0	0	1	0	0	0	0	0
Total	2521	32	1845	430	17	149	6	0	17	3	0	17	0	5
%		1.3	73.2	17.1	0.7	5.9	0.2	0.0	0.7	0.1	0.0	0.7	0.0	0.2

PREPARED BY TRAFFIC DATA SERVICES

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

A - 23

24 Hour Vehicle Classification
Channel: N/B

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	4	0	3	1	0	0	0	0	0	0	0	0	0	0
1:00 AM	6	0	6	0	0	0	0	0	0	0	0	0	0	0
2:00 AM	3	0	3	0	0	0	0	0	0	0	0	0	0	0
3:00 AM	6	0	6	0	0	0	0	0	0	0	0	0	0	0
4:00 AM	31	0	25	3	0	3	0	0	0	0	0	0	0	0
5:00 AM	66	2	54	7	1	2	0	0	0	0	0	0	0	0
6:00 AM	154	1	120	29	0	4	0	0	0	0	0	0	0	0
7:00 AM	204	1	160	28	2	8	2	0	3	0	0	0	0	0
8:00 AM	164	1	112	35	0	11	0	0	3	0	0	2	0	0
9:00 AM	181	3	137	24	2	12	0	0	2	0	0	1	0	0
10:00 AM	206	2	159	32	2	8	1	0	2	0	0	0	0	0
11:00 AM	157	3	115	25	1	11	0	0	0	1	0	1	0	0
12:00 PM	172	0	121	28	1	16	1	0	4	1	0	0	0	0
1:00 PM	181	1	136	25	0	10	1	0	6	0	0	2	0	0
2:00 PM	181	2	138	21	0	16	1	0	1	0	0	2	0	0
3:00 PM	163	3	110	26	5	13	0	0	2	0	0	4	0	0
4:00 PM	145	5	96	31	1	9	0	0	1	0	0	1	0	1
5:00 PM	160	3	114	32	4	2	0	0	2	0	0	3	0	0
6:00 PM	125	3	84	22	3	6	0	0	4	0	0	2	0	1
7:00 PM	87	1	63	13	1	8	0	0	1	0	0	0	0	0
8:00 PM	64	0	53	7	1	3	0	0	0	0	0	0	0	0
9:00 PM	43	0	36	4	0	3	0	0	0	0	0	0	0	0
10:00 PM	37	0	29	6	0	2	0	0	0	0	0	0	0	0
11:00 PM	7	1	5	0	0	1	0	0	0	0	0	0	0	0
Total	2547	32	1885	399	24	148	6	0	31	2	0	18	0	2
%		1.3	74.0	15.7	0.9	5.8	0.2	0.0	1.2	0.1	0.0	0.7	0.0	0.1

PREPARED BY SNOHOMISH COUNTY TRAFFIC OPERATIONS

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

24 Hour Vehicle Classification
Channel: S/B

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	22	0	18	3	1	0	0	0	0	0	0	0	0	0
1:00 AM	7	0	6	1	0	0	0	0	0	0	0	0	0	0
2:00 AM	4	0	3	0	0	1	0	0	0	0	0	0	0	0
3:00 AM	18	0	16	1	0	1	0	0	0	0	0	0	0	0
4:00 AM	13	0	10	3	0	0	0	0	0	0	0	0	0	0
5:00 AM	44	0	33	9	0	2	0	0	0	0	0	0	0	0
6:00 AM	62	0	47	7	0	6	0	0	1	1	0	0	0	0
7:00 AM	73	0	54	15	0	4	0	0	0	0	0	0	0	0
8:00 AM	107	0	82	18	0	7	0	0	0	0	0	0	0	0
9:00 AM	117	0	80	25	3	6	0	0	2	0	0	1	0	0
10:00 AM	113	2	69	29	0	11	1	0	0	0	0	1	0	0
11:00 AM	110	1	68	31	0	8	1	0	1	0	0	0	0	0
12:00 PM	145	1	101	23	2	13	1	0	1	1	0	2	0	0
1:00 PM	181	2	129	28	3	16	0	0	2	0	0	1	0	0
2:00 PM	159	0	122	24	2	10	0	0	0	0	0	1	0	0
3:00 PM	222	2	169	32	0	12	0	0	4	0	0	1	0	2
4:00 PM	232	3	164	47	3	9	0	0	2	0	0	3	0	1
5:00 PM	269	3	197	41	2	19	0	0	3	0	0	3	0	1
6:00 PM	233	6	190	26	0	7	0	0	1	0	0	2	0	1
7:00 PM	109	0	92	10	0	6	0	0	1	0	0	0	0	0
8:00 PM	116	1	96	13	0	5	1	0	0	0	0	0	0	0
9:00 PM	90	1	75	9	1	3	0	0	1	0	0	0	0	0
10:00 PM	49	0	40	8	0	1	0	0	0	0	0	0	0	0
11:00 PM	22	1	16	3	0	2	0	0	0	0	0	0	0	0
Total	2517	23	1877	406	17	149	4	0	19	2	0	15	0	5
%		0.9	74.6	16.1	0.7	5.9	0.2	0.0	0.8	0.1	0.0	0.6	0.0	0.2

PREPARED UNDER THE SUPERVISION OF

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

24 Hour Vehicle Classification
Channel: S/B

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	16	0	16	0	0	0	0	0	0	0	0	0	0	0
1:00 AM	13	1	8	2	1	1	0	0	0	0	0	0	0	0
2:00 AM	5	0	4	0	0	0	0	0	1	0	0	0	0	0
3:00 AM	5	0	5	0	0	0	0	0	0	0	0	0	0	0
4:00 AM	19	0	16	3	0	0	0	0	0	0	0	0	0	0
5:00 AM	32	1	24	5	0	2	0	0	0	0	0	0	0	0
6:00 AM	67	1	51	8	2	4	1	0	0	0	0	0	0	0
7:00 AM	88	0	61	18	1	7	0	0	1	0	0	0	0	0
8:00 AM	122	1	75	23	0	14	0	0	4	0	1	4	0	0
9:00 AM	102	1	58	35	1	6	0	0	0	0	0	1	0	0
10:00 AM	106	0	74	19	1	12	0	0	0	0	0	0	0	0
11:00 AM	142	2	101	21	1	15	0	0	2	0	0	0	0	0
12:00 PM	158	2	108	36	1	9	1	0	0	0	0	1	0	0
1:00 PM	156	1	114	27	2	8	1	0	0	0	0	3	0	0
2:00 PM	155	3	116	21	1	12	0	0	2	0	0	0	0	0
3:00 PM	196	6	138	33	1	14	0	0	1	0	0	3	0	0
4:00 PM	251	4	189	38	0	13	0	0	3	0	0	3	0	1
5:00 PM	245	3	187	37	7	8	0	0	2	0	0	1	0	0
6:00 PM	188	4	145	28	3	8	0	0	0	0	0	0	0	0
7:00 PM	126	2	107	11	1	2	0	0	2	0	0	0	0	1
8:00 PM	118	0	102	10	1	4	0	0	1	0	0	0	0	0
9:00 PM	96	4	80	9	0	3	0	0	0	0	0	0	0	0
10:00 PM	56	0	49	4	0	3	0	0	0	0	0	0	0	0
11:00 PM	33	0	30	0	0	3	0	0	0	0	0	0	0	0
Total	2495	36	1858	388	24	148	3	0	19	0	1	16	0	2
%		1.4	74.5	15.6	1.0	5.9	0.1	0.0	0.8	0.0	0.0	0.6	0.0	0.1

PREPARED BY TRAFFIC DATA

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

24 Hour Speed
Combined Channels

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	26	0	0	0	0	0	0	3	10	11	2	0	0	0
1:00 AM	11	0	0	0	0	0	0	3	1	6	0	0	1	0
2:00 AM	8	0	0	0	0	0	0	3	4	1	0	0	0	0
3:00 AM	25	0	0	0	0	0	0	3	10	11	0	1	0	0
4:00 AM	37	0	0	0	0	0	1	2	11	14	4	4	1	0
5:00 AM	122	0	0	0	0	0	0	3	33	70	13	2	1	0
6:00 AM	190	4	0	0	0	0	0	12	55	99	17	3	0	0
7:00 AM	272	9	0	0	0	0	0	19	90	127	21	6	0	0
8:00 AM	299	10	0	0	0	1	4	19	124	120	14	5	1	1
9:00 AM	306	22	0	1	1	2	5	29	117	96	20	12	0	1
10:00 AM	284	18	1	1	0	4	10	33	109	93	11	2	0	2
11:00 AM	266	8	0	0	0	4	16	44	112	70	10	2	0	0
12:00 PM	324	24	0	1	0	4	8	58	133	86	7	2	1	0
1:00 PM	358	25	0	0	1	1	18	64	164	77	6	2	0	0
2:00 PM	361	15	0	0	1	1	20	59	148	104	11	2	0	0
3:00 PM	387	32	0	0	1	0	5	49	177	110	10	3	0	0
4:00 PM	402	50	0	1	1	0	14	49	155	116	13	3	0	0
5:00 PM	420	47	0	0	0	3	6	52	152	135	16	7	1	1
6:00 PM	337	17	0	0	0	1	5	46	119	137	9	3	0	0
7:00 PM	177	0	0	0	0	0	3	21	63	84	5	1	0	0
8:00 PM	175	5	0	0	1	0	3	21	77	58	6	2	0	2
9:00 PM	123	0	0	0	0	1	2	27	52	34	5	2	0	0
10:00 PM	90	0	0	0	0	0	3	15	33	34	4	0	0	1
11:00 PM	38	0	0	0	0	0	2	4	12	17	2	1	0	0
Total	5038	286	1	4	6	22	125	638	1961	1710	206	65	6	8
%		5.7	0.0	0.1	0.1	0.4	2.5	12.7	38.9	33.9	4.1	1.3	0.1	0.2

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	40.5	43.3	49.0	53.2	54.8

10 mph Pace Speed 43.3 - 53.3
Number in Pace 3792 (75.3 %)

Average 46.2 mph
Minimum 1.0 mph
Maximum 93.1 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	78.5 %	5.7 %	0.3 %
Count	3956	285	14

PREPARED FOR PUBLIC DISCLOSURE

A - 26

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

24 Hour Speed
Combined Channels

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	20	0	0	0	0	0	0	3	7	8	2	0	0	0
1:00 AM	19	0	0	0	0	0	2	0	8	6	2	1	0	0
2:00 AM	8	0	0	0	0	0	0	0	4	2	1	0	0	1
3:00 AM	11	0	0	0	0	0	1	3	3	2	1	0	1	0
4:00 AM	50	0	0	0	0	1	0	2	14	20	8	3	2	0
5:00 AM	98	0	0	0	0	1	0	10	24	52	7	4	0	0
6:00 AM	221	1	1	0	0	0	4	9	61	117	18	10	0	0
7:00 AM	292	9	1	0	0	1	6	21	85	140	24	5	0	0
8:00 AM	286	31	0	0	0	0	9	32	97	99	16	2	0	0
9:00 AM	283	24	1	2	1	3	9	45	104	82	8	3	0	1
10:00 AM	312	12	0	0	2	0	6	57	136	91	5	2	0	1
11:00 AM	299	10	0	1	1	0	14	54	122	84	8	3	0	2
12:00 PM	330	26	0	0	1	1	8	60	137	83	11	2	1	0
1:00 PM	337	31	0	1	0	1	12	66	125	90	9	2	0	0
2:00 PM	336	21	0	0	1	3	14	61	142	83	7	4	0	0
3:00 PM	359	27	3	1	0	3	18	51	133	108	13	0	2	0
4:00 PM	396	32	0	0	0	1	16	50	163	110	21	3	0	0
5:00 PM	405	45	0	0	0	1	5	44	170	122	15	3	0	0
6:00 PM	313	24	1	0	0	3	11	24	117	121	9	2	1	0
7:00 PM	213	7	0	0	1	0	8	20	91	78	3	5	0	0
8:00 PM	182	2	0	1	0	0	8	23	80	53	8	6	1	0
9:00 PM	139	0	0	0	0	1	5	35	55	40	3	0	0	0
10:00 PM	93	0	0	0	0	0	4	17	31	35	3	3	0	0
11:00 PM	40	0	0	0	0	0	0	3	19	15	2	0	1	0
Total	5042	302	7	6	7	20	160	690	1928	1641	204	63	9	5
%		6.0	0.1	0.1	0.1	0.4	3.2	13.7	38.2	32.5	4.0	1.2	0.2	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	40.5	42.3	49.0	53.2	53.2

10 mph Pace Speed 43.3 - 53.3
Number in Pace 3775 (74.9 %)

Average 45.8 mph
Minimum 1.0 mph
Maximum 93.1 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	76.4 %	5.6 %	0.3 %
Count	3850	281	14

PREPARED FOR LITIGATION

A - 27

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

24 Hour Vehicle Classification
Combined Channels

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	26	0	21	4	1	0	0	0	0	0	0	0	0	0
1:00 AM	11	0	9	2	0	0	0	0	0	0	0	0	0	0
2:00 AM	8	0	5	1	0	2	0	0	0	0	0	0	0	0
3:00 AM	25	0	23	1	0	1	0	0	0	0	0	0	0	0
4:00 AM	37	1	29	6	0	1	0	0	0	0	0	0	0	0
5:00 AM	122	1	95	18	1	7	0	0	0	0	0	0	0	0
6:00 AM	190	0	148	29	0	10	0	0	2	1	0	0	0	0
7:00 AM	272	1	212	41	0	17	1	0	0	0	0	0	0	0
8:00 AM	299	0	224	52	1	18	1	0	2	1	0	0	0	0
9:00 AM	306	0	225	53	4	17	0	0	4	0	0	3	0	0
10:00 AM	284	6	203	52	4	15	1	0	1	0	0	2	0	0
11:00 AM	266	2	180	58	1	22	1	0	1	1	0	0	0	0
12:00 PM	324	3	233	57	2	22	2	0	1	2	0	2	0	0
1:00 PM	358	5	250	61	4	30	1	0	5	0	0	2	0	0
2:00 PM	361	5	269	56	2	25	0	0	0	0	0	3	0	1
3:00 PM	387	3	280	66	0	25	0	0	6	0	0	3	0	4
4:00 PM	402	6	266	88	6	22	0	0	5	0	0	8	0	1
5:00 PM	420	8	292	76	5	27	0	0	4	0	0	5	0	3
6:00 PM	337	9	258	46	1	14	2	0	2	0	0	4	0	1
7:00 PM	177	0	147	20	0	9	0	0	1	0	0	0	0	0
8:00 PM	175	2	146	17	1	8	1	0	0	0	0	0	0	0
9:00 PM	123	2	100	16	1	3	0	0	1	0	0	0	0	0
10:00 PM	90	0	77	12	0	1	0	0	0	0	0	0	0	0
11:00 PM	38	1	30	4	0	2	0	0	1	0	0	0	0	0
Total	5038	55	3722	836	34	298	10	0	36	5	0	32	0	10
%		1.1	73.9	16.6	0.7	5.9	0.2	0.0	0.7	0.1	0.0	0.6	0.0	0.2

PREPARED BY: NOT FOR PUBLIC RELEASE

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

24 Hour Vehicle Classification
Combined Channels

Time	Total	Bike	Cars & Trailer	2 Axle Long	Buses	2 Axle 6 Tire	3 Axle Single	4 Axle Single	<5 Axl Double	5 Axle Double	>6 Axl Double	<6 Axl Multi	6 Axle Multi	>6 Axl Multi
12:00 AM	20	0	19	1	0	0	0	0	0	0	0	0	0	0
1:00 AM	19	1	14	2	1	1	0	0	0	0	0	0	0	0
2:00 AM	8	0	7	0	0	0	0	0	1	0	0	0	0	0
3:00 AM	11	0	11	0	0	0	0	0	0	0	0	0	0	0
4:00 AM	50	0	41	6	0	3	0	0	0	0	0	0	0	0
5:00 AM	98	3	78	12	1	4	0	0	0	0	0	0	0	0
6:00 AM	221	2	171	37	2	8	1	0	0	0	0	0	0	0
7:00 AM	292	1	221	46	3	15	2	0	4	0	0	0	0	0
8:00 AM	286	2	187	58	0	25	0	0	7	0	1	6	0	0
9:00 AM	283	4	195	59	3	18	0	0	2	0	0	2	0	0
10:00 AM	312	2	233	51	3	20	1	0	2	0	0	0	0	0
11:00 AM	299	5	216	46	2	26	0	0	2	1	0	1	0	0
12:00 PM	330	2	229	64	2	25	2	0	4	1	0	1	0	0
1:00 PM	337	2	250	52	2	18	2	0	6	0	0	5	0	0
2:00 PM	336	5	254	42	1	28	1	0	3	0	0	2	0	0
3:00 PM	359	9	248	59	6	27	0	0	3	0	0	7	0	0
4:00 PM	396	9	285	69	1	22	0	0	4	0	0	4	0	2
5:00 PM	405	6	301	69	11	10	0	0	4	0	0	4	0	0
6:00 PM	313	7	229	50	6	14	0	0	4	0	0	2	0	1
7:00 PM	213	3	170	24	2	10	0	0	3	0	0	0	0	1
8:00 PM	182	0	155	17	2	7	0	0	1	0	0	0	0	0
9:00 PM	139	4	116	13	0	6	0	0	0	0	0	0	0	0
10:00 PM	93	0	78	10	0	5	0	0	0	0	0	0	0	0
11:00 PM	40	1	35	0	0	4	0	0	0	0	0	0	0	0
Total	5042	68	3743	787	48	296	9	0	50	2	1	34	0	4
%		1.3	74.2	15.6	1.0	5.9	0.2	0.0	1.0	0.0	0.0	0.7	0.0	0.1

PREPARED FOR INFORMATIONAL PURPOSES ONLY

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

24 Hour Speed
Channel: N/B

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	4	0	0	0	0	0	0	0	2	2	0	0	0	0
1:00 AM	4	0	0	0	0	0	0	2	0	2	0	0	0	0
2:00 AM	4	0	0	0	0	0	0	1	2	1	0	0	0	0
3:00 AM	7	0	0	0	0	0	0	0	0	7	0	0	0	0
4:00 AM	24	0	0	0	0	0	1	1	5	9	4	3	1	0
5:00 AM	78	0	0	0	0	0	0	0	18	48	9	2	1	0
6:00 AM	128	2	0	0	0	0	0	6	30	79	10	1	0	0
7:00 AM	199	3	0	0	0	0	0	11	58	106	18	3	0	0
8:00 AM	192	5	0	0	0	1	2	8	72	90	10	3	0	1
9:00 AM	189	9	0	0	1	0	2	19	70	67	13	7	0	1
10:00 AM	171	9	1	1	0	3	4	17	69	59	5	2	0	1
11:00 AM	156	2	0	0	0	3	12	25	59	45	9	1	0	0
12:00 PM	179	12	0	0	0	4	5	28	73	49	6	2	0	0
1:00 PM	177	13	0	0	0	1	9	21	74	52	5	2	0	0
2:00 PM	202	9	0	0	1	1	12	32	84	56	6	1	0	0
3:00 PM	165	14	0	0	0	0	1	22	68	53	5	2	0	0
4:00 PM	170	26	0	0	0	0	11	24	49	51	7	2	0	0
5:00 PM	151	26	0	0	0	0	5	22	47	37	11	3	0	0
6:00 PM	104	9	0	0	0	1	3	14	24	44	6	3	0	0
7:00 PM	68	0	0	0	0	0	2	10	19	34	2	1	0	0
8:00 PM	59	3	0	0	0	0	0	6	23	20	4	1	0	2
9:00 PM	33	0	0	0	0	0	1	9	9	13	1	0	0	0
10:00 PM	41	0	0	0	0	0	1	4	18	18	0	0	0	0
11:00 PM	16	0	0	0	0	0	1	1	6	8	0	0	0	0
Total	2521	142	1	1	2	14	72	283	879	950	131	39	2	5
%		5.6	0.0	0.0	0.1	0.6	2.9	11.2	34.9	37.7	5.2	1.5	0.1	0.2

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	40.5	43.3	49.0	53.2	54.8

10 mph Pace Speed 43.3 - 53.3
Number in Pace 1836 (72.8 %)

Average 46.6 mph
Minimum 1.0 mph
Maximum 84.6 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	79.6 %	7.0 %	0.3 %
Count	2006	177	7

PREPARED FOR PUBLIC RELEASE

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

24 Hour Speed
Channel: N/B

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	4	0	0	0	0	0	0	0	3	0	1	0	0	0
1:00 AM	6	0	0	0	0	0	1	0	1	2	1	1	0	0
2:00 AM	3	0	0	0	0	0	0	0	1	1	1	0	0	0
3:00 AM	6	0	0	0	0	0	0	1	1	2	1	0	1	0
4:00 AM	31	0	0	0	0	0	0	2	5	14	6	2	2	0
5:00 AM	66	0	0	0	0	1	0	4	15	38	6	2	0	0
6:00 AM	154	1	0	0	0	0	1	7	42	86	11	6	0	0
7:00 AM	204	4	1	0	0	0	4	13	53	106	19	4	0	0
8:00 AM	164	14	0	0	0	0	5	15	45	71	12	2	0	0
9:00 AM	181	14	1	2	1	0	4	25	65	59	6	3	0	1
10:00 AM	206	9	0	0	1	0	4	32	90	63	5	1	0	1
11:00 AM	157	5	0	1	0	0	7	27	55	53	6	2	0	1
12:00 PM	172	13	0	0	0	0	3	33	66	46	9	1	1	0
1:00 PM	181	17	0	0	0	1	5	27	62	61	6	2	0	0
2:00 PM	181	13	0	0	0	0	5	31	70	54	5	3	0	0
3:00 PM	163	14	3	1	0	0	2	15	63	59	5	0	1	0
4:00 PM	145	16	0	0	0	0	12	9	50	46	9	3	0	0
5:00 PM	160	22	0	0	0	0	1	13	60	51	11	2	0	0
6:00 PM	125	12	1	0	0	1	7	12	33	54	4	0	1	0
7:00 PM	87	4	0	0	1	0	6	9	29	34	2	2	0	0
8:00 PM	64	1	0	1	0	0	3	15	18	16	4	5	1	0
9:00 PM	43	0	0	0	0	1	4	9	15	14	0	0	0	0
10:00 PM	37	0	0	0	0	0	3	3	11	17	1	2	0	0
11:00 PM	7	0	0	0	0	0	0	1	1	5	0	0	0	0
Total	2547	159	6	5	3	4	77	303	854	952	131	43	7	3
%		6.2	0.2	0.2	0.1	0.2	3.0	11.9	33.5	37.4	5.1	1.7	0.3	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	39.6	42.3	49.0	53.2	54.8

10 mph Pace Speed 43.3 - 53.3
Number in Pace 1851 (72.7 %)

Average 46.3 mph
Minimum 1.0 mph
Maximum 84.6 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	78.1 %	7.2 %	0.4 %
Count	1990	184	10

PREPARED FOR PUBLIC DISCLOSURE

A - 31

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/22/2010
Tuesday

24 Hour Speed
Channel: S/B

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	22	0	0	0	0	0	0	3	8	9	2	0	0	0
1:00 AM	7	0	0	0	0	0	0	1	1	4	0	0	1	0
2:00 AM	4	0	0	0	0	0	0	2	2	0	0	0	0	0
3:00 AM	18	0	0	0	0	0	0	3	10	4	0	1	0	0
4:00 AM	13	0	0	0	0	0	0	1	6	5	0	1	0	0
5:00 AM	44	0	0	0	0	0	0	3	15	22	4	0	0	0
6:00 AM	62	2	0	0	0	0	0	6	25	20	7	2	0	0
7:00 AM	73	6	0	0	0	0	0	8	32	21	3	3	0	0
8:00 AM	107	5	0	0	0	0	2	11	52	30	4	2	1	0
9:00 AM	117	13	0	1	0	2	3	10	47	29	7	5	0	0
10:00 AM	113	9	0	0	0	1	6	16	40	34	6	0	0	1
11:00 AM	110	6	0	0	0	1	4	19	53	25	1	1	0	0
12:00 PM	145	12	0	1	0	0	3	30	60	37	1	0	1	0
1:00 PM	181	12	0	0	1	0	9	43	90	25	1	0	0	0
2:00 PM	159	6	0	0	0	0	8	27	64	48	5	1	0	0
3:00 PM	222	18	0	0	1	0	4	27	109	57	5	1	0	0
4:00 PM	232	24	0	1	1	0	3	25	106	65	6	1	0	0
5:00 PM	269	21	0	0	0	3	1	30	105	98	5	4	1	1
6:00 PM	233	8	0	0	0	0	2	32	95	93	3	0	0	0
7:00 PM	109	0	0	0	0	0	1	11	44	50	3	0	0	0
8:00 PM	116	2	0	0	1	0	3	15	54	38	2	1	0	0
9:00 PM	90	0	0	0	0	1	1	18	43	21	4	2	0	0
10:00 PM	49	0	0	0	0	0	2	11	15	16	4	0	0	1
11:00 PM	22	0	0	0	0	0	1	3	6	9	2	1	0	0
Total	2517	144	0	3	4	8	53	355	1082	760	75	26	4	3
%		5.7	0.0	0.1	0.2	0.3	2.1	14.1	43.0	30.2	3.0	1.0	0.2	0.1

Percentile Speeds	10 %	15 %	50 %	85 %	90 %
(mph)	40.5	43.3	47.7	51.7	53.2

10 mph Pace Speed 43.3 - 53.3
Number in Pace 1956 (77.7 %)

Average 45.8 mph
Minimum 1.0 mph
Maximum 93.1 mph

Speeds Exceeded	45 mph	55 mph	65 mph
	77.5 %	4.3 %	0.3 %
Count	1950	108	7

PREPARED IN THE OFFICE OF STEVEN M. THOMAS

Snohomish County Traffic Operations
3000 Rockefeller Admin 5-W
Everett, WA 98201

Location: OLD PACIFIC HWY N/O 286 ST NW
Weather: 2 MIXED
Client: INT

Site: 97885-1.02
Date: 6/23/2010
Wednesday

24 Hour Speed
Channel: S/B

mph	Total	0 - < 15	15 - < 20	20 - < 25	25 - < 30	30 - < 35	35 - < 40	40 - < 45	45 - < 50	50 - < 55	55 - < 60	60 - < 65	65 - < 70	70 - < 200
12:00 AM	16	0	0	0	0	0	0	3	4	8	1	0	0	0
1:00 AM	13	0	0	0	0	0	1	0	7	4	1	0	0	0
2:00 AM	5	0	0	0	0	0	0	0	3	1	0	0	0	1
3:00 AM	5	0	0	0	0	0	1	2	2	0	0	0	0	0
4:00 AM	19	0	0	0	0	1	0	0	9	6	2	1	0	0
5:00 AM	32	0	0	0	0	0	0	6	9	14	1	2	0	0
6:00 AM	67	0	1	0	0	0	3	2	19	31	7	4	0	0
7:00 AM	88	5	0	0	0	1	2	8	32	34	5	1	0	0
8:00 AM	122	17	0	0	0	0	4	17	52	28	4	0	0	0
9:00 AM	102	10	0	0	0	3	5	20	39	23	2	0	0	0
10:00 AM	106	3	0	0	1	0	2	25	46	28	0	1	0	0
11:00 AM	142	5	0	0	1	0	7	27	67	31	2	1	0	1
12:00 PM	158	13	0	0	1	1	5	27	71	37	2	1	0	0
1:00 PM	156	14	0	1	0	0	7	39	63	29	3	0	0	0
2:00 PM	155	8	0	0	1	3	9	30	72	29	2	1	0	0
3:00 PM	196	13	0	0	0	3	16	36	70	49	8	0	1	0
4:00 PM	251	16	0	0	0	1	4	41	113	64	12	0	0	0
5:00 PM	245	23	0	0	0	1	4	31	110	71	4	1	0	0
6:00 PM	188	12	0	0	0	2	4	12	84	67	5	2	0	0
7:00 PM	126	3	0	0	0	0	2	11	62	44	1	3	0	0
8:00 PM	118	1	0	0	0	0	5	8	62	37	4	1	0	0
9:00 PM	96	0	0	0	0	0	1	26	40	26	3	0	0	0
10:00 PM	56	0	0	0	0	0	1	14	20	18	2	1	0	0
11:00 PM	33	0	0	0	0	0	0	2	18	10	2	0	1	0
Total	2495	143	1	1	4	16	83	387	1074	689	73	20	2	2
%		5.7	0.0	0.0	0.2	0.6	3.3	15.5	43.0	27.6	2.9	0.8	0.1	0.1

Percentile Speeds (mph)

10 %	15 %	50 %	85 %	90 %
40.5	42.3	47.7	51.7	53.2

10 mph Pace Speed 43.3 - 53.3
Number in Pace 1924 (77.1 %)

Average 45.4 mph
Minimum 1.0 mph
Maximum 93.1 mph

Speeds Exceeded

	45 mph	55 mph	65 mph
	74.5 %	3.9 %	0.2 %
Count	1860	97	4

PREPARED BY STEVE

A - 33

Transportation Element Information

Analysis of Needed Capacity Improvements

The following analysis addresses improvements to deficient facilities and to maintain LOS standards as the City grows.

Near Term

SR-532/72nd Avenue NW - This intersection is calculated to operating currently at level of service "C," but the northbound and southbound movements suffer long delays, especially at the end of the school day. Significant additional capacity can be provided with construction of a second southbound lane, which would allow more efficient protected/permitted left-turn movements to operate, and would allow left-turn vehicles to queue without impeding southbound through traffic. This improvement is included in the TIP in Table TR-11.

SR-532/102nd Avenue NW – The poor level of service at this intersection warrants signalization. This is expected to be part of the WSDOT improvements along SR-532, but may occur sooner. Together with some minor channelization improvements, this signal could be made as a first phase of the longer range widening plan for the entire corridor. This signal and channelization should address existing congestion and safety concerns.

Future Roadway Improvement Needs

Future traffic needs and conditions were predicted with the aid of regional plans, established LOS standards and designated land uses in the Land Use Element. These were all were used to establish needed improvements and new roadway facilities in the next 20 years.

The City has these long-term goals for its future transportation system:

1. To move local residents safely and efficiently back and forth across SR-532. This will require the following at minimum:
   A. Traffic signal and crosswalks on SR-532 at or near 98th Avenue NW;
   B. Pedestrian improvements on SR-532 and crosswalks at all signalized intersections.
   C. Pedestrian overpass or tunnel (location to be determined).

2. To improve access to commercial land between SR-532 and 271st Street NW. This will require the following:
   A. A new street connecting 98th Drive NW with 94th Drive NW, along an extension of 269th Street or 270th Street NW and eventually extending east to 92nd Avenue NW;
   B. Widening of 98th Drive NW from SR-532 to 271st Street NW, and possible consolidation with Camano Drive;

C. Signalization of SR-532/98th Avenue NW, along with coordination of signal at 88th Avenue NW;
D. Signalization of 102nd Avenue NW/SR-532;
E. Retention of signal at 88th Avenue NW, as warranted.

3. To improve access to and from SR-532, eventual roadway and lane widening, turn lanes, and signalization of all major intersections.

4. Research the viability of additional routes between the residential area "on the hill" and the low-lying commercial area of the city.

Other Considerations

Stanwood UGA

Until the Urban Growth Boundary is adjusted, it is clear that most residential growth will occur north of 272nd Street and east of Pioneer Highway. There are vacant pockets of land throughout the city where infill can also occur, but a more noticeable increase in residential activity will be to the northeast of the city. Based on this information, the City can expect to see a substantial increase in traffic volumes from vehicles coming from that general area. This increase will strain current morning and afternoon peak capacities beyond adopted LOS standards if no road improvements are made on the major collector roads.

The major collector roads that will need improvements because of an increase city population include:

1. 72nd Avenue NW (north of SR-532);
2. 80th Avenue NW;
3. East-west connection at approximately 280th Street NW between 80th Avenue and 68th Avenue;
4. Cedarhome Drive NW;
5. Cedarhome Drive N;
6. 68th Avenue NW (extension to Woodland Rd);
7. 276th Street NW (east of current city limits).

72nd Avenue NW will be a natural feeder for vehicles coming south toward SR-532 from anticipated new residential development on either side of 80th Avenue NW, north of 276th Street. Street improvements to 72nd Avenue NW will be essential in the near future. Currently, traffic backups already occur on 72nd Avenue NW during peak traffic periods.

Also, 85th Drive NW, 86th Drive NW, and Cedarhome Drive NW will need improvements in the future. There is an established pattern of interest for several

properties to the north of 280th Street NW for residential development. These three roads will require roadway improvements to handle increased activity serving Pioneer Highway. These local streets were designed to handle lower traffic volumes and not to serve as local collector roads. With an anticipated increase in traffic volumes, engineering studies will need to be undertaken to access the appropriate action for those roads.

Downtown

Improvements to 271st Street NW will also need to be investigated. This street is one of only three roads that connect East and West Stanwood. An increase in commercial development is expected along 271st Street NW, and increased traffic volumes will need to be accommodated. An estimate of current daily traffic volumes for areas located close to 271st Street NW is approximately 16,000 trips per day. Historically, the majority of daytime business in the downtown area has come from residents outside the city limits, including Camano Island. This economic pattern may change in the next several years because of an increase in residential development within the City. Proportionally, more homes are expected to be built inside the City limits than in surrounding unincorporated areas. This may create a shift in roadway use and greater demands on 271st Street NW can be anticipated.

SR-532 Roadway Needs

The City's proposed future network would still rely on SR-532 as the primary route for both local and regional travel needs. Based on the land use and traffic growth assumptions for 2025, SR-532 would require a four-lane cross-section within the City limits to meet future projected traffic levels. In addition, intersection improvements such as turn lanes and signalization will be required to ensure future mobility within Stanwood.

The current WSDOT 20-year *State Highway System Plan* and the RDP suggest SR-532 should be widened to four lanes from the Island County line to Interstate 5 to correct for projected mobility deficiencies along the corridor. While these deficiencies are recognized, WSDOT has excluded these improvements from its fiscally constrained plan, meaning state funding for widening cannot be assumed in the near future. The estimated cost (WSDOT) for widening the segment between Island County line and 64th Avenue NW is at least $23 million to $30 million.

Non-Motorized Facilities

Non-motorized facilities including sidewalks, trails and bike-lanes are needed along many major collectors and on SR 532. As noted in the Capital Facilities Element, trails are also needed to meet level of service standards, but also to provide meaningful connections for alternative modes of travel.

Accident History Data

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

COUNTY	CITY	JURISDICTION	COUNTY ROAD NAME	PRIMARY TRAFFICWAY (Refer to column "D" for County Rd name, county 5 digit road log # in this column)	BLOCK NUMBER	INTERSECTING TRAFFICWAY	DIST FROM REF POINT	MI or FT	COMP DIR FROM REF POINT
Snohomish	Stanwood	City Street		CEDARHOME DR	8600	RR TRACKS			
Snohomish	Stanwood	City Street		CEDARHOME DR N	8500	RR TRACKS			
Snohomish	Stanwood	County Road	48 AVE NW	70450					
Snohomish	Stanwood	County Road	OLD PACIFIC HWY	97885		97910			
Snohomish	Stanwood	County Road	OLD PACIFIC HWY	97885		97950			
Snohomish	Stanwood	County Road	OLD PACIFIC HWY	97885					

+ 271st PED /TRAIN 1/7/08
+ 48th NW CAR/TRAIN 1/28/10

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

REFERENCE POINT NAME	CITY AND MISC ONLY SECONDARY TRAFFICWAY 1	CITY AND MISC ONLY SECONDARY TRAFFICWAY 2	MILE POST	A/B	*REPORT NUMBER	DATE	TIME	MOST SEVERE INJURY TYPE	# INJ	# FAT	# VEH	# PEDS	# PEDAL
					2496702	7/3/2006	10:09	Possible Injury	1	0	2		
					1410105	12/29/2005	18:25	Evident Injury	1	0	2		
			1.00		2995175	8/21/2007	20:55	Evident Injury	1	0	1		
			2.47		2269229	3/7/2006	20:18	No Injury	0	0	1		
			2.47		2268983	7/26/2006	2:42	No Injury	0	0	1		
			2.45		1919534	3/17/2005	15:00	No Injury	0	0	1		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

VEHICLE 1 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	VEHICLE 2 TYPE (*As of 1/1/2010, a new Vehicle Type code called "Railway Vehicle" became effective.*)	JUNCTION RELATIONSHIP	ROADWAY SURFACE CONDITIONS	LIGHTING CONDITIONS
Motorcycle	Motorcycle	At Intersection and Related	Dry	Daylight
Pickup,Panel Truck or Vanette under 10,000 lb	Passenger Car	At Intersection and Related	Wet	Dark-Street Lights Off
Pickup,Panel Truck or Vanette under 10,000 lb		At Intersection and Related	Dry	Dark-No Street Lights
Passenger Car		At Intersection and Related	Wet	Dark-No Street Lights
Passenger Car		At Intersection and Related	Dry	Dark-Street Lights On
Pickup,Panel Truck or Vanette under 10,000 lb		Not at Intersection and Not Related	Dry	Daylight

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

REPORTED COLLISIONS INVOLVING TRAINS, RR SIGNS and/or LOCATED AT RR TRACKS THAT OCCURRED ON ALL ROADS STATEWIDE
1/1/2005 - 10/31/2010 (2010 is preliminary)
*As if 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")

FIRST COLLISION TYPE / OBJECT STRUCK	MV DRIVER CONT CIRC 1 (UNIT 1)	MV DRIVER CONT CIRC 1 (UNIT 2)	VEH 1 COMP DIR FROM	VEH 1 COMP DIR TO	VEH 2 COMP DIR FROM	VEH 2 COMP DIR TO
From same direction - both going straight - both moving - rear-end	Follow Too Closely	None	West	East	West	East
From same direction - both going straight - both moving - rear-end	None	Follow Too Closely	Northeast	Southwest	Northeast	Southwest
Train struck moving vehicle	Did Not Grant RW to Vehicle		North	South		
Guardrail - Leading End	Improper Turn		North	West		
Guardrail - Face	Exceeding Reas. Safe Speed		North	West		
Wood Sign Post	Exceeding Reas. Safe Speed		South	North		

UNDER 23 UNITED STATES CODE – SECTION 409, THIS DATA CANNOT BE USED
IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES
AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 106648
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084687C	01/07/08	09:22 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
MOUNT VERNON	PAC	SNOHOMISH	53	WA

11. City *(if in a city)* | 12. Highway Name or No. CITY ST; 271ST ST NW | ☑ Public ☐ Private

Highway User Involved

13. Type — A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other *(specify)* — Code: K

14. Vehicle Speed *(est. mph at impact)*

15. Direction *(geographical)* — 1. North 2. South 3. East 4. West — Code: 4

16. Position — 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance — 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by — 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 35 °F

22. Visibility *(single entry)* — 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 2

23. Weather *(single entry)* — 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 2

24. Type of Equipment Consist *(single entry)* — A. Spec. MoW Equip 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car — Code: 2

25. Track Type Used by Rail Equipment Involved — 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: MAIN TRACK

27. FRA Track Class: 4

28. Number of Locomotive Units: 1

29. Number of Cars: 13

30. Consist Speed *(Recorded if available)* — R. Recorded E. Estimated: 79 mph — Code: R

31. Time Table Direction — 1. North 2. South 3. East 4. West — Code: 2

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 01 | 03 | 06

33. Signaled Crossing Warning: 20 sec warn min (1);

34. Whistle Ban — 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning — 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals — 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights — 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age: 63

39. Driver's Gender — 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — 1. Yes 2. No 3. Unknown — Code:

41. Driver — 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code:

42. Driver Passed Standing Highway Vehicle — 1. Yes 2. No 3. Unknown — Code:

43. View of Track Obscured by *(primary obstruction)* — 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — 1. Killed 2. Injured 3. Uninjured — Code:

45. Was Driver in the Vehicle? — 1. Yes 2. No — Code:

47. Highway Vehicle Property Damage *(est. dollar damage)*: $0

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 49

51. Is a Rail Equipment Accident / Incident Report Being Filed — 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

TRAIN 513 OPERATING WITH LOCOMOTIVE 467 AND 13 CARS STRUCK A PEDESTRIAN AT MP55.40, 271ST STREET CROSSING.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57 * NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	BNSF Rwy Co. [BNSF]	1a. BNSF	1b. NW0110200
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. NW0110200

4. U.S. DOT-AAR Grade Crossing ID No.	5. Date of Accident/Incident	6. Time of Accident/Incident
084683A	01/28/10	01:30 AM

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
STANWOOD	NORTHWEST	SKAGIT (SNOHOMISH)	53	WA

11. City *(if in a city)*	12. Highway Name or No.	
	48TH NW	☑ Public ☐ Private

Highway User Involved

13. Type — Code: B
C. Truck-trailer F. Bus J. Other Motor Vehicle
A. Auto D. Pick-up truck G. School Bus K. Pedestrian
B. Truck E. Van H. Motorcycle M. Other *(specify)*

14. Vehicle Speed *(est. mph at impact)*: 10

15. Direction *(geographical)* — Code: 4
1. North 2. South 3. East 4. West

16. Position — Code: 3
1. Stalled on crossing 3. Moving over crossing
2. Stopped on Crossing 4. Trapped

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? — Code: 2
1. Highway User 2. Rail Equipment 3. Both 4. Neither

Rail Equipment Involved

17. Equipment — Code: 1
1. Train *(units pulling)* 4. Car(s) *(moving)* 8. Other *(specify)*
2. Train *(units pushing)* 5. Car(s) *(standing)* A. Train pulling- RCL
3. Train *(standing)* 6. Light loco(s) *(moving)* B. Train pushing- RCL
7. Light loco(s) *(standing)* C. Train standing- RCL

18. Position of Car Unit in Train: 36

19. Circumstance — Code: 2
1. Rail equipment struck highway user
2. Rail equipment struck by highway user

20b. Was there a hazardous materials release by — Code: 4
1. Highway User 2. Rail Equipment 3. Both 4. Neither

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 44 °F

22. Visibility *(single entry)* — Code: 4
1. Dawn 2. Day 3. Dusk 4. Dark

23. Weather *(single entry)* — Code: 2
1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

24. Type of Equipment Consist *(single entry)* — Code: 1
A. Spec. MoW Equip
1. Freight train 4. Work train 7. Yard/Switching
2. Passenger train 5. Single car 8. Light loco(s)
3. Commuter train 6. Cut of cars 9. Main./inspect. car

25. Track Type Used by Rail Equipment Involved — Code: 1
1. Main 2. Yard 3. Siding 4. Industry

26. Track Number or Name: SINGLE MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)* — Code	31. Time Table Direction — Code
4	4	40	R. Recorded E. Estimated 25 mph: E	1. North 2. South 3. East 4. West: 1

32. Type of Crossing Warning — Code(s): 08 07
1. Gates 4. Wig wags 7. Crossbucks 10. Flagged by crew
2. Cantilever FLS 5. Hwy. traffic signals 8. Stop signs 11. Other *(specify)*
3. Standard FLS 6. Audible 9. Watchman 12. None

33. Signaled Crossing Warning

34. Whistle Ban — Code: 3
1. Yes
2. No
3. Unknown

35. Location of Warning — Code: 1
1. Both Sides
2. Side of Vehicle Approach
3. Opposite Side of Vehicle Approach

36. Crossing Warning Interconnected with Highway Signals — Code: 2
1. Yes 2. No 3. Unknown

37. Crossing Illuminated by Street Lights or Special Lights — Code: 2
1. Yes 2. No 3. Unknown

38. Driver's Age	39. Driver's Gender — Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train — Code	41. Driver — Code
	1. Male 2. Female	1. Yes 2. No 3. Unknown: 3	1. Drove around or thru the gate 4. Stopped on crossing 2. Stopped and then proceeded 5. Other *(specify)* 3. Did not stop: 3

42. Driver Passed Standing Highway Vehicle — Code: 2
1. Yes 2. No 3. Unknown

43. View of Track Obscured by *(primary obstruction)* — Code: 8
1. Permanent Structure 3. Passing Train 5. Vegetation 7. Other *(specify)*
2. Standing railroad equipment 4. Topography 6. Highway Vehicles 8. Not Obstructed

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	0
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was — Code
1. Killed 2. Injured 3. Uninjured

45. Was Driver in the Vehicle? — Code: 2
1. Yes 2. No

47. Highway Vehicle Property Damage *(est. dollar damage)*: $3,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 0

50. Total Number of People on Train *(include passengers and crew)*: 3

51. Is a Rail Equipment Accident / Incident Report Being Filed — Code: 2
1. Yes 2. No

53a. Special Study Block

53b. Special Study Block

54. Narrative Description

AGE/GENDER OF DRIVER UNKNOWN - UNOCCUPIED VEHICLE WAS CRASHED INTO THE SIDE OF TRAIN.

55. Typed Name and Title	56. Signature	57. Date

FORM FRA F 6180.57

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak [ATK]	1a. ATK	1b. 105400
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	BNSF Rwy Co. [BNSF]	3a. BNSF	3b. XXX
4. U.S. DOT-AAR Grade Crossing ID No. 084683A	5. Date of Accident/Incident 08/21/07	6. Time of Accident/Incident 08:45 PM	

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr.	Code
EVERETT	PAC	SNOHOMISH	53	WA

11. City *(if in a city)* | 12. Highway Name or No. CO70450; 48TH N.W. | ☑ Public ☐ Private

Highway User Involved

13. Type — C. Truck-trailer F. Bus J. Other Motor Vehicle; A. Auto D. Pick-up truck G. School Bus K. Pedestrian; B. Truck E. Van H. Motorcycle M. Other *(specify)* — Code: D

14. Vehicle Speed *(est. mph at impact)*: 25

15. Direction *(geographical)* 1. North 2. South 3. East 4. West — Code: 2

16. Position 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

Rail Equipment Involved

17. Equipment — 1. Train *(units pulling)* 2. Train *(units pushing)* 3. Train *(standing)* 4. Car(s) *(moving)* 5. Car(s) *(standing)* 6. Light loco(s) *(moving)* 7. Light loco(s) *(standing)* 8. Other *(specify)* A. Train pulling- RCL B. Train pushing- RCL C. Train standing- RCL — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature *(specify if minus)*: 61 °F

22. Visibility *(single entry)* 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather *(single entry)* 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist *(single entry)* 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Main./inspect. car A. Spec. MoW Equip — Code: 2

25. Track Type Used by Rail Equipment Involved 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: SINGLE MAIN

27. FRA Track Class	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded if available)*	Code	31. Time Table Direction	Code
4	1	3	R. Recorded E. Estimated 79 mph	R	1. North 2. South 3. East 4. West	4

32. Type of Crossing Warning — 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other *(specify)* 12. None

Code(s): 08 07

33. Signaled Crossing Warning

34. Whistle Ban 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age

39. Driver's Gender 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train 1. Yes 2. No 3. Unknown — Code: 2

41. Driver 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code: 2

42. Driver Passed Standing Highway Vehicle 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by *(primary obstruction)* 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other *(specify)* 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
46. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was 1. Killed 2. Injured 3. Uninjured — Code: 2

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage *(est. dollar damage)*: $10,000

48. Total Number of Highway-Rail Crossing Users *(include driver)*: 1

50. Total Number of People on Train *(include passengers and crew)*: 107

51. Is a Rail Equipment Accident / Incident Report Being Filed 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description

TRAIN #517 OPERATING WITH LOCOMOTIVE E/467 AND 3 CARS STRUCK A PICK-UP TRUCK AT MP52.41, 48TH STREET CROSSING.

55. Typed Name and Title	56. Signature	57. Date

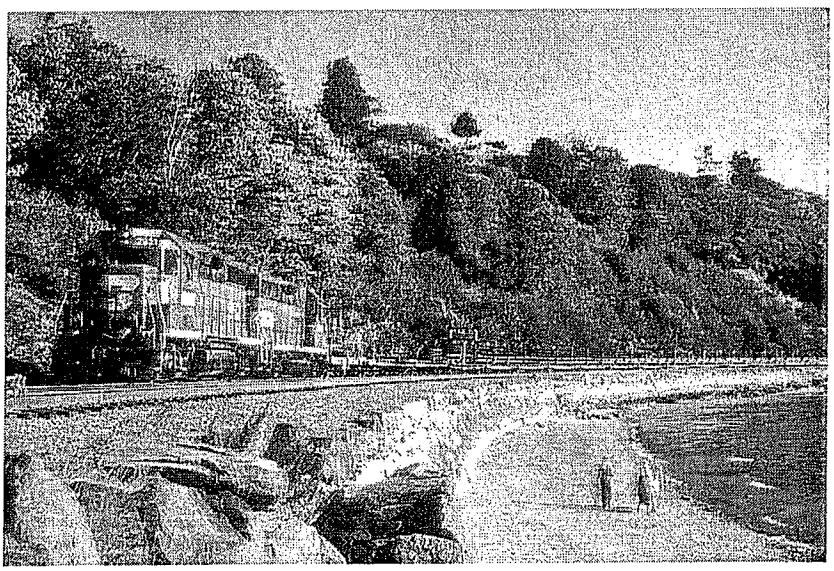
FORM FRA F 6180.57

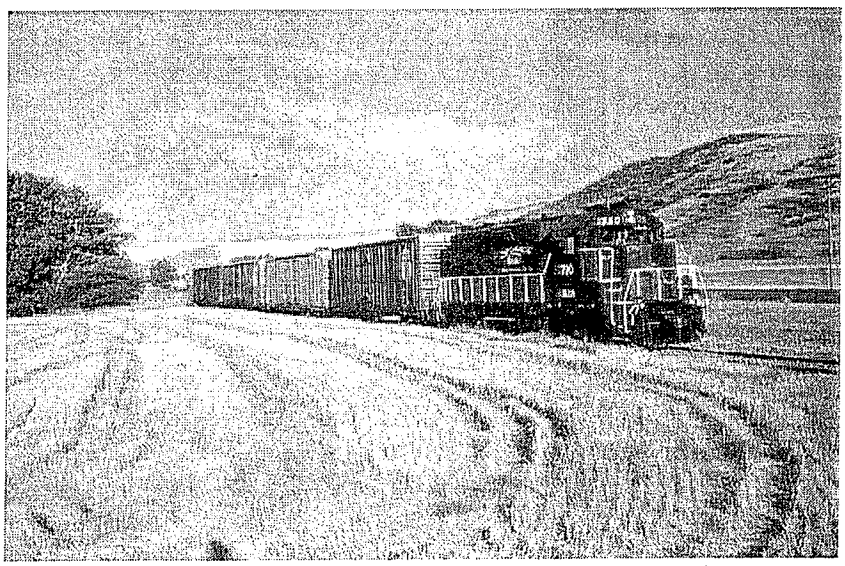
* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

State Information

Washington State

2010-2030 Freight Rail Plan

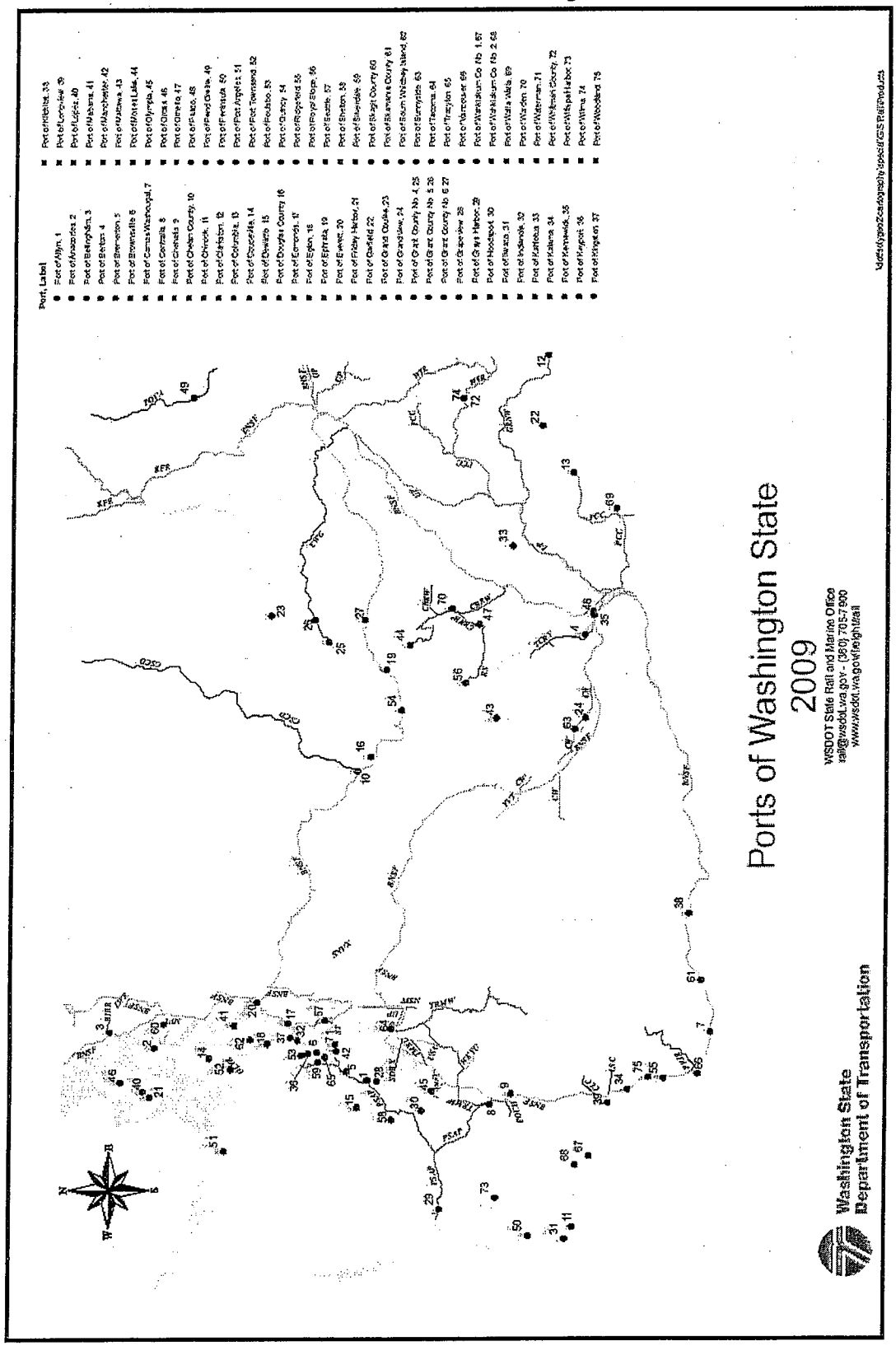




December 2009

Washington State
Department of Transportation

Exhibit ES-7: Ports of Washington State



Freight Rail Service Corridors

The state currently has ten major rail corridors and 12 low-density corridors. These corridors are defined and operated by BNSF and UP. Exhibit 3-6 lists all the corridors. Appendix 3-B has a description of each rail service corridor. While these rail corridors are defined by private railroads, the state has an interest in defining rail corridors in terms of public benefits. The Freight Mobility Strategic Investment Board is authorized to define strategic rail corridors and update them periodically. Some short-line routes are critical to the economic viability of local communities and certain industries. The state needs to develop criteria to define rail corridors in terms of their impacts on the state's economic and societal needs, as discussed in Chapter 5.

Exhibit 3-6: Rail Service Corridors in Washington State

Railroads	Major Corridors	Low-Density Corridors
BNSF	Seattle-Spokane	Tukwila-Snohomish
	Seattle-Portland, Oregon (OR)	Woodinville-Redmond
	Portland, OR-Pasco	Burlington-Sumas
	Auburn-Pasco	Sumas-Lynden
	Pasco-Spokane	Burlington-Anacortes
	Spokane-Sandpoint, Idaho (ID)	Intalco-Cherry Point
	Everett-Vancouver, British Columbia (B.C.)	Marysville-Arlington
		Lakeview-Roy
		Spokane-Chewelah
UP	Hinkle, OR-Spokane	Spokane-Plummer, ID; Manito-Fairfield
	Spokane-Eastport, ID	Ayer Junction-Riparia
	Tacoma-Seattle	Wallula-Kennewick

Source: *Statewide Rail Capacity and System Needs Study* (2006)

Railroad Profiles

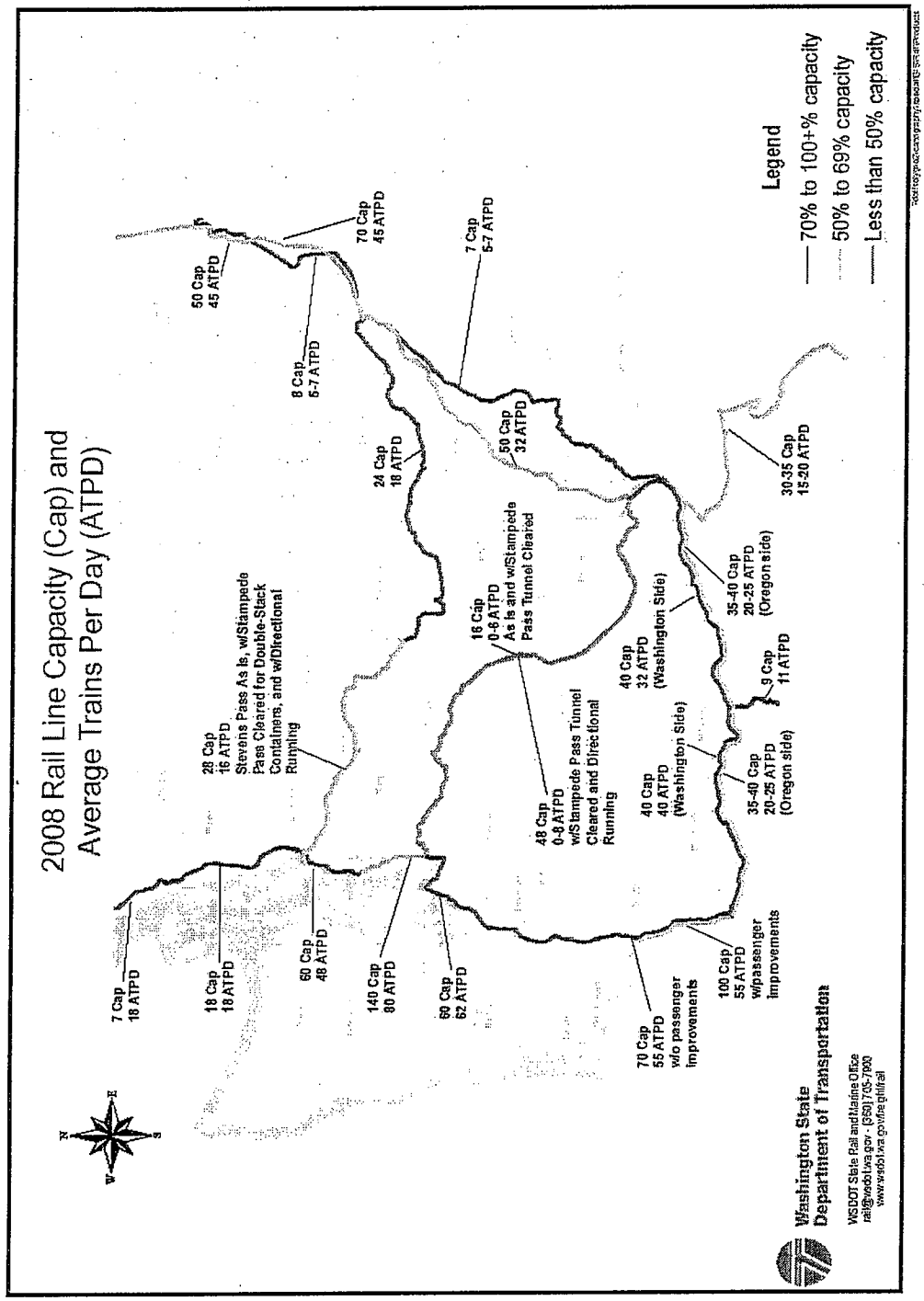
Appendix 3-B also contains more information about the freight rail carriers in the state including descriptions, maps, revenue, and history.

Class I Railroads

BNSF Railway

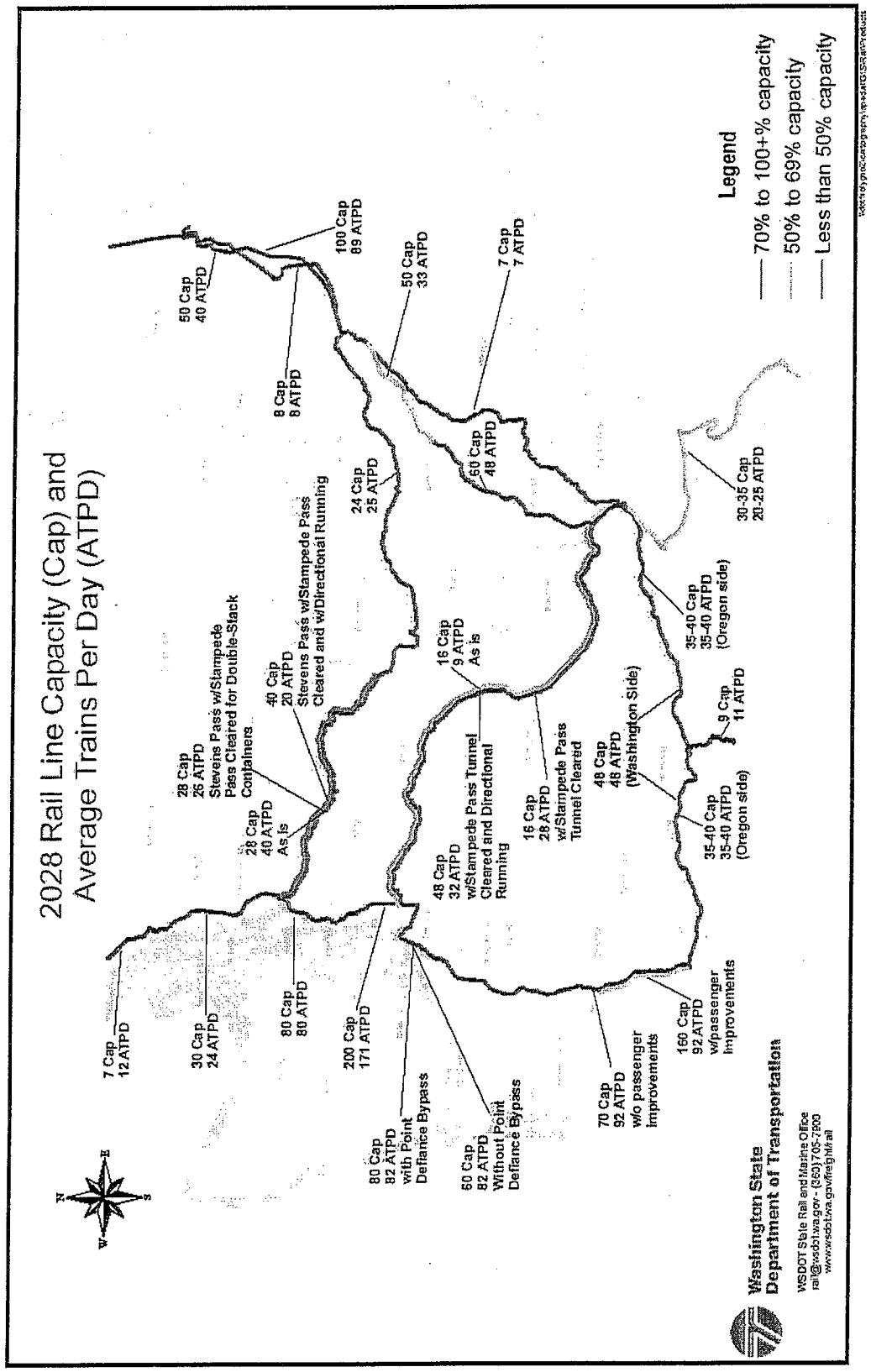
BNSF, one of the four largest U.S. railroads, owns and operates track over seven major corridors and nine low-density corridors in the state. BNSF

Exhibit 3-9: 2008 Rail Line Capacity[17]



[17] Train volumes (average trains per day) reflect business activities that are fluctuated sharply and sensitive to economic climate. Although the long-term trend is upward, the short-term trend could drop significantly. The information in this map reflects the long-term forecast results. These numbers were derived based on the best knowledge of the researchers and information available at the time of the research. The recent recession impacts may not be captured by this map.

Exhibit 3-10: 2028 Rail Line Capacity



Bottleneck	Type of Bottleneck
Tacoma (BNSF)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Tacoma (Tacoma Rail)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Fife (UP)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Argo (UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Port of Seattle (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
SIG/Stacy (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Interbay (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Everett (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Wishram (BNSF)	Yard Infrastructure
Arco (Cherry Point; BNSF)	Yard Infrastructure
Longview Jct. (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems
Pasco (BNSF)	Yard Infrastructure
Centralia (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation
Spokane (BNSF)	Yard Infrastructure

Source: Washington State Transportation Commission (WSTC) *Statewide Rail System and Capacity Study*, 2006

Montana Rail Link (MRL) system; the MRL has operating rights over BNSF into Spokane.

The Funnel was part of the original Northern Pacific mainline, completed to Spokane in 1881. After the 1970 Burlington Northern merger, the Northern Pacific route was selected over the parallel ex-Great Northern route as the primary mainline from the east into Spokane, a function that it retains today for BNSF. Portions of the original Great Northern route continue under operation as segments of the Pend Oreille Valley Railroad and BNSF's Kettle Falls Subdivision, but abandonments have rendered that line no longer viable as a through route.

As the corridor experienced substantial growth in recent years, BNSF began to increase capacity by adding a second main track. As of April 2005, only 20 miles remained under single-track operation. Except for a short stretch in Spokane, the entire line is controlled by CTC. Annual freight traffic consists of intermodal, forest and agricultural products, coal, chemicals, and finished automobiles.

Everett-Vancouver, British Columbia Mainline

The 152-mile corridor spanning the Bellingham and New Westminster Subdivisions is the only remaining mainline link between the Washington State rail network and Canada (low-volume connections are served by BNSF at Sumas and KFR at Columbia Gardens, B.C.). An average of 23 freight trains operates on the line daily, with approximately 12 running through to Vancouver, B.C. Four daily Amtrak *Cascades* trains run between Everett and Vancouver, B.C.

This stretch of U.S. and Canadian railroad was completed by the Great Northern in 1891. From Blanchard to Bellingham, the line closely follows the shores of Samish and Bellingham Bays, a condition that limits both train speed and the ability to increase capacity without incurring great expenses. Additional delays are encountered while passing through Customs at the Blaine/White Rock border crossing. BNSF also operates a 2-mile stretch of former Milwaukee Road trackage in Bellingham that is owned by the Bellingham International Railroad (BIRR); the BIRR was formed for the purpose of preventing an industry from losing service on a line that BNSF intended to abandon.

The corridor is single-track CTC from Everett to New Westminster, with the exception of a few short stretches of Automatic Block Signaling/ Occupancy Control System (ABS/OCS). From New Westminster to Vancouver, the line is double-track CTC. Maximum train speeds are:

- Everett to Delta Junction: Talgo[22] 50 mph, passenger 35 mph, freight 15 mph.
- Delta Junction to Blaine: Talgo 79 mph, passenger 79 mph, freight 60 mph.
- Blaine to Vancouver, B.C.: Talgo 60 mph, passenger 60 mph, freight 40 mph.

Freight traffic includes intermodal, forest and agricultural products, refuse, chemicals, and finished automobiles.

Tukwila-Snohomish Branch Line

BNSF's 51-mile Woodinville Subdivision traverses the east side of the Seattle metropolitan area, connecting Tukwila, Renton, Bellevue, Woodinville, and Snohomish. BNSF operates one round-trip local on weekdays that serves industrial customers along the line, including delivery of 737 fuselages to Boeing's assembly plant in Renton.

The Woodinville Subdivision is a remnant of the former Northern Pacific (NP) mainline from Seattle to Sumas. The line to Sumas and a connection with the Canadian Pacific Railroad was completed by the Seattle, Lake Shore, & Eastern Railroad (SLS&E) in 1891; the SLS&E was subsequently absorbed into the NP in 1901. In the wake of the 1970 Burlington Northern merger, the Sumas line from Snohomish Junction to Sedro-Woolley was abandoned. In 2006 a study was conducted on the segment from Tukwila to Snohomish to consider potential future uses, including a parallel bicycle/pedestrian trail, mass transit, and as an emergency bypass route for freight traffic normally operating via Interbay, Edmonds, and Everett.

Traffic on the Woodinville Subdivision operates via TWC. Maximum permitted train speeds are 30 mph for passenger and 25 mph for freight. Railcar weights up to 143 tons can be operated from Snohomish Junction to Woodinville, while the remainder of the line is restricted to 134 tons. Tukwila-Woodinville freight corridor traffic consists of aircraft fuselages, forest products, and chemicals.

[22] Talgo, Inc. manufactures high-speed articulated trains. These operate as a set, with adjacent cars sharing axles and wheels and functioning as a single unit. This technology increases stability and improves safety and the smoothness of the ride. Talgo trains were initially allowed into the United States on a temporary basis and were leased for use in the Pacific Northwest from 1994 through 1998. Today, five trains built by Talgo operate in the Pacific Northwest and British Columbia as the Amtrak *Cascades* service.

segment of a former Great Northern branch that connected Anacortes and Rockport.

The line is operated as an industrial track with a speed limit of 10 mph, and railcars up to 134 tons are permitted. Traffic includes petrochemicals.

Intalco-Cherry Point Branch Line

BNSF's Cherry Point Subdivision splits off the Bellingham Subdivision at Intalco, near the town of Custer, and runs southwest to serve a collection of industries at Cherry Point. BNSF operates two daily round trips on the line.

The Cherry Point Subdivision is operated by TWC, with a speed limit of 25 mph and a maximum railcar weight of 143 tons. The line was built in 1965 to serve the Intalco aluminum smelter, and later a series of petroleum-related industries were constructed on the line. Traffic includes metals and petrochemicals.

Marysville-Arlington Branch Line

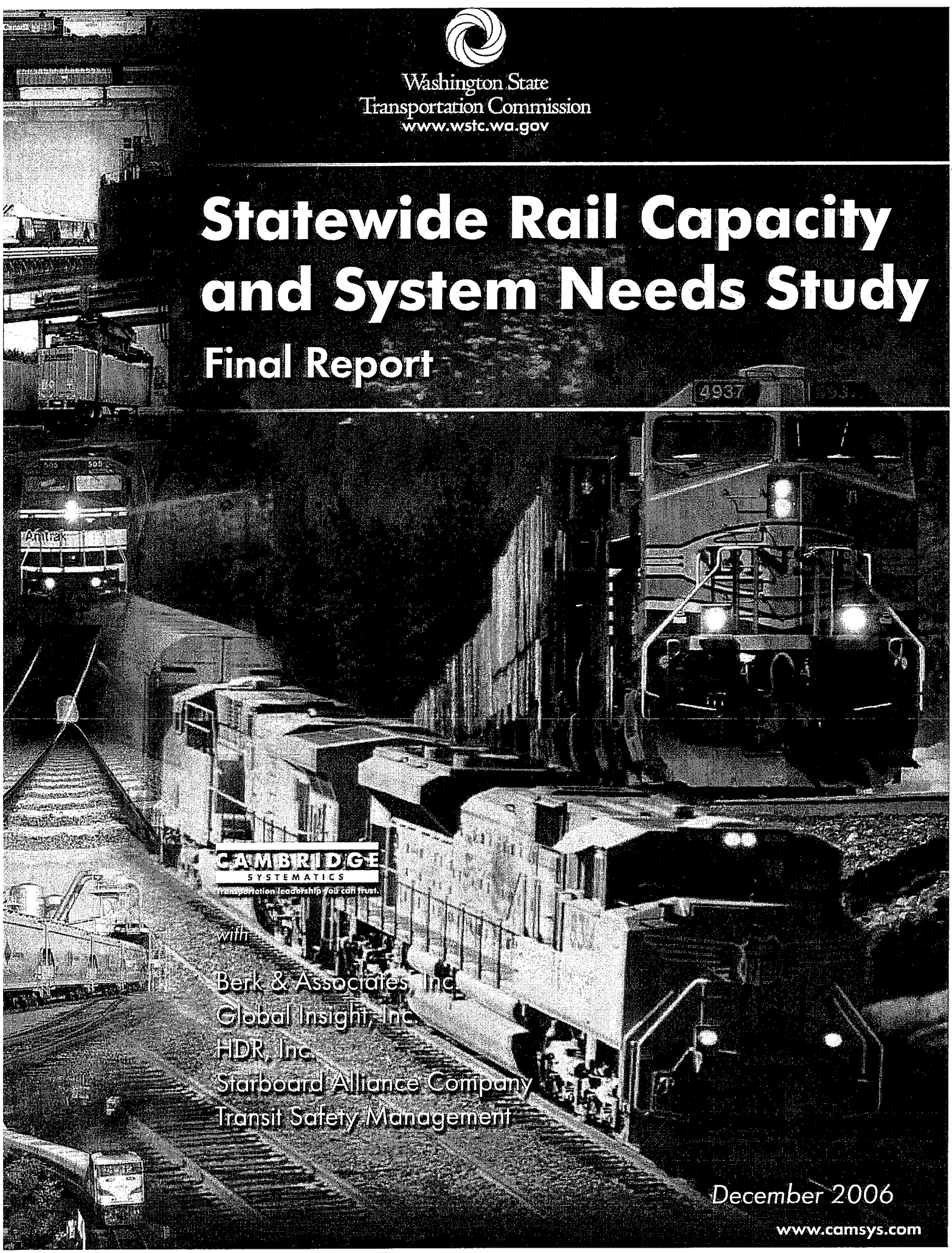
Breaking off the Bellingham Subdivision at Kruse Junction, BNSF's Arlington Spur connects Arlington to the national rail network, and is classified by BNSF as an industrial spur. The line is served twice weekly by a road switcher based in Everett. Track speed on the line is 10 mph, and 143-ton railcars are permitted.

Lakeview-Roy Branch Line

Although BNSF sold freight rights on the north end of its Lakeview Subdivision and the entire length of the connecting Lakeview Spur to Tacoma Rail in 2004, it retained the remainder of the Lakeview Subdivision from Lakeview to Roy. The customers on the line are the U.S. Army's Fort Lewis, which occasionally ships or receives military equipment, and Wilcox Farms, which receives feed at Roy twice a week. Track speed on the line is 10 mph, and 143-ton railcars are permitted; however, as of spring 2006, the only connection to the rest of the BNSF network, via the Lakeview Spur and Nisqually, is restricted to 134-ton railcars.

Spokane-Chewelah Branch Line

BNSF's Kettle Falls Subdivision was constructed in 1889 by the Spokane Falls and Northern Railway, and came under control of James Hill's Great Northern in 1898. In late 2004, BNSF sold the Kettle Falls and San Poil Subdivisions north of Kettle Falls to OmniTRAX's Kettle Falls International Railway (KFR), and leased the Kettle Falls-Chewelah segment to the KFR; the two railroads interchange daily at the latter



Washington State
Transportation Commission
www.wstc.wa.gov

Statewide Rail Capacity and System Needs Study

Final Report

CAMBRIDGE SYSTEMATICS
Transportation leadership you can trust.

with

Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management

December 2006

www.camsys.com

1.0 Executive Summary

The Washington Rail Capacity and System Needs Study was requested by the Washington State Legislature to:

- Assess rail needs in the State;
- Determine the State's interest in the rail system;
- Develop policies to govern the State's participation in the rail system; and
- Develop a plan for managing the rail lines, railcars, and service rights owned by the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity rail service. In the last decade, it also has provided emergency relief to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature for this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The Economic Vitality of Washington State Requires a Robust Rail System

The economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. For example:

- Manufacturers, lumber and wood products producers, and central and eastern Washington agriculture and food products businesses rely on rail transportation to move heavy, bulky products to market cost effectively. These businesses generate 14 percent of the State's gross state product and 15.5 percent of its employment. If rail service deteriorates, these businesses may shift their freight to trucks, but this will increase their transportation costs and may increase the cost to state and

local government of maintaining roads. In some cases, the loss of rail service could drive businesses to relocate or close.

- The State's ports and international trade industry depend on rail to export grain and other agricultural products and to import intermodal containers of consumer goods. The ports generate more than 200,000 jobs directly and indirectly, and over $500 million in state and local tax revenues. If the rail system cannot deliver high-quality transportation services, especially for intermodal cargo that is not destined for Washington State, shippers will quickly shift to other ports. This could result in lower growth at Washington ports and a loss of port-related jobs. In addition, export trade plays a major role in the Washington economy, ranking it first among states in export value per capita. Without good rail connections to support both import and export trade, the Washington ports will become less attractive to ocean carriers, and ultimately, the State will become a less attractive location for export businesses.

- A high-quality intercity passenger rail service offers an alternative to automobile and air travel that can help reduce congestion, energy use, and environmental impacts of highways. If the rail system cannot accommodate frequent and reliable intercity passenger rail service, the State risks losing the benefits of passenger rail as an alternative to highway and air travel.

The System Is Nearing Capacity

The benefits that Washington State can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. For example:

- The Everett-Spokane line over Stevens Pass is the Burlington Northern Santa Fe Railway's (BNSF) major transcontinental route for double-stack intermodal trains. It operates today at about 123 percent of practical capacity.[1]

[1] Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is the point at which the system ceases to operate freely and reliably and begins to suffer slowdowns and congestion. At higher percentages, rail congestion increases and service reliability deteriorates quickly. For more information about how rail capacity is determined, see Technical Memorandum #3, *Rail Capacity Needs and Constraints.*

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic – most of which is associated with short- and medium-distance trips – on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 – Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

Heavy Traffic Ahead

Rail Impacts of Powder River Basin Coal to Asia By Way of Pacific Northwest Terminals

Report Prepared For

Western Organization of Resource Councils

July 2012

Heavy Traffic Ahead

Rail Impacts of Powder River Basin Coal to Asia

By Way of Pacific Northwest Terminals

Prepared For:

Western Organization of Resource Councils
220 South 27th Street
Billings, MT 59101
(406) 252-9672

Prepared With Assistance From:

Terry C. Whiteside
Whiteside & Associates
3203 Third Avenue North, Suite 301
Billings, Montana 59101
(406) 245-5132

Gerald W. Fauth III
G. W. Fauth & Associates, Inc.
116 S. Royal Street
Alexandria, VA 22314
(703) 549-6161

Richard H. Streeter, Esq.
Attorney at Law
5255 Partridge Lane, N.W.
Washington, D.C. 20016
Tele: 202-363-2011

Copyright © 2012

Table of Contents

Section	Page
Introduction	1
Executive Summary	5
Study Assumptions	8
PNW Export Coal Terminals	11
1. Roberts Bank, BC (Westshore)	11
2. North Vancouver, BC (Neptune)	11
3. Prince Rupert, BC (Ridley)	12
4. Cherry Point, WA	12
5. Longview, WA	15
6. Grays Harbor, WA (Hoquiam)	16
7. Coos Bay, OR	16
8. St. Helens, OR (Westward)	16
9. Boardman, OR (Morrow)	17
PRB Coal	18
1. PRB Coal Mines and Origins	18
2. PRB Railroad Coal Lines	20
3. Current PRB Coal Market & Destinations	20
4. Current PRB to PNW Coal Movements (Centralia, WA and Boardman, OR)	23
5. Projected PRB Export Coal Tons	23
Impacted Railroad Routes	25
1. BNSF Market Domination	25
2. BNSF Railroad Routes Impacted	27
3. BNSF Routing Options	28
4. Mileage Differences For BNSF Routing Options	30
5. Impacted Railroad Line Segments	31
Projected Traffic Flow	33
Major Choke Points & Bottlenecks	35
Major Railroad Traffic Congestion Areas	36
Rail Capacity Issues	37
Impacted Railroad Traffic	40
1. PNW Import and Export Intermodal Container Traffic	40
2. PNW Export Grain Traffic	43
3. Bakken Oil Shipments	44
4. Passenger & Commuter Traffic	46
Major Track and Infrastructure Improvements Are Required	47
Environmental Impacts	50
Economic Impacts	51
Regulatory Review & Mitigation	52
Potential Legislation	58
Conclusion & Recommendations	59

List of Tables, Charts, Maps & Illustrations

Figure		Page
1	U.S. Export Coal Tonnage Since 2005	1
2	Existing and Proposed PNW Export Coal Terminals	2
3	Projected Annual PNW Export Coal Tons (*Millions of Short Tons*)	3
4	Impacted Railroad Line Segments (*Sorted By Projected 2022 Export Coal Trains Per Day*)	7
5	Loaded & Empty Trains Per Day at Various Tonnage Levels	10
6	Map of BNSF's Line Serving Cherry Point	13
7	MIT's Tonnage and Train Projections for Cherry Point	14
8	Site Rendering of Longview Terminal	15
9	Western Coal Price Comparison	18
10	Current and Proposed PRB Coal Mines and Origins	19
11	PRB Railroad Coal Lines	20
12	2011 Distribution of PRB Coal Tons	22
13	Projected Annual PRB to PNW Coal Tons (*Millions of Short Tons*)	24
14	BNSF & UP PRB to PNW Export Coal Estimated Delivered Cost Comparison	26
15	BNSF's PRB to PNW Routes (Map)	27
16	BNSF Routing Options For Export Coal Movements From Antelope, WY to Longview, WA	30
17	Railroad Line Segments Impacted	32
18	Projected Traffic Flow PRB Cool Mines to Spokane, WA	33
19	Projected Traffic Flow From Spokane, WA to PNW Export Coal Terminals	34
20	Comparison of BNSF Intermodal Service Goal Hours For Movements To Chicago, IL	41
21	2010 Rail Shipments of Farm Products (STCC 01) PNW Destinations	43
22	North Dakota and Montana Crude Oil Production	44
23	BNSF's Bakken Oil Formation Service Area (Map)	45
24	Practical Track Capacity (Trains Per Day)	48
25	Comparison of Projected PRB to PNW Export Coal Volumes With DM&E and TRRC	54

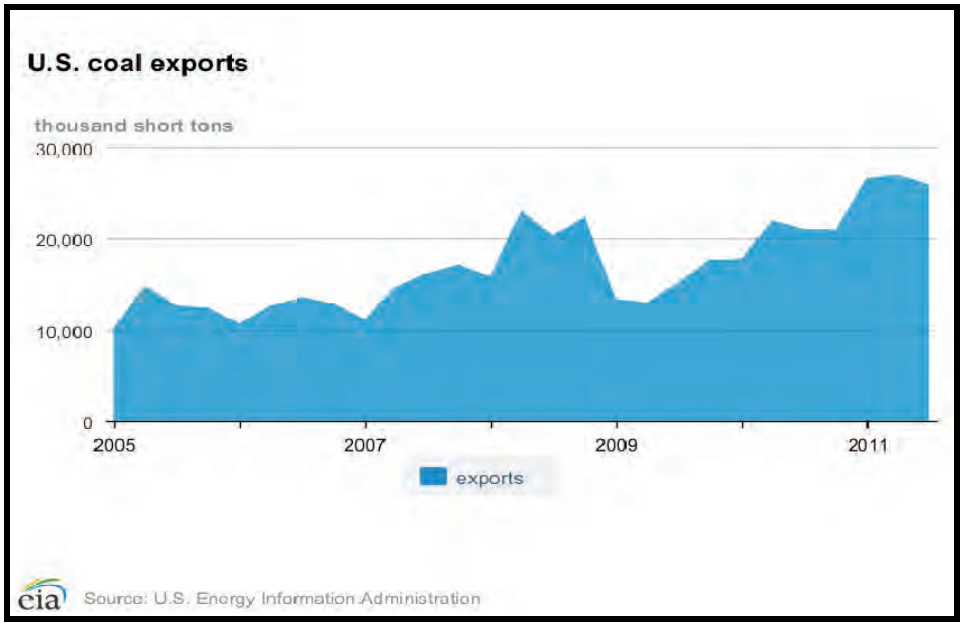
Introduction

Western Organization of Resource Councils (WORC) is a regional network of seven (7) grassroots community organizations that include 10,000 members and 38 local chapters. WORC's member organizations are: Dakota Rural Action; Dakota Resource Council; Idaho Rural Council; Northern Plains Resource Council; Oregon Rural Action; Powder River Basin Resource Council; and Western Colorado Congress. WORC's mission is to advance the vision of a democratic, sustainable and just society through community action. WORC is committed to building sustainable environmental and economic communities that balance economic growth with the health of people and stewardship of their land, water and air resources.

WORC is concerned about the potential impacts associated with the recent and projected significant increase in U.S. coal exports and related railroad shipments. Total U.S. export coal shipments increased from approximately 81.7 million tons in 2010 to 107.3 million in 2011.[1] This increase in U.S. coal exports is illustrated in the following chart:

Figure 1

U.S. Export Coal Tonnage Since 2005



[1] U.S. Energy Information Administration (EIA), U.S. Coal Exports, Table 7. Export coal tons are often expressed in metric tons (2,204.6 lbs.), whereas U.S. mine production and railroad coal tons are normally expressed in U.S. short tons (2,000 lbs.). Unless otherwise noted, the tons referenced herein, such as the referenced 82 and 107 million U.S. export coal tons, are listed in short tons.

The increase in U.S. coal exports can be attributed, in part, to the significant growth in export coal shipments to Asian markets, such as China, Japan, and South Korea, which increased from approximately 17.9 million in 2010 to 27.5 million in 2011. Total steam coal exports to Asia have increased from approximately 4.9 million in 2010 to over 7.8 million in 2011 and will likely exceed 12 million in 2012.[2]

U.S. coal producers and suppliers are actively looking to expand steam coal production from mines and origins in the Powder River Basin (PRB) in Montana and Wyoming and shift significant coal volumes away from domestic destinations to existing and proposed Pacific Northwest (PNW) export coal terminals, in order to compensate for a recent and projected decline in domestic steam coal-fired power production and take advantage of the growing Asian steam coal market. Currently, there are only three (3) PNW export coal terminals in British Columbia (BC), which handle approximately 5 million tons of PRB coal per year. In order to meet large export tonnage goals and reduce transportations costs, at least six (6) U.S. PNW export terminals are being considered in Washington and Oregon. The nine (9) existing and planned PNW export coal terminals are listed in the following table and described in more detail herein:

Figure 2

Existing and Proposed PNW Export Coal Terminals

British Columbia
Roberts Bank, BC (Westshore) N. Vancouver, BC (Neptune) Prince Rupert, BC (Ridley)
Washington
Cherry Point, WA (Bellingham) Longview, WA Grays Harbor,WA (Hoquiam)
Oregon
Coos Bay, OR St. Helens, OR (Westward) Boardman, OR (Morrow)

[2] In the past, most U.S. export coal shipments have been metallurgical coal (approximately 69.5 million tons in 2011). Europe, which received over 53.9 million tons of U.S. coal exports in 2011, has historically been the largest destination market for U.S coal exports. Consequently, the largest U.S. export coal ports are currently East coast ports such as Norfolk, Virginia and Baltimore, Maryland and Gulf coast ports such as New Orleans, Louisiana and Mobile, Alabama.

State and local governments have expressed concerns about the proposed expansion of PNW export coal terminals. For example, in a recent letter from Oregon Governor John A. Kitzhaber to U.S. Secretary of Interior Ken Salazar and others, the Governor requested a programmatic and comprehensive environmental impact statement (EIS) under the National Environmental Policy Act to look at the "unprecedented number of export coal proposals."[3] The Seattle City Council also recently unanimously passed a resolution in opposition to the transportation of coal through Seattle, which highlights the negative impacts from the significant increase in coal trains that would run through Seattle.[4]

Based on announced and proposed expansion plans associated with these existing and proposed PNW export coal terminals, PRB to PNW export coal shipments, which amounted to only a few million tons five years ago, could very well exceed 75 million tons per year by 2017 and 170 million tons by 2022. The projected annual volumes are shown in the following table:

Figure 3

Projected Annual PRB to PNW Export Coal Tons

(Millions of Short Tons)

PNW Export Coal Terminals	2012	2017	2022
Roberts Bank, BC (Westshore)	5.0	8.0	15.0
N. Vancouver, BC (Neptune)	0.0	2.0	5.0
Prince Rupert, BC (Ridley)	0.0	1.5	5.0
Existing British Columbia Coal	**5.0**	**11.5**	**25.0**
Cherry Point, WA (Bellingham)	0.0	27.5	52.5
Longview, WA	0.0	27.5	48.0
Grays Harbor, WA (Hoquiam)	0.0	0.0	5.0
Proposed Washington Coal Terminals	**0.0**	**55.0**	**105.5**
Coos Bay, OR	0.0	0.0	10.0
St. Helens, OR (Westward)	0.0	5.0	21.0
Boardman, OR (Morrow)	0.0	3.5	8.5
Proposed Oregon Coal Terminals	**0.0**	**8.5**	**39.5**
Total to PRB to PNW Export Coal Tons	**5.0**	**75.0**	**170.0**

[3] Letter from Governor John A. Kitzhaber dated April 25, 2012.
[4] http://www.seattle.gov/council/newsdetail.asp?id=12809&dept=28

The proposed expansion of PNW export coal terminal capacity will likely result in an explosion in PRB to PNW coal exports and railroad export coal movements. Two major U.S. Class I railroads dominate the PNW region as well as the PRB coal transportation market: BNSF Railway Company (BNSF) and Union Pacific Corporation (UP).[5] BNSF serves PRB origins in Montana and Wyoming. UP serves PRB origins in Wyoming, which are jointly served by BNSF. There are currently six railroad PRB coal lines in Montana and Wyoming and one proposed new coal line in Montana, which serve approximately twenty coal mines and would feed PRB export coal trains onto railroad mainlines for movement to the nine existing and proposed PNW terminals. The coal mines served by BNSF and UP are owned and operated by a few major coal companies, such as Peabody Energy, Arch Coal and Cloud Peak, which would work with the railroads and PNW export terminals in regard to export coal shipments. These PRB coal mines, railroad coal lines and railroad routes are described in more detail herein.

Repetitive and voluminous PRB to PNW export coal movements will obviously benefit the coal companies, railroads and terminal companies by generating billions of dollars in annual revenues and profits, but these coal movements will have a wide-range of adverse environmental, economic, transportation, public safety and other impacts. As described herein, the rail routes potentially impacted by the increase in PRB to PNW export coal cover an extremely broad impact area covering a total rail distance of over 4,000 miles. The impacted railroad routes traverse through many major populated areas, such as Spokane and Seattle, Washington, Billings, Montana and Portland, Oregon, as well as many environmentally sensitive areas, such as Glacier National Park in Montana.

WORC is concerned about the environmental, economic, transportation and other impacts associated with the expected increase in rail tonnage from the PRB coal mines to PNW export terminals and prepared this report to study the possible impacts associated with the expected increase in railroad export coal movements from PNW origins to PNW export terminals. WORC retained the consulting firms of Whiteside & Associates (TCW), a transportation and marketing consulting firm located in Billings, Montana, and G. W. Fauth & Associates, Inc. (GWF), an economic consulting firm specializing in transportation issues located in Alexandria, Virginia, to study the possible environmental, economic and transportation impacts associated with the expected increase in railroad export coal movements from PNW origins to PNW export terminals. Richard H. Streeter, an attorney in Washington, DC specializing in transportation issues, also contributed to this report.

---

[5] On Feb. 12, 2010, Burlington Northern Santa Fe, LLC, (formerly known as Burlington Northern Santa Fe Corporation) and BNSF Railway Company became subsidiaries of Berkshire Hathaway Inc.

Executive Summary

The U.S. coal export market is headed for explosive growth of coal movements from the PRB region in Montana and Wyoming to nine existing and proposed PNW export terminals in Oregon, Washington and British Columbia.

The projected movement of 75 million tons per year by 2017 to 170 million tons per year by 2022 will generate billions of dollars in annual revenues for railroad, coal and terminal companies.

Although BNSF, UP and other railroads will be involved in the PRB to PNW export coal transportation market to some extent, BNSF's routes are significantly shorter than UP's routes and BNSF has a lower cost structure. Thus, BNSF can provide transportation rates which are significantly lower than UP and will likely capture the lion's share and dominate the expanding and lucrative PRB to PNW export coal market.

The total rail route miles potentially impacted cover an extremely broad impact area covering a total rail distance of over 4,000 miles. The impacted railroad route miles would directly impact over 48,977 acres based on a 100 ft. right-of-way (ROW).

The projected movement of 75 million tons per year by 2017 to 170 million tons per year by 2022 will equate to the movements of 27.86 to 63.15 loaded and empty coal trains per day. These repetitive 1¼-mile long loaded and empty coal trains will be going through numerous populated cities, towns, communities (such as Spokane, Washington, Seattle, Washington, Billings, Montana and Portland, Oregon), parks, forests, historical areas and other environmentally sensitive areas (such as Glacier National Park in Montana).

In addition to the obvious environmental and traffic concerns, the expected large coal volumes will result in several major choke points and bottlenecks and will likely cause rail congestion problems for the entire route. Many of the impacted railroad line segments, such as the line known as "The Funnel" from Sandpoint, ID to Spokane, WA, already have significant rail capacity and congestion issues.

Current railroad traffic, such as PNW import and export intermodal container traffic and export grain railroad traffic, would be adversely impacted by the reduction of rail capacity and would likely experience a deterioration of rail service, such as higher transit and cycle times and would likely incur higher costs in the form of higher freight rates and equipment costs.

The west bound movement of coal is likely to disrupt the frequency and reliability of inbound and outbound shipments of containerized traffic and that traffic would likely experience a diversion to California and Canadian ports where it will not be impacted by the congestion associated with the increased PRB to PNW coal shipments.

The two major cities that would be the most adversely impacted in terms of the expected export coal trains per day are: Spokane, Washington (pop. 208,916) and Billings, Montana (pop. 104,170). Nearly every PRB to PNW loaded and empty coal train would move through these two cities (up to 63.2 trains per day through Spokane and 57.6 trains per day through Billings).

There are many areas along the railroad routes which would require major upgrading and expansion of existing railroad tracks and related infrastructure which could cost billions of dollars. State and local governments would likely bear the brunt and burden of the related infrastructure costs in their localities and would likely be required to spend hundreds of millions of dollars in related mitigation, litigation, debt and other costs associated with the necessary improvements to accommodate export coal traffic levels.

The following table shows the projected annual tons for 2017 and 2022 and estimated loaded and empty coal trains per day for 38 indentified and studied railroad line segments covering 4,054.1 route miles:

Figure 4

Impacted Railroad Line Segments

(Sorted By Projected 2022 Export Coal Trains Per Day)

Railroad Line Segment	Railroad	Miles	Coal Tons/Year *(Millions)*		Coal Trains/Day *(Loaded & Empty)*	
			2017	2022	2017	2022
Sandpoint, ID to Spokane, WA (Latah Jct.) (The Funnel)	BNSF	70.5	75.0	170.0	27.9	63.2
Huntley, MT to Mossmain, MT (Billings)	BNSF/MRL	24.8	60.0	155.0	22.3	57.6
W. Dutch, WY to Huntley, MT	BNSF	138.9	60.0	105.0	22.3	39.0
Mossmain, MT to Sandpoint, ID (Helena, Missoula)	MRL	564.2	35.0	90.0	13.0	33.4
Spokane, WA (Latah Jct.) to Pasco, WA (SP&S Jct.)	BNSF	149.4	40.5	88.0	15.0	32.7
Campbell, WY to W. Dutch, WY	BNSF	100.5	45.0	80.0	16.7	29.7
Broadview, MT to Great Falls, MT	BNSF	188.0	40.0	80.0	14.9	29.7
Great Falls, MT to Shelby, MT	BNSF	99.1	40.0	80.0	14.9	29.7
Shelby, MT to Sandpoint, ID (Hi-Line)	BNSF	337.9	40.0	80.0	14.9	29.7
Everett, WA (PA Jct.) to Intalco, WA (Bellingham)	BNSF	78.3	38.0	77.5	14.1	28.8
Mossmain, MT to Broadview, MT	BNSF	35.8	25.0	65.0	9.3	24.1
Pasco, WA to Vancouver, WA (Columbia River Gorge)	BNSF	219.8	28.5	58.5	10.6	21.7
Spokane, WA (Latah Jct.) to Everett, WA (Stevens Pass)	BNSF	301.1	28.5	58.0	10.6	21.5
Intalco, WA to Cherry Point, WA	BNSF	8.9	27.5	52.5	10.2	19.5
Sarpy Jct., MT to Huntley, MT	BNSF	66.1	0.0	50.0	0.0	18.6
Eagle Butte Jct., WY to Campbell, WY	BNSF	25.6	25.0	45.0	9.3	16.7
Nichols, MT to Sarpy, Jct., MT	BNSF	16.4	0.0	45.0	0.0	16.7
Vancouver, WA to Longview, WA	BNSF	35.4	25.0	43.0	9.3	16.0
Ashland, MT to Miles City, MT	TRRC	89.0	0.0	40.0	0.0	14.9
Miles City, MT to Nichols, MT	BNSF	51.6	0.0	40.0	0.0	14.9
Shawnee Jct., WY to Campbell, WY (Joint Line)	BNSF/UP	140.2	20.0	35.0	7.4	13.0
Pasco, WA to Auburn, WA (Yakima) (Stampede Pass)	BNSF	227.5	12.0	29.5	4.5	11.0
Spring Creek, MT to W. Dutch, WY	BNSF	22.8	15.0	25.0	5.6	9.3
Intalco, WA to British Columbia Terminals	BNSF/CN	49.7	11.5	25.0	4.3	9.3
Spokane, WA to Hinkle, OR	UP	171.0	6.0	24.0	2.2	8.9
Hinkle, OR to Boardman, OR (Morrow)	UP	20.0	6.0	24.0	2.2	8.9
Portland, OR to St. Helens, OR (Port Westward)	PNWR	56.0	5.0	21.0	1.9	7.8
Auburn, WA to Everett, WA (PA Jct.) (Seattle)	BNSF	55.6	9.5	19.5	3.5	7.2
Vancouver, WA to Portland, OR	BNSF	9.9	2.5	15.5	0.9	5.8
Portland, OR to Boardman, OR (Morrow)	UP	164.0	2.5	15.5	0.9	5.8
Signal Peak, MT to Broadview, MT	BNSF	35.0	15.0	15.0	5.6	5.6
Auburn, WA to Centralia, WA (Tacoma)	BNSF	72.6	2.5	10.0	0.9	3.7
Portland, OR to Eugene, OR	UP	124.0	0.0	10.0	0.0	3.7
Eugene, WA to Coos Bay, OR	CORP	122.0	0.0	10.0	0.0	3.7
Centralia, WA to Longview, WA	BNSF	47.1	2.5	5.0	0.9	1.9
Big Sky, MT to Nichols, MT	BNSF	39.0	0.0	5.0	0.0	1.9
Kuehn, MT to Sarpy Jct., MT	BNSF	37.4	0.0	5.0	0.0	1.9
Centralia, WA to Port of Grays Harbor, WA	PSAP	59.0	0.0	5.0	0.0	1.9
Total / Average		**4.054.**	**24.8**	**57.1**	**9.2**	**21.2**

Study Assumptions

For the purpose of this report, it was assumed that PRB to PNW export coal shipments, which amounted to only a few million tons five years ago, will reach 75 million tons per year by 2017 and 170 million tons by 2022. The 170 million ton level assumes that all nine existing and proposed export coal terminals will be fully operational at projected capacity by 2022 and PRB coal would originate from all PRB coal lines.

It was necessary to make certain assumptions for this report in terms of export coal origin and destination annual tonnage levels and railroad route utilization. Since relatively very little PRB coal currently moves to PNW destinations and the projected annual volumes to the proposed PNW terminals may change based on the ongoing environment review process and other unforeseen factors, the PRB to PNW export coal tonnage levels included herein will obviously change and fluctuate as events transpire and as that market changes and expands over time.

BNSF can originate coal from several PRB origins. The economics may favor BNSF's PRB coal origins which involve the shortest rail distances to the various PNW export terminals, but the large projected annual coal volumes and PRB origin capacity constraints will likely result in coal being originated from nearly *all* PRB coal origins to some extent.

In addition, BNSF has several routing options in Montana and Washington which could be utilized for PRB to PNW export coal movements. Again, the economics may favor the shortest available route, however, the large projected annual coal volumes, current railroad traffic levels and current capacity constraints will likely result in BNSF's utilization of *all* of the BNSF available routing options to some extent. The tonnages assigned to each origin, destination and route were estimated by attempting to take these and other factors into account.

For the purpose of this report, it has been assumed that BNSF would originate 100% of the PRB coal, but UP would terminate approximately 14% of the tonnage by 2022 via its interchange with BNSF at Spokane, Washington[6]. UP could originate PRB coal and obtain a larger market share by the utilization of its longer, but less congested, southern routes. However, an evaluation of these UP routes was not included as part of this study.

[6] It has been assumed that UP would terminate 100% of the Boardman tonnage (8.5 million tons in 2022) and 50% of the Coos Bay tons (5 million tons by 2022) and 50% of the St. Helens tons (10.5 million tons by 2022), for a total of 24 million tons or approximately 14% of the 170 million total tons.

Longview is jointly served by BNSF and UP, however, this report assumes that BNSF would terminate 100% of the Longview traffic. Initially, Ambre Energy projected that 60 million metric tons (66 million short tons) would move via Longview, but subsequently lowered the projection to 44 million metric tons (48.5 million short tons)[7]. UP had been interested in capturing a share of the large Longview market, but recently expressed wariness of the controversies surrounding the PNW export terminals.[8] UP currently carries high-BTU, low-sulfur coal from Colorado and Utah for export to Mexico.

It is doubtful that UP will abandon the profitable and voluminous PNW export coal market, however. UP's role may be limited to more of that of a *congestion reliever* for BNSF (by delivering coal via the Spokane interchange) rather than a vigorous competitor to BNSF by originating PRB coal and the utilization of its southern routes. Although the use of UP for coal movements from Spokane could help alleviate some congestion of BNSF's lines in Washington, any Longview coal traffic handled by UP would result in more coal traffic moving through Portland, Oregon. Moreover, the use of UP's expansive southern routes would significantly broaden the adverse impacts.

There are several cases in which the allocated PRB to PNW export coal traffic may exceed the existing capacity of line segment. For example, MRL currently handles approximately five (5) loaded and empty coal trains per day and projects that it has the capacity to handle up to 10 loaded and empty coal trains per day in the next ten years. MRL's President Tom Walsh MRL indicates that it has capacity problems with two tunnels: "Probably, our biggest pinch points really are the two mountain passes when it comes down to it, especially the Continental Divide."[9] This analysis assumes that MRL would handle 13 loaded and empty coal trains by 2017 and 33 loaded and empty coal trains by 2022. Therefore, in these cases, the study assumes that the capacity issues would be resolved by either the diversion of other traffic or by increasing capacity. In the MRL case, if the projected traffic levels are lowered, traffic levels would increase on other lines segments, namely BNSF's line through Great Falls, Montana.

[7] http://seattletimes.nwsource.com/html/localnews/2017582357_coalterminal24m.html
[8] http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6202450.
[9] http://missoulian.com/news/local/booming-asia-demands-more-energy-and-montana-has-it-by/article_ee425fa2-86b3-11e1-bb17-001a4bcf887a.html?cid=print

BNSF's unit coal trains average approximately 125 cars per train and carry approximately 14,750 loaded tons per train.[10] Each loaded and empty train is over 1¼ miles long.[11] These coal train characteristics were utilized in this report. Based on these characteristics (125 cars per train and 14,750 loaded tons per train), the following table shows the number of loaded and empty trains at various annual tonnage levels:[12]

Figure 5

Loaded & Empty Trains
Per Day at Various Tonnage Levels

Annual Tons	Trains Per Day (L&E)
1,000,000	**0.37**
5,000,000	**1.86**
10,000,000	**3.71**
25,000,000	**9.29**
50,000,000	**18.57**
75,000,000	**27.86**
100,000,000	**37.15**
150,000,000	**55.72**
170,000,000	**63.15**

In 2006, BNSF began using 150-car unit coal trains for a limited number of domestic unit train coal movements. The ultimate train size utilized for PRB to PNW export coal movements will depend on several factors, including the origin and destination car capacity and weight and train size restrictions along the utilized routes. Whether 125 or 150 cars per train are utilized, the same number of cars per day will be moving over the impacted railroad routes. There may be fewer trains with the use of 150-car unit trains, but the trains will be longer (i.e., approximately 1½ miles versus 1¼ miles long).

---

[10] Testimony of Matthew K. Rose, Chairman, BNSF President and CEO, April 26, 2006, before the U. S. House of Representatives Transportation and Infrastructure Committee and 2010 Railroad Carload Waybill Sample data.

[11] Each railroad car is approximately 53.1 ft. long and each locomotive is approximately 70 ft. long. A unit coal train with 4 locomotives and 125 cars would be approximately 6,917.5 ft. long or 1.31 miles long.

[12] Tons per year / 14,750 tons per train / 365 days x 2.0 empty return ratio.

Pacific Northwest Export Coal Terminals

Plans, discussions and permitting are already in progress concerning several PNW export coal terminals. The following describes nine (9) current and proposed PNW export coal terminals:

1. Roberts Bank, BC (Westshore)

Westshore Terminals in Roberts Bank, BC is in the Vancouver Port Metro area. It is currently the largest PNW export coal terminal, with an annual capacity of approximately 32 million tons.[13] Westshore indicates that it currently moves U.S. coal from the PRB, but the majority of the coal exported from Roberts Bank is from Canada. U.S. PRB coal was first shipped through Westshore in 1988. Since then PRB coal shipments have gradually increased. In 2009, Westshore shipped a record 2 million tons of US coal, including several shipments from Utah mines.[14] Cloud Peak, which has PRB coal operations in Antelope, WY, Cordero Rojo, WY and Spring Creek, MT, exported approximately 3.3 million tons to Asian customers in 2010 through Westshore and indicated that it would ship 4 million tons in 2011. Gunvor Group, which recently acquired Signal Peak mine, also has an agreement with Westshore Terminals to ship export coal.[15]

2. North Vancouver, BC (Neptune)

Neptune Bulk Terminals (Canada) Ltd. in the Vancouver Port Metro area handles potash, steelmaking coal, bulk vegetable oils, fertilizers and agricultural products. The coal handled at Neptune Terminals is predominantly metallurgical grade, which is primarily used in steel production. Currently, Neptune has a total coal capacity of approximately 8 million tons, but is expanding its capacity to over 10 million tons to meet the growing demand from Asia.[16]

---

13 http://www.westshore.com/background.html (29 million metric tonnes)
14 http://www.westshore.com/milestones.html
15 http://www.businessweek.com/ap/financialnews/D9QEVCBO4.htm
16 http://www.em.gov.bc.ca/Mining/investors/Documents/Coal15Feb2010web.pdf

3. Prince Rupert, BC (Ridley)

The Prince Rupert coal export facility is operated by Ridley Terminals, Inc. (Ridley), a Federal Crown Corporation owned by Canada. The coal terminal is in a remote location in the northwestern part of the province near Alaska, which is a long distance away from the PRB mines in Wyoming and Montana, but closer in nautical miles to the Asian market. Currently, Prince Rupert has an annual capacity of approximately 13 million tons, but plans are underway to double the capacity to over 26 million tons.[17] Ridley Terminals indicates that it began to receive U.S. PRB coal shipments in 2011.[18] In its 2010 Annual Report, Ridley stated: "Commencing in 2011 the Terminal will be receiving coal from customers based in the United States, their throughput volume combined with our Canadian producers have helped the Terminal realize a goal that has been 28 years in the making, to double the Terminal's capacity from 12 million tonnes per annum to 24 million tonnes." In its most recent report (Third Quarter 2011), Ridley indicated that its multi-year "Modification Project" will bring its total throughput capacity to 24-25 million tonnes by the end of 2014." (26.5 to 27.6 million short tons). In January 2011, Arch Coal announced that it had reached agreement with Ridley to export approximately 2.75 million tons from Prince Rupert.[19] CP and CN rail are also examining increased Canadian coal movements to Prince Rupert.

4. Cherry Point, WA (Bellingham)

In June 2010, SSA Marine began the environmental review process for a $500 million Gateway Pacific Terminal project at near Bellingham, WA.[20] The project, known as Cherry Point, could export up to 60 million tons per year.[21] On March 19, 2012, SSA Marine, through its subsidiary Pacific International Terminals, Inc. (PIT) submitted additional information to Whatcom County, Washington concerning the Cherry Point project. The submission indicates that the project will be completed in two stages. The first stage is planned to commence in 2014 and the second stage is expected to be completed by 2017.

---

17 http://www.rti.ca/en_terminalprofile.html

18 According to Ridley Terminals, Inc. 2010 Annual Report, in early 2011 Ridley Terminals Inc. signed an amended long-term terminal services agreement with Western Coal Corp. and entered into a multi-year terminal service agreement with Arch Coal Sales Company, Inc. The Arch Coal agreement is for coal exports which originate from the PRB (page 26).

19 http://news.archcoal.com/phoenix.zhtml?c=107109&p=irol-newsArticle&ID=1517028&highlight

20 http://gatewaypacificterminal.com/gateway-pacific-terminal-at-cherry-point-starts-permit-process/

21 An economic analysis prepared by Martin Associates for Gateway Pacific Terminals dated October 27, 2011 states "In the first phase, the terminal is projected to handle 25 million metric tons per year (27.6 million short tons). The second phase will take the terminal capacity up to 54 million metric tons per year" (59.5 million short tons), 6 million slated to be potash and coke.

BNSF would provide rail service to Cherry Point via the 6.2 mile Custer Spur, which branches out west from BNSF's line near Custer, Washington, which is north of Bellingham. The rail line was originally built in 1965 to serve the Intalco aluminum smelter, and later a series of petroleum-related industries were constructed on the line.[22] The following map shows the BNSF line serving Cherry Point:

Figure 6

Map of BNSF's Line Serving Cherry Point

Although BNSF currently provides service to Cherry Point, significant railroad improvements will be required to achieve the projected capacity. BNSF expects to acquire an additional 43 acres of contiguous adjacent to its current right-of-way in order to double track the line. In addition, up to three receiving and departure or "R&D" tracks are planned near the Custer connection and two independent loop tracks (the "East" and "West" loops) and rail unloading stations are planned at Cherry Point.[23]

---

[22] Washington State Statewide Rail Capacity and System Needs Study dated May 2006, page 12.

[23] March 19, 2012, Pacific International Terminals, Inc. additional information submitted to Whatcom County, Washington (see pages 4-33 and 4-34).

Initially, 7,000 ft. long trains (approximately 125 cars per train) are expected, but the facilities are being planned to accommodate 8,500 ft. long coal trains (approximately 150 cars per train). SSA Marine has already signed a contract with Peabody Energy, an investor in the project, agreeing to export 26.5 million tons of coal from its proposed terminal.[24] The following tonnage and train projections were included in PIT's March 2012 application:[25]

Figure 7

MIT's Tonnage and Train Projections For Cherry Point

Item	2016			2018			2021			2026		
	East Loop	West Loop	2016 Total	East Loop	West Loop	2018 Total	East Loop	West Loop	2021 Total	East Loop	West Loop	2026 Total
Metric Tons / Year (millions)	25.0	0.0	25.0	25.0	6.0	31.0	39.0	6.0	45.0	48.0	6.0	54.0
Short Tons / Year (millions)	27.6	0.0	27.6	27.6	6.6	34.2	43.0	6.6	49.6	52.9	6.6	59.5
Metric Tons / Train	13,625	0	---	13,625	17,272	---	16,350	17,272	---	16,350	17,272	---
Short Tons / Train	15,019	0	---	15,019	19,039	---	18,023	19,039	---	18,023	19,039	---
Cars / Train	125	0	---	125	170	---	150	170	---	150	170	---
Loaded Trains / Year	1,835	0	1,835	1,835	347	2,182	2,385	347	2,733	2,936	347	3,283
Loaded Trains / Day	5.0	0.0	5.0	5.0	1.0	6.0	6.5	1.0	7.5	8.0	1.0	9.0
Loaded & Empty Trains/Day	10.1	0.0	10.1	10.1	1.9	12.0	13.1	1.9	15.0	16.1	1.9	18.0

The proposed export coal movements would move from the East Loop, whereas export petroleum coke and potash trains would be unloaded at the West Loop. PIT's analysis assumes that by 2021 all export coal trains moving from Cherry Point would consist of 150 cars per train and carry 18,023 short tons per train. This 150-car per train assumption could result in an understatement in the expected number of trains per day. Although Cherry Point may be able to accommodate 150 cars per train, the ultimate train size will depend on several factors, including the origin car capacity and weight restrictions along the utilized route. Moreover, whether 125 or 150 cars per train are utilized, the same number of cars per day will be moving over the impacted railroad routes. There may be fewer trains, but the trains will be longer (i.e., approximately 1½ miles versus 1¼ miles long).

[24] Cascadia Weekly, March 2, 2011, *Cherry Point Shipping Terminal Signs its First Customer – A Coal Exporter*. (24 Million Metric Tonnes).

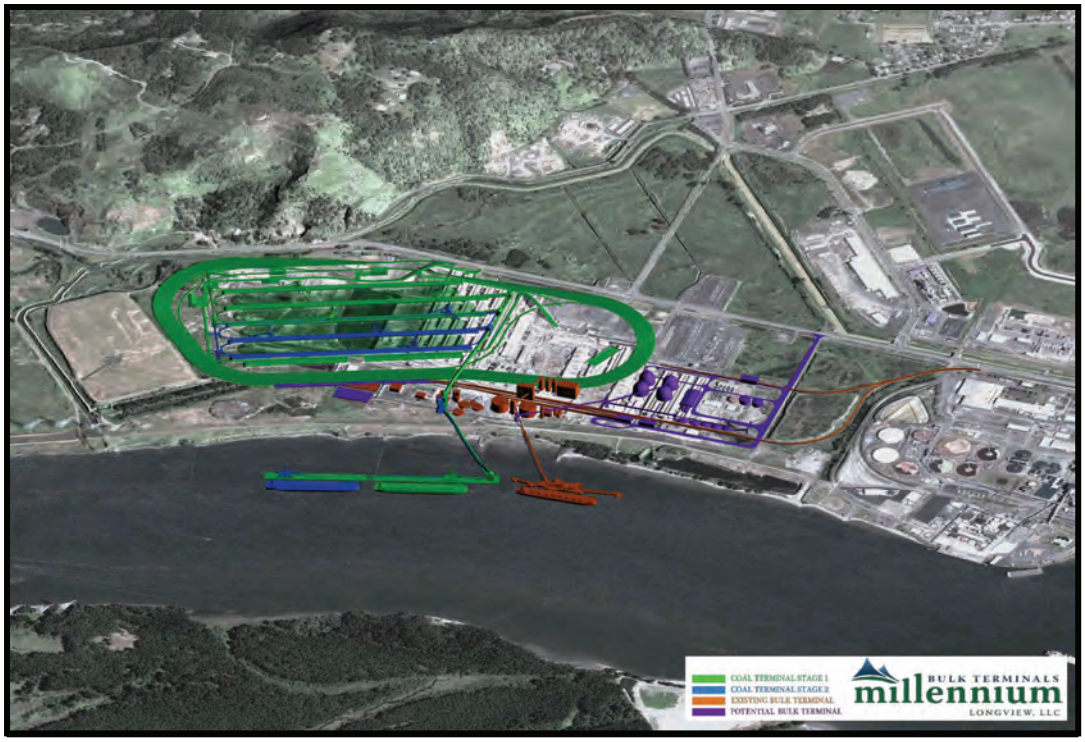
[25] PIT March 2012 Application, Chapter 4.5 Terminal Operations, Tables 4-2 and 4-5.

5. Longview, WA

In February 2012, Millennium Bulk Terminals Longview, LLC (MBTL), submitted several permit applications in order to seek permission to build a $643 million coal terminal on a 416 acre site on the Columbia River near Longview, Washington, which, by 2018, would handle 48.5 million tons per year.[26] MBTL is a Limited Liability Company (LLC) with two shareholders. Ambre Energy owns 62 percent of the shares and Arch Coal, Inc., the second largest U.S. coal producer, owns the remaining 38 percent.[27] Longview is served by both BNSF and UP. The Longview Switching Company (LSC) is a jointly owned subsidiary of BNSF and UP that performs terminal switching duties at the Port of Longview.[28] The following is a site rendering of the proposed Longview terminal:

Figure 8

Site Rendering of Longview Terminal



[26] See study prepared by Berk titled: *Economic & Fiscal Impacts of Millennium Bulk Terminals Longview*, dated April 12, 2012 (44 million metric tonnes).

[27] http://ambreenergy.com/projects/millennium

[28] Washington State Statewide Rail Capacity and System Needs Study dated May 2006, page 15.

6. Grays Harbor, WA (Hoquiam)

RailAmerica, which owns the Puget Sound and Pacific Railroad (PSAP) that serves the Port of Grays Harbor, near Hoquiam, Washington, has been actively exploring an export coal terminal. RailAmerica states that the Port of Grays Harbor "is the only deep-draft shipping port on Washington's coast, only 2 hours from open sea."[29] RailAmerica states that this would be a "relatively small project" ($45 Million) with a capacity of 5 million metric tons (5.5 million short tons).[30] PSAP connects with UP at Blakeslee Jct., Washington and with BNSF at Centralia, Washington.

7. Coos Bay, OR

The Port of Coos Bay, Oregon is considering an international shipping terminal. Coos Bay is served by Coos Bay Rail Link (CORP). The Oregon International Port of Coos Bay bought the 126-mile railroad in 2009, which interchanges with BNSF (via PNWR) and UP at Eugene, OR. The line is currently in serious disrepair. The line was embargoed in 2007 and abandonment was filed in 2008. CORP plans to resume freight service, but requires significant funding to repair and upgrade 110 bridges (70 of which are in poor condition) and 9 tunnels.[31] The port has been actively negotiating with investors. David Koch, the port's CEO, states that three companies are drawing up plans for a coal terminal that could export up to 10 million tons per year. Mitsui, an international trading firm headquartered in Japan, and Metro Ports, a company that specializes in terminals, are reportedly involved in the negotiations with Coos Bay.[32]

8. St. Helens, OR (Westward)

In January 2012, Kinder Morgan Terminals and Pacific Transloading, a subsidiary of Ambre Energy, submitted a proposal to export coal from St. Helens, Oregon, Port of Westward. Ambre Energy expects to ship as much as 30 million tons from St. Helens.[33] The proposed terminal is estimated to require $150 to $200 million in capital investment for construction and development. Port of Westward is served by PNWR, which connects with both BNSF and UP at Portland, Oregon.[34]

---

29 http://www.railamerica.com/RailServices/PSAP.aspx

30 http://www.washingtonports.org/washington_ports/pgh%20newsletter%202011-08.pdf

31 See, e.g., Coos Bay Rail Link Infrastructure Evaluation Report, Revised August 20, 2010

32 See KLCC Public Radio story by Amelia Templeton titled: *International Investors Plan Coal Terminal at Coos Bay*, dated April 19, 2012. http://klcc.org/Feature.asp?FeatureID=3324

33 To date, Kinder Morgan has not released specific tonnage levels. Estimates of 15 to 30 million tons have appeared in various press reports.

34 http://portwestwardproject.com/PortWestwardFactSheet.pdf

9. Boardman, OR (Morrow)

The Port of St. Helens plans also call for a water transloading facility, which is part of the "The Morrow Pacific Project" under which PRB would be shipped by train to Morrow and from there by barge to Port Westward Industrial Park at the Port of St. Helens and then transferred directly from the barges to oceangoing vessels bound for Japan, South Korea or Taiwan.[35] Port of Morrow, near Boardman, OR, recently signed a one-year lease option with a subsidiary of Australian coal giant Ambre Energy (Coyote Island Terminal LLC of Salt Lake City) to shift Montana and Wyoming coal from trains to river barges. The company wants to build a rail off-loading terminal use the area to transfer the coal onto barges for shipment to St. Helens.[36] Initially, Ambre anticipates shipping 3.5 million metric tons (3.85 short tons) of coal per year to trade allies such as Japan, South Korea and Taiwan beginning as soon as mid-2013. Full operational and permitted capacity is expected to be 8 million metric tons (8.82 short tons) annually, subject to approval.[37] Port of Morrow is served by UP.

[35] http://morrowpacific.com/
[36] *Ibid*.
[37] http://morrowpacific.com/wp-content/uploads/2012/04/Morrow_Pacific_Project-Packet.pdf

Powder River Basin Coal

Steam coal can originate from many areas in the U.S., but it is expected and probable that the vast majority of the PNW export coal shipments will originate from the PRB coal mines and origins in Montana and Wyoming, which is the largest coal mining region in the United States.[38] As a result of the economics associated with mining the large seams of PRB coal, the price of PRB coal is the lowest in the United States. The following table compares the price of PRB coal with coal prices from other western coal origins. As can be seen, the low-cost PRB coal dominates the western coal market:

Figure 9

Western Coal Price Comparison[39]

Origin	Tons (Millions)	Average Sale Price
PRB Coal Origins		
Campbell County, WY	392.6	$12.05
Montana	44.5	$15.20
Other Western Coal Origins		
Sweetwater, WY	8.8	$32.09
Colorado	24.9	$40.00
Utah	19.0	$29.15

1. PRB Coal Mines and Origins

The PRB area in Montana and Wyoming, is dominated by several large coal companies. The current and proposed PRB coal mines and coal companies are listed below:

---

[38] There are also other western coal origins in southwestern Wyoming, Colorado and Utah which also could be utilized for PNW exports, but this report focuses on the PRB coal origins in Montana and Wyoming.

[39] Source: U.S. Energy Information Administration, Table 30, Average Sales Price of Coal by State, County, and Number of Mines, 2010.

Figure 10

Current and Proposed PRB Coal Mines and Origins

Railroad	Mine	Station	Coal Company
Montana PRB Coal Mines and Origins			
BNSF	Absaloka	Kuehn, MT	Westmoreland Coal Co.
BNSF	Decker	Decker, MT	Kiewit Mining Group
BNSF	Rosebud	Colstrip, MT	Westmoreland Coal Co.
BNSF	Signal Peak[40]	Roundup, MT	Signal Peak Energy
BNSF	Spring Creek	Nerco Jct., MT	Cloud Peak Energy
TRRC/BNSF	Otter Creek[41]	Ashland, MT	Arch Coal
Wyoming PRB Coal Mines and Origins			
BNSF	Buckskin	Buckskin, WY	Kiewit Mining Group
BNSF	Clovis Point	Clovis Point., WY	Wyodak Resources
BNSF	Dry Fork	Dry Fork Jct., WY	Western Fuels
BNSF	Eagle Butte	Eagle Jct., WY	Alpha Natural Resources
BNSF	Rawhide	Rawhide, WY	Peabody Energy
BNSF/UP	Antelope	Converse Jct., WY	Cloud Peak Energy
BNSF/UP	Belle Ayr	Belle Ayr, WY	Alpha Natural Resources
BNSF/UP	Black Thunder	Black Thunder, WY	Arch Coal
BNSF/UP	Caballo	Caballo Jct., WY	Peabody Energy
BNSF/UP	Cordero Rojo	Cordero/Rojo, WY	Cloud Peak Energy
BNSF/UP	Coal Creek	Coal Creek, WY	Arch Coal
BNSF/UP	North Antelope Rochelle	Nacco Jct., WY	Peabody Energy
BNSF/UP	School Creek	Thunder Jct., WY	Peabody Energy
BNSF	Youngs Creek[42]	Decker, MT	Consol Energy

[40] Signal Peak is not technically in the PRB. The bituminous coal from Signal Peak is considered high-quality, producing higher heat and lower mercury than PRB coal. However, it is being marketed for the Pacific Rim and lies within the scope of the rail system being studied.

[41] The Otter Creek property near Ashland, Montana contains significant (731 million tons) coal reserves, which were recently obtained by Arch Coal. The Otter Creek mine would be served by the Tongue River Railroad Company (TRRC), a proposed 89-mile new coal line in Montana which would connect with BNSF's mainline at Miles City, Montana. Arch has not yet filed an application for a mine permit with the Montana Dept. of Environmental Quality.

[42] CONSOL of Wyoming LLC, and Chevron NPRB, LLC, have formed a new company, Youngs Creek Mining Company, LLC. to develop and operate the proposed Youngs Creek mine north of Sheridan, Wyoming. Youngs Creek mine has coal reserves of approximately 315 million tons. Based on initial feasibility studies, the mine has the potential to reach 15 million tons per year when at full production. This would require building a short spur line which would connect to BNSF's line near Decker, Montana. Youngs Creek is already permitted by the Wyoming Department of Environmental Quality.

2. PRB Railroad Coal Lines

The PRB coal mines are located on six (6) current lines and one (1) proposed line in Montana and Wyoming:

Figure 11

PRB Railroad Coal Lines

From	To	Railroad	Miles	Mines
Shawnee Jct. WY	Campbell, WY	BNSF/UP	140.2	10
Eagle Butte Jct., WY	Campbell, WY	BNSF	25.6	5
Spring Creek, MT	Dutch, WY	BNSF	22.8	2
Kuehn, MT	Sarpy Jct.	BNSF	37.4	1
Big Sky, MT	Nichols, MT	BNSF	39.0	1
Signal Peak, MT	Broadview, MT	BNSF	35.0	1
Ashland, MT	Miles City, MT	TRRC/BNSF	89.0	1

The largest PRB coal volumes currently originate from the so-called "Joint Line" from Shawnee Jct., to Campbell, WY, which is served by both BNSF and UP.[43] In 2011, the PRB coal mines in Wyoming originated 422 million tons whereas the mines in Montana originated 22 million tons.[44]

3. Current PRB Coal Market & Destinations

PRB coal movements are voluminous and repetitive. PRB coal production was approximately 444 million tons in 2011 and could exceed 500 million in a few years.[45] Currently, approximately 80 loaded coal trains move out of the PRB each day.

---

[43] Under a Joint Line Agreement between BNSF and UP, the two railroads jointly serve the large coal mining operations on the line, which mine the "Wyodak" PRB coal seam. The BNSF's Orin Subdivision Line runs from Donkey Creek Jct., WY (MP 0.4) to Bridger Jct., WY (MP 127.3), which is approximately 127 miles (126.9). The portion of the line which is jointly owned and maintained by BNSF and UP (i.e., the Joint Line) actually runs 103 miles from MP 14.7 near Caballo Jct. to the interchange with UP at Shawnee Jct., WY (MP 117.7) . This study looks at the characteristics of the line from Campbell, WY (which is 3.5 miles before Donkey Creek Jct.) to the UP interchange at Shawnee Jct., which is a total of 120.8 miles.

[44] Source EIA-423 Monthly Non Utility Fuel Receipts and Fuel Quality Data for 2011.

[45] Source EIA-423 Monthly Non Utility Fuel Receipts and Fuel Quality Data for 2011.

The majority of these PRB coal trains move *south* from the BNSF/UP Joint Line in Wyoming and then either: south, east or west to numerous domestic destinations (168 destinations in 2011) stretching from Arizona to New York.[46] In comparison, very little coal traffic currently moves *northwest* from the PRB to PNW destinations. For example, only 6 million of the 444 million 2011 PRB coal tons, or 1.3%, moved to destinations in Washington and Oregon.

As a result of the expected increase in demand for export coal and a gradual decrease in demand from domestic users, a significant *shift* in PRB railroad coal traffic from current domestic destinations (e.g., less economical in eastern destinations such as New York and New Jersey) to the PNW export terminals will likely take place. [47] The following table shows the wide-distribution of PRB domestic coal tons to electric generating stations in 2011:

[46] *Ibid*.

[47] There are several other factors which have resulted in a decrease in demand for domestic coal, such as: the boom in availability of low cost natural gas; proposed new rules by the U.S. Environmental Protection Agency (EPA) to bring new coal-fired electric power plants in compliance with the Federal Clean Air Act and Clean Water Act.; increasing competitiveness of renewable energy sources; investments in energy efficiency, and the economic downturn - all of which have combined to affect a drop in domestic demand for coal.

Figure 12

2011 Distribution of PRB Coal Tons

Destination States	PRB Tons From:	
	Montana	Wyoming
2011 PRB to PNW Coal Tons		
Oregon	108,462	2,243,208
Washington	2,436,289	1,180,782
Total to OR and WA	**2,544,751**	**3,423,990**
2011 PRB Coal Tons to Other Destination States		
Alabama	0	12,315,605
Arizona	761,439	5,818,897
Arkansas	0	17,497,425
Colorado	0	9,516,900
Georgia	0	13,619,370
Illinois	237,701	61,291,247
Indiana	0	9,836,466
Iowa	0	23,799,910
Kansas	0	19,962,502
Kentucky	0	2,638,466
Louisiana	0	11,452,691
Maryland	0	582,606
Michigan	2,109,260	17,142,197
Minnesota	6,709,385	9,321,579
Mississippi	0	986,649
Missouri	0	44,227,641
Montana	8,405,469	0
Nebraska	0	13,732,077
Nevada	0	1,361,874
New Jersey	0	14,308
New York	0	2,020,463
North Dakota	0	301,381
Ohio	369,947	4,967,528
Oklahoma	13,967	18,884,374
Pennsylvania	0	378,352
South Dakota	0	1,676,078
Tennessee	0	9,409,077
Texas	0	62,096,767
Wisconsin	394,779	20,097,511
West Virginia	0	487,784
Wyoming	0	23,106,731
Total to Other States	**19,001,947**	**418,544,456**
Total 2011 PRB Coal Tons		
Total PRB Coal	**21,546,698**	**421,968,446**

4. Current PRB to PNW Coal Movements

Currently, approximately 10 to 12 million tons of coal per year move in railroad trains through the impacted PNW area, which is a significant volume, but small in comparison to the expected 75 to 175 million tons of PNW export coal traffic. There are only two (2) active coal fired generating stations which currently receive coal in unit trains from PRB mines:

Centralia, WA - In 2011, 3.5 million tons of coal moved via BNSF from PRB mines in Montana and Wyoming to Transalta's coal-fired Centralia generating station, which is Washington State's largest base-load power source with a capacity of 1,376 megawatts. The Centralia plant provides 10 percent of Washington State's power. In April 2011, legislation was passed which will close the plant by 2025.[48]

Boardman, OR - In 2011, 2.3 million tons of coal moved via BNSF and UP from PRB mines in Montana and Wyoming to Portland General Electric's (PGE) coal-fired Boardman generating station, which has a 585-megawatt capacity. In 2010, PGE announced plans to close Boardman by 2020.[49]

In addition to the domestic PRB coal traffic to these PNW plants, there is also current export coal (approximately 3 to 5 million tons), which currently moves through the PNW to the British Columbia export terminals (primarily Roberts Bank, BC). The current PRB to PNW coal traffic utilizes many of the same railroad line segments which will be used to haul the export coal traffic.

5. Projected PRB Export Coal Tons

As a result of the expected dramatic increase in demand for export coal, PRB coal production is likely to increase, but, because of the decrease in demand from domestic users, a significant *shift* in PRB traffic can also be expected. PRB coal production was approximately 445 million tons in 2011. PRB coal production could exceed 500 million, but the estimated demand for 75 to 170 million tons will likely result in shifting traffic from current destinations (e.g., less economical movements to New York and New Jersey) to the PNW. The following projections of the annual coal volumes from these railroad coal lines were used in this report:

---

[48] On April 29, 2011, Gov. Chris Gregoire signed Senate Bill 5769 into law a collaborative agreement to close Centralia's two coal boilers – the first in 2020 and the second in 2025.

[49] On December 29, 2010, Oregon's Environmental Quality Commission unanimously approved Portland General Electric plan to close the state's only coal-fired power plant by Dec. 31, 2020 in exchange for a far smaller investment in pollution controls.

Figure 13

Projected Annual PRB to PNW Coal Tons

(Millions of Short Tons)

Railroad Coal Lines	2017	2022
Shawnee Jct. ("Joint Line")	20.0	35.0
Eagle Butte Jct., WY	25.0	45.0
Total From Wyoming Origins	**45.0**	**80.0**
Spring Creek, MT [50]	15.0	25.0
Big Sky, MT	0.0	5.0
Kuehn, MT	0.0	5.0
Signal Peak, MT	15.0	15.0
Ashland, MT (TRRC)	0.0	40.0
Total From Montana Origins	**30.0**	**90.0**
Total to PRB to PNW Export Coal Tons	**75.0**	**170.0**

[50] Includes projected tonnage from Youngs Creek Mine in Wyoming.

Impacted Railroad Routes

Currently, two Class I railroads dominate the western coal market as well as all rail shipments from the PRB to the PNW - BNSF and UP. Although UP also has access to the PRB coal origins, as a result of geographical and other advantages enjoyed by BNSF, it is reasonable and logical to assume that BNSF will dominate the PRB to PNW export coal market.

1. BNSF Market Domination

UP has access to Longview, but does not serve Cherry Point. BNSF's routes associated with its longest PRB movements to Longview are at least 200 miles shorter than UP's routes from the PRB.[51] BNSF's unit costs are also lower than UP's cost. BNSF's expected domination of the PRB to PNW export coal market can be seen by the current coal movements to PGE's Boardman generating station. Although Boardman is served by UP and has in years past received coal directly from UP via the PRB Joint Line and UP's routes, BNSF currently originates all the coal movements to Boardman (2.1 million tons) and interchanges the traffic with UP at Spokane, WA for delivery to Boardman.

Due to the expected large coal volumes, it is likely that all of BNSF's PRB coal origins, including the Joint Line origins, will be involved at some point in export coal movements to the PNW. However, the BNSF/UP Joint Line is already near capacity (primarily from existing coal traffic moving south on the line and then east and south to coal-fired generating stations) and there are several closer BNSF-served Montana origins (such as Signal Peak, MT), which will likely originate more of the export PNW coal as a result of the shorter distances.[52]

The following table compares the estimated total delivered cost for BNSF and UP PRB to PNW export coal movements and illustrates the economic advantages enjoyed by BNSF:

---

[51] UP shipped 1.5 million tons of export coal in 2010, but expects exports to increase. Morrow, Coos Bay or St. Helens would be the most likely PNW destinations for UP. It is possible that UP could more effectively compete with BNSF for the Asia export market with non-PRB coal shipments from southern WY (Green River coal area) or UT (Uinta coal area). For example, the mileage from Hanna, WY to Longview, WA is approximately 200 miles shorter than BNSF's miles from Antelope, WY (which is on the Joint Line) to Longview, WA. However, this study concentrates on potential export coal movements from the PRB to the PNW and these potentially alternative western coal movements (which would have substantially different characteristics, e.g., cost, sulfur content, btu., etc, and rail routings) have not been studied here.

[52] Russian energy trader, Gunvor, recently invested $400 million to take a 33% stake in the Signal Peak coal mine in Montana and expects to increase production from 9 million to 15 million tons by exporting coal to Asia through Westport, BC.

Figure 14

BNSF & UP PRB to PNW Export Coal
Estimated Delivered Cost Comparison [53]

Item	Amount
Shortest BNSF Joint Line Movement (Caballo Jct.) to Longview, WA	
Coal Price Per Ton (Campbell County, WY)	$12.05
Route Miles	1,318
BNSF 2010 URCS Variable Cost Per Ton (120 Cars)	$18.65
Rate Per Ton (at 180% R/VC)	$33.57
Total Delivered Cost	$45.62
Shortest BNSF PRB Movement (Signal Peak) to Longview, WA	
Coal Price Per Ton (Montana)	$15.20
Route Miles	1,135
BNSF 2010 URCS Variable Cost Per Ton (120 Cars)	$16.18
Rate Per Ton (at 180% R/VC)	$29.12
Total Delivered Cost	$44.32
Shortest UP Joint Line Movement (Antelope) to Longview, WA	
Coal Price Per Ton (Campbell County, WY)	$12.05
Route Miles	1,582
UP 2010 URCS Variable Cost Per Ton (120 Cars)	$20.96
Rate Per Ton (at 180% R/VC)	$37.73
Total Delivered Cost	$49.78

As can be seen, the added distance associated with UP's route places UP in significant economic disadvantage with BNSF (i.e., UP $49.78 versus BNSF $44.32 to $45.62 per ton).

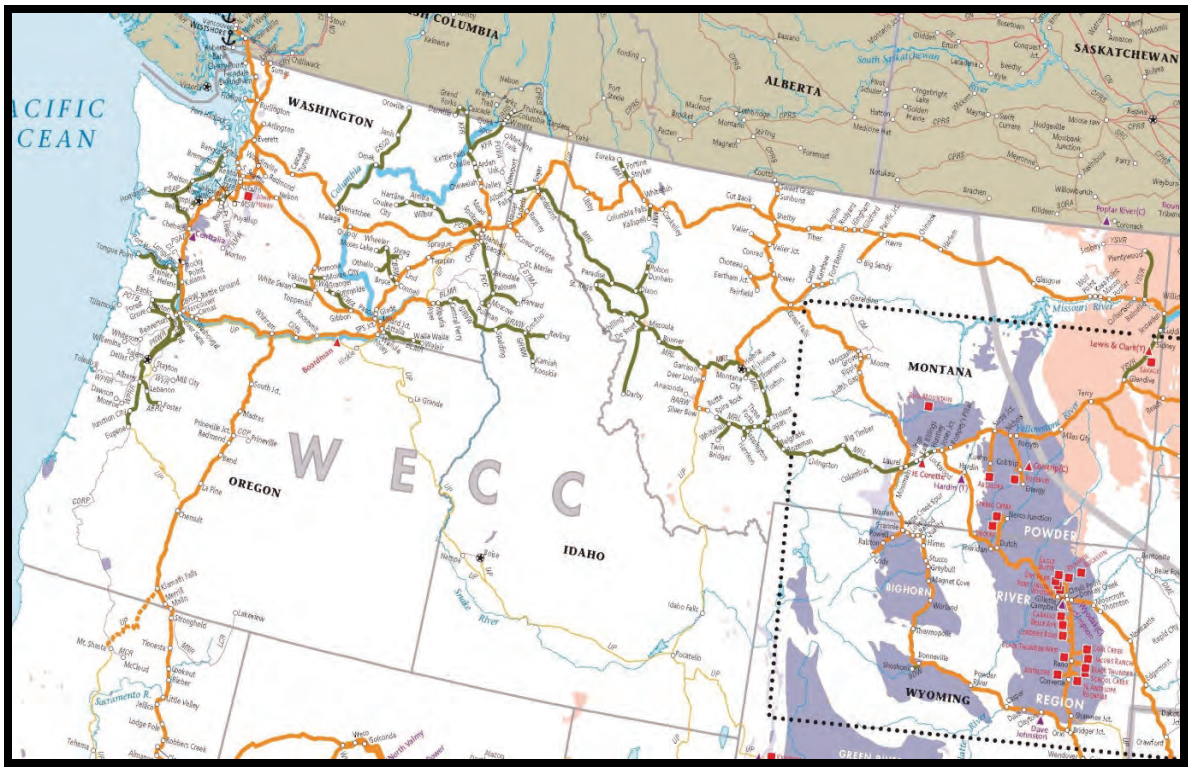
[53] Costs are based on STB's Uniform Railroad Costing System (URCS) 2010 unadjusted unit cost data for BNSF and UP. Rail rates are based on a 180% revenue-to-variable cost ratio, which is the STB's jurisdictional threshold level.

2. BNSF Railroad Routes Impacted

The possible railroad routes of movement and the individual railroad line segments which would likely be involved in coal movements from PRB coal mines to PNW export coal terminals have been carefully evaluated and studied for this report. These routes are expansive and cover a total distance of over 4,000 miles.[54] The vast majority of PRB export coal traffic would likely move north via BNSF from PRB mines in Wyoming and Montana, through Montana, Idaho and Washington to the PNW export coal terminals in Washington and Oregon.[55] The following is a portion of BNSF's system map which shows an overview of BNSF's routes from the PRB to the PNW:

Figure 15

BNSF's PRB to PNW Routes



[54] The over 4,000 route miles which will be potentially impacted excludes potential coal movements via UP's southern routes through Wyoming, Colorado, Utah , Idaho and Oregon and the miles in British Columbia to Prince Rupert, which were not part of this study.

[55] There are other BNSF routing options, such as the movement south from the PRB mines and then west with the utilization of UP's routes west though Colorado, Utah and then north through Idaho and Oregon (BNSF has trackage rights over a portion of the UP's Central Corridor route), but these other routing options are more circuitous.

As can be seen from Figure 14, BNSF's PRB to PNW routes are expansive, stretching from eastern Wyoming to the Pacific coast. These rail routes traverse many environmentally sensitive areas, such as Glacier National Park in Montana, as well as many major populated areas, such as Billings, Montana and Spokane, Washington. Most export coal movements from Montana and Wyoming would move north and connect with and utilize most of the western portion of BNSF's heavily utilized Great Northern Corridor, which runs from the PNW to Chicago, IL. Most of the freight moving along BNSF's Great Northern Corridor is consumer, industrial and agricultural products, such as double-stack intermodal container traffic and export grain traffic. Passenger trains such as Amtrak's Empire Builder and Cascades in the Northwest; and commuter trains, including Sound Transit in Washington, use the Great Northern Corridor. In addition, there are a growing number of unit-train tank car movements of oil from the Bakken shale formation in North Dakota and Montana to PNW destinations which are and will be increasing using this important corridor.[56]

3. BNSF's Routing Options

BNSF does have the benefit of have several viable routing options, which may lessen the impact on certain areas, but also significantly broadens the impact area. For example, the shortest rail distance is from Eagle Butte Jct., WY to Longview, WA which is 1,313 miles, but BNSF's viable routing options cover a distance of 2,321 miles. BNSF has two viable routing options in Montana and three routing options in Washington from Spokane:[57]

a. **BNSF/MRL Helena Route -** Montana Rail Link's (MRL) 564.2 mile line from Mossmain, MT (near Billings) to Sandpoint, ID runs through Helena and Missoula, MT and reconnects with BNSF at Sandpoint, ID. MRL, which is owned by Washington Companies, assumed control of the western portion of BNSF's mainline in Montana in 1987. MRL is considered a "bridge carrier" for BNSF as it only connects with BNSF at Huntley, MT and Sandpoint, ID and BNSF retains ownership of the MRL lines. BNSF and MRL have a long-term lease purchase plan for MRL to acquire the line. The MRL route is approximately 100 miles shorter than the BNSF route. BNSF currently uses MRL route to move the current PRB to PNW coal traffic to Centralia and Boardman, as well as grain traffic to the PNW and other traffic.

---

[56] For example, in July, 2011, Tesoro Corp. announced that it intends to move 30,000 barrels per day (or approximately 50 loaded cars per day) of Bakken oil by rail in a dedicated unit trains to the Anacortes, Washington refinery and expects to spend $50 million on the project.

[57] BNSF has other available routing options, such as moving east or south and then west, but these routes are significantly more circuitous and thus not economically viable.

b. **BNSF Great Falls Route -** BNSF's northbound line from Mossmain, MT through Great Falls, which connects to BNSF's main east-west "Hi-Line" at Shelby, MT. Although the BNSF/MRL Helena route is approximately 100 miles shorter, as a result of the expected high volumes, it is likely that both of these routes will be heavily utilized by BNSF for export coal shipments.

c. **Stevens Pass / Cascade Tunnel -** BNSF's northern line from Spokane through Wenatchee, WA connecting with BNSF's north-south line along the coast at Everett, WA. This mainline, which passes through the Cascade Tunnel, is BNSF's major transcontinental route for double-stack intermodal container trains. Currently, this line has a capacity of 24 to 28 trains per day and is operating at 57 percent to 75 percent capacity.[58]

d. **Columbia River Gorge -** The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Columbia River Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the PNW ports, and other carload traffic. The line is operating today at about 80 percent of practical capacity with an estimated capacity of 40 trains per day.[59]

e. **Stampede Pass & Tunnel -** The Stampede Pass route moves south from Spokane and then west through Yakima, connecting with BNSF's north-south line along the coast south of Seattle, WA (Auburn). The line passes through the Stampede Tunnel and operates at a lower capacity because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains and the grades over the Stampede Pass also make it difficult to haul heavily-loaded unit trains. As a result, BNSF could use the Columbia River Gorge or Steven Pass / Cascade Tunnel routes for loaded trains and the Stampede Pass route for empty trains.[60]

---

[58] Washington State 2010-2030 Freight Rail Plan, page 3-28.

[59] *Ibid*.

[60] *Ibid*. It should be noted that these three (3) alternative routes in Washington have some common line segments. For example, both the Stampede Pass and Columbia River Gorge routes would use the line segment from Spokane to Pasco, WA and the Stevens Pass/Cascade Tunnel and Stampede Pass routes would use the line from Auburn to Longview, WA.

4. Mileage Differences For BNSF Routing Options

The following table shows the mileage differences for the six different viable routing options available to BNSF for export coal movements from Antelope, WY to Longview, WA:

Figure 16

BNSF Routing Options For Export Coal Movements
From Antelope, Wyoming to Longview, Washington

Route	Miles
From Antelope, WY to Spokane, WA	
Via BNSF/MRL Helena Route	966
Via BNSF Great Falls Route	1,064
From Spokane, WA to Longview, WA	
Via Columbia River Gorge Route	403
Via Stevens Pass / Cascade Tunnel Route	479
Via Stampede Pass Route	493
From Antelope, WY to Longview, WA	
Via BNSF/MRL Helena & Columbia River Gorge Routes	1,368
Via BNSF/MRL Helena & Stevens Pass/Cascade Tunnel Routes	1,445
Via BNSF/MRL Helena & Stampede Pass Routes	1,459
Via BNSF Great Falls & Columbia River Gorge Routes	1,467
Via BNSF Great Falls & Stevens Pass/Cascade Tunnel Routes	1,543
Via BNSF Great Falls & Stampede Pass Routes	1,558

As can be seen, the shortest route to Longview would involve the utilization of the MRL line in Montana and the Columbia River Gorge line in Washington (1,368 miles) whereas the longest route would involve BNSF's line through Great Falls and its Stampede Pass route in Washington (1,558 miles).[61] The economics would generally favor the shortest routes, however, because of the massive volumes expected, it is likely that all of the routing options will be utilized to a certain extent which will likely result in congestion problems for all the routes.

[61] For Cherry Point, which is in northern Washington, the shortest route would involve the BNSF/MRL Helena and Stevens Pass/Cascade Tunnel routes.

5. Impacted Railroad Line Segments

The characteristics of the identified railroad line segments will be described in more detail herein. The following is a list of the major railroad line segments in Wyoming, Montana, Idaho, Washington and Oregon which could be impacted by various degrees by the expected increase in export coal movements from PRB to PNW:

Figure 17

Railroad Line Segments Impacted

Section	Line Segment	Railroad	Miles[62]
1.	Shawnee Jct., WY to Campbell, WY ("Joint Line")	BNSF/UP	140.2
2.	Eagle Butte Jct., WY to Campbell, WY	BNSF	25.6
3.	Campbell, WY to W. Dutch, WY	BNSF	100.5
4.	Spring Creek, MT to W. Dutch, WY	BNSF	22.8
5.	W. Dutch, WY to Huntley, MT	BNSF	138.9
6.	Big Sky, MT to Nichols, MT	BNSF	39.0
7.	Ashland, MT to Miles City, MT	TRRC	89.0
8.	Miles City, MT to Nichols, MT	BNSF	51.6
9.	Nichols, MT to Sarpy, Jct., MT	BNSF	16.4
10.	Kuehn, MT to Sarpy Jct., MT	BNSF	37.4
11.	Sarpy Jct., MT to Huntley, MT	BNSF	66.1
12.	Huntley, MT to Mossmain, MT	BNSF/MRL	24.8
13.	Mossmain, MT to Broadview, MT	BNSF	35.8
14.	Signal Peak, MT to Broadview, MT	BNSF	35.0
15.	Broadview, MT to Great Falls, MT	BNSF	188.0
16.	Great Falls, MT to Shelby, MT	BNSF	99.1
17.	Shelby, MT to Sandpoint, ID	BNSF	337.9
18.	Mossmain, MT to Sandpoint, ID	MRL	564.2
19.	Sandpoint, ID to Spokane, WA (Latah Jct.)	BNSF	70.5
20.	Spokane, WA (Latah Jct.) to Everett, WA (PA Jct.)	BNSF	301.1
21.	Spokane, WA (Latah Jct.) to Pasco, WA (SP&S Jct.)	BNSF	149.4
22.	Pasco, WA (SP&S Jct.) to Vancouver, WA	BNSF	219.8
23.	Vancouver, WA to Longview, WA	BNSF	35.4
24.	Vancouver, WA to Portland, OR	BNSF	9.9
25.	Pasco, WA (SP&S Jct.) to Auburn, WA	BNSF	227.5
26.	Auburn, WA to Centralia, WA	BNSF	72.6
27.	Centralia, WA to Longview, WA	BNSF	47.1
28.	Auburn, WA to Everett, WA (PA Jct.)	BNSF	55.6
29.	Everett, WA (PA Jct.) to Intalco, WA	BNSF	78.3
30.	Intalco, WA to Cherry Point, WA	BNSF	8.9
31.	Intalco, WA to British Columbia Terminals	BNSF/CN	49.7
32.	Centralia, WA to Port of Grays Harbor, WA	PSAP	59.0
33.	Spokane, WA to Hinkle, OR	UP	171.0
34.	Hinkle, OR to Boardman, OR	UP	20.0
35.	Portland, OR to Boardman, OR	UP	164.0
36.	Portland, OR to St. Helens, OR (Port Westward)	PNWR	56.0
37.	Portland, OR to Eugene, OR	UP	124.0
38.	Eugene, WA to Coos Bay, OR	CORP	122.0
	Total Railroad Route Miles		**4,054.1**

[62] Includes route miles and mileage of connecting lines.

Projected Traffic Flow

The following charts show the impacted line segments and the potential the routing options and choke points:

Figure 18

Projected Traffic Flow From PRB Coal Mines to Spokane, WA

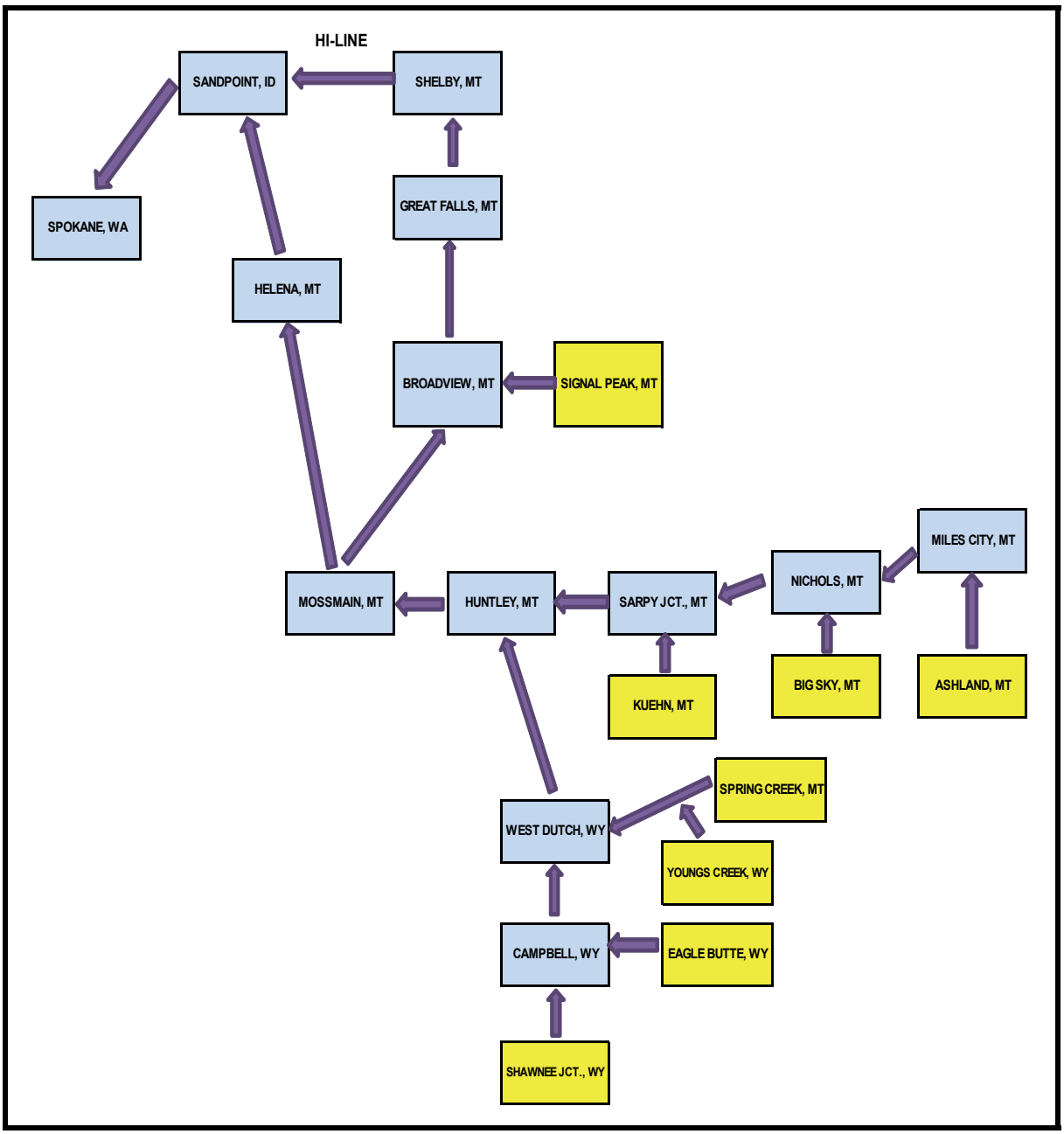
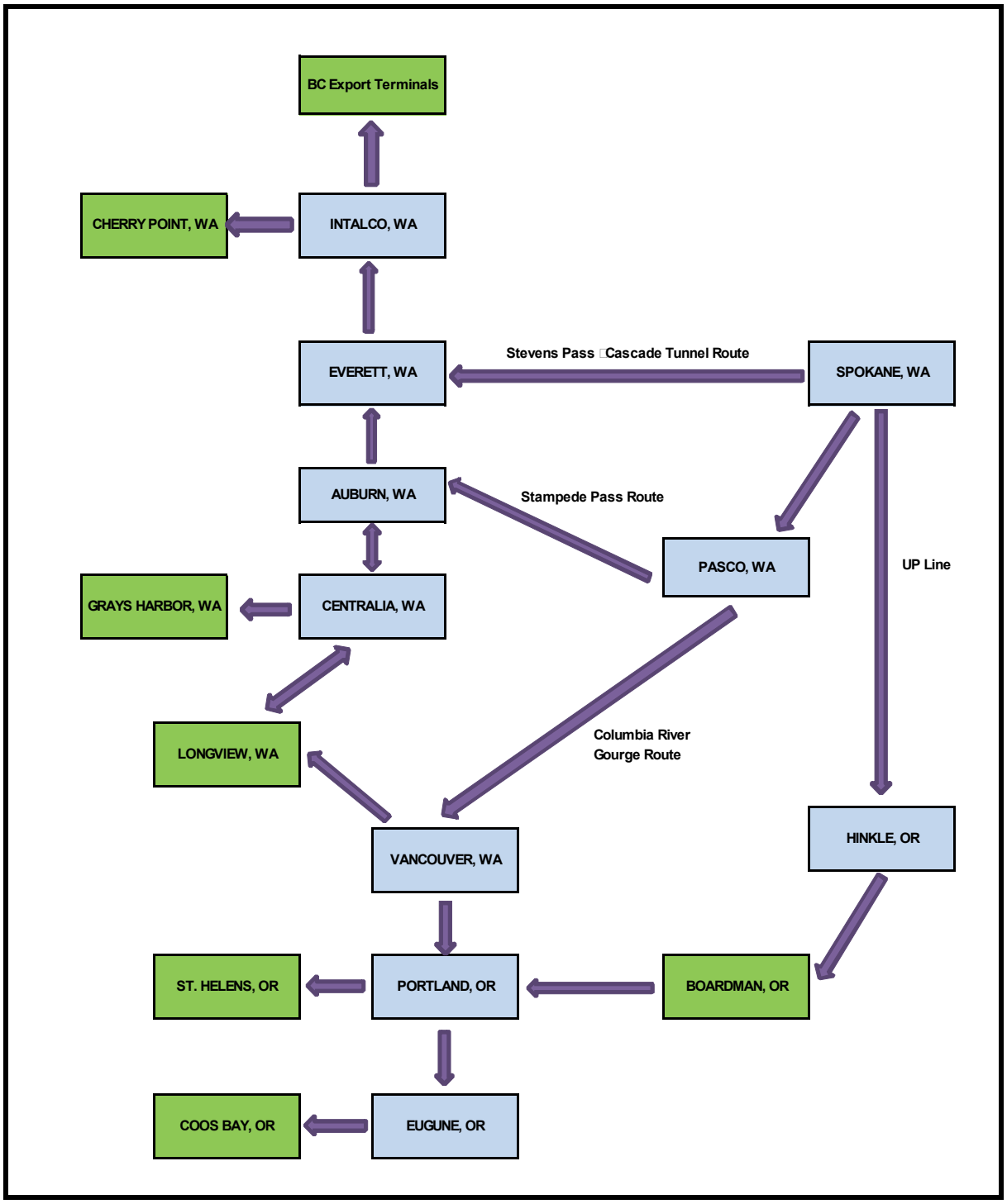


Figure 19

Projected Traffic Flow From Spokane, Washington
To PNW Export Coal Terminals



Major Choke Points & Bottlenecks

As indicated by Figures 17 and 18, the majority of the PRB coal shipments (all but Signal Peak) will converge at Huntley, MT and move to Mossmain, MT, where there is the routing option of either the shorter MRL route through Helena or the longer BNSF route through Great Falls, MT. All PRB coal shipments would then meet again at Sandpoint, ID and converge at Spokane, WA. Although BNSF has routing options from Spokane, WA, there are problems associated with each option, such as existing congestion on the Stevens Pass/Cascade Tunnel and Columbia River Gorge routes and the restrictions associated with the Stampede Pass route.

BNSF's internal routing options will help distribute the tonnage and could help lessen the impact in certain areas, however, the expected large coal volumes will likely result in congestion problems for the entire route. As illustrated by previous flowcharts (Figures 17 and 18), there are two key line segments which will carry nearly *all* the coal traffic and represent major choke points and bottlenecks:

Huntley, MT to Mossmain, MT (Billings) (BNSF/MRL - 24.8 Miles) - Coal shipments from the BNSF/UP Joint Line coal origins or the BNSF served origins would converge at Huntley, MT (Jones Jct.).[63] From Huntley the coal would move 24.8 miles on the MRL line to Mossmain, where it could then move on BNSF's direct route or via the shorter MRL route. It is projected that 22.3 to 57.6 PRB to PNW export coal trains per day will move over this line segments through Billings.

Sandpoint, ID to Spokane, WA (BNSF - 78.3 Miles) - The MRL route from Mossmain would converge with BNSF-direct coal from Shelby at Sandpoint, ID and move on the BNSF line to Spokane, WA. *All* (100%) BNSF export coal to the PNW would likely move over this 78.3 mile line segment. This line is commonly known as the "*Funnel*," and is the second-busiest rail corridor in Washington. It is projected that 27.9 to 63.2 PRB to PNW export coal trains per day will move through Spokane.

[63] The only exception would be Signal Peak, which is served by a new 35-mile spur, which connects to BNSF's line north of Mossmain near Broadview, MT, thus avoiding the bottleneck from Huntley to Mossmain.

Major Traffic Congestion Areas

In addition to these major choke points, there are also several sections in the routings which are already congested and may not be able to adequately handle the expected large volumes of export coal:

BNSF/UP Joint Line - Currently, the majority of PRB coal (357.1 million tons in 2010) originates on the high-density BNSF/UP Joint Line or Orin Subdivision Line, which runs 120.8 miles from an interchange with UP at Shawnee Jct., WY north to Campbell, WY. This line is already near capacity. In addition, most of the coal from the Joint Line moves south whereas as most PRB to PNW coal traffic would move north, which could cause operational problems on the Joint Line.

BNSF "Hi-Line" - BNSF export coal shipments would connect to its mainline, (known as the "Hi-Line") at Shelby, MT and move west to Sandpoint, ID and beyond. This is one of BNSF's heaviest used mainline, carrying intermodal container trains and west-bound grain shipments. The additional PRB to PNW export coal trains will add 14.9 to 29.7 trains per day to the already congested Hi-Line.

Stevens Pass / Cascade Tunnel - BNSF's Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major northern transcontinental route for double-stack intermodal container trains. It is heavily used, operated at about 70 percent of practical capacity in 2008.

Columbia River Gorge - The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Columbia River Gorge, is used by double-stack intermodal container trains moving east and grain trains moving west to PNW export grain terminals. The line is operating today at about 80 percent of practical capacity.

North-South I-5 Corridor - BNSF's line connecting Seattle with Portland, OR, is the most heavily trafficked rail line in Washington State, conveying BNSF and UP trains (the latter via trackage rights) to and from the major PNW ports. The corridor hosts an average of 58 freight trains each day. PRB to PNW export coal tons will move over this route from Vancouver, WA to Longview and between Longview, WA and Seattle, WA.

Rail Capacity Issues

This report carefully examines and describes these 38 impacted railroad line segments covering over 4,000 route miles in more detail herein. In addition to the obvious environmental and traffic concerns, the expected large coal volumes will result in several major choke points and bottlenecks and will likely cause congestion problems for the entire route. These choke points and congestion areas will be described in more detail herein. The two major cities that will be the most adversely impacted in terms of the expected export coal trains per day are: Spokane, Washington (pop. 208,916) and Billings, Montana (pop. 104,170). Nearly every PNW to PRB loaded and empty coal train will move through these two cities (63.2 trains per day through Spokane and 57.6 trains per day through Billings).[64]

Many of the impacted railroad line segments already have significant rail capacity and congestion issues associated with the current rail traffic, such as PNW import and export intermodal container traffic and grain railroad traffic. For example, for many years there have been rail traffic congestion problems and capacity issues associated with the rail lines between Sandpoint, ID to Spokane, WA, which is appropriately named "*The Funnel*" as four rail lines converge at Spokane and any east/west shipments must travel through the Funnel. It is the second-busiest rail corridor in the state of Washington and hosts an average of 46 freight trains each day, along with daily operation of Amtrak's Empire Builder service connecting Seattle and Portland to Chicago.[65]

Over a decade ago, State, regional and local agencies in Washington and Idaho worked with BNSF, UP and others in developing an infrastructure and capital spending plan called "*Bridging the Valley*," which involved the separation of railroad and roadway grades and increasing the capacity of the line from Spokane, Washington to Athol, Idaho.[66] The improvements were originally designed to handle a gradual growth in intermodal and grain traffic of up to a total of 70 trains per day. However, the expected rapid growth in PRB to PNW export coal traffic was not envisioned or considered when these improvements were first designed (2000) and approved (2006). Now, in few short years, instead of the expected 70 trains per day, Spokane could see more than 130 trains per day, or 5.42 trains per hour moving through the city.

---

[64] It is projected that all PRB to PNW export coal trains would move over the line from Sandpoint, ID to Spokane, WA, which is known as the "Funnel." With the exception of coal from the Signal Peak, MT mine, all other PRB to PNW coal trains would move over the Huntley, MT to Mossmain, MT line, which runs through Billings, MT.

[65] Washington State 2010-2030 Freight Rail Plan, December 2009, Appendix 3-B32 Appendix 3-B: Railroad History, Profiles, Service Corridors, & Safety Regulatory History.

[66] See, for example, Spokane Regional Transportation Council site: http://www.srtc.org/btv.html

Clearly, the Bridging the Valley plans and other similar infrastructure improvement plans are obsolete and will have to be reconsidered and significantly revised based on the expected growth in PRB to PNW export coal traffic.

The railroad traffic and associated problems in Billings, the largest city in Montana, have been the issue of many studies over the years. In 2004, the City of Billings, with Federal funding, conducted a Railroad Crossing Feasibility Study.[67] The 2004 report stated that the growth of rail traffic "has resulted in traffic slowdowns, safety hazards and air pollution." The report also concluded that the rail lines through Billings have "created a barrier" and "have played a role in the development and continuation of a social divider between downtown Billings and surrounding neighborhoods." The report looked at various alternatives to improving railroad traffic problems and made recommendations and recommended improved signage, signal controls and other low-cost improvements, as well as an underpass under the railroad tracks crossing 27th street combined with a small track shift appeared, to be the best alternative. It estimated that the cost would be approximately $20 million.

The 2004 Billings report was based on an estimated 30 trains per day through Billings. This traffic level, however, excluded the unexpected rapid growth in PRB to PNW export coal traffic, which could result in an additional 22.3 to 57.6 loaded and empty coal trains per day through Billings. The report also failed to reflect the significant increase in Bakken oil shipments, many of which move to three refineries around Billings or through Billings to Cushing, Oklahoma and other destinations, and the related rail shipments of tubulars, fracturing sand and other supplies into the Bakken, which have resulted in additional loaded and empty trains moving through Billings. With the added export coal trains and the existing coal, grain, intermodal, Bakken oil and other rail traffic already moving from, to and through Billings, there could be as many as 60 to 90 trains per day moving through the city in the near future.

In addition to potential improvements to downtown railroad crossings, the 2004 Billings report considered several options which involved major track relocations, which it estimated would cost between $60 and $150 million. These track relocation options involved possible by-passes around Billings (south of I-90, north of I-90 and north of Billings) and the relocation of MRL's switching yard in Billings. The report concluded that there would be major impacts associated with the track relocation options and they were too costly. Undoubtedly, Billings transportation planners will have to reevaluate these track relocation and by-pass options.

---

[67] See: http://ci.billings.mt.us/DocumentView.aspx?DID=8159

Several other cities along the route have examined their railroad traffic and congestion issues in the past and will be impacted by the increased movements. Helena, Missoula, Great Falls and other cities in Montana have task forces that have studied the problems associated with increased rail movements. These cities have rail yards and main rail routes that traverse through the heart of their towns. Additionally, the Montana and Washington Departments of Transportation have had continued involvement in studying rail movements, traffic densities, congestion and capacity issues.

As a result of these capacity and congestion problems, there are many areas which will require major upgrading and expansion of existing railroad tracks. In some cases (such as Spokane and Billings) new rail by-passes may be required around populated areas. It is likely that hundreds of miles of railroad lines will require expansion from single to double or even triple track. Other railroad infrastructure, such as bridges, tunnels, high-way crossings, will also need to be replaced or upgraded in order to adequately, efficiently and safely handle the expected traffic levels.

The required upgrading and expansion of railroad tracks and related infrastructure could well cost billions of dollars. State and local governments will likely be called upon to bear the brunt and burden of these related costs local costs and will likely be required to spend hundreds of millions of dollars in related mitigation, litigation, debt and other costs associated with the necessary improvements to accommodate export coal traffic levels.

Impacted Railroad Traffic

Many of the impacted rail lines are already at or near capacity. Even with substantial infrastructure improvements, such a significant increase in export coal rail tonnage and coal trains (as well as related construction projects) will likely significantly interrupt and disrupt other railroad traffic lanes. Existing rail traffic, such as export grain traffic and import and export intermodal container traffic, will likely experience a deterioration of rail service, such as higher transit and cycle times, and will likely incur higher costs in the form of higher freight rates and equipment costs.

PRB to PNW export coal traffic (which will move in efficient unit trains and, in most cases, involve shorter distances) will likely be significantly more profitable than the existing PNW import/export intermodal container traffic and as or more profitable than PNW export grain traffic. As a result of the economics (high volume and revenues), PRB to PNW export coal movements will likely be favored by the railroads over other types of existing railroad traffic. The remaining capacity available to other railroad shippers will be limited, constrained and more expensive. As a result, railroad freight rates for other traffic will increase, which will be an additional benefit for the railroads.

The increase in export coal traffic will likely create numerous railroad shipping and logistic problems and result in increased costs and railroad rates for other shippers as a result of rail congestion and the limitations on available rail capacity. Railroad transit times will likely increase for other railroad traffic as a result of congestion and it may be forced to move over more circuitous routes, which will increase private railroad equipment utilization and related costs.

1. PNW Import and Export Intermodal Container Traffic

Although the Port of Los Angeles and Long Beach, CA handles the largest number of import and export containers (approximately 33% of the total U.S. container traffic), a significant amount of container traffic moves inbound and outbound from the PNW Ports of Seattle, Tacoma and Portland. In 2009, over 3 million containers or TEU's (twenty-foot equivalent units) were handled by these PNW Ports. BNSF also dominates this PNW intermodal container traffic, which will also likely be adversely impacted by the increase in congestion on BNSF's Hi-Line and the impacted lines in Washington and Oregon. PNW container volumes recently increased after cargoes were shifted from Southern California to PNW due to continuing congestion problems in Southern California and the search for new gateways by shippers and carriers.

As export coal trains consume the remaining rail capacity, intermodal transit times to and from PNW ports will be adversely impacted which will reduce the ability of the PNW container ports to compete with the Southern California ports. The following table shows and compares BNSF's current service goal hours for intermodal traffic from S. Seattle, WA and Los Angeles, CA to Chicago, IL:

Figure 20

Comparison of BNSF Intermodal
Service Goal Hours For Movements To Chicago, IL

From	To	BNSF Service Goal Hours [68]		
		Premium COFC	Expedited COFC	Expedited TOFC
S. Seattle, WA	Chicago, IL	85	79	79
Los Angeles, CA	Chicago, IL	84-92	78	78

As can be seen, BNSF's service goal hours for movements of intermodal containers and trailers on flat cars from S. Seattle, WA to Chicago, IL are currently approximately the same as the hours from Los Angeles, CA. This transit time from S. Seattle will be adversely impacted by the added rail congestion resulting from the increased export coal movements, which will reduce the ability to compete with the Southern California ports.

The ability of PNW intermodal container ports to compete with the expanding Canadian Port of Prince Rupert, B.C. will also be hurt. As a review of various comments filed in response to the Federal Maritime Commission's (FMC) Notice of Inquiry, U.S. Inland Containerized Cargo Moving Through Canadian and Mexican Seaports, demonstrates, the recent growth of Trans-Pacific services through Prince Rupert is due "in substantial part to the transportation advantages of that service, especially the shorter ocean transit time from Asia, and the excellent rail connection and service from the railroad(s) providing service from that port into the U.S. Midwest."[69] As was also repeatedly stressed, the primary considerations affecting the ports used for cargo imported to the U.S. are market-driven.

---

[68] Source: BNSF. COFC = Container on Flat Car. TOFC = Trailer on Flat Car

[69] Joint Comments Submitted by World Shipping Council, The National Industrial Transportation League, and National Retail Federation, at p. 2.

Hence, the "business requirements of U.S. importers for timely, efficient and cost-effective service that will satisfy their delivery requirements are paramount considerations."[70] In other words, speed to market will increasingly play a major role in causing shippers to route cargo through maritime gateways in Canada.

Given the need for fast, reliable supply chains for container shipments, of which the railroads are a major component, a substantial increase in the number of coal trains will further clog BNSF's congested lines and will provide an economic incentive to shippers to divert containerized traffic to the Port at Prince Rupert and to Canadian National Railway Company (CN). As CN observed in its Comments, once its recent acquisition of the Elgin, Joliet and Eastern Railway Company (EJ&E) has been fully integrated, it "will allow CN to move trains from the congested downtown Chicago area onto the EJ&E line circling the city" and enable it to provide seamless service from Prince Rupert to customers located throughout the eastern part of the U.S.[71]

In his response to the FMC's inquiry into possible cargo diversion, Tay Yoshitani, Chief Executive Officer of the Port of Seattle, pointed out that "Washington is the most trade-dependent state in the nation" and that the Port of Seattle is "a primary economic engine for Washington State, generating nearly 200,000 jobs and $867 million in state and local tax revenue."[72] He also observed that "foreign cargo is crucial to the state's future competitiveness, because cargo creates jobs, and because farmers and other manufacturers across Washington need the robust infrastructure a strong import trade creates – without it, they cannot get their goods to markets across the globe."

Plainly, if the west-bound movement of coal disrupts the frequency and reliability of inbound and outbound shipments of containerized traffic, that traffic likely will be diverted to Canadian ports where it will not be impacted by the congestion caused by the increased coal shipments. Unfortunately, no similar relief will be accorded outbound movements of agricultural products and other goods manufactured in Washington. As a result, the warehousing, distribution and transloading centers, third party logistics companies and brokers at the Port of Seattle who offer services and facilities to shippers will also be harmed. Therefore, it is imperative that the total consequences of moving coal to PNW export terminals must be carefully explored.

---

[70] Id.at 6.
[71] CN Comments at 4.
[72] Letter to Secretary Gregory dated January 9, 2012

2. PNW Export Grain Traffic

In 2011, U.S exports of corn, wheat and soybeans to Asia exceeded 60 million tons. The majority of this export grain traffic moved from PNW export terminals, primarily located in and around Vancouver, WA, Kalama, WA, Tacoma, WA, Portland, Oregon and other PNW destinations. BNSF dominates this transportation market with significant railroad grain movements, such as wheat movements from Montana, soybean movements from North Dakota and corn movements from Iowa.

The following table shows the total railroad agricultural shipments (Farm Products - STCC 01) moving to PNW destinations in 2010:[73]

Figure 21

2010 Railroad Shipments of
Farm Products (STCC 01) to PNW Destinations

Commodity	STCC	Carloads	Tons	Railroad Revenue
Soy Beans	01-144	129,580	14,152,756	$631,053,156
Corn	01-132	128,257	14,051,553	$597,014,673
Wheat	01-137	84,334	9,040,273	$300,406,569
Grain, NEC	01-139	13,240	427,024	$17,050,356
Peas, Dry Ripe	01-342	3,260	327,040	$14,496,108
Barley	01-131	4,616	240,272	$8,986,304
Beans, Dry Ripe	01-341	2,120	79,588	$3,563,960
Cottonseeds	01-141	516	29,484	$2,354,356
Total	**01**	**365,923**	**38,347,990**	**$1,574,925,482**

This railroad export grain traffic will likely be adversely impacted by the increase in congestion on BNSF's Hi-Line and the impacted lines in Washington and Oregon. In addition to the large volumes of grain moving to the PNW, the traffic also fluctuates seasonally with increased volumes taking place after the fall harvests. As a result, the traffic congestion would likely be greater during these post-harvest periods.

[73] Based on the STB's 2010 Public Waybill Sample for (BEA's 167, 168, 169 and 170)

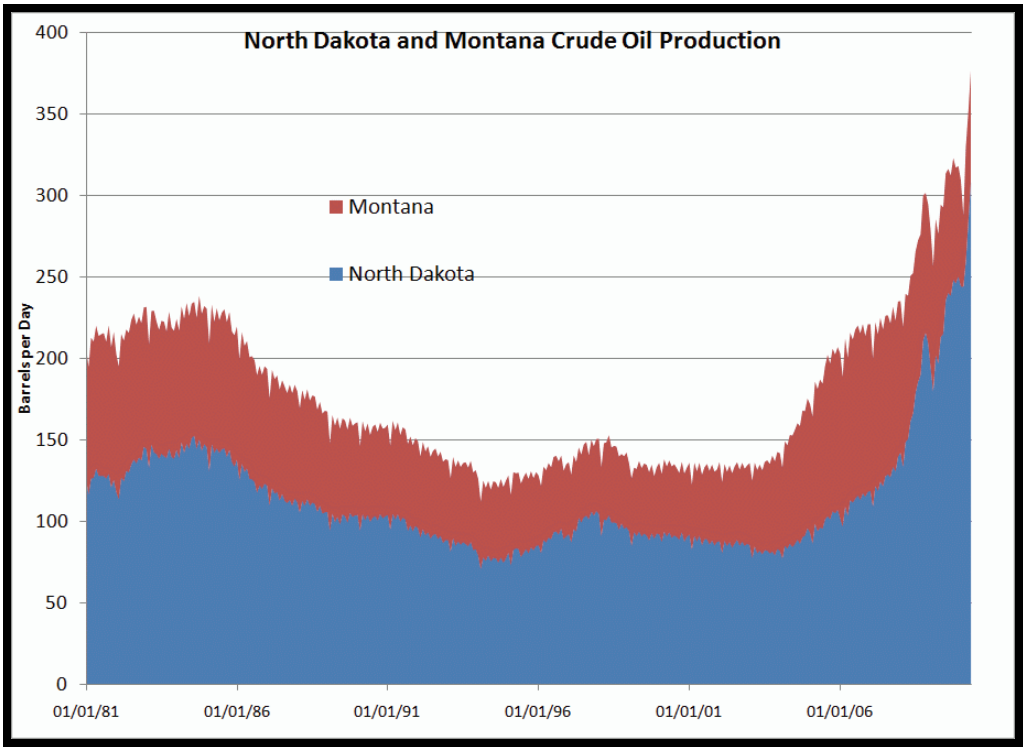
During the past decade, BNSF has increasingly promoted the use of 110-car shuttle trains for PNW export grain shipments. These shuttle trains will have to compete for capacity with the export coal unit trains, which will result in higher rates. Grain movements use a combination of privately-owned and railroad-owned covered hoppers. Transit times are likely to increase, which will increase equipment costs. Grain traffic from smaller elevators (non-shuttle elevators), such as 52-car elevators in Montana, will likely be hurt the most as BNSF will continue to favor the large shuttle facilities.

3. Bakken Oil Shipments

The Bakken Oil formation on North Dakota and Montana has been producing oil since its initial discovery in 1953, however, new discoveries coupled with the success of horizontal drilling in 1987 and the use of a new technique known as multi-stage fracturing or "fracking" in the early 2000's has resulted in an explosion of oil production from this area. The following chart shows this dramatic increase in North Dakota and Montana oil production in the last few years:

Figure 22

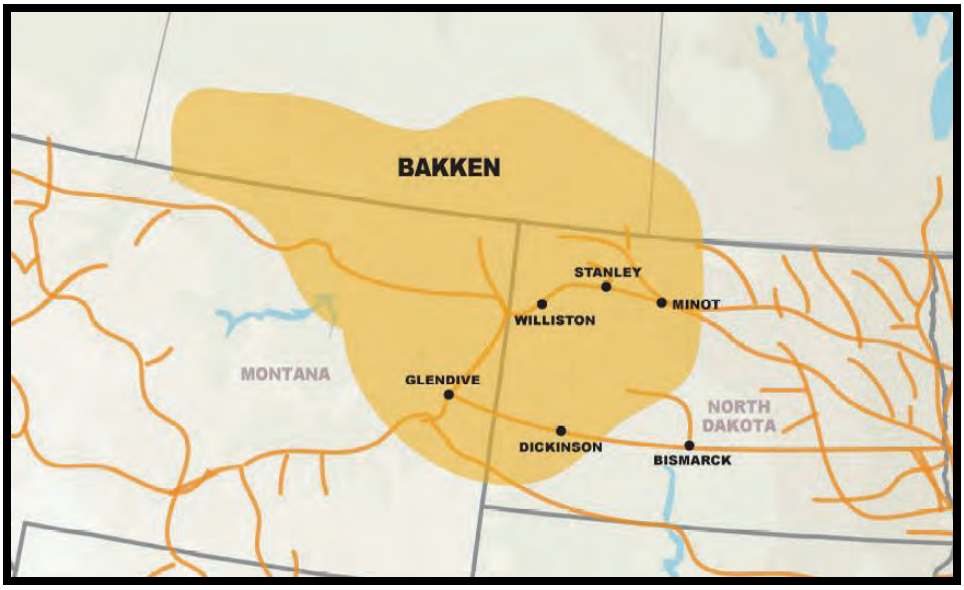
North Dakota and Montana Crude Oil Production



The railroads, especially BNSF, see this as a major growth area. BNSF estimates that nine (9) unit train loading facilities will be located in the area by 2013.[74] These facilities include: Trenton, ND, Tioga, ND, Epping, ND, and Dickinson, ND. BNSF estimates that it is positioned to transport 730,000 barrels of crude per day and that it directly serves 30% of U.S. refineries in 14 states.[75] The following map shows the Bakken area and BNSF's routes through the area:

Figure 23

BNSF's Bakken Oil Formation Service Area



A significant amount of the Bakken oil traffic will move over many of the lines that are also impacted by the increase in export coal shipments to the PNW. Bakken oil will move to refineries through-out the U.S, including the three refineries in the Billings area. Plans are also underway to move dedicated BNSF unit trains of Bakken crude oil to refineries to PNW.[76]

---

[74] Presentation titled "Bakken Shale Overview" by Denis Smith, BNSF Vice President, Industrial Products Marketing, dated July 12, 2011.

[75] One 100-car unit train carries approximately 60,000 barrels. As a result, 730,000 barrels would equate to over 12 unit trains per day.

[76] In July, 2011, Tesoro Corp. announced that it intends to move 30,000 barrels per day (or approximately 50 loaded cars per day) of Bakken oil by rail in a dedicated unit trains to its 120,000 barrels per day refinery in Anacortes, WA and expects to spend $50 million on the project. Shell Oil also has a large refinery in Anacortes (147,500 barrels per day). In addition, to the two refineries in Anacortes, there are two large refineries in Ferndale, WA (i.e., BP Oil – 232,000 barrels per day and ConocoPhillips – 101,000 barrels per day), which is close to Cherry Point, WA. In addition, there is a small refinery in Tacoma, WA (US Oil & Refining Co. – 36,250 barrels per day).

Bakken oil will also move to Gulf coast refineries, such as those located in Houston, TX, Beaumont, TX, Port Arthur, TX, Lake Charles, LA and St. James, LA. One major BNSF destination is Cushing, OK, which is a crude-oil epicenter that is connected to a pipeline network tied to many major U.S. markets. Bakken oil shipments to Cushing would move through Billings. In fact, MRL's Billings yard has become a staging yard for Bakken oil tank cars over the last 24 months. This trend should continue as one of BNSF's major routes for getting Bakken oil to distribution points such as Cushing is through Billings and Laurel and down the west side of the Big Horn Mountains.

4. Passenger & Commuter Traffic

Passenger and commuter rail traffic will also be disrupted by the increased rail congestion caused by the increase in export coal trains. Amtrak's Empire Builder travels daily along BNSF's routes between Chicago, Illinois and Seattle, Washington and Portland, Oregon. Amtrak serves many stations along the impact route, including: Shelby, MT, Cut Bank, MT; Browning, MT; East Glacier Park, MT; Essex, MT; West Glacier, MT; Whitefish, MT; Libby, MT, Sandpoint, ID; Spokane, WA; Pasco, WA; Wishram, WA; Bingen, WA; Vancouver, WA; Portland, OR; Ephrata, WA; Wenatchee, WA; Leavenworth, WA; Everett, WA; Edmonds, WA and Seattle, WA. This Amtrak service is likely to be disrupted and impacted by the increase in congestion.

Amtrak also operates Amtrak Cascades Intercity Passenger Rail, which is sponsored by ticket-buying passengers, the states of Washington and Oregon, and Amtrak. Amtrak Cascades service operates on the same railroad tracks as freight trains, makes a limited number of stops, and connects central cities between Vancouver, B.C. and Eugene, OR.

Sound Transit's Sounder Commuter offers commuter rail service between Tacoma and downtown Seattle with stops in Puyallup, Sumner, Auburn, Kent, and Tukwila, and between Everett and downtown Seattle with stops in Edmonds and Mukilteo. It shares the same railroad tracks as freight trains and Amtrak. In contrast to Amtrak, Sounder commuter rail makes frequent stops along the 70-mile corridor between Everett and Tacoma, with service currently provided only during the weekday morning and evening commute hours. Sounder commuter trains make additional stops along the route at Mukilteo, Auburn, Kent, Sumner, Puyallup, and Tacoma's Tacoma Dome station.

Major Track and Infrastructure Improvements are Required

Many of the impacted railroad tracks are already at, near or exceed capacity and the existing infrastructure needs significant upgrades and improvements in order to handle the existing traffic and relieve existing congestions.[77] For example, BNSF's Stevens Pass / Cascade Tunnel route across Washington is already nearing capacity and BNSF has been forced to route intermodal trains south via the circuitous I-5 rail corridor to Vancouver (WA) and then east, which has added considerable volume to the Vancouver-Pasco line along the Columbia River Gorge, and made the scheduling of trains moving through the Gorge and along the I-5 rail corridor more complex. BNSF's rail routes will require major upgrading and expansion of existing railroad tracks, bridges, tunnels, high-way crossings and other infrastructure in order to adequately and safely handle such high annual volumes. Most of the infrastructure improvements related to coal movements made by BNSF and UP in recent years have focused on the east bound coal traffic lanes. As a result of the expected increase in PRB coal traffic to the PNW, many of the north-west bound line segments will require substantial infrastructure improvements and modifications in order to adequately handle the expected export coal volumes.

In 2007, the Association of American Railroads (AAR) released the National Rail Freight Infrastructure Capacity and Investment Study, which was an assessment of the long-term capacity expansion needs of the continental U.S. freight railroads and provided an approximation of the rail freight infrastructure improvements and investments needed to meet the U.S. Department of Transportation's (U.S. DOT) projected demand for rail freight transportation in 2035. The report included the following approximation of the capacity associated with various track configurations:

[77] e.g., see, December 2009, Washington State 2010-2030 Freight Rail Plan, which identified numerous existing rail bottlenecks and over 100 required capital improvement projects throughout the state.

Figure 24

Practical Track Capacity (Trains Per Day)

Number of Tracks	Train Control	Trains Per Day	
		Lower Bound	Upper Bound
1	No Signal and Track Warrant Control (NS-TWC)	16	20
1	Automatic Block Signaling (ABS)	18	25
2	No Signal and Track Warrant Control (NS-TWC)	28	35
1	Centralized Traffic Control (CTC)	30	48
2	Automatic Block Signaling (ABS)	53	80
2	Centralized Traffic Control (CTC)	75	100
3	Centralized Traffic Control (CTC)	133	163
4	Centralized Traffic Control (CTC)	173	230
5	Centralized Traffic Control (CTC)	248	340
6	Centralized Traffic Control (CTC)	360	415

These AAR standards were used in the evaluation of the capacity of the studied line segments associated with the potential PRB to PNW export coal movements. In numerous instances, the existing traffic levels fall within (and in some cases already exceed) these capacity ranges and the addition of the expected PRB to PNW export coal trains per day will exceed the existing capacity.

Railroad by-passes and track relocations in and around major populated areas, such as Spokane and Billings, may also be required. For example, in 2004, a by-pass around Billings was estimated to cost between $60 and $150 million. The majority of the impacted line segments are single track, which has a capacity ranging from 16 to 48 trains per day depending on the type of train control. Based on AAR's capacity standards, over 800 route miles (or approximately 20% of the route miles) will need to be expanded to double track in order to expand the capacity to efficiently and safely handle the expected volumes. Based on AAR's estimate of cost $3.8 million per mile, it would cost over $3 billion to double track 800 miles.

For example, most of the 149.4-mile line segment from Spokane, WA to Pasco, WA is single track with CTC.[78] According to Washington State, this line segment has an average utilization of 32 trains per day, which is within the 30 to 48 trains per day range for single track with CTC. However, the expected PRB to PNW export coal will add an additional 15.0 to 32.7 loaded and empty coal trains per day, which will likely exceed the 48 trains per day capacity. As a result, it is likely that this entire 149.4-mile segment will likely require double track with CTC.

There are also over 800 miles of road which have not been upgraded to Centralized Traffic Control (CTC), which would probably be required for many of these lines. The largest of these non-CTC line segments are the key line segments from Mossmain, MT to Shelby, MT, which runs 322.9 miles through Great Falls, MT. AAR estimates that the conversion of a line to CTC can cost up to $700,000 per mile, which would equate to over $500 million. In addition to installing double tracks and CTC, there are numerous bridges, tunnels, grade crossings and other railroad-related infrastructure which will need to be expanded, upgraded or rebuilt to efficiently and effectively move the expected coal volumes from the PRB to PNW.

The costs associated with the required infrastructure improvements will certainly be in the billions. In 2009, the State of Washington identified over 100 capital improvement projects and other initiatives and estimated the cost to exceed $2 billion, but Washington's estimate did not reflect the potential impact associated with a significant increase in railroad shipments of export coal. The total required improvements in Washington, Oregon, Montana, Wyoming and Idaho could well exceed $5 billion. This report includes a separate evaluation of the identified 38 individual line segments, which generally describe the required improvements associated with each line segment.

[78] The line includes approximately 10.9 miles of double track.

Environmental Impacts

The movement of 75 to 170 million tons per year would equate to the movements of 27.86 to 63.15 loaded and empty coal trains per day. These repetitive 1¼-mile long loaded and empty coal trains will be going through numerous populated cities, towns, communities (such as Spokane, Washington, Seattle, Washington, and Billings, Montana and Portland, Oregon), parks, forests, historical areas and other environmentally sensitive areas (such as Glacier National Park in Montana). As indicated Governor Kitzhaber's recent letter requesting a full EIS of the proposals, there are environmental concerns associated with: protection of water quality, including risk of spills; impacts to listed protected fish species; coal dust emissions at the facilities and during product transport; emissions of other air pollutants, including diesel particulate, ozone, mercury and greenhouse gases; and increased rail traffic, noise and delay times for communities along the proposed lines, including emergency vehicles at rail crossings.[79]

Although BNSF's shortest PRB to PNW railroad route (Signal Peak, MT to Longview, WA) covers a distance of 1,135 miles, there are 7 PRB existing and proposed coal lines in Wyoming and Montana which will likely be used and 9 existing and proposed PNW export coal terminals stretching from Prince Rupert, British Columbia to Coos Bay, Oregon. In addition, BNSF has several available routing options in Montana and Washington, which could lessen the impact on certain areas, but also significantly broadens the total impact area. As a result, the total rail route miles potentially impacted cover an extremely broad impact area covering a total rail distance of over 4,000 miles. The impacted railroad route miles would directly impact over 48,977 acres based on a 100 ft. right-of-way (ROW), as well as the adjoining and surrounding areas. These routes and impacted areas are described in more detail herein.

The PNW destination areas and communities in Washington, Oregon and British Columbia will obviously be adversely impacted by the increase in coal trains and pollution from coal dust and diesel fumes. Meeting these PNW export coal goals will also likely require coal companies to open brand new areas of mining and expand existing PRB coal mining operations in Montana and Wyoming, which could further increase air pollution, jeopardize water quality and require the industrialization of thousands of acres of agricultural land and wildlife habitat. The impacted areas will experience blocked vehicular traffic crossings and related traffic congestion, as well as an increase in related traffic accidents, injuries and deaths. The increase in export coal traffic could also adversely impact wildlife, pollute the air and ground, create noise and result in numerous other environmental problems along the entire route.

---

[79] Letter from Governor John A. Kitzhaber dated April 25, 2012. Evaluating and quantifying the environmental impacts while they exist, is beyond the scope of this analysis.

Economic Impacts

In addition to the related environmental problems, however, there will be significant economic impacts. The railroads, terminals companies and coal companies plan to spend millions in expanding and upgrading the PNW export terminals. For example, Millennium Bulk Terminals is proposing to spend $600 million terminal for the proposed Longview export coal terminal.[80]

However, there are many areas along the railroad routes which will require major upgrading and expansion of existing railroad tracks and related infrastructure which could well cost billions of dollars. In some cases new rail by-passes may be required around major populated areas. Hundreds of miles of railroad lines will likely require expansion from single to double or even triple track. Other railroad infrastructure, such as bridges, tunnels, high-way crossings, will also need to be replaced or upgraded in order to adequately, efficiently and safely handle the expected increase in traffic levels.

State and local governments will likely bear the brunt and burden of these related local infrastructure costs and will likely be required to spend hundreds of millions of dollars in related mitigation, litigation, debt and other costs associated with the necessary improvements to accommodate export coal traffic levels.

Railroad shippers will also likely experience higher costs in terms and railroad rates, charges and related expenses. Many of the impacted rail lines are already at or near capacity. Even with substantial infrastructure improvements, such a significant increase in export coal rail tonnage and coal trains (as well as related construction projects) will likely significantly interrupt and disrupt other railroad traffic lanes and consume the majority of the existing rail capacity. Existing rail traffic, such as export grain traffic and import and export intermodal container traffic, will likely experience a deterioration of rail service, such as higher transit and cycle times, and will likely incur higher costs in the form of higher freight rates and equipment costs.

[80] http://millenniumbulk.com/wp-content/uploads/pdfs/BerkStudy.pdf

Regulatory Review & Mitigation

There are many areas along the impacted railroad routes which would require significant mitigation in order to alleviate the adverse impacts associated with the significant increase in coal traffic. State and local governments and other impacted and interested parties may have little input into related rail infrastructure requirements and needs.

The new PNW export coal terminals, such as Cherry Point and Longview, will have Environmental Impact Statements (EIS) associated with the local improvements and installations. U.S. Army Corps of Engineers (USACE) will serve as the lead federal agency in the preparation of these EIS reviews. USACE may look at the cumulative impacts as required by National Environmental Policy Act (NEPA), however, USACE has no authority over interstate railroad movements.[81]

The U.S. Surface Transportation Board (STB) is an economic regulatory agency that Congress has charged with resolving railroad rate and service disputes and reviewing proposed railroad mergers. The STB has often been involved in cases which involved mitigation resulting from increased railroad traffic levels and has been involved in several cases involving the proposed expansion of PRB coal movements.

For example, in the 1995 railroad merger between UP and Southern Pacific (UP/SP), the city of Reno, Nevada, along with many other cities and impacted parties, protested the merger, which required STB approval, because of the predicted 40 to 50 trains per day which would run through town as a result of the merger. Mitigation for Reno was a very expensive undertaking because the railroad tracks run through the heart of Reno's casino district. Several alternatives were considered and discarded, including track relocation or by-pass and a tunnel. After a decade of litigation and negotiations, an agreement was finally reached to excavate a 2.25-mile long, 33-feet-deep, and 54-foot-wide trench through the city, which was not completed until 2005. The Reno trench cost an estimated $265 million (excluding debt), of which the railroad contributed only $17 million.[82]

---

[81] Recently, the EPA requested that USACE conduct a "thorough and broadly scoped cumulative impacts analysis" of a project at Port of Morrow in Oregon which has "the potential to significantly impact human health and the environment." The EPA stated that the Corps should address overall impacts, including increases in greenhouse gas emissions, rail traffic and mining activity on public lands.

[82] See *Railway Age* article by Willie Albright: We told you so - Predictions of calamity was not enough to derail Reno's runaway train trench. Now what ?, published July 11, 2011.

Although Reno was forced to spend millions in order to mitigate the adverse impact resulting from the UP/SP merger and the railroad's portion of the total cost was relatively small, Reno did obtain the benefit of STB-ordered mitigation. STB ordered relief which was intended to preserve the "environmental status quo." As a result, UP was forced to negotiate and Reno had some leverage in its subsequent negotiations.

Previous other potential expansions of railroad PRB coal movements have also been under the jurisdiction of, and the subject of approval by, the STB, namely:

- **DM&E -** The application filed by the Dakota, Minnesota & Eastern Railroad Corporation (DM&E) to construct and operate 280 miles of new rail line and the rehabilitation of approximately 600 miles of existing rail line in Wyoming, South Dakota, and Minnesota;[83] and

- **TRRC** - The Tongue River Railroad Company (TRRC), which involves the construction of an 89-mile coal line from Ashland, MT to Miles City, MT.[84]

In both the DM&E and TRRC cases, the railroads projected the movement of million tons of coal through either populated or environmentally sensitive areas, or both. As a result, STB identified and examined potential environmental and economic impacts associated with the project and ordered hundreds of environmental conditions.

For example, in the DM&E case, the STB prepared a Draft and a Final Environmental Impact Statement (EIS). The STB conducted biological surveys for threatened and endangered species and cultural resource surveys for archaeological sites and historic structures. Additionally, the STB gathered extensive data on air quality, crossing safety and potential

---

83 DM&E filed an application for the expansion with the STB) on February 20, 1998. The STB subsequently approved DM&E's application in 2001. In 2007, the Canadian Pacific (CP) acquired DM&E. To date, no action has been taken on the construction of the line since CP's acquisition of DM&E.

84 A new coal line in Montana, which would be operated by the Tongue River Railroad Company (TRRC), has been proposed and approved for construction by the STB which would connect with BNSF's mainline at Miles City, MT. TRRC was first applied for regulatory approval in 1983 and has been the subject of numerous STB decisions and modifications. A recent agreement between one of the major opponents, billionaire Forrest Mars, and BNSF and Arch Coal, appears to have limited the proposed rail route to the 89-mile line from Ashland, MT to Miles City, MT. After a recent ruling in the 9th Circuit Court of Appeals, the STB in June reopened the Ashland to Miles City segment permit to require a revised application that reflects current plans to ship coal west to ports and the agency will conduct an environmental review of the revised project.

delays, railroad and vehicular traffic volumes, wetlands and aquatic resources, noise receptors, wildlife migration, and potential impacts to ranching operations.

There was extensive public involvement in the development of the original EIS. STB worked with five cooperating Federal agencies, conducted dozens of meetings and received approximately nearly 10,000 comments from agencies, elected officials, tribes, organizations, businesses, affected communities, landowners, and other members of the public. As a result, STB identified and examined potential environmental impacts associated with the project and ordered 147 environmental conditions.

The DM&E and TRRC proposals involved the construction of new rail lines in order to access PRB coal, whereas, the rail construction associated with the proposed PNW export terminals primarily involves the construction of railroad track, storage areas and unloading facilities. The required new construction may be smaller, but the size, scope and problems associated with DM&E's proposed PRB coal project are similar in many respects to the proposals to move PRB export coal tonnage to the PNW (i.e., same commodity (coal), same origin area (PRB), similar distances, similar congestion and environmental problems, etc.). Indeed, the traffic levels and adverse impacts associated with expansion of PRB to PNW export coal movements are likely bigger than the TRRC and DM&E cases combined:

Figure 25

Comparison of Projected PRB to PNW
Export Coal Volumes With DM&E and TRRC

Item	Low	High
Projected PRB to PNW Export Coal Volumes		
PRB to PNW Export Coal Tons Per Year (Millions)	75	170
PRB to PNW Export Coal Trains Per Day (L&E)	28	63
Projected DM&E PRB to U.S. Coal Volumes		
DM&E Proposed PRB Coal Tons Per Year (Millions)	20	100
DM&E Proposed PRB Coal Trains Per Day (L&E)	8	34
Projected TRRC PRB to U.S. Coal Volumes		
TRRC Proposed PRB Coal Tons Per Year (Millions)	33	44
TRRC Proposed PRB Coal Trains Per Day (L&E)	19	25

In the previous STB cases involving the expansion of PRB coal movements, i.e., DM&E and TRRC, the STB considered the "*downline*" and overall impacts associated with the proposed construction projects. Here, the size of the railroad track construction and expansion of the PNW export terminals may be smaller in comparison to the DM&E and TRRC PRB build-in proposals, but the "*upline*" and overall impacts will be much broader and more adverse to the areas along the impacted over 4,000 plus route miles.

However, the railroads, coal companies and other interested parties may resist an STB review of the cumulative impacts associated with the proposed expansion of PRB to PNW export coal movements - even though the proposed PRB to PNW export coal movements are much larger than any previous case that have been decided by the STB. Consequently, impacted and interested parties may be required to advocate and promote Federal legislation which would require a thorough STB review of the proposed cumulative impacts associated with the projected increase in PRB to PNW export coal movements.

Given the vast increase in the number of trains per day that are anticipated, it is imperative that State and local governments must be made aware that they will likely bear the brunt and burden of the local impacts. Without question, the increase will have substantial adverse environmental and economic consequences as it will increase the number of emissions, particulates, and delays in vehicular traffic. In order to address the adverse consequences, State and local governments must be prepared to seek relief from the STB and/or Congress.

The railroads, coal companies and PNW terminal companies may resist STB jurisdiction in regard to the proposed increase in PRB to PNW export coal movements and maintain that little or no mitigation is required because the railroads are not constructing a new line or merging with another railroad, but are instead constructing new facilities within existing rail corridors. However, in the event that new construction is required to reach new export terminals, that construction would likely entail an extension of a line of railroad into new territory, which would require STB approval.

In addition, the reopened TRRC proceeding opens the door for further environmental impact studies. As the Ninth Circuit recently recognized, "[t]he propose of TRRC II was to bring coal from Wyoming's PRB to the BNSF main line in Miles City, and then on to other destinations in the Midwest." (Slip Op. at 7, emphasis added). Given the absence of any prior focus on potential PNW movements, the argument can be made that the Board must perform a new cumulative impact analysis and that the shift in market destinations is a material change. (The STB ruled on June 18, 2012, to reopen the TRRC application to review the revised plans to ship the coal west.)

There are at least two STB precedents that provide some guidance regarding the STB's jurisdiction to consider the entirety of a project that is composed of both new construction and the rehabilitation and expansion of an existing line. In the DM&E case, the Board specifically rejected DM&E's argument that it lacked "jurisdiction to impose conditions related to the existing line."[85] As the Board explained, while it may not have jurisdiction over proposed improvements and upgrades of an existing line, it has jurisdiction to examine the potential environmental impacts resulting from increased rail operations over the portion of the rebuilt line as well as the impacts from the construction of the new line. As the Board further explained in slightly different terms:

> [W]e have broad power to impose conditions, so long as they are supported by the record and there is a sufficient nexus between the condition imposed and the transaction before us. Accordingly, we plainly have authority to impose mitigation to address the effects of increased operations on the existing line that would not occur but for the expansion of [the railroad's] system authorized here. (DM&E, 6 STB at 36).

It can also be anticipated that the railroad may argue that little or no mitigation is necessary and that the Board, as part of its conditioning authority, may not require the railroad to fund other than a small percentage of the cost of grade separations and other mitigation. Once again, there are two recent proceedings in which the Board required a railroad applicant to assume more than the minimal 5% of costs generally associated with the construction of grade crossing separation projects initiated at the request of a community and funded with federal highway grants.

When the Board approved the Canadian National Railroad Company's (CN) acquisition of EJ&E West Company, a wholly owned, non-carrier subsidiary of Elgin, Joliet and Eastern Railway Company (EJ&E), it reasoned that because the applicants were receiving the substantial benefit of the Board's approval of the transaction, they would be responsible for a higher share of the cost of grade-separation costs than would be the case if local governments were seeking to impose a grade-separation project on the railroad. As the STB realized in its approval of the transaction:

---

[85] Dakota, MN & Eastern RR—Construction—Powder River Basin, 6 STB 8, 36 (2002) (DM&E). In so ruling, the STB relied on prior reasoning in Burlington Northern Santa Fe Corporation, BNSF Acquisition Corp., and Burlington Northern Railroad Company—Control—Washington Central Railroad Company, 1 STB 792 (1996), aff'd City of Auburn v. STB, 154 F.3d 1025 (9th Cir. 1998), cert. denied, 527 U.S. 1022 (1999) (City of Auburn).

> . . . will change the character of the EJ&E line from a line serving local traffic that also facilitates longer-haul movements through haulage and trackage rights into a line that will be integrated into CN's North American rail network at the very heart of the system. As the Final EIS shows, this transaction would have a substantial adverse effect on vehicular traffic delays and, in some areas, regional and local mobility and safety at grade crossings. (Slip op. at 46) Thus, CN's "share of the cost should be more than the traditional railroad share for grade-separation projects." (Id.)

Although CN appealed the Board's decision, the D.C. Circuit upheld the Board's decision when it found that "the higher proportion of costs the Board imposed on Canadian National is not unusual where, as here, the railroad, as opposed to the government, proposes the action that creates the need from grade separation and where no federal funds are involved."[86] The court also found that the Board's decision to require CN to pay as much as 78.5% of the cost of one grade separation and 67% of the cost of a second grade separation was "entirely consistent with [the Board's] policy of 'requiring {railroads} to mitigate transaction-related impacts, but not pre-existing conditions." Id.

In the DM&E case, the Board also required the railroad applicant to fund more than the minimal 5% of the cost of crossing-protection upgrades on the existing line and not only on the new line. See DM&E, 6 STB at 32. Plainly, the foregoing rationale is applicable to the situation involved herein where the overall adverse impacts will be much broader and more adverse than was the case in either the EJ&E, DM&E or TRRC proceedings.

[86] Village of Barrington, Illinois v. Surface Transportation Board, D.C. Cir. No. 09-1002 (March 15, 2011), slip op. at 42.

Potential Legislation

Impacted and interested parties may want to consider seeking or promoting Federal legislation which would require STB approval for such increases in traffic levels or extensive infrastructure improvements.

For example, impacted and interested parties could seek and promote Federal legislation which would amend the Interstate Commerce Act to would require railroads, prior to engaging in extensive improvements and upgrades of an existing line that would increase the number of trains by more than a certain percentage (perhaps 25% to 50%), to notify the Board of such improvements so that the Board may determine whether such improvements and upgrades might have a significant impact on the human environment. Should it determine that the planned improvements might have a likely adverse impact, the Board shall be required to hold public hearings on the proposed project to determine the safety and environmental effects of the proposed project, including the effects on local communities, such as public safety, grade crossing safety, hazardous materials transportation safety, emergency response time, noise, and socioeconomic impacts. Should it determine after such hearings that the proposed improvements and upgrades would have an adverse impact, the Board would have jurisdiction to impose conditions that would mitigate the adverse impacts.

As an alternative approach, any increase in the number of trains above a specified percentage would establish a presumption that the project would have an adverse impact that the Board would be required to address. As noted earlier, the expected rapid growth in PRB to PNW export coal traffic was not envisioned or considered when the Bridging the Valley plan was first designed (2000) and approved (2005). Now, in a few short years, instead of the expected 70 trains per day, Spokane could see as many as 140 trains per day, or 5.83 trains per hour moving through the city. As a result, if the STB has no oversight jurisdiction to impose mitigation conditions, the State of Washington and the local communities will bear the burden of responding to the adverse environmental impacts even though they will not share in the resulting economic gains that will flow only to the railroads and the coal mines.

Conclusion & Recommendations

The movement of 75 to 170 million tons per year would equate to the movements of 27.9 to 63.2 loaded and empty coal trains per day. These repetitive 1¼-mile long loaded and empty coal trains will be going through numerous populated cities, towns, communities, parks, forests and other environmentally sensitive areas - blocking traffic, causing vehicular and railroad traffic congestion, creating logistics problems, adversely impacting wildlife, polluting the air and ground, creating noise and resulting in numerous other problems.

BNSF will likely dominate this large and expanding PRB to PNW export coal market. BNSF's routes from the PRB to the PNW are significantly shorter than UP's routes and BNSF has a lower cost structure. As a result, BNSF can provide transportation rates which are significantly lower than UP and thus will likely capture the lion's share of the expanding and lucrative PRB to PNW export coal market. BNSF's shortest PRB to PNW railroad route covers a distance of 1,135 miles, however, the potentially impacted area is extremely broad covering a total rail distance of over 4,000 miles. These railroad routes traverse many environmentally sensitive areas, such as Glacier National Park in Montana, as well as many major populated areas, such as Spokane, Washington, Seattle, Washington, and Billings, Montana and Portland, Oregon.

Many of the impacted railroad line segments already have significant rail capacity and congestion issues associated with the current rail traffic, such as PNW import and export intermodal container traffic and grain railroad traffic. As a result of these capacity and congestion problems, there are many areas which will require major upgrading and expansion of existing railroad tracks. In some cases (such as Spokane and Billings) new rail by-passes may be required around populated areas. It is likely that hundreds of miles of railroad lines will require expansion from single to double or even triple track. Other railroad infrastructure, such as bridges, tunnels, high-way crossings, will also need to be replaced or upgraded in order to adequately, efficiently and safely handle the expected traffic levels.

There are many areas along the impacted railroad routes which would require significant mitigation in order to alleviate the adverse impacts associated with the significant increase in coal traffic. The required upgrading and expansion of railroad tracks and related infrastructure could well cost billions of dollars. State and local governments will likely bear the brunt and burden of these related local costs and will likely be required to spend hundreds of millions of dollars in related mitigation, litigation, debt and other costs associated with the necessary improvements to accommodate export coal traffic levels.

The STB is an economic regulatory agency that Congress charged with resolving railroad rate and service disputes and reviewing proposed railroad mergers. The STB has often been involved in cases which involved mitigation resulting from increased railroad traffic levels. In the previous STB cases involving the expansion of PRB coal movements, i.e., DM&E and TRRC, the STB considered the overall impacts associated with the proposed construction projects. Here, the size of the railroad track construction and expansion of the PNW export terminals may be smaller in comparison to the DM&E and TRRC PRB build-in proposals, but the overall impacts will be much broader and more adverse to the areas along the over 4,000 miles of impacted rail route.

Impacted and interested parties may want to consider seeking or promoting an STB full environmental review of the effects of exporting PRB coal via PNW ports or Federal legislation which would require STB approval for such increases in traffic levels or extensive infrastructure improvements.

National Rail Freight Infrastructure Capacity and Investment Study

prepared for

Association of American Railroads

by

Cambridge Systematics, Inc.

September 2007

www.camsys.com

CAMBRIDGE SYSTEMATICS

CAMBRIDGE SYSTEMATICS

National Rail Freight Infrastructure Capacity and Investment Study

final

report

prepared for

Association of American Railroads

prepared by

Cambridge Systematics, Inc.

September 2007

www.camsys.com

final report

National Rail Freight Infrastructure Capacity and Investment Study

prepared for

Association of American Railroads

prepared by

Cambridge Systematics, Inc.
100 Cambridge Park Drive, Suite 400
Cambridge, Massachusetts 02140

date

September 2007

Table of Contents

Executive Summary **ES-1**

1.0 Objective **1-1**

2.0 Background **2-1**

3.0 Methodology **3-1**

4.0 Current Train Volumes and Capacity **4-1**
- 4.1 Primary Corridors 4-1
- 4.2 Current Volumes 4-2
- 4.3 Current Capacity 4-5
- 4.4 Current Volumes Compared to Current Capacity 4-8
- 4.5 Current Railroad Investment in Capacity 4-11

5.0 Future Train Volumes and Capacity **5-1**
- 5.1 Future Volumes 5-1
- 5.2 Future Volumes Compared to Current Capacity 5-5

6.0 Rail Capacity Improvements **6-1**
- 6.1 Capacity Improvements 6-1
- 6.2 Future Volumes Compared to Future Capacity 6-2

7.0 Investment Requirements **7-1**
- 7.1 Cost of Improvements 7-1
- 7.2 Cost Savings from Productivity Improvements 7-4
- 7.3 Railroad Investment Capacity 7-5
- 7.4 Investment Requirements for Class I Railroads 7-6

8.0 Conclusions **8-1**

A. National Rail Freight Infrastructure Capacity and Investment Study: Methodology **A-1**
- A.1 Introduction A-1
- A.2 Line Capacity Expansion A-2
- A.3 Intermodal and Carload Terminals, and Service Facility Capacity Expansion A-19

List of Tables

Table 4.1 Typical Number of Cars or Intermodal Units by Train Service Type....4-3

Table 4.2 Average Capacities of Typical Rail-Freight Corridors *Trains per Day* 4-7

Table 4.3 Volume-to-Capacity Ratios and Level of Service (LOS) Grades 4-8

Table 4.4 Primary Rail Corridor Mileage by Current Level of Service Grade *Current Volumes and Current Capacity* 4-10

Table 5.1 Primary Rail Corridor Mileage by Future Level of Service Grade *2035 without Improvements* 5-6

Table 6.1 Average Capacities of Typical Rail-Freight Corridors *Trains per Day* 6-1

Table 6.2 Primary Rail Corridor Mileage by Future Level of Service Grade *2035 with Improvements* 6-3

Table 7.1 Cost of Rail Freight Infrastructure Improvements *Millions of 2007 Dollars* 7-2

Table 7.2 Average Unit Costs 7-3

Table A.1 Empty Return Ratios Used in the STB's URCS Phase 3 and Waybill Costing Programs *All Cars, 2005 Ratios* A-5

Table A.2 Average Train Length *Number of Cars* A-6

Table A.3 FAF2.2 Commodity Assignment to Rail Service Type for Establishing Forecast Growth Rates A-8

List of Figures

Figure 2.1 Vehicle Miles of Travel and Lane Miles *1980 to 2005* 2-2

Figure 2.2 Rail Freight Ton-Miles and Track Miles *Class I Railroads, 1980 to 2006* 2-3

Figure 2.3 Total Logistics Cost *Percentage of Gross Domestic Product* 2-4

Figure 2.4 Truck and Rail Market Shares in Ton-Miles *2005 and 2035* 2-6

Figure 4.1 National Rail Freight Network and Primary Rail Freight Corridors 4-1

Figure 4.2 Primary Rail Freight Corridors 4-2

Figure 4.3 Current Corridor Volumes by Primary Rail Freight Corridor *2005 Freight Trains and 2007 Passenger Trains per Day* 4-4

Figure 4.4 Current Train Volumes Compared to Current Train Capacity 4-10

Figure 4.5 Class I Railroad Operating Expenditures *2006* 4-11

Figure 5.1 Future Corridor Volumes by Primary Rail Freight Corridor *2035 Freight Trains and 2007 Passenger Trains per Day* 5-2

Figure 5.2 Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor 5-3

Figure 5.3 Percentage Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor 5-4

Figure 5.4 Future Corridor Volumes Compared to Current Corridor Capacity *2035 without Improvements* 5-5

Figure 6.1 Future Train Volumes Compared to Future Train Capacity *2035 with Improvements* 6-3

Figure 7.1 Capital Investment and Income *Class I Railroads, 1981 to 2006, in Current Dollars* 7-5

Figure 8.1 Percentage of Rail-Freight Primary Corridor Route Miles by Level of Service Grade in 2005, 2035 without Capacity Improvements, and 2035 with Capacity Improvements 8-1

Figure A.1 National Rail Network and Primary Rail Corridors A-3

Figure A.2 2005 and 2035 Train Volumes Compared to Current Train Capacity A-13

Figure A.3 Future Train Volumes Compared to Future Train Capacity *2035 with Improvements* A-15

Acknowledgments

This study was prepared by Cambridge Systematics, Inc. under contract to the Association of American Railroads. The major authors of the study were Lance R. Grenzeback, David T. Hunt, and Daniel F. Beagan. The key contributing staff were John Lewis, Siddharth A. Pandit, Jessica E. Tump, Thomas C. Messer, and Nathan R. Higgins.

The AAR's steering committee provided invaluable information and advice to the consultant team throughout the study. Their time and effort were very much appreciated.

- BNSF Railway
  - Peter J. Rickershauser
  - Nathan M. Asplund
  - Christopher Bigoness
- CSX Transportation
  - Lester (Les) M. Passa
  - Lawrence Ratcliffe
- Norfolk Southern
  - Daniel Mazur
  - Jackie Corletto
- Union Pacific
  - John T. Gray
  - John H. Ransom
  - Eric Wilson
  - Simon J. Hjelm
- Association of American Railroads
  - Craig F. Rockey, Project Manager
  - Frank Hardesty, Deputy Project Manager
  - Paul Posey
  - Dan Saphire

The assistance of the American Short Line and Regional Railroad Association, CN, Canadian Pacific, and Kansas City Southern was also appreciated.

Executive Summary

This study is an assessment of the long-term capacity expansion needs of the continental U.S. freight railroads. It provides a first approximation of the rail freight infrastructure improvements and investments needed to meet the U.S. Department of Transportation's (U.S. DOT) projected demand for rail freight transportation in 2035. The U.S. DOT estimates that the demand for rail freight transportation—measured in tonnage—will increase 88 percent by 2035.

The study was commissioned by the Association of American Railroads (AAR) at the request of the National Surface Transportation Policy and Revenue Study Commission. The Commission is charged by Congress to develop a plan of improvements to the nation's surface transportation systems that will meet the needs of the United States for the 21st century.

The study focuses on 52,340 miles of primary rail freight corridors, which carry the preponderance of rail freight traffic.[1] These corridors, which constitute about one-third of all continental U.S. rail freight miles, are expected to absorb the bulk of the forecast traffic and nearly all of the investment to expand capacity.

The study estimates the need for new tracks, signals, bridges, tunnels, terminals, and service facilities in the primary corridors. The study does not estimate the cost of acquiring additional land, locomotives, and freight cars, or the cost of replacing and updating existing track, facilities, locomotives, and freight cars. The study assumes no shift in modal tonnage shares among rail, truck, and water beyond those projected by the U.S. DOT.

The study does not forecast passenger rail demand or estimate future passenger rail capacity needs; however, capacity is provided for the long-distance Amtrak and local commuter passenger rail services that are currently operated over rail freight lines. Additional investment, beyond that projected in this report, will be needed if the freight railroads host increased levels of passenger rail service. The Commission has convened a passenger rail committee that is studying the need for improvements and investments to support passenger rail demand through 2035. The findings of that committee will be reported separately.

This study estimates that an investment of $148 billion (in 2007 dollars) for infrastructure expansion over the next 28 years is required to keep pace with economic growth and meet the U.S. DOT's forecast demand. Of this amount, the Class I freight railroads' share is projected to be $135 billion and the short line

[1] Nearly all of these primary corridor miles are owned and operated by the seven Class I freight railroads: BNSF Railway, Canadian National (Grand Trunk Corporation), Canadian Pacific (Soo Line), CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. There are more than 550 short line and regional freight railroads.

and regional freight railroads' share is projected to be $13 billion. Without this investment, 30 percent of the rail miles in the primary corridors will be operating above capacity by 2035, causing severe congestion that will affect every region of the country and potentially shift freight to an already heavily congested highway system.

The investment requirement is driven by three factors: demand, current system capacity, and infrastructure expansion costs. The U.S. DOT estimates that population growth, economic development, and trade will almost double the demand for rail freight transportation by 2035. The projected rate of growth over the next 30 years is not extraordinary, but it comes after two decades of growth in rail freight tonnage that has absorbed much of the excess capacity in the existing rail freight system. Most of the moderate-cost capacity expansions have already been made; future capacity expansions will be purchased at a higher cost because they will require expensive new bridges and tunnels and more track and larger terminals in developed areas.

Meeting the U.S. DOT's forecast demand will require the Class I freight railroads to increase their investment in infrastructure expansion. The Class I railroads anticipate that they will be able to generate approximately $96 billion of their $135 billion share through increased earnings from revenue growth, higher volumes, and productivity improvements, while continuing to renew existing infrastructure and equipment. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads will be less able to meet the U.S. DOT's forecast demand.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

In summary, the findings point clearly to the need for more investment in rail freight infrastructure and a national strategy that supports rail capacity expansion and investment.

1.0 Objective

The objective of this study is to identify rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. Department of Transportation's (U.S. DOT) projected demand for rail freight transportation in 2035. The U.S. DOT estimates that the demand for rail freight transportation—measured in tonnage—will increase 88 percent by 2035. This projected rate of growth over the next 30 years is not extraordinary, but it comes after two decades of growth in rail freight tonnage that has absorbed much of the excess capacity in the existing rail freight system. The study assumes no shift in modal tonnage shares among rail, truck, and water beyond those projected by the U.S. DOT.

The study looks at infrastructure improvements that expand the capacity of rail lines, bridges, tunnels, terminals, and service facilities along the 52,340 miles of primary rail corridors within the U.S. owned and operated primarily by the seven Class I railroads—BNSF Railway, Canadian National (Grand Trunk Corporation), Canadian Pacific (Soo Line), CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. These primary corridors constitute about one-third of all U.S. rail miles and carry the preponderance of rail freight traffic.

The investment estimates include capital costs for expansion only; that is, the cost of the new rail lines and support facilities needed to accommodate future demand. The estimates do not include costs to maintain and operate the new rail lines and support facilities; acquire additional locomotives and railcars to provide services; or operate, maintain, and replace existing rail lines and facilities. Finally, the study does not include the costs to rail shippers to accommodate growth in rail traffic volumes at their facilities. The study does include a general estimate of the investment required to bring the weight-bearing capacity of Class I branch lines and short line and regional railroad lines up to current standards.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

2.0 Background

The study was done at the request of the National Surface Transportation Policy and Revenue Study Commission. The Commission was established by Congress in 2005 to provide a national vision and recommendations that will "preserve and enhance the surface transportation system to meet the needs of the United States for the 21st century."[2] The Commission is charged with completing a comprehensive study of the national surface transportation system and the Highway Trust Fund, then developing a conceptual plan with alternative approaches to ensure that the system continues to serve the needs of the United States.

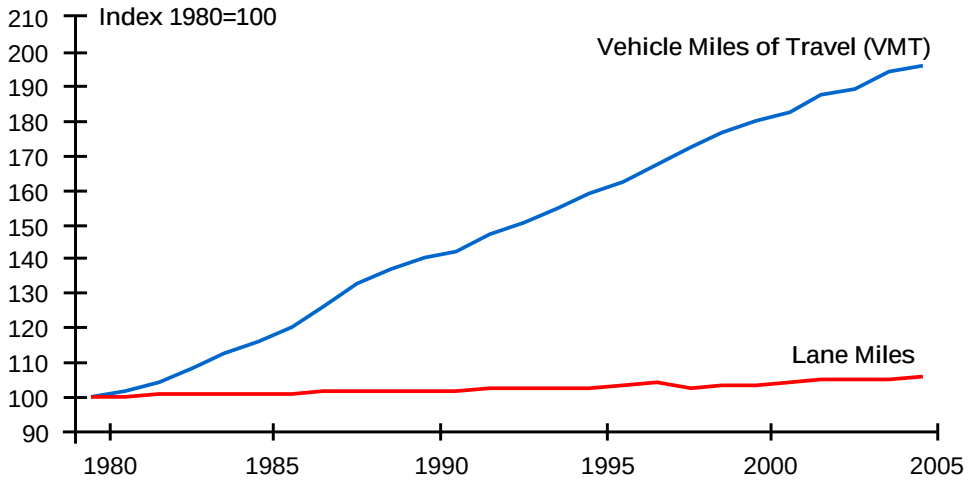
Since May 2006, the Commission has met regularly to hear about the challenges facing America's surface transportation network. The Commissioners have heard testimony from national transportation advocates, policymakers, industry, labor, and the general public. Congress is actively following the activities of the Commission, and the Commission's report (anticipated in December 2007) is expected to provide information that will be helpful to Congress as it considers reauthorization of the Federal surface transportation programs in 2009.

Over the course of its hearings, the Commission has expressed concern about the capacity and future of the nation's freight transportation systems. Freight transportation is vitally important to domestic economic productivity, the international competitiveness of American businesses, and the economic well-being of all Americans.

The demand for transportation is pressing the capacity of the nation's transportation systems, especially its critical highway and rail freight transportation infrastructure. On the highway system, vehicle-miles of travel grew by 96 percent between 1980 and 2005, while lane miles of road increased by only 5.7 percent. Figure 2.1, based on Federal Highway Administration (FHWA) statistics, illustrates the widening gap between vehicle-miles of travel and roadway capacity.

[2] See Section 1909 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU).

Figure 2.1 Vehicle Miles of Travel and Lane Miles
1980 to 2005



Source: Federal Highway Administration, *Highway Statistics*.

The result has been increasing highway congestion. The Texas Transportation Institute reports that over the decade between 1993 and 2003, the cost of highway congestion in the nation's urban areas increased from $39.4 billion to $63.1 billion, an increase of 60.2 percent.[3] The U.S. DOT estimates that the cost of congestion across all modes of transportation could be three times as high—approaching $200 billion per year—if productivity losses, costs associated with cargo delays, and other economic impacts are included. These include losses accruing to auto drivers, freight carriers, businesses, consumers, and the general public.[4]

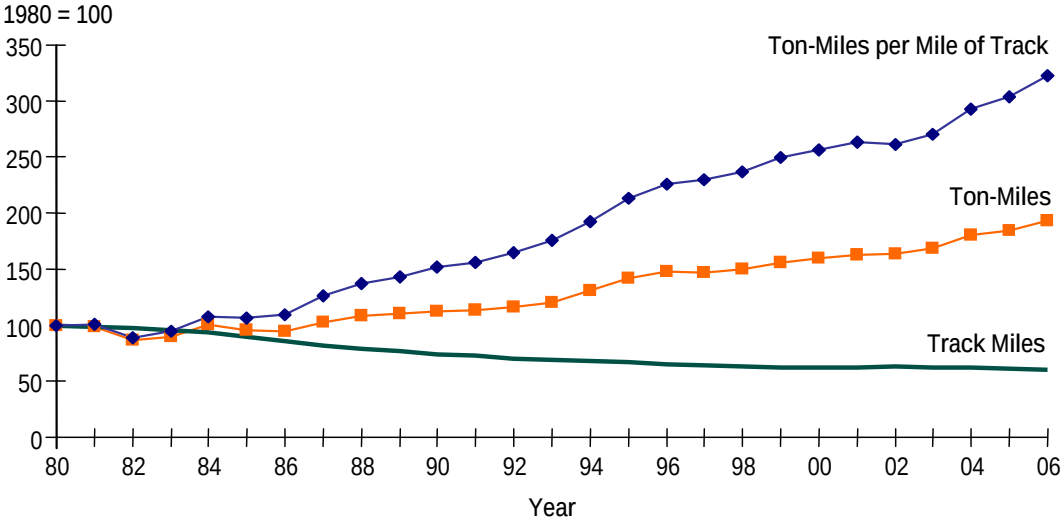
As the cost of highway congestion has increased, public policy-makers at all levels of government have started looking to the railroads to carry more freight to relieve truck and highway congestion, and to help conserve energy, reduce engine emissions, and improve safety. Shippers, too, have started looking to railroads to carry more longer-distance shipments, especially as the costs of truck fuel and labor have increased.

[3] David Schrank and Tim Lomax, *The 2005 Urban Mobility Report*, Texas Transportation Institute, May 2005, available at http://mobility.tamu.edu.

[4] U.S. Department of Transportation, *National Strategy to Reduce Congestion on America's Transportation Network*, Washington, D.C., March 2007.
See http://www.fightgridlocknow.gov/docs/conginitoverview070301.htm.

However, the growing demand for freight transportation is also pressing the capacity of the nation's rail freight system. Ton-miles of rail freight (one ton of freight moved one mile counts as one ton-mile) carried over the national rail system have doubled since 1980, and the density of train traffic—measured in ton-miles per mile of track—has tripled since 1980. Figure 2.2 illustrates the widening gap between ton-miles of rail travel and track miles.[5]

Figure 2.2 Rail Freight Ton-Miles and Track Miles
Class I Railroads, 1980 to 2006

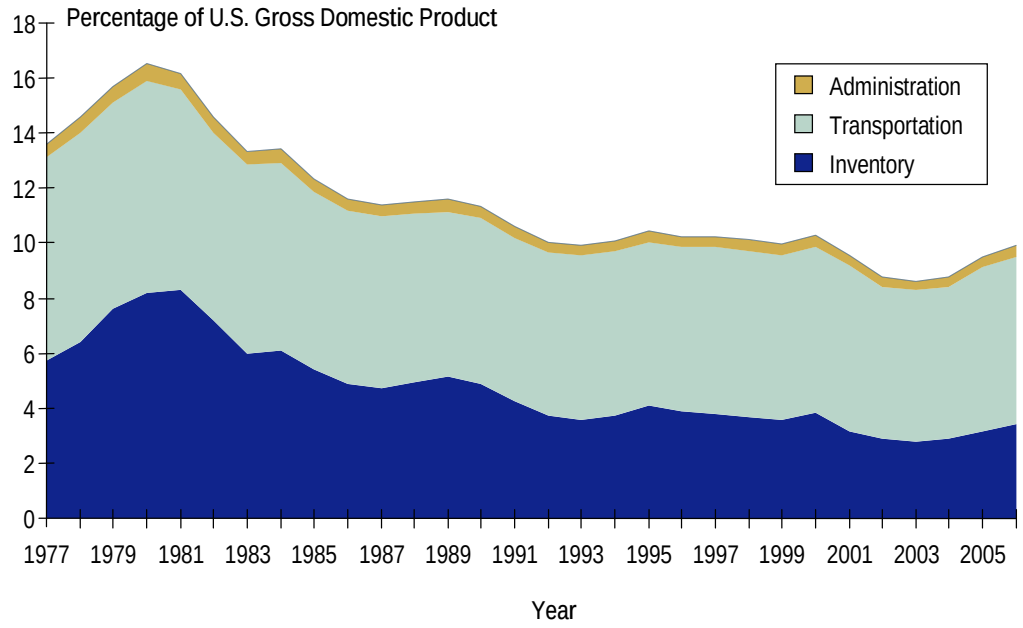


Source: AAR and Annual Report Form R-1.

The tightening of system capacity across all modes of freight transportation has likely contributed to the first notable increase in total logistics cost in over 25 years. Total logistics cost is the cost of managing, moving, and storing goods. Figure 2.3 shows the total logistics cost as a percentage of the U.S. gross domestic product (GDP).

[5] Association of American Railroads data and Annual Report Form R-1.

Figure 2.3 Total Logistics Cost
Percentage of Gross Domestic Product



Source: *State of Logistics Report*, Council of Supply Chain Management Professionals, 2006.

Logistics costs rose through the 1970s to a high of about 16 percent of GDP in 1980, reflecting rising fuel prices, increasing interest rates, and deteriorating productivity across the freight transportation system. Renewed investment in highways, economic deregulation of the freight transportation industry in the early 1980s, adoption of new technologies, and lower interest rates drove down the costs of truck, rail, air, and water freight transportation. The total logistics cost declined through the 1980s and 1990s to a low of about 8.6 percent of GDP in 2003. Businesses and consumers benefited because lower transportation costs resulted in lower-cost goods and better access to global markets.

But the total logistics cost is rising again. In 2006, the total logistics cost was 9.9 percent of GDP.[6] The change reflects recent increases in fuel prices and increases in congestion on the nation's highways and rail lines and at its international trade gateways and ports. Freight shippers and carriers are worried that the productivity of the nation's freight systems may continue to drop and that logistics costs may rise further, undermining future domestic economic productivity, international competitiveness, and economic growth.

[6] Rosalyn A. Wilson, *State of Logistics Report*, Council of Supply Chain Management Professionals, 2006 and 2007.

Freight shippers and carriers are especially concerned about the future capacity and productivity of the freight system because the demand for freight transportation is projected to nearly double by 2035. The U.S. DOT Freight Analysis Framework (FAF Version 2.2) estimates that the demand for freight transportation will grow from 19.3 billion tons today to 37.2 billion tons in 2035, an increase of about 93 percent.[7]

To absorb this growth and maintain their existing shares of the freight transportation market, the nation's truck and rail freight systems must increase their capacity and productivity substantially. Trucks and the highway system must add capacity to handle 98 percent more tonnage. And railroads must add capacity to handle 88 percent more tonnage. The U.S. DOT estimates assume no shift in modal tonnage shares among rail and truck beyond those created by structural changes in the economy (i.e., different growth rates across freight-generating industries).

The anticipated rates of growth for the U.S. economy and freight transportation demand are about the same as those experienced over the last 30 years; however, much of the capacity existing or created over those years has been filled, leaving the nation with a need to provide new capacity through expanded infrastructure and improved productivity.[8]

Figure 2.4 shows the relative shares of freight—measured in ton-miles—carried by truck and rail in 2005.[9] If railroads cannot carry their share in 2035, then freight will be shed to trucks and an already heavily congested highway system. Conversely, if trucks cannot carry their share in 2035, then freight must be shifted to rail and the capacity of the rail system expanded even more than currently forecast.

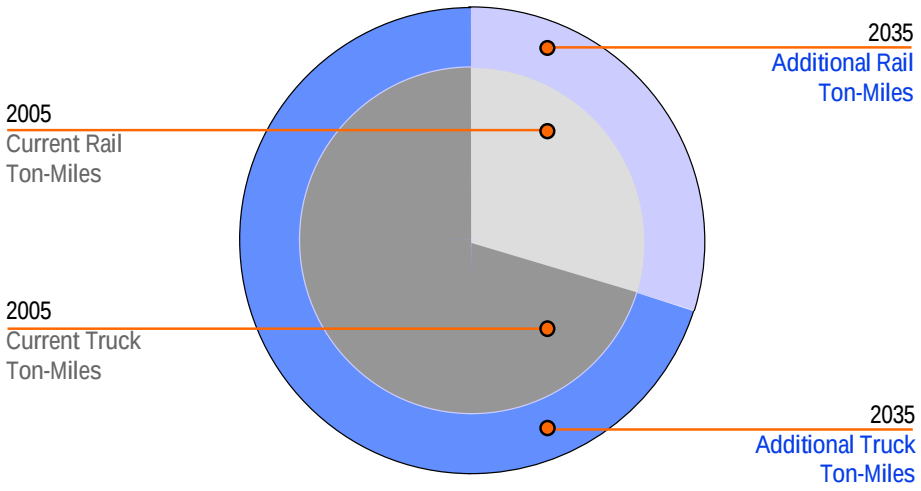
---

[7] See U.S. Department of Transportation, Freight Analysis Framework, *Freight Facts and Figures* at http://www.ops.fhwa.dot.gov/freight/. This study uses the current Freight Analysis Framework (FAF Version 2.2) forecasts.

[8] Global Insight, Inc. forecasts that the U.S. economy will grow at a compound annual rate of about 2.8 percent over the next 30 years. Source: Global Insight, Inc. in *Freight Demand and Logistics Bottom Line Report* prepared by Cambridge Systematics, Inc. for the American Association of State Highway and Transportation Officials (AASHTO), (forthcoming, 2007).

[9] Ton-miles estimated by Global Insight for the AASHTO *Freight Demand and Logistics Bottom Line Report*.

Figure 2.4 Truck and Rail Market Shares in Ton-Miles
2005 and 2035



Source: Cambridge Systematics, Inc., based on Global Insight, Inc. freight demand forecasts.

In response to these projections and concerns, the Commission asked the Association of American Railroads (AAR) to assess the capacity of the nation's rail system to accommodate the estimated increase in freight-rail traffic. The AAR, supported by the four largest Class I railroads—the BNSF Railway, CSX Transportation, the Norfolk Southern Corporation, and the Union Pacific Railroad—undertook this study to estimate the additional rail freight capacity and investment required to meet the U.S. DOT forecast.

This study is a hallmark study, the first effort of its kind. The U.S. DOT and the Federal Highway Administration (FHWA) have developed national infrastructure needs and cost estimates for the publicly owned highway systems, but no comparable, long-term, national estimates have been developed for the rail system. The railroads are publicly traded or privately owned companies, and the planning horizons for railroad capital projects typically do not extend out 30 years. And neither the U.S. DOT nor individual state DOTs have comprehensive rail infrastructure databases suitable for long-term planning. This study is the first collective assessment by the major freight railroads of their long-term capacity expansion and investment needs.

3.0 Methodology

This study provides a first approximation of the rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. DOT's projected demand for rail freight transportation in 2035. It addresses two major rail freight infrastructure elements:

- Line expansion:
  - Upgrades to the Class I railroad system mainline tracks and signal control systems;
  - Improvements to significant rail bridges and tunnels;[10]
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad tracks and bridges to accommodate 286,000-pound freight cars.[11]
- Facility expansion:
  - Expansion of carload terminals, intermodal yards, and international gateway facilities owned by railroads; and
  - Expansion of Class I railroad service and support facilities such as fueling stations and maintenance facilities.

[10] Included in this category are expansions of major bridges and tunnels (or construction of new parallel bridges and tunnels) to add rail capacity along a corridor, and corridor overhead clearance projects, which typically involve raising dozens of highway bridges crossing a rail line to permit the movement of double-stacked intermodal container trains.

[11] Most Class I railroad tracks and bridges have been designed or reconstructed to carry railcars weighing 286,000 pounds, and some Class I lines accommodate railcars weighing up to 315,000 pounds. Older rail lines, including some Class I railroad secondary mainlines and branch lines and about half of the short line and regional railroad tracks and bridges, were designed and constructed to carry railcars weighing up to 263,000 pounds. The heavier, "standard," 286,000-pound cars can be operated over many lines designed for lighter cars, but usually at very low speeds.

The study includes the cost of designing and constructing these improvements, but does not include the cost of acquiring real estate to accommodate new rail lines and terminals.[12] This is consistent with the approach used in national highway system needs and investment studies, which do not estimate the cost of acquiring real estate for widening or adding highways. The study does not include the cost of capital depreciation or the cost of buying additional locomotives and rail cars to expand service. Railroad maintenance and operating costs are not included, for either existing or expanded lines and facilities.

The study assumes that capacity is provided for long-distance Amtrak and local commuter passenger rail services that are currently operated over rail freight lines, but the study does not forecast the need for new passenger rail services or the necessary capacity to support passenger rail growth. The Commission has convened a passenger rail committee that is studying the need for improvements and investments to support passenger-rail demand through 2035. The findings of that committee will be reported separately.

This study estimates rail line capacity and investment requirements by:

- Dividing the continental U.S. Class I railroad network into primary corridors;
- Establishing current corridor volume in freight and passenger trains per day for each primary corridor, based on 2005 Surface Transportation Board Carload Waybill data, the most recent comprehensive information available;
- Estimating current corridor capacity in trains per day for each primary corridor, based on current information;
- Comparing current corridor volume to current corridor capacity;
- Estimating future corridor volume in trains per day, using U.S. DOT's Freight Analysis Framework Version 2.2 forecasts of rail freight demand in 2035 by type of commodity and by the origin and destination locations of shipments moving within the U.S. and through international land and port gateways;
- Comparing the future corridor volume to current corridor capacity;

[12] Current capital expenditures by the Class I railroads for expansion of lines and terminals (as reported in Section 4.5) include the cost of acquiring real estate. However, with the exception of land acquired for new or expanded intermodal terminals, the cost of real estate acquisition has been a small part of current capital expenditures because most new rail lines have been constructed within existing railroad-owned rights-of-way. As the space in existing rights-of-way is used up, the cost of acquiring real estate for new lines is expected to be a larger percentage of capital expenditures for expansion. The real estate costs will be in addition to the infrastructure costs estimated in this study.

- Determining the additional capacity needed to accommodate future train volumes at an acceptable level of service reliability;
- Identifying the rail line and signal control system improvements required to provide the additional capacity; and
- Estimating the costs of the improvements.

The study estimates the need for expansion of Class I railroad carload terminals, intermodal yards, and railroad-owned international gateway facilities by analyzing the projected increases in the number of railcars and intermodal units (containers and truck trailers) handled at major facilities and comparing them to current handling capacity. Expansion costs are estimated using unit costs per railcar or intermodal container, or estimated using recent and comparable terminal expansion project costs. Estimates of the cost of expanding service and support facilities such as fueling stations were provided by the railroads based on the anticipated changes in the number and type of trains.

Finally, the study estimates the capacity and investment requirements for secondary mainlines, branch lines, and short line and regional railroads by updating information from a prior study of short line system investment needs commissioned by the American Short Line and Regional Railroad Association.[13]

Wherever possible, the analysis is based upon existing and publicly available data sources. The key sources of data are the following:

- Oak Ridge National Laboratory (ORNL) Center for Transportation Analysis' Rail Network (Version 5-5) is used to develop a primary corridor network model and identify the key corridor characteristics such as the number of tracks and type of signal system;
- The U.S. DOT Surface Transportation Board's (STB) 2005 Carload Waybill Sample is used to estimate current corridor volumes based on 2005 loaded-car movements;
- Data from the Surface Transportation Board's Uniform Rail Costing System (URCS) on empty-return ratios by railroad, car type, and car ownership are used to estimate empty car movements;
- The U.S. DOT's Freight Analysis Framework (FAF Version 2.2) forecast is used to establish rail freight traffic growth by type of train service (e.g., intermodal train, manifest/carload train, auto train, and bulk train) from 2005 to 2035;

[13] Zeta-Tech Associates, Inc., *An Estimation of the Investment in Track and Structures Needed to Handle 286,000-Pound Rail Cars*, prepared for the American Short Line and Regional Railroad Association, May 26, 2000.

- Data from the railroads and the AAR are used to estimate the capacity in trains per day for archetypical rail corridors representing different combinations of number of tracks and signal types. The capacities of the archetypical rail corridors are used to identify the improvements needed to accommodate future train volumes.
- Data from the Class I railroads, the AAR, and published construction industry information are used to estimate the cost of adding tracks, upgrading signal systems, expanding terminals, and adding rail-support facilities.

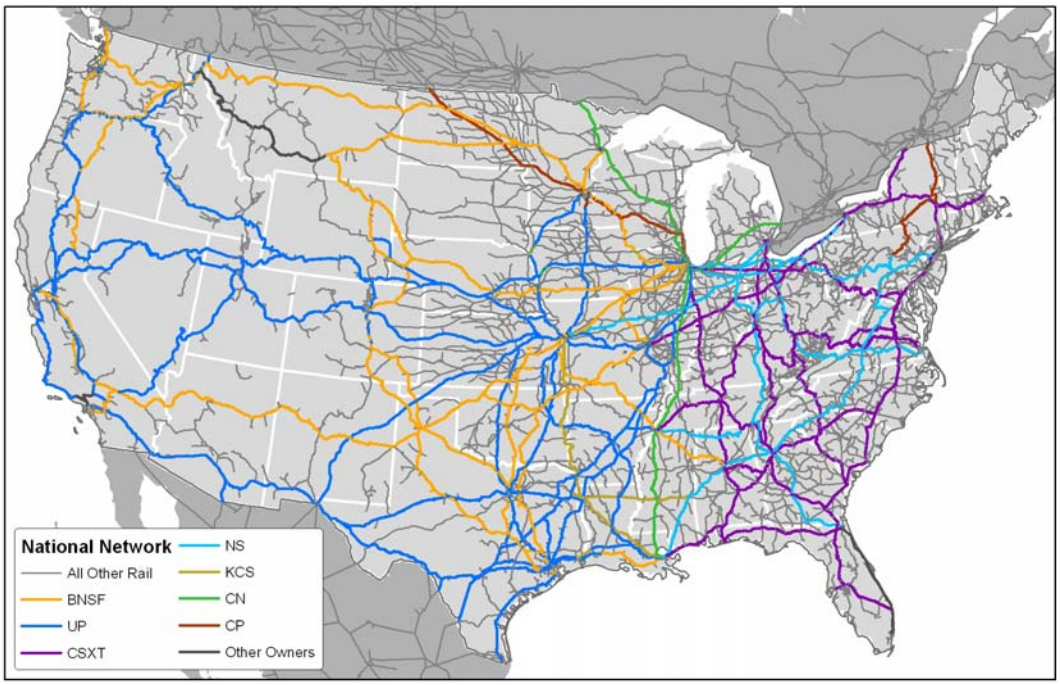
Appendix A describes the technical methodology in more detail.

4.0 Current Train Volumes and Capacity

4.1 PRIMARY CORRIDORS

The study focuses on the primary rail corridors within the national rail freight system. Figure 4.1 shows the national rail network. The primary corridors for each of the seven Class I railroads are shown in color; all other rail lines are shown in gray.

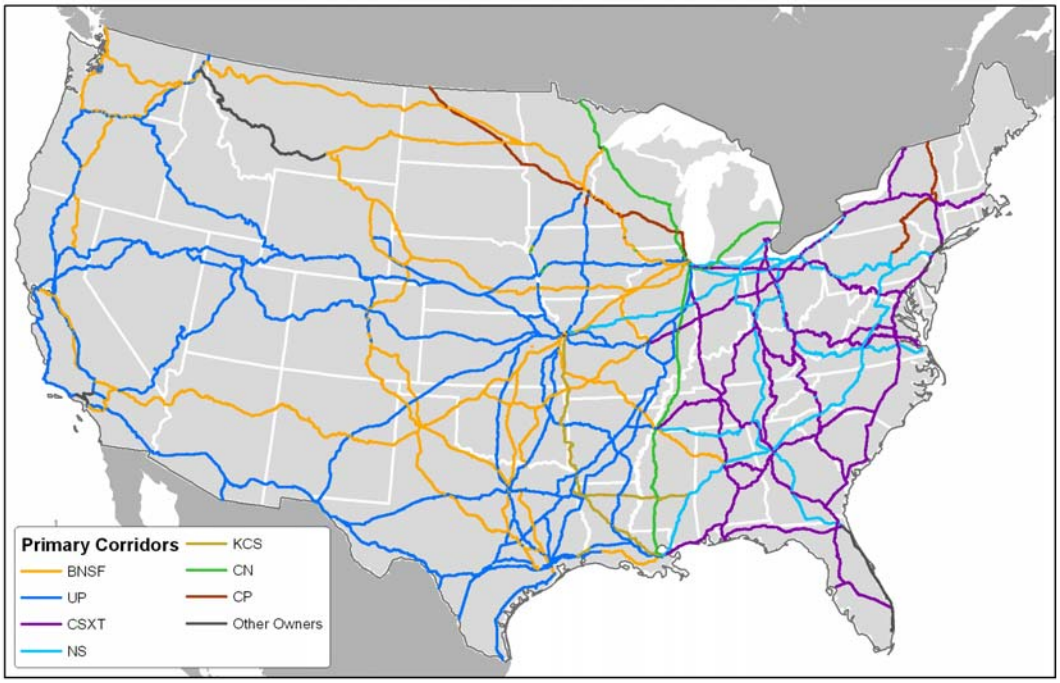
Figure 4.1 National Rail Freight Network and Primary Rail Freight Corridors



Source: Cambridge Systematics, Inc.

Figure 4.2 shows just the primary corridors used for this study of rail freight capacity. The primary corridors were designated by the Class I railroads for this study. The primary corridors represent the higher-volume corridors for rail freight. The primary corridors total about 52,340 miles of road (or centerline miles), representing about half of all Class I-operated miles in the U.S. and about one-third of the 140,810 miles in the U.S. rail freight network. For comparison, the Interstate Highway System comprises about 47,000 route miles, and the National Highway System, which adds other major U.S. and state freight highways, comprises about 162,000 route miles.

Figure 4.2 Primary Rail Freight Corridors



Source: Cambridge Systematics, Inc.

4.2 CURRENT VOLUMES

Current corridor volumes in trains per day were established for each primary corridor using data from the Surface Transportation Board's 2005 Carload Waybill Sample. The Waybill Sample is an annual survey of railcar movements on the national rail network. The survey collects information from a sample of loaded, revenue-producing railcar movements. The data include information about the commodity shipped, the type of railcar used, the origin and destination station of the shipment, any interchanges between railroads, and the names of railroads handling the shipment. The sample data are statistically expanded to represent 100 percent of the loaded revenue railcar moves in a year. The Waybill Sample is used in many regulatory proceedings and is generally considered an accurate reflection of U.S. railroad shipments. The 2005 Waybill Sample is the most recent comprehensive data available.

The Waybill Sample does not collect information about empty, non-revenue-producing railcar movements. These were estimated using information from the Uniform Rail Costing System (URCS) on empty-return ratios by railroad, car type, and car ownership. The number of empty, non-revenue-producing railcar movements were added to the number of loaded, revenue-producing railcar movements to estimate total railcar movements.

The number of carloads moving on the rail system varies daily, weekly, and seasonally. To select a representative day, the distribution of the number of carload movements for each day in 2005 was examined and the volume for the 85th percentile day was selected for analysis. This approach is consistent with the analysis procedures for highway needs studies.

The carload volumes were then allocated among four types of train service based on the commodity being carried and the type of operation:

1. **Auto Train Service –** For assembled automobiles, vans, and trucks moving in multilevel cars;
2. **Bulk Train Service –** For grain, coal, and similar bulk commodities moving in unit trains;
3. **Intermodal Train Service –** For commodities moving in containers or truck trailers on flat cars or specialized intermodal cars; and
4. **General-Merchandise Train Service –** Everything else, including commodities moved in box cars and tank cars.

The number of trains of each type needed to move the cars were estimated using information on the typical number of cars hauled by train service type, as summarized in Table 4.1. The number of intermodal trains needed is based on the number of intermodal units (e.g., container-on-flat-car [COFC] units and trailer-on-flat-car [TOFC] units). Separate calculations were made for Eastern and Western Class I railroads because differences in regional geography and topography allow Western railroads to operate longer trains.[14]

Table 4.1 Typical Number of Cars or Intermodal Units by Train Service Type

Type of Train Service	Eastern Railroads	Western Railroads
Auto	57.0	63.9
Bulk	86.0	112.4
General Merchandise	82.0	80.7
Intermodal (TOFC/COFC count)	110.7	164.3

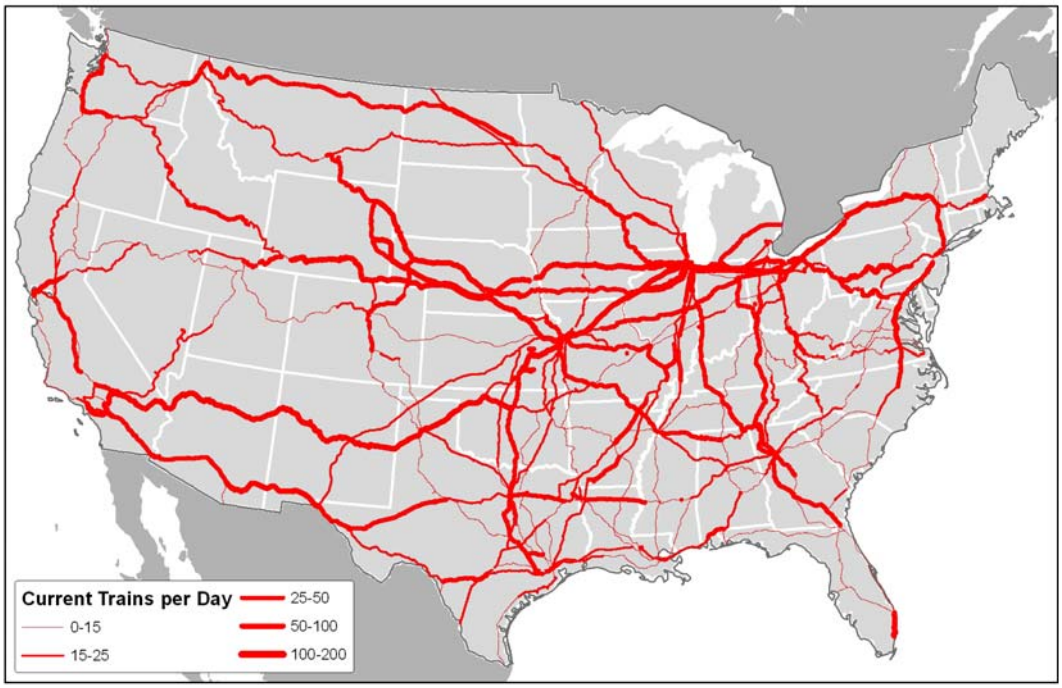
Source: Class I railroad data.

[14]For details, see Appendix A.

Finally, the number of long-distance Amtrak and local commuter passenger rail trains operating over the primary rail freight corridors was added to the number of freight trains to calculate the total number of trains per day per corridor. The number of passenger trains was estimated from published information on Amtrak and commuter passenger rail schedules for 2007.

Figure 4.3 maps the current corridor volumes in trains per day for the primary rail freight corridors. The number of trains per day is indicated by the width of the corridor line. The thinnest line indicates that a corridor carries up to 15 trains per day; the widest line indicates that a corridor carries between 100 and 200 trains per day.

Figure 4.3 Current Corridor Volumes by Primary Rail Freight Corridor
2005 Freight Trains and 2007 Passenger Trains per Day



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

4.3 CURRENT CAPACITY

To determine whether a corridor is congested, current volume was compared to current capacity. Three variables were used to estimate the current capacity of the primary corridors: the number of tracks, the type of control system, and the mix of train types.[15]

- **Tracks –** Most sections of the national rail freight system are single-tracked with multiple sidings for trains to meet and pass each other, and a significant portion of the heaviest-volume corridors are double-tracked. A limited number of sections have three or four tracks.
- **Control System –** The type of control system affects capacity by maintaining a safe spacing between trains meeting and passing on the same track. There are three major types of signal systems:
  - **Automatic Block Signaling (ABS)** is a signal system that controls when a train can advance into the next track block. A block is a section of track with traffic control signals at each end. The length of the block is based on the length of a typical train and the distance needed to stop the train in a safe manner. When a train exits a block, the signal changes to yellow, indicating to the engineer of a following train that the block is now empty, but that the following train should be prepared to stop before entering the next block (currently occupied by the train ahead). Automatic block signaling is governed by block occupancy and cannot be controlled by a railroad dispatcher from a remote location.
  - **Centralized Traffic Control (CTC)** and **Traffic Control System (TCS)** are systems that use electrical circuits in the tracks to monitor the location of trains, allowing railroad dispatchers to control train movements from a remote location, typically a central dispatching office. CTC and TCS increase capacity by detecting track occupancy and allowing dispatchers to safely decrease the spacing between trains because the signal systems automatically prevent trains from entering sections of track already occupied by other trains.
  - **No Signal (N/S)** and **Track Warrant Control (TWC)** are basic train control systems that require the train crew to obtain permission or warrants

[15] The capacity of rail corridors is determined by a large number of factors, including the number of tracks, the frequency and length of sidings, the capacity of the yards and terminals along a corridor to receive the traffic, the type of control systems, the terrain, the mix of train types, the power of the locomotives, track speed, and individual railroad operating practices. Complete, consistent, and current information on all these factors was not available for the study, so the capacity of the primary corridors was estimated using only the three dominant factors (e.g., number of tracks, type of signal system, and mix of train types).

before entering a section of track. Crews receive track warrants by radio, phone, or electronic transmission from dispatcher. TWC is used on low-volume track instead of more expensive ABS or CTC/TCS systems.

- **Train Types –** The mix of train types determines the speed and spacing of trains on a track. Different types of trains operate at different speeds and have different braking capabilities. A corridor that serves a single type of train will usually accommodate more trains per day than a corridor that serves a mix of train types. Trains of the single type can be operated at similar speeds and with more uniform spacing between the trains because they have similar braking capabilities. This increases the total number of trains that can traverse the corridor per day. When trains of different types—each with different length, speed, and braking characteristics—use a corridor, greater spacing is required to ensure safe braking distances. As a result, the average speed drops, reducing the total number of trains that can traverse the corridor per day. For the study, trains were grouped into three train-type groups based on their operating characteristics:
  - **Train-Type Group 1 –** includes merchandise/carload trains and bulk coal and grain trains. These trains tend to haul heavier, bulkier commodities such as coal, grain, gravel, and phosphates, and operate at slower speeds.
  - **Train-Type Group 2 –** includes intermodal trains and multilevel auto carriers hauling assembled automobiles. These trains tend to operate at higher speeds because they are lighter than merchandise and bulk trains and are run to more exacting schedules.
  - **Train-Type Group 3 –** includes passenger trains such as Amtrak's long-distance trains and local commuter rail trains. Passenger trains operate at high speeds and on fixed schedules, similar to the speeds and schedules of intermodal trains. They require close control to ensure safe operation and stopping distances, especially when operating along corridors carrying merchandise trains or a mix of merchandise and intermodal trains. By law, Amtrak passenger trains operating over rail freight lines must be given priority; this means that when Amtrak trains meet or overtake freight trains, the freight trains are shunted to sidings or parallel lines until the passenger train has passed.

There are eight combinations of number of tracks and type of signal system that are in common use across the primary corridors today. Table 4.2 lists the combinations, along with five- and six-track corridor types, which are used in this study to accommodate future demand. The first column lists the number of tracks, and the second column lists the type of control system. For each combination of number of tracks and type of control system, the maximum number of trains that can typically be accommodated is determined by the mix of train types operating along the corridor. The third column in the table lists the maximum practical capacity in trains per day that can be accommodated if multiple train types (e.g., merchandise, bulk, and passenger trains) use the corridor. The

rightmost column lists the maximum practical capacity in trains per day that can be accommodated if a single train type (e.g., all intermodal trains) uses the corridor.

Table 4.2 Average Capacities of Typical Rail-Freight Corridors
Trains per Day

		Trains per Day	
Number of Tracks	Type of Control	Practical Maximum If Multiple Train Types Use Corridor*	Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, a mix of merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

The table presents average capacities for typical rail freight corridors. The actual capacities of the corridors were estimated using railroad-specific capacity tables. At the request of the railroads, these detailed capacity tables were not included in this report to protect confidential railroad business information.

Source: Class I railroad data aggregated by Cambridge Systematics, Inc.

Typically, a corridor serving multiple train types will have a lower capacity than a corridor serving a single train type. For example, a railroad corridor with two tracks, a centralized traffic control (CTC) system, and a mix of merchandise/bulk trains, intermodal/auto trains, and passenger trains would typically operate at a capacity of about 75 trains per day. The same corridor, serving all merchandise trains, would typically operate at a capacity of about 100 trains per day.

For the study, each primary corridor in the national rail network was assigned a capacity based its actual number of tracks, type of control system, and mix of train types. The calculated capacity of each corridor was reviewed with the railroads. The railroads made adjustments to update network information and better represent their actual corridor train volumes and capacities.

4.4 CURRENT VOLUMES COMPARED TO CURRENT CAPACITY

Current corridor volumes were compared to current corridor capacity to assess congestion levels. This was done by calculating a volume-to-capacity ratio expressed as a level of service (LOS) grade. The LOS grades are listed in Table 4.3.

Table 4.3 Volume-to-Capacity Ratios and Level of Service (LOS) Grades

LOS Grade	Description		Volume/Capacity Ratio
A	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2
B			0.2 to 0.4
C			0.4 to 0.7
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
E	At Capacity	Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents	0.8 to 1.0
F	Above Capacity	Unstable flows; service breakdown conditions	> 1.00

Source: Cambridge Systematics, Inc.

Rail corridors operating at LOS A, B, or C are operating below capacity; they carry train flows with sufficient unused capacity to accommodate maintenance work and recover quickly from incidents such as weather delays, equipment failures, and minor accidents. Corridors operating at LOS D are operating near capacity; they carry heavy train flows with only moderate capacity to accommodate maintenance and recover from incidents. Corridors operating at LOS E are operating at capacity; they carry very heavy train flows and have very limited capacity to accommodate maintenance and recover from incidents without substantial service delays. Corridors operating at LOS F are operating above capacity; train flows are unstable, and congestion and service delays are persistent and substantial. The LOS grades and descriptions correspond generally to the LOS grades used in highway system capacity and investment requirements studies.

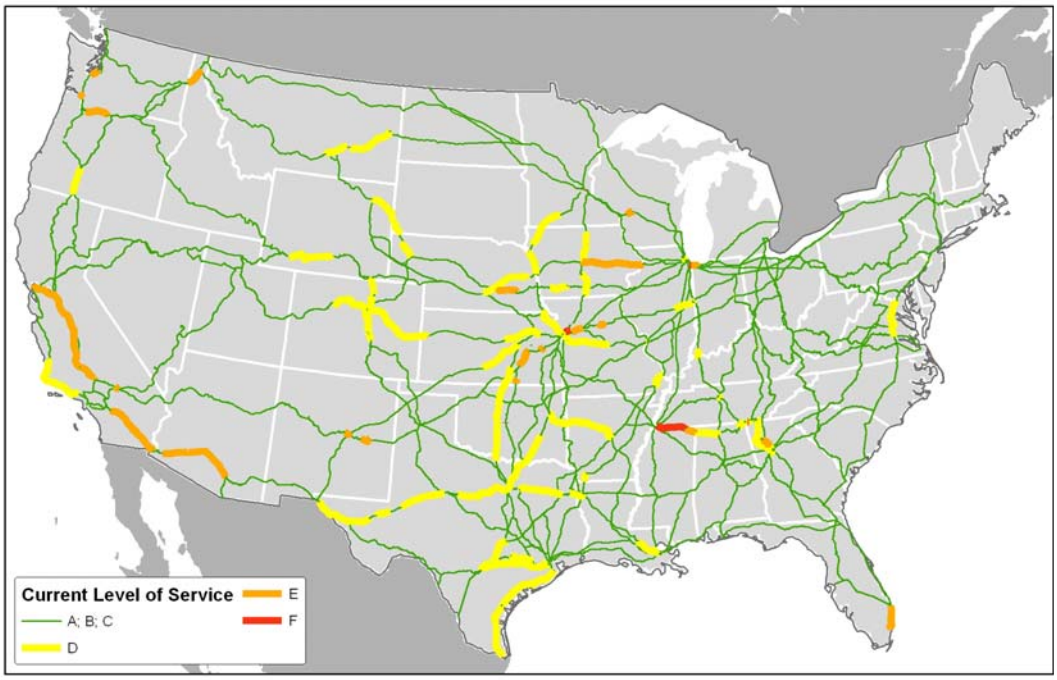
A rail corridor that is operating at a volume-to-capacity ratio of 0.7 (the boundary between LOS C and LOS D), is operating at 70 percent of its theoretical maximum capacity. This is considered to be the corridor's practical capacity because a portion of the theoretical maximum capacity is lost to maintenance, weather delays, equipment failures, and other factors. A corridor operating at LOS C will have stable train flows, ensuring that schedules can be met reliably and safely, and permitting timely recovery from service disruptions. At LOS D, a corridor will have stable operations under normal conditions, but service can quickly become unstable with unplanned and unanticipated disruptions. At volume-to-capacity ratios significantly greater than 0.8 (e.g., at LOS E or F), train flow rates and schedule reliability deteriorate and it takes longer and longer to recover from disruptions. To provide acceptable and competitive service to shippers and receivers, railroads typically aim to operate rail corridors at LOS C/D or better.

Figure 4.4 maps the volume-to-capacity ratios, expressed as LOS grades, for each primary rail corridor, based on current train volumes and current capacity.[16] For legibility, rail corridors operating at LOS A, B and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Analysis of the current levels of service, summarized in Table 4.4, shows that 88 percent of today's primary corridor mileage is operating below practical capacity (LOS A/B/C), 12 percent is near or at practical capacity (LOS D/E), and less than 1 percent is operating above capacity (LOS F).

[16] Current volumes are based primarily on shipment volumes reported in the 2005 STB Carload Waybill Sample. These volumes do not reflect fully recent increases in coal shipments moving from Western coal fields (e.g., Powder River Basin) to Eastern utilities nor the recent increases in intermodal containers delivered by water to East Coast ports and transferred to rail for inland delivery. Current capacity is based on 2007 information.

Figure 4.4 Current Train Volumes Compared to Current Train Capacity



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Table 4.4 Primary Rail Corridor Mileage by Current Level of Service Grade
Current Volumes and Current Capacity

LOS Grade	Total Mileage	Percentage
A	9,719	19%
B	15,417	30%
C	20,683	39%
D	4,952	9%
E	1,461	3%
F	108	<1%
Totals	52,340	100%

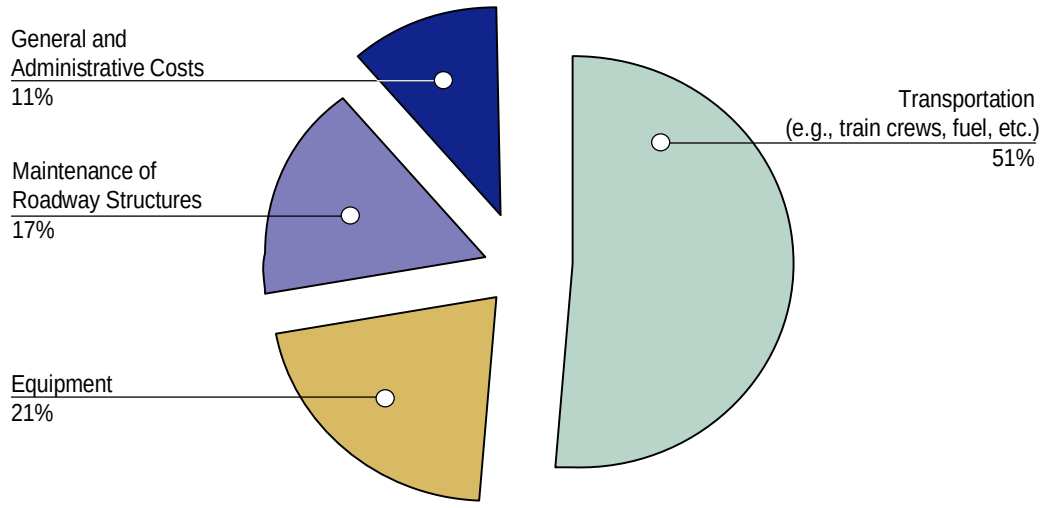
Source: Cambridge Systematics, Inc.

4.5 CURRENT RAILROAD INVESTMENT IN CAPACITY

The Class I railroads generated $52.2 billion in revenue in 2006 and incurred $41 billion in operating expenses.[17] After deducting interest charges, taxes and other miscellaneous items, the Class I railroads earned a net income of $6.5 billion in 2006.

Of the $41 billion in expenses, $21.1 billion (40 percent of revenue) was spent on transportation, which includes the costs of train crews and fuel; $8.5 billion (16 percent of revenue) on equipment; $6.8 billion (13 percent of revenue) on maintenance of roadway (e.g., rails, ties, ballast and substructure) and structures (e.g., bridges, tunnels, service building, etc.); and $4.6 billion (9 percent of revenue) on general and administrative costs. A breakdown of the operating expenditures is shown in Figure 4.5.

Figure 4.5 Class I Railroad Operating Expenditures
2006



Source: American Association of Railroads.

In 2006, the Class I railroads' capital expenditures totaled $8.5 billion. Of this, $1.5 billion (about 18 percent) was spent on equipment, and $7.0 billion (about

[17] In 2006, the operations and maintenance (O&M) cost for Class I railroads was $210,380 per mile of track and $359,097 per mile of road. This O&M cost is a fully burdened cost including transportation, equipment maintenance, G&A (but not maintenance of way and structures), and capital expenditures for equipment (but not way and structures). Depreciation is deducted to avoid double-counting. The calculations are based on 162,056 miles of operated track and 94,942 miles of road, less miles operated under trackage rights to avoid double-counting. This information is for the seven Class I railroads, U.S. operations only.

82 percent) on roadway and structures.[18] These capital expenditures include amounts for renewal of the existing roadway, structures, and equipment, as well as expenditures for expansion to serve additional traffic.

Combining operating and capital spending and adjusting for depreciation, 40 percent of the Class I railroads' revenue is spend on maintenance, replacement, or expansion of their track, structures, and equipment.[19] In 2006, the Class I railroads spent $10.6 billion maintaining and improving their infrastructure, and another $8.7 billion on equipment.[20]

The AAR estimates that the Class I railroads will spend approximately $1.9 billion in 2007 for expansion of capacity through the construction of new roadway and structures. This is the highest level of investment for expansion in recent years and reflects a steady increase in investment in expansion of roadway and structures. The Class I railroads invested $1.1 billion in expansion of roadway and structures in 2005. The Class I railroads invested $1.4 billion in infrastructure expansion in 2006. This was in addition to an expenditure of $17.9 billion for renewal of roadway, structures, and equipment and additions to locomotives and freight cars. The average annual investment in infrastructure expansion over the three year period from 2005 to 2006 was $1.5 billion per year.[21]

As these numbers demonstrate, rail transportation is capital intensive, requiring high levels of spending on infrastructure such as track, bridges, and signals; locomotives, freight cars, and maintenance equipment; and information technology. From 1996 through 2005, Class I railroad capital expenditures averaged 17 percent of revenue. (The comparable figure for the average U.S. manufacturer was 3 percent of revenue.) Railroad capital expenditures for ties alone have exceeded $1 billion every year since 2003, and spending for rail has been even higher.

Even though the railroads must invest heavily in infrastructure, the railroads have had substantial surplus capacity in the rail network for many years. This has enabled them to absorb traffic growth with relatively modest additional capital commitments to expand infrastructure. With this surplus capacity largely absorbed by two decades of growth and with major traffic increases in the past few years, an increasing portion of the capital investment in roadway and structures has been devoted to capacity expansion. And with traffic growth through 2035 expected to be significant, increasing amounts of capital will need to be devoted to expansion.

---

[18] These capital expenditures do not include some equipment that was acquired under operating leases.

[19] Capital expenditures plus operating expenses for infrastructure and equipment, minus depreciation to avoid double-counting capital spending.

[20] Association of American Railroads economists estimate that each $1 billion of investment in rail infrastructure generates over 20,000 jobs.

[21] Association of American Railroads data.

5.0 Future Train Volumes and Capacity

5.1 FUTURE VOLUMES

2035 train volumes were projected using economic growth and commodity forecasts from the U.S. DOT's Freight Analysis Framework (FAF Version 2.2). The FAF forecasts are national freight transportation estimates covering all types of shipments by truck, rail, water, pipeline, and air. The U.S. DOT and the Federal Highway Administration use the FAF forecasts to analyze truck freight demand and help estimate highway capacity needs and investment requirements.

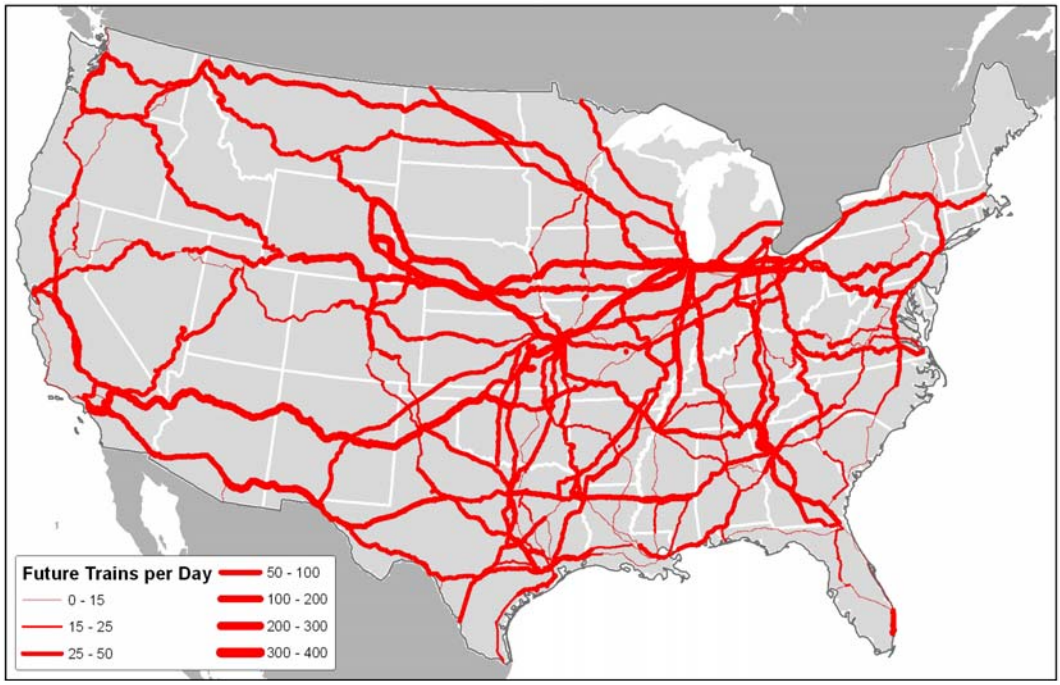
The FAF forecasts consider growth in population, the economy, and international trade. Forecasts of the demand for freight transportation are derived by examining production, consumption, and trade by major industry sector and economic region in the U.S., North America, and the rest of the world. The rail freight forecasts cover over 40 categories of commodities and estimate the volume of each type of commodity moving among 138 economic zones (114 zones representing economic areas and international trade gateways within the U.S., and 24 zones representing economic areas in Canada, Mexico, and overseas).

The forecasts are driven by demand only; they are not constrained by supply. This means that if an industry grows and the industry currently ships and receives a commodity by rail, then the industry will ship and receive more of that commodity by rail in the future. Conversely, if an industry declines and the industry currently ships and receives a commodity by rail, then the industry will ship and receive less by rail in the future. The forecasts assume that the rail system (and other freight modes) will have the capacity to meet the future demand. The forecasts also do not attempt to presuppose how markets and demand will change in response to future, but unknown, changes in technology, regulation, and politics. The forecasts are a starting point for consideration of the effect of future demand on infrastructure capacity and investment requirements, but are not comprehensive in their estimation of future freight demand.

The FAF Version 2.2 2035 commodity forecasts were used to develop weighted growth rates for the four types of train services—auto train service (for finished automobiles), bulk train service (for grain, coal, and similar bulk commodities), intermodal train service (for commodities moving in containers or truck trailer on flat cars or specialized intermodal cars), and general-merchandise train service (for everything else, including commodities moved in box cars and tank cars). The growth rates were applied to the number of 2005 trains to approximate the number of 2035 trains. The number of passenger trains was held at 2007 levels and added to the estimated number of freight trains in 2035.

Figure 5.1 maps the future corridor volumes in trains per day for the primary rail freight corridors. The number of trains per day is indicated by the width of the corridor line. The thinnest line indicates that a corridor carries up to 15 trains per day; the widest line indicates that a corridor carries between 300 and 400 trains per day.

Figure 5.1 Future Corridor Volumes by Primary Rail Freight Corridor
2035 Freight Trains and 2007 Passenger Trains per Day

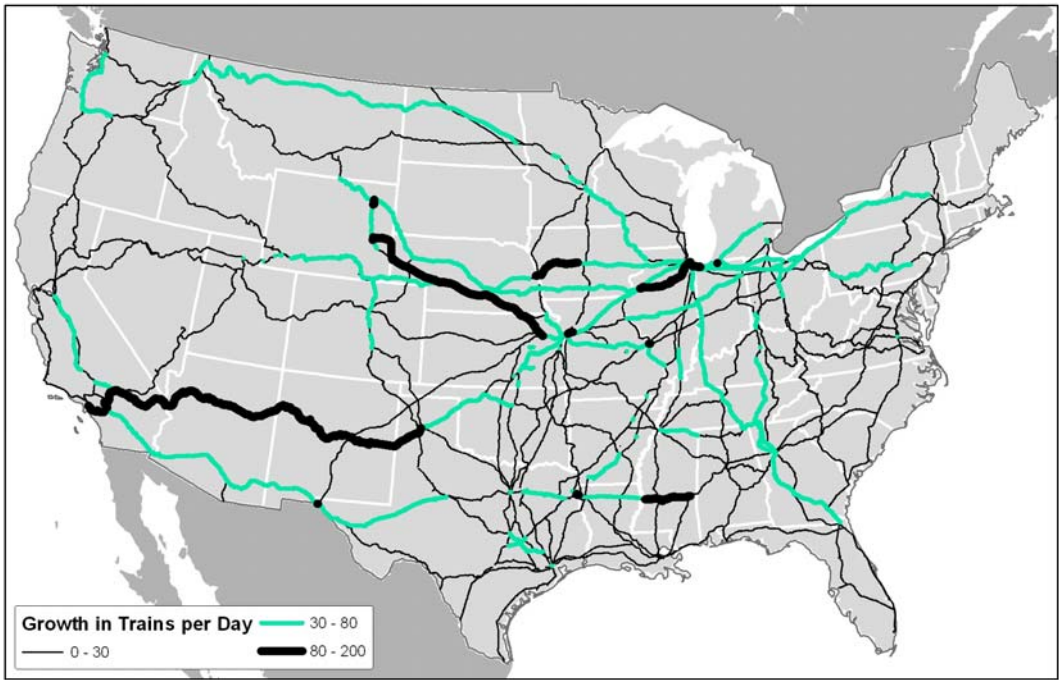


Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Figure 5.2 compares current and future volumes by primary corridor. The figure shows the growth in trains per day between the 2005 volumes and the 2035 volumes. The growth is indicated by the width and color of the corridor line. A thin black line indicates that a corridor will carry up to 30 additional trains per day by 2035; a green line indicates that a corridor will carry between 30 and 80 additional trains per day; and a thick black line indicates that a corridor will carry between 80 and 200 additional trains per day.

Figure 5.2 Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor

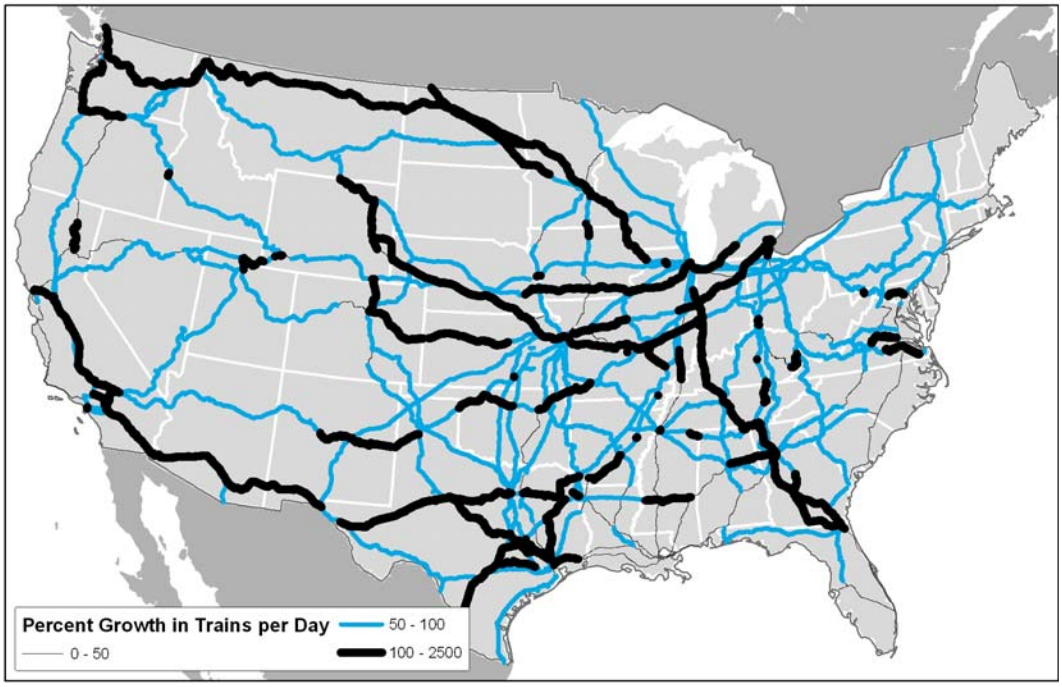


Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Figure 5.3 also compares current and future volumes by primary corridor, but the figure shows the percentage growth in trains per day from 2005 to 2035. The percentage growth is indicated by the width and color of the corridor line. A thin black line indicates that a corridor will carry up to 50 percent more trains per day by 2035; a blue line indicates that a corridor will carry between 50 and 100 percent more trains per day; and a thick black line indicates that a corridor will carry over 100 percent more trains per day.

Figure 5.3 Percentage Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor



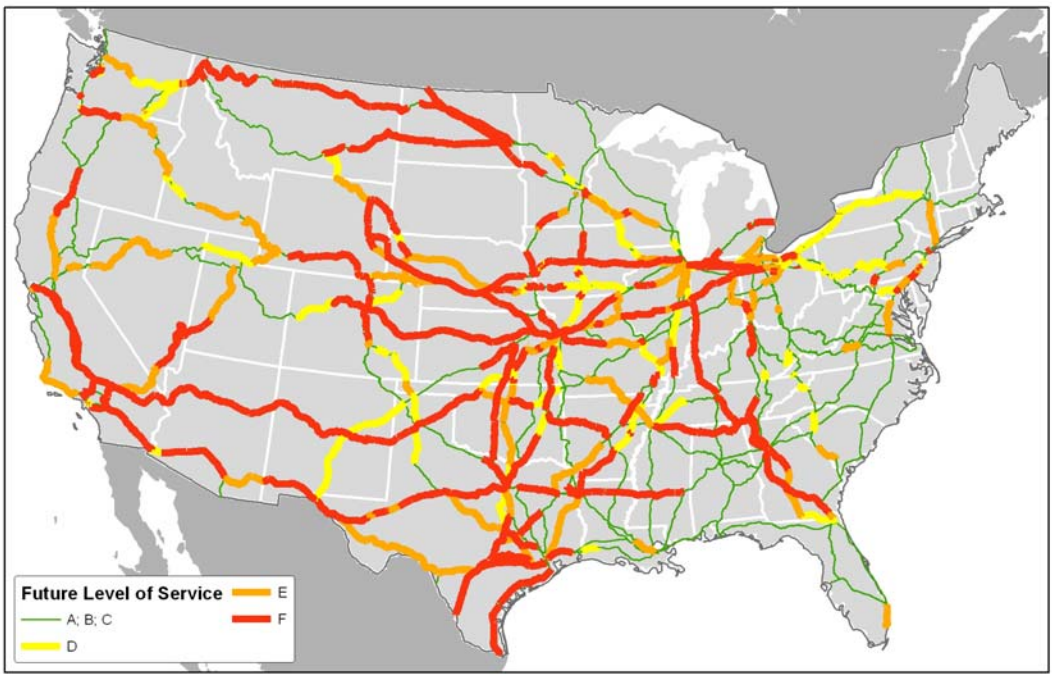
Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

5.2 FUTURE VOLUMES COMPARED TO CURRENT CAPACITY

Future volumes were compared to current capacity to estimate future volume-to-capacity ratios. This information was used to determine where demand will exceed capacity and where improvements will be required to avoid congestion. Figure 5.4 compares 2035 volumes in trains per day to current corridor capacity. The volume-to-capacity ratios are expressed as LOS grades for each primary rail corridor. Again, for legibility, rail corridors operating at LOS A, B, and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Figure 5.4 Future Corridor Volumes Compared to Current Corridor Capacity
2035 without Improvements



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Analysis of the 2035 levels of service, summarized in Table 5.1, shows that—without improvements—45 percent of primary corridor mileage will be operating below capacity (LOS A/B/C), 25 percent will be operating near or at capacity (LOS D/E), and 30 percent will be operating above capacity (LOS F). The resulting level of congestion would affect nearly every region of the country and would likely shut down the national rail network.

Table 5.1 Primary Rail Corridor Mileage by Future Level of Service Grade
2035 without Improvements

LOS Grade	Total Mileage	Percentage
A	4,895	9%
B	6,626	13%
C	11,708	23%
D	5,353	10%
E	7,980	15%
F	15,778	30%
Totals	52,340	100%

Source: Cambridge Systematics, Inc.

6.0 Rail Capacity Improvements

6.1 CAPACITY IMPROVEMENTS

Rail improvements were determined by comparing the current capacity in each primary corridor to the capacity needed to accommodate future train volumes. Capacities estimates were based on the capacities of typical rail corridor combinations of tracks, controls, and mix of train types as shown in Table 6.1. (This table was described in Section 4.0 and is repeated here for reference.)

Table 6.1 Average Capacities of Typical Rail-Freight Corridors
Trains per Day

		Trains per Day	
Number of Tracks	Type of Control	Practical Maximum If Multiple Train Types Use Corridor*	Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

The table presents average capacities for typical rail freight corridors. The actual capacities of the corridors were estimated using railroad-specific capacity tables. At the request of the railroads, these detailed capacity tables were not included in this report to protect confidential railroad business information.

Source: Class I railroad data aggregated by Cambridge Systematics, Inc.

For example, if a corridor with "one track and N/S-TWC control," which today accommodates 15 trains per day, must accommodate 35 trains per day in 2035, it is upgraded to "one track with CTC-TCS control," which accommodates 30 to 48 trains per day, depending on the mix of train types operating in the corridor.

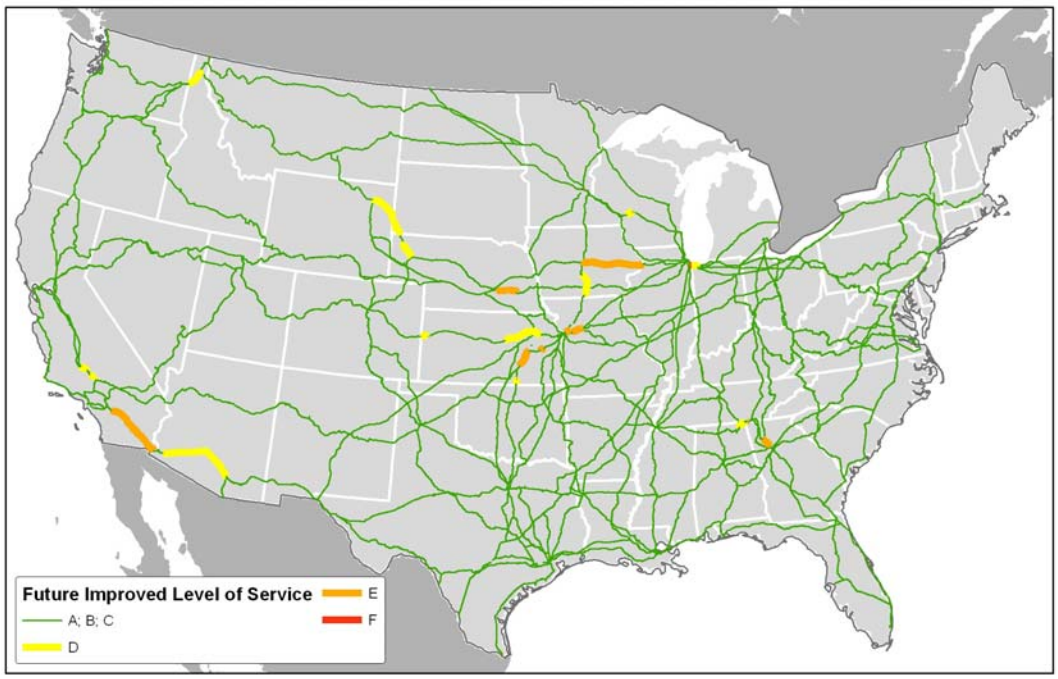
To avoid double-counting improvements that are currently programmed or underway, new improvements were selected to accommodate only forecast demand, not to correct current capacity shortfalls. If a corridor is at or above capacity today and needs additional capacity to accommodate future demand, improvements were programmed to bring the volume-to-capacity ratio back to the current ratio. For example, if the current volume-to-capacity ratio of a corridor is 0.85 and the future volume-to-capacity ratio without improvements is estimated to be 1.6, improvements were made to bring the volume-to-capacity ratio back to 0.85, not to 0.70. If a corridor is below capacity today and needs additional capacity to accommodate future demand, improvements were selected to bring the volume-to-capacity ratio up to a maximum of 0.70.

6.2 FUTURE VOLUMES COMPARED TO FUTURE CAPACITY

Figure 6.1 compares projected future corridor volumes in trains per day to projected future corridor capacity assuming that the necessary improvements are made. The volume-to-capacity ratios are expressed as LOS grades for each primary rail corridor. Again, rail corridors operating at LOS A, B and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Analysis of the 2035 levels of service, summarized in Table 6.2, shows that—with improvements—97 percent of primary corridor mileage will be operating below capacity (LOS A/B/C), 2 percent will be near or at capacity (LOS D/E), and less than 1 percent will be operating above capacity (LOS F).

Figure 6.1 Future Train Volumes Compared to Future Train Capacity
2035 with Improvements



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Table 6.2 Primary Rail Corridor Mileage by Future Level of Service Grade
2035 with Improvements

LOS Grade	Total Mileage	Percentage
A	4,895	9%
B	15,198	29%
C	31,036	59%
D	608	1%
E	597	1%
F	6	<1%
Totals	52,340	100%

Source: Cambridge Systematics, Inc.

7.0 Investment Requirements

7.1 COST OF IMPROVEMENTS

The cost of improvements needed to accommodate rail freight demand in 2035 is estimated at $148 billion (in 2007 dollars). The Class I freight railroads' share of this cost is projected to be $135 billion; the short line and regional freight railroads' share is projected to be $13 billion. The cost estimates cover:

- Line expansion:
  - Upgrades to mainline tracks and signal control systems;
  - Improvements to significant rail bridges and tunnels;
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad tracks and bridges to accommodate 286,000-pound freight cars.
- Facility expansion:
  - Expansion of carload terminals, intermodal yards, and international gateway facilities owned by railroads; and
  - Expansion of Class I railroad service and support facilities such as fueling stations and maintenance facilities.

Table 7.1 summarizes the investments required by type of improvement for the Class I and the short line and regional railroads.

Table 7.1 Cost of Rail Freight Infrastructure Improvements
Millions of 2007 Dollars

	Class I Freight Railroads	Short Line and Regional Freight Railroads	Totals
Line Haul Expansion	$94,750	$320	$95,070
Major Bridges, Tunnels, and Clearance	$19,400	$5,000	$24,400
Branch Line Upgrades	$2,390	$7,230	$9,620
Intermodal Terminal Expansion	$9,320		$9,320
Carload Terminal Expansion	$6,620		$6,620
Service Facilities	$2,550		$2,550
Totals	$135,030	$12,550	$147,580

Source: Cambridge Systematics, Inc.

Notes: All estimates exclude real estate acquisition costs, consistent with national highway needs analysis study practices.

Line expansion costs for short line and regional railroads are only for segments used to connect the primary corridors, not the entire system.

The category Major Bridges, Tunnels, and Clearance covers very large projects such as expansion of major bridges and tunnels (or construction of new parallel bridges and tunnels) and corridor overhead clearance projects that are not adequately accounted for by per mile unit costs.

The category Branch Line Upgrades covers upgrades to secondary main and branch lines to meet 286,000-pound weight-limit standards for the Class I railroads. A preliminary analysis shows limited need to upgrade the capacity of secondary mainlines and branch lines.

Line expansion cost estimates were based on per mile construction costs to upgrade from one level of corridor capacity to another. Table 7.2 lists the average construction cost per mile for each set of upgrades. For example, upgrading a corridor from "one track and N/S-TWC control" to "one track with CTC-TCS control" would cost $700,000 per mile. All costs are reported in current (2007) dollars.

Table 7.2 Average Unit Costs

From		To		Construction Cost (per mile)
Tracks	Control	Tracks	Control	
1	N/S-TWC	1	CTC-TCS	$700,000
2	NS-TWC	2	CTC-TCS	$700,000
1	ABS	1	CTC-TCS	$500,000
2	ABS	2	CTC-TCS	$600,000
1	CTC-TCS	2	CTC-TCS	$3,800,000
2	CTC-TCS	3	CTC-TCS	$4,400,000
3	CTC-TCS	4	CTC-TCS	$4,400,000
4	CTC-TCS	5	CTC-TCS	$4,400,000
5	CTC-TCS	6	CTC-TCS	$4,400,000

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Note: The table presents average costs for typical rail freight corridors. The actual costs of the corridors were estimated using railroad-specific capacity tables. Per mile construction costs for Eastern rail corridors were higher than the averages presented in the table because of the number of urbanized areas, hilly terrain, and numerous river crossings. Conversely, per mile construction costs for Western rail corridors in non-urban areas were lower than the averages presented in the table because of the prevalence of flatter, non-urbanized areas along some Western railroad primary corridors. At the request of the railroads, the railroad-specific cost tables were not included in this report to protect confidential railroad business information.

Source: Cambridge Systematics based on Association of American Railroads and Class I railroads' data.

Expansion costs for major bridges and tunnels were estimated separately for each facility based on the cost of recent and comparable projects. Expansion costs for facilities such as intermodal yards, carload terminals, fueling stations, and maintenance facilities were estimated using the anticipated number of intermodal units, cars, and trains operating in the corridor.

The estimates do not include all line expansion costs on short line and regional railroads, nor the cost of expanding tunnels, bridges, and service facilities on the short lines and regionals. Neither the Class I nor the short line and regional railroad estimates include the cost of additional real estate, the cost to maintain or replace existing rail lines and facilities, or the cost to acquire additional locomotives and railcars.

Appendix A provides more information on the cost estimating methods.

7.2 COST SAVINGS FROM PRODUCTIVITY IMPROVEMENTS

The recommended improvements and the cost estimates assume that the future demand for rail freight transportation will be met by using current technology and existing rail corridors. The analysis also assumes that there will be no shift in freight traffic among modes (i.e., rail, truck, water), and no significant changes in regulation or other factors that could change the demand for or supply of rail freight services.

However, there are alternative futures that could, and eventually should, be examined. These include futures that assume significant changes in rail technology, major shifts in markets or trade patterns, and new innovations in railroad operations. A full examination of these alternative futures was not attempted for this first approximation study. However, a preliminary estimate was made of the potential cost savings from productivity improvements.

The railroads anticipate that they can improve train productivity by up to 0.5 percent per year over the 28-year period from 2007 to 2035. The productivity would be gained by carrying more freight over each primary rail corridor. This would be done by increasing the number of trains, hauling more cars per train, and loading railcars more efficiently to make better use of the 286,000-pound capacity of current railcars. These improvements would allow the railroads to carry the same amount of rail freight in 2035, but carry it with fewer trains.

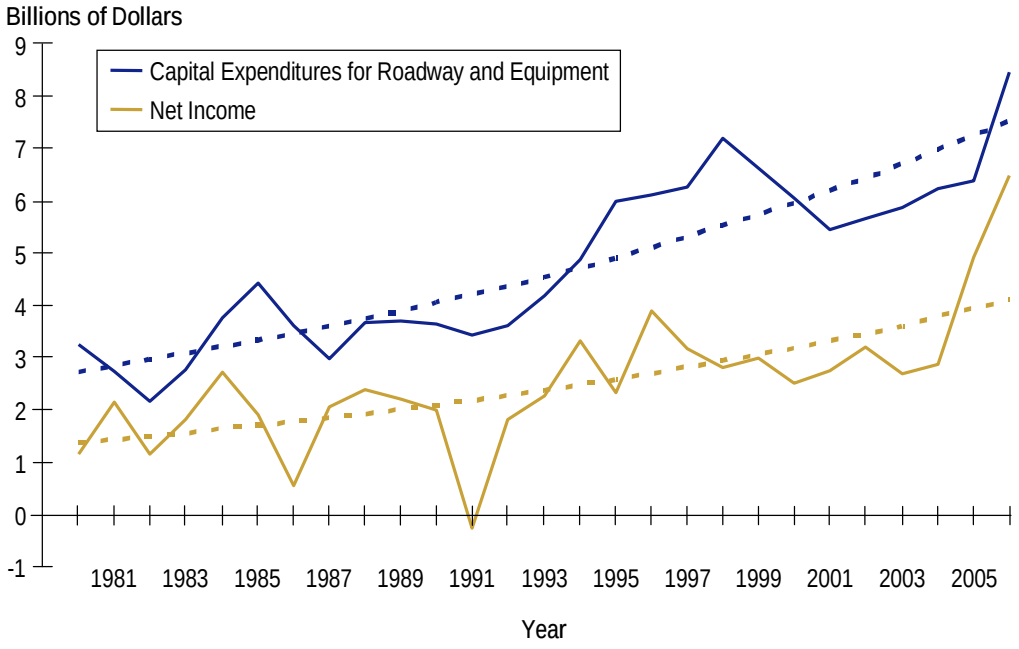
A 0.5 percent productivity improvement would reduce the number of trains to about 87 percent of the initial 2035 forecast number of trains. This would reduce capacity expansion needs in many corridors, reducing the cost of line expansion across all railroads from $148 billion to about $121 billion.[22] The Class I freight railroads' share for infrastructure expansion would be reduced from $135 billion to $109 billion, a savings of $26 billion. The short line and regional freight railroads' share of capital expenditures would be reduced from $12.6 billion to $12.3 billion, a savings of about $0.3 billion.

[22] Productivity improvements are only applied to line costs, not to terminals, yards, facilities, etc.

7.3 RAILROAD INVESTMENT CAPACITY

In general, Class I railroad capital expenditures have tracked income, as shown in Figure 7.1, increasing consistently (in current dollars) since the economic deregulation of the railroad industry in 1980. Class I capital expenditures for infrastructure expansion totaled $1.1 billion in 2005 and $1.4 billion in 2006. The AAR estimates that Class I capital expenditures for infrastructure expansion will total $1.9 billion in 2007.

Figure 7.1 Capital Investment and Income
Class I Railroads, 1981 to 2006, in Current Dollars



Source: American Association of Railroads data.

If rail revenues grow proportionally to rail tonnage, currently forecast to increase by 88 percent by 2035, and if the railroads maintain their current level of effort for expansion, then the Class I railroads will invest cumulatively about $70 billion over the 28-year period.

7.4 INVESTMENT REQUIREMENTS FOR CLASS I RAILROADS

The estimated cost of the improvements needed to accommodate rail freight demand in 2035 is $148 billion. Of this amount, the Class I freight railroads' share is projected to be $135 billion.

The Class I railroads anticipate that they will be able to generate approximately $96 billion of their $135 billion share through increased earnings from revenue growth, higher volumes, and productivity improvements, while continuing to renew existing infrastructure and equipment. If revenue and capital expenditures for expansion follow the growth in rail tonnage, as the railroads expect, the Class I railroads could realize about $70 billion of the $135 billion from growth. And if the Class I railroads can continue to achieve train productivity gains of up to 0.5 percent per year, the railroads could realize savings of $26 billion in reduced capital expenditures. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

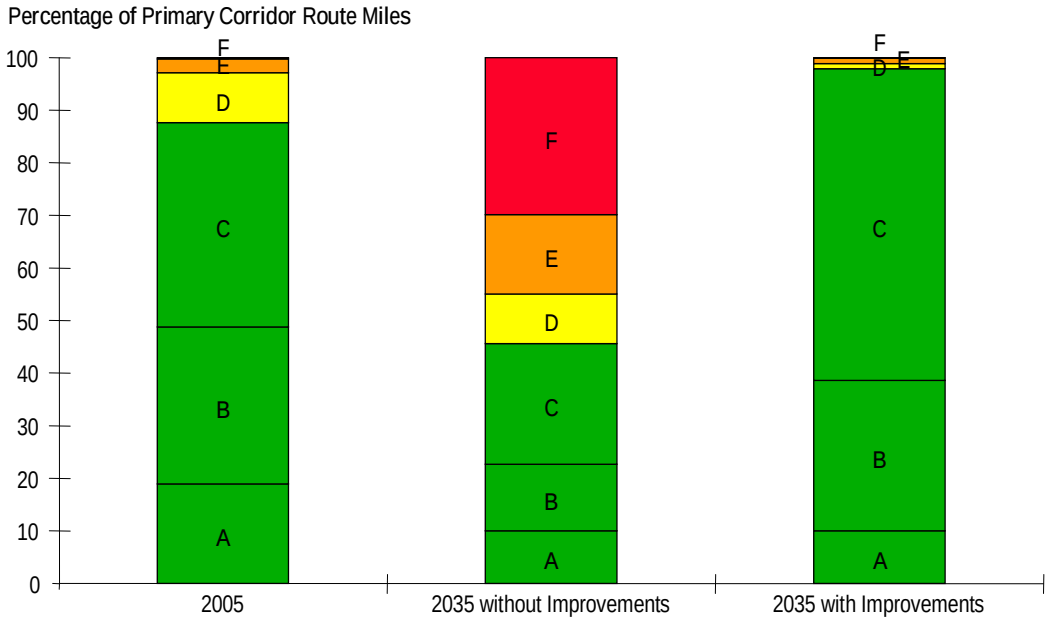
These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads may not be able to meet the U.S. DOT's forecast demand.

8.0 Conclusions

On first approximation, the investment in the continental U.S. rail network required to allow the freight railroads to meet the U.S. DOT's projected demand for rail freight transportation is $148 billion (in 2007 dollars). This level of investment would enable the freight railroads to keep pace with economic growth and meet the U.S. DOT's forecast demand for rail freight transportation in 2035.

The impact of the investment is illustrated in Figure 8.1, which compares the percentage of primary rail freight corridor miles by LOS grade and year.

Figure 8.1 Percentage of Rail-Freight Primary Corridor Route Miles by Level of Service Grade in 2005, 2035 without Capacity Improvements, and 2035 with Capacity Improvements



Source: Cambridge Systematics, Inc.

The left column shows the percentage of miles by LOS grade for the current rail system (2005 train volumes on the 85th percentile day compared to 2007 capacity). Red indicates the percentage of miles operating above capacity; yellow and orange the percentage of miles near or at capacity; and green, the percentage of miles below capacity. The center column shows the percentage of miles by LOS grade for the primary corridors in 2035 without improvements. Thirty percent of the rail miles in the primary corridors will be operating above capacity, causing severe congestion that will affect every region of the country and potentially shift freight to an already heavily congested highway system. Finally, the right column shows the estimated LOS grades in 2035 with improvements. The

improvements sharply reduce the number of primary corridor miles operating above capacity.

Meeting the U.S. DOT's forecast demand will require the Class I freight railroads to increase their investment in infrastructure expansion. The AAR estimates that between 2005 and 2007, Class I freight railroad capital expenditures for infrastructure expansion averaged $1.5 billion per year. To meet the U.S. DOT's forecast demand for 2035, the Class I freight railroads must invest $135 billion over the next 28 years or about $4.8 billion per year.

The Class I freight railroads anticipate that they will be able to meet most of this increase in investment through growth and productivity gains. If revenue and capital expenditures for expansion follow the growth in rail tonnage, the Class I railroads could realize about $70 billion of the $135 billion from growth. And if the Class I railroads can continue to achieve train productivity gains of up to 0.5 percent per year, the railroads could realize savings of $26 billion in reduced capital expenditures. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads may not be able to meet the U.S. DOT's forecast demand.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

In summary, the findings point clearly to the need for more investment in rail freight infrastructure and a national strategy that supports rail capacity expansion and investment.

A. National Rail Freight Infrastructure Capacity and Investment Study: Methodology

A.1 INTRODUCTION

The objective of this study is to identify rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. Department of Transportation's (DOT) projected demand for rail-freight transportation in 2035. This requires an understanding of the current and forecasted demand for rail services and the current and projected capacity of the rail network. The study encompasses the continental United States rail system.

The general approach was to divide the continental U.S. Class I railroad network into primary corridors; establish the volume of trains in 2005 and 2035; compare those volumes to current capacity; determine the additional capacity needed to accommodate 2035 volumes; identify the types of improvements warranted; and estimate the investment needed for these improvements. The improvements can be divided into line expansion and facility expansion, each with multiple components.

- Line expansion includes:
  - Upgrades to the Class I system mainlines control systems and/or number of tracks;
  - Improvements to significant bridges, tunnels, clearances, and other items above average costs;
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad track and bridges to accommodate 286,000-pound freight cars.
- Facility expansion includes:
  - Expansion of capacity at Class I railroad-owned intermodal facilities, including terminals, ports and gateways;
  - Expansion of capacity at carload terminals (e.g., classification yards); and
  - Expansion of capacity at Class I railroad-owned service facilities (e.g., fueling stations, maintenance facilities).

A.2 LINE CAPACITY EXPANSION

The work steps to estimate the cost of expanding line capacity along primary Class I railroad corridors to meet U.S. DOT projected demand was as follows:

1. Divide the continental U.S. Class I railroad network into primary corridors;[23]
2. Establish the number of freight trains for a day representing the 85th percentile of the maximum trains per day from the 2005 Surface Transportation Board (STB) Carload Waybill Sample (Waybill);
3. Establish the number of scheduled passenger trains for a current average weekday, and combine with the freight trains;
4. Estimate the number of freight trains per day in 2035 by applying forecast rates from the Freight Analysis Framework Version 2.2 to the 2005 STB Waybill. Passenger train volumes were held constant;
5. Estimate the current capacity on the nation's primary rail corridors in trains per day based on current track configurations;
6. Compare the 2005 and 2035 freight and passenger trains per day to the current capacity, and identify the types of improvements necessary to maintain reliable rail service in 2035;
7. Estimate the construction costs of the improvement lines;
8. Estimate the cost of significant bridges, tunnels, clearance projects, etc.; and
9. Estimate the cost to upgrade all Class I branch lines and all short line and regional lines that are currently below 286,000-pound weight standards to the current standard.

Each of these is described in more detail in the following sections.

Divide the Continental U.S. Class I Railroad Network into Primary Corridors

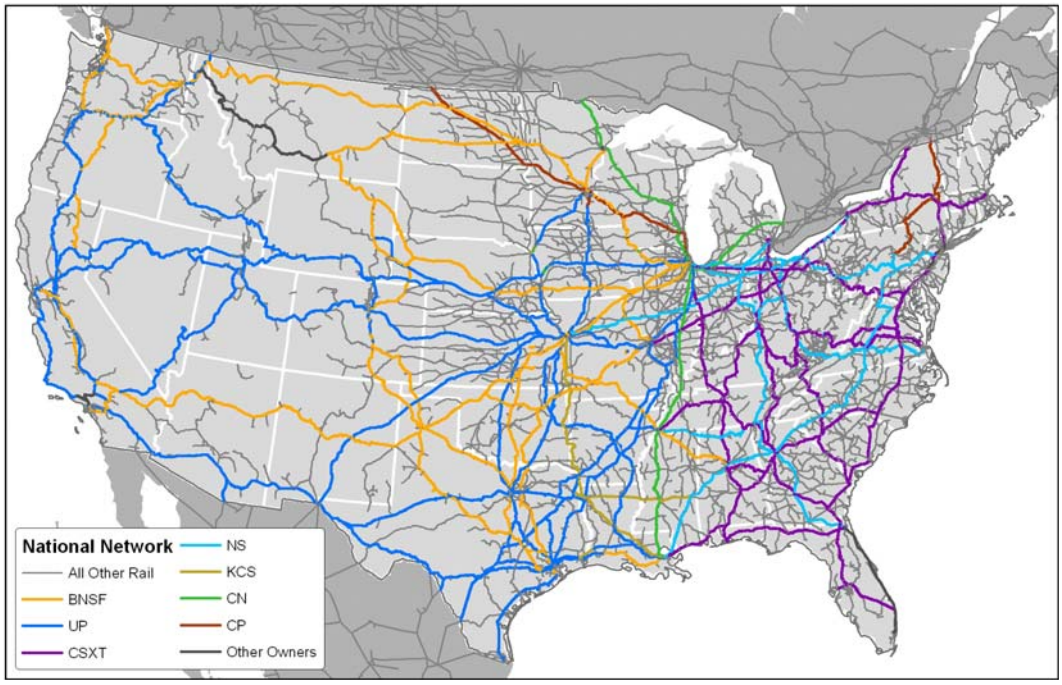
The initial work step was to divide the continental U.S. Class I railroad network into primary corridors. The corridors are mainline track and represent the lanes that haul the majority of the freight rail traffic. A corridor is roughly homogeneous with respect to traffic mix and type of infrastructure (i.e., number of tracks and control system).

[23] The Class I railroads covered in this study are BNSF, CN (U.S. operations), CP (U.S. operations), CSX, KCS, NS, and UP.

The beginnings and ends of the corridors are major urban areas corresponding with the U.S. Department of Transportation Freight Analysis Framework Version 2.2 (FAF2.2) zones, major rail traffic generators such as the Powder River Basin coal fields, port complexes, and major rail traffic junctions.

Each of the Class I railroads participating in the study provided to Cambridge Systematics (CS) a map of their recommended primary corridors. CS aggregated this information into a national network of primary corridors for use in this study.

Figure A.1 National Rail Network and Primary Rail Corridors



Source: Cambridge Systematics, Inc.

The primary corridors were then mapped to a network combining the Oak Ridge National Laboratory (ORNL) Center for Transportation Analysis Rail Network Version 5-5 containing infrastructure attributes, with a network developed for the Tennessee Department of Transportation that assigns rail flows using minimum distance paths. In the course of this project the TDOT network was revised to include missing links with information from the ORNL network. The mapping was done in TransCAD, a commercially available transportation network modeling program.

Establish the Number of Freight Trains Operating on an 85th Percentile Day along Each Corridor in 2005

Data from the 2005 Surface Transportation Board Carload Waybill Sample was used to establish the total number of trains operating in each corridor with the following caveats:[24]

- Northbound Canadian traffic and southbound Mexican traffic will not be accounted for fully in this study because much of this traffic is absent from the Waybill Sample. Traffic terminating in Canada and Mexico (both U.S. originations and pass-through NAFTA traffic) often is waybilled to the U.S. border crossing, but much of the northbound Canadian traffic and southbound Mexican traffic is not reported.
- The Waybill Sample will not provide a complete picture of rail shipments end-to-end. The Waybill Sample is subject to "re-waybilling" (Rule 11 traffic) at key junctions such as Chicago. For example, one waybill may be written to cover a shipment from Los Angeles to Chicago, and a second waybill written to cover the same shipment as it moves on from Chicago to New York. This reporting practice makes it difficult to trace the entire route of some rail shipment. This issue did not affect the estimate of the number of trains operating in each corridor, and no effort was made to "link" these movements.

The Waybill Sample, which represents loaded revenue movements on the railroads, was adjusted to account for empty rail car moves. To estimate the empty car movements, empty return ratios were supplied by the AAR from the Uniform Rail Costing System (URCS), as shown in Table A.1. CS matched the empty return ratios to the Waybill data based on origin railroad, car type, and the car ownership flag. Table A.1 represents averaged empty return ratios for all cars ownerships – railroad, private, and leased. For a car ownership flag in the STB Waybill of "railroad" or "Trailer Train," specific ratios for railroad-owned cars were used. For a car ownership flag of "private," the privately owned car ratios were used. When the loaded car originated on a Class I carrier, the ratios for that carrier were applied. When a short line or regional railroad originated the load, the empty ratio was based on the East or West average, depending on whether the load originated east or west of the Mississippi River.

The carloads and intermodal units in the Waybill Sample were multiplied by the appropriate empty return ratio, reverse routed to represent the return movement from destination to origin, and then appended to the loaded cars in the Waybill. The assumption of reverse routing of the empties does not accurately reflect railroad operations, but it does place the correct amount of empty car miles on the network and it offers a reasonable approximation for this analysis.

[24] The Waybill Sample is expanded to represent 100 percent of the movements on U.S. railroads.

Table A.1 Empty Return Ratios Used in the STB's URCS Phase 3 and Waybill Costing Programs
All Cars, 2005 Ratios

URCS CT Number	Car Type	BNSF	CN (U.S.)	CP (U.S.)	CSX	KCS	NS	UP	East	West
1	Box – 40-foot	1.33	1.72	1.75	1.59	1.52	1.72	1.38	1.65	1.38
2	Box – 50-foot	1.33	1.72	1.75	1.59	1.52	1.72	1.38	1.65	1.38
3	Box – Equipped	1.69	1.89	1.86	1.87	1.76	1.99	1.76	1.92	1.74
4	Gondola – Plain	1.96	1.86	2.31	1.94	1.97	1.91	2.36	1.92	2.26
5	Gondola – Equipped	1.85	2.11	1.98	1.83	2.00	1.89	1.89	1.86	1.88
6	Hopper – Covered	1.77	1.98	1.82	1.94	2.02	2.04	2.01	1.99	1.90
7	Hopper – Open Top General	1.94	1.92	2.14	1.95	1.94	1.96	2.09	1.95	2.05
8	Hopper – Open Top Special	1.96	2.03	2.11	1.95	2.00	2.01	2.13	1.98	2.09
9	Reefer – Mechanical	1.73	1.73	1.36	1.77	1.51	1.93	1.75	1.79	1.74
10	Reefer – Nonmechanical	1.58	2.35	1.88	1.93	5.42	1.81	1.86	1.90	1.72
11	Flat – Intermodal	1.15	1.18	1.10	1.15	1.05	1.09	1.15	1.12	1.15
12	Flat – Multilevel	1.27	1.45	1.38	1.54	1.19	1.59	1.45	1.55	1.41
13	Flat – General	2.41	2.47	2.24	1.79	1.94	2.66	201	2.29	2.16
14	Flat – Other	1.74	2.03	1.94	1.84	1.90	2.05	1.88	1.95	1.82
15	Tank < 22,000 Gallons	1.47	1.70	6.16	1.97	2.01	2.01	2.08	1.98	1.80
16	Tank >= 22,000 Gallons	1.54	1.88	2.30	2.01	2.06	2.03	2.04	2.02	1.83
17	All Other Freight Cars	1.34	1.70	2.56	1.94	2.04	1.52	2.03	1.69	1.59
18	Average Freight Car	1.51	1.85	1.59	1.75	1.83	1.70	1.82	1.74	1.69

Note: Empty Return Ratio defined as total miles divided by loaded miles. Ratios in spreadsheet are available to six significant digits – only three shown above. Ratios for 40-foot Box Cars use same value as 50-foot Box Car as a default. URCS Phase 3 and Waybill costing use ratios for All Other Freight Cars as defaults for railroad-owned tank cars.

Source: AAR, from the Uniform Rail Costing System.

Annual cars were then converted into average daily cars. This was done by first summarizing the Waybill Sample by waybill date and number of cars. The volume from the day representing the 85th percentile (based on volume of cars) was used to scale the annual volume to a daily volume. The 85th percentile threshold is consistent with highway capacity analysis methods.[25] This multiplier to convert annual cars and intermodal units in the Waybill Sample to an 85th percentile day was 0.00357. An 85th percentile day has 9.9 percent more cars than a 50th percentile day in the 2005 Waybill Sample.

The cars were subdivided into four service types – intermodal, bulk, general merchandise, and auto – the same four defined in the Waybill Sample. For each service type, the number of daily cars was converted into daily trains based on average train lengths supplied by BNSF, CSX, NS and UP. For the other railroads, CS estimated the train lengths. Table A.2 contains the average values used for eastern and western railroads. Intermodal unit train conversions were based on TOFC/COFC counts rather than cars. Adjustments were made in some corridors (e.g., Powder River Basin) to reflect actual operations of significantly longer trains.

Table A.2 Average Train Length
Number of Cars

Type of Service	Eastern Railroads	Western Railroads
Auto	57.0	63.9
Bulk	86.0	112.4
General Merchandise	82.0	80.7
Intermodal (TOFC/COFC count)	110.7	164.3

Source: Class I Railroad data averaged by Cambridge Systematics, Inc.

The next step was to unlink the trips. The Waybill Sample has records with a junction frequency up to six, indicating that seven railroads participated in the move (six junctions). The unlinked records break these apart so that each "trip" is only for a single railroad. The geographic endpoints of the trip can either be the origin and destination, or the junction location. These are generically referred to as the on-point and off-point. The Waybill does not have information on internal routings and classifications on an individual railroad.

The final step was to assign the train estimates to the ORNL rail network, using an all or nothing assignment in TransCAD. After combining the freight and

[25] This method of scaling the annual volume based on the 85th percentile is preferred over simply selecting the traffic on the day representing the 85th percentile. Scaling the annual volume will provide a more robust distribution of traffic over the rail lines that accounts for seasonality, instead of a snapshot of traffic for a single day.

passenger trains (see next section), density maps were developed and provided to BNSF, CSX, NS, and UP for review. The AAR reviewed the traffic density maps for CN, CP, and KCS. Corrections were made to the assignments and volumes when needed, and new maps were generated for further review.

As in all cases with this study, care was taken not to distribute confidential data about one railroad to the other railroads. Only the AAR and CS had access to the full information.

Establish the Current Number of Passenger Trains per Day

In addition to the total number of freight trains, the number of passenger trains operating on the network was determined. This includes estimates of Amtrak service, and commuter services such as the Virginia Railway Express and the Southeastern Pennsylvania Transportation Agency that make significant use of freight railroad lines. Not every commuter service was included, only those operating on the primary corridor network.

Most of the train information was obtained from available published schedules. Although the term "train" is used, it should more appropriately be called a "trip." A train that goes out and back was counted as two "trains." An average day was considered to be a weekday, not a weekend or holiday.

The passenger train estimates were assigned directly to the ORNL rail network using TransCAD, rather than applying a traffic assignment algorithm. Passenger train maps were generated and distributed to the study participants for review and comment.

The final step was to add the daily passenger train counts directly to the freight trains that had been assigned to the network.

Establish the Forecasted Number of Train Equivalents Operating Along Each Corridor for the Year 2035

The U.S. Department of Transportation's Freight Analysis Framework Version 2.2 ($FAF^{2.2}$) provides an estimate of all freight traffic moving in the U.S. by origin, destination, commodity, and mode. It has a 2002 base year and forecasts from 2010 to 2035 in five-year increments. The geography is based on 138 zones, with 114 zones in the U.S. It includes domestic traffic, North American traffic (Canada and Mexico border crossings, with the gateway location), and international traffic (by foreign region and U.S. zone, with an intermediate port). $FAF^{2.2}$ contains seven different modes of transportation: air and truck, other intermodal, pipeline and unknown, rail, truck, truck-rail, and water.

CS used the $FAF^{2.2}$ forecasts for 2035 for the rail and truck-rail modes by origin, destination, and commodity. The rail and truck-rail modes were combined into a single set of forecasts rates. The Waybill data was geographically matched to the $FAF^{2.2}$ zones by using a translation table mapping county to zone. Since the Waybill "starts" and "stops" trips at ports, the international forecasts were

included in the forecast rates based on the location of the port. For example, a move from Europe to the Atlanta zone with a port of Charleston, was considered a Charleston – Atlanta move and the forecasts rates were blended with the domestic forecast rates for other Charleston – Atlanta traffic by commodity. Rates by commodity for both Canadian and Mexican traffic were developed, and applied to Waybill data originating or terminating in those countries.

FAF2.2 uses Standard Classification of Transported Goods (SCTG) codes. CS developed weighted averages of the forecast growth rates to establish growth factors for the general merchandise, intermodal, bulk and auto service types, based on the assignments in Table A.3. Weighted forecast growth rates for each service type were calculated for each FAF2.2 origin-destination zone.

Table A.3 FAF2.2 Commodity Assignment to Rail Service Type for Establishing Forecast Growth Rates

Auto	Bulk	Intermodal	Merchandise
• Motorized vehicles	• Animal feed • Cereal grains • Coal • Coal-n.e.c. • Metallic ores • Gravel • Nonmetallic minerals	• Alcoholic beverages • Electronics • Furniture • Machinery • Meat/seafood • Miscellaneous manufactured products • Mixed freight • Pharmaceuticals • Plastics/rubber • Precision instruments • Printed products • Textiles/leather • Tobacco products • Transport equipment	• Articles-base metal • Base metals • Basic chemicals • Building stone • Chemical products • Crude petroleum • Fertilizers • Fuel oils • Gasoline • Live animals/fish • Logs • Milled grain products • Natural sands • Nonmetal mineral products • Other agriculture products • Other foodstuffs • Unknown • Waste/scrap • Wood products • Newsprint/paper • Paper articles

The 2035 forecast growth rates were applied to the 2005 base-year loaded and empty cars by FAF2.2 origin-destination zone and railroad service type. (The rates were adjusted to reflect the difference between the FAF2.2 2002 base year the Waybill 2005 survey year). This makes the assumption that empty return ratios will be the same in 2035 as they were in 2005. For empty cars, the forecast rate was based on the last commodity hauled. The forecast number of loaded and empty cars were converted into average trains per day, using the same conversion factors established for the 2005 data (i.e., average train lengths were held constant.)

The number of passenger trains was held at current levels. This study did not attempt to forecast 2035 passenger rail demand and service. A separate study is being conducted to develop passenger rail needs for presentation to the Commission.

The forecasted 2035 freight trains were then assigned to the ORNL rail network using an all or nothing assignment based on minimum distances, adjusted to reflect current rail road operating restrictions validated against existing volumes. Current passenger trains were added directly to the network to provide the complete 2035 year volumes. The results was mapped and sent to the railroads for review.

Estimate the Current Capacity for Each of the Primary Corridors

The capacity of the primary rail corridors was determined by defining a set of archetypical corridors, based on track and type of control, and then defining the capacity in terms of trains per day. Readily available information was supplied by the railroads participating in this study drawing from previously performed simulation studies. The information ranged from generic data to simulation results of specific corridors and general knowledge of operations.

CS used this information to identify a set of archetypical corridors that represented the various track and control combinations present along the corridors. The number of tracks was 1, 2, 3, or 4 and the type of controls included no signal or track warrant control (N/S-TWC), automated block signal (ABS), and centralized traffic control or train control system (CTC-TCS). To accommodate future demand, archetypical corridors of 5 and 6 tracks were added.

Comparison of the capacity information from each railroad yielded a range of values. One reason for this range was the mix of trains on the line. Lines with a nearly homogenous train mix have a higher capacity than lines with a mixture of train types. To adjust for this, each archetype was assigned a lower and an upper bound for the maximum number of trains. The lower bound was defined as the maximum number of trains per day, assuming an equal mix of merchandise-bulk, intermodal-auto, and passenger trains (one-third each). The upper bound was defined as the maximum number of trains per day, assuming 100 percent one type, and 0 percent of the other two types (complete homogeneity). To move between the lower bound and the upper bound, the standard deviation of the

train mix was used to scale the range between the bounds. For a train mix of 33 percent, 33 percent, and 33 percent for each of the three types, the standard deviation is zero; therefore a zero adjustment is added to the lower bound. A train mix of 100 percent, 0 percent, and 0 percent yields a standard deviation of 0.47, which was scaled to produce a factor that added to the lower bound equaled the upper bound.[26] A standard deviation falling between the minimum of zero and the maximum of 0.47 produced a capacity somewhere between the lower and upper bounds. Table A.4 contains the archetypes used in this study, along with the lower and upper capacity bounds.

Another reason for differences in capacity is due to differences in geography and topography. For similar types of track, a regions with longer runs and greater distances between urban areas can achieve higher speeds and greater throughput than areas with short runs and more closely spaced urban areas. Therefore, different capacity tables were developed based on regional variations. Table A.4 contains the average lower and upper maximum capacity bounds for the archetypes used in this study.

Rail capacity can take two forms. The "theoretical capacity" is the maximum number of trains assuming perfect conditions. The "practical capacity" considers factors such as possible disruptions, maintenance, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand. Practical capacity is about 70 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of C or D (described in the next section). At higher percentages, rail congestion increases and service reliability begins to deteriorate. The values established in Table A.4 represent practical capacity.

Using the number of tracks and the control system information from the ORNL rail network, CS developed a series of maps of track characteristics that were reviewed by the railroads. The track characteristics information was updated using feedback from the railroads, and then each of the primary rail corridors was assigned to one of the archetypes in Table A.4. Using the capacity for each archetype, and adjusting between the lower and upper bounds based on the standard deviation of the train mix, a practical capacity in trains per day was assigned to each of the primary corridors.

[26] The population standard deviation, not the sample standard deviation, was used since the three data points representing the percent mix of merchandise/bulk, intermodal/auto, and passenger encompasses the entire population.

Table A.4 Average Capacities of Archetypical Rail Corridors
Trains per Day

Number of Tracks	Type of Control	Trains per Day: Practical Maximum If Multiple Train Types Use Corridor*	Trains per Day: Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, a mix of merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

Source: Class I railroads' data aggregated by Cambridge Systematics, Inc.

Compare the 2005 and 2035 Train Volumes to the Current Capacity, and Identify the Types of Improvements Needed to Maintain Reliable Rail Service in 2035

Current corridor volumes were compared to current corridor capacity to assess congestion levels. This was done by calculating a volume-to-capacity ratio expressed as a level of service (LOS) grade. The LOS grades are listed in Table A.5. The LOS designations and descriptions correspond to the LOS designations used in highway system capacity and investment requirements studies.

Table A.5 Volume-to-Capacity Ratios and Level of Service (LOS) Grades

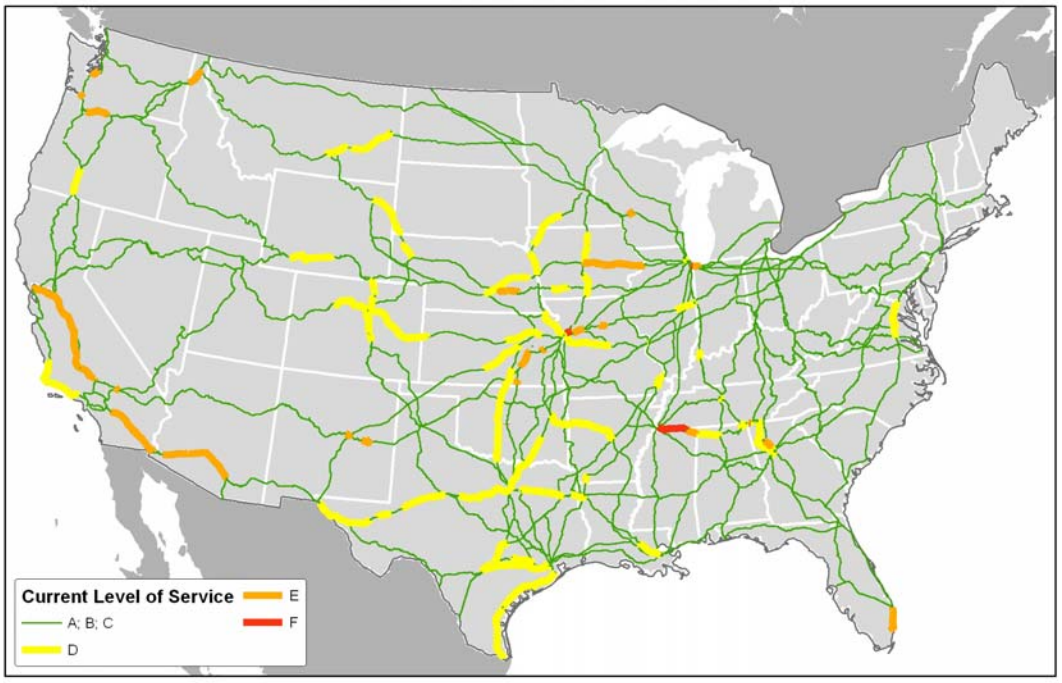
LOS Grade	Description		Volume/Capacity Ratio
A	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2
B			0.2 to 0.4
C			0.4 to 0.7
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
E	At Capacity	Very heavy train flow with very limited capacity to accommo-date maintenance and recover from incidents	0.8 to 1.0
F	Above Capacity	Unstable flows; service break-down conditions	> 1.00

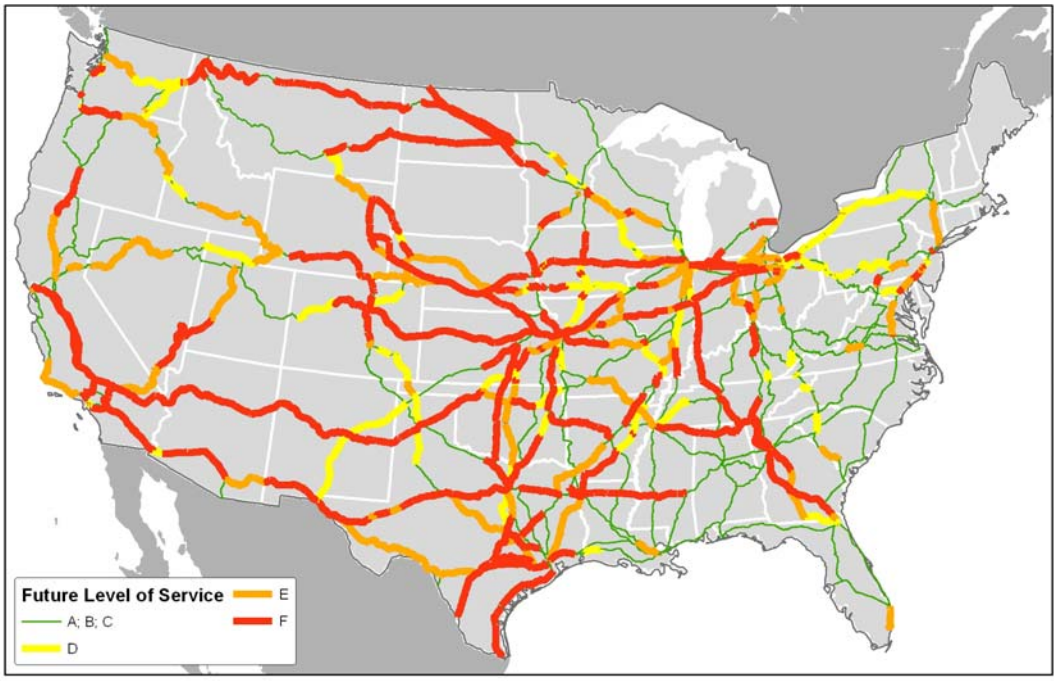
Source: Cambridge Systematics, Inc.

Rail corridors operating at LOS A, B or C are operating below capacity; they carry light to moderate train flows with sufficient unused capacity to accommodate maintenance work and recover quickly from incidents such weather delays, equipment failures, and minor accidents. Corridors operating at LOS D are operating near capacity; they carry heavy train flows with moderate capacity to accommodate maintenance and recover from incidents. Corridors operating at LOS E are operating at capacity; they carry very heavy train flows and have very limited capacity to accommodate maintenance and recover from incidents without substantial service delays. Corridors operating at LOS F are operating above capacity; train flows are unstable, and congestion and service delays are persistent and substantial. The LOS grades and descriptions correspond generally to the LOS grades used in highway system capacity and investment requirements studies.

Maps of the volume-to-capacity ratios, expressed as LOS classes, for the primary rail corridors are shown in Figure A.2. Rail corridors operating under capacity (at LOS A, B, or C) have been mapped in green, corridors operating near capacity (LOS D) have been mapped in yellow, rail corridors operating at capacity (LOS E) have been mapped in orange, and rail corridors operating over capacity (LOS F) have been mapped in red. Current volumes are those reported in the 2005 STB Waybill Sample (factored for empties and using an 85th percentile day). These volumes do not reflect fully recent trends, such as the increase in coal shipments moving from the Powder River Basin in Wyoming and Montana to Eastern utilities, nor the recent increase in intermodal containers delivered to East Coast marine ports and transferred to rail for inland delivery. Current capacity is the capacity as of 2007, and does not represent planned expansion.

Figure A.2 2005 and 2035 Train Volumes Compared to Current Train Capacity





Source: Cambridge Systematics, Inc.

Rail capacity line expansion improvements were estimated by identifying the upgrades to current capacity needed to accommodate future train volumes. To avoid double-counting improvements that are currently programmed or

underway, new improvements were selected to accommodate only forecast demand, not to correct current capacity shortfalls. If a corridor is below capacity today and needs additional capacity to accommodate future demand, improvements were selected to bring the volume-to-capacity ratio up to a maximum of 0.70. If a corridor is at or above capacity today and needs additional capacity to accommodate future demand, improvements were programmed to bring the volume-to-capacity ratio back to the current ratio. For example, if the current volume-to-capacity ratio of a corridor is 0.85 and the future volume-to-capacity ratio without improvements is estimated to be 1.6, improvements were made to bring the volume-to-capacity ratio back to 0.85, not to 0.70.

The hierarchy of corridor upgrades is shown in Table A.6. This hierarchy was used to expand from one archetypical corridor to another, until the capacity of the corridor could accommodate the forecasted 2035 volumes at a LOS of C or at current LOS if already operating at LOS D, E, or F. For example, if a corridor with "one track and N/S-TWC control" that today accommodates 16 to 20 trains per day needs to accommodate 35 trains per day in 2035, it would be upgraded to "one track with CTC-TCS control." As a rule, upgrades were selected to provide the appropriate level of service at the least cost. For the primary corridors under consideration, it was determined that any new construction would at a minimum involve a one-track CTC system (e.g., no expansion of lines operating on track warrants or with ABS on the primary corridors).

Table A.6 Hierarchy of Archetypical Rail-Freight Corridors
Practical Capacity in Trains per Day

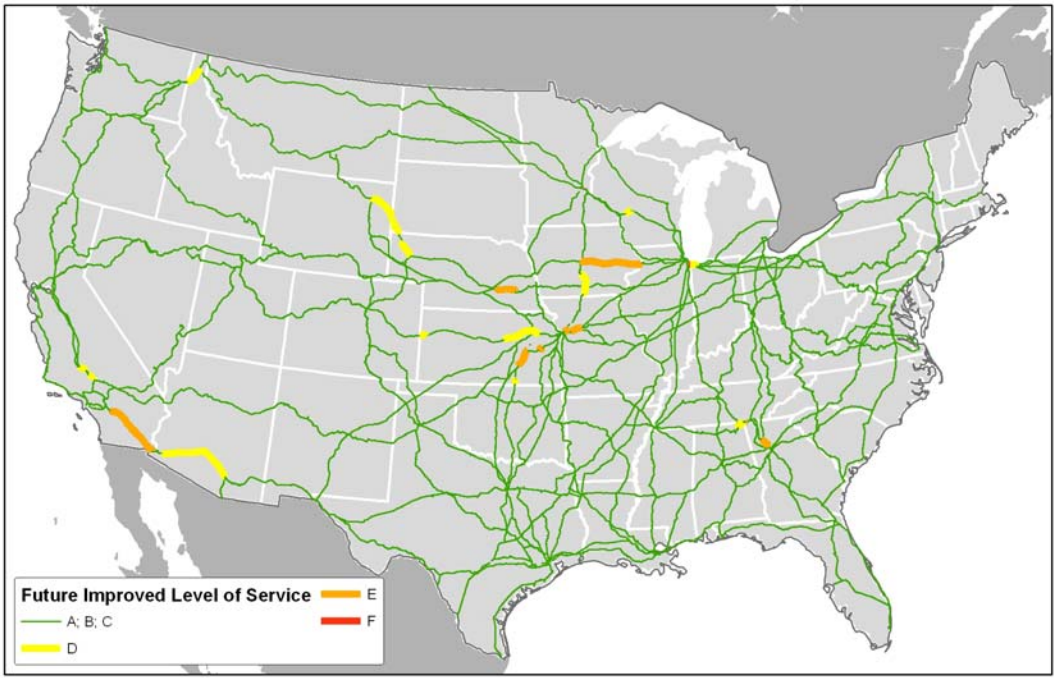
From				To			
Number of Tracks	Control	Lower Bound	Upper Bound	Number of Tracks	Control	Lower Bound	Upper Bound
1	NS-TWC	16	20	1	CTC-TCS	30	48
2	NS-TWC	28	35	2	CTC-TCS	75	100
1	ABS	18	25	1	CTC-TCS	30	48
2	ABS	53	80	2	CTC-TCS	75	100
1	CTC-TCS	30	48	2	CTC-TCS	75	100
2	CTC-TCS	75	100	3	CTC-TCS	133	163
3	CTC-TCS	133	163	4	CTC-TCS	173	230
4	CTC-TCS	173	230	5	CTC-TCS	248	340
5	CTC-TCS	248	340	6	CTC-TCS	360	415

Source: Class I railroads' data aggregated by Cambridge Systematics, Inc.

Note: N/S-TWC is No Signal and Track Warrant Control. ABS is Automatic Block Signaling. CTC-TCS is Centralized Traffic Control and Traffic Control System.

Figure A.3 compares future corridor volumes in trains per day to future corridor capacity assuming the necessary improvements are made. The volume-to-capacity ratios are expressed as LOS classes for each primary rail corridor. This map should look similar to the 2005 map in Figure A.2, since the goal was not to improve a corridor beyond the current level of service. This is not entirely possible due to the step-function nature of adding capacity. Adding an additional track can cause the LOS to drop several levels.

Figure A.3 Future Train Volumes Compared to Future Train Capacity
2035 with Improvements



Source: Cambridge Systematics, Inc.

Estimate the Construction Costs of the Improvement Lines

The costs to upgrade from one level of corridor capacity to another are listed in Table A.7. The costs are in unit costs per mile for construction. All costs are reported in current (2007) dollars. In the example cited above, upgrading a corridor from "one track and N/S-TWC control" to "one track with CTC-TCS control" would cost $700,000 per mile for construction. This is inclusive of design, engineering, and installation expenses. It is exclusive of any real estate costs.

Table A.7 presents average costs for typical rail freight corridors. The actual costs of the corridors were estimated using railroad-specific capacity tables. Per mile construction costs for Eastern rail corridors were about 25 percent higher than the averages presented in the table because of the number of urbanized areas, hilly terrain, and numerous river crossings. At the request of the railroads, the railroad-specific cost tables were not included in this report to protect confidential railroad business information.

Table A.7 Hierarchy of Archetypical Rail-Freight Corridors
Unit Cost to Upgrade Lines

From		To		Average Construction Cost Per Mile
Number of Tracks	Control	Number of Tracks	Control	
1	NS-TWC	1	CTC-TCS	$700,000
2	NS-TWC	2	CTC-TCS	$700,000
1	ABS	1	CTC-TCS	$500,000
2	ABS	2	CTC-TCS	$600,000
1	CTC-TCS	2	CTC-TCS	$3,800,000
2	CTC-TCS	3	CTC-TCS	$4,400,000
3	CTC-TCS	4	CTC-TCS	$4,400,000
4	CTC-TCS	5	CTC-TCS	$4,400,000
5	CTC-TCS	6	CTC-TCS	$4,400,000

Source: AAR and Class I railroads' data aggregated by Cambridge Systematics, Inc.

The costs in Table A.7 are additive. To expand from a one track CTC to a three track CTC would cost $8.2 million per mile ($3.8 million plus $4.4 million). The lower cost to go from one to two tracks (as opposed to 2 to 3 and 3 to 4) reflects cost savings from connecting existing sidings, less need to upgrade drainage, and other savings. The costs to maintain this additional track is not included in the total.

Estimate the Cost of Significant Bridges, Tunnels, Clearance Projects, etc.

Significant projects that are well outside the average unit cost in Table A.7, such as bridges spanning the Mississippi or Ohio River or expensive new or expanded tunnels and clearances, were included as additional costs in this study. The railroads, using maps provided by CS of where and how much capacity would be needed in 2035, individually provided estimates for significant structures.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. In most cases, the estimates were based on averages ranging from $200 to $300 million per structure. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A significant structures cost estimate was developed for CN, CP, and KCS by prorating the total significant structures cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Estimate the Cost to Upgrade Class I Branch Lines and Short Line and Regional Railroad Lines Currently Below 286,000-Pound Standards to Current Standards

The American Short Line and Regional Railroad Association (ASLRRA) released a report in 2000 that identified $6.9 billion in costs (1999 dollars) to upgrade the track of America's short line and regional railroads to accommodate the current standard weight of 286,000-pounds. This estimate was updated as part of this study. The update involved:

- The cost was inflated to represent 2007 dollars based on a construction price index developed from the U.S. Bureau of Labor statistics. This raised the cost from $6.9 billion to $10.8 billion.
- The cost of upgrading bridges was removed, and an ASLRRA provided estimate of $5 billion was included as a significant structures costs for short line and regional railroads.
- The AAR provided an estimate 898 route miles that has been upgraded between 2004 and 2007, an average of 299 miles per year. Using this ratio, an estimate of 2,395 miles were assumed to be upgraded to 286,000-pound standards between 1999 and 2007.
- The inflated cost to upgrade was reduced to reflect track already upgraded.

The final estimate for upgrading short line and regional railroad track to accommodate 286,000-pound loads is $7.2 billion (in 2007 dollars). The calculations are contained in Table A.8.

For the Class I railroad's branch lines, an average cost to upgrade was calculated at $300,000 per mile using the revised estimates from the ASLRRA. The miles of track not 286,000-pound ready was provided by BNSF, CSXT, NS, and UP. For CN, CP, and KCS, the estimated cost was prorated from the ratio of line expansion costs for those three railroads to the total line expansion costs.

Table A.8 Estimation of Cost to Upgrade Short Line and Regional Railroads to 286,000-Pound Weight Standard

Year	Inflation	Cost (Millions)	Cost Less Bridges (Millions)	Total Miles	Miles/Year Upgraded (2005 to 2007)	Estimated Miles Upgraded (1999 to 2007)	Assume 50 Percent Not 286,000-Ready (2007)	Estimated Percent Upgraded Since 1999	Estimated Cost to Upgrade (Millions)	Cost/Mile to Use for Class I (Millions)
1999	N/A	$6,861	$5,100	49,985	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.575	$10,806	$8,033	48,194	299	2,395	24,097	9.94%	$7,234	$0.300

Source: 1999 Information from ASLRRA *An Estimation of the Investment in Track and Structures Needed to Handle 286,000-pound Rail Cars*.

Note: Assumption of 50 percent not 286,000 ready provided by AAR. Based on 22,256 miles (46 percent) not 286,000 ready in 2004 less 898 miles upgraded between 2004 and 2007. Exact percentage unavailable since 10 percent of track has unknown weight limit.

A.3 INTERMODAL AND CARLOAD TERMINALS, AND SERVICE FACILITY CAPACITY EXPANSION

The work steps to estimate the cost of expanding terminal and facility capacity necessary for the Class I railroads to meet U.S. DOT projected demand was as follows:

- Expansion of capacity at Class I railroad-owned intermodal facilities, including terminals, ports and gateways;
- Expansion of capacity at carload terminals; and
- Expansion of capacity at Class I railroad-owned service (e.g., fueling stations, maintenance facilities).

Expand Capacity at Class I Railroad-Owned Intermodal Facilities, Including Terminals, Ports and Gateways

The cost of expanding intermodal facilities, whether they are intermodal yards, railroad-owned port facilities, or international gateways, was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035. The railroads individually provided costs estimates for expanding the largest and most important intermodal facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

An intermodal facility cost estimate was developed for CN, CP, and KCS by pro-rating the total intermodal facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded intermodal facilities are not included.

Expand Capacity at Carload Terminals

The cost of expanding carload facilities (e.g., classification yards) was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035. The railroads individually provided costs estimates for expanding the largest and most important carload facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A carload facility cost estimate was developed for CN, CP, and KCS by prorating the total carload facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded carload facilities are not included.

Expand Capacity at Class I Railroad-Owned Service Facilities

The cost of expanding service facilities (e.g., fueling, car shops) was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035, and a series of maps showing traffic volumes by corridor for 2035. The railroads individually provided costs estimates for expanding service facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A service facility cost estimate was developed for CN, CP, and KCS by prorating the total service facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded service facilities are not included.

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
American Heart Association®
Learn and Live℠

Particulate Matter Air Pollution and Cardiovascular Disease : An Update to the Scientific Statement From the American Heart Association

Robert D. Brook, Sanjay Rajagopalan, C. Arden Pope III, Jeffrey R. Brook, Aruni Bhatnagar, Ana V. Diez-Roux, Fernando Holguin, Yuling Hong, Russell V. Luepker, Murray A. Mittleman, Annette Peters, David Siscovick, Sidney C. Smith, Jr, Laurie Whitsel and Joel D. Kaufman

Circulation 2010, 121:2331-2378: originally published online May 10, 2010
doi: 10.1161/CIR.0b013e3181dbece1
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 72514
Copyright © 2010 American Heart Association. All rights reserved. Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/121/21/2331

Subscriptions: Information about subscribing to Circulation is online at
http://circ.ahajournals.org//subscriptions/

Permissions: Permissions & Rights Desk, Lippincott Williams & Wilkins, a division of Wolters Kluwer Health, 351 West Camden Street, Baltimore, MD 21202-2436. Phone: 410-528-4050. Fax: 410-528-8550. E-mail:
journalpermissions@lww.com

Reprints: Information about reprints can be found online at
http://www.lww.com/reprints

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

AHA Scientific Statement

Particulate Matter Air Pollution and Cardiovascular Disease

An Update to the Scientific Statement From the American Heart Association

Robert D. Brook, MD, Chair; Sanjay Rajagopalan, MD; C. Arden Pope III, PhD; Jeffrey R. Brook, PhD; Aruni Bhatnagar, PhD, FAHA; Ana V. Diez-Roux, MD, PhD, MPH; Fernando Holguin, MD; Yuling Hong, MD, PhD, FAHA; Russell V. Luepker, MD, MS, FAHA; Murray A. Mittleman, MD, DrPH, FAHA; Annette Peters, PhD; David Siscovick, MD, MPH, FAHA; Sidney C. Smith, Jr, MD, FAHA; Laurie Whitsel, PhD; Joel D. Kaufman, MD, MPH; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism

***Abstract*—**In 2004, the first American Heart Association scientific statement on "Air Pollution and Cardiovascular Disease" concluded that exposure to particulate matter (PM) air pollution contributes to cardiovascular morbidity and mortality. In the interim, numerous studies have expanded our understanding of this association and further elucidated the physiological and molecular mechanisms involved. The main objective of this updated American Heart Association scientific statement is to provide a comprehensive review of the new evidence linking PM exposure with cardiovascular disease, with a specific focus on highlighting the clinical implications for researchers and healthcare providers. The writing group also sought to provide expert consensus opinions on many aspects of the current state of science and updated suggestions for areas of future research. On the basis of the findings of this review, several new conclusions were reached, including the following: Exposure to PM <2.5 μm in diameter ($PM_{2.5}$) over a few hours to weeks can trigger cardiovascular disease–related mortality and nonfatal events; longer-term exposure (eg, a few years) increases the risk for cardiovascular mortality to an even greater extent than exposures over a few days and reduces life expectancy within more highly exposed segments of the population by several months to a few years; reductions in PM levels are associated with decreases in cardiovascular mortality within a time frame as short as a few years; and many credible pathological mechanisms have been elucidated that lend biological plausibility to these findings. It is the opinion of the writing group that the overall evidence is consistent with a causal relationship between $PM_{2.5}$ exposure and cardiovascular morbidity and mortality. This body of evidence has grown and been strengthened substantially since the first American Heart Association scientific statement was published. Finally, $PM_{2.5}$ exposure is deemed a modifiable factor that contributes to cardiovascular morbidity and mortality. **(*Circulation*. 2010;121:2331-2378.)**

Key Words: AHA Scientific Statements ■ atherosclerosis ■ epidemiology ■ prevention ■ air pollution ■ public policy

In 2004, the American Heart Association (AHA) published its first scientific statement regarding air pollution and cardiovascular disease (CVD).[1] The rationale was to provide researchers, healthcare providers, and regulatory agencies with a comprehensive review of the evidence linking air pollution exposure with cardiovascular morbidity and mor-

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on February 22, 2010. A copy of the statement is available at http://www.americanheart.org/presenter.jhtml?identifier=3003999 by selecting either the "topic list" link or the "chronological list" link (No. KB-0038). To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

The American Heart Association requests that this document be cited as follows: Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association. *Circulation.* 2010;121:2331–2378.

Expert peer review of AHA Scientific Statements is conducted at the AHA National Center. For more on AHA statements and guidelines development, visit http://www.americanheart.org/presenter.jhtml?identifier=3023366.

Permissions: Multiple copies, modification, alteration, enhancement, and/or distribution of this document are not permitted without the express permission of the American Heart Association. Instructions for obtaining permission are located at http://www.americanheart.org/presenter.jhtml?identifier=4431. A link to the "Permission Request Form" appears on the right side of the page.

© 2010 American Heart Association, Inc.

***Circulation* is available at http://circ.ahajournals.org** **DOI: 10.1161/CIR.0b013e3181dbece1**

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

tality. There was also an explicit aim to educate clinicians about the importance of this issue, because the cardiovascular health consequences of air pollution generally equal or exceed those due to pulmonary diseases.[1–4] Finally, a list of key remaining scientific questions and strategic avenues for investigation were provided to help foster and guide future research.

The first AHA writing group concluded that short-term exposure to particulate matter (PM) air pollution contributes to acute cardiovascular morbidity and mortality[1] and that exposure to elevated PM levels over the long term can reduce life expectancy by a few years. Although some mechanistic details remained incompletely described, the existing science was deemed adequate to substantiate several plausible biological pathways whereby PM could instigate acute cardiovascular events and promote chronic disease.

There is mounting evidence from a rapid growth of published data since the previous statement related to the harmful cardiovascular effects of air pollution.[3,4] Most, but not all, epidemiological studies corroborate the elevated risk for cardiovascular events associated with exposure to fine PM <2.5 μm in aerodynamic diameter ($PM_{2.5}$). $PM_{2.5}$ generally has been associated with increased risks of myocardial infarction (MI), stroke, arrhythmia, and heart failure exacerbation within hours to days of exposure in susceptible individuals. Several new studies have also demonstrated that residing in locations with higher long-term average PM levels elevates the risk for cardiovascular morbidity and mortality. Some recent evidence also implicates other size fractions, such as ultrafine particles (UFPs) <0.1 μm, gaseous copollutants (eg, ozone and nitrogen oxides [NO_x]), and specific sources of pollution (eg, traffic). In addition, there have been many insights into the mechanisms whereby PM could prove capable of promoting CVDs.[2–4] Air pollutants have been linked with endothelial dysfunction and vasoconstriction, increased blood pressure (BP), prothrombotic and coagulant changes, systemic inflammatory and oxidative stress responses, autonomic imbalance and arrhythmias, and the progression of atherosclerosis. In the interim, the US Environmental Protection Agency (EPA) completed its updated "Air Quality Criteria for Particulate Matter"[5] and afterward strengthened the National Ambient Air Quality Standards (NAAQS) for daily $PM_{2.5}$ levels starting in 2006 (down from 65 to 35 $\mu g/m^3$).[6] The most recent scientific review coordinated by the EPA, the final report of the Integrated Science Assessment for Particulate Matter (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546), has also been made available publicly. These numerous changes and advances provide the rationale for the present updated AHA scientific statement on PM air pollution and CVD. This updated statement is similar in scope, content, and overall structure to the first document; however, it provides many additional conclusions and recommendations that can now be made because of the expanded number and quality of studies.

Objectives and Methods

The primary objective of this scientific statement is to provide a comprehensive updated evaluation of the evidence linking PM exposure with CVDs. The focus of this review is explicitly on PM because the majority of air pollution studies have centered on its cardiovascular effects, and the strength of the evidence makes it possible to provide consensus opinions and recommendations. Except for in a few circumstances, such as when copollutants have been shown to (or not to) modify the responses to PM exposure or to have independent cardiovascular effects in epidemiological studies of major importance, a detailed discussion of other air pollutants (eg, ozone and NO_2) is beyond the scope of this document. Additional objectives are to provide expert consensus opinions on aspects related to the current state of science, to specifically highlight the health and clinical implications of the reviewed findings, and to provide prudent and practical recommendations for measures to reduce PM exposure that might thereby lower the associated cardiovascular risk. This updated scientific statement is structured to first provide a clinical perspective on the cardiovascular risks posed by PM exposure and then briefly review the components of air pollution. The following sections highlight the major findings from epidemiological studies, including mortality, morbidity, and surrogate outcome results. Next, the animal and human mechanistic studies are reviewed, and an overall framework whereby PM exposure could cause CVDs is outlined. Finally, updated consensus opinions and conclusions are provided, followed by suggestions for areas of future research and policy considerations.

Members of the current writing group were selected from across a broad range of disciplines, including cardiovascular and environmental epidemiology and statistics, atmospheric sciences, cardiovascular and pulmonary medicine, basic science research, and public policy. The writing group identified studies published in the English language between January 1, 2004, and March 31, 2009, by a World Wide Web–based literature search using Medline, PubMed, and Google search engines. Key terms included *air pollution* or *particulate matter* plus any of the following: *cardiovascular, myocardial, heart, cardiac, stroke, heart failure, arrhythmia, heart rate variability, autonomic, sympathetic, atherosclerosis, vascular, blood pressure, hypertension, diabetes, metabolic, thrombosis,* and *coagulation*. Additional studies were identified within the references of these publications and by the personal knowledge of the writing group members. A few studies published after March 31, 2009, were added during the review process. All of the identified epidemiological studies that provided mortality data or hard cardiovascular outcomes (eg, MIs) and controlled human exposure protocols were included. In a few circumstances, studies before 2004 were included briefly in the discussion or tables when it was believed that they provided contextual background and/or relevant findings from earlier analyses of ongoing studies (eg, Harvard Six Cities and American Cancer Society [ACS] cohorts) from which new results after 2004 have been published. It is a limitation of the present review that it was not possible to cite all surrogate outcome human studies because of the enormous number of publications. Some were not included, without intentional bias with regard to results, when multiple referenced studies demonstrated similar findings. In such a situation (eg, heart rate variability [HRV]), this

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

limitation was noted within the specific section. A main theme of the present statement is to provide clinical context and recommendations for healthcare providers, and thus, it was beyond the scope and not the intent of this document to include all animal, ex vivo, or toxicological studies. A number of these publications were also not included, without intentional bias with regard to results. The writing group included publications that were believed to have relevant implications for human cardiovascular health, those that formed the foundation of the mechanistic hypotheses, and studies that were deemed of major importance. Finally, the "evidence summary" statements and all points in the conclusions and recommendations represent consensus expert opinions agreed on by all members of the writing group during formal discussions. It is explicitly stated when no such agreement was reached. These statements and the points within Tables 6 and 7 do not represent the result of applying the standard AHA criteria (ie, level and class) to the sum findings of the present review, because those do not apply, but rather the qualitative consensus opinions agreed on by the writing group. The purpose is to provide expert opinions on the comparative relative ranking and the strength of the overall evidence regarding different areas within this field of science.

Perspective on the Air Pollution–Cardiovascular Risk Association

Traditional cardiovascular risk factors account for the major portion of the risk for ischemic cardiac events within a population.[7] Individuals with optimal levels of all risk factors have been shown to have a low lifetime cardiovascular event rate.[8] Thus, control of the traditional risk factors is recognized to be of paramount importance to prevent CVDs. In this context, there has been some debate about the overall clinical relevance and utility of adding novel risk factors to risk-prediction models to incrementally improve their overall predictive value, even when assessed by multiple methodologies.[9] On the other hand, the ability to predict future events by existing models remains imperfect. In addition to several mathematical and statistical explanations for this shortcoming,[10,11] it is important to recognize that the development of vascular or atherosclerotic disease (the factor predicted by most statistical models) is usually a necessary but insufficient cause of future ischemic events in and of itself. Cardiovascular events must also be triggered by an additional factor at some unknowable future time, and therefore, they transpire as a stochastic process within a population.[12] This is one of several reasons why PM air pollution is a uniquely important public health issue among the list of novel risk factors; PM inhalation is an established trigger of cardiovascular events that occur within hours to days after exposure.[12] Because of the ubiquitous and involuntary nature of PM exposure, it may continuously enhance acute cardiovascular risk among millions of susceptible people worldwide in an often inconspicuous manner. Moreover, beyond serving as a simple trigger, PM elicits numerous adverse biological responses (eg, systemic inflammation) that, in premise, may further augment future cardiovascular risk over the long term after months to years of exposure.

Effects of Short-Term Exposure

Time-series studies estimate that a 10-μg/m^3 increase in mean 24-hour $PM_{2.5}$ concentration increases the relative risk (RR) for daily cardiovascular mortality by approximately 0.4% to 1.0%.[3] Despite theoretical statistical risks ascribed to all individuals, this elevated risk from exposure is not equally distributed within a population. At present-day levels, $PM_{2.5}$ likely poses an acute threat principally to susceptible people, even if seemingly healthy, such as the elderly and those with (unrecognized) existing coronary artery or structural heart disease.[13] Therefore, the absolute risk rather than the RR of exposure may more effectively convey the tangible health burden within a population. A 10-μg/m^3 increase during the preceding day contributes on average to the premature death of approximately 1 susceptible person per day in a region of 5 million people (based on annual US death rates in 2005).[3,14] Although the dangers to 1 individual at any single time point may be small, the public health burden derived from this ubiquitous risk is enormous. Short-term increases in $PM_{2.5}$ levels lead to the early mortality of tens of thousands of individuals per year in the United States alone.[1,3,5]

Effects of Long-Term Exposure

Cohort studies estimate that the RR associated with living in areas with higher PM levels over the long term is of greater magnitude than that observed from short-term exposure increases (RR between 1.06 and 1.76 per 10 μg/m^3 $PM_{2.5}$).[3] In this context, the World Health Organization estimated that $PM_{2.5}$ contributes to approximately 800 000 premature deaths per year, ranking it as the 13th leading cause of worldwide mortality.[15] Hence, PM air pollution appears to be an important modifiable factor that affects the public health on a global scale.

Air Pollution

The first AHA statement on air pollution reviewed the size fractions, sources, and chemical constituents of PM and the main gaseous air pollutants: Nitrogen oxides (NO_x; ie, $NO+NO_2$), carbon monoxide (CO), sulfur dioxide (SO_2), and ozone (O_3).[1] Therefore, this section within the updated statement focuses on several other contemporary aspects of air pollution characterization and exposure assessment, particularly in relation to their potential influences on cardiovascular health. In brief, PM is broadly categorized by aerodynamic diameter: All particles <10 μm (thoracic particles [PM_{10}]), all particles <2.5 μm (fine particles [$PM_{2.5}$]), all particles <0.1 μm (UFP), and particles between 2.5 and 10 μm (coarse particles [$PM_{10-2.5}$]). Hence, PM_{10} contains within it the coarse and $PM_{2.5}$ fractions, and $PM_{2.5}$ includes UFP particles. The concentrations of PM_{10} and $PM_{2.5}$ are typically measured in their mass per volume of air (μg/m^3), whereas UFPs are often measured by their number per cubic centimeter (Table 1). The major source of $PM_{2.5}$ throughout

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 1. Ambient Air Pollutants

Pollutant	US Average Range	US Typical Peak*	Most Recent NAAQS for Criteria Pollutants (Averaging Time)
O_3†	0–125 ppb	200 ppb	75 ppb (8 h)‡
NO_2†	0.5–50 ppb	200 ppb	100 ppb (1 h)§ 53 ppb (Annual mean)
NO†	0–100 ppb	200 ppb	
SO_2†	0.1–50 ppb	150 ppb	140 ppb (24 h)‖ 30 ppb (Annual mean)
CO†	0.1–5 ppm	20 ppm	35 ppm (1 h)‖ 9 ppm (8 h)‖
PM_{10}¶	10–100 $\mu g/m^3$	300 $\mu g/m^3$	150 $\mu g/m^3$ (24 h)#
$PM_{2.5}$¶	5–50 $\mu g/m^3$ (Mean=13.4±5.6)	100 $\mu g/m^3$	15 $\mu g/m^3$ (Annual mean) 35 $\mu g/m^3$ (24 h)**
$PM_{2.5}$ lead¶	0.5–5 ng/m^3	150 ng/m^3	0.15 $\mu g/m^3$ (Rolling 3-month average)††
NH_3†	0.1–20 ppb	100 ppb	
HNO_3†	0–5 ppb	10 ppb	
Methane†	1–2 ppm	5 ppm	
Formaldehyde†	0.1–10 ppb	40 ppb	
Acetaldehyde†	0.1–5 ppb	20 ppb	
NMHC (VOC)¶	20–100 $\mu g/m^3$	250 $\mu g/m^3$	
Propane¶	2–20 $\mu g/m^3$	500 $\mu g/m^3$	
Benzene¶	0.5–10 $\mu g/m^3$	100 $\mu g/m^3$	
1,3-Butadiene¶	0.1–2 $\mu g/m^3$	10 $\mu g/m^3$	
Total suspended particles¶	20–300 $\mu g/m^3$	1000 $\mu g/m^3$	
$PM_{10-2.5}$¶	5–50 $\mu g/m^3$	200 $\mu g/m^3$	
Sulfate¶	0.5–10 $\mu g/m^3$	30 $\mu g/m^3$	
Nitrate¶	0.1–5 $\mu g/m^3$	20 $\mu g/m^3$	
Organic carbon¶	1–20 $\mu g/m^3$	30 $\mu g/m^3$	
Elemental carbon¶	0.1–3 $\mu g/m^3$	10 $\mu g/m^3$	
PAH¶	2–50 ng/m^3	200 ng/m^3	
UFP†	1000–20 000/cm^3	100 000/cm^3	

ppb Indicates parts per billion; ppm, parts per million; and PAH, polycyclic aromatic hydrocarbon.

*Generally not in concentrated plumes or locations of direct source emission impact.

†Typical hourly average concentrations reached in US cities.

‡The 8-hour standard is met when the 3-year average of the 4th highest daily maximum 8-hour average is less than or equal to the indicated number. In January 2010, the EPA proposed a more stringent 8-hour standard within the range of 60 to 70 ppb (http://www.epa.gov/air/ozonepollution/actions.html).

§To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average at each monitor within an area must not exceed this value.

‖The level is not to be exceeded more than once per year.

¶Typical 24-hour average concentrations.

#The level is not to be exceeded more than once per year on average over 3 years.

**The daily standard is met when the 3-year average of the 98th percentile of 24-hour PM level is less than or equal to the indicated number.

††Although the typical concentrations shown in the table are for $PM_{2.5}$, the lead standard continues to be based on measurements in total suspended particulate.

the world today is the human combustion of fossil fuels from a variety of activities (eg, industry, traffic, and power generation). Biomass burning, heating, cooking, indoor activities, and nonhuman sources (eg, fires) may also be relevant sources, particularly in certain regions.

Common air pollutants and those designated as EPA criteria pollutants (ie, specifically targeted in regulations through limits on emissions or government standards such as the NAAQS) are listed in Table 1. The World Health Organization also provides ambient guidelines (http://www.euro.who.int/Document/E90038.pdf). As a result, many pollutant concentrations are tracked in the United States by nationwide monitoring networks, with up to approximately 1200 sites for O_3 and $PM_{2.5}$. Data are archived by the EPA and are available to the public (http://www.epa.gov/ttn/airs/airsaqs/). O_3 levels exceed the national standard in many areas, and thus, daily information is provided to assist the public in reducing their exposure. A lower standard for ozone concentrations was proposed recently, which will lead to more frequent occurrences of outdoor exposures deemed to be excessive (Table 1). The reporting of $PM_{2.5}$ is also becoming common because of its impact on public health and frequent violations of standards. Current and forecast air quality indices and information on both $PM_{2.5}$ and ozone are available (http://airnow.gov/). At the end of 2008, 211 US counties (or portions of counties) were in nonattainment of the 2006 daily $PM_{2.5}$ NAAQS (http://www.epa.gov/pmdesignations/2006standards/state.htm). On a positive note, the various regulations that have been established have led to substantial reductions in PM and other pollutant levels over the past 40 years in the United States and contributed toward similar improvements in other countries. However, reducing the levels of some pollutants, such as O_3, remains a challenge because of the complex chemical processes that lead to their formation in the atmosphere.[16] The population of many developing nations (China, India, Middle Eastern countries) continues to be exposed to high levels, particularly of PM, which can routinely exceed 100 $\mu g/m^3$ for prolonged periods (http://siteresources.worldbank.org/DATASTATISTICS/Resources/table 3_13.pdf).

Air Pollution Mixtures, Chemistry, and Sources

Detailed information regarding PM sizes, composition, chemistry, sources, and atmospheric interactions is beyond the scope of this document but can be found in the 2004 US EPA Air Quality Criteria for Particulate Matter final report (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=87903). The source for much of the information provided in this brief summary is this document, unless otherwise specifically referenced. The typical range of ambient concentrations for several air pollutants in the United States, including the latest US NAAQS for the criteria pollutants, is given in Table 1. Classification of air quality according to 1 single pollutant and by size or mass provides an incomplete picture, because ambient air pollution is a complex mixture of gases, particles, and liquids that are continually changing and interacting with each other and natural atmospheric gases. Although $PM_{2.5}$ mass has rightfully attracted considerable attention as a target for regulation and epidemiological study, more than 98% of

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

the air pollutant mass in the mixture we breathe in urban settings is from gases or vapor-phase compounds such as CO, nonmethane hydrocarbons or volatile organic carbons (VOCs), NO_2, NO, O_3, and SO_2. Each of these can have independent and potentially synergistic or antagonistic effects with each other and with PM; however, at present, the cardiovascular health impact of exposure to combinations of air pollutants is not well understood.

Most of the studies linking CVDs with PM exposures have focused on particle mass; thus, this association is evaluated and reported in the majority of epidemiological and toxicological studies reviewed. Although PM is regulated by mass concentration, the aspect of PM most harmful to cardiovascular health may not be best quantified by mass measurement alone. The sum effect of many features related to chemical composition and size/morphology (eg, oxidative stress potential, solubility, charge, surface area, particle count, lung deposition, and stability within the atmosphere and biological tissues) is important to consider. With regard to specific "toxic" compounds within PM, several lines of existing evidence support the idea that transition metals, organic compounds, semiquinones, and endotoxin are likely relevant in relation to promoting CVDs. In addition, certain characteristics of UFPs (eg, high surface area, particle number, metal and organic carbon content) suggest that they may pose a particularly high cardiovascular risk after short-term exposure.[17] Both the additional characterization of "criteria" pollutants and the measurement of several other pollutants (discussed below) are important to inform air quality management practices that involve air quality modeling, as well as epidemiological studies and risk assessment, which ultimately aim to improve risk-reduction strategies.

In addition to their mass concentration, pollutants can be characterized on the basis of their origin or chemical and physical properties. In terms of origin, nitrogen oxides ($NO+NO_2$), CO, SO_2, and $PM_{2.5,}$ as well as carbon dioxide (CO_2), are mainly associated with combustion of fuel or other high-temperature industrial processes. Combustion PM is composed of many chemical compounds, including organic carbon species, elemental or black carbon, and trace metals (eg, lead and arsenic). They range in size from molecular clusters a few nanometers in diameter to light-scattering particles that peak on a mass contribution basis in the diameter range of 200 to 1000 nm (0.2 to 1 μm). UFP numbers are also strongly linked to fresh combustion and traffic-related pollution. Ammonia, methane, pesticides (persistent organic pollutants), reduced sulfur compounds, resuspended dust, and natural coarse particles ($PM_{10-2.5}$) are associated with noncombustion surface or fugitive releases that arise from a variety of human (eg, agriculture) and natural (eg, erosion) activities. Agricultural emissions and releases from a range of industrial processes and waste management are also important sources. Road and wind-blown dust from agricultural practices and from certain industrial facilities (eg, mineral industry) also contribute to these particles, which are typically in the coarse ($PM_{10-2.5}$) or even larger ($>PM_{10}$) range.

In addition to pollutants formed directly by combustion, many others are produced primarily through chemical reactions in the atmosphere among directly emitted pollutants. These are known as secondary pollutants. Sunlight, water vapor, and clouds are often involved in this atmospheric chemistry, which leads to greater oxidation of the pollutants. Examples include PM-associated sulfate, nitrate, and ammonium and many of the organic compounds within $PM_{2.5}$. Besides O_3, which is the most prevalent secondary gaseous oxidant, a number of inorganic and organic acids and VOCs form in the atmosphere. Examples are the hydroxyl radical, peroxyacetyl nitrate, nitric acid, formic and acetic acid, formaldehyde, and acrolein.

VOCs and semivolatile organic compounds (SVOCs), the latter of which are found in both the gas and particle phase, are an additional large class of pollutants. They are associated with both combustion and fugitive emissions, as well as with secondary formation. Key examples are benzene, toluene, xylene, 1,3-butadiene, and polycyclic aromatic hydrocarbons. VOCs are among the 188 hazardous air pollutants listed by the EPA, and their main emission sources have been identified and are regulated (http://www.epa.gov/ttn/atw/mactfnlalph.html). VOCs can undergo reactions that convert toxic substances to less toxic products or vice versa. Many VOCs contribute to the formation of O_3 and are oxidized in the atmosphere, becoming SVOCs, and subsequently partition within particles and contribute to the composition of $PM_{2.5}$, as well as to its mass. A great deal of research has focused on $PM_{2.5}$ in the past decade, which has led to advances in measurement technologies[18] and greater understanding of its chemistry and atmospheric behavior.[19] Nonetheless, understanding is incomplete, particularly with regard to formation of the secondary organic fraction, the relative role of anthropogenic and biogenic emissions to organics, surface chemistry, oxidative potential,[20] and gas-to-particle partitioning.

An alternative to attempting to identify one by one which pollutant(s) or chemical compounds are most harmful is to focus on identifying the sources, which typically emit mixtures of pollutants, of greatest concern. It may be the mixture of pollutants (along with the source from which it is derived, which determines its characteristics) that is most pertinent to human health outcomes. Such information may actually be more relevant for aiding the development of effective air quality policies. One important example reviewed in the epidemiology section is that the evidence continues to grow regarding the harmful cardiovascular effects of traffic-related pollution. Traffic is ubiquitous in modern society, with a sizeable proportion of the population, particularly persons disadvantaged by low socioeconomic status, living close enough (within 500 m) to a major road or a freeway to be chronically exposed to elevated concentrations. Additionally, daily behavior brings most people close to this source, with the average US citizen over 15 years of age spending 55 minutes each day traveling in motor vehicles.[21] However, despite the consistent epidemiological findings, these studies have yet to elucidate which of the many pollutants or other associated risks (ie, noise) produced by traffic are responsible for the increase in risk for CVD. Until the most harmful agents are identified, the only practical manner to potentially reduce health consequences would be to reduce overall traffic and related emissions and to configure cities and lifestyles

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

such that there is greater separation between the people and the source, so that we could spend less time in traffic (a major source of personal exposures in our society). There are also a myriad of other important pollutant sources of known toxic pollutants that have been implicated in health-effect studies (eg, power generation, industrial sources, steel mills, and wood smoke). A better understanding of the factors that influence population exposure to these sources, of how their emissions and mixtures of different sources affect health, and about the factors that make individuals more susceptible will aid in the development of more effective environmental health policies.

Determinants of Air Pollution Exposure

Many aspects of air pollution play a role in the characteristics of population- and individual-level exposures. Pollutants vary on multiple time scales, with emission rates, weather patterns, and diurnal/seasonal cycles in solar radiation and temperature having the greatest impact on concentrations. The temporal behavior of a pollutant is also governed by its formation rate and the length of time it remains in the atmosphere. As such, the concentrations of many air pollutants tend to co-vary. For example, NO_x and CO are emitted during combustion, as are some particle constituents (eg, elemental carbon) and VOCs, and thus, their concentrations peak during rush hour. On the other hand, O_3 and other photochemical oxidants, including secondary $PM_{2.5}$ and secondary VOCs, peak in the afternoon, particularly given certain meteorologic conditions (eg, more sunshine). Among the common air pollutants, O_3 and $PM_{2.5}$ have the longest atmospheric lifetime and thus can build up over multiple days and spread, by the prevailing winds, over large geographic regions. This can lead to similarities in their temporal and spatial patterns over broad regions and to greater numbers of people being exposed to similar levels, thus lessening interindividual variability in exposure.

Periods of suppressed horizontal and vertical mixing in the lower atmosphere lead to the buildup of multiple pollutants. These situations are most common under slow-moving or stationary high-pressure systems, which bring light winds, a stable atmosphere, and more sunshine. The frequency and seasonality of these meteorologic conditions and how they affect concentrations vary geographically, which leads to differences in the characteristics of pollution episodes from the western to the eastern United States, as well as within these regions.

The commonality of meteorology and emission sources leads to covariation in pollutant concentrations on multiple temporal and spatial scales, which makes it more challenging for epidemiological studies to identify the health effects of individual pollutants and the effects of copollutants or mixtures. Studies that depend on daily counts of mortality or morbidity events have difficulties separating the effects of the different pollutants in the urban mix. Even prospective panel studies measuring specific end points on a subdaily time scale are hindered by pollutant covariation. Some of these challenges could potentially be addressed by undertaking studies covering multiple geographic locations with differences in the structure of pollutant covariation due to different meteorology and source mixes. Indeed, this has been done, at least in part, by several existing multicity studies. Consistency in the findings in individual studies conducted in different cities also helps isolate the pollutants that may be more responsible for the health effects. The consistent positive findings with certain pollutants (eg, PM mass concentration) have helped strengthen the evidence regarding PM_{10} and $PM_{2.5}$ effects, but regardless of location, there remains the strong underlying commonality of fossil fuel combustion for many pollutants.

A final issue to consider is the cardiovascular health effects of exposures that occur at the personal level because of the different microenvironments or activities an individual experiences (eg, time in traffic, indoor sources, secondhand tobacco smoke, occupational exposure, and degree of indoor penetration of ambient PM into homes) versus the effects of exposures from less variable urban- to regional-scale ambient concentrations (ie, background pollution that most individuals encounter more uniformly). Personal monitoring demonstrates substantial variations among individual pollution exposures or characteristics among those living within the same metropolitan area and even the same neighborhood.[22,23] However, the differing additive, synergistic, and/or confounding effects on cardiovascular health of these 2 contrasting components of a person's overall exposure have not been well described. For the most part, the magnitude of the findings reported by the major epidemiological studies (see next section) are indicative of the effects of the urban- to regional-scale ambient concentrations. Actual exposures to all pollutants also vary at the personal level. The cardiovascular health importance of these individual-level variations (above and beyond the effect of urban/regional levels) remains largely unknown, in part because it has been difficult to quantify. The degree to which measurement of personal exposures or more precise exposure assessment (eg, use of geographic information systems, land-use regression models, spatial-temporal models, and adjustments for indoor penetration) can reduce the effects of exposure misclassification in epidemiological studies also remains to be fully elucidated.[24–26]

Epidemiological Studies of Air Pollution

Epidemiological studies of air pollution have examined the health effects of exposures observed in real-world settings at ambient levels. Associations between relevant health end points and measures of air pollution are evaluated while attempting to control for effects of other pertinent factors (eg, patient and environmental characteristics). Despite substantial study and statistical improvements and the relative consistency of results, some potential for residual confounding of variables and publication bias[27] of positive studies are limitations to acknowledge. Probably the most relevant, well-defined, and extensively studied health end points include mortality (all-cause and cause-specific), hospitalizations, and clinical cardiovascular events. This section reviews the results of the epidemiological research with a focus on new studies since the first AHA statement was published,[1] as well as on the cardiovascular health implications. In sum, numerous studies of varied design have been published in the interim that significantly add to the overall weight of evi-

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 2. Comparison of Pooled Estimated of Percent Increase (and 95% CI or Posterior Interval or *t* Value) in RR of Mortality Estimated Across Meta-Analyses and Multicity Studies of Daily Changes in Exposure

			Percent Increases in Mortality (95% CI)		
	Primary Source	Exposure Increment	All-Cause	Cardiovascular	Respiratory
Meta-estimate with and without adjustment for publication bias	Anderson et al[27] 2005	20 $\mu g/m^3$ PM_{10}	1.0 (0.8–1.2) 1.2 (1.0–1.4)	…	…
Meta-estimates from COMEAP report to the UK Department of Health on CVD and air pollution	COMEAP[31] 2006	20 $\mu g/m^3$ PM_{10} 10 $\mu g/m^3$ $PM_{2.5}$	… …	1.8 (1.4–2.4) 1.4 (0.7–2.2)	… …
NMMAPS, 20 to 100 US cities	Dominici et al[34] 2003	20 $\mu g/m^3$ PM_{10}	0.4 (0.2–0.8)	0.6 (0.3–1.0)*	…
APHEA-2, 15 to 29 European cities	Katsouyanni et al[35] 2003 Analitis et al[36] 2006	20 $\mu g/m^3$ PM_{10}	1.2 (0.8–1.4)	1.5 (0.9–2.1)	1.2 (0.4–1.9)
US, 6 cities	Klemm and Mason[37] 2003	10 $\mu g/m^3$ $PM_{2.5}$	1.2 (0.8–1.6)	1.3 (0.3–2.4)†	0.6 (−2.9, 4.2)‡
US, 27 cities, case-crossover	Franklin et al[38] 2007	10 $\mu g/m^3$ $PM_{2.5}$	1.2 (0.3–2.1)	0.9 (−.1, 2.0)	1.8 (0.2, 3.4)
California, 9 cities	Ostro et al[39] 2006	10 $\mu g/m^3$ $PM_{2.5}$	0.6 (0.2–1.0)	0.6 (0.0, 1.1)	2.2 (0.6, 3.9)
France, 9 cities	Le Tertre et al[40] 2002	20 $\mu g/m^3$ BS	1.2 (0.5–1.8)§	1.2 (0.2–2.2)§	1.1 (−1.4, 3.2)§
Japan, 13 cities, age >65 y	Omori et al[41] 2003	20 $\mu g/m^3$ SPM	1.0 (0.8–1.3)	1.1 (0.7–1.5)	1.4 (0.9–2.1)
Asia, 4 cities	Wong et al[42] 2008	10 $\mu g/m^3$ PM_{10}	0.55 (0.26–0.85)	0.59 (0.22–0.93)	0.62 (0.16–1.04)
US, 112 cities	Zanobetti et al[43] 2009	10 $\mu g/m^3$ $PM_{2.5}$	0.98 (0.75–1.22)	0.85 (0.46–1.24)	1.68 (1.04–2.33)
		10 $\mu g/m^3$ $PM_{10-2.5}$‖	0.46 (0.21–0.71)	0.32 (0.00–0.64)	1.16 (0.43–1.89)
		10 $\mu g/m^3$ $PM_{2.5}$¶	0.77 (0.43–1.12)	0.61 (0.05–1.17)	1.63 (0.69–2.59)
		10 $\mu g/m^3$ $PM_{10-2.5}$¶	0.47 (0.21–0.73)	0.29 (−0.04, 0.61)	1.14 (0.043–1.85)

CI indicates confidence interval or posterior interval.
*Cardiovascular and respiratory deaths combined.
†Ischemic heart disease deaths.
‡Chronic obstructive pulmonary disease deaths.
§Includes general additive model–based analyses with potentially inadequate convergence.
‖Results for $PM_{10-2.5}$ are from 47 cities.
¶Results of 2 pollutant models controlling for alternate PM size in 47 cities.

dence that exposure to air pollutants at present-day levels contributes to cardiovascular morbidity and mortality.

Mortality and Air Pollution

Time-Series and Related Studies

Time-series and case-crossover studies explore associations between short-term changes in air pollution and daily changes in death counts. The sum of current evidence supports the findings of an earlier review[28] that demonstrated that short-term elevations in daily PM levels lead to a greater absolute risk for CVD-related mortality than for all other causes. Even if similar acute RR elevations (≈1.01) are estimated between cardiovascular and pulmonary mortality, CVDs account for 69% of the increase in absolute mortality rates compared with 28% for pulmonary diseases attributable to short-term PM exposure. Recently, more rigorous modeling techniques have been used in attempts to better estimate pollution-mortality associations while controlling for other time-dependent confounding covariables.[29,30] There have been well over 100 published daily time-series studies reporting small but statistically significant PM-mortality associations that have been the subject of quantitative reviews or meta-analyses.[3,27,31–33] Table 2 summarizes recent multicity analyses and studies published since 2004.

To address concerns about city selection bias, publication bias, and influences of copollutants, several large, multicity, daily time-series studies have been conducted worldwide. One of the largest was the National Morbidity, Mortality, and Air Pollution Study (NMMAPS). Published reports from this study included as few as 20 US cities,[44,45] as many as 100 cities,[46,47] and more recently, data for hundreds of counties (Table 2).[48] The observed relationship between PM exposure and excess mortality remained independent of several gaseous copollutants (NO_2, CO, or SO_2). Recent analyses suggest that O_3 may also independently contribute to cardiopulmonary mortality risk[49,50]; however, coexposures to secondary particle pollutants may be responsible in part for this latter association.[51]

Several studies have also been conducted outside the United States, including the Air Pollution and Health: A European Approach (APHEA and APHEA-2) projects, which examined daily PM-related mortality effects in multiple cities.[36,52] PM air pollution was significantly associated with daily mortality counts for all-cause, cardiovascular, and respiratory mortality (Table 2). Further analyses of the European data suggest that CVD deaths are also associated with exposure to NO_2[53] and CO.[54] A few new time-series studies have also confirmed similar increases in cardiovascular mortality related to short-term PM exposure in China[55–57] and Bangkok, Thailand.[42] Additional multicity studies have been conducted worldwide with analyses of CVD deaths (Table 2).[38–42,58–60] Finally, in a recent analysis that included several Asian

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

cities, SO_2, NO_2, O_3, and PM_{10} were all associated with excess cardiovascular mortality.[42]

In an attempt to evaluate the coherence of multicity studies across continents, the Air Pollution and Health: A Combined European and North American Approach (APHENA) study analyzed data from the APHEA, NMMAPS, and Canadian studies.[61] The combined effect on all-cause mortality ranged from 0.2% to 0.6% for a 10-$\mu g/m^3$ elevation in daily ambient PM_{10}, with the largest effects observed in Canada. Among individuals older than 75 years, the effects were greater for cardiovascular mortality than for overall and pulmonary mortality (0.47% to 1.30%). Older age (>75 years) and higher rates of unemployment were related to greater PM mortality risks in both continents. Higher NO_2 levels were associated with larger PM_{10} effects on mortality, particularly in Europe. Finally, there appeared to be no lower-limit threshold below which PM_{10} was not associated with excess mortality across all regions.

Evidence Summary

The overall evidence from time-series analyses conducted worldwide since publication of the first AHA statement[1] confirms the existence of a small, yet consistent association between increased mortality and short-term elevations in PM_{10} and $PM_{2.5}$ approximately equal to a 0.4% to 1.0% increase in daily mortality (and cardiovascular death specifically) due to a 10-$\mu g/m^3$ elevation in $PM_{2.5}$ during the preceding 1 to 5 days (Table 2).

Cohort and Related Studies

Although short-term changes in PM concentrations have deleterious health effects, longer-term exposures may have a more pertinent clinical health effect on cardiovascular morbidity and mortality given that individuals are typically exposed to higher air pollution levels over extended periods of time. An additional source of exposure variability that has been exploited in epidemiological studies is spatial variability, which includes differences in average ambient concentrations over extended periods of time across metropolitan areas or across smaller communities within local areas. Recent emphasis has been on prospective cohort studies that control for individual differences in multiple confounding variables and cardiovascular risk factors. A summary of these studies is presented in Table 3 and Figure 1. These cohort studies generally demonstrate larger overall mortality effects than the results of time-series analyses.

Harvard Six Cities and ACS Studies

Two landmark cohort-based mortality studies, the Harvard Six Cities[62] and the ACS studies,[66] were reported in the mid 1990s and were discussed previously.[1] In both, $PM_{2.5}$ and sulfate particulate pollution were associated with increases in all-cause and cardiopulmonary disease (Table 3). In addition, intensive independent reanalyses[63] corroborated the original findings of both studies and resulted in innovative methodological contributions that demonstrated the robustness of the results to alternative modeling approaches. In both the Harvard Six Cities[62,64] and the ACS[67] studies, PM air pollution–related mortality was substantially higher for cardiovascular- than for pulmonary-related causes.

Since 2004, there have been further analyses of both studies. Laden et al[64] extended the mortality follow-up of the Harvard Six Cities cohort for an additional 8 years. $PM_{2.5}$ associations, similar to those found in the original analysis, were observed for all-cause and CVD mortality (Table 3). Furthermore, reductions in $PM_{2.5}$ concentrations for the extended follow-up period were associated with reduced mortality risk. Further analysis suggested that the health effects of changes in exposure were seen primarily within 2 years.[84] In addition to confirming the earlier mortality relationship, the recent observations suggest that the adverse health effects mediated by longer-term PM air pollution exposure can be estimated reasonably accurately by the previous few years of particle levels.

Extended analyses of the ACS cohort that emphasize efforts to control for the effects of other covariates and risk factors have corroborated the previously reported mortality associations with particulate and sulfur oxide pollution.[68] Elevated mortality risks were most strongly associated with $PM_{2.5}$. Coarse particles ($PM_{10-2.5}$) and gaseous pollutants, except for SO_2, were generally not significantly related to mortality. In another extended analysis,[67] the death certificate classifications of underlying causes of death due to $PM_{2.5}$ exposures were observed to be principally ischemic heart disease, arrhythmias, heart failure, and cardiac arrest. Finally, recent additional analyses attempted to control for the fact that variations in exposure to air pollution across cities or within cities may correlate with socioeconomic or demographic gradients that influence health and susceptibility to environmental exposures.[85,86] When controlled for individual risk factor data, the mortality associations for intrametropolitan $PM_{2.5}$ concentration differences within the Los Angeles, Calif, area were generally larger than those observed in the full cohort across metropolitan areas.[69] However, the results were somewhat sensitive to the inclusion of zip code–level ecological variables, which suggests potential contextual neighborhood confounding. Krewski et al[70] subsequently observed that full adjustments for multiple ecological covariates did not reduce the estimated $PM_{2.5}$-related mortality effect. The association for ischemic heart disease mortality in particular was highly robust across various study areas and modeling strategies and after controlling for both individual and ecological covariates.

An additional recent analysis of the ACS cohort evaluated the health effects of ozone compared with $PM_{2.5}$.[87] The findings reconfirmed the independent cardiovascular mortality increase related to fine-particle exposure. However, after adjustment for $PM_{2.5}$, ozone was associated solely with an elevated risk of death due to respiratory causes; there was no independent risk of ozone exposure on CVD-related mortality. This suggests that the positive findings reported in NMMAPS[50] regarding cardiopulmonary mortality and short-term ozone exposure could be explained at least in part by the enhanced risk of mortality due to lung disease categories.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 3. Summary of Cohort Study Results

Study	Size of Cohort (000s)	Follow-Up Period	Covariates Controlled for	Percent Increases in Mortality (95% CI) Associated With 10 $\mu g/m^3$ $PM_{2.5}$ (or Other When Indicated)			
				All-Cause	Cardiopulmonary	Cardiovascular	Ischemic Heart Disease
Harvard Six Cities, original (Dockery et al[62] 1993)	≈8	1974–1991	Individual (smoking+others)	13 (4.2–23)	18 (6.0–32)	…	…
Harvard Six-Cities, HEI reanalysis, Krewski et al[63] 2004	≈8	1974–1991	Individual (smoking+others)	14 (5.4–23)	19 (6.5–33)	…	…
Harvard Six-Cities, extended, Laden et al[64] 2006	≈8	1974–1998	Individual (smoking+others)	16 (7–26)	…	28 (13–44)	…
Six-Cities Medicare cohort, Eftim et al[65] 2008	≈340	2000–2002	Individual (age, sex)	21 (15–27)	…	…	…
ACS, Original, Pope et al[66] 1995	≈500	1982–1989	Individual (smoking+others)	6.6 (3.5–9.8)	12 (6.7–17)	…	…
ACS, HEI reanalysis, Krewski et al[63] 2004	≈500	1982–1989	Individual (smoking+others) +ecological	7.0 (3.9 10)	12 (7.4–17)	13 (8.1–18)	…
ACS, extended I, Pope et al[67,68] 2002, 2004	≈500	1982–1998	Individual (smoking+others)	6.2 (1.6–11)	9.3 (3.3–16)	12 (8–15)	18 (14–23)
ACS, intrametro Los Angeles, Jerrett et al[69] 2005	≈23	1982–2000	Individual (smoking+others) +ecological	17 (5–30)	12 (−3–30)	…	39 (12–73)
ACS, extended II, Krewski et al[70] 2009	≈500	1982–2000	Individual (smoking+others) +ecological	5.6 (3.5–7.8)	13 (9.5–16)	…	24 (20–29)
ACS, Medicare cohort, Eftim et al[65] 2008	7333	2000–2002	Individual (age, sex)+ecological +COPD	11 (9–13)	…	…	…
US Medicare cohort, east/central/west, Zeger et al[71] 2008	13 200	2000–2005	Individual (age, sex)+ecological +COPD	6.8 (4.9–8.7),* 13 (9.5–17) −1.1 (−3 to 0.8)	…	…	…
Women's Health Initiative, Miller et al[72] 2007	≈66	1994–2002	Individual (smoking+others)	…	…	76 (25–147), 24 (9–41)†	…
Nurses' Health Study, Puett et al[73] 2008	≈66	1992–2002	Individual (smoking+others) ecological	7.0 (−3.0 to 18)‡	…	30 (0–71)‡	…
AHSMOG, males only, McDonnell et al[74] 2000	≈4	1977–1992	Individual (smoking+others)	8.5 (−2.3 to 21)	23 (−3 to 55)	…	…
AHSMOG, females only, Chen et al[75] 2005	≈4	1977–2000	Individual (smoking+others)	…	…	42 (6–90)	…
VA hypertensive male I study, Lipfert et al[76] 2006	≈42	1989–1996	Individual (smoking+others) +ecological	15 (5–26)§	…	…	…
VA hypertensive male II study, Lipfert et al[77] 2006	≈30	1997–2001	Individual (smoking+others) +ecological	6 (−6 to 22)	…	…	…
11 CA county, elderly, Enstrom[78] 2005	≈36	1973–2002	Individual (smoking+others) +ecological	4 (1–7)‖, 1 (−0.6 to 2.6)	…	…	…
French PAARC, Filleul et al[79] 2005	≈14	1974–2000	Individual (smoking+others)	7 (3–10)‡	5 (−2 to 12)‡	…	…
German women, Gehring et al[80] 2006	≈5	1980s, 1990s–2003	Individual smoking and socioeconomic status	12 (−8 to 38)	52 (9–115)	…	…

(*Continued*)

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 3. Continued

Study	Size of Cohort (000s)	Follow-Up Period	Covariates Controlled for	Percent Increases in Mortality (95% CI) Associated With 10 $\mu g/m^3$ $PM_{2.5}$ (or Other When Indicated)			
				All-Cause	Cardiopulmonary	Cardiovascular	Ischemic Heart Disease
Oslo, Norway, intrametro, Naess et al[81] 2007	≈144	1992–1998	Individual age, occupational class, education	…	…	10 (5–16),¶ 14 (6–21), 5 (1–8), 3 (0–5)	…
Dutch cohort, Beelen et al[82] 2008	≈121	1987–1996	Individual (smoking+others) +ecological	6 (−3 to 16)	…	4 (−10 to 21)	…
Great Britain, Elliott et al[83] 2007	≈660	1966–1998	Socioeconomic status	1.3 (1.0–1.6)‡#	1.7 (1.3–2.2)‡#	1.2 (0.7–1.7)‡#	

HEI indicates Health Effects Institute; VA, Veterans Affairs; COPD, chronic obstructive pulmonary disease; and CA, California.

*Three estimates are for the East, Central, and West regions of the United States, respectively.

†Any cardiovascular event.

‡Associated with 10 $\mu g/m^3$ British Smoke (BS) or PM_{10}.

§Estimates from the single-pollutant model. Effect estimates were smaller and statistically insignificant in analyses restricted to counties with nitrogen dioxide data. County-level traffic density was a strong predictor of survival, and stronger than $PM_{2.5}$ when included with $PM_{2.5}$ in joint regressions.

||Two estimates are for the follow-up period 1973–1982 and the follow-up period 1983–2002, respectively.

¶Four estimates are for men 51–70 y old, women 51–70 y old, men 71–90 y old, and women 71–90 y old, respectively.

#Using last 0- to 4-year exposure window.

Additional Cohort Studies

Several additional cohort studies have been published in the past few years (Table 3). Eftim and colleagues[65] studied 2 very large "cohorts" of US Medicare participants who lived in locations included in the Harvard Six Cities and ACS studies. Effects of $PM_{2.5}$ exposure on mortality for the period 2000 to 2002 were estimated after controlling for multiple factors, although not at the individual patient level. For all-cause mortality, the $PM_{2.5}$-mortality associations were larger than those observed in the Harvard Six Cities or ACS cohorts. In an additional analysis of 13.2 million US Medicare participants for the time period 2000 to 2005,[71] $PM_{2.5}$-mortality associations were shown to be similar to those observed in the Harvard Six Cities and ACS studies in the East and Central regions of the United States (and when the data were pooled for the entire United States). However, $PM_{2.5}$ was not associated with mortality in the Western United States or for the oldest age group (>85 years old). These findings generally corroborate the earlier cohort studies and add evidence that aspects of exposure (PM sources or composition) and patient susceptibility might play important roles in determining the health risks.

In a cohort of postmenopausal women without prior CVD from the Women's Health Initiative Observational Study,[72] an association between longer-term $PM_{2.5}$ exposure (median follow-up of 6 years) and cardiovascular events (primary end point) was observed. After adjustment for age and other risk factors, an incremental difference of 10 $\mu g/m^3$ $PM_{2.5}$ was associated with a 24% (95% confidence interval [CI]9% to 41%) increase in all first cardiovascular events (fatal and nonfatal, with a total of 1816 cases). Notably, an incremental difference of 10 $\mu g/m^3$ $PM_{2.5}$ was also associated with a large 76% (95% CI 25% to 147%) increase in fatal cardiovascular events, based on 261 deaths. The risks for both coronary heart disease and strokes were found to be similarly elevated. Interestingly, within-city $PM_{2.5}$ gradients appeared to have larger cardiovascular effects than those between cities, although this difference was not statistically significant. Finally, overweight women (body mass index >24.8 kg/m^2) were at relatively greater cardiovascular risk due to particulate air pollution than leaner women. Noteworthy aspects of this study were improved assessment of the end points by medical record review (rather than by death certificate) and long-term particle exposure estimation. The control for individual-level confounding variables was also superior to that of previous cohort studies.

In another cohort of women, a subset of the Nurses' Health Study from the northeastern United States,[73] an increase of 10 $\mu g/m^3$ modeled estimates of PM_{10} exposures was associated with an approximately 7% to 16% increased risk of all-cause mortality and a 30% to 40% increase in fatal coronary heart disease, depending on the level of adjustment for covariates. This study found that the strongest health risks for all-cause and cardiovascular mortality were seen in association with the average PM_{10} exposure during the previous 24 months before death. Similar to the findings of the Women's Health Initiative, the cardiovascular mortality risk estimates were larger than those of previous cohort studies. In addition, obese women (body mass index >30 kg/m^2) were at greater relative risk, and the increases in mortality (all-cause and cardiovascular) were larger than the effects on nonfatal events. The results were also in accordance with the latest Harvard Six Cities analyses[64] that show that exposure over the most recent preceding 1 to 2 years can accurately estimate the majority of the health risks due to longer-term PM air pollution exposures.

The pollution-mortality association has also been assessed in several other cohort studies in the United States and Europe (Table 3).[76–83] In a recent analysis of the Adventist Health Study of Smog (AHSMOG) cohort with a much

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

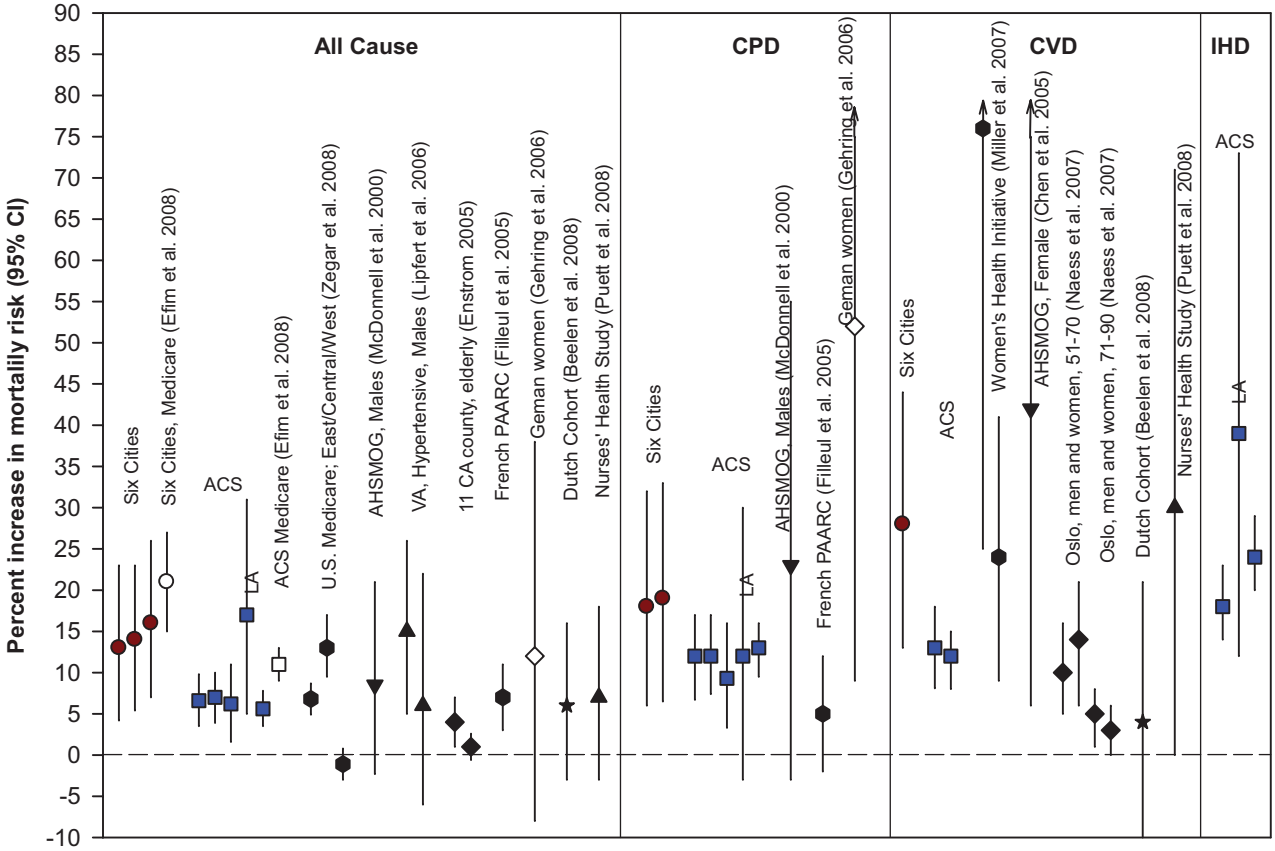


Figure 1. Risk estimates provided by several cohort studies per increment of 10 $\mu g/m^3$ in $PM_{2.5}$ or PM_{10}. CPD indicates cardiopulmonary disease; IHD, ischemic heart disease.

longer follow-up than the original studies,[74,88] fatal coronary heart disease was significantly associated with $PM_{2.5}$ among females but not males.[75] These observations along with the remarkably robust health effects in the Women's Health Initiative Observational Study and Nurses' Health Study suggest that women may be at special risk from PM exposure. The overall cohort study evidence demonstrates that a 10-$\mu g/m^3$ increase in $PM_{2.5}$ exposure is in general positively associated with excess mortality, largely driven by increases in cardiopulmonary or cardiovascular deaths (Figure 1). Independent results from the Women's Health Initiative Study,[72] the US Medicare cohorts,[71] the German women cohort,[80] and the intracity Oslo (Norway) study[81] contribute substantially to this evidence. Although the Dutch cohort,[82] AHSMOG,[74,75] French PAARC (Pollution Atmosphérique et Affections Respiratoires Chroniques [air pollution and chronic respiratory diseases]),[79] Veterans Affairs hypertensive male study,[77] and 11 CA county[78] studies observed increased mortality risks associated with higher $PM_{2.5}$ exposure that were statistically significant in some analyses, the observed health risks were less robust. A finding that is somewhat consistent across the Veterans Affairs hypertensive male study,[77] 11 CA county,[78] Oslo,[81] and US Medicare cohorts[71] is that the $PM_{2.5}$-mortality effect estimates tend to decline with longer periods of follow up or in a substantially older cohort. These studies also often observed elevated mortality risks according to alternative indicators of air pollution exposure, especially metrics of traffic-related exposure.

Evidence Summary

The overall evidence from the cohort studies demonstrates on average an approximate 10% increase in all-cause mortality per 10-$\mu g/m^3$ elevation in long-term average $PM_{2.5}$ exposure. The mortality risk specifically related to CVD appears to be elevated to a similar (or perhaps even greater) extent, ranging from 3% to 76% (Table 3). This broader estimated range in risk compared with the short-term effects observed in time series is due to several recent cohort studies[72,73] that demonstrated larger cardiovascular mortality risks (eg, >30%) than in earlier cohort observations. This may reflect superior aspects of these studies that allowed for a better characterization of the cardiovascular risk of long-term exposure, the fact that these cohorts consisted of only women, or other unclear reasons. Compared with cardiovascular mortality, there is less existing evidence to support an increase in the risk for nonfatal cardiovascular events related to $PM_{2.5}$ exposure among the existing cohort studies, because many of them did not specifically investigate nonfatal outcomes, and several of the more recent studies reported nonsignificant relationships.[72,73]

Natural Experiment and Intervention Studies

Several studies have shown improvements in health outcomes in association with exposures using well-defined natural experiments or interventions, such as abrupt reductions in air pollution[89–91] or changes over a longer period of time.[64,92]

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 4. Comparison of Pooled Estimated of Percent Increase in Risk of Hospital Admission for CVD Estimated Across Meta-Analyses and Multicity Studies of Daily Changes in Exposure

	Primary Source	Exposure Increment	% Increase (95% CI)
Cardiac admissions, meta-analysis of 51 estimates	COMEAP[31] 2006	20 $\mu g/m^3$ PM_{10}	1.8 (1.4–1.2)
Cardiac admissions, 8 US cities	Schwartz[96] 1999	20 $\mu g/m^3$ PM_{10}	2.0 (1.5–2.5)
Cardiac admissions, 10 US cities	Zanobetti et al[97] 2000	20 $\mu g/m^3$ PM_{10}	2.6 (2.0–3.0)
Cardiac admissions, 14 US cities	Samet et al[98] 2000	20 $\mu g/m^3$ PM_{10}	2.0 (1.5–2.5)
	Schwartz et al[99] 2003		
Cardiac admissions, 8 European cities	Le Tertre et al[40] 2002	20 $\mu g/m^3$ PM_{10}	1.4 (0.8–2.0)
Cardiovascular admissions, 14 Spanish cities	Ballester et al[100] 2006	20 $\mu g/m^3$ PM_{10}	1.8 (7–3.0)
Cardiovascular admission, 8 French cities	Larrieu et al[101] 2007	20 $\mu g/m^3$ PM_{10}	1.6 (0.4–3.0)
Cardiovascular admissions, 202 US counties	Bell et al[102] 2008	20 $\mu g/m^3$ PM_{10}	0.8 (0.6–1.0)
Medicare national claims history files	Dominici et al[103] 2006	10 $\mu g/m^3$ $PM_{2.5}$	
Ischemic heart disease,			0.44 (0.02–0.86)
Cerebrovascular disease			0.81 (0.30–1.32)
Heart failure			1.28 (0.78–1.78)
Heart rhythm			0.57 (−0.01 to 1.15)

Small but statistically significant drops in mortality were associated with an 8½-month copper smelter strike that resulted in sharp reductions in sulfate PM and related air pollutants across 4 Southwest states, even after controlling for other factors.[93] Data from US Medicare enrollment files were used to estimate the association between changes in monthly mortality rates for US counties and average $PM_{2.5}$ concentrations for the previous 12 months.[94] $PM_{2.5}$-mortality associations were observed at the national scale but not the local scale, which raises concerns about possible statistical confounding due to unmeasured individual and ecological variables as a cause for any positive findings in this study. However, a recent large study found that reductions in PM air pollution exposure on a local scale (across US counties) over a 2-decade period (1980s and 1990s) were associated with increased life expectancy even after controlling for changes in socioeconomic, demographic, and proxy smoking variables.[95] Indeed, a decrease of 10 $\mu g/m^3$ in the long-term $PM_{2.5}$ concentration was related to an increase in mean life expectancy of 0.61 ± 0.20 years.

Hospitalization Rates

There are many daily time-series or case-crossover studies that have evaluated associations between cardiovascular hospitalizations and short-term changes in air pollution. Because of the great number of publications, all studies (particularly those focusing on nonparticulate air pollutants) cannot be discussed individually. Nevertheless, Table 4 presents a comparison of pooled estimates of percent increase in RR of hospital admission for general cardiac conditions across a previous meta-analysis of 51 published estimates (COMEAP [Committee on the Medical Effects of Air Pollutants]) and results from many selected multicity studies published after 2004. Several studies before 2004 are included in Table 4 only to demonstrate the consistency of effect.

Because of its comparatively large size and importance, the results of a recent analysis of Medicare files in 204 US urban counties with 11.5 million individuals older than 65 years merit discussion. Daily changes in $PM_{2.5}$ levels were associated with a variety of cardiovascular hospital admission subtypes.[103] A 10-$\mu g/m^3$ increase in $PM_{2.5}$ exposure was related to increases in hospitalizations for cerebrovascular disease by 0.81% (95% CI 0.3% to 1.32%), peripheral vascular disease by 0.86% (95% CI −0.06% to 1.79%), ischemic heart disease by 0.44% (95% CI 0.02% to 0.86%), arrhythmias by 0.57% (95% CI −0.01% to 1.15%), and heart failure by 1.28 (95% CI 0.78% to 1.78%). The most rapid effects, which occurred largely on the same day of $PM_{2.5}$ elevation, were seen for cerebrovascular, arrhythmia, and heart failure admissions. Ischemic heart disease events tended to increase to a greater extent 2 days after exposures. A consistent finding was that the cardiovascular effects of pollution were much stronger in the Northeast than in other regions. In fact, there were few significant associations in Western US regions. It was speculated that these differences reflected variations in particle composition (eg, greater sulfate in the East and nitrate components in the West) and pollution sources (eg, power generation in the East and transportation sources in the West). In a follow-up analysis by Peng et al,[104] $PM_{10-2.5}$ levels were not statistically associated with cardiovascular hospitalizations after adjustment for $PM_{2.5}$. This suggests that the smaller particles (ie, $PM_{2.5}$) are principally responsible for the cardiovascular hospitalizations attributed in prior studies to the combination of both fine and coarse particles (ie, PM_{10}). Given the differences between the size fractions, the results imply that particles and their components derived from combustion sources (ie, $PM_{2.5}$) are more harmful to the cardiovascular system than larger coarse particles. Finally, there is some evidence that gaseous pollutants may also instigate hospitalizations. Hospital admissions for cardiovascular causes, particularly ischemic heart disease, were found to rise in relation to the previous-day and same-day level of SO_2, even after adjustment for PM_{10} levels.[105]

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 5. Comparisons of Estimated Percent Increase in Risk of Ischemic Heart Disease Events due to Concurrent or Recent Daily PM Exposure

Event/Study Area	Primary Source	Exposure Increment	% Increase (95% CI)
MI events–Boston, Mass	Peters et al[110] 2001	10 $\mu g/m^3$ $PM_{2.5}$	20 (5.4–37)
MI, 1st hospitalization–Rome, Italy	D'Ippoliti et al[112] 2003	30 $\mu g/m^3$ TSP	7.1 (1.2–13.1)
MI, emergency hospitalizations–21 US cities	Zanobetti and Schwartz[113] 2005	20 $\mu g/m^3$ PM_{10}	1.3 (0.2–2.4)
Hospital readmissions for MI, angina, dysrhythmia, or heart failure of MI survivors–5 European cities	Von Klot et al[114] 2005	20 $\mu g/m^3$ PM_{10}	4.2 (0.8–8.0)
MI events–Seattle, Wash	Sullivan et al[115] 2005	10 $\mu g/m^3$ $PM_{2.5}$	4.0 (−4.0–14.5)
MI and unstable angina events–Wasatch Front, Utah	Pope et al[13] 2006	10 $\mu g/m^3$ $PM_{2.5}$	4.8 (1.0–6.6)
Tokyo metropolitan area	Murakami et al[109] 2006	TSP >300 $\mu g/m^3$ for 1 h vs reference periods <99 $\mu g/m^3$	40 (0–97)*
Nonfatal MI, Augsburg, Germany	Peters et al[111] 2004	Exposure to traffic 1 h before MI (note: not PM but self-reported traffic exposure)	292 (222–383)
Nonfatal MI, Augsburg, Germany	Peters et al[116] 2005	Ambient UFP, $PM_{2.5}$, and PM_{10} levels	No association with UFP or $PM_{2.5}$ on same day. Positive associations with $PM_{2.5}$ levels on 2 days prior

TSP indicates total suspended particulate matter.
*Adjusted rate ratio for MI deaths.

Evidence Summary

Excess cardiovascular mortality and increased rates of hospitalizations are similarly associated with day-to-day changes in PM air pollution (Tables 2 and 4). However, significant differences between geographic regions in the risk relationships have been observed, and more investigation is required to explain this heterogeneity.

Specific Cardiovascular Events/Conditions

Ischemic Heart Disease

Among the cohort studies that provided relevant results, the ACS study found a relationship between increased risk for ischemic heart disease death and long-term exposure to elevated $PM_{2.5}$ levels (Table 3).[67,69,106] Indeed, ischemic cardiac events accounted for the largest relative (RR 1.18, 95% CI 1.14 to 1.23) and absolute risk for mortality per 10-$\mu g/m^3$ elevation in $PM_{2.5}$.[67] A survival analysis of US Medicare data for 196 000 survivors of acute MI in 21 cities showed the risk of an adverse post-MI outcome (death, subsequent MI, or first admission for congestive heart failure) was increased with higher exposure to PM_{10}.[107] Data from the Worcester Heart Attack study also found that long-term exposure to traffic-related air pollution was associated with significantly increased risk of acute MI.[108] However, in the Women's Health Initiative[72] and the Nurses' Health Study,[73] only disease categories that included fatal coronary events, but not nonfatal MI alone, were statistically elevated in relation to $PM_{2.5}$. The effect size for cardiovascular mortality was much larger and much more statistically robust than for nonfatal events such as MI in both studies.

Various time-series and case-crossover studies have also reported increased ischemic heart disease hospital admissions associated with short-term elevated concentrations of inhalable and/or fine PM air pollution.[31,40,103] In the US Medicare study, a reduction of $PM_{2.5}$ by 10 $\mu g/m^3$ was estimated to reduce ischemic heart disease admissions in 204 counties by 1523 (95% posterior interval 69 to 2976) cases per year.[103] Several studies have also found positive associations between elevated PM or traffic exposures over a period as brief as a few hours[109–111] or a few days and an elevated risk for MI (Table 5).[13,110,112–115] In general, acute increases in risk for ischemic heart disease events have been observed consistently, even as rapidly as 1 to 2 hours after exposure to elevated PM, in case-crossover analyses.[109–111] Other studies have reported an increased risk for MI shortly after exposure to traffic. Peters et al[111] reported in 691 subjects in Augsburg, Germany, a strong association (odds ratio 2.92, 95% CI 2.22 to 3.83) between onset of MI and traffic exposure within the past hour, although whether this was a result of the air pollution or a combination of other factors (eg, noise and stress) is not certain. Additional analyses did not report an association between recent UFP exposures and MI onset; however, the levels of $PM_{2.5}$ and several gaseous pollutants 2 days earlier were related to MI risk.[116] The lack of relationship between MI and UFPs may be due to the fact that the levels were measured regionally and remote from the localized source and may therefore reflect exposure misclassification. Finally, in the only study in which participating subjects had coronary angiograms performed previously, ischemic cardiac events were found to occur in relation to PM air pollution exposure solely among individuals with obstructive coronary atherosclerosis in at least 1 vessel.[13] This finding suggests the importance of patient susceptibility (eg, the presence of preexisting coronary artery disease) for PM to trigger an acute ischemic event within hours to days after exposure.

Heart Failure

In the ACS cohort study, it appeared that deaths due to arrhythmias, heart failure, and cardiac arrest (RR 1.13, 95% CI 1.05 to 1.21 per 10 $\mu g/m^3$) were also associated with

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

prolonged exposure to $PM_{2.5}$, although not as strongly as ischemic heart disease mortality,[67] although potential mortality misclassification on death certificates makes the actual cause of death not entirely certain in all circumstances. Heart failure rates or mortality associations were not reported in the other cohort studies.

Daily hospitalizations for heart failure have also been associated with short-term changes in PM exposure.[31] Heart failure associations with PM were observed in a large daily time-series analysis of $PM_{2.5}$ and cardiovascular and respiratory hospitalizations by use of a national database constructed from US Medicare files.[103] A 10-$\mu g/m^3$ increase in concurrent-day $PM_{2.5}$ was associated with a 1.28% (95% CI 0.78% to 1.78%) increase in heart failure admissions, the single largest cause for hospitalization in this cohort. A reduction of $PM_{2.5}$ by 10 $\mu g/m^3$ was estimated to reduce heart failure admissions in 204 counties by 3156 (95% posterior interval 1923 to 4389) cases per year.[103] Another analysis in Medicare recipients in 7 US cities found a 10-$\mu g/m^3$ increase in concurrent-day PM_{10} was associated with a 0.72% (95% CI 0.35% to 1.10%) increase in heart failure admissions.[117] Traffic-related air pollution has also been shown to be significantly associated with increased mortality risk after acute heart failure.[118] Finally, a study from Utah's Wasatch Front area explored longer lagged-exposure periods and found that a 14-day lagged cumulative moving average of 10 $\mu g/m^3$ $PM_{2.5}$ was associated with a 13.1% (95% CI 1.3% to 26.2%) increase in heart failure admissions.[119]

Cerebrovascular Disease

Among the cohort studies that provided pertinent results, the Women's Health Initiative reported significant increases in both nonfatal stroke (hazard ratio 1.28, 95% CI 1.02 to 1.61) and fatal cerebrovascular disease (hazard ratio 1.83, 95% CI 1.11 to 3.00) per 10-$\mu g/m^3$ elevation in prolonged exposure to $PM_{2.5}$.[72] However, no significant association between stroke mortality and PM air pollution was found in the ACS study.[67]

Several studies have also reported small but statistically significant associations between short-term PM exposure and cerebrovascular disease. Daily time-series studies of stroke mortality in Seoul, Korea,[120,121] observed that elevated air pollution (including measures of PM, NO_2, CO, and O_3) was associated with increases in stroke mortality. When analyzed separately by stroke type,[121] the pollution association was associated with ischemic but not hemorrhagic stroke. Risk of stroke mortality was also associated with daily increases in PM_{10} and NO_2 in Shanghai, China.[56] A daily time-series study in Helsinki, Finland,[122] found that $PM_{2.5}$ and CO were associated with stroke mortality in the warm but not the cold seasons. Several studies have also observed increased stroke or cerebrovascular hospital admissions associated with increased exposure to PM or related pollutants.[31,38,40,46,123–125] For example, a study of hospital admissions for Medicare recipients in 9 US cities[125] found that several measures of air pollution (PM_{10}, CO, NO_2, and SO_2) 0 to 2 days before admission were associated with ischemic but not hemorrhagic stroke. Studies of ischemic stroke and transient ischemic attacks based on population-based surveillance have also been conducted in Dijon, France,[126] where O_3 exposure (but not PM_{10}) was associated with ischemic stroke, and in Corpus Christi, Tex,[127] where both $PM_{2.5}$ and O_3 were associated with ischemic strokes and transient ischemic attacks.

Peripheral Arterial and Venous Diseases

There have been only a few studies that have explored a relationship between air pollution and peripheral vascular diseases. Studies using Medicare data for 204 US counties observed nearly statistically significant positive associations between daily changes in measures of PM pollution and hospitalizations for peripheral vascular diseases.[103,104] The ACS cohort found no association between other atherosclerotic and aortic aneurysm deaths and long-term $PM_{2.5}$ exposure.[67]

Recently, a case-control study from the Lombardy region of Italy found a 70% increase in risk of deep vein thrombosis per 10-$\mu g/m^3$ elevation in long-term PM_{10} level.[128] This is the first observation that particulate air pollution can enhance coagulation and thrombosis risk in a manner that adversely affects the venous circulation in addition to the arterial cardiovascular system.

Cardiac Arrhythmias and Arrest

Several studies have observed associations between fine PM and related pollutants and cardiac arrhythmias, often based on data from implanted cardioverter-defibrillators.[129–136] However, no clear pollution-related associations were observed in studies from a relatively clean metropolitan area, Vancouver, British Columbia, Canada,[137,138] or from a relatively large study in Atlanta, Ga.[139] Similarly, pollution-related associations have been observed with cardiac arrest in Rome, Italy,[140] and Indianapolis, Ind,[141] but not in Seattle, Wash.[142,143] The mixed results may reflect different PM compositions due to different sources or variations among the methods used.

Evidence Summary

On the basis of the available epidemiological studies that have reported the associations between PM exposures with specific subsets of cardiovascular outcomes (morbidity, mortality, or hospitalizations), the existing level of overall evidence is strong for an effect of PM on ischemic heart disease, moderate (yet growing) for heart failure and ischemic stroke, and modest or mixed for peripheral vascular and cardiac arrhythmia/arrest (Table 6).

Ambient Air Pollution and Subclinical Pathophysiological Responses in Human Populations

It is likely that many subclinical physiological changes occur in individuals in response to $PM_{2.5}$ exposures that do not become overtly manifest as a cardiovascular event (eg, death or MI). The illustration of these more subtle responses bolsters the plausibility of the observable outcome associations and provides insight into the pathways whereby air

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Table 6. Overall Summary of Epidemiological Evidence of the Cardiovascular Effects of $PM_{2.5}$, Traffic-Related, or Combustion-Related Air Pollution Exposure at Ambient Levels

Health Outcomes	Short-Term Exposure (Days)	Longer-Term Exposure (Months to Years)
Clinical cardiovascular end points from epidemiological studies at ambient pollution concentrations		
Cardiovascular mortality	↑ ↑ ↑	↑ ↑ ↑
Cardiovascular hospitalizations	↑ ↑ ↑	↑
Ischemic heart disease*	↑ ↑ ↑	↑ ↑ ↑
Heart failure*	↑ ↑	↑
Ischemic stroke*	↑ ↑	↑
Vascular diseases	↑	↑†
Cardiac arrhythmia/cardiac arrest	↑	↑
Subclinical cardiovascular end points and/or surrogate measures in human studies		
Surrogate markers of atherosclerosis	N/A	↑
Systemic inflammation	↑ ↑	↑
Systemic oxidative stress	↑	
Endothelial cell activation/ blood coagulation	↑ ↑	↑
Vascular/endothelial dysfunction	↑ ↑	
BP	↑ ↑	
Altered HRV	↑ ↑ ↑	↑
Cardiac ischemia	↑	
Arrhythmias	↑	

The arrows are not indicators of the relative size of the association but represent a qualitative assessment based on the consensus of the writing group of the strength of the epidemiological evidence based on the number and/or quality, as well as the consistency, of the relevant epidemiological studies.

↑ ↑ ↑ Indicates strong overall epidemiological evidence.

↑ ↑ Indicates moderate overall epidemiological evidence.

↑ Indicates some but limited or weak available epidemiological evidence.

Blank indicates lack of evidence.

N/A indicates not applicable.

*Categories include fatal and nonfatal events.

†Deep venous thrombosis only.

pollutants mediate CVDs. The "Biological Mechanisms" section discusses the hypothesized global pathways and reviews the studies related to the fundamental cellular/molecular mechanisms elucidated by controlled human and animal exposures and toxicological/basic science experiments. The following section reviews the recent evidence that ambient exposure to air pollution can mediate potentially harmful subclinical cardiovascular effects. In general, many positive associations are found (Table 6). Numerous complex interactions between variations in the characteristics, sources, and chemistry of the particles, coupled with diversity in time frames, mixtures of exposures, and degrees of individual susceptibility, likely explain some of the disparity among findings.

Systemic Inflammation

There is evidence that under some circumstances, exposure to ambient PM can be associated with elevated circulating proinflammatory biomarkers that are indicative of a systemic response after PM air pollution inhalation that is not limited to the confines of the lung. Early reports found associations with day-to-day variation in acute-phase proteins, such as C-reactive protein (CRP), fibrinogen, or white blood cell counts,[144–147] as reviewed previously.[1] Limited evidence on the association between cumulative PM exposures and fibrinogen levels and counts of platelets and white blood cells was also available.[148]

A number of more recent studies have reported positive associations with short-term ambient PM exposure and day-to-day elevations in inflammatory markers. These include increases in CRP in an elderly population[149] and individuals with coronary atherosclerosis[150]; CRP and fibrinogen in young adults[151] and elderly overweight individuals[152]; and CRP, tumor necrosis factor-α (TNF-α), and interleukin (IL)-1β in children.[153] Recent evidence has also been found for an upregulation of circulating soluble adhesion molecules (eg, intercellular adhesion molecule-1) in 92 Boston, Mass–area individuals with diabetes[154] and 57 male subjects with coronary artery disease in Germany.[150] In a larger analysis of 1003 MI survivors, also in Germany, CRP was not related to PM exposure; however, ambient particle number concentration and PM_{10} were associated with increased IL-6 and fibrinogen, respectively.[155] Short-term levels of in-vehicle $PM_{2.5}$ have also been linked to increases in CRP among healthy highway patrol troopers.[156] In a follow-up analysis, elevations in certain particulate components of traffic pollution (eg, chromium) were associated with increased white blood cell counts and increased IL-6 levels.[157] Short-term changes in ambient PM levels have also been linked to acute (1 to 3 days later) alterations in biomarkers of inflammation, oxidative stress, and platelet activation among elderly adults with coronary artery disease living in retirement communities in Los Angeles, Calif.[158,159] Pollutants associated with primary combustion (eg, elemental and black carbon, primary organic carbon) and UFPs rather than $PM_{2.5}$ appeared to be strongly associated with adverse responses in this population.

Regarding more long-term exposures,[160] a positive association between white blood cell count and estimated long-term 1-year exposure to PM_{10} was reported in the Third National Health and Nutrition Examination Survey. Among 4814 adults in Germany, small increases in annual mean $PM_{2.5}$ (3.9 $\mu g/m^3$) were associated with increases in high-sensitivity CRP by 23.9% and in fibrinogen by 3.9% among men only. Estimated long-term traffic exposure was not related to inflammatory changes in either sex.[161]

Several studies, including some with improved exposure assessment,[162] some that included analyses of large population cohorts,[163,164] and a recent evaluation of long-term annual PM_{10} levels in England,[165] have not found a relationship between particulate exposure and inflammation. It is

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

conceivable that differences in the magnitude or character of the inflammatory response will occur because of variations in the particulate chemistry and duration/intensity of exposures. Certain individuals may also be more susceptible. The evidence suggests that subjects with underlying cardiovascular risk factors and the metabolic syndrome may exhibit stronger associations.[152,160,166] Conversely, antiinflammatory medications such as statins may mitigate the actions of ambient particles.[152,155] All together, there is some evidence for a positive association between recent and long-term PM exposure and a systemic proinflammatory response; nevertheless, there is variation in the strength and consistency of changes among the variety of biomarkers and patient populations evaluated (Table 6).

Systemic Oxidative Stress

A state of oxidative stress refers to a condition in which levels of free radicals or reactive oxygen/nitrogen species (eg, O_2^-, H_2O_2, $ONOO^-$) are higher than normal (eg, healthy individuals in whom they are countered by homeostatic processes such as antioxidants) and thus are capable of exerting many adverse biological effects (eg, lipid/protein/deoxyribonucleic acid [DNA] oxidation, initiation of proinflammatory cascades). Although many biomarkers of differing systemic responses are available (eg, lipid or protein oxidation products), oxidative stress may occur at the local cellular/tissue level and not be directly observable by circulating markers. In addition, oxidative stress is often induced by and elicits inflammatory processes. The 2 processes are biologically linked. Therefore, human studies investigating the effect of PM on oxidative stress per se are difficult to perform. Only a few studies have directly investigated the occurrence of systemic oxidative stress in humans in relation to ambient PM exposure. Three studies of young adults conducted in Denmark demonstrated elevations in biomarkers of protein, lipid, or DNA oxidation in relation to PM exposure from traffic sources.[167–169] In a study of 76 young adults from Taipei, Taiwan,[151] the investigators found evidence of increased levels of 8-hydroxy-2′-deoxyguanosine adducts in DNA in relation to short-term elevations in ambient PM. Two studies have also demonstrated increases in plasma homocysteine, evidence that exposure to ambient PM can elevate this circulating mediator of oxidative stress.[170,171] Finally, Romieu et al[172] found that dietary supplementation with omega-3 polyunsaturated fatty acids might be capable of altering the systemic oxidative stress response (reduction in copper/zinc superoxide dismutase and glutathione) induced by air pollutants among residents living in a nursing home in Mexico City, Mexico. Because of the relatively small number of studies, more investigation is required to make firm conclusions and to understand the nature of the systemic oxidative stress response potentially induced by ambient PM (Table 6).

Thrombosis and Coagulation

Early reports indicated that increased plasma viscosity[144] and elevated concentrations of fibrinogen[146] are associated with short-term changes in ambient PM concentrations. More recent evidence was found for an upregulation of circulating von Willebrand factor in 57 male subjects with coronary artery disease in Germany[150] and 92 Boston-area individuals with diabetes.[154] Riediker[157] found that components of in-vehicle $PM_{2.5}$ were also related to increased von Willebrand factor and decreased protein C among highway patrol troopers. In the Atherosclerosis Risk in Communities study, a 12.8-$\mu g/m^3$ elevation in ambient PM_{10} was associated with a 3.9% higher von Willebrand factor level,[173] but only among those with diabetes. There was no linkage between PM_{10} exposure and fibrinogen or white blood cell levels.

Alterations in other markers that indicate changes in thrombosis, fibrinolysis, and global coagulation have also been reported. An immediate elevation in soluble CD40-ligand concentration, possibly reflecting platelet activation, recently was found to be related to ambient UFP and accumulation-mode particle ($PM_{0.1–1.0}$) levels in patients with coronary artery disease.[155] Ambient PM_{10} levels have also been associated with augmented platelet aggregation 24 to 96 hours after exposure among healthy adults.[174] In this study, there were no concomitant observable changes in thrombin generation, CRP, or fibrinogen induced by PM_{10}. Increases in plasminogen activator inhibitor-1 and fibrinogen levels have been noted in healthy subjects,[151] as well as elevated plasminogen activator inhibitor-1 in patients with coronary artery disease only,[175] in association with ambient PM levels in Taipei. Chronic indoor pollution exposure to biomass cooking in rural India has also been associated with elevated circulating markers of platelet activation.[176] Recently, Baccarelli et al[128,177] demonstrated in healthy subjects and among individuals with deep venous thrombosis living in the Lombardy region of Italy that prothrombin time was shortened in relation to recent and long-term ambient PM_{10} concentrations. Nevertheless, some studies found no effects of ambient pollution,[178] nor have significant changes been reported among all the biomarkers or subgroups of individuals investigated.[150,154,170,173] Similar to the study on systemic inflammation, the results related to thrombosis/coagulation are quite variable given the differences in study designs, patients, biomarkers evaluated, and pollutants; however, these adverse effects appear somewhat more consistent among higher-risk individuals (Table 6).

Systemic and Pulmonary Arterial BP

Several studies have reported that higher daily PM levels are related to acute increases in systemic arterial BP (approximately a 1- to 4-mm Hg increase per 10-$\mu g/m^3$ elevation in PM).[179–184] In a small study of patients with severe heart failure,[185] pulmonary artery and right ventricular diastolic BP were found to increase slightly in relation to same-day levels of PM. Chronic exposure to elevated $PM_{2.5}$ was associated with increased levels of circulating endothelin (ET)-1 and elevated mean pulmonary arterial pressure in children living in Mexico City.[186] These results may explain in part the risk for heart failure exacerbations due to PM

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

exposure; however, not all studies of systemic arterial BP have been positive.[187–189]

Recently, Dvonch et al[190] demonstrated significant associations between increases in systolic BP and daily elevations in $PM_{2.5}$ across 347 adults living in 3 distinct communities within metropolitan Detroit, Mich. Much larger effects were observed 2 to 5 days after higher $PM_{2.5}$ levels within a specific urban location of southwest Detroit (8.6 mm Hg systolic BP increase per 10-$\mu g/m^3$ $PM_{2.5}$) than throughout the entire region or cohort (3.2 mm Hg). This suggests that specific air pollution sources and components contribute significantly to the potential for PM exposure to raise BP. Interestingly, it was recently reported in a crossover study of 15 healthy individuals that systolic BP was significantly lower (114 versus 121 mm Hg) during a 2-hour walk in Beijing, China, while the subjects were wearing a high-efficiency particulate-filter facemask than when they were not protected.[191] Wearing the facemask was also associated with increased HRV, which suggests that the rapid BP-raising effects of particle inhalation may be mediated through the autonomic nervous system (ANS). In a similar fashion,[192] reducing exposure to particulate pollution from cooking stoves was shown to be associated with lower systolic (3.7 mm Hg, 95% CI −8.1 to 0.6 mm Hg) and diastolic (3.0 mm Hg, 95% CI −5.7 to −0.4 mm Hg) BP among Guatemalan women than among control subjects after an average of 293 days. These findings demonstrate that indoor sources of PM (eg, cooking, biomass) may have important cardiovascular health consequences and that reductions in particulate exposure are capable of lowering BP, and they suggest that chronic exposure to PM air pollution may alter long-term basal BP levels. Even given the rapid variability of BP on a short-term basis and the numerous factors involved in determining individual responses (eg, patient susceptibility, PM composition, and time frames of exposure), overall, it appears that ambient PM can adversely affect systemic hemodynamics, at least under certain circumstances (Table 6).

Vascular Function

In the first ambient PM study related to changes in vascular function, O'Neill et al[193] reported that both endothelium-dependent and -independent vasodilation were blunted in relation to air pollution levels in Boston. The largest changes occurred in association with sulfate and black carbon, suggestive of coal-burning and traffic sources, respectively. Significant adverse responses were observed within 1 day yet were still present and slightly more robust up to 6 days after exposure. Moreover, the adverse responses occurred solely among diabetic individuals and not in patients at risk for diabetes mellitus. Two other studies[184,194] also demonstrated impaired vascular function due to short-term changes in ambient PM among diabetic patients. In the study by Schneider et al,[194] endothelium-dependent vasodilation was blunted during the first day, whereas small-artery compliance was impaired 1 to 3 days after elevated ambient PM levels. Interestingly, higher concentrations of blood myeloperoxidase were related to a greater degree of endothelial dysfunction, which suggests that white blood cell sources of reactive oxygen species (ROS) may be involved.

In healthy adults, very short-term exposure to elevated levels of ambient PM from traffic sources while exercising for 30 minutes near roadways[195] and when resting by bus stops for 2 hours[196] has been related to impaired endothelium-dependent vasodilation. Daily changes in ambient gaseous pollutants (SO_2 and NO_x) in Paris, France, have also been associated with impaired endothelium-dependent vasodilation among nonsmoking men.[197] Finally, indoor particulate air pollution may also be harmful to vascular function. Bräuner and colleagues[198] recently reported that reductions in 48-hour $PM_{2.5}$ levels due to filtering of air in subjects' homes resulted in improved microvascular vascular function among elderly subjects. Nevertheless, changes in short-term ambient PM levels have not been linked with impaired conduit[197] or microvascular[178] endothelial function in all studies. Even when the few negative studies are considered, the overall evidence supports the concept that ambient PM is capable of impairing vascular function, particularly among higher-risk individuals (eg, those with diabetes) and after traffic-related exposure (Table 6).

Atherosclerosis

A few cross-sectional studies have reported an association between measures of atherosclerosis in humans and long-term exposures to ambient air pollution levels. The first study to demonstrate this relationship was an analysis of data from 798 participants in 2 clinical trials conducted in the Los Angeles area. A cross-sectional contrast in exposure of 10 $\mu g/m^3$ $PM_{2.5}$ was associated with an adjusted nonsignificant 4.2% (95% CI −0.2% to 8.9%) increase in common carotid intima-media thickness[199]; however, in certain subgroups of patients, such as women, the effect was much larger (13.8%, 95% CI 4.0% to 24.5%). In a population-based sample of 4494 subjects from Germany,[200] it was found that residential proximity to major roadways was associated with increased coronary artery calcification. A reduction in distance from a major road by half was associated with a 7% (95% CI 0.1% to 14.4%) higher coronary artery calcium score. Proximity to traffic was also related to an increased risk for peripheral artery disease in women but not men.[201] In an analysis of 3 measures of subclinical disease (carotid intima-media thickness, coronary calcium, and ankle-brachial index) among 5172 adults from the Multi-Ethnic Study of Atherosclerosis, only common carotid intima-media thickness was modestly (yet significantly) associated with 20-year exposure to $PM_{2.5}$.[202] In a related study from the same cohort, abdominal aortic calcium was associated with long-term $PM_{2.5}$ exposure, especially for residentially stable participants who resided near a $PM_{2.5}$ monitor.[203] Although it appears that long-term exposure to higher levels of ambient PM might accelerate the progression of atherosclerosis, more investigations are needed (Table 6).

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Heart Rate Variability

Numerous studies have continued to explore associations between daily changes in PM air pollution exposure and alterations (typically reductions) in HRV metrics, putative markers of cardiac autonomic balance.[129,149,156,204–242] Recent observations in the Normative Aging Study cohort have shown strong effect modification of the PM-HRV relationship by obesity and genes that modulate endogenous oxidative stress or xenobiotic metabolism, such as glutathione S-transferase M1, methylenetetrahydrofolate reductase, and the hemochromatosis gene.[207,243,244] Additional findings suggest protective effects of statins, dietary antioxidants, and B vitamins, as well as omega-3 polyunsaturated fatty acids.[205,207,215,243,244] These results suggest that pathways that reduce endogenous oxidative stress have a protective effect that mitigates reductions in HRV due to ambient PM exposure.

However, the overall results are not entirely consistent. Some studies have reported increases in HRV mediated by PM, specifically among younger healthy people and patients with chronic obstructive lung disease.[156,208,216] Nevertheless, the general pattern suggests that PM exposure is associated with increased heart rate and reductions in most indices of HRV among older or susceptible individuals, such as those with obesity and the metabolic syndrome. Typically, time-domain measures (eg, standard deviation of normal RR intervals) and total power are reduced within hours after exposure. Most, but not all, pertinent studies have also found that the largest reduction in power is within the high-frequency domain. In sum, these observations provide some evidence that ambient PM air pollution exposure rapidly reduces HRV, a surrogate marker for a worse cardiovascular prognosis (Table 6). Although studies corroborating changes in autonomic activity by other methods (eg, microneurography or norepinephrine kinetics) have not been performed, the HRV findings are perhaps reflective of the instigation of a generalized cardiovascular autonomic imbalance due to relatively greater parasympathetic than sympathetic nervous system withdrawal.

Cardiac Ischemia and Repolarization Abnormalities

There has been limited direct evidence for the actual induction of cardiac ischemia or repolarization abnormalities in the electrocardiogram (ECG) by exposure to ambient levels of PM.[223,245] Recent follow-up analyses from the initial ULTRA study (Exposure and Risk Assessment for Fine and Ultrafine Particles in Ambient Air)[245] suggested that traffic-related combustion pollutants were most strongly related to the promotion of ST-segment depression among elderly nonsmokers during exercise stress testing.[246] Moreover, even very acute $PM_{2.5}$ exposure within the past 1 or 4 hours has been associated with cardiac ischemia during exercise.[247] New findings support these associations in elderly subjects[248] and in patients with coronary artery disease in Boston.[249] In the latter study, traffic-related PM was most strongly related to the incidence of ST-segment depression during 24-hour Holter monitoring, and the risk for ischemia was greatest within the first month after a cardiac event among patients with diabetes. Overall, there is a modest level of evidence that PM exposure can promote cardiac ischemia in susceptible individuals (Table 6).

Epigenetic Changes

There have been relatively few studies examining gene–air pollution exposure interactions, and most have done so while investigating a small number of loci for genetic polymorphisms. Although some studies have suggested greater air pollution susceptibility with one or another genomic polymorphism,[207,243,244] few have evaluated the potential for epigenetic changes after exposures. Reduced levels of DNA methylation have been linked to aging, oxidative stress, and CVD. Recently, Baccarelli et al[250] have shown among 718 elderly participants in the Normative Aging Study that short-term exposures (over 1 to 7 days) to $PM_{2.5}$ and black carbon are associated with decreased "global" DNA methylation in long interspersed nucleotide elements. It was posited that oxidative stress from air pollution exposure could have interfered with the capacity for methyltransferases to interact with DNA or altered the expression of genes involved in the methylation process. This observed effect of pollution exposure was analogous to changes seen with 3.4 years of aging in the cohort. Additional findings among workers in a furnace steel plant support these observations.[251] Nevertheless, the mechanisms involved and the cardiovascular implications of these preliminary, although provocative, epigenetic changes require more investigation.

Traditional Cardiovascular Risk Factors

In addition to the fact that individuals with traditional risk factors are likely to be at higher risk for cardiovascular events due to PM exposure, air pollutants may also promote the development of these risk factors over a prolonged period of time. Few published studies have investigated this possibility. A report from the Multi-Ethnic Study of Atherosclerosis has demonstrated that residential proximity to major roadways was associated with a higher left ventricular mass index as measured by cardiac magnetic resonance imaging.[252] The degree of increase was analogous to a 5.6-mm Hg increase in systolic BP among the study participants. This suggests that traffic-related exposures may have increased left ventricular mass by chronically elevating systemic arterial BP, a common cause of left ventricular hypertrophy. However, other mechanisms cannot be excluded, such as systemic inflammation and oxidative stress, which could potentially activate neurohormonal pathways (eg, ANS imbalance, renin-angiotensin system) that could directly mediate such a finding. In addition, a recent study of adults older than 30 years of age (n=132 224) participating in the National Health Interview Survey reported a significant association between self-reported hypertension and estimated annual $PM_{2.5}$ exposure using US EPA monitoring data.[253] A 10-$\mu g/m^3$ elevation in $PM_{2.5}$ was associated with an

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

adjusted odds ratio of 1.05 (CI 1.00 to 1.10) for the presence of hypertension. The increase in risk was found only among non-Hispanic whites. These studies provide some initial evidence that longer-term PM exposures may augment the risk for developing chronically elevated BP levels or even overt hypertension.

Brook et al[254] have also demonstrated a novel relationship between a metric of long-term traffic exposure (NO_2 level by residence) and the odds of having the diagnosis of diabetes mellitus among patients in 2 respiratory clinics in Ontario, Canada. In women only, the odds ratio of diabetes was 1.04 (95% CI 1.00 to 1.08) for each increase of 1 parts per billion (ppb) of NO_2. Across the interquartile range (4 ppb NO_2), exposures were associated with nearly a 17% increase in odds for diabetes mellitus. The first biological support for this finding comes from a study in Iran that demonstrated that the previous 7-day-long exposure to PM_{10} was independently associated with worse metabolic insulin sensitivity among 374 children 10 to 18 years of age.[255] These findings suggest that the systemic proinflammatory and oxidative responses due to long-term PM air pollution exposure could potentially increase the risk for developing clinically important aspects of the metabolic syndrome, such as hypertension and diabetes mellitus. Further studies in this regard are warranted.

Evidence Summary

Table 6 provides a consensus qualitative synopsis based on the expert opinions of the writing group members of the overall level of existing support, linking each surrogate or intermediate cardiovascular outcome with exposures to PM at ambient concentrations, based solely on the database of observational studies.

Additional Epidemiological Findings and Areas of Continued Research

Responsible Sources and Pollution Constituents

Although PM concentration (mass per cubic meter) has been associated with cardiovascular events in numerous studies, the specific particulate constituents and the sources responsible remain less clear. Despite the fact that it is a difficult undertaking, several epidemiological studies have attempted to identify the culprit components within the PM mixtures. With regard to PM-associated inorganic ions (nitrate and sulfate), it has been suggested that the overall toxicological data do not clearly implicate these compounds as responsible for mediating the cardiovascular health effects of $PM_{2.5}$.[256] Nevertheless, sulfate particles have been associated with cardiopulmonary mortality in the ACS and Harvard Six Cities studies.[62,68] A recent time-series analysis among 25 US cities found that cardiovascular risk was increased when PM mass contained a higher proportion of sulfate, as well as some metals (aluminum, arsenic, silicon, and nickel).[257] It is possible that these positive findings represent sulfate serving as a marker for an effect mediated by a toxic PM mixture derived from commonly associated sources (eg, coal combustion). Nevertheless, a direct role for particle sulfate in causing cardiovascular events cannot be excluded entirely.[256]

In California, short-term exposures to several different PM constituents that likely reflect combustion-derived particulates, including organic and elemental carbon and nitrates, were most strongly associated with higher cardiovascular mortality.[258] Certain metals (zinc, titanium, potassium, and iron) and sulfate levels in the winter months were also positively related. Similarly, ambient levels of organic and elemental carbon have been most strongly linked among PM constituents with hospitalizations for CVDs in multipollutant models in a study among 119 US cities.[259] Finally, $PM_{2.5}$ composed of higher levels of elemental carbon, along with the metals nickel and vanadium,[48] has also been linked with greater risks for cardiovascular hospitalizations.[260] These results support that the chemistry or composition of the $PM_{2.5}$ (eg, organic/elemental carbon and certain metals) along with the responsible source from which these mixtures are derived (eg, fresh combustion, traffic) may play important roles in determining the risk for cardiovascular events. However, the extent to which these constituents mediate specific responses, alone or together, and their importance beyond the concentration of $PM_{2.5}$ mass alone represent an area of active research that requires more investigation to reach firm conclusions.

Many experiments have demonstrated the especially toxic properties and strong oxidizing potential of the smallest particle sizes (eg, UFP) and of the specific chemical species typically rich within this size fraction (eg, transition metals, organic compounds, and semiquinones).[261] Although some epidemiological evidence suggests that exposure to ultrafine compounds[17] may be associated with higher cardiovascular risk (eg, an elevation of UFP count by 9748/cm^3 has been associated with an increase in cardiovascular mortality of approximately 3% within 4 days in Erfurt, Germany[262]) and adverse responses,[158,159] there have been few such studies because they are challenging to conduct, for numerous reasons. Moreover, there are few UFP monitors, and the levels measured at regional sites may not accurately reflect an individual person's exposure because of marked spatial heterogeneity, because the concentrations are dominated by local point sources of fresh combustion (eg, roadways). This could help explain some of the previously negative study findings.[116]

Similarly, coarse particulates between 0.25 and 1.0 μm in diameter may affect the cardiovascular system,[221,264,265] and although the available data related to hard events and cardiovascular mortality have suggested a relationship,[265,266] recent findings have been less consistent.[104] In the most recent time-series analysis of 112 US cities, coarse PM was independently associated with elevated all-cause, stroke, and pulmonary, but not cardiovascular, mortality after controlling for $PM_{2.5}$.[43] Coarse PM was also not associated with either fatal or nonfatal cardiovascular events after controlling for $PM_{2.5}$ levels in the Nurses' Health Study[267] or the Women's Health Initiative cohort analyses.[72] Additional research is required to establish whether there are independent health effects of the other

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

particulate size fractions beyond those posed by fine particles. On the other hand, $PM_{2.5}$ mass concentration is the metric most consistently associated with cardiovascular morbidity and mortality. It remains to be determined whether this reflects limitations of available data, the long-lived and regionally homogenous atmospheric nature of $PM_{2.5}$, that few studies have investigated the independent effects of the other sizes, difficulties in performing epidemiology studies with adequate UFP exposure estimates, or that specific constituents within the fine PM fraction (or another unidentified agent correlated with that fraction) are actually responsible for causing cardiovascular events. Although particles <0.1 μm (ie, UFPs) do make up a small fraction of $PM_{2.5}$ mass, the correlation between UFP particle number and total $PM_{2.5}$ mass concentration is often weak. Because of their minute size, UFPs make up only a small portion of the total $PM_{2.5}$ mass, even though they represent the largest actual number of particles within fine PM. They also have the highest surface area and a differing surface chemistry. Therefore, changes in the underlying UFP concentration do not likely account for or explain the linkages between $PM_{2.5}$ mass concentration and cardiovascular events observed in large multicity studies. The overall epidemiological evidence thus indicates that fine PM poses an independent cardiovascular risk and that any putative effects of these other size fractions cannot fully explain the observed $PM_{2.5}$–cardiovascular morbidity/mortality relationship.

On the other hand, there is mounting evidence for a distinctive role played by motor vehicle traffic–related exposures in elevating cardiovascular risk.[108,111,268,269] Lipfert et al[76,77] interpreted the results of their analysis of the Veterans Affairs hypertensive male cohort as suggesting that traffic density was a more "significant and robust predictor of survival in this cohort" than $PM_{2.5}$. Analyses of the Oslo,[81] Dutch,[82] AHSMOG,[74,75,88] French PAARC,[79] and German women cohorts[80] and related studies from areas in the United Kingdom,[270] Canada,[271] Norway,[272] and Rome[273] found that measures that often indicate traffic-related exposure (NO_2, NO_x, traffic density, and living near major roads) were also associated with increased mortality. Long-term 5-year average traffic-generated air pollution exposure has been associated with an increased risk of fatal MI (odds ratio 1.23, 95% CI 1.15 to 1.32 per 31-$\mu g/m^3$ increase in NO_2) but not nonfatal MI in Stockholm County, Sweden.[274] The results mirror the results of several cohort studies[72,73] that found that air pollution exposures appeared to be more strongly linked with cardiovascular mortality than nonfatal events. Recently, an analysis from a cohort in the Netherlands demonstrated that several metrics of traffic-related air pollution exposure remained significantly associated with increased risk for cardiovascular events even after adjustment for higher levels of traffic noise.[275]

The effect of long-term traffic-related exposure on incidence of fatal and nonfatal coronary heart disease was recently assessed after adjustment for background air pollutants and cardiovascular risk factors in 13 309 adults in the Atherosclerosis Risk in Communities study.[276] Interestingly, background chronic ambient $PM_{2.5}$ concentrations were not related to the interpolated traffic exposure levels or to heart disease outcomes, which supports the highly localized nature of traffic sources of exposure. After 13 years of follow-up in 4 US communities, individuals residing within the highest quartile of traffic density had a relative risk of 1.32 (95% CI 1.06 to 1.65) for fatal and nonfatal heart disease events. Despite multiple statistical adjustments, the investigators also acknowledged the possibility for residual confounding as a potential source of bias. The specific traffic-related pollution components, such as UFP or gaseous-phase chemicals (eg, SVOCs), that are responsible for the positive findings among these studies remain unknown. The close proximity to roadways within these epidemiological studies (eg, 400 m) required to observe an association with elevated cardiovascular risk, however, matches the atmospheric fate of these shorter-lived pollutants. The findings may thus suggest the existence of cardiovascular health effects mediated by specific air pollutants rather than $PM_{2.5}$ per se. There is room for improvement in assessment of traffic exposures in epidemiological research, and better approaches are now being incorporated into research projects, such as accounting for associated factors (eg, noise or spatial autocorrelation with socioeconomic status).[275,277]

Geographic differences in cardiovascular risk due to PM have also been observed across US regions, with more consistent or stronger effects observed in Eastern versus Western states.[71,103,257] Differences between North American and European cities have also been reported.[61] PM exposures are typically, but not always,[258] associated with larger effects during warmer months (spring through fall) than in the winter.[45,103,257] Variations in pollution characteristics (eg, sulfate), time spent outdoors, air conditioning usage and particle penetration indoors, ambient temperature and meteorology, and mobile (eg, diesel) or stationary (eg, coal combustion) sources of exposure may help explain these differences. Finally, variations in the cardiovascular risk posed by PM may also occur because of heterogeneity in the metric of exposure, such as personal versus background regional,[25] indoor versus outdoor sources, and differences in intracity versus intercity gradients.[69] A better understanding of the responsible constituents and sources is important and could potentially lead to more targeted and effective regulations. On the other hand, finding continued evidence that the adverse cardiovascular health effects cannot be linked conclusively to a particular or specific chemical species or source of pollution but rather that they occur in response to a variety of exposure types or mixtures would support the present-day policy of reducing exposure to overall fine particulate mass to achieve public health benefits.

Time Course and Concentration-Response Relationships

Many studies have demonstrated that PM air pollution exposure does not simply advance the mortality by a few days of critically ill individuals who would have otherwise died (eg, mortality displacement or "harvesting").[278,279] There also appears to be a monotonic (eg, linear or log-linear) concentration-response relationship between $PM_{2.5}$ and mor-

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

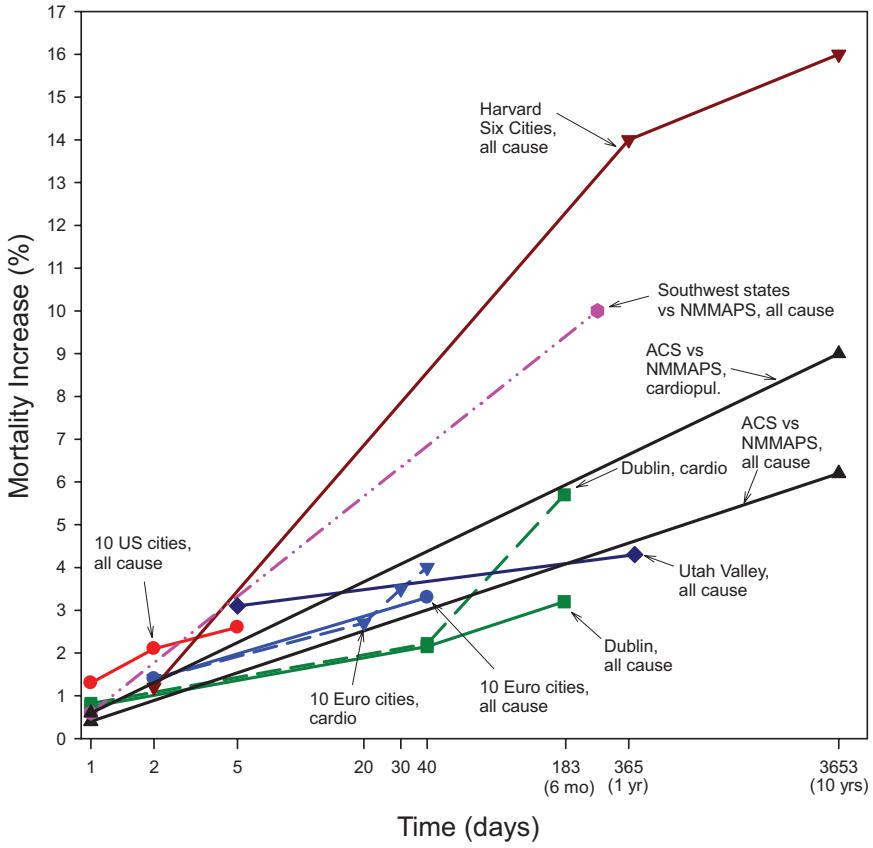


Figure 2. Comparison of estimates of percent change in mortality risk associated with an increment of 10 $\mu g/m^3$ in $PM_{2.5}$ or 20 $\mu g/m^3$ of PM_{10} or British Smoke (BS) for different time scales of exposure (log scale of approximate number of days, updated and adapted from Pope[281a]). Euro indicates European; cardio, cardiovascular disease; and cardiopul, cardiopulmonary.

tality risk observed in cohort studies that extends below present-day regulations of 15 $\mu g/m^3$ for mean annual levels, without a discernable "safe" threshold.[67,70,84] Cardiovascular risk due to particle exposure was also shown to extend below 15 $\mu g/m^3$ in the recent analysis of the Women's Health Initiative Observational Study.[72] This monotonic association supports the idea that any reduction in particulate pollution will translate into health benefits within a population of people, each with their own individual level of susceptibility. It also suggests that a larger decrease in $PM_{2.5}$ exposures will produce a greater reduction in mortality. Finally, a recent analysis of the literature provided important new insights into the nature of the PM exposure-response relationship.[280] The risk for cardiovascular mortality was shown to increase in a linear fashion across a logarithmically increasing dosage of inhaled fine-particle levels that ranged from ambient PM air pollution (≈0.2 mg/d), through secondhand smoke (≈1 mg/d), to active smoking (200 mg/d). This means that the exposure response is extremely steep at very low PM levels (ie, ambient air pollution) and flattens out at higher concentrations (ie, active smoking). This may help explain the seemingly incongruent and comparatively very high degree of cardiovascular risk posed by the much lower levels of PM exposure from ambient pollution and secondhand smoke versus the much higher doses due to active smoking. Thus, the cardiovascular system may be extremely sensitive to very low levels of PM inhalation as encountered with ambient pollution.

At present, the underlying nature and full scope of the temporal-risk relationship posed by longer-term PM exposures remain uncertain.[2,281] The writing group members did concur that the available epidemiological studies demonstrate larger cardiovascular risks posed by more prolonged exposures to higher PM levels than observed over only a few days (Figure 2). Cohort studies using Cox regression survival analyses (over months to years) are capable of evaluating a more complete portion of the temporal-risk relationship than time-series analyses over only a few days that use Poisson regression. However, given the lack of complete information, no conclusions could be drawn on the full magnitude of the augmented risk posed by chronic exposures, the time window (a few months versus decades) required to exhibit this enhanced risk, the underlying biological causes, the extent to which statistical differences between study types explain the variations in risk, and whether clinically relevant chronic CVDs are precipitated by chronic exposures. Some writing group members believe it is important to differentiate as 2 distinct issues the potentially greater effect of long-term exposures on increasing the risk for acute events (eg, cardiovascular mortality) compared with the putative effect on initiating or accelerating the development of chronic CVD processes per se (eg, coronary atherosclerosis). As such, it is possible that the greater risks observed in cohort studies could be capturing the fact that repetitive exposures over months or years augment the risk for sudden cardiovascular events in susceptible people, without actually worsening an underlying "chronic" disease process.

On the one hand, the available studies demonstrate that the majority of the larger risk-effect sizes posed by longer-term versus short-term exposures appear to be manifested within

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

only 1 to 2 years of follow-up. Extending the duration of follow-up increases cardiovascular risk, but to a progressively smaller degree over time (Figure 2). The discrepancy in the effect sizes among study types (eg, cohort versus time-series studies) could also reflect differences in statistical methodologies or population susceptibilities.[282–284] Recent attempts to investigate this matter[64,84] suggest that the risk for acute events associated with chronic exposures may be reasonably well estimated by only the most proximal 1 to 2 years of PM levels. The most recent time frames of exposure also explain a substantial portion of the excess cardiovascular risk observed in several cohort studies.[70,72,73,83] These findings bolster the argument that relatively rapid and pliable (and potentially reversible) biological responses, such as the instigation of plaque instability or the enhanced thrombotic potential caused by PM-mediated inflammation or endothelial dysfunction (which can occur and abate over only a few weeks to months), could explain the biology responsible for this greater relative risk.

On the other hand, cogent alternative arguments can be made to explain the differences in relative risk between the cohort and time-series studies. The likely high correlation of a recent year's exposure levels with exposures over many years, as well as the uniform rank ordering of exposure severity over time among cities, can explain why only a short period of PM exposure assessment is required to understand the risk of longer-term exposures. In addition, no studies have evaluated the potential risks of exposure over decades or a lifetime. PM augments the ability of traditional risk factors to accelerate the development of atherosclerosis in experimental settings. As such, it is also plausible that long-term exposures may enhance cardiovascular risk to an even greater extent by increasing an individual's susceptibility for future cardiovascular events or acute exposures. In addition, the full extent of this possibility may not be illustrated by the limited follow-up period (4 to 5 years) of the majority of cohort studies. The writing group thus agreed that this important issue requires more investigation.

It is also possible that these 2 explanations are not mutually exclusive. Furthermore, it cannot be concluded from available information that a long period of time is required for reductions in PM levels to translate into a decrease in cardiovascular risk. On the contrary, reductions in secondhand smoke[285] and PM air pollution levels[64,84,90,95] appear to produce fairly rapid decreases in cardiovascular event rates, within a few months to years.[284] At present, the available data do not allow for firm conclusions regarding the underlying biology and the full extent of the potentially nonuniform PM exposure–to–cardiovascular risk temporal relationship.

Susceptibility to Air Pollution Exposure

Susceptibility refers to a heightened risk for a particular cardiovascular end point or event to occur compared with the general population at the same concentration of PM exposure. Typically, this is indicative of an underlying medical condition (eg, diabetes) or personal characteristic (eg, old age) that causes this enhanced risk. This is in contrast to the term "vulnerability," which refers to a population of individuals at greater risk for more frequent or high levels of exposures.

Earlier studies reviewed in the first AHA scientific statement[1] suggested that susceptible populations include the elderly; individuals with diabetes; patients with preexisting coronary heart disease, chronic lung disease, or heart failure; and individuals with low education or socioeconomic status. In the ACS study, current and previous smokers appeared to be at the same or greater degree of risk.[67] Among more recent studies, the Women's Health Initiative also reported positive findings among active smokers and an elevated risk for cardiovascular mortality induced by $PM_{2.5}$.[72] Conversely, current smokers were found to be at no increased risk for cardiovascular mortality in response to $PM_{2.5}$ exposure in the Nurses' Health Study.[73] Thus, the effect modification of smoking status requires more investigation. The APHENA study of European and North American cities recently confirmed that elderly and unemployed individuals are at higher risk of short-term PM exposure.[61] In a multicity time-series study in Asia, women, the elderly, and individuals with lower education and socioeconomic status were also shown to be at elevated risk.[286] A few additional studies have reported some evidence of susceptibility to short-term PM exposures among older individuals, people with diabetes, and those with a lower level of education.[287–289] Finally, a recent study illustrated that present-day levels of $PM_{2.5}$ likely increase the risk for a cardiac event within a few days of exposure principally (or even solely) among individuals with preexisting significant coronary artery disease, even if they are seemingly healthy (eg, without anginal symptoms). Patients without obstructive lesions on heart catheterization were not at any risk for $PM_{2.5}$-induced myocardial events over the short term.[13] This is not surprising, because most acute cardiovascular events occur among individuals with underlying vulnerable substrate (eg, unstable plaques) and not in individuals with normal coronary arteries.

Obesity has been newly recognized as a possible susceptibility factor. Two cohort studies have shown that a greater body mass index enhances the susceptibility for PM-induced cardiovascular mortality, at least among women.[72,73] Although individuals with diabetes showed a trend toward greater risk in the Women's Health Initiative,[72] hypertension, high cholesterol, smoking, elderly age, education, and income did not alter the risk association. Overall, there appears to be little effect modification by race, hypercholesterolemia, or BP among the studies. Finally, sex may also be a risk-effect modifier. The particularly robust risk estimates of the 2 cohort studies that included only women,[72,73] the fact that PM increased cardiovascular risk in female but not male participants of the AHSMOG study,[75] and the multicity time-series findings in Asia[286] suggest that women may be at greater risk for cardiovascular mortality related to PM. Further studies are needed to clarify whether obese individuals and women are indeed susceptible populations.

Biological Mechanisms

There has been substantial improvement in our understanding of the biological mechanisms involved in PM-mediated

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

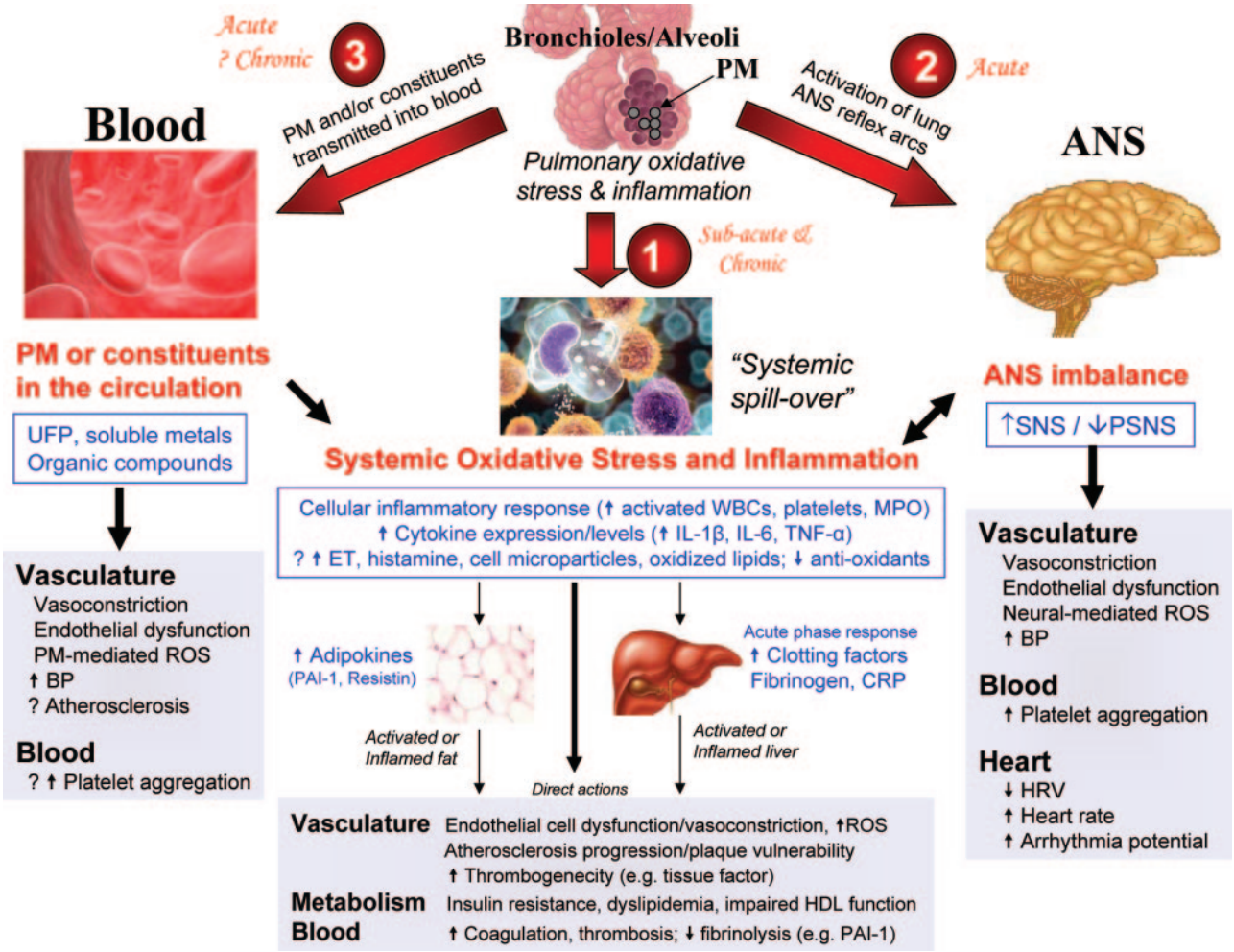


Figure 3. Biological pathways linking PM exposure with CVDs. The 3 generalized intermediary pathways and the subsequent specific biological responses that could be capable of instigating cardiovascular events are shown. MPO indicates myeloperoxidase; PAI, plasminogen activator inhibitor; PSNS, parasympathetic nervous system; SNS, sympathetic nervous system; and WBCs, white blood cells. A question mark (?) indicates a pathway/mechanism with weak or mixed evidence or a mechanism of likely yet primarily theoretical existence based on the literature.

cardiovascular effects. Studies before 2004 were reviewed previously,[1] and only some are again discussed here for contextual background. A number of new experiments have demonstrated very rapid effects of air pollution, such as vascular dysfunction, which argues for the existence of pathways that convey signals systemically within hours of PM inhalation. On the other hand, there is also support for chronic biological effects, such as the promotion of atherosclerosis. At the molecular level, persuasive evidence supports an integral role for ROS-dependent pathways at multiple stages, such as in the instigation of pulmonary oxidative stress, systemic proinflammatory responses, vascular dysfunction, and atherosclerosis. In sum, new studies continue to support the idea that inhalation of PM can instigate extrapulmonary effects on the cardiovascular system by 3 general "intermediary" pathways. These include pathway 1, the release of proinflammatory mediators (eg, cytokines, activated immune cells, or platelets) or vasculoactive molecules (eg, ET, possibly histamine, or microparticles) from lung-based cells; pathway 2, perturbation of systemic ANS balance or heart rhythm by particle interactions with lung receptors or nerves; and pathway 3, potentially the translocation of PM (ie, UFPs) or particle constituents (organic compounds, metals) into the systemic circulation (Figure 3).

Exposure Considerations

Animal and human exposure studies are discussed separately and apart from the effect of ambient PM because their methodologies and clinical relevancies vary widely. Controlled exposure studies involve exposing a subject to various size fractions of PM within a chamber connected to ambient air (concentrated or nonconcentrated) or a source of aerosolized particles. Virtual impactor systems that deliver concentrated ambient particles (CAPs) from "real-world" ambient air are a commonly used approach for mimicking exposures to higher levels of ambient particles without requiring invasive methods or the generation of artificial particles.[3] Both a strength and limitation, however, is that CAPs can vary considerably from day to day in composition. Additionally, only certain particle size ranges are typically concentrated (eg, PM from 0.1 to 2.5 μm in the fine-CAP system), whereas

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

ambient air contains a mixture of particle sizes, volatile organics, and gases that are not concentrated (and can be lowered). Potential interactions between PM and gaseous copollutants on health end points are therefore excluded, unless the latter are reintroduced in an artificial fashion. Other methods of controlled-inhalation exposures include diesel engine exhaust (diluted and aged mixtures of high numbers of fresh combustion UFPs with vapor-phase components), roadside aerosols, and wood-burning sources. Regarding animal exposures, intratracheal instillation methods may sometimes be required because of the limited availability of inhalation exposure systems. Unfortunately, particle size and surface characteristics—mostly retained in inhalation systems with fresh sources of pollution and which may be important in influencing biological effects—are likely significantly altered in instillation systems or by methods that use previously collected particulate. However, the use of carefully modeled exposures (eg, deposition calculation) and the recognition that areas of "hot spots" containing markedly higher PM levels within the lung may occur even during normal inhalation make the results of these experiments potentially relevant.[2] Further detailed discussions of exposure considerations are reviewed elsewhere.[290]

The protocol details vary considerably among the studies. Many aspects of exposure, including the duration, concentration, PM size ranges and composition, and gaseous copollutants, are important to consider. A wide variety of outcomes may be anticipated depending on the biological pathways evoked by differing exposures. Moreover, there are multiple determinants of the subsequent physiological responses, including the time frames of investigation, preexisting susceptibility, animal models, and the details of the outcomes investigated. All of these factors may explain some of the heterogeneity in the reported study results and must be taken into consideration when interpreting the findings.

Animal Exposure and Toxicological Studies

Studies that investigate the effects of exposure on susceptible animals (eg, those with preexisting cardiovascular or metabolic abnormalities) may be preferable in many circumstances because of the increasing recognition that the pathways underlying the biological effects of PM overlap (ie, modify and/or enhance) those of conventional cardiovascular risk factors. Such factors (eg, hypertension or atherosclerosis) may also be necessary or at least responsible for the evocation of a more readily observable or robust response. For example, in the context of systemic oxidative stress or inflammation, the cellular machinery for the generation of excess ROS and proinflammatory responses (eg, adhesion molecule and cytokine expression) is already primed or operational in susceptible animals.

Pulmonary Oxidative Stress and Inflammation

The molecular events responsible for triggering pulmonary oxidative stress and inflammation, along with the interactions between lung and immune cells, the inhaled PM, and the protective secretions (eg, surfactant, proteins, and antioxidants), are highly complex,[4–6] as reviewed in detail elsewhere.[290a,290b,414] In brief, size, charge, solubility, aggregation, ROS-producing potential, and chemistry play roles in determining the responses. These include the particle fate (eg, lung clearance versus retention rates), the nature of the PM-cell interactions (eg, immune versus lung cell uptake, host cell responses, and intracellular sequestration/location), and the dose (likely typically a small percentage of inhaled PM) and pathways of potential systemic transmission of PM or its constituents, such as in the circulation [free, intracellular within circulating cells, (lipo)protein-bound] or via lymphatic spread.[4,5,290a,290b] Because of their nano-scale size, UFPs may directly enter multiple lung cell types via nonphagocytic pathways and adversely affect organelles, such as mitochondria.[6,290a,290b] Larger unopsonized fine particles are more typically taken up by phagocytes through interactions with innate immunity receptors such as MARCO (macrophage receptor with collagenous structure) or other scavenger receptors.[5,290a,290b] This may in fact be a protective mechanism that sometimes prevents harmful lung inflammation. Certain particle compounds may directly generate ROS in vivo because of their surface chemistry (eg, metals, organic compounds, and semiquinones) or after bioactivation by cytochrome P450 systems (eg, polycyclic aromatic hydrocarbon conversion to quinones).[6,290a,290b] A particle surface or anions present on otherwise more inert particles may disrupt iron homeostasis in the lung and thereby also generate ROS via Fenton reactions.[291] Other PM constituents may do so indirectly by the upregulation of endogenous cellular sources (eg, nicotinamide adenine dinucleotide phosphate [NADPH]) oxidase)[292,293] or by perturbing organelle function (eg, mitochondria) by taken-up PM components.[261] Particle stimulation of irritant and afferent ANS fibers may also play a role in local and systemic oxidative stress formation.[294] Given the rich antioxidant defenses in the lung fluid, secondarily generated oxidization products of endogenous molecules (eg, oxidized phospholipids, proteins) or a reduction in endogenous antioxidants per se may be responsible at least in part for the state of oxidative stress in the lungs (along with instigating the subsequent cellular responses) rather than ROS derived directly from PM and its constituents.

Subsequent to oxidative stress, antioxidant and phase II defenses may be activated (eg, inducible nitric oxide synthase, glutathione) via transcription factor Nrf2-dependent pathways.[261] When inadequate, pathological oxidative stress can initiate a variety of pulmonary inflammatory responses. For example, ROS in the lungs has been shown to augment the signal transduction of membrane ligand (eg, epidermal growth factor by disrupting phosphatases) or pattern-recognition receptors (eg, toll-like receptors [TLR])[295–299] and/or stimulate intracellular pathways (eg, mitogen-activated protein kinases) that lead to the activation of proinflammatory transcription factors (eg, nuclear factor-$\kappa\beta$) that upregulate expression of a variety of cytokines and chemokines.[261] Alteration in lung cell redox status may itself stimulate nuclear factor-$\kappa\beta$. Biological components within coarse PM could also directly trigger inflammation (eg, nuclear factor-$\kappa\beta$ pathways) by binding to TLR2 or TLR4 receptors or other innate immune pattern-recognition receptors.[297] It is also possible that other components of metal-rich

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

PM could instigate inflammatory pathways via TLR activation directly or via the oxidation of endogenous biological compounds that then serve as TLR ligands.[300] Finally, there is some evidence that PM can activate inflammatory mitogen-activated protein kinase signaling by angiotensin II receptor–dependent pathways.[295] These inflammatory responses can also exacerbate the initial oxidative stress [eg, via upregulation of cellular NAD(P)H oxidase] and thus initiate a positive-feedback cycle.

Available studies support important contributions to pulmonary inflammation from innate immune cells such as neutrophils and macrophages (TNF-α, IL-6), as well as from the adaptive immune system, such as T cells (IL-1, IL-4, IL-6, and IL-10). Although the dominant source of cytokines likely represents the alveolar macrophages and lung epithelial cells, the role of other innate and adaptive immune cells cannot be ruled out.[299,301,302] Recently, myeloperoxidase activity was shown to increase after PM exposure in the same time course of appearance of cellular inflammation (primarily neutrophils) in the lung.[303] Gaseous components such as ozone may also amplify the toxicity of PM.[304]

Systemic Inflammation

In the context of examining the cardiovascular effects of air pollution, it is important to consider the inflammatory mediators that are released from lung cells after contact with PM, because some could conceivably spill over to the general circulation or increase liver production of acute-phase proteins (eg, CRP, fibrinogen). An increase in circulating proinflammatory mediators (eg, activated immune cells, cytokines) could thus serve as a pathway to instigate adverse effects on the heart and vasculature. Numerous experiments have demonstrated increased cellular and inflammatory cytokine content, such as IL-6, IL-1β, TNF-α, interferon-γ, and IL-8, of bronchial fluid and sometimes in circulating blood after acute exposure to a variety of pollutants.[292,305–311]

Critical roles for the elevations in systemic and pulmonary levels of IL-6 and TNF-α have been observed after PM exposure, typically coincident with pulmonary inflammation.[292,302,306,309,311–314] There is at least some evidence that the degree of pulmonary inflammation and systemic inflammation (IL-6) correlates with the elevation of systemic cytokines and systemic vascular dysfunction.[314] In a 4-week inhalation exposure to freshly generated diesel exhaust, IL-6 knockout mice did not demonstrate increased cellular inflammation or TNF-α in bronchial fluid, which implies a role for IL-6.[315] Consistent with these findings, acute intratracheal exposure to PM_{10} resulted in an increase in IL-6, TNF-α, and interferon-γ in the bronchial fluid.[316] However, in this study, IL-6$^{-/-}$ mice showed roughly the same levels of TNF-α in bronchial fluid as wild-type mice, although interferon-γ was decreased to control values.[316] The results also suggested that lung macrophages play an important role, because depletion of these cells abolished the increases in some of the cytokines and systemic cardiovascular responses. Although our understanding of the source of IL-6 and TNF-α and their involvement in the systemic inflammatory response after PM exposure remains incomplete, these and other experiments appear to suggest that at least with PM_{10} particles, alveolar macrophages play a dominant role.[309,314,316]

Among remaining uncertainties, the upstream signaling pathway responsible for the recognition of PM components that in turn produce the systemic inflammation has not been fully elucidated[317]; however, there is some evidence with other particulates and experimental models of lung injury that ROS generated by NADPH oxidase or pattern-recognition receptors may modulate some of these responses.[292,299,318] NADPH-oxidase knockout mice demonstrated significantly lower IL-6 and macrophage inflammatory protein-2 responses to collected PM than wild-type mice.[292] Extrapulmonary sources may also be involved in promulgating the systemic inflammation. $PM_{2.5}$ exposure in a model of diet-induced obesity in C57Bl/6 mice for a duration of 24 weeks resulted in elevations in TNF-α and IL-6. In addition, there were increases in circulating adipokines, such as resistin and plasminogen activator inhibitor-1.[319] The elevation in cytokines, thought to be derived from adipose sources, in addition to findings of adipose inflammation in that study, raises the possibility of additional systemic nonpulmonary sources of such cytokines.

Systemic Oxidative Stress

Numerous in vitro studies have demonstrated activation of ROS-generating pathways by PM incubation, such as NADPH oxidases, mitochondrial sources, cytochrome P450 enzymes, and endothelial nitric oxide synthase in cultured cells or in pulmonary and vascular tissue.[293,311,320–329] Similar to inflammation, the oxidative stress after PM inhalation may not always stay confined within the lungs.[330] The sources of excess ROS within cardiovascular tissue may include circulating immune cells or cytokines, depletion of defense mechanisms (eg, impaired high-density lipoprotein function), oxidation of lipoproteins or other plasma constituents,[331] activation of ANS pathways,[294] or circulating PM constituents (eg, soluble metals, organic compounds) reaching the vasculature.[261] Activation of ROS-dependent pathways modulates diverse responses with far-reaching consequences, including vascular inflammation/activation, atherosclerosis, impaired basal vasomotor balance, enhanced coagulation/thrombosis, and platelet activation.[290b]

Recent experiments have indeed confirmed the existence of footprints or markers of oxidative stress within the cardiovascular system in the in vivo context. Acute-exposure studies[332] have shown a relationship between the vascular dysfunction in spinotrapezius microvessels and the release of myeloperoxidase from leukocytes into the vasculature within only hours after the pulmonary instillation of PM.[332] Interestingly, an insoluble particle (TiO_2) induced very similar effects. More long-term studies[333] have demonstrated that 10 weeks of exposure to $PM_{2.5}$ increased superoxide production in response to angiotensin II and resulted in upregulation of NAD(P)H oxidase subunits and depletion of tetrahydrobiopterin in the vasculature. These effects had functional consequences in terms of increases in systemic vascular resistance and BP. In another investigation that involved apolipoprotein E–deficient (ApoE$^{-/-}$) fed a high-fat diet, chronic exposure

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

to $PM_{2.5}$ exacerbated vascular oxidant stress and promoted atherosclerosis progression.[334] The proatherogenic effects of ambient UFPs[331] versus $PM_{2.5}$ in genetically susceptible $ApoE^{-/-}$ mice in a mobile facility close to a Los Angeles freeway have also been compared. Exposure to UFPs resulted in an inhibition of the antiinflammatory capacity of plasma high-density lipoprotein and greater systemic oxidative stress, as evidenced by increased hepatic malondialdehyde and upregulation of Nrf2-regulated antioxidant genes.[331]

Other experiments[294] have suggested that ANS imbalance may play an important role in PM-induced cardiac oxidative stress. Pharmacological inhibition of the ANS could significantly reduce chemiluminescence in the heart after exposure.[303] More recently, an upstream modulator, the transient receptor potential vanilloid receptor-1, within the lung was identified as central to the inhaled CAP-mediated induction of cardiac chemiluminescence.[335] In these studies, capsazepine was able to abrogate ECG alterations in rats during the 5-hour exposure, which suggests that neural ANS pathways are crucial.

Thrombosis and Coagulation

Earlier studies using intratracheal instillation of high concentrations of diesel exhaust particles demonstrated the induction of lung inflammation, platelet activation, and increased peripheral vascular thrombosis in both arteries and veins after photochemical injury.[336,337] Thrombosis susceptibility was ascribed to direct passage of the instilled UFPs in the blood, because large polystyrene particles unlikely to cross the lung-blood barrier did not increase peripheral thrombosis. In a subsequent study, a persistent increase in thrombosis susceptibility to diesel exhaust particles was shown after 24 hours, an effect that was mitigated by pretreatment with sodium cromoglycate, which indicates that this response was secondary to histamine release from basophil degranulation.[338] These same effects, however, were mimicked by 400-nm polystyrene particles with a low likelihood of transgressing the pulmonary barrier, which implicates pulmonary release of histamine as a mediator of thrombosis at the later time point. Because histamine was increased in the plasma at 6 and 24 hours after exposure, and diphenhydramine mitigated diesel PM–induced thrombosis at later time points but not at 1 hour, it was hypothesized that additional direct effects of PM constituents reaching the circulation may be responsible for the earliest prothrombotic effects.[339] No increase in circulating von Willebrand factor was observed after instillation of both particles. Finally, pulmonary instillation of carbon nanotubes produced neutrophil lung influx 24 hours later. Circulating platelet-leukocyte conjugates were elevated 6 hours after exposure, whereas procoagulant microvesicular tissue factor activity and peripheral thrombotic potential were increased 24 hours later. Inhibition of P-selectin abrogated these responses, which demonstrates that rapid activation of circulating platelets by the pulmonary deposition of PM plays a vital role.[340] This series of studies suggests that release of lung cell–derived mediators (eg, histamine) after several hours along with the more rapid activation of circulating platelets by lung inflammation via P-selectin–dependent processes may mediate distant system prothrombotic effects without necessarily inducing systemic endothelial damage.

In a study using C57BL/6J mice, intratracheal PM_{10} particles rich in transition metals decreased bleeding, prothrombin, and activated partial thromboplastin times and enhanced the levels of several coagulation factors as well as thrombosis times in response to experimental $FeCl_3$ injury.[316] This prothrombotic effect was mitigated in IL-$6^{-/-}$ and macrophage-depleted mice, which suggests that IL-6, lung macrophages, and pulmonary inflammation are necessary initial steps. It is possible, however, that coarse-particle components (eg, endotoxin) could have been important mechanistically via TLR activation. The effect of fine PM or UFPs per se requires more investigation. Chronic ambient exposure to $PM_{2.5}$ has also been shown to increase tissue factor expression in macrophages and smooth muscle cells in atherosclerotic lesions. Complementary in vitro studies with cultured human smooth muscle cells and monocytes demonstrate dose-dependent increases in tissue factor in response to collected ambient particles.[341] Other findings also support potential procoagulant and thrombotic effects of PM.[342,343] These collective studies suggest that both short- and long-term PM inhalation can enhance thrombotic and coagulation tendencies, potentially via increases in circulating histamine and inflammatory cytokines and/or activated white cells and platelets. The plausibility of these pathways is supported by the well-recognized cross talk between inflammation and thrombosis.[344] Potential additional roles for UFPs or soluble constituents that reach the circulation and directly enhance platelet aggregation or systemic oxidative stress (thus activating the endothelium and blunting platelet-derived nitric oxide) require more investigation.

Systemic and Pulmonary Hypertension

Early animal studies suggested small or inconsistent effects of PM on BP,[345–347] sometimes dependent on the season[348] of exposures. A potential explanation may be variations in experimental protocols, including differences in the delivery, duration, and composition of exposure and the methods used to measure BP. Moreover, PM by itself may represent a relatively weak stimulus but may act more robustly in concert with other predisposing factors to affect BP. Sun et al[333] recently demonstrated a significant interactive effect of fine-CAP exposure with the vasoconstrictor angiotensin II in rats. Preexposure to $PM_{2.5}$ for a 10-week period resulted in enhancement of its prohypertensive response measured continuously by intra-arterial radiotelemetry. The exaggerated BP elevation was accompanied by endothelial dysfunction, including blunted endothelium-dependent vasodilation and enhanced vasoconstrictor reactivity, along with upregulation of NAPDH oxidase and Rho-kinase–signaling pathways. In vitro exposure to UFPs and $PM_{2.5}$ was also associated with an increase in Rho-kinase activity, phosphorylation of myosin light chain, and myosin phosphatase target subunit. Pretreatment with the nonspecific antioxidant *N*-acetylcysteine and Rho-kinase inhibitors prevented these responses, which suggests an ROS-mediated mechanism for particle-mediated effects on vascular smooth muscle constriction. Further

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

studies corroborated the role of exaggerated Rho-kinase pathway activity in potentiating the hypertensive response to angiotensin II in mice exposed to $PM_{2.5}$.[349] Moreover, particle exposure augmented angiotensin-mediated cardiac hypertrophy and collagen deposition. Blockade of Rho-kinase abolished these effects. These responses suggest that chronic $PM_{2.5}$ exposure disrupts normal vascular homeostasis and vasoactive mediator balance through ROS-dependent mechanisms in a manner that sensitizes the vessel toward vasoconstrictors. Activation of RhoA/Rho-kinase signaling pathways appears to play an important mechanistic role.

In conscious canines with implanted BP catheters, systemic arterial BP increased and baroreceptor sensitivity was rapidly altered over a few hours during CAP exposure.[350] Interestingly, α-adrenergic antagonism abrogated the responses. The findings support a mechanistic role for acute activation of the sympathetic nervous system by inhaled particles. In a study with Wistar-Kyoto male rats, CAP exposure for 4 days upregulated ET-A receptor expression in the heart. This alteration was also weakly correlated with an increase in BP, which suggests a role for enhance ET activity.[351] PM has also been demonstrated to alter the release of ET-1 and ET-3 from the lungs.[352] Elevation in pulmonary vascular resistance and pulmonary arterial pressure, which suggests constriction of the pulmonary vessels, has also been demonstrated in response to respirable carbon black particles.[353] Recently, ultrafine carbon particles were shown to increase BP in spontaneously hypertensive rats 1 to 3 days after a 24-hour exposure.[354] This response occurred concomitant with increased ET-1 messenger ribonucleic acid levels in lung tissue and small elevations in plasma renin concentration and angiotensin I and II in the systemic circulation. These findings further support the idea that ET may play a role in cardiovascular responses to PM exposure and suggest that activation of the renin-angiotensin system may also be involved. It is not clear whether the elevated circulating ET levels reflect increased release from the lungs and whether this mediates a systemic vasoconstrictor response. Alternatively, the increase may be more indicative of enhanced vascular tissue activity of these systems. Longer-term exposures of carbon black for 4 weeks in Sprague-Dawley rats has also been shown to significantly increase systolic BP concomitant with increases in serum levels of IL-6 and CRP.[355]

Finally, in vitro exposure to soluble and insoluble components of UFPs induces constriction in isolated pulmonary arterial rings and activates intracellular signaling pathways such as phosphorylation of extracellular signal–regulated kinase-1/2 and p38 mitogen-activated protein kinase in pulmonary endothelial cells. These effects were antagonized by losartan, and several metal components (copper and zinc) could replicate the responses.[295] This suggests a possible role for activation of angiotensin II receptor pathways relevant for the maintenance of vasomotor tone and smooth muscle constriction after inhalation of metal constituents within PM.

In sum, the studies demonstrate that long-term PM exposures over a period of weeks are capable of enhancing vasoconstrictive responsiveness of the vasculature (eg, increased Rho-kinase activity and reduced nitric oxide bioavailability) by inflammatory and ROS-dependent cell-signaling pathways. Shorter-term exposures over several hours to days may lead to vasoconstriction and increased pulmonary and systemic BP by pathways dependent on enhanced ET or angiotensin II signaling. Lung cells may release ET into the systemic circulation and thus increase its systemic activity, or the vascular ET system may be relatively upregulated because of increased ROS or reduced nitric oxide. Activation of the renin-angiotensin system may also occur because of systemic oxidative stress or inflammation or as a consequence of ANS imbalance. The very acute increase in BP that occurs concomitant with the inhalation of particles or within only minutes to hours after exposure appears to be mediated by autonomic imbalance that favors a relative activation of the sympathetic nervous system. No study has evaluated the effect of air pollution on renal sodium handling or long-term pressure natriuresis mechanisms, which are fundamental to the generation of chronic hypertension.

Vascular Dysfunction and Atherosclerosis

Many early experiments demonstrated the capacity of PM constituents to blunt nitric oxide–dependent dilation and enhance vasoconstrictor tone in ex vivo vascular studies because of excess ROS formation.[1] The first in vivo experiment demonstrated the proatherosclerotic actions of intratracheal PM_{10} instillation.[356] More recently, the pulmonary instillation of several different PM types was shown to rapidly impair microvascular endothelium-dependent vasodilation within days, likely by proinflammatory or ROS-dependent mechanisms (eg, myeloperoxidase).[332] Several animal studies have now demonstrated that long-term exposure to ambient $PM_{2.5}$, by use of ambient-exposure facilities without direct pulmonary instillation, not only causes endothelial dysfunction but also accelerates the progression of atherosclerosis. Sun et al[334] demonstrated that exposure of atherosclerosis-prone $ApoE^{-/-}$ mice to environmentally relevant levels of CAP, derived from regional northeastern $PM_{2.5}$, for 6 months in conjunction with a high-fat chow diet potentiated plaque development and heightened vascular inflammation (CD68+ macrophage infiltration and inducible nitric oxide synthase expression) and oxidant stress. The atherosclerotic plaque progression was also accompanied by alterations in vasomotor tone, including decreased endothelium-dependent vasodilation and heightened vasoconstriction to adrenergic stimuli. Importantly, the normalized average $PM_{2.5}$ concentration over the entire period was 15.2 $\mu g/m^3$, which approximates the annual NAAQS. Similar findings were reported in other chronic CAP exposures that involved an $ApoE^{-/-}$ model.[357] However, exposures to a double-knockout model of ApoE-deficient and low-density lipoprotein receptor–deficient mice increased plaque cellularity, reflective of inflammation, but did not enhance plaque burden. It is possible that the atherosclerotic severity of this phenotype precluded the observation of more subtle effects of CAP exposures.

Intratracheal instillation of UFP can acutely impair aortic endothelium-dependent vasodilation.[358] Moreover, repeated 10-week-long endotracheal dispersion of UFP carbon black increased atherosclerosis in low-density lipoprotein receptor–

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

knockout mice.[359] This occurred without evidence of systemic translocation of particles into the cardiovascular tissues. UFP inhalation by use of exposure facilities has also recently been shown to augment atherosclerosis, perhaps to a greater degree than $PM_{2.5}$. When investigating the effects of different PM size fractions, Araujo et al[331] compared the proatherogenic potential of exposure over 40 days to ambient particles <0.18 μm versus $PM_{2.5}$ in $ApoE^{-/-}$ mice. UFPs caused more adverse cardiovascular responses (eg, systemic oxidative stress, impaired high-density lipoprotein function) and greater potency in accelerating atherosclerotic lesion formation, although $PM_{2.5}$ did demonstrate qualitatively similar effects. Recent studies have also demonstrated that PM exposure likely promulgates systemic atherosclerosis by mechanisms that overlap those of other conventional cardiovascular risk factors.[360] Intratracheal instillation of PM_{10} particles caused a rapid impairment in endothelium-dependent vasodilation, stimulation of bone marrow–derived cells, and increased migration of monocytes into atherosclerotic plaques.[361,362] Systemic inflammation (IL-6) was also related to the degree of endothelial dysfunction.[314] Finally, the most compelling evidence for rapid impairment in nitric oxide bioavailability being directly involved in the origin of PM-induced endothelial dysfunction was demonstrated recently. Both fine-PM and UFM inhalation for only a few hours in normal rats blunted agonist-stimulated nitric oxide production within the microvasculature, measured by direct electrochemical sensors, concomitant with an observed impairment in vasomotor relaxation. Inhibition of myeloperoxidase or NADP(H) oxidase partially restored normal nitric oxide bioavailability and endothelial function, which suggests a role of activation of these endogenous radical-generating enzymes in this biological response.[363]

Potentially relevant adverse vascular effects of nonparticulate PM components should not be discounted. There may also exist some synergy between vapor phase, gas, and particle constituents in relation to instigation of cardiovascular responses. Recently,[364] it was demonstrated in $apoE^{-/-}$ mice that whole gasoline engine exhaust over 1 or 7 days increased vascular messenger ribonucleic acid expression of matrix metalloproteinase (MMP)-2 and MMP-9. Levels of ET-1 and ROS were similarly increased. The vascular ROS and MMP-2 elevations were attenuated by tempol. Endothelial receptor antagonism ameliorated the vascular expression of MMP-2, MMP-9, and ROS. In separate experiments, diesel exhaust exposure to rats for 5 hours augmented ET-induced vasoconstriction, potentially via a blunting of ET-B–induced nitric oxide release.[365] The findings suggest that exposure to a fresh mixture of PM, gases, and vapors may play a role in rapidly triggering atherosclerotic plaque vulnerability via ROS and ET-dependent upregulation of MMP levels.

Some studies suggest that predisposed animals may be more susceptible to air pollution–mediated vascular dysfunction. Diesel exhaust particles delivered by intraperitoneal injection impaired nitric oxide–dependent vasodilation only in $apoE^{-/-}$ mice with atherosclerosis and not in healthy control animals.[366] Aortas from prediabetic rats were found to be more susceptible to repeated exposures to oil combustion particles in causing noradrenergic-mediated constriction and impaired endothelium-dependent vasodilation.[367]

Taken together, the available studies suggest that short- and long-term particle exposures (including PM_{10}, $PM_{2.5}$, and UFP) can impair conduit and resistance arterial endothelium-dependent vasodilation. Chronic exposures have been shown to be capable of promoting atherosclerosis progression and enhancing plaque vulnerability. The underlying mechanisms likely involve vascular sequelae of systemic inflammation (due to interactions with innate immune cells and cytokines) or exaggerated oxidative stress pathways. Excess vascular ROS and inflammation will impair endogenous vasodilator bioavailability (eg, nitric oxide), enhance vasoconstrictor tone (eg, ET), and chronically activate multiple intracellular pathways that promote atherosclerosis.[368–370]

Heart Rate Variability

Some of the earliest indications of systemic effects of PM came from ECG studies in rats.[371] In general, reductions in several measures of HRV have been shown.[372–376] Most of the recent research has focused on exploring the roles of susceptibility and exposure characteristics. Decreases in heart rate and HRV indices have been reported to be pronounced in senescent mice, which indicates that aging may be a susceptibility factor.[353] Using an anesthetized model of postinfarction myocardium sensitivity, Wellenius and colleagues[377] did not demonstrate an effect of 1 hour of CAP exposure on heart rate or spontaneous ventricular arrhythmias. In contrast, in a post-MI heart failure model in Sprague-Dawley rats, diesel exhaust emissions reduced HRV in both healthy and heart failure groups and increased the incidence of premature ventricular contractions. Studies in mice have also indicated a potential role for transition metals and nickel in HRV alterations[376] and provide initial clues on the PM components that could influence autonomic tone.[48]

Some beginning insight into the neural pathways involved has been reported recently. PM-induced ECG changes in rats were shown to be prevented by inhibiting the transient receptor potential vanilloid receptor in the lungs. This suggests that the relevant neural mechanism that leads to alterations in HRV or heart rhythm may be induced by activation of receptor-mediated autonomic reflexes in the lung.[335] Circulating particle constituents or inflammatory mediators interacting with myocardial ion channels or electrophysiology did not appear to be a pertinent mechanism, at least in these studies.[335] However, it is unknown whether similar mechanisms can account for the HRV changes observed in humans, and a more detailed understanding of the anatomic pathways involved is required. Finally, it remains unclear whether the changes in cardiac HRV are actually caused by or merely illustrate an underlying alteration in ANS balance. Experiments that clearly define the direct contribution of sympathetic and parasympathetic nervous system activities (eg, microneurography, norepinephrine spillover rates, or autonomic receptor or ganglionic blockade) are needed.

MI and Arrhythmia

PM exposure can increase experimental infarct size and potentiate myocardial ischemia and arrhythmias in experi-

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

mental MI models. Relatively high concentrations of intratracheal UFP instillation induced pulmonary inflammation and doubled MI size in mice.[358] Conscious dogs exposed to fine CAP for several days experienced greater ST-segment changes during transient coronary artery occlusion.[378] These studies suggested that particulate-related changes in myocardial blood flow may be responsible, a hypothesis recently supported by experiments in chronically instrumented dogs exposed to fine CAP before transient occlusion of the left anterior descending artery. PM exposure was associated with a small but significant decrease in total myocardial flow, especially in the ischemic zone, and increases in coronary vascular resistance without an alteration in rate-pressure product.[379] The abnormalities were inversely related to PM mass, particle number, and black carbon concentration.

Exposure to residual oil fly ash increases arrhythmia frequency in rats with preexisting premature ventricular complexes, which suggests that PM sensitizes ischemic myocardium to abnormal automaticity[372]; however, CAP had no effect in rats.[380] Nevertheless, the data suggest that PM exposure may potentially be capable increasing the sensitivity of the myocardium to ischemia, likely by impairing myocardial blood flow and perfusion. In theory, this could play a role in enhancing the propensity for ventricular arrhythmias.

Insulin Resistance

Recently, Sun et al[319] exposed C57BL/6 mice fed high-fat chow to fine CAP or filtered air for 24 weeks. Mice exposed to $PM_{2.5}$ exhibited marked worsening of whole-body insulin resistance, systemic inflammation (increased IL-6 and TNF-α), and higher levels of adipokines, such as resistin and plasminogen activator inhibitor-1. $PM_{2.5}$ increased visceral adiposity and inflammation ($F4/80^+$ cells), with stromal vascular cells expressing higher TNF-α and IL-6 and lower IL-10 levels. Exposure also induced insulin-signaling abnormalities and reduced phosphorylation of Akt and endothelial nitric oxide synthase in aortic tissue, accompanied by abnormalities in vascular relaxation to insulin. Additionally, there was evidence that $PM_{2.5}$ exaggerated adhesion of monocytes in mesenteric microvessels, culminating in accumulation in visceral adipose. These intriguing findings suggest that longer-term exposure to PM air pollution may promote the chronic development of insulin resistance, obesity, and the metabolic syndrome.

Controlled-Exposure Studies in Humans

Several new human exposure studies have been published, a few of which have even included patients with CVD or risk factors. Similar to the animal studies, large variations among the exposure protocols, measured outcomes, and subject susceptibilities likely explain much of the differences among findings and must be considered when interpreting the results.

Systemic Inflammation

Controlled human exposure studies have measured the effects on circulating inflammatory markers such as CRP, IL-6, and TNF-α. In many of these single-episode short-term exposures, no overt changes in plasma cytokine levels were observed after CAP[381–383] or diesel exhaust.[345,384–386] Similarly, CRP levels have not consistently been found to increase in the time frame and context of most of these studies.[313,384–386]

However, there have also been some positive findings. Increases in IL-6[313] and TNF-α 24 hours after exposure to diesel exhaust in healthy adults have been reported. High levels of ambient particles can stimulate the bone marrow to enhance the release of neutrophils, band cells, and monocytes into the circulation, which causes a cellular inflammatory response.[387,388] Some controlled-exposure studies corroborate the existence of a cellular proinflammatory response that manifests as increases in circulating white blood cell or immune cell counts. In 1 study, increased peripheral basophils in healthy older adults were noted 4 hours after a 2-hour exposure to fine CAP.[389] In a similar study, increased white blood cell counts were observed in healthy young adults 12 hours after exposure.[381] Recently, investigators observed an increased in total white blood cell and neutrophil levels immediately after a 2-hour exposure to CAP in downtown Toronto, Ontario, Canada.[390] Conversely, decreases in blood monocytes, basophils, eosinophils, and CD54 and CD18 adhesion molecule expression on monocytes after exposure to ultrafine carbon (10 to 50 $\mu g/m^3$) among exercising asthmatic individuals and healthy adults have also been reported.[391] The authors suggested in the latter study that these results may represent the sequestration of these cells in tissue compartments such as the lung or vasculature, where there may be selective expression of the corresponding receptors for these ligands.[362] However, other recent human clinical studies have found no association between peripheral blood cell counts and exposure to fine PM or UFPs such as zinc oxide,[392] ultrafine carbon,[393] or diesel exhaust.[313,384,385]

More subtle, yet physiologically relevant or functional proinflammatory changes may be overlooked by the measurement of circulating cytokines or cell counts alone in human studies. Peretz et al[394] recently evaluated gene expression using an expression array in monocytes after 2 hours of exposure to diesel exhaust. Although initially a small study, 10 genes involved in the inflammatory response were modulated in response to exposure (8 upregulated, 2 downregulated). These findings will need to be reproduced in larger studies and raise the possibility that functional changes in inflammatory cells may occur without discernible changes in their levels in the peripheral circulation.[394]

In sum, the findings from controlled human exposures do not demonstrate a robust inflammatory response; however, they have been limited by the fact that they are, by necessity, of short duration and relatively low concentration. Additionally, the results do not preclude an effect of higher exposures, the presence of more subtle responses, or alterations in other cellular inflammatory pathways not measurable by circulating markers.

Systemic Oxidative Stress

The demonstration of systemic oxidative stress is difficult in human studies. Nonetheless, a few studies have reported positive findings. These include an increase in urinary excre-

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

tion of free 8-iso-prostaglandin-2α among healthy adults after a 4-hour exposure to concentrated wood smoke[395] and an increase in plasma antioxidant capacity 24 hours after a 1-hour exposure to diesel exhaust in a group of healthy volunteers.[313] The investigators speculated that systemic oxidative stress after exposure may have been responsible for this upregulation in antioxidant defense.[313] Other investigators[394] have observed significant differences in expression of genes involved in oxidative stress pathways due to diesel exhaust exposure. Bräuner et al[167] recently investigated the effect of ultrafine traffic particles on oxidative stress–induced damage to DNA in healthy young adults exposed to low concentrations of ambient urban particles ($PM_{2.5}$ and $PM_{10-2.5}$ mass of 9.7 and 12.6 $\mu g/m^3$, respectively) in an exposure chamber above a busy road with high traffic density. The authors observed increased levels of DNA strand breaks and formamidopyrimidine-DNA glycosylase sites in monocytes after exposure to PM but no changes in the DNA repair enzyme 7,8-dihydro-8-oxoguanine-DNA glycosylase. Similar to their previous findings with ambient levels,[168] the results suggest that short-term exposure to UFPs may result in damage to DNA. This may occur through oxidative stress pathways, although there was no increase in messenger ribonucleic acid levels in heme oxygenase-1, a gene known to be regulated by Nrf2, a transcription factor regulated by oxidative stress.[396] Moreover, more recent observations by the same investigators failed to demonstrate significant biomarker signals for lipid or protein oxidative damage after similar near-roadway exposures.[178] Although not entirely consistent, the available studies demonstrate that acute exposure to PM, perhaps even at ambient levels, may be capable of inducing acute systemic oxidative stress in human subjects under certain circumstances. The assays used to assess the footprint of systemic "oxidative stress" or damage may also play a significant role in the results.

Thrombosis and Coagulation

Several new studies of controlled human exposure have evaluated the effects of PM on hemostatic markers (eg, factor VII, fibrinogen, platelet count, D-dimer, and von Willebrand factor). Although some of these studies have not observed changes after acute exposures,[392] others have reported increases in fibrinogen levels at 8 to 24 hours after exposure to CAP.[381,397] Mills and colleagues[384,385] recently demonstrated a significant effect of diesel exhaust on fibrinolytic function in response to intermittent exercise both in healthy men and in men with coronary heart disease. In both groups of volunteers, bradykinin-induced release of tissue plasminogen activator was observed to decrease compared with filtered air at 6 hours after exposure to diesel exhaust. These perturbations in tissue plasminogen activator release did not persist 24 hours after exposure.[313] In a randomized, controlled crossover study involving "at-risk" metabolic syndrome patients, no changes in plasminogen activator inhibitor-1 were noted over a 24-hour duration; paradoxically, a decrease in von Willebrand factor was noted in this study.[398] In a similar experiment conducted in healthy adults, diesel exhaust had no effect on D-dimer, von Willebrand factor, CRP, or platelet counts compared with filtered air up to 22 hours after exposure.[386] Other investigators[395] recently evaluated the effect of wood smoke on markers of coagulation, inflammation, and lipid peroxidation in young healthy subjects. Serum amyloid A and the ratio of factor VIII to von Willebrand factor, an indicator of an increased risk of venous thromboembolism, were increased at 4 hours after exposure.[395] Samet et al[383] reported an association between various coagulation markers and exposure to ultrafine, fine, and thoracic coarse CAP among healthy young adults. Although exposure to coarse CAP did not result in significant changes in hemostatic variables, the overall trend suggested a prothrombotic effect. Exposure to UFPs increased D-dimer levels, whereas fine-CAP effects tended to increase fibrinogen, similar to previously reported findings.[381]

The measurement of blood levels of coagulation factors or biomarkers of thrombosis could potentially miss a relevant biological effect at the vascular wall. Recently, ex vivo thrombus formation was assessed by use of the Badimon chamber after controlled exposures to dilute diesel exhaust in healthy volunteers.[399] This protocol measures thrombus formation in native (nonanticoagulated) whole blood triggered by exposure to a physiologically relevant substrate, under flow conditions that mimic those found in diseased coronary arteries. It may therefore provide a superior estimate of actual in vivo conditions related to thrombosis potential. Interestingly, dilute diesel exhaust exposure increased thrombus formation within 2 hours, in association with increased platelet activation (ie, increased circulating platelet-monocyte aggregates and soluble CD40 ligand). Taken together, these new studies have provided additional evidence that short-term exposure to PM at near-ambient levels may have small yet potentially significant effects on hemostasis in humans. Whether direct interactions of circulating PM constituents with platelets, activation of platelets due to lung inflammation or secondary to elevated systemic cytokine levels, or an increase in procoagulant factors (eg, fibrinogen) as an acute-phase response to inflammation (or a combination of these pathways) is responsible warrants attention in future studies.

Arterial BP

Although several studies have evaluated the BP response to acute exposures, many inconsistencies in results have been reported.[400] This must be considered in the context that BP was not the primary outcome of interest in most studies, nor was it typically assessed with adequate sophistication. In one of the earliest studies, $PM_{2.5}$ increased systolic BP in healthy subjects but decreased it in asthmatic individuals.[401] Three other controlled studies did not report changes among healthy adults.[345,402,403] However, in a more detailed reanalysis of the changes in BP during the actual period of exposure to CAP plus ozone, Urch et al[404] found a significant increase in diastolic BP of 6 mm Hg. The magnitude of response was associated with the concentration of organic carbon within $PM_{2.5}$.[405] Recent follow-up studies redemonstrated an acute prohypertensive response during the inhalation of CAP in 2 separate cities.[390] The $PM_{2.5}$ mass during exposure and decreases in several HRV metrics were associated with the

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

magnitude of the short-lived diastolic BP elevation. This suggested that the most plausible mechanism for this acute response was CAP-induced ANS imbalance that favored sympathetic over parasympathetic cardiovascular tone. Whether this reaction occurred because of a generalized stress response, as a consequence of specific soluble PM constituents directly altering central nervous system activity, or via altered ANS reflex arcs due to the interaction of inhaled particles with lung receptors/nerve endings remains to be elucidated.

The effect of inhaled particulates on BP has also been investigated in several other recent controlled human exposure studies. Two new studies assessed BP changes after a 1-hour exposure to diesel exhaust. Mills et al[384] found a 6-mm Hg increase in diastolic BP 2 hours after exposure, which was of marginal statistical significance ($P=0.08$); however, this trend did not persist for 24 hours,[384] nor was it found among patients with coronary artery disease.[385] The available data to date suggest that short-term exposure to $PM_{2.5}$ or diesel exhaust is capable in certain circumstances of rapidly raising BP. The most consistent and largest effects were seen concomitant with the inhalation of particles. Thus far, the most likely mechanism for such rapid hemodynamic responses appears to be ANS imbalance. However, it is possible that reductions in nitric oxide bioavailability that modulate basal arterial tone toward vasoconstriction or increases in ET among other hemodynamically active molecules (eg, angiotensin II) also play a role in some circumstances.

Vascular Dysfunction

The first controlled human exposure study related to vascular function reported that CAP plus ozone exposure caused acute conduit arterial vasoconstriction in healthy adults.[1] Endothelium-dependent and -independent vasodilation remained intact. Recent follow-up experiments determined that $PM_{2.5}$, not ozone, was responsible for the adverse vascular effects. However, in these subsequent and larger experiments, fine-CAP exposure did prove capable of diminishing conduit artery endothelium-dependent vasodilation 24 hours (but not immediately) after exposure.[390] Postexposure $PM_{2.5}$ mass and TNF-α level were both associated with the degree of endothelial dysfunction, which suggests that systemic inflammation induced by higher levels of particles was likely responsible. Finally, the CAP-induced endothelial dysfunction occurred during exposures in Toronto, Canada, but not Ann Arbor, Mich, which suggests that the composition of the particles is probably an important determinant of the vascular responses.

An acute alteration in vascular function/tone after short-term controlled PM air pollution exposure was corroborated recently.[406] In 27 adults (10 healthy adults and 17 with the metabolic syndrome), a 2-hour exposure to dilute diesel exhaust caused a dose-dependent constriction of the brachial artery and elevation in plasma ET level without impairing endothelium-dependent vasodilation. Contrary to the hypothesis that metabolic syndrome patients would show greater effects, vasoconstriction was greater in magnitude among the healthy participants. In an additional study, 2-hour exposure to UFPs composed of elemental carbon impaired peak forearm blood flow response to ischemia 3.5 hours later. There were no other vascular changes or alterations at other time points. BP was also not affected.[407]

Several recent studies have also shown that dilute diesel exhaust can impair peripheral resistance vessel responses to acetylcholine, bradykinin, and nitroprusside 6 hours after exposure.[384] The blunted responses to acetylcholine persisted for 24 hours in healthy adults.[313] In contrast, bradykinin and sodium nitroprusside–mediated vasodilation and bradykinin-induced acute plasma tissue plasminogen activator release were not altered 24 hours later. In subsequent studies, patients with stable coronary artery disease exposed to dilute diesel exhaust for 1 hour during intermittent exercise demonstrated reduced bradykinin-mediated tissue plasminogen activator release; however, microvascular endothelial function was not impaired.[385] This may be related to some degree of preexisting endothelial dysfunction in these patients. However, exercise-induced ST-segment depression and ischemic burden were significantly greater during diesel compared with filtered air exposure. These important findings experimentally highlight that PM air pollution exposure can trigger, or augment existing, myocardial ischemia extremely rapidly (in fact, concomitant with exposure). Reduced coronary flow reserve (that was not observed or resolved at the time of the postexposure brachial artery studies) due to rapid alterations in coronary microvascular function may have contributed to the acute myocardial ischemia. Alternatively, acute ANS imbalance induced by diesel exhaust inhalation may have acutely altered coronary tone and impaired myocardial perfusion.

In a study that exposed healthy young adults to 100 $\mu g/m^3$ of diesel exhaust for 2 hours,[364] it was recently demonstrated that this air pollution mixture acutely raised plasma ET-1 and MMP-9 expression and activity within 30 minutes. These results corroborate the animal data that even short-term exposures can rapidly alter factors, such as MMP activity, that are mechanistically linked with causing atherosclerotic plaque disruption (and thus acute MI). The increase in ET levels also corroborates previous studies[406] that showed that diesel exhaust can acutely affect important endogenous regulators of vasomotor tone.

Controlled air pollution exposures have not always been shown to impair endothelial function or vasomotor tone. Despite an increase in exhaled 8-isoprostane concentrations that suggested pulmonary oxidative stress, fine CAP did not affect brachial flow–mediated dilation or basal diameter in northern Scotland exposures.[382] However, the $PM_{2.5}$ consisted of relatively inert ambient sea-salt particles and was extremely low in combustion-derived sources. This is in contrast to the particle chemistry in the investigators' previous diesel exposure studies that showed positive findings.[408,409] Moreover, 24-hour exposure to ambient pollution shunted into a chamber next to a busy street did not impair microvascular endothelial function in 29 healthy subjects, as assessed by digital tonometry.[178] This exposure to near-roadway ambient air, which consisted of ambient UFP and $PM_{2.5}$, did not alter biomarkers of inflammation, hemostasis,

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

or protein and lipid oxidation. The authors speculated that the relatively low concentrations of UFP numbers and PM mass or the young, healthy status of the subjects could explain the null findings. Taken together, these studies suggest that brief PM exposure can trigger conduit arterial vasoconstriction, possibly in relation to increased ET activity or augmented sympathetic ANS tone. Under certain circumstances, conduit and resistance arteriole endothelium-dependent vasodilation can also be impaired within a few hours. This abnormality is more likely due to reduced nitric oxide bioavailability as a consequence of systemic proinflammatory and oxidative responses; however, alternative mechanisms and endogenous vasoactive pathways have not been fully explored. It is also apparent that the composition, source, and concentration of pollution, along with the susceptibility of the human subjects, play important roles in determining the vascular effects of acute air pollution exposure.

Heart Rate Variability

The results of several new controlled human exposure studies provide limited evidence to suggest that acute exposure to near-ambient levels of PM may be associated with small changes in HRV. There are at least 4 studies to support this. In the first study, healthy elderly individuals experienced significant decreases in HRV immediately after exposure.[233] Some of these changes persisted for at least 24 hours. Gong et al[410] studied healthy and asthmatic adults exposed to coarse CAPs with intermittent exercise. HRV was not affected immediately after the exposure but decreased in both groups at 4 and 22 hours after the end of the exposure; greater responses were observed in nonasthmatic individuals.[410] In another study, healthy elderly subjects and patients with chronic obstructive pulmonary disease were exposed to approximately 200 $\mu g/m^3$ CAP and filtered air for 2 hours with intermittent mild exercise. HRV over multihour intervals was lower after CAP than after filtered air in healthy elderly subjects but not in subjects with lung disease. A significant negative effect of CAP on ectopic heartbeats during or after CAP exposure relative to filtered air was noted in the healthy subjects, whereas the group with pulmonary disease experienced an improvement during or after CAP relative to filtered air.[389] Other investigators recently compared the effects of 2-hour exposures with intermittent exercise to ultrafine (average concentration 47 $\mu g/m^3$), fine (average concentration 120 $\mu g/m^3$), and coarse (average concentration 89 $\mu g/m^3$) CAP among healthy subjects.[383] In both the ultrafine and coarse studies, a crossover design was used in which each subject was exposed to both PM and filtered air. In the case of the fine-PM study, subjects did not serve as their own control but were exposed to either PM or filtered air. Thoracic coarse fraction CAP produced a statistically significant decrease in the standard deviation of normal-to-normal heart rate 20 hours after exposure compared with filtered air. No statistically significant effects on HRV were observed after exposure to UFPs as measured during controlled 5-minute intervals. However, the authors did observe a significant decrease in the standard deviation of normal-to-normal heart rate after exposure to UFPs based on an analysis of the 24-hour measurements. No differences were reported in HRV with fine-PM exposures. Although some controlled-exposure studies have reported either no acute changes[390] or, on occasion, increases in HRV metrics in subsets of individuals,[208,393,401] these studies generally demonstrate that acute PM exposure is capable of reducing HRV. More consistent reductions have been found among older adults (compared with younger subjects or those with lung diseases, who show mixed responses) and perhaps with exposures to larger particles.[233,389] Whether pulmonary ANS reflex arcs are activated by the deposition of PM within the lung or whether other pathways are responsible for these physiological changes in human exposure studies requires more investigation.

Table 7. Summary of Level of Evidence Supporting Global Biological Pathways and Specific Mechanisms Whereby $PM_{2.5}$, Traffic-Related, or Combustion-Related Air Pollution Exposure Can Affect the Cardiovascular System

	Animal Studies	Human Studies
General "intermediary" pathways whereby PM inhalation can instigate extrapulmonary effects on the cardiovascular system		
Pathway 1: Instigation of systemic proinflammatory responses	↑ ↑ ↑	↑ ↑ ↑
Pathway 2: Alterations in systemic ANS balance/activity	↑	↑ ↑
Pathway 3: PM and/or associated constituents directly reaching the systemic circulation	↑	↑
Specific biological mechanisms directly responsible for triggering cardiovascular events		
Vascular dysfunction or vasoconstriction	↑ ↑ ↑	↑ ↑
Enhanced thrombosis or coagulation potential	↑ ↑	↑ ↑
Elevated arterial BP	↑ ↑	↑ ↑
Enhanced atherosclerosis or plaque vulnerability	↑ ↑	↑
Arrhythmias	↑	↑

The arrows are not indicators of the relative size of the association but represent a qualitative assessment based on the consensus of the writing group of the strength of the mechanistic evidence based on the number and/or quality, as well as the consistency, of the relevant studies.

↑ ↑ ↑ Indicates strong overall mechanistic evidence.

↑ ↑ Indicates moderate overall mechanistic evidence.

↑ Indicates some but limited or weak available mechanistic evidence.

Blank indicates lack of evidence.

Evidence Summary and Contextual Framework for Biological Mechanisms

Table 7 provides an outline of the level of evidence supporting the generalized intermediary pathways and specific mechanisms whereby PM exposures can be capable of eliciting

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

cardiovascular events. At the molecular level, oxidative stress as a critically important cause and consequence of PM-mediated cardiovascular effects has a sound experimental basis.[261,290b,294,319,333,334,345–349,351,361–364,411] At the integrated physiological level, the collective body of evidence continues to support the existence of 3 general pathways (Figure 3). Some of these responses, such as systemic inflammation (via pathway 1), likely require antecedent pulmonary oxidative stress or inflammation in order to be initiated. Others, including ANS imbalance (via pathway 2) and PM or its constituents reaching the systemic circulation (via pathway 3), may not. Although PM-associated metals[412] and certain UFPs[261,413–415] might be capable of translocating into the blood stream, some studies have been negative in this regard.[355,416] Many issues related to this pathway are controversial and require resolution.[416] These include the relevance of the dosages delivered to cardiovascular organs, the consequences of particle constituent modifications after interactions with lung tissue/fluids and plasma components, the means of transport within the circulation (eg, protein bound or within cells),[417] and the time course and ultimate sites of PM sequestration. It is also possible that increases in some vasoactive mediators or molecules with adverse effects on cardiovascular tissue, such as ET-1,[351–354] may occur in the lung and systemic circulation without the need for antecedent lung inflammation. Moreover, the 3 general pathways represent a simplification of complicated biological processes. They may not be mutually exclusive, may overlap temporally, and likely exhibit synergies in causing manifest cardiovascular disease events. Many of the biological pathways are also known to exhibit mutual interactions (eg, inflammation with thrombosis/coagulation and with autonomic function). The pathways are also likely to be principally active at differing time points (eg, more rapid cardiovascular effects of autonomic imbalance than systemic inflammation) and likely vary in importance in relation to different durations of exposure and in causing different cardiovascular sequelae. The chemical characteristics and sizes of inhaled PM may also determine the pathways activated. As opposed to UFPs or some particulate components or chemicals, larger fine and coarse PM are not likely transported into the circulation to any large degree and therefore are more apt to require intermediary pathways to cause extrapulmonary effects. It may also be that surface-bound components may be delivered into the circulation, whereas larger particles themselves serve as a means to deliver the responsible constituent into the pulmonary tree.

The hyperacute physiological responses that occur minutes to hours after PM inhalation are likely mediated principally via pathways 2 and 3. These include ANS-mediated changes (eg, elevated BP, arrhythmias, and vasoconstriction), along with direct effects of circulating PM constituents on platelets (eg, procoagulant and thrombotic changes) and the endothelium (eg, oxidative stress and vasoconstriction). These responses are liable to be the dominant mechanisms responsible for the actual triggering of acute cardiovascular events. Clinically meaningful effects undoubtedly become manifest only in the context of a susceptible patient, typified by the individual with "vulnerable plaque" in the case of acute coronary syndromes or strokes, "vulnerable myocardium" in the context of arrhythmias, or the "vulnerable circulation" in the context of a heart failure patient at risk for circulatory overload. On the other hand, the biological consequences of systemic inflammation, such as activated white cells and elevated cytokines (via pathway 1), typically require longer periods. Their penultimate effect is the induction of a chronic underlying vulnerable milieu that leads to atherosclerotic plaque vulnerability, enhanced coagulation/thrombotic and arrhythmia potential, and impaired basal vasomotor balance. These actions thereby predispose individuals for future cardiovascular events, particularly when they occur in conjunction with traditional risk factors or prompt susceptibility to the acute biological actions (via pathways 2 and 3) of later air pollution exposures.

This hypothetical segregation of the biological effects of PM exposure as acute or chronic and into the broad pathways is artificial. It is useful in the broad context of understanding potential pathways; however, there is no doubt a large degree of overlap among the mechanisms and the timing of physiological responses. This is most aptly conveyed as the influence of "acute on chronic" actions of exposure. For example, the activation of circulating platelets by the pulmonary deposition of particles or lung inflammation (eg, by P-selectin–dependent pathways, histamine, or IL-6) could occur within hours and more rapidly than typical of the other consequences of inflammation (eg, progression of atherosclerosis). In the presence of a vulnerable or eroded coronary plaque due to long-term air pollution exposure, this sudden prothrombotic tendency could instigate an acute ischemic event (alone or in conjunction with other effects of short-term PM exposure via pathways 2 and 3). Furthermore, the epidemiological cohort studies demonstrate a larger relative risk for increased cardiovascular-related mortality than for morbidity.[72,73,227,274] If this is a true biological response and not simply a statistical phenomenon or a shortcoming of the available data, it not only suggests that exposures are capable of triggering acute cardiovascular events but that PM air pollution may also exaggerate their severity even if they would have otherwise occurred for reasons unrelated to air pollution. Therefore, exposure to PM could also be responsible for promoting fatal over nonfatal events.

Conclusions and Recommendations

A wide array of new studies that range from epidemiology to molecular and toxicological experiments have provided additional persuasive evidence that present-day levels of air pollutants contribute to cardiovascular morbidity and mortality. Although not unexpected given the numerous and heterogeneous nature of the published studies, all findings related to every single cardiovascular end point have not been consistent. However, the overall weight of scientific evidence now supports several new conclusions since the 2004 statement. These consensus points are given below by the AHA writing group after considering the strength, consistency, and coherence of the epidemiological findings, as well as in the context of evaluating the extent of the studies that provided related mechanistic support.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

- The preponderance of findings indicate that short-term exposure to $PM_{2.5}$ over a period of a few hours to weeks can trigger CVD-related mortality and nonfatal events, including myocardial ischemia and MIs, heart failure, arrhythmias, and strokes.
- The increase in risk for acute $PM_{2.5}$-associated cardiovascular morbidity and mortality is principally among susceptible, but not necessarily critically ill, individuals. Several studies suggest that susceptible individuals at greater risk may include the elderly, patients with preexisting coronary artery disease, and perhaps those with diabetes. Recent data suggest that women and obese individuals might also be at higher risk.
- Most studies support the idea that longer-term $PM_{2.5}$ exposures increase the risk for cardiovascular mortality to an even greater extent than short-term exposures. Because most studies have focused on mortality data, the effect of long-term exposures on nonfatal cardiovascular events is less consistent and requires more investigation.
- The $PM_{2.5}$ concentration–cardiovascular risk relationships for both short- and long-term exposures appear to be monotonic, extending below 15 $\mu g/m^3$ (the 2006 annual NAAQS level) without a discernable "safe" threshold.
- Long-term exposure to elevated concentrations of ambient $PM_{2.5}$ at levels encountered in the present-day environment (ie, any increase by 10 $\mu g/m^3$) reduces life expectancy within a population probably by several months to a few years. Given that $PM_{2.5}$ is most strongly associated with cardiovascular deaths in the cohort studies, the reduced life expectancy is most likely predominantly due to excess cardiovascular mortality.
- The available studies are suggestive that reductions in PM levels decrease cardiovascular mortality within a time frame as short as a few years.
- Many potential biological mechanisms exist whereby PM exposure could exacerbate existing CVDs and trigger acute cardiovascular events (over the short term) and instigate or accelerate chronic CVDs (over the long run). Experimental support is increasingly strong for several mechanisms, which lends biological plausibility for the epidemiological findings.
- The existing evidence suggests that PM air pollution is capable of augmenting the development and progression of atherosclerosis. There is some support for a potential effect on several other chronic CVDs, including hypertension, heart failure, and diabetes.
- Most recent studies support the conclusion that the overall absolute risk for mortality due to PM exposure is greater for cardiovascular than pulmonary diseases after both short- and long-term exposures.

There are several additional areas worthy of highlighting in which the study results are reasonably consistent but in which the writing group believed further research was required to formulate firm conclusions.

- Although there is only limited epidemiological evidence directly linking UFPs with cardiovascular health problems,[262] the toxicological and experimental exposure evidence is suggestive that this size fraction may pose a particularly high risk to the cardiovascular system. The likelihood of health effects and the causal pathways mediated specifically by UFP exposure have been debated among experts recently.[418] Future research may help to more fully elucidate whether particles within the ultrafine size range (0.001 to 0.1 μm) and/or their constituents are more harmful to the cardiovascular system or pose a relatively greater cardiovascular risk than particles between 0.1 and 2.5 μm in diameter.
- Similarly, many studies have found a strong association between metrics of traffic-related air pollution exposure and elevated cardiovascular risk. Whether this represents the harmful effects of UFPs or diesel exhaust particulates, major components of the traffic mixture, or other pollution components is unclear. Diesel and UFPs possess toxic properties that instigate harmful biological responses in experimental models. However, the particle size fraction(s) and roles played by other copollutants (gases, VOCs, SVOCs) within the traffic-related mixture have not been fully elucidated. Nevertheless, traffic-related pollution as a whole appears to be a specific source associated with cardiovascular risk. It likely poses a major public health burden, regardless of a putative higher toxicity, because of the commonness of exposure in modern society (eg, accounting for ≈60% of daily UFP exposure; http://www.catf.us/projects/diesel/).
- The importance of other specific sources, regional differences in pollution composition, and other specific constituents remains less clear. However, toxicological studies have identified several transition metals (eg, iron, vanadium, nickel, copper, and zinc), organic carbon species, semiquinones, and endotoxin as specific PM-related components capable of prompting oxidative stress and inflammation and thus likely imparting biological harm. Some source-apportionment studies also demonstrate that attention should be given to these compounds as being among the most likely mediators of clinical CVD. More studies are required in this regard to clarify this issue and to better define these and other potentially responsible constituents and sources.
- Although the focus of the present statement is on PM, we recognize that other air pollutants may also pose cardiovascular risk alone or in conjunction with fine-particle exposure. In this context, we believe additional research is necessary to make firm conclusions regarding the independent cardiovascular risks posed by several gaseous pollutants (eg, ozone and NO_2). Although ozone has been linked to increased cardiopulmonary mortality,[50] strokes,[126] and MIs[419] in some short-term studies, long-term exposure was not associated with cardiovascular mortality after accounting for PM in a recent analysis.[87] The recent finding that small changes in low levels of ambient carbon monoxide concentrations are related to cardiovascular hospitalizations also merits further exploration.[420]
- Several secondary aerosols (eg, nitrate and sulfate) are often associated with cardiovascular mortality; however, whether these compounds are directly harmful or are surrogate markers of toxic sources of exposure requires

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

more investigation. Similarly, the current literature regarding the independent cardiovascular risks posed by coarse particles is mixed, with most recent findings not supporting an association after accounting for the effects of $PM_{2.5}$.[43,72,104]

- Several recent cohort studies and intermediate end-point experiments suggest that obese individuals (and/or those with the metabolic syndrome) may be a susceptible population at greater risk for cardiovascular events due to $PM_{2.5}$ exposure. This is a tremendously important public health issue to corroborate because of the enormous and growing prevalence of obesity worldwide.

This updated review by the AHA writing group corroborates and strengthens the conclusions of the initial scientific statement. In this context, we agree with the concept and continue to support measures based on scientific evidence, such as the US EPA NAAQS, that seek to control PM levels to protect the public health. Because the evidence reviewed supports that there is no safe threshold, it appears that public health benefits would accrue from lowering $PM_{2.5}$ concentrations even below present-day annual (15 $\mu g/m^3$) and 24-hour (35 $\mu g/m^3$) NAAQS, if feasible, to optimally protect the most susceptible populations. Evaluations of the effectiveness of such efforts would be warranted as well. Within the framework of attempting to establish causality between associated variables in epidemiological studies, there are several generally accepted "aspects" that have been evaluated (the following phrases in italics per the Bradford Hill criteria)[421]: With regard to cardiovascular mortality and $PM_{2.5}$ exposure, there is a *consistent association* that satisfies both a *temporal and exposure-response relationship*. There is *coherence of findings* among several fields of science, including toxicology, human and animal exposures, and different types of epidemiological studies and time frames of exposure. Rigorous experiments demonstrate multiple *plausible biological mechanisms*. Finally, natural experiments have confirmed that a change (ie, reduction) in exposure produces a change (ie, decrease) in cardiovascular mortality. In this case, *specificity of outcomes* and *strength of the observation* are less pertinent, because PM exposure could be capable of causing multiple different types of events (eg, MIs, arrhythmias, and heart failure exacerbations), and the overall cardiovascular mortality relative risk posed for any single individual is expected to be small. Nevertheless, given the ubiquity of exposure, the overall public health consequences can be substantial and observable in population- or large cohort–based studies.

It is the opinion of the writing group that the overall evidence is consistent with a causal relationship between $PM_{2.5}$ exposure and cardiovascular morbidity and mortality. This body of evidence has grown and has been strengthened substantially since publication of the first AHA scientific statement.[1] At present, no credible alternative explanation exists. These conclusions of our independent review are broadly similar to those found in the EPA's Integrated Science Assessment for Particulate Matter final report (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546). In summary, the AHA writing group deems that $PM_{2.5}$ exposure is a "modifiable factor contributing to cardiovascular morbidity and mortality."

Clinical Recommendations

Several precautionary recommendations can be made for healthcare providers who interact with individuals who are at risk for CVDs. Although they have not been clinically tested or proven to reduce mortality, they are practical and feasible measures that may help to reduce exposures to air pollution and therefore potentially lower the associated cardiovascular risk. Moreover, a recent observational study found that patient awareness of air quality indices and media alerts along with health professional advice can significantly affect reported changes in outdoor activity to avoid exposure to air pollution.[422]

- Evidence-based appropriate treatment of the traditional cardiovascular risk factors should be emphasized. This may also lessen the susceptibility of patients to air pollution exposures.
- All patients with CVD should be educated about the cardiovascular risks posed by air pollution.
- Consideration should also be given to educating patients without CVD but who are at high risk (eg, the elderly, individuals with the metabolic syndrome or multiple risk factors, and those with diabetes).
- Part of patient education should include the provision of information regarding the available sources (local and national newspapers [*USA Today*], EPA World Wide Web site [http://airnow.gov/], and The Weather Channel and its World Wide Web site [http://www.weather.com/]) that provide a daily EPA Air Quality Index.
- On the basis of the forecast Air Quality Index, prudent recommendations for reducing exposure and limiting activity should be provided based on the patient's level of risk. A list of such recommendations is provided on the EPA World Wide Web site (http://airnow.gov/). For example, when the Air Quality Index for PM is "unhealthy" (151 to 200), then the recommendations are as follows: "People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion." The action recommendations are as follows: "You can reduce your exposure to particles by 1) planning strenuous activity when particle levels are forecast to be lower, 2) reducing the amount of time spent at vigorous activity, or 3) choosing a less strenuous activity (eg, going for a walk instead of a jog). When particle levels are high outdoors, they also can be high indoors. Certain filters and room air cleaners are available that can help reduce particles indoors."
- Practical recommendations to reduce air pollution exposure should be given to at-risk patients. Although unproven to reduce cardiovascular events, there are a number of prudent and feasible measures, including reducing optional or unnecessary exposures. Additional measures could include eliminating or reducing nonmandatory travel to highly polluted regions and avoiding exposures or outdoor activities (eg, exercising, commut-

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

ing) during highly polluted times (eg, rush hours) or in proximity to major sources of pollution (eg, roadways, industrial sources). Choosing to exercise indoors with windows closed and using efficient air conditioning and filtering systems may be prudent for certain high-risk patients, particularly during peak pollution periods. Indeed, not only can central air conditioners reduce the indoor exposure level to PM from outdoor sources, there is some evidence that they might reduce the risk for cardiovascular hospitalizations associated with higher ambient pollution levels.[423] If travel/commutes cannot be avoided, maintaining optimal car filter systems, driving with windows closed, and recycling inside vehicle air may help reduce PM exposures (http://www.catf.us/projects/diesel/).[424,425]

However, at present, no specific recommendations regarding the appropriateness of undertaking more aggressive measures, even those shown to provide some benefits in a few studies (eg, wearing facemasks, installing PM filters in households), can be made based on the limited evidence. Similarly, although measures that decrease long-term PM exposures may produce even greater cardiovascular health benefits than the provided recommendations that focus on reducing short-term exposures, no specific recommendations (eg, moving to less polluted regions) can be prudently made at this time given the limited evidence. We acknowledge that occupational and indoor sources along with secondhand tobacco smoke are additional significant sources of personal PM exposures that should be avoided or reduced as much as possible. Finally, in developing nations, reducing exposure to indoor cooking sources of PM and air pollution from biomass combustion is a major issue of concern.[426] Additional suggestions are available on the EPA World Wide Web site.

Finally, although the existing evidence supports a causal relationship between $PM_{2.5}$ and cardiovascular mortality, we acknowledge the importance of continued research in areas of controversy and uncertainty to further understand the full nature of this issue. Although numerous insights have greatly enhanced our understanding of the PM-cardiovascular relationship since the first AHA statement was published,[1] the following list represents broad strategic avenues for future investigation:

Mechanistic Studies

- Better describe the physiological relevance in humans and the fundamental details of the mechanisms underlying the intermediate general mediating pathways (ie, PM or constituent transport into the circulation versus effects of inflammatory cytokines or activated immune cells versus ANS imbalance or other pathways) through which PM inhalation might mediate cardiovascular effects remote from the site of pulmonary deposition.
- Understand the clinical significance and relative importance of the observed biological responses (eg, vascular dysfunction, thrombosis, arrhythmia, ANS imbalance) in relation to the various causes of PM-mediated cardiovascular morbidity and mortality.
- Examine the efficacy of preventive measures (eg, patient education) and treatment modalities (eg, statins, antioxidants, fish oil, treatment of traditional risk factors, and reducing exposures by engineering controls, including filtration, personal protection via facemasks, or behavior modification) on cardiovascular health outcomes.
- Investigate the interaction between preexisting traditional cardiovascular risk factors (eg, diabetes, hypertension) and PM exposure, as well as the potential of air pollutants to exacerbate or worsen these risk factors. Determine the extent to which treatment of such factors (eg, with statins, aspirin, or angiotensin-converting enzyme inhibitors), especially among patients with known CVD, may modify the risk associated with PM exposure.
- Describe the biological effects of acute on top of chronic exposures (eg, synergistic effects versus reduced susceptibility to acute exposures due to augmented protective mechanisms).
- Determine the ability of long-term exposure to precipitate the development of chronic diseases, including clinically relevant atherosclerosis, hypertension, diabetes, and other vascular, metabolic, renal, or neurological diseases.

Epidemiological and Exposure Studies

- Expand our knowledge related to the "responsible" PM pollution constituents (eg, metals, organic compounds, semiquinones, endotoxin, and VOC and SVOC compounds), size fractions (eg, UFPs), sources (eg, traffic, power generation, and biomass combustion), and mixtures of pollutants.
- Investigate the cardiovascular health implications and importance of regional and intracity differences in composition and combinations of pollutants.
- Better understand the effects of mixtures of ambient pollutants (ie, potential synergism between PM and gaseous or vapor-phase pollutants such as ozone).
- Investigate the feasibility and utility of quantifying risk coefficients (concentration-response functions) according to PM source or relevant indices of pollutant mixtures, as a function of susceptibility (eg, age, preexisting disease), for reliable application in integrated, multipollutant risk assessments.
- Investigate the relative importance of various time frames of exposure in relation to PM causing cardiovascular events, including the relevance of epochs not well described, such as ultra-acute peak PM excursions (eg, 1 to 2 hours) and exposures of intermediate duration (eg, 1 to 12 months).
- Better document the time course and specific cardiovascular health benefits induced by reductions in PM.
- Better define susceptible individuals or vulnerable populations.
- Determine whether any "safe" PM threshold concentration exists that eliminates both acute and chronic cardiovascular effects in healthy and susceptible individuals and at a population level.

Acknowledgments

We would like to thank Robert Bard Consulting for reviewing and editing the manuscript and Tom Dann from Environment Canada and Joseph Pinto from the US EPA for assistance in the preparation of Table 1.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Robert D. Brook	University of Michigan	Electric Power Research Institute†; EPA†; Harvard University, School of Public Health†; NIEHS†; Pfizer†	None	None	None	None	None	None
Aruni Bhatnagar	University of Louisville	PI on NIH study "Cardiovascular toxicity of environmental aldehydes"†	None	None	None	None	None	None
Jeffrey R. Brook	University of Toronto, Environment Canada	None	None	None	None	None	None	None
Ana V. Diez-Roux	University of Michigan	EPA†; 1st EPA STAR grant to study the effects of long-term PM exposures on subclinical atherosclerosis and inflammatory markers in MESA; #2 is a subcontract to the University of Washington to participate in a long-term study of air pollution and progression of atherosclerosis, also in MESA	None	None	None	None	None	None
Fernando Holguin	Centers for Disease Control and Prevention/Emory University	American Lung Association*; NIH*; Pan-American Health Organization in conjunction with EPA*	Emory University*	None	None	None	None	None
Yuling Hong	American Heart Association‡	None	None	None	None	None	None	None
Joel D. Kaufman	University of Washington	Health Effects Institute*; NIH/NIEHS*; US EPA*; NIEHS Discovery Center Study focused on air pollution and CVD†	None	California Air Resources Board*	None	None	None	None
Russell V. Luepker	University of Minnesota	None	None	None	None	None	None	None
Murray A. Mittleman	Beth Israel Deaconess Medical Center/Harvard University	PI on a component of an NIH/NIEHS program project grant evaluating the effects of ambient air pollution on CVD†	None	None	None	None	None	None
Annette Peters	Helmholtz Zentrum Munchen (German Research Institute for Environmental Health)	Co-PI on the Rochester Particle Center funded through the EPA†; European Union†	None	None	None	None	None	None
C. Arden Pope III	Brigham Young University	None	None	None	None	None	None	None
Sanjay Rajagopalan	Ohio State University	None	None	Takeda*	None	None	None	None
David Siscovick	University of Washington	MESA AIR (ancillary study to MESA) funded by EPA†; NIEHS Discovery Center Study focused on air pollution and CVD†; NIH†	None	None	None	None	None	None
Sidney C. Smith, Jr	University of North Carolina	None	None	None	None	None	None	None
Laurie Whitsel	American Heart Association	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

‡Dr Hong is currently with the Centers for Disease Control and Prevention, Atlanta, Ga.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Michael Brauer	University of British Columbia	Health Canada†; British Columbia Lung Association†	None	None	None	None	MESA-Air Study (US EPA, University of Washington) External Scientific Advisory Committee*; British Columbia Lung Association, Air Quality and Health Steering Committee*	None
Doug Dockery	Harvard University	National Institute of Environmental Health Sciences†; Health Effects Institute†	None	None	None	None	Science Advisory Board to MESA Air Study, University of Washington*	None
Mark Frampton	University of Rochester	National Institutes of Health†; American Petroleum Institute†; US EPA†	None	None	None	None	Health Effects Institute*	None
Jonathan M. Samet	University of Southern California	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

References

1. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, Luepker R, Mittleman M, Samet J, Smith SC Jr, Tager I; Expert Panel on Population and Prevention Science of the American Heart Association. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004;109:2655–2671.
2. Brook RD. Cardiovascular effects of air pollution. *Clin Sci (Lond)*. 2008;115:175–187.
3. Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc*. 2006;56:709–742.
4. Simkhovich BZ, Kleinman MT, Kloner RA. Air pollution and cardiovascular injury epidemiology, toxicology, and mechanisms. *J Am Coll Cardiol*. 2008;52:719–726.
5. US Environmental Protection Agency. Air Quality Criteria for Particulate Matter (October 2004). Available at: http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html. Accessed March 26, 2010.
6. US Environmental Protection Agency. National Ambient Air Quality Criteria Standards. Available at: http://www.epa.gov/air/criteria.html. Accessed September 1, 2008.
7. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F, McQueen M, Budaj A, Pais P, Varigos J, Lisheng L; INTERHEART Study Investigators. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. *Lancet*. 2004;364:937–952.
8. Lloyd-Jones DM, Leip EP, Larson MG, D'Agostino RB, Beiser A, Wilson PW, Wolf PA, Levy D. Prediction of lifetime risk for cardiovascular disease by risk factor burden at 50 years of age. *Circulation*. 2006;113:791–798.
9. Wang TJ, Gona P, Larson MG, Tofler GH, Levy D, Newton-Cheh C, Jacques PF, Rifai N, Selhub J, Robins SJ, Benjamin EJ, D'Agostino RB, Vasan RS. Multiple biomarkers for the prediction of first major cardiovascular events and death. *N Engl J Med*. 2006;355:2631–2639.
10. Cook NR. Use and misuse of the receiver operating characteristic curve in risk prediction. *Circulation*. 2007;115:928–935.
11. Stern RH. Evaluating new cardiovascular risk factors for risk stratification. *J Clin Hypertens (Greenwich)*. 2008;10:485–488.
12. Tofler GH, Muller JE. Triggering of acute cardiovascular disease and potential preventive strategies. *Circulation*. 2006;114:1863–1872.
13. Pope CA 3rd, Muhlestein JB, May HT, Renlund DG, Anderson JL, Horne BD. Ischemic heart disease events triggered by short-term exposure to fine particulate air pollution. *Circulation*. 2006;114:2443–2448.
14. Kung H-C, Hoyert DL, Xu J, Murphy SL. Deaths: Final Data for 2005. *National Vital Statistics Reports*. 2005;561–121.
15. World Health Organization. *World Health Report 2002*. Geneva, Switzerland: World Health Organization; 2002.
16. Geddes JA, Murphy JG, Wang DK. Long term changes in nitrogen oxides and volatile organic compounds in Toronto and the challenges facing local ozone control. *Atmos Environ*. 2009;43:3407–3415.
17. Delfino RJ, Sioutas C, Malik S. Potential role of ultrafine particles in associations between airborne particle mass and cardiovascular health. *Environ Health Perspect*. 2005;113:934–946.
18. Wexler AS, Johnston MV. What have we learned from highly time-resolved measurements during EPA's Supersites Program and related studies? *J Air Waste Manag Assoc*. 2008;58:303–319.
19. Solomon PA, Hopke PK, Froines J, Scheffe R. Key scientific findings and policy- and health-relevant insights from the U.S. Environmental Protection Agency's Particulate Matter Supersites Program and related studies: an integration and synthesis of results. *J Air Waste Manag Assoc*. 2008;58(suppl):S3–S92.
20. Hopke PK. New directions: reactive particles as a source of human health effects. *Atmos Environ*. 2008;42:3192–3194.
21. Bureau of Transportation Statistics. *Highlights of the 2001 National Household Travel Survey*. Washington, DC: US Department of Transportation; 2003.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

22. Sarnat JA, Wilson WE, Strand M, Brook J, Wyzga R, Lumley T. Panel discussion review: session 1: exposure assessment and related errors in air pollution epidemiologic studies. *J Expo Sci Environ Epidemiol.* 2007;17(suppl):S75–S82.
23. Monn C. Exposure assessment of air pollutants: a review on spatial heterogeneity and indoor/outdoor/personal exposure to suspended particulate matter, nitrogen dioxide and ozone. *Atmos Environ*. 2001;35:1–32.
24. Brauer M, Hoek G, van Vliet P, Meliefste K, Fischer P, Gehring U, Heinrich J, Cyrys J, Bellander T, Lewne M, Brunekreef B. Estimating long-term average particulate air pollution concentrations: application of traffic indicators and geographic information systems. *Epidemiology*. 2003;14:228–239.
25. Ebelt ST, Wilson WE, Brauer M. Exposure to ambient and nonambient components of particulate matter: a comparison of health effects. *Epidemiology*. 2005;16:396–405.
26. Molitor J, Jerrett M, Chang CC, Molitor NT, Gauderman J, Berhane K, McConnell R, Lurmann F, Wu J, Winer A, Thomas D. Assessing uncertainty in spatial exposure models for air pollution health effects assessment. *Environ Health Perspect*. 2007;115:1147–1153.
27. Anderson HR, Atkinson RW, Peacock JL, Sweeting MJ, Marston L. Ambient particulate matter and health effects: publication bias in studies of short-term associations. *Epidemiology*. 2005;16:155–163.
28. Pope CA 3rd. Epidemiology of fine particulate air pollution and human health: biologic mechanisms and who's at risk? *Environ Health Perspect.* 2000;108(suppl):713–723.
29. Dominici F. Time-series analysis of air pollution and mortality: a statistical review. *Res Rep Health Eff Inst.* 2004:3–27.
30. Dominici F, Burnett RT. Risk models for particulate air pollution. *J Toxicol Environ Health A*. 2003;66:1883–1889.
31. Committee on the Medical Effects of Air Pollutants. *Cardiovascular Disease and Air Pollution: A Report by the Committee on the Medical Effects of Air Pollutant's Cardiovascular Sub-Group.* London, UK: Department of Health, National Health Service; 2006.
32. Levy JI, Hammitt JK, Spengler JD. Estimating the mortality impacts of particulate matter: what can be learned from between-study variability? *Environ Health Perspect*. 2000;108:109–117.
33. Stieb DM, Judek S, Burnett RT. Meta-analysis of time-series studies of air pollution and mortality: update in relation to the use of generalized additive models. *J Air Waste Manag Assoc*. 2003;53:258–261.
34. Dominici F, Daniels M, McDermott A, Zeger SL, Samet J. Shape of the exposure-response relation and mortality displacement in the NMMAPS database. In: *Revised Analyses of Time-Series of Air Pollution and Health. Special Report.* Boston, Mass: Health Effects Institute; 2003.
35. Katsouyanni K, Touloumi G, Samolu E, Petasakis Y, Analitis A, Le Tertre A, Rossi G, Zmirou D, Ballester F, Boumghar A, Anderson HR, Wojtyniak B, Paldy A, Braustein R, Pekkanen J, Schindler C, Schwartz J. Sensitivity analysis of various models of short-term effects of ambient particles on total mortality in 29 cities in APHEA2. In: *Revised Analyses of Time-Series of Air Pollution and Health.* Boston, Mass: Health Effects Institute; 2003.
36. Analitis A, Katsouyanni K, Dimakopoulou K, Samoli E, Nikoloulopoulos AK, Petasakis Y, Touloumi G, Schwartz J, Anderson HR, Cambra K, Forastiere F, Zmirou D, Vonk JM, Clancy L, Kriz B, Bobvos J, Pekkanen J. Short-term effects of ambient particles on cardiovascular and respiratory mortality. *Epidemiology*. 2006;17:230–233.
37. Klemm RJ, Mason R. Replication of reanalysis of Harvard six-city mortality study. In: *Revised Analyses of Time-Series of Air Pollution and Health.* Boston, Mass: Health Effects Institute; 2003.
38. Franklin M, Zeka A, Schwartz J. Association between PM2.5 and all-cause and specific-cause mortality in 27 US communities. *J Expo Sci Environ Epidemiol*. 2007;17:279–287.
39. Ostro B, Broadwin R, Green S, Feng WY, Lipsett M. Fine particulate air pollution and mortality in nine California counties: results from CALFINE. *Environ Health Perspect*. 2006;114:29–33.
40. Le Tertre A, Medina S, Samoli E, Forsberg B, Michelozzi P, Boumghar A, Vonk JM, Bellini A, Atkinson R, Ayres JG, Sunyer J, Schwartz J, Katsouyanni K. Short-term effects of particulate air pollution on cardiovascular diseases in eight European cities. *J Epidemiol Community Health*. 2002;56:773–779.
41. Omori T, Fujimoto G, Yoshimura I, Nitta H, Ono M. Effects of particulate matter on daily mortality in 13 Japanese cities. *J Epidemiol*. 2003;13:314–322.
42. Wong CM, Vichit-Vadakan N, Kan H, Qian Z. Public Health and Air Pollution in Asia (PAPA): a multicity study of short-term effects of air pollution on mortality. *Environ Health Perspect*. 2008;116:1195–1202.
43. Zanobetti A, Schwartz J. The effect of fine and coarse particulate air pollution on mortality: a national analysis. *Environ Health Perspect*. 2009;117:898–903.
44. Samet JM, Dominici F, Curriero FC, Coursac I, Zeger SL. Fine particulate air pollution and mortality in 20 U.S. cities, 1987–1994. *N Engl J Med*. 2000;343:1742–1749.
45. Dominici F, Zeger SL, Samet JM. A measurement error model for time-series studies of air pollution and mortality. *Biostatistics*. 2000;1:157–175.
46. Dominici F, McDermott A, Zeger SL, Samet JM. National maps of the effects of particulate matter on mortality: exploring geographical variation. *Environ Health Perspect*. 2003;111:39–44.
47. Peng RD, Dominici F, Pastor-Barriuso R, Zeger SL, Samet JM. Seasonal analyses of air pollution and mortality in 100 US cities. *Am J Epidemiol*. 2005;161:585–594.
48. Dominici F, Peng RD, Ebisu K, Zeger SL, Samet JM, Bell ML. Does the effect of PM10 on mortality depend on PM nickel and vanadium content? A reanalysis of the NMMAPS data. *Environ Health Perspect*. 2007;115:1701–1703.
49. Bell ML, Kim JY, Dominici F. Potential confounding of particulate matter on the short-term association between ozone and mortality in multisite time-series studies. *Environ Health Perspect.* 2007;115:1591–1595.
50. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987–2000. *JAMA*. 2004;292:2372–2378.
51. Franklin M, Schwartz J. The impact of secondary particles on the association between ambient ozone and mortality. *Environ Health Perspect*. 2008;116:453–458.
52. Katsouyanni K. Ambient air pollution and health. *Br Med Bull*. 2003;68:143–156.
53. Samoli E, Aga E, Touloumi G, Nisiotis K, Forsberg B, Lefranc A, Pekkanen J, Wojtyniak B, Schindler C, Niciu E, Brunstein R, Dodic Fikfak M, Schwartz J, Katsouyanni K. Short-term effects of nitrogen dioxide on mortality: an analysis within the APHEA project. *Eur Respir J*. 2006;27:1129–1138.
54. Samoli E, Touloumi G, Schwartz J, Anderson HR, Schindler C, Forsberg B, Vigotti MA, Vonk J, Kosnik M, Skorkovsky J, Katsouyanni K. Short-term effects of carbon monoxide on mortality: an analysis within the APHEA project. *Environ Health Perspect.* 2007;115:1578–1583.
55. Wong CM, Ou CQ, Chan KP, Chau YK, Thach TQ, Yang L, Chung RY, Thomas GN, Peiris JS, Wong TW, Hedley AJ, Lam TH. The effects of air pollution on mortality in socially deprived urban areas in Hong Kong, China. *Environ Health Perspect*. 2008;116:1189–1194.
56. Kan H, Jia J, Chen B. Acute stroke mortality and air pollution: new evidence from Shanghai, China. *J Occup Health*. 2003;45:321–323.
57. Qian Z, He Q, Lin HM, Kong L, Bentley CM, Liu W, Zhou D. High temperatures enhanced acute mortality effects of ambient particle pollution in the "oven" city of Wuhan, China. *Environ Health Perspect*. 2008;116:1172–1178.
58. Klemm RJ, Lipfert FW, Wyzga RE, Gust C. Daily mortality and air pollution in Atlanta: two years of data from ARIES. *Inhal Toxicol.* 2004;16(suppl):131–141.
59. Klemm RJ, Mason RM Jr, Heilig CM, Neas LM, Dockery DW. Is daily mortality associated specifically with fine particles? Data reconstruction and replication of analyses. *J Air Waste Manag Assoc*. 2000;50:1215–1222.
60. Laden F, Neas LM, Dockery DW, Schwartz J. Association of fine particulate matter from different sources with daily mortality in six U.S. cities. *Environ Health Perspect*. 2000;108:941–947.
61. Samoli E, Peng R, Ramsay T, Pipikou M, Touloumi G, Dominici F, Burnett R, Cohen A, Krewski D, Samet J, Katsouyanni K. Acute effects of ambient particulate matter on mortality in Europe and North America: results from the APHENA study. *Environ Health Perspect.* 2008;116:1480–1486.
62. Dockery DW, Pope CA 3rd, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG Jr, Speizer FE. An association between air pollution and mortality in six U.S. cities. *N Engl J Med*. 1993;329:1753–1759.
63. Krewski D, Burnett RT, Goldberg MS, Hoover K, Siemiatycki J, Abrahamowicz M, White WH. Validation of the Harvard Six Cities Study of particulate air pollution and mortality. *N Engl J Med.* 2004;350:198–199.
64. Laden F, Schwartz J, Speizer FE, Dockery DW. Reduction in fine particulate air pollution and mortality: Extended follow-up of the Harvard Six Cities study. *Am J Respir Crit Care Med.* 2006;173:667–672.
65. Eftim SE, Samet JM, Janes H, McDermott A, Dominici F. Fine particulate matter and mortality: a comparison of the six cities and American Cancer Society cohorts with a Medicare cohort. *Epidemiology*. 2008;19:209–216.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

66. Pope CA 3rd, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW Jr. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *Am J Respir Crit Care Med*. 1995;151:669–674.
67. Pope CA 3rd, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, Godleski JJ. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation*. 2004;109:71–77.
68. Pope CA 3rd, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*. 2002;287:1132–1141.
69. Jerrett M, Burnett RT, Ma R, Pope CA 3rd, Krewski D, Newbold KB, Thurston G, Shi Y, Finkelstein N, Calle EE, Thun MJ. Spatial analysis of air pollution and mortality in Los Angeles. *Epidemiology*. 2005;16:727–736.
70. Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner MC, Pope CA 3rd, Thurston G, Calle EE, Thun MJ. *Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality: Special Report.* Cambridge, MA: Health Effects Institute; 2009.
71. Zeger SL, Dominici F, McDermott A, Samet JM. Mortality in the Medicare population and chronic exposure to fine particulate air pollution in urban centers (2000–2005). *Environ Health Perspect*. 2008;116:1614–1619.
72. Miller KA, Siscovick DS, Sheppard L, Shepherd K, Sullivan JH, Anderson GL, Kaufman JD. Long-term exposure to air pollution and incidence of cardiovascular events in women. *N Engl J Med*. 2007;356:447–458.
73. Puett RC, Schwartz J, Hart JE, Yanosky JD, Speizer FE, Suh H, Paciorek CJ, Neas LM, Laden F. Chronic particulate exposure, mortality, and coronary heart disease in the nurses' health study. *Am J Epidemiol*. 2008;168:1161–1168.
74. McDonnell WF, Nishino-Ishikawa N, Petersen FF, Chen LH, Abbey DE. Relationships of mortality with the fine and coarse fractions of long-term ambient PM10 concentrations in nonsmokers. *J Expo Anal Environ Epidemiol*. 2000;10:427–436.
75. Chen LH, Knutsen SF, Shavlik D, Beeson WL, Petersen F, Ghamsary M, Abbey D. The association between fatal coronary heart disease and ambient particulate air pollution: are females at greater risk? *Environ Health Perspect*. 2005;113:1723–1729.
76. Lipfert FW RW, JD Baty JD, JP Miller. Traffic density as a surrogate measure of environmental exposures in studies of air pollution health effects: long-term mortality in a cohort of US veterans. *Atmos Environ.* 2006;40:154–169.
77. Lipfert FW, Baty JD, Miller JP, Wyzga RE. PM2.5 constituents and related air quality variables as predictors of survival in a cohort of U.S. military veterans. *Inhal Toxicol*. 2006;18:645–657.
78. Enstrom JE. Fine particulate air pollution and total mortality among elderly Californians, 1973–2002. *Inhal Toxicol*. 2005;17:803–816.
79. Filleul L, Rondeau V, Vandentorren S, Le Moual N, Cantagrel A, Annesi-Maesano I, Charpin D, Declercq C, Neukirch F, Paris C, Vervloet D, Brochard P, Tessier JF, Kauffmann F, Baldi I. Twenty five year mortality and air pollution: results from the French PAARC survey. *Occup Environ Med*. 2005;62:453–460.
80. Gehring U, Heinrich J, Krämer U, Grote V, Hochadel M, Sugiri D, Kraft M, Rauchfuss K, Eberwein HG, Wichmann HE. Long-term exposure to ambient air pollution and cardiopulmonary mortality in women. *Epidemiology*. 2006;17:545–551.
81. Naess Ø, Nafstad P, Aamodt G, Claussen B, Rosland P. Relation between concentration of air pollution and cause-specific mortality: four-year exposures to nitrogen dioxide and particulate matter pollutants in 470 neighborhoods in Oslo, Norway. *Am J Epidemiol*. 2007;165:435–443.
82. Beelen R, Hoek G, van den Brandt PA, Goldbohm RA, Fischer P, Schouten LJ, Jerrett M, Hughes E, Armstrong B, Brunekreef B. Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR study). *Environ Health Perspect*. 2008;116:196–202.
83. Elliott P, Shaddick G, Wakefield JC, de Hoogh C, Briggs DJ. Long-term associations of outdoor air pollution with mortality in Great Britain. *Thorax*. 2007;62:1088–1094.
84. Schwartz J, Coull B, Laden F, Ryan L. The effect of dose and timing of dose on the association between airborne particles and survival. *Environ Health Perspect*. 2008;116:64–69.
85. Jerrett M, Burnett RT, Brook J, Kanaroglou P, Giovis C, Finkelstein N, Hutchison B. Do socioeconomic characteristics modify the short term association between air pollution and mortality? Evidence from a zonal time series in Hamilton, Canada. *J Epidemiol Community Health*. 2004;58:31–40.
86. Jerrett M, Burnett RT, Willis A, Krewski D, Goldberg MS, DeLuca P, Finkelstein N. Spatial analysis of the air pollution-mortality relationship in the context of ecologic confounders. *J Toxicol Environ Health A*. 2003;66:1735–1777.
87. Jerrett M, Burnett RT, Pope CA 3rd, Ito K, Thurston G, Krewski D, Shi Y, Calle E, Thun M. Long-term ozone exposure and mortality. *N Engl J Med*. 2009;360:1085–1095.
88. Abbey DE, Nishino N, McDonnell WF, Burchette RJ, Knutsen SF, Lawrence Beeson W, Yang JX. Long-term inhalable particles and other air pollutants related to mortality in nonsmokers. *Am J Respir Crit Care Med*. 1999;159:373–382.
89. Pope CA 3rd. Particulate pollution and health: a review of the Utah valley experience. *J Expo Anal Environ Epidemiol.* 1996;6:23–34.
90. Clancy L, Goodman P, Sinclair H, Dockery DW. Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study. *Lancet*. 2002;360:1210–1214.
91. Hedley AJ, Wong CM, Thach TQ, Ma S, Lam TH, Anderson HR. Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study. *Lancet*. 2002;360:1646–1652.
92. Dominici F, Peng RD, Zeger SL, White RH, Samet JM. Particulate air pollution and mortality in the United States: did the risks change from 1987 to 2000? *Am J Epidemiol*. 2007;166:880–888.
93. Pope CA 3rd, Rodermund DL, Gee MM. Mortality effects of a copper smelter strike and reduced ambient sulfate particulate matter air pollution. *Environ Health Perspect*. 2007;115:679–683.
94. Janes H, Dominici F, Zeger SL. Trends in air pollution and mortality: an approach to the assessment of unmeasured confounding. *Epidemiology*. 2007;18:416–423.
95. Pope CA 3rd, Ezzati M, Dockery DW. Fine-particulate air pollution and life expectancy in the United States. *N Engl J Med*. 2009;360:376–386.
96. Schwartz J. Air pollution and hospital admissions for heart disease in eight U.S. counties. *Epidemiology*. 1999;10:17–22.
97. Zanobetti A, Schwartz J, Dockery DW. Airborne particles are a risk factor for hospital admissions for heart and lung disease. *Environ Health Perspect*. 2000;108:1071–1077.
98. Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Dockery DW, Schwartz J, Zanobetti A. The National Morbidity, Mortality, and Air Pollution Study. Part II: Morbidity and mortality from air pollution in the United States. *Res Rep Health Eff Inst*. 2000;94:5–70.
99. Schwartz J, Zanobetti A, Bateson T. Morbidity and mortality among elderly residents of cities with daily PM measurements. In: *Revised Analyses of Time-Series Studies of Air Pollution and Health.* Boston, Mass: Health Effects Institute; 2003.
100. Ballester F, Rodríguez P, Iñíguez C, Saez M, Daponte A, Galán I, Taracido M, Arribas F, Bellido J, Cirarda FB, Cañada A, Guillén JJ, Guillén-Grima F, López E, Pérez-Hoyos S, Lertxundi A, Toro S. Air pollution and cardiovascular admissions association in Spain: results within the EMECAS project. *J Epidemiol Community Health*. 2006;60:328–336.
101. Larrieu S, Jusot JF, Blanchard M, Prouvost H, Declercq C, Fabre P, Pascal L, Tertre AL, Wagner V, Rivière S, Chardon B, Borrelli D, Cassadou S, Eilstein D, Lefranc A. Short term effects of air pollution on hospitalizations for cardiovascular diseases in eight French cities: the PSAS program. *Sci Total Environ*. 2007;387:105–112.
102. Bell ML, Ebisu K, Peng RD, Walker J, Samet JM, Zeger SL, Dominici F. Seasonal and regional short-term effects of fine particles on hospital admissions in 202 US counties, 1999–2005. *Am J Epidemiol*. 2008;168:1301–1310.
103. Dominici F, Peng RD, Bell ML, Pham L, McDermott A, Zeger SL, Samet JM. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA*. 2006;295:1127–1134.
104. Peng RD, Chang HH, Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Coarse particulate matter air pollution and hospital admissions for cardiovascular and respiratory diseases among Medicare patients. *JAMA*. 2008;299:2172–2179.
105. Sunyer J, Ballester F, Tertre AL, Atkinson R, Ayres JG, Forastiere F, Forsberg B, Vonk JM, Bisanti L, Tenías JM, Medina S, Schwartz J, Katsouyanni K. The association of daily sulfur dioxide air pollution levels with hospital admissions for cardiovascular diseases in Europe (The Aphea-II study). *Eur Heart J*. 2003;24:752–760.
106. Krewski D. Evaluating the effects of ambient air pollution on life expectancy. *N Engl J Med*. 2009;360:413–415.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

107. Zanobetti A, Schwartz J. Particulate air pollution, progression, and survival after myocardial infarction. *Environ Health Perspect*. 2007; 115:769–775.
108. Tonne C, Melly S, Mittleman M, Coull B, Goldberg R, Schwartz J. A case-control analysis of exposure to traffic and acute myocardial infarction. *Environ Health Perspect*. 2007;115:53–57.
109. Murakami Y, Ono M. Myocardial infarction deaths after high level exposure to particulate matter. *J Epidemiol Community Health*. 2006; 60:262–266.
110. Peters A, Dockery DW, Muller JE, Mittleman MA. Increased particulate air pollution and the triggering of myocardial infarction. *Circulation*. 2001;103:2810–2815.
111. Peters A, von Klot S, Heier M, Trentinaglia I, Hörmann A, Wichmann HE, Löwel H; Cooperative Health Research in the Region of Augsburg Study Group. Exposure to traffic and the onset of myocardial infarction. *N Engl J Med*. 2004;351:1721–1730.
112. D'Ippoliti D, Forastiere F, Ancona C, Agabiti N, Fusco D, Michelozzi P, Perucci CA. Air pollution and myocardial infarction in Rome: a case-crossover analysis. *Epidemiology*. 2003;14:528–535.
113. Zanobetti A, Schwartz J. The effect of particulate air pollution on emergency admissions for myocardial infarction: a multicity case-crossover analysis. *Environ Health Perspect*. 2005;113:978–982.
114. von Klot S, Peters A, Aalto P, Bellander T, Berglind N, D'Ippoliti D, Elosua R, Hörmann A, Kulmala M, Lanki T, Löwel H, Pekkanen J, Picciotto S, Sunyer J, Forastiere F; Health Effects of Particles on Susceptible Subpopulations (HEAPSS) Study Group. Ambient air pollution is associated with increased risk of hospital cardiac readmissions of myocardial infarction survivors in five European cities. *Circulation*. 2005;112:3073–3079.
115. Sullivan J, Sheppard L, Schreuder A, Ishikawa N, Siscovick D, Kaufman J. Relation between short-term fine-particulate matter exposure and onset of myocardial infarction. *Epidemiology*. 2005;16:41–48.
116. Peters A, von Klot S, Heier M, Trentinaglia I, Cyrys J, Hörmann A, Hauptmann M, Wichmann HE, Löwel H. Air pollution, personal activities, and onset of myocardial infarction in a case-crossover study, Part I. In: *Particulate Air Pollution and Nonfatal Cardiac Events.* Boston, Mass: Health Effects Institute; 2005:124.
117. Wellenius GA, Schwartz J, Mittleman MA. Particulate air pollution and hospital admissions for congestive heart failure in seven United States cities. *Am J Cardiol*. 2006;97:404–408.
118. Medina-Ramón M, Goldberg R, Melly S, Mittleman MA, Schwartz J. Residential exposure to traffic-related air pollution and survival after heart failure. *Environ Health Perspect*. 2008;116:481–485.
119. Pope CA III, Renlund DG, Kfoury AG, May HT, Horne BD. Relation of heart failure hospitalization to exposure to fine particulate air pollution. *Am J Cardiol*. 2008;102:1230–1234.
120. Hong YC, Lee JT, Kim H, Ha EH, Schwartz J, Christiani DC. Effects of air pollutants on acute stroke mortality. *Environ Health Perspect*. 2002; 110:187–191.
121. Hong YC, Lee JT, Kim H, Kwon HJ. Air pollution: a new risk factor in ischemic stroke mortality. *Stroke*. 2002;33:2165–2169.
122. Kettunen J, Lanki T, Tiittanen P, Aalto PP, Koskentalo T, Kulmala M, Salomaa V, Pekkanen J. Associations of fine and ultrafine particulate air pollution with stroke mortality in an area of low air pollution levels. *Stroke*. 2007;38:918–922.
123. Chan CC, Chuang KJ, Chien LC, Chen WJ, Chang WT. Urban air pollution and emergency admissions for cerebrovascular diseases in Taipei, Taiwan. *Eur Heart J*. 2006;27:1238–1244.
124. Tsai SS, Goggins WB, Chiu HF, Yang CY. Evidence for an association between air pollution and daily stroke admissions in Kaohsiung, Taiwan. *Stroke*. 2003;34:2612–2616.
125. Wellenius GA, Schwartz J, Mittleman MA. Air pollution and hospital admissions for ischemic and hemorrhagic stroke among Medicare beneficiaries. *Stroke*. 2005;36:2549–2553.
126. Henrotin JB, Besancenot JP, Bejot Y, Giroud M. Short-term effects of ozone air pollution on ischaemic stroke occurrence: a case-crossover analysis from a 10-year population-based study in Dijon, France. *Occup Environ Med*. 2007;64:439–445.
127. Lisabeth LD, Escobar JD, Dvonch JT, Sánchez BN, Majersik JJ, Brown DL, Smith MA, Morgenstern LB. Ambient air pollution and risk for ischemic stroke and transient ischemic attack. *Ann Neurol*. 2008;64:53–59.
128. Baccarelli A, Martinelli I, Zanobetti A, Grillo P, Hou LF, Bertazzi PA, Mannucci PM, Schwartz J. Exposure to particulate air pollution and risk of deep vein thrombosis. *Arch Intern Med*. 2008;168:920–927.
129. Peters A, Liu E, Verrier RL, Schwartz J, Gold DR, Mittleman M, Baliff J, Oh JA, Allen G, Monahan K, Dockery DW. Air pollution and incidence of cardiac arrhythmia. *Epidemiology*. 2000;11:11–17.
130. Dockery DW, Luttmann-Gibson H, Rich DQ, Link MS, Mittleman MA, Gold DR, Koutrakis P, Schwartz JD, Verrier RL. Association of air pollution with increased incidence of ventricular tachyarrhythmias recorded by implanted cardioverter defibrillators. *Environ Health Perspect*. 2005;113:670–674.
131. Rich DQ, Schwartz J, Mittleman MA, Link M, Luttmann-Gibson H, Catalano PJ, Speizer FE, Dockery DW. Association of short-term ambient air pollution concentrations and ventricular arrhythmias. *Am J Epidemiol*. 2005;161:1123–1132.
132. Berger A, Zareba W, Schneider A, Rückerl R, Ibald-Mulli A, Cyrys J, Wichmann HE, Peters A. Runs of ventricular and supraventricular tachycardia triggered by air pollution in patients with coronary heart disease. *J Occup Environ Med*. 2006;48:1149–1158.
133. Rich DQ, Kim MH, Turner JR, Mittleman MA, Schwartz J, Catalano PJ, Dockery DW. Association of ventricular arrhythmias detected by implantable cardioverter defibrillator and ambient air pollutants in the St Louis, Missouri metropolitan area. *Occup Environ Med*. 2006;63:591–596.
134. Rich DQ, Mittleman MA, Link MS, Schwartz J, Luttmann-Gibson H, Catalano PJ, Speizer FE, Gold DR, Dockery DW. Increased risk of paroxysmal atrial fibrillation episodes associated with acute increases in ambient air pollution. *Environ Health Perspect*. 2006;114:120–123.
135. Sarnat SE, Suh HH, Coull BA, Schwartz J, Stone PH, Gold DR. Ambient particulate air pollution and cardiac arrhythmia in a panel of older adults in Steubenville, Ohio. *Occup Environ Med*. 2006;63:700–706.
136. Santos UP, Terra-Filho M, Lin CA, Pereira LA, Vieira TC, Saldiva PH, Braga AL. Cardiac arrhythmia emergency room visits and environmental air pollution in Sao Paulo, Brazil. *J Epidemiol Community Health*. 2008;62:267–272.
137. Rich KE, Petkau J, Vedal S, Brauer M. A case-crossover analysis of particulate air pollution and cardiac arrhythmia in patients with implantable cardioverter defibrillators. *Inhal Toxicol*. 2004;16:363–372.
138. Vedal S, Rich K, Brauer M, White R, Petkau J. Air pollution and cardiac arrhythmias in patients with implantable cardioverter defibrillators. *Inhal Toxicol*. 2004;16:353–362.
139. Metzger KB, Klein M, Flanders WD, Peel JL, Mulholland JA, Langberg JJ, Tolbert PE. Ambient air pollution and cardiac arrhythmias in patients with implantable defibrillators. *Epidemiology*. 2007;18:585–592.
140. Forastiere F, Stafoggia M, Picciotto S, Bellander T, D'Ippoliti D, Lanki T, von Klot S, Nyberg F, Paatero P, Peters A, Pekkanen J, Sunyer J, Perucci CA. A case-crossover analysis of out-of-hospital coronary deaths and air pollution in Rome, Italy. *Am J Respir Crit Care Med*. 2005;172:1549–1555.
141. Rosenthal FS, Carney JP, Olinger ML. Out-of-hospital cardiac arrest and airborne fine particulate matter: a case-crossover analysis of emergency medical services data in Indianapolis, Indiana. *Environ Health Perspect*. 2008;116:631–636.
142. Levy D, Sheppard L, Checkoway H, Kaufman J, Lumley T, Koenig J, Siscovick D. A case-crossover analysis of particulate matter air pollution and out-of-hospital primary cardiac arrest. *Epidemiology*. 2001;12:193–199.
143. Sullivan J, Ishikawa N, Sheppard L, Siscovick D, Checkoway H, Kaufman J. Exposure to ambient fine particulate matter and primary cardiac arrest among persons with and without clinically recognized heart disease. *Am J Epidemiol*. 2003;157:501–509.
144. Peters A, Döring A, Wichmann HE, Koenig W. Increased plasma viscosity during an air pollution episode: a link to mortality? *Lancet*. 1997;349:1582–1587.
145. Seaton A, Soutar A, Crawford V, Elton R, McNerlan S, Cherrie J, Watt M, Agius R, Stout R. Particulate air pollution and the blood. *Thorax*. 1999;54:1027–1032.
146. Pekkanen J, Brunner EJ, Anderson HR, Tiittanen P, Atkinson RW. Daily concentrations of air pollution and plasma fibrinogen in London. *Occup Environ Med*. 2000;57:818–822.
147. Peters A, Fröhlich M, Döring A, Immervoll T, Wichmann HE, Hutchinson WL, Pepys MB, Koenig W. Particulate air pollution is associated with an acute phase response in men: results from the MONICA-Augsburg Study. *Eur Heart J*. 2001;22:1198–1204.
148. Schwartz J Air pollution and blood markers of cardiovascular risk. *Environ Health Perspect.* 2001;109(suppl):405–409.
149. Pope CA 3rd, Hansen ML, Long RW, Nielsen KR, Eatough NL, Wilson WE, Eatough DJ. Ambient particulate air pollution, heart rate variability, and blood markers of inflammation in a panel of elderly subjects. *Environ Health Perspect*. 2004;112:339–345.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

150. Rückerl R, Ibald-Mulli A, Koenig W, Schneider A, Woelke G, Cyrys J, Heinrich J, Marder V, Frampton M, Wichmann HE, Peters A. Air pollution and markers of inflammation and coagulation in patients with coronary heart disease. *Am J Respir Crit Care Med*. 2006;173:432–441.
151. Chuang KJ, Chan CC, Su TC, Lee CT, Tang CS. The effect of urban air pollution on inflammation, oxidative stress, coagulation, and autonomic dysfunction in young adults. *Am J Respir Crit Care Med*. 2007;176:370–376.
152. Zeka A, Sullivan JR, Vokonas PS, Sparrow D, Schwartz J. Inflammatory markers and particulate air pollution: characterizing the pathway to disease. *Int J Epidemiol*. 2006;35:1347–1354.
153. Calderón-Garcidueñas L, Villarreal-Calderon R, Valencia-Salazar G, Henríquez-Roldán C, Gutiérrez-Castrellón P, Torres-Jardón R, Osnaya-Brizuela N, Romero L, Torres-Jardón R, Solt A, Reed W. Systemic inflammation, endothelial dysfunction, and activation in clinically healthy children exposed to air pollutants. *Inhal Toxicol*. 2008;20:499–506.
154. O'Neill MS, Veves A, Sarnat JA, Zanobetti A, Gold DR, Economides PA, Horton ES, Schwartz J. Air pollution and inflammation in type 2 diabetes: a mechanism for susceptibility. *Occup Environ Med*. 2007;64:373–379.
155. Rückerl R, Phipps RP, Schneider A, Frampton M, Cyrys J, Oberdörster G, Wichmann HE, Peters A. Ultrafine particles and platelet activation in patients with coronary heart disease: results from a prospective panel study. *Part Fibre Toxicol*. 2007;4:1.
156. Riediker M, Cascio WE, Griggs TR, Herbst MC, Bromberg PA, Neas L, Williams RW, Devlin RB. Particulate matter exposure in cars is associated with cardiovascular effects in healthy young men. *Am J Respir Crit Care Med*. 2004;169:934–940.
157. Riediker M. Cardiovascular effects of fine particulate matter components in highway patrol officers. *Inhal Toxicol*. 2007;19(suppl):99–105.
158. Delfino RJ, Staimer N, Tjoa T, Gillen DL, Polidori A, Arhami M, Kleinman MT, Vaziri ND, Longhurst J, Sioutas C. Air pollution exposures and circulating biomarkers of effect in a susceptible population: clues to potential causal component mixtures and mechanisms. *Environ Health Perspect*. 2009;117:1232–1238.
159. Delfino RJ, Staimer N, Tjoa T, Polidori A, Arhami M, Gillen DL, Kleinman MT, Vaziri ND, Longhurst J, Zaldivar F, Sioutas C. Circulating biomarkers of inflammation, antioxidant activity, and platelet activation are associated with primary combustion aerosols in subjects with coronary artery disease. *Environ Health Perspect*. 2008;116:898–906.
160. Chen JC, Schwartz J. Metabolic syndrome and inflammatory responses to long-term particulate air pollutants. *Environ Health Perspect*. 2008;116:612–617.
161. Hoffmann B, Moebus S, Dragano N, Stang A, Möhlenkamp S, Schmermund A, Memmesheimer M, Bröcker-Preuss M, Mann K, Erbel R, Jöckel KH. Chronic residential exposure to particulate matter air pollution and systemic inflammatory markers. *Environ Health Perspect*. 2009;117:1302–1308.
162. Sullivan JH, Hubbard R, Liu SL, Shepherd K, Trenga CA, Koenig JQ, Chandler WL, Kaufman JD. A community study of the effect of particulate matter on blood measures of inflammation and thrombosis in an elderly population. *Environ Health*. 2007;6:3.
163. Steinvil A, Kordova-Biezuner L, Shapira I, Berliner S, Rogowski O. Short-term exposure to air pollution and inflammation-sensitive biomarkers. *Environ Res*. 2008;106:51–61.
164. Diez Roux AV, Auchincloss AH, Astor B, Barr RG, Cushman M, Dvonch T, Jacobs DR Jr, Kaufman J, Lin X, Samson P. Recent exposure to particulate matter and C-reactive protein concentration in the multiethnic study of atherosclerosis. *Am J Epidemiol*. 2006;164:437–448.
165. Forbes LJ, Patel MD, Rudnicka AR, Cook DG, Bush T, Stedman JR, Whincup PH, Strachan DP, Anderson RH. Chronic exposure to outdoor air pollution and markers of systemic inflammation. *Epidemiology*. 2009;20:245–253.
166. Dubowsky SD, Suh H, Schwartz J, Coull BA, Gold DR. Diabetes, obesity, and hypertension may enhance associations between air pollution and markers of systemic inflammation. *Environ Health Perspect*. 2006;114:992–998.
167. Bräuner EV, Forchhammer L, Møller P, Simonsen J, Glasius M, Wåhlin P, Raaschou-Nielsen O, Loft S. Exposure to ultrafine particles from ambient air and oxidative stress-induced DNA damage. *Environ Health Perspect*. 2007;115:1177–1182.
168. Vinzents PS, Møller P, Sørensen M, Knudsen LE, Hertel O, Jensen FP, Schibye B, Loft S. Personal exposure to ultrafine particles and oxidative DNA damage. *Environ Health Perspect*. 2005;113:1485–1490.
169. Sørensen M, Daneshvar B, Hansen M, Dragsted LO, Hertel O, Knudsen L, Loft S. Personal PM2.5 exposure and markers of oxidative stress in blood. *Environ Health Perspect*. 2003;111:161–166.
170. Baccarelli A, Zanobetti A, Martinelli I, Grillo P, Hou L, Lanzani G, Mannucci PM, Bertazzi PA, Schwartz J. Air pollution, smoking, and plasma homocysteine. *Environ Health Perspect*. 2007;115:176–181.
171. Park SK, O'Neill MS, Vokonas PS, Sparrow D, Spiro A 3rd, Tucker KL, Suh H, Hu H, Schwartz J. Traffic-related particles are associated with elevated homocysteine: the VA normative aging study. *Am J Respir Crit Care Med*. 2008;178:283–289.
172. Romieu I, Garcia-Esteban R, Sunyer J, Rios C, Alcaraz-Zubeldia M, Velasco SR, Holguin F. The effect of supplementation with omega-3 polyunsaturated fatty acids on markers of oxidative stress in elderly exposed to PM(2.5). *Environ Health Perspect*. 2008;116:1237–1242.
173. Liao D, Heiss G, Chinchilli VM, Duan Y, Folsom AR, Lin HM, Salomaa V. Association of criteria pollutants with plasma hemostatic/inflammatory markers: a population-based study. *J Expo Anal Environ Epidemiol*. 2005;15:319–328.
174. Rudez G, Janssen NA, Kilinc E, Leebeek FW, Gerlofs-Nijland ME, Spronk HM, ten Cate H, Cassee FR, de Maat MP. Effects of ambient air pollution on hemostasis and inflammation. *Environ Health Perspect*. 2009;117:995–1001.
175. Su TC, Chan CC, Liau CS, Lin LY, Kao HL, Chuang KJ. Urban air pollution increases plasma fibrinogen and plasminogen activator inhibitor-1 levels in susceptible patients. *Eur J Cardiovasc Prev Rehabil*. 2006;13:849–852.
176. Ray MR, Mukherjee S, Roychoudhury S, Bhattacharya P, Banerjee M, Siddique S, Chakraborty S, Lahiri T. Platelet activation, upregulation of CD11b/CD18 expression on leukocytes and increase in circulating leukocyte-platelet aggregates in Indian women chronically exposed to biomass smoke. *Hum Exp Toxicol*. 2006;25:627–635.
177. Baccarelli A, Zanobetti A, Martinelli I, Grillo P, Hou L, Giacomini S, Bonzini M, Lanzani G, Mannucci PM, Bertazzi PA, Schwartz J. Effects of exposure to air pollution on blood coagulation. *J Thromb Haemost*. 2007;5:252–260.
178. Bräuner EV, Møller P, Barregard L, Dragsted LO, Glasius M, Wåhlin P, Vinzents P, Raaschou-Nielsen O, Loft S. Exposure to ambient concentrations of particulate air pollution does not influence vascular function or inflammatory pathways in young healthy individuals. *Part Fibre Toxicol*. 2008;5:13.
179. Chuang KJ, Chan CC, Shiao GM, Su TC. Associations between submicrometer particles exposures and blood pressure and heart rate in patients with lung function impairments. *J Occup Environ Med*. 2005;47:1093–1098.
180. Ibald-Mulli A, Stieber J, Wichmann HE, Koenig W, Peters A. Effects of air pollution on blood pressure: a population-based approach. *Am J Public Health*. 2001;91:571–577.
181. Zanobetti A, Canner MJ, Stone PH, Schwartz J, Sher D, Eagan-Bengston E, Gates KA, Hartley LH, Suh H, Gold DR. Ambient pollution and blood pressure in cardiac rehabilitation patients. *Circulation*. 2004;110:2184–2189.
182. Choi JH, Xu QS, Park SY, Kim JH, Hwang SS, Lee KH, Lee HJ, Hong YC. Seasonal variation of effect of air pollution on blood pressure. *J Epidemiol Community Health*. 2007;61:314–318.
183. Auchincloss AH, Diez Roux AV, Dvonch JT, Brown PL, Barr RG, Daviglus ML, Goff DC, Kaufman JD, O'Neill MS. Associations between recent exposure to ambient fine particulate matter and blood pressure in the Multi-ethnic Study of Atherosclerosis (MESA). *Environ Health Perspect*. 2008;116:486–491.
184. Liu L, Ruddy TD, Dalipaj M, Szyszkowicz M, You H, Poon R, Wheeler A, Dales R. Influence of personal exposure to particulate air pollution on cardiovascular physiology and biomarkers of inflammation and oxidative stress in subjects with diabetes. *J Occup Environ Med*. 2007;49:258–265.
185. Rich DQ, Freudenberger RS, Ohman-Strickland P, Cho Y, Kipen HM. Right heart pressure increases after acute increases in ambient particulate concentration. *Environ Health Perspect*. 2008;116:1167–1171.
186. Calderón-Garcidueñas L, Vincent R, Mora-Tiscareño A, Franco-Lira M, Henríquez-Roldán C, Barragán-Mejía G, Garrido-García L, Camacho-Reyes L, Valencia-Salazar G, Paredes R, Romero L, Osnaya H, Villarreal-Calderón R, Torres-Jardón R, Hazucha MJ, Reed W. Elevated plasma endothelin-1 and pulmonary arterial pressure in children exposed to air pollution. *Environ Health Perspect*. 2007;115:1248–1253.
187. Harrabi I, Rondeau V, Dartigues JF, Tessier JF, Filleul L. Effects of particulate air pollution on systolic blood pressure: a population-based approach. *Environ Res*. 2006;101:89–93.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

188. Ibald-Mulli A, Timonen KL, Peters A, Heinrich J, Wölke G, Lanki T, Buzorius G, Kreyling WG, de Hartog J, Hoek G, ten Brink HM, Pekkanen J. Effects of particulate air pollution on blood pressure and heart rate in subjects with cardiovascular disease: a multicenter approach. *Environ Health Perspect*. 2004;112:369–377.
189. Madsen C, Nafstad P. Associations between environmental exposure and blood pressure among participants in the Oslo Health Study (HUBRO). *Eur J Epidemiol*. 2006;21:485–491.
190. Dvonch JT, Kannan S, Schulz AJ, Keeler GJ, Mentz G, House J, Benjamin A, Max P, Bard RL, Brook RD. Acute effects of ambient particulate matter on blood pressure: differential effects across urban communities. *Hypertension.* 2009;53:853–859.
191. Langrish JP, Mills NL, Chan JK, Leseman DL, Aitken RJ, Fokkens PH, Cassee FR, Li J, Donaldson K, Newby DE, Jiang L. Chan JKK. Beneficial cardiovascular effect of reducing exposure to particulate air pollution with a simple facemask. *Part Fibre Toxicol*. 2009;6:8.
192. McCracken JP, Smith KR, Díaz A, Mittleman MA, Schwartz J. Chimney stove intervention to reduce long-term wood smoke exposure lowers blood pressure among Guatemalan women. *Environ Health Perspect*. 2007;115:996–1001.
193. O'Neill MS, Veves A, Zanobetti A, Sarnat JA, Gold DR, Economides PA, Horton ES, Schwartz J. Diabetes enhances vulnerability to particulate air pollution-associated impairment in vascular reactivity and endothelial function. *Circulation*. 2005;111:2913–2920.
194. Schneider A, Neas L, Herbst MC, Case M, Williams RW, Cascio W, Hinderliter A, Holguin F, Buse JB, Dungan K, Styner M, Peters A, Devlin RB. Endothelial dysfunction: associations with exposure to ambient fine particles in diabetic individuals. *Environ Health Perspect*. 2008;116:1666–1674.
195. Rundell KW, Hoffman JR, Caviston R, Bulbulian R, Hollenbach AM. Inhalation of ultrafine and fine particulate matter disrupts systemic vascular function. *Inhal Toxicol*. 2007;19:133–140.
196. Dales R, Liu L, Szyszkowicz M, Dalipaj M, Willey J, Kulka R, Ruddy TD. Particulate air pollution and vascular reactivity: the bus stop study. *Int Arch Occup Environ Health*. 2007;81:159–164.
197. Briet M, Collin C, Laurent S, Tan A, Azizi M, Agharazii M, Jeunemaitre X, Alhenc-Gelas F, Boutouyrie P. Endothelial function and chronic exposure to air pollution in normal male subjects. *Hypertension*. 2007; 50:970–976.
198. Bräuner EV, Forchhammer L, Møller P, Barregard L, Gunnarsen L, Afshari A, Wåhlin P, Glasius M, Dragsted LO, Basu S, Raaschou-Nielsen O, Loft S. Indoor particles affect vascular function in the aged: an air filtration-based intervention study. *Am J Respir Crit Care Med*. 2008;177:419–425.
199. Künzli N, Jerrett M, Mack WJ, Beckerman B, LaBree L, Gilliland F, Thomas D, Peters J, Hodis HN. Ambient air pollution and atherosclerosis in Los Angeles. *Environ Health Perspect*. 2005;113:201–206.
200. Hoffmann B, Moebus S, Möhlenkamp S, Stang A, Lehmann N, Dragano N, Schmermund A, Memmesheimer M, Mann K, Erbel R, Jöckel KH; Heinz Nixdorf Recall Study Investigative Group. Residential exposure to traffic is associated with coronary atherosclerosis. *Circulation*. 2007; 116:489–496.
201. Hoffmann B, Moebus S, Möhlenkamp S, Stang A, Lehmann N, Dragano N, Schmermund A, Memmesheimer M, Mann K, Erbel R, Jöckel KH; Heinz Nixdorf Recall Study Investigative Group. Residential exposure to urban air pollution, ankle-brachial index, and peripheral arterial disease. *Epidemiology*. 2009;20:280–288.
202. Diez Roux AV, Auchincloss AH, Franklin TG, Raghunathan T, Barr RG, Kaufman J, Astor B, Keeler J. Long-term exposure to ambient particulate matter and prevalence of subclinical atherosclerosis in the Multi-Ethnic Study of Atherosclerosis. *Am J Epidemiol*. 2008;167:667–675.
203. Allen RW, Criqui MH, Diez Roux AV, Allison M, Shea S, Detrano R, Sheppard L, Wong ND, Stukovsky KH, Kaufman JD. Fine particulate matter air pollution, proximity to traffic, and aortic atherosclerosis. *Epidemiology*. 2009;20:254–264.
204. Cavallari JM, Fang SC, Eisen EA, Schwartz J, Hauser R, Herrick RF, Christiani DC. Time course of heart rate variability decline following particulate matter exposures in an occupational cohort. *Inhal Toxicol*. 2008;20:415–422.
205. Chahine T, Baccarelli A, Litonjua A, Wright RO, Suh H, Gold DR, Sparrow D, Vokonas P, Schwartz J. Particulate air pollution, oxidative stress genes, and heart rate variability in an elderly cohort. *Environ Health Perspect*. 2007;115:1617–1622.
206. Park SK, O'Neill MS, Vokonas PS, Sparrow D, Wright RO, Coull B, Nie H, Hu H, Schwartz J. Air pollution and heart rate variability: effect modification by chronic lead exposure. *Epidemiology*. 2008;19:111–120.
207. Baccarelli A, Cassano PA, Litonjua A, Park SK, Suh H, Sparrow D, Vokonas P, Schwartz J. Cardiac autonomic dysfunction: effects from particulate air pollution and protection by dietary methyl nutrients and metabolic polymorphisms. *Circulation*. 2008;117:1802–1809.
208. Peretz A, Kaufman JD, Trenga CA, Allen J, Carlsten C, Aulet MR, Adar SD, Sullivan JH. Effects of diesel exhaust inhalation on heart rate variability in human volunteers. *Environ Res*. 2008;107:178–184.
209. Min KB, Min JY, Cho SI, Paek D. The relationship between air pollutants and heart-rate variability among community residents in Korea. *Inhal Toxicol*. 2008;20:435–444.
210. Cavallari JM, Eisen EA, Fang SC, Schwartz J, Hauser R, Herrick RF, Christiani DC. PM2.5 metal exposures and nocturnal heart rate variability: a panel study of boilermaker construction workers. *Environ Health*. 2008;7:36.
211. Cárdenas M, Vallejo M, Romano-Riquer P, Ruiz-Velasco S, Ferreira-Vidal AD, Hermosillo AG. Personal exposure to PM2.5 air pollution and heart rate variability in subjects with positive or negative head-up tilt test. *Environ Res*. 2008;108:1–6.
212. Chen JC, Cavallari JM, Stone PH, Christiani DC. Obesity is a modifier of autonomic cardiac responses to fine metal particulates. *Environ Health Perspect*. 2007;115:1002–1006.
213. Chuang KJ, Chan CC, Su TC, Lin LY, Lee CT. Associations between particulate sulfate and organic carbon exposures and heart rate variability in patients with or at risk for cardiovascular diseases. *J Occup Environ Med*. 2007;49:610–617.
214. Cavallari JM, Eisen EA, Chen JC, Fang SC, Dobson CB, Schwartz J, Christiani DC. Night heart rate variability and particulate exposures among boilermaker construction workers. *Environ Health Perspect*. 2007;115:1046–1051.
215. Adar SD, Gold DR, Coull BA, Schwartz J, Stone PH, Suh H. Focused exposures to airborne traffic particles and heart rate variability in the elderly. *Epidemiology*. 2007;18:95–103.
216. Wheeler A, Zanobetti A, Gold DR, Schwartz J, Stone P, Suh HH. The relationship between ambient air pollution and heart rate variability differs for individuals with heart and pulmonary disease. *Environ Health Perspect*. 2006;114:560–566.
217. Vallejo M, Ruiz S, Hermosillo AG, Borja-Aburto VH, Cárdenas M. Ambient fine particles modify heart rate variability in young healthy adults. *J Expo Sci Environ Epidemiol*. 2006;16:125–130.
218. Timonen KL, Vanninen E, de Hartog J, Ibald-Mulli A, Brunekreef B, Gold DR, Heinrich J, Hoek G, Lanki T, Peters A, Tarkiainen T, Tiittanen P, Kreyling W, Pekkanen J. Effects of ultrafine and fine particulate and gaseous air pollution on cardiac autonomic control in subjects with coronary artery disease: the ULTRA study. *J Expo Sci Environ Epidemiol*. 2006;16:332–341.
219. Riojas-Rodríguez H, Escamilla-Cejudo JA, González-Hermosillo JA, Téllez-Rojo MM, Vallejo M, Santos-Burgoa C, Rojas-Bracho L. Personal PM2.5 and CO exposures and heart rate variability in subjects with known ischemic heart disease in Mexico City. *J Expo Sci Environ Epidemiol*. 2006;16:131–137.
220. Luttmann-Gibson H, Suh HH, Coull BA, Dockery DW, Sarnat SE, Schwartz J, Stone PH, Gold DR. Short-term effects of air pollution on heart rate variability in senior adults in Steubenville, Ohio. *J Occup Environ Med*. 2006;48:780–788.
221. Lipsett MJ, Tsai FC, Roger L, Woo M, Ostro BD. Coarse particles and heart rate variability among older adults with coronary artery disease in the Coachella Valley, California. *Environ Health Perspect*. 2006;114: 1215–1220.
222. Chen JC, Stone PH, Verrier RL, Nearing BD, MacCallum G, Kim JY, Herrick RF, You J, Zhou H, Christiani DC. Personal coronary risk profiles modify autonomic nervous system responses to air pollution. *J Occup Environ Med*. 2006;48:1133–1142.
223. Henneberger A, Zareba W, Ibald-Mulli A, Rückerl R, Cyrys J, Couderc JP, Mykins B, Woelke G, Wichmann HE, Peters A. Repolarization changes induced by air pollution in ischemic heart disease patients. *Environ Health Perspect*. 2005;113:440–446.
224. Sullivan JH, Schreuder AB, Trenga CA, Liu SL, Larson TV, Koenig JQ, Kaufman JD. Association between short term exposure to fine particulate matter and heart rate variability in older subjects with and without heart disease. *Thorax*. 2005;60:462–466.
225. Schwartz J, Litonjua A, Suh H, Verrier M, Zanobetti A, Syring M, Nearing B, Verrier R, Stone P, MacCallum G, Speizer FE, Gold DR.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Traffic related pollution and heart rate variability in a panel of elderly subjects. *Thorax*. 2005;60:455–461.
226. Romieu I, Téllez-Rojo MM, Lazo M, Manzano-Patiño A, Cortez-Lugo M, Julien P, Bélanger MC, Hernandez-Avila M, Holguin F. Omega-3 fatty acid prevents heart rate variability reductions associated with particulate matter. *Am J Respir Crit Care Med*. 2005;172:1534–1540.
227. Park SK, O'Neill MS, Vokonas PS, Sparrow D, Schwartz J. Effects of air pollution on heart rate variability: the VA normative aging study. *Environ Health Perspect*. 2005;113:304–309.
228. Chuang KJ, Chan CC, Chen NT, Su TC, Lin LY. Effects of particle size fractions on reducing heart rate variability in cardiac and hypertensive patients. *Environ Health Perspect*. 2005;113:1693–1697.
229. Chan CC, Chuang KJ, Shiao GM, Lin LY. Personal exposure to submicrometer particles and heart rate variability in human subjects. *Environ Health Perspect*. 2004;112:1063–1067.
230. Chan CC, Chuang KJ, Su TC, Lin LY. Association between nitrogen dioxide and heart rate variability in a susceptible population. *Eur J Cardiovasc Prev Rehabil*. 2005;12:580–586.
231. Liao D, Duan Y, Whitsel EA, Zheng ZJ, Heiss G, Chinchilli VM, Lin HM. Association of higher levels of ambient criteria pollutants with impaired cardiac autonomic control: a population-based study. *Am J Epidemiol*. 2004;159:768–777.
232. Holguín F, Téllez-Rojo MM, Hernández M, Cortez M, Chow JC, Watson JG, Mannino D, Romieu I. Air pollution and heart rate variability among the elderly in Mexico City. *Epidemiology*. 2003;14:521–527.
233. Devlin RB, Ghio AJ, Kehrl H, Sanders G, Cascio W. Elderly humans exposed to concentrated air pollution particles have decreased heart rate variability. *Eur Respir J Suppl*. 2003;40:76s–80s.
234. Magari SR, Hauser R, Schwartz J, Williams PL, Smith TJ, Christiani DC. Association of heart rate variability with occupational and environmental exposure to particulate air pollution. *Circulation*. 2001;104:986–991.
235. Magari SR, Schwartz J, Williams PL, Hauser R, Smith TJ, Christiani DC. The association between personal measurements of environmental exposure to particulates and heart rate variability. *Epidemiology*. 2002;13:305–310.
236. Pope CA 3rd, Eatough DJ, Gold DR, Pang Y, Nielsen KR, Nath P, Verrier RL, Kanner RE. Acute exposure to environmental tobacco smoke and heart rate variability. *Environ Health Perspect*. 2001;109:711–716.
237. Pope CA 3rd, Verrier RL, Lovett EG, Larson AC, Raizenne ME, Kanner RE, Schwartz J, Villegas GM, Gold DR, Dockery DW. Heart rate variability associated with particulate air pollution. *Am Heart J*. 1999;138:890–899.
238. Creason J, Neas L, Walsh D, Williams R, Sheldon L, Liao D, Shy C. Particulate matter and heart rate variability among elderly retirees: the Baltimore 1998 PM study. *J Expo Anal Environ Epidemiol*. 2001;11:116–122.
239. Peters A, Perz S, Döring A, Stieber J, Koenig W, Wichmann HE. Increases in heart rate during an air pollution episode. *Am J Epidemiol*. 1999;150:1094–1098.
240. Gold DR, Litonjua A, Schwartz J, Lovett E, Larson A, Nearing B, Allen G, Verrier M, Cherry R, Verrier R. Ambient pollution and heart rate variability. *Circulation*. 2000;101:1267–1273.
241. Liao D, Creason J, Shy C, Williams R, Watts R, Zweidinger R. Daily variation of particulate air pollution and poor cardiac autonomic control in the elderly. *Environ Health Perspect*. 1999;107:521–525.
242. Dockery DW, Pope CA 3rd, Kanner RE, Martin Villegas G, Schwartz J. Daily changes in oxygen saturation and pulse rate associated with particulate air pollution and barometric pressure. *Res Rep Health Eff Inst*. 1999;1–19.
243. Park SK, O'Neill MS, Wright RO, Hu H, Vokonas PS, Sparrow D, Suh H, Schwartz J. HFE genotype, particulate air pollution, and heart rate variability: a gene-environment interaction. *Circulation*. 2006;114:2798–2805.
244. Schwartz J, Park SK, O'Neill MS, Vokonas PS, Sparrow D, Weiss S, Kelsey K. Glutathione-S-transferase M1, obesity, statins, and autonomic effects of particles: gene-by-drug-by-environment interaction. *Am J Respir Crit Care Med*. 2005;172:1529–1533.
245. Pekkanen J, Peters A, Hoek G, Tiittanen P, Brunekreef B, de Hartog J, Heinrich J, Ibald-Mulli A, Kreyling WG, Lanki T, Timonen KL, Vanninen E. Particulate air pollution and risk of ST-segment depression during repeated submaximal exercise tests among subjects with coronary heart disease: the Exposure and Risk Assessment for Fine and Ultrafine Particles in Ambient Air (ULTRA) study. *Circulation*. 2002;106:933–938.
246. Lanki T, de Hartog JJ, Heinrich J, Hoek G, Janssen NA, Peters A, Stölzel M, Timonen KL, Vallius M, Vanninen E, Pekkanen J. Can we identify sources of fine particles responsible for exercise-induced ischemia on days with elevated air pollution? The ULTRA study. *Environ Health Perspect*. 2006;114:655–660.
247. Lanki T, Hoek G, Timonen KL, Peters A, Tiittanen P, Vanninen E, Pekkanen J. Hourly variation in fine particle exposure is associated with transiently increased risk of ST segment depression. *Occup Environ Med*. 2008;65:782–786.
248. Gold DR, Litonjua AA, Zanobetti A, Coull BA, Schwartz J, MacCallum G, Verrier RL, Nearing BD, Canner MJ, Suh H, Stone PH. Air pollution and ST-segment depression in elderly subjects. *Environ Health Perspect*. 2005;113:883–887.
249. Chuang KJ, Coull BA, Zanobetti A, Suh H, Schwartz J, Stone PH, Litonjua A, Speizer FE, Gold DR. Particulate air pollution as a risk factor for ST-segment depression in patients with coronary artery disease. *Circulation*. 2008;118:1314–1320.
250. Baccarelli A, Wright RO, Bollati V, Tarantini L, Litonjua AA, Suh HH, Zanobetti A, Sparrow D, Vokonas PS, Schwartz J. Rapid DNA methylation changes after exposure to traffic particles. *Am J Respir Crit Care Med*. 2009;179:572–578.
251. Tarantini L, Bonzini M, Apostoli P, Pegoraro V, Bollati V, Marinelli B, Cantone L, Rizzo G, Hou L, Schwartz J, Bertazzi PA, Baccarelli A. Effects of particulate matter on genomic DNA methylation content and iNOS promoter methylation. *Environ Health Perspect*. 2009;117:217–222.
252. Van Hee VC, Adar SD, Szpiro AA, Barr RG, Bluemke DA, Diez Roux AV, Gill EA, Sheppard L, Kaufman JD. Exposure to traffic and left ventricular mass and function: the Multi-Ethnic Study of Atherosclerosis. *Am J Respir Crit Care Med*. 2009;179;827–834.
253. Johnson D, Parker JD. Air pollution exposure and self-reported cardiovascular disease. *Environ Res*. 2009;109:582–589.
254. Brook RD, Jerrett M, Brook JR, Bard RL, Finkelstein MM. The relationship between diabetes mellitus and traffic-related air pollution. *J Occup Environ Med*. 2008;50:32–38.
255. Kelishadi R, Mirghaffari N, Poursafa P, Gidding SS. Lifestyle and environmental factors associated with inflammation, oxidative stress and insulin resistance in children. *Atherosclerosis*. 2009;203:311–319.
256. Schlesinger RB. The health impact of common inorganic components of fine particulate matter (PM2.5) in ambient air: a critical review. *Inhal Toxicol*. 2007;19:811–832.
257. Franklin M, Koutrakis P, Schwartz P. The role of particle composition on the association between PM2.5 and mortality. *Epidemiology*. 2008;19:680–689.
258. Ostro B, Feng WY, Broadwin R, Green S, Lipsett M. The effects of components of fine particulate air pollution on mortality in California: results from CALFINE. *Environ Health Perspect*. 2007;115:13–19.
259. Peng RD, Bell ML, Geyh AS, McDermott A, Zeger SL, Samet JM, Dominici F. Emergency admissions for cardiovascular and respiratory diseases and the chemical composition of fine particle air pollution. *Environ Health Perspect*. 2009;117:957–963.
260. Bell ML, Ebisu K, Peng RD, Samet JM, Dominici F. Hospital admissions and chemical composition of fine particle air pollution. *Am J Respir Crit Care Med*. 2009;179:1115–1120.
261. Nel A, Xia T, Mädler L, Li N. Toxic potential of materials at the nanolevel. *Science*. 2006;311:622–627.
262. Stölzel M, Breitner S, Cyrys J, Pitz M, Wölke G, Kreyling W, Heinrich J, Wichmann HE, Peters A. Daily mortality and particulate matter in different size classes in Erfurt, Germany. *J Expo Sci Environ Epidemiol*. 2007;17:458–467.
263. Brunekreef B, Forsberg B. Epidemiological evidence of effects of coarse airborne particles on health. *Eur Respir J*. 2005;26:309–318.
264. Yeatts K, Svendsen E, Creason J, Alexis N, Herbst M, Scott J, Kupper L, Williams R, Neas L, Cascio W, Devlin RB, Peden DB. Coarse particulate matter (PM2.5–10) affects heart rate variability, blood lipids, and circulating eosinophils in adults with asthma. *Environ Health Perspect*. 2007;115:709–714.
265. Host S, Larrieu S, Pascal L, Blanchard M, Declercq C, Fabre P, Jusot JF, Chardon B, Le Tertre A, Wagner V, Prouvost H, Lefranc A. Short-term associations between fine and coarse particles and hospital admissions for cardiorespiratory diseases in six French cities. *Occup Environ Med*. 2008;65:544–551.
266. Kan H, London SJ, Chen G, Zhang Y, Song G, Zhao N, Jiang L, Chen B. Differentiating the effects of fine and coarse particles on daily mortality in Shanghai, China. *Environ Int*. 2007;33:376–384.
267. Puett RC, Hart JE, Yanosky JD, Paciorek C, Schwartz J, Suh H, Speizer FE, Laden F. Chronic fine and coarse particulate exposure, mortality, and coronary heart disease in the Nurses' Health Study. *Environ Health Perspect*. 2009;117:1697–1701.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

268. Hoffmann B, Moebus S, Stang A, Beck EM, Dragano N, Möhlenkamp S, Schmermund A, Memmesheimer M, Mann K, Erbel R, Jöckel KH; Heinz Nixdorf RECALL Study Investigative Group. Residence close to high traffic and prevalence of coronary heart disease. *Eur Heart J*. 2006;27:2696–2702.
269. Maynard D, Coull BA, Gryparis A, Schwartz J. Mortality risk associated with short-term exposure to traffic particles and sulfates. *Environ Health Perspect*. 2007;115:751–755.
270. Maheswaran R, Haining RP, Brindley P, Law J, Pearson T, Fryers PR, Wise S, Campbell MJ; Small-area level ecological study. Outdoor air pollution, mortality, and hospital admissions from coronary heart disease in Sheffield, UK: a small-area level ecological study. *Eur Heart J*. 2005;26:2543–2549.
271. Finkelstein MM, Jerrett M, Sears MR. Traffic air pollution and mortality rate advancement periods. *Am J Epidemiol*. 2004;160:173–177.
272. Nafstad P, Håheim LL, Wisløff T, Gram F, Oftedal B, Holme I, Hjermann I, Leren P. Urban air pollution and mortality in a cohort of Norwegian men. *Environ Health Perspect*. 2004;112:610–615.
273. Rosenlund M, Forastiere F, Stafoggia M, Porta D, Perucci M, Ranzi A, Nussio F, Perucci CA. Comparison of regression models with land-use and emissions data to predict the spatial distribution of traffic-related air pollution in Rome. *J Expo Sci Environ Epidemiol*. 2008;18:192–199.
274. Rosenlund M, Bellander T, Nordquist T, Alfredsson L. Traffic-generated air pollution and myocardial infarction. *Epidemiology*. 2009; 20:265–271.
275. Beelen R, Hoek G, Houthuijs D, van den Brandt PA, Goldbohm RA, Fischer P, Schouten LJ, Armstrong B, Brunekreef B. The joint association of air pollution and noise from road traffic with cardiovascular mortality in a cohort study. *Occup Environ Med*. 2009;66:243–250.
276. Kan H, Heiss G, Rose KM, Whitsel EA, Lurmann F, London SJ. Prospective analysis of traffic exposure as a risk factor for incident coronary heart disease: the Atherosclerosis Risk in Communities (ARIC) study. *Environ Health Perspect*. 2008;116:1463–1468.
277. Havard S, Deguen S, Zmirou-Navier D, Schillinger C, Bard D. Traffic-related air pollution and socioeconomic status: a spatial autocorrelation study to assess environmental equity on a small-area scale. *Epidemiology*. 2009;20:223–230.
278. Goodman PG, Dockery DW, Clancy L. Cause-specific mortality and the extended effects of particulate pollution and temperature exposure. *Environ Health Perspect*. 2004;112:179–185.
279. Zanobetti A, Schwartz J, Samoli E, Gryparis A, Touloumi G, Peacock J, Anderson RH, Le Tertre A, Bobros J, Celko M, Goren A, Forsberg B, Michelozzi P, Rabczenko D, Hoyos SP, Wichmann HE, Katsouyanni K. The temporal pattern of respiratory and heart disease mortality in response to air pollution. *Environ Health Perspect*. 2003;111:1188–1193.
280. Pope CA 3rd, Burnett RT, Krewski D, Jerrett M, Shi Y, Calle EE, Thun MJ. Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke: shape of the exposure-response relationship. *Circulation*. 2009;120:941–948.
281. Thomas D. Why do estimates of the acute and chronic effects of air pollution on mortality differ? *J Toxicol Environ Health A*. 2005;68: 1167–1174.
281a. Pope CA 3rd. Mortality effects of longer term exposures to fine particulate air pollution: review of recent epidemiological evidence. *Inhalant Toxicol*. 2007;19(suppl I):S33–S38.
282. Brook RD, Rajagopalan S. Air pollution and cardiovascular events. *N Engl J Med*. 356:2104–2105, 2007; author reply 2105–2106.
283. Künzli N, Medina S, Kaiser R, Quénel P, Horak F Jr, Studnicka M. Assessment of deaths attributable to air pollution: should we use risk estimates based on time series or on cohort studies? *Am J Epidemiol*. 2001;153:1050–1055.
284. Brook RD. Potential health risks of air pollution beyond triggering acute cardiopulmonary events. *JAMA*. 2008;299:2194–2196.
285. Dinno A, Glantz S. Clean indoor air laws immediately reduce heart attacks. *Prev Med*. 2007;45:9–11.
286. Kan H, London SJ, Chen G, Zhang Y, Song G, Zhao N, Jiang L, Chen B. Season, sex, age, and education as modifiers of the effects of outdoor air pollution on daily mortality in Shanghai, China: The Public Health and Air Pollution in Asia (PAPA) Study. *Environ Health Perspect*. 2008;116:1183–1188.
287. Forastiere F, Stafoggia M, Berti G, Bisanti L, Cernigliaro A, Chiusolo M, Mallone S, Miglio R, Pandolfi P, Rognoni M, Serinelli M, Tessari R, Vigotti M, Perucci CA; SISTI Group. Particulate matter and daily mortality: a case-crossover analysis of individual effect modifiers. *Epidemiology*. 2008;19:571–580.
288. Ostro BD, Feng WY, Broadwin R, Malig BJ, Green RS, Lipsett MJ. The impact of components of fine particulate matter on cardiovascular mortality in susceptible subpopulations. *Occup Environ Med*. 2008;65:750–756.
289. Zeka A, Zanobetti A, Schwartz J. Individual-level modifiers of the effects of particulate matter on daily mortality. *Am J Epidemiol*. 2006; 163:849–859.
290. Frampton. Human clinical studies of airborne pollutants. In: Gardner D, ed. *Toxicology of the Lung*. Boca Raton, Fla: Taylor & Francis; 2006: 29–82.
290a. Mühlfeld C, Rothen-Rutishauser B, Blank F, Vanhecke D, Ochs M, Gehr P. Interactions of nanoparticles with pulmonary structures and cellular responses. *Am J Physiol Lung Cell Mol Physiol*. 2008;294: L817–L829.
290b. Møller P, Jackobsen NR, Folkmann JK, Danielsen PH, Mikkelsen L, Hemmingsen JG, Vesterdal LK, Forchhammer L, Wallin K, Loft S. Role of oxidative damage in toxicity of particulates. *Free Radic Res*. 2010; 44:1–46.
291. Ghio AJ, Cohen MD. Disruption of iron homeostasis as a mechanism of biologic effect by ambient air pollution particles. *Inhal Toxicol*. 2005; 17:709–716.
292. Becher R, Bucht A, Øvrevik J, Hongslo JK, Dahlman HJ, Samuelsen JT, Schwarze PE. Involvement of NADPH oxidase and iNOS in rodent pulmonary cytokine responses to urban air and mineral particles. *Inhal Toxicol*. 2007;19:645–655.
293. Li Z, Hyseni X, Carter JD, Soukup JM, Dailey LA, Huang YC. Pollutant particles enhanced H2O2 production from NAD(P)H oxidase and mitochondria in human pulmonary artery endothelial cells. *Am J Physiol Cell Physiol*. 2006;291:C357–365.
294. Rhoden CR, Wellenius GA, Ghelfi E, Lawrence J, González-Flecha B. PM-induced cardiac oxidative stress and dysfunction are mediated by autonomic stimulation. *Biochim Biophys Acta*. 2005;1725:305–313.
295. Li Z, Carter JD, Dailey LA, Huang YC. Pollutant particles produce vasoconstriction and enhance MAPK signaling via angiotensin type I receptor. *Environ Health Perspect*. 2005;113:1009–1014.
296. Cao D, Tal TL, Graves LM, Gilmour I, Linak W, Reed W, Bromberg PA, Samet JM. Diesel exhaust particulate-induced activation of Stat3 requires activities of EGFR and Src in airway epithelial cells. *Am J Physiol Lung Cell Mol Physiol*. 2007;292:L422–429.
297. Becker S, Dailey L, Soukup JM, Silbajoris R, Devlin RB. TLR-2 is involved in airway epithelial cell response to air pollution particles. *Toxicol Appl Pharmacol*. 2005;203:45–52.
298. Huang YC, Wu W, Ghio AJ, Carter JD, Silbajoris R, Devlin RB, Samet JM. Activation of EGF receptors mediates pulmonary vasoconstriction induced by residual oil fly ash. *Exp Lung Res*. 2002;28:19–38.
299. Hollingsworth JW 2nd, Cook DN, Brass DM, Walker JK, Morgan DL, Foster WM, Schwartz DA. The role of Toll-like receptor 4 in environmental airway injury in mice. *Am J Respir Crit Care Med*. 2004;170:126–132.
300. Cho HY, Jedlicka AE, Clarke R, Kleeberger SR. Role of Toll-like receptor-4 in genetic susceptibility to lung injury induced by residual oil fly ash. *Physiol Genomics*. 2005;22:108–117.
301. Hollingsworth JW, Maruoka S, Li Z, Potts EN, Brass DM, Garantziotis S, Fong A, Foster WM, Schwartz DA. Ambient ozone primes pulmonary innate immunity in mice. *J Immunol*. 2007;179:4367–4375.
302. Fujii T, Hayashi S, Hogg JC, Mukae H, Suwa T, Goto Y, Vincent R, van Eeden SF. Interaction of alveolar macrophages and airway epithelial cells following exposure to particulate matter produces mediators that stimulate the bone marrow. *Am J Respir Cell Mol Biol*. 2002;27:34–41.
303. Rhoden CR, Ghelfi E, González-Flecha B. Pulmonary inflammation by ambient air particles is mediated by superoxide anion. *Inhal Toxicol*. 2008;20:11–15.
304. Bosson J, Pourazar J, Forsberg B, Adelroth E, Sandström T, Blomberg A. Ozone enhances the airway inflammation initiated by diesel exhaust. *Respiratory medicine*. 2007;101:1140–1146.
305. Kennedy T, Ghio AJ, Reed W, Samet J, Zagorski J, Quay J, Carter J, Dailey L, Hoidal JR, Devlin RB. Copper-dependent inflammation and nuclear factor-kappaB activation by particulate air pollution. *Am J Respir Cell Mol Biol*. 1998;19:366–378.
306. Quay JL, Reed W, Samet J, Devlin RB. Air pollution particles induce IL-6 gene expression in human airway epithelial cells via NF-kappa B Activation. *Am J Respir Cell Mol Biol*. 1998;19:98–106.
307. Veronesi B, Oortgiesen M, Carter JD, Devlin RB. Particulate matter initiates inflammatory cytokine release by activation of capsaicin and acid receptors in a human bronchial epithelial cell line. *Toxicol Appl Pharmacol*. 1999;154:106–115.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

308. Harder SD, Soukup JM, Ghio AJ, Devlin RB, Becker S. Inhalation of PM2.5 does not modulate host defense or immune parameters in blood or lung of normal human subjects. *Environmental health perspectives*. 2001;109(suppl):599–604.
309. van Eeden SF, Tan WC, Suwa T, Mukae H, Terashima T, Fujii T, Qui D, Vincent R, Hogg JC. Cytokines involved in the systemic inflammatory response induced by exposure to particulate matter air pollutants (PM(10)). *Am J Respir Crit Care Med*. 2001;164:826–830.
310. Hartz AM, Bauer B, Block ML, Hong JS, Miller DS. Diesel exhaust particles induce oxidative stress, proinflammatory signaling, and P-glycoprotein up-regulation at the blood-brain barrier. *FASEB J*. 2008;22:2723–2733.
311. Shukla A, Timblin C, BeruBe K, Gordon T, McKinney W, Driscoll K, Vacek P, Mossman BT. Inhaled particulate matter causes expression of nuclear factor (NF)-kappaB-related genes and oxidant-dependent NF-kappaB activation in vitro. *Am J Respir Cell Mol Biol*. 2000;23:182–187.
312. Boland S, Baeza-Squiban A, Fournier T, Houcine O, Gendron MC, Chévrier M, Jouvenot G, Coste A, Aubier M, Marano F. Diesel exhaust particles are taken up by human airway epithelial cells in vitro and alter cytokine production. *Am J Physiol*. 1999;276:L604–L613.
313. Törnqvist H, Mills NL, Gonzalez M, Miller MR, Robinson SD, Megson IL, Macnee W, Donaldson K, Söderberg S, Newby DE, Sandström T, Blomberg A. Persistent endothelial dysfunction in humans after diesel exhaust inhalation. *Am J Respir Crit Care Med*. 2007;176:395–400.
314. Tamagawa E, Bai N, Morimoto K, Gray C, Mui T, Yatera K, Zhang X, Xing L, Li Y, Laher I, Sin DD, Man SF, van Eeden SF. Particulate matter exposure induces persistent lung inflammation and endothelial dysfunction. *Am J Physiol Lung Cell Mol Physiol*. 2008;295:L79–L85.
315. Fujimaki H, Kurokawa Y, Yamamoto S, Satoh M. Distinct requirements for interleukin-6 in airway inflammation induced by diesel exhaust in mice. *Immunopharmacol Immunotoxicol*. 2006;28:703–714.
316. Mutlu GM, Green D, Bellmeyer A, Baker CM, Burgess Z, Rajamannan N, Christman JW, Foiles N, Kamp DW, Ghio AJ, Chandel NS, Dean DA, Sznajder JI, Budinger GR. Ambient particulate matter accelerates coagulation via an IL-6-dependent pathway. *J Clin Invest*. 2007;117:2952–2961.
317. Becker S, Mundandhara S, Devlin RB, Madden M. Regulation of cytokine production in human alveolar macrophages and airway epithelial cells in response to ambient air pollution particles: further mechanistic studies. *Toxicol Appl Pharmacol*. 2005;207(suppl):269–275.
318. Dostert C, Pétrilli V, Van Bruggen R, Steele C, Mossman BT, Tschopp J. Innate immune activation through Nalp3 inflammasome sensing of asbestos and silica. *Science*. 2008;320:674–677.
319. Sun Q, Yue P, Deiuliis JA, Lumeng CN, Kampfrath T, Mikolaj MB, Cai Y, Ostrowski MC, Lu B, Parthasarathy S, Brook RD, Moffatt-Bruce SD, Chen LC, Rajagopalan S. Ambient air pollution exaggerates adipose inflammation and insulin resistance in a mouse model of diet-induced obesity. *Circulation*. 2009;119:538–546.
320. Han JY, Takeshita K, Utsumi H. Noninvasive detection of hydroxyl radical generation in lung by diesel exhaust particles. *Free Radic Biol Med*. 2001;30:516–525.
321. Squadrito GL, Cueto R, Dellinger B, Pryor WA. Quinoid redox cycling as a mechanism for sustained free radical generation by inhaled airborne particulate matter. *Free Radic Biol Med*. 2001;31:1132–1138.
322. Baulig A, Garlatti M, Bonvallot V, Marchand A, Barouki R, Marano F, Baeza-Squiban A. Involvement of reactive oxygen species in the metabolic pathways triggered by diesel exhaust particles in human airway epithelial cells. *Am J Physiol Lung Cell Mol Physiol*. 2003;285:L671–L679.
323. Donaldson K, Stone V, Borm PJ, Jimenez LA, Gilmour PS, Schins RP, Knaapen AM, Rahman I, Faux SP, Brown DM, MacNee W. Oxidative stress and calcium signaling in the adverse effects of environmental particles (PM10). *Free Radic Biol Med*. 2003;34:1369–1382.
324. Beck-Speier I, Dayal N, Karg E, Maier KL, Schumann G, Schulz H, Semmler M, Takenaka S, Stettmaier K, Bors W, Ghio A, Samet JM, Heyder J. Oxidative stress and lipid mediators induced in alveolar macrophages by ultrafine particles. *Free Radic Biol Med*. 2005;38:1080–1092.
325. Prahalad AK, Soukup JM, Inmon J, Willis R, Ghio AJ, Becker S, Gallagher JE. Ambient air particles: effects on cellular oxidant radical generation in relation to particulate elemental chemistry. *Toxicol Appl Pharmacol*. 1999;158:81–91.
326. Dellinger B, Pryor WA, Cueto R, Squadrito GL, Hegde V, Deutsch WA. Role of free radicals in the toxicity of airborne fine particulate matter. *Chem Res Toxicol*. 2001;14:1371–1377.
327. González-Flecha B. Oxidant mechanisms in response to ambient air particles. *Mol Aspects Med*. 2004;25:169–182.
328. Ikeda M, Watarai K, Suzuki M, Ito T, Yamasaki H, Sagai M, Tomita T. Mechanism of pathophysiological effects of diesel exhaust particles on endothelial cells. *Environ Toxicol Pharmacol*. 1998;6:117–123.
329. Bai Y, Suzuki AK, Sagai M. The cytotoxic effects of diesel exhaust particles on human pulmonary artery endothelial cells in vitro: role of active oxygen species. *Free Radic Biol Med*. 2001;30:555–562.
330. Risom L, Møller P, Loft S. Oxidative stress-induced DNA damage by particulate air pollution. *Mutat Res*. 2005;592:119–137.
331. Araujo JA, Barajas B, Kleinman M, Wang X, Bennett BJ, Gong KW, Navab M, Harkema J, Sioutas C, Lusis AJ, Nel AE. Ambient particulate pollutants in the ultrafine range promote early atherosclerosis and systemic oxidative stress. *Circ Res*. 2008;102:589–596.
332. Nurkiewicz TR, Porter DW, Barger M, Millecchia L, Rao KM, Marvar PJ, Hubbs AF, Castranova V, Boegehold MA. Systemic microvascular dysfunction and inflammation after pulmonary particulate matter exposure. *Environ Health Perspect*. 2006;114:412–419.
333. Sun Q, Yue P, Ying Z, Cardounel AJ, Brook RD, Devlin R, Hwang JS, Zweier JL, Chen LC, Rajagopalan S. Air pollution exposure potentiates hypertension through reactive oxygen species-mediated activation of Rho/ROCK. *Arterioscler Thromb Vasc Biol*. 2008;28:1760–1766.
334. Sun Q, Wang A, Jin X, Natanzon A, Duquaine D, Brook RD, Aguinaldo JG, Fayad ZA, Fuster V, Lippmann M, Chen LC, Rajagopalan S. Long-term air pollution exposure and acceleration of atherosclerosis and vascular inflammation in an animal model. *JAMA*. 2005;294:3003–3010.
335. Ghelfi E, Rhoden CR, Wellenius GA, Lawrence J, Gonzalez-Flecha B. Cardiac oxidative stress and electrophysiological changes in rats exposed to concentrated ambient particles are mediated by TRP-dependent pulmonary reflexes. *Toxicol Sci*. 2008;102:328–336.
336. Nemmar A, Hoylaerts MF, Hoet PH, Dinsdale D, Smith T, Xu H, Vermylen J, Nemery B. Ultrafine particles affect experimental thrombosis in an in vivo hamster model. *Am J Respir Crit Care Med*. 2002;166:998–1004.
337. Nemmar A, Hoet PH, Dinsdale D, Vermylen J, Hoylaerts MF, Nemery B. Diesel exhaust particles in lung acutely enhance experimental peripheral thrombosis. *Circulation*. 2003;107:1202–1208.
338. Nemmar A, Hoet PH, Vermylen J, Nemery B, Hoylaerts MF. Pharmacological stabilization of mast cells abrogates late thrombotic events induced by diesel exhaust particles in hamsters. *Circulation*. 2004;110:1670–1677.
339. Nemmar A, Nemery B, Hoet PH, Vermylen J, Hoylaerts MF. Pulmonary inflammation and thrombogenicity caused by diesel particles in hamsters: role of histamine. *Am J Respir Crit Care Med*. 2003;168:1366–1372.
340. Nemmar A, Hoet PH, Vandervoort P, Dinsdale D, Nemery B, Hoylaerts MF. Enhanced peripheral thrombogenicity after lung inflammation is mediated by platelet-leukocyte activation: role of P-selectin. *J Thromb Haemost*. 2007;5:1217–1226.
341. Sun Q, Yue P, Kirk RI, Wang A, Moatti D, Jin X, Lu B, Schecter AD, Lippmann M, Gordon T, Chen LC, Rajagopalan S. Ambient air particulate matter exposure and tissue factor expression in atherosclerosis. *Inhal Toxicol*. 2008;20:127–137.
342. Cozzi E, Wingard CJ, Cascio WE, Devlin RB, Miles JJ, Bofferding AR, Lust RM, Van Scott MR, Henriksen RA. Effect of ambient particulate matter exposure on hemostasis. *Transl Res*. 2007;149:324–332.
343. Gilmour PS, Morrison ER, Vickers MA, Ford I, Ludlam CA, Greaves M, Donaldson K, MacNee W. The procoagulant potential of environmental particles (PM10). *Occup Environ Med*. 2005;62:164–171.
344. Esmon CT. Inflammation and thrombosis. *J Thromb Haemost*. 2003;1:1343–1348.
345. Nightingale JA, Maggs R, Cullinan P, Donnelly LE, Rogers DF, Kinnersley R, Chung KF, Barnes PJ, Ashmore M, Newman-Taylor A. Airway inflammation after controlled exposure to diesel exhaust particulates. *Am J Respir Crit Care Med*. 2000;162:161–166.
346. Wichers LB, Nolan JP, Winsett DW, Ledbetter AD, Kodavanti UP, Schladweiler MC, Costa DL, Watkinson WP. Effects of instilled combustion-derived particles in spontaneously hypertensive rats. Part I: Cardiovascular responses. *Inhal Toxicol*. 2004;16:391–405.
347. Cheng TJ, Hwang JS, Wang PY, Tsai CF, Chen CY, Lin SH, Chan CC. Effects of concentrated ambient particles on heart rate and blood pressure in pulmonary hypertensive rats. *Environ Health Perspect*. 2003;111:147–150.
348. Chang CC, Hwang JS, Chan CC, Wang PY, Hu TH, Cheng TJ. Effects of concentrated ambient particles on heart rate, blood pressure, and cardiac contractility in spontaneously hypertensive rats. *Inhal Toxicol*. 2004;16:421–429.
349. Ying Z, Yue P, Xu X, Zhong M, Sun Q, Mikolaj M, Wang A, Brook RD, Chen LC, Rajagopalan S. Air pollution and cardiac remodeling: a role

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

for RhoA/Rho-kinase. *Am J Physiol Heart Circ Physiol.* 2009;296: H1540–1550.
350. Bartoli CR, Wellenius GA, Diaz EA, Lawrence J, Coull BA, Akiyama I, Lee LM, Okabe K, Verrier RL, Godleski JJ. Mechanisms of inhaled fine particulate air pollution- induced arterial blood pressure changes. *Environ Health Perspect.* 2009;117:361–366.
351. Ito T, Suzuki T, Tamura K, Nezu T, Honda K, Kobayashi T. Examination of mRNA expression in rat hearts and lungs for analysis of effects of exposure to concentrated ambient particles on cardiovascular function. *Toxicology.* 2008;243:271–283.
352. Thomson E, Kumarathasan P, Goegan P, Aubin RA, Vincent R. Differential regulation of the lung endothelin system by urban particulate matter and ozone. *Toxicol Sci.* 2005;88:103–113.
353. Tankersley CG, Champion HC, Takimoto E, Gabrielson K, Bedja D, Misra V, El-Haddad H, Rabold R, Mitzner W. Exposure to inhaled particulate matter impairs cardiac function in senescent mice. *Am J Physiol Regul Integr Comp Physiol*. 2008;295:R252–263.
354. Upadhyay S, Stoeger T, Harder V, Thomas RF, Schladweiler MC, Semmler-Behnke M, Takenaka S, Karg E, Reitmeir P, Bader M, Stampfl A, Kodavanti UP, Schulz H. Exposure to ultrafine carbon particles at levels below detectable pulmonary inflammation affects cardiovascular performance in spontaneously hypertensive rats. *Part Fibre Toxicol*. 2008;5:19.
355. Niwa Y, Hiura Y, Sawamura H, Iwai N. Inhalation exposure to carbon black induces inflammatory response in rats. *Circ J*. 2008;72:144–149.
356. Suwa T, Hogg JC, Quinlan KB, Ohgami A, Vincent R, van Eeden SF. Particulate air pollution induces progression of atherosclerosis. *J Am Coll Cardiol*. 2002;39:935–942.
357. Chen LC, Nadziejko C. Effects of subchronic exposures to concentrated ambient particles (CAPs) in mice: V. CAPs exacerbate aortic plaque development in hyperlipidemic mice. *Inhal Toxicol*. 2005;17:217–224.
358. Cozzi E, Hazarika S, Stallings HW 3rd, Cascio WE, Devlin RB, Lust RM, Wingard CJ, Van Scott MR. Ultrafine particulate matter exposure augments ischemia-reperfusion injury in mice. *Am J Physiol Heart Circ Physiol*. 2006;291:H894–H903.
359. Niwa Y, Hiura Y, Murayama T, Yokode M, Iwai N. Nano-sized carbon black exposure exacerbates atherosclerosis in LDL-receptor knockout mice. *Circ J*. 2007;71:1157–1161.
360. Tsou CL, Peters W, Si Y, Slaymaker S, Aslanian AM, Weisberg SP, Mack M, Charo IF. Critical roles for CCR2 and MCP-3 in monocyte mobilization from bone marrow and recruitment to inflammatory sites. *J Clin Invest*. 2007;117:902–909.
361. Goto Y, Ishii H, Hogg JC, Shih CH, Yatera K, Vincent R, van Eeden SF. Particulate matter air pollution stimulates monocyte release from the bone marrow. *Am J Respir Crit Care Med*. 2004;170:891–897.
362. Yatera K, Hsieh J, Hogg JC, Tranfield E, Suzuki H, Shih CH, Behzad AR, Vincent R, van Eeden SF. Particulate matter air pollution exposure promotes recruitment of monocytes into atherosclerotic plaques. *Am J Physiol Heart Circ Physiol*. 2008;294:H944–H953.
363. Nurkiewicz TR, Porter DW, Hubbs AF, Stone S, Chen BT, Frazer DG, Boegehold MA, Castranova V. Pulmonary nanoparticle exposure disrupts systemic microvascular nitric oxide signaling. *Toxicol Sci*. 2009;110:191–203.
364. Lund AK, Lucero J, Lucas S, Madden MC, McDonald JD, Seagrave JC, Knuckles TL, Campen MJ. Vehicular emissions induce vascular MMP-9 expression and activity associated with endothelin-1-mediated pathways. *Arterioscler Thromb Vasc Biol*. 2009;29:511–517.
365. Cherng TW, Campen MJ, Knuckles TL, Gonzalez Bosc L, Kanagy NL. Impairment of coronary endothelial cell ET(B) receptor function after short-term inhalation exposure to whole diesel emissions. *Am J Physiol Regul Integr Comp Physiol*. 2009;297:R640–R647.
366. Hansen CS, Sheykhzade M, Møller P, Folkmann JK, Amtorp O, Jonassen T, Loft S. Diesel exhaust particles induce endothelial dysfunction in apoE−/− mice. *Toxicol Appl Pharmacol*. 2007;219:24–32.
367. Proctor SD, Dreher KL, Kelly SE, Russell JC. Hypersensitivity of prediabetic JCR:LA-cp rats to fine airborne combustion particle-induced direct and noradrenergic-mediated vascular contraction. *Toxicol Sci*. 2006;90:385–391.
368. Hansson GK. Inflammation, atherosclerosis, and coronary artery disease. *N Engl J Med*. 2005;352:1685–1695.
369. Lee MY, Griendling KK. Redox signaling, vascular function, and hypertension. *Antioxid Redox Signal*. 2008;10:1045–1059.
370. Miller MR, Borthwick SJ, Shaw CA, McLean SG, McClure D, Mills NL, Duffin R, Donaldson K, Megson IL, Hadoke PW, Newby DE. Direct impairment of vascular function by diesel exhaust particulate through reduced bioavailability of endothelium-derived nitric oxide induced by superoxide free radicals. *Environ Health Perspect*. 2009;117:611–616.
371. Watkinson WP, Campen MJ, Costa DL. Cardiac arrhythmia induction after exposure to residual oil fly ash particles in a rodent model of pulmonary hypertension. *Toxicol Sci*. 1998;41:209–216.
372. Wellenius GA, Saldiva PH, Batalha JR, Krishna Murthy GG, Coull BA, Verrier RL, Godleski JJ. Electrocardiographic changes during exposure to residual oil fly ash (ROFA) particles in a rat model of myocardial infarction. *Toxicol Sci*. 2002;66:327–335.
373. Chang CC, Hwang JS, Chan CC, Wang PY, Hu TH, Cheng TJ. Effects of concentrated ambient particles on heart rate variability in spontaneously hypertensive rats. *J Occup Health*. 2005;47:471–480.
374. Chang CC, Hwang JS, Chan CC, Cheng TJ. Interaction effects of ultrafine carbon black with iron and nickel on heart rate variability in spontaneously hypertensive rats. *Environ Health Perspect*. 2007;115: 1012–1017.
375. Chen LC, Hwang JS. Effects of subchronic exposures to concentrated ambient particles (CAPs) in mice: IV. Characterization of acute and chronic effects of ambient air fine particulate matter exposures on heart-rate variability. *Inhal Toxicol*. 2005;17:209–216.
376. Anselme F, Loriot S, Henry JP, Dionnet F, Napoleoni JG, Thuillez C, Morin JP. Inhalation of diluted diesel engine emission impacts heart rate variability and arrhythmia occurrence in a rat model of chronic ischemic heart failure. *Arch Toxicol*. 2007;81:299–307.
377. Wellenius GA, Coull BA, Batalha JR, Diaz EA, Lawrence J, Godleski JJ. Effects of ambient particles and carbon monoxide on supraventricular arrhythmias in a rat model of myocardial infarction. *Inhal Toxicol*. 2006;18:1077–1082.
378. Wellenius GA, Coull BA, Godleski JJ, Koutrakis P, Okabe K, Savage ST, Lawrence JE, Murthy GG, Verrier RL. Inhalation of concentrated ambient air particles exacerbates myocardial ischemia in conscious dogs. *Environ Health Perspect*. 2003;111:402–408.
379. Bartoli CR, Wellenius GA, Coull BA, Akiyama I, Diaz EA, Lawrence J, Okabe K, Verrier RL, Godleski JJ. Concentrated ambient particles alter myocardial blood flow during acute ischemia in conscious canines. *Environ Health Perspect.* 2009;117:333–337.
380. Wellenius GA, Batalha JR, Diaz EA, Lawrence J, Coull BA, Katz T, Verrier RL, Godleski JJ. Cardiac effects of carbon monoxide and ambient particles in a rat model of myocardial infarction. *Toxicol Sci*. 2004;80:367–376.
381. Ghio AJ, Hall A, Bassett MA, Cascio WE, Devlin RB. Exposure to concentrated ambient air particles alters hematologic indices in humans. *Inhal Toxicol*. 2003;15:1465–1478.
382. Mills NL, Robinson SD, Fokkens PH, Leseman DL, Miller MR, Anderson D, Freney EJ, Heal MR, Donovan RJ, Blomberg A, Sandström T, MacNee W, Boon NA, Donaldson K, Newby DE, Cassee FR. Exposure to concentrated ambient particles does not affect vascular function in patients with coronary heart disease. *Environ Health Perspect*. 2008;116:709–715.
383. Samet JM, Graff D, Berntsen J, Ghio AJ, Huang YC, Devlin RB. A comparison of studies on the effects of controlled exposure to fine, coarse and ultrafine ambient particulate matter from a single location. *Inhal Toxicol.* 2007;19(suppl):29–32.
384. Mills NL, Törnqvist H, Robinson SD, Gonzalez M, Darnley K, MacNee W, Boon NA, Donaldson K, Blomberg A, Sandstrom T, Newby DE. Diesel exhaust inhalation causes vascular dysfunction and impaired endogenous fibrinolysis. *Circulation*. 2005;112:3930–3936.
385. Mills NL, Törnqvist H, Gonzalez MC, Vink E, Robinson SD, Söderberg S, Boon NA, Donaldson K, Sandström T, Blomberg A, Newby DE. Ischemic and thrombotic effects of dilute diesel-exhaust inhalation in men with coronary heart disease. *N Engl J Med*. 2007;357:1075–1082.
386. Carlsten C, Kaufman JD, Peretz A, Trenga CA, Sheppard L, Sullivan JH. Coagulation markers in healthy human subjects exposed to diesel exhaust. *Thromb Res*. 2007;120:849–855.
387. Tan WC, Qiu D, Liam BL, Ng TP, Lee SH, van Eeden SF, D'Yachkova Y, Hogg JC. The human bone marrow response to acute air pollution caused by forest fires. *Am J Respir Crit Care Med*. 2000;161:1213–1217.
388. van Eeden SF, Yeung A, Quinlam K, Hogg JC. Systemic response to ambient particulate matter: relevance to chronic obstructive pulmonary disease. *Proc Am Thorac Soc*. 2005;2:61–67.
389. Gong H, Linn WS, Terrell SL, Anderson KR, Clark KW, Sioutas C, Cascio WE, Alexis N, Devlin RB. Exposures of elderly volunteers with and without chronic obstructive pulmonary disease (COPD) to concentrated ambient fine particulate pollution. *Inhal Toxicol*. 2004;16:731–744.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

390. Brook RD, Urch B, Dvonch JT, Bard RL, Speck M, Keeler G, Morishita M, Marsik FJ, Kamal AS, Kaciroti N, Harkema J, Corey P, Silverman F, Gold DR, Wellenius G, Mittleman MA, Rajagopalan S, Brook JR. Insights into the mechanisms and mediators of the effects of air pollution exposure on blood pressure and vascular function in healthy humans. *Hypertension*. 2009;54:659–667.
391. Frampton MW, Stewart JC, Oberdörster G, Morrow PE, Chalupa D, Pietropaoli AP, Frasier LM, Speers DM, Cox C, Huang LS, Utell MJ. Inhalation of ultrafine particles alters blood leukocyte expression of adhesion molecules in humans. *Environ Health Perspect*. 2006;114:51–58.
392. Beckett WS, Chalupa DF, Pauly-Brown A, Speers DM, Stewart JC, Frampton MW, Utell MJ, Huang LS, Cox C, Zareba W, Oberdörster G. Comparing inhaled ultrafine versus fine zinc oxide particles in healthy adults: a human inhalation study. *Am J Respir Crit Care Med*. 2005; 171:1129–1135.
393. Routledge HC, Manney S, Harrison RM, Ayres JG, Townend JN. Effect of inhaled sulphur dioxide and carbon particles on heart rate variability and markers of inflammation and coagulation in human subjects. *Heart*. 2006;92:220–227.
394. Peretz A, Peck EC, Bammler TK, Beyer RP, Sullivan JH, Trenga CA, Srinouanprachnah S, Farin FM, Kaufman JD. Diesel exhaust inhalation and assessment of peripheral blood mononuclear cell gene transcription effects: an exploratory study of healthy human volunteers. *Inhal Toxicol*. 2007;19:1107–1119.
395. Barregard L, Sällsten G, Gustafson P, Andersson L, Johansson L, Basu S, Stigendal L. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation. *Inhal Toxicol*. 2006;18:845–853.
396. Rangasamy T, Cho CY, Thimmulappa RK, Zhen L, Srisuma SS, Kensler TW, Yamamoto M, Petrache I, Tuder RM, Biswal S. Genetic ablation of Nrf2 enhances susceptibility to cigarette smoke-induced emphysema in mice. *J Clin Invest*. 2004;114:1248–1259.
397. Ghio AJ, Kim C, Devlin RB. Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers. *Am J Respir Crit Care Med*. 2000;162:981–988.
398. Carlsten C, Kaufman JD, Trenga CA, Allen J, Peretz A, Sullivan JH. Thrombotic markers in metabolic syndrome subjects exposed to diesel exhaust. *Inhal Toxicol*. 2008;20:917–921.
399. Lucking AJ, Lundback M, Mills NL, Faratian D, Barath SL, Pourazar J, Cassee FR, Donaldson K, Boon NA, Badimon JJ, Sandstrom T, Blomberg A, Newby DE. Diesel exhaust inhalation increases thrombus formation in man. *Eur Heart J*. 2008;29:3043–3051.
400. Brook RD, Rajagopalan S. Particulate matter, air pollution, and blood pressure. *J Am Soc Hypertens*. 2009;3:332–350.
401. Gong H Jr, Linn WS, Sioutas C, Terrell SL, Clark KW, Anderson KR, Terrell LL. Controlled exposures of healthy and asthmatic volunteers to concentrated ambient fine particles in Los Angeles. *Inhal Toxicol*. 2003; 15:305–325.
402. Brook RD, Brook JR, Urch B, Vincent R, Rajagopalan S, Silverman F. Inhalation of fine particulate air pollution and ozone causes acute arterial vasoconstriction in healthy adults. *Circulation*. 2002;105:1534–1536.
403. Frampton MW. Systemic and cardiovascular effects of airway injury and inflammation: ultrafine particle exposure in humans. *Environ Health Perspect*. 2001;109(suppl):529–532.
404. Urch B, Silverman F, Corey P, Brook JR, Lukic KZ, Rajagopalan S, Brook RD. Acute blood pressure responses in healthy adults during controlled air pollution exposures. *Environ Health Perspect*. 2005;113:1052–1055.
405. Urch B, Brook JR, Wasserstein D, Brook RD, Rajagopalan S, Corey P, Silverman F. Relative contributions of PM2.5 chemical constituents to acute arterial vasoconstriction in humans. *Inhal Toxicol*. 2004;16:345–352.
406. Peretz A, Sullivan JH, Leotta DF, Trenga CA, Sands FN, Allen J, Carlsten C, Wilkinson CW, Gill EA, Kaufman JD. Diesel exhaust inhalation elicits acute vasoconstriction in vivo. *Environ Health Perspect*. 2008;116:937–942.
407. Shah AP, Pietropaoli AP, Frasier LM, Speers DM, Chalupa DC, Delehanty JM, Huang LS, Utell MJ, Frampton MW. Effect of inhaled carbon ultrafine particles on reactive hyperemia in healthy human subjects. *Environ Health Perspect*. 2008;116:375–380.
408. Duffin R, Tran L, Brown D, Stone V, Donaldson K. Proinflammogenic effects of low-toxicity and metal nanoparticles in vivo and in vitro: highlighting the role of particle surface area and surface reactivity. *Inhal Toxicol*. 2007;19:849–856.
409. Oberdörster G, Oberdörster E, Oberdörster J. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. *Environ Health Perspect*. 2005;113:823–839.
410. Gong H Jr, Linn WS, Terrell SL, Clark KW, Geller MD, Anderson KR, Cascio WE, Sioutas C. Altered heart-rate variability in asthmatic and healthy volunteers exposed to concentrated ambient coarse particles. *Inhal Toxicol*. 2004;16:335–343.
411. Bartoli CR, Wellenius GA, Diaz EA, Lawrence J, Coull BA, Akiyama I, Lee LM, Okabe K, Verrier RL, Godleski JJ. Mechanisms of inhaled fine particulate air pollution-induced arterial blood pressure changes. *Environ Health Perspect*. 2009;117:361–366.
412. Wallenborn JG, McGee JK, Schladweiler MC, Ledbetter AD, Kodavanti UP. Systemic translocation of particulate matter-associated metals following a single intratracheal instillation in rats. *Toxicol Sci*. 2007;98: 231–239.
413. Phalen RF, Oldham MJ, Nel AE. Tracheobronchial particle dose considerations for in vitro toxicology studies. *Toxicol Sci*. 2006;92: 126–132.
414. Kreyling WG, Semmler-Behnke M, Möller W. Ultrafine particle-lung interactions: does size matter? *J Aerosol Med*. 2006;19:74–83.
415. Peters A, Veronesi B, Calderón-Garcidueñas L, Gehr P, Chen LC, Geiser M, Reed W, Rothen-Rutishauser B, Schürch S, Schulz H. Translocation and potential neurological effects of fine and ultrafine particles a critical update. *Part Fibre Toxicol*. 2006;3:13.
416. Mills NL, Amin N, Robinson SD, Anand A, Davies J, Patel D, de la Fuente JM, Cassee FR, Boon NA, Macnee W, Millar AM, Donaldson K, Newby DE. Do inhaled carbon nanoparticles translocate directly into the circulation in humans? *Am J Respir Crit Care Med*. 2006;173:426–431.
417. Furuyama A, Kanno S, Kobayashi T, Hirano S. Extrapulmonary translocation of intratracheally instilled fine and ultrafine particles via direct and alveolar macrophage-associated routes. *Arch Toxicol*. 2009;83:429–437.
418. Knol AB, de Hartog JJ, Boogaard H, Slottje P, van der Sluijs JP, Lebret E, Cassee FR, Wardekker JA, Ayres JG, Borm PJ, Brunekreef B, Donaldson K, Forastiere F, Holgate ST, Kreyling WG, Nemery B, Pekkanen J, Stone V, Wichmann HE, Hoek G. Expert elicitation on ultrafine particles: likelihood of health effects and causal pathways. *Part Fibre Toxicol*. 2009;6:19.
419. Ruidavets JB, Cournot M, Cassadou S, Giroux M, Meybeck M, Ferrières J. Ozone air pollution is associated with acute myocardial infarction. *Circulation*. 2005;111:563–569.
420. Bell ML, Peng RD, Dominici F, Samet JM. Emergency hospital admissions for cardiovascular diseases and ambient levels of carbon monoxide: results for 126 United States urban counties, 1999–2005. *Circulation*. 2009;120:949–955.
421. Hill AB. The environment and disease: association or causation? *Proc R Soc Med*. 1965;58:295–300.
422. Wen XJ, Balluz L, Mokdad A. Association between media alerts of air quality index and change of outdoor activity among adult asthma in six states, BRFSS, 2005. *J Community Health*. 2009;34:40–46.
423. Bell ML, Ebisu K, Peng RD, Dominici F. Adverse health effects of particulate air pollution: modification by air conditioning. *Epidemiology*. 2009; 20:682–686.
424. Pui DY, Qi C, Stanley N, Oberdörster G, Maynard A. Recirculating air filtration significantly reduces exposure to airborne nanoparticles. *Environ Health Perspect*. 2008;116:863–866.
425. Zhu Y, Eiguren-Fernandez A, Hinds WC, Miguel AH. In-cabin commuter exposure to ultrafine particles on Los Angeles freeways. *Environ Sci Technol*. 2007;41:2138–2145.
426. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Trans R Soc Trop Med Hyg*. 2008;102:843–851.

Downloaded from http://circ.ahajournals.org/ by guest on July 24, 2011

Position Statement on Coal Exports from
Concerned Oregon Physicians to Governor Kitzhaber
July 19, 2012

Multinational coal companies propose to send coal mined in the Powder River Basin by rail and barge through the Pacific Northwest to be loaded onto large ships and exported to Asia. If current proposals are approved, that could result in more than 150 million tons of coal shipped each year. An average of 26 loaded coal trains, each one-mile long (or longer) with over 100 cars propelled by four diesel engines, could pass through Oregon and/or Washington every day. This will result in the release of significant amounts of airborne pollutants and related disease from diesel engines and coal dust. The increased train traffic will also cause significant delays at many rail crossings, increased risk of vehicle and pedestrian injuries along the tracks, and increased noise pollution. As a group of Oregon physicians, we are deeply concerned about the health and safety impacts these proposals.

A group of Washington physicians has carefully reviewed data published in peer-reviewed medical journals which show that:

Diesel particulate matter is associated with: (See *Appendix A*, *Appendix C)*

- impaired pulmonary development in adolescents;
- increased cardiopulmonary mortality and all-cause mortality;
- measurable pulmonary inflammation;
- increased severity and frequency of asthma attacks, ER visits, and hospital admissions in children;
- increased rates of myocardial infarction (heart attack) in adults; and
- increased risk of ischemic stroke.

Coal dust is associated with: (See *Appendix B*)

- chronic bronchitis;
- emphysema;
- pulmonary fibrosis (pneumoconiosis); and
- environmental contamination through the leaching of toxic heavy metals.

Noise exposure causes: (See *Appendix D*)

- cardiovascular disease, including increased blood pressure, arrhythmia,
- stroke, and ischemic heart disease;
- cognitive impairment in children;
- sleep disturbance and resultant fatigue, hypertension, arrhythmia, and increased rate of accidents and injuries; and
- exacerbation of mental health disorders such as depression, stress and anxiety, and psychosis.

Frequent long trains at rail crossings will mean: (See *Appendix E*)

- delayed emergency medical service response times; and

- increased accidents, traumatic injury and death.

More recent research published in major medical journals augments prior concerns including, but not limited to: (See *Appendix F*)

- increased risk of lung cancer.

Additionally, several recent studies have shown that powerful spring trade winds can carry Asian pollution into the atmosphere above North America**.** Some of the imported pollution descends to the surface, where it affects ground-level concentrations of ozone, mercury, sulfur compounds and soot. Ground-level ozone can cause severe respiratory problems, including asthma, in susceptible individuals.

A 2008 study (see *Appendix G*) found that Asian emissions of mercury contribute 18% of springtime mercury concentrations at Mount Bachelor. Snowpack runoff ends up in our rivers and lakes where the mercury contaminates the fish we eat. Pregnant women and children are particularly vulnerable to the toxic effects of mercury. Mercury is a potent neurotoxin that can damage developing brains in fetuses and children.

The effects of air pollution are not hypothetical, but real and measurable. Many of the reviewed studies show significant health effects of exposure to everyday airborne pollutant levels that are below national U.S. Environment Protection Agency (EPA) guidelines. The data show a linear effect with no specific "safe threshold."

The conclusion that airborne pollutants pose a significant and measurable health risk was also reached by the American Lung Association, in their review, "State of the Air 2011,"and by the American Heart Association, in their 2011 review, "Particulate Matter Air Pollution and Cardiovascular Disease."

As physicians, we believe the risks to human health from massive coal shipments across our state, down the Columbia River, and through our communities are significant. We are particularly concerned with the health of our most vulnerable populations: prenatal, early childhood, the elderly and those with pre-existing conditions. We must identify likely exposures for affected workers and individuals all along the line, from the mines to the trains, to the barges, and to the ports of the Northwest. We want to prevent new sources of morbidity and mortality. We seek your help in doing so.

Specifically, we request that you call for and examine both a comprehensive Health Impact Assessment (to include cumulative effects) and a programmatic Environmental Impact Statement before any coal export facility, infrastructure or related transport is approved by any Oregon state agency.

With respect,

A. Sonia Buist, MD, PhD

Jonathan Betlinski, MD

Jon A. Blackman, MD

Nathan K. Boddie, MD, MS

Harriet Cooke, MD, MPH

Thomas G. Cooney, MD

Nancy Crumpacker, MD

Rhett Cummings, MD

Maggie Bennington-Davis, MD

Mary Ellen Coulter, MD

Linda De Sitter, MD

Maxine Dexter, MD

Stone Doggett, MD

Martin Donohoe, MD

Lucy M. Douglass, MD

Patrick Dunn, MD

Grace Dunsmore, MD

Catherine Ellison, MD

Frank Erickson, MD

George Feldman, MD

Virginia Feldman, MD

Larry G. Fickenscher, MD

Bruce Free, DO

Nick Gideonse, MD

Bradford J. Glavan, MD

Marshall Goldberg, MD, MPH

Charles Grossman, MD

Keith Harcourt, MD

Andrew Harris, MD

William K. Harris, MD

Arthur D. Hayward, MD

Ron Heintz, MD

William S. Herz, MD

John Howieson, MD

Linda Humphrey, MD

Lyn Jacobs, MD

Lawrence Jacobson, MD

Paul Kaplan, MD

Susan Katz, MD

Joel Kay, MD

Steve Kohl, MD

Jay D. Kravitz, MD, MPH

Rod Krehbiel, MD

Michael Lefor, MD

Louis Libby, MD

Holger Link, MD

Cat Livingston, MD, MPH

Rebecca MacGregor, MD

Janet Madill, MD

Marissa Maier, MD

Jack McAnulty, MD

Robert A. McFarlane, MD

James Metcalfe, MD

Susan Mikkelson, MD

Craig Miller, MD

Mizuho Mimoto, MD

Marwan Mouammar, MD

John Muench, MD, MPH

Richard A. Mularski, MD

Phil Newman, MD

Paul Norman, MD

William Nunley, MD, MPH

Melissa Nyendak, MD, MHS

Philip Paden, MD

James R. Patterson, MD

John Partridge, MD

John Pearson, MD

Carolyn Polansky, MD

David A. Pollack, MD

Jenny Pompilio MD, MPH

J. Powell, MD

Martin Raitiere, MD

Bonnie Reagan, MD

Peter Reagan, MD

Jonathan A. Rettman, MD

James B. Reuler, MD

Vincent P. Reyes, MD

Eric Richards, MD

Robert H. Richardson, MD

Constance Rosson, MD

David Ruud, MD

Irene Saikevych, MD

Anne Sammis, MD

Thomas Schaumberg, MD

Christine Schjelderup-Free, MD

James P. Scott, MD

John F. Schilke, MD

Jerry M. Slepack, MD

Sharon Smith, MD

Praseeda R. Sridharan, MD

Elizabeth Steiner, MD

Karen Steingart, MD, MPH

Tom Stibolt, MD

Frances Storrs, MD

Renee Stronglamill, MD

Richard U'Ren, MD

Andrew J. Uri, MD

Thomas T. Ward, MD

Lanier Williams, MD

William H. Wilson, MD

C. Todd Woolley, MD

Douglas Walta, MD

Philip Wu, MD

Maureen Becker, ND, LAc

Audrey Bergsma, ND

Alicia Bigelow, ND

Meghan Brinson, ND

Patrick Chapman, ND

Joe Coletto, ND, LAc

John Collins, ND

Stephanie Kaplan, ND

Jeanette Lyons, ND

Patricia Murphy, ND, LAc

Patricia J. Meyer, ND

David Naimon, ND

Bonnie Neilnu, ND

Peggy Rollo, ND, LAc

Alison Schulz, ND

Rene Schwartz, ND

Igor Schwartzman, ND

Robert Sklovsky, Pharm.D., ND

Drew Scott, ND

Mary Scott, ND, LAc

Lisa Shaver, ND

Eric F. Stephens, DAOM, LAc

Patricia Timberlake, LCSW, ND

Laura Torgerson, ND

Nigel David Adler, DC, LAc

Laura Baffes, DC

Cathy Cummins, DC

Hari Dass Khalsa, DC

Key References:

American Heart Association statement

American Lung Association statement

Puget Sound Clear Air Agency document

Appendices:

Download Appendix A: Pulmonary Impacts of Airborne Pollutants (including diesel particulate matter) (PDF, 152 KB)
Download Appendix B: Health Impacts of Coal Dust (PDF, 94 KB)
Download Appendix C: Cardiovascular Impacts of Airborne Pollutants (including particulate matter) (PDF, 86 KB)
Download Appendix D: Health Impacts of Noise Pollution (PDF, 94 KB)
Download Appendix E: Anticipated Impacts of Frequent Long Trains on Emergency Medical Service Response Times and Risk of Injuries at Crossings (PDF, 82 KB)
Download Appendix F: March 12, 2012 Letter from Whatcom, Skagit and King County Physicians (PDF, 304 KB)
Download Appendix G: "Trans-Pacific Transport of Mercury" (PDF)

APPENDIX A: Pulmonary Impacts of Airborne Pollutants (including diesel particulate matter):

The notion that air pollution can have a direct and measurable impact on human health is not a new one. On Dec. 5, 1952, a London temperature inversion led to an increase in airborne fossil fuel pollutants that caused an estimated excess 4000 deaths. Similar acute events have been observed in Belgium and Pennsylvania (Schenker, M. editorial 1993, *New Engl J Med* 329(24):1807-1808). Since that time, and particularly in the 1990's and 2000's, numerous studies have been conducted that demonstrate measurable adverse effects associated with pollutant levels, not just associated with severe inversions, but at ongoing levels that currently exist in the United States.

Airborne pollution can be measured by multiple parameters, including carbon monoxide, ozone, NO_2, NO_3, and particulate matter (PM). Much focus has been on $PM_{2.5}$, which refers to particulate matter with particle diameter < 2.5 microns. These particles appear to be particularly deleterious to health, as the small size enables deposition in the distal pulmonary air spaces. The EPA has recognized this, and strengthened $PM_{2.5}$ standards 2006 to 35ug/mm^3 daily, and 15ug/mm^3 annual average. $PM_{2.5}$ in the Puget Sound area is usually between 5 and 30, often 40, with spikes up to 60 ug/mm^3. The majority of particulate matter is derived from combustion of fossil fuels, particularly diesel. Coal dust also contributes to particulate matter.

The pulmonary health impact of air pollution has been measured in many ways. These include measurements of lung function (pulmonary function studies), measurements of lung inflammation, increased rate and severity of asthma attacks, increased ER visits and hospital admissions, and remarkably, even increased death rates (mortality rates). These studies show data of statistical significance, and some of the studies have even been done in the Puget Sound area, with exposure to everyday pollutant levels that are often below national EPA guidelines.

Listed below are key findings of relevant studies, divided into sections regarding A) impaired pulmonary development and function; B) increased childhood asthma attacks, ER visits, and hospitalizations; and C) increased mortality and decreased life expectancy. These studies are not relegated to obscure journals; most of these are in major peer-reviewed medical journals. A more complete description of each listed study can be found at the end of this appendix in "Summary of Studies," and further details can be found in the primary references.

A. Impaired pulmonary development and function:

Airborne pollution has been associated with:

- Reduction in pulmonary development in adolescents, measured by decreased pulmonary function test (PFT) results in adolescents. (Gauderman, W. et al. 2004. The effect of air pollution on lung development from 10 to 18 years of age. *New Engl J Med* 351(11):1057-1067).
- Decreased pulmonary function in young, healthy people, measured at pollution levels far below EPA standards. (Thaller, E. et al. 2008. Moderate increases in ambient $PM_{2.5}$ and ozone are associated with lung function decreases in beach lifeguards. *J Occup Environ Med*. 50:202-211.)
- Measurable pulmonary inflammation, induced by airborne particulate matter, which may be undetectable by symptoms or pulmonary function tests. (Ghio, A. J et al. 2000. Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers. *Am J Respir Crit Care Med* 162: 981-2000).

B. Childhood asthma attacks, ER visits, and hospital admissions:

Airborne pollution has been associated with:

- Increased frequency and severity of asthma attacks in children; a 10ug/m^3 increase in $PM_{2.5}$ was associated with a 1.2 fold increase chance of having a severe attack (including a prolonged attack lasting >2 hr). Study done in Seattle; Seattle area shown to range between 10 and 60 ug/m^3, with most days between 10 and 40. (Slaughter, J. C. et al. 2003. Effects of ambient air pollution on symptom severity and medication use in children with asthma. *Ann Allergy Asthma & Immunol* 91:346-353.)

- Increased ER visits in children, with a relative risk of 1.15 for every increase in PM_{10} of 11ug/mm3. This study was conducted in Seattle, and the effect was observed even when $PM_{2.5}$ was below the National Ambient Air Quality Standards of 15ug/mm^3. (Norris, G. et al. 1999. An association between fine particles and asthma emergency department visits for children in Seattle. *Environ Health Perspect* 107:489-493.)

- Increased hospital admissions for children with asthma, with an odds ratio of 1.93 for those living within 200m of roads traveled by diesel trucks. Diesel trucks are noted to produce as much as 100x as much particulate matter as gasoline-powered vehicles. (Lin, S. et al. 2002. Childhood asthma hospitalization and residential exposure to state route traffic. *Environ Res* Sect A 88:73-81.)

- Increased risk of hospital admissions for pneumonia, acute bronchitis, and asthma. Children < 5 were particularly susceptible. Increased risk of 4-7% were observed for each interquartile range. (Ostro, B. et al. 2009. The effects of fine particle components on respiratory hospital admissions in children. *Environ Health Perspect* 117(3):475-480.)

C. Increased mortality and decreased life expectancy:

Airborne pollution has been associated with:

- Increased mortality in more heavily polluted cities. A relative risk of 1.26 was identified for living in the most heavily polluted city than the least polluted city. This relative risk was equivalent to that of a 25 pack-year smoking history. (Dockery, D. et al. 1993. An association between air pollution and mortality in six US cities. *New Engl J Med* 329(24): 1753-1759.)

- Increased cardiopulmonary mortality in cities with higher particulate matter, with relative risk of 1.26-1.31, corresponding to 8 to 10 deaths/year/100,000 people in metropolitan areas (Pope, C. A. III et al. 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *Am J Respir Crit Care* Med 151: 669-674.)

- Increased cardiopulmonary mortality, with a linear relationship of 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality for each 10 ug/m^3 increase in $PM_{2.5}$ (Pope, C. A. III et al. 2002 Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA* 287: 1132-1141.)

- Increased risk of all-cause and cardiopulmonary mortality associated with long term exposure to $PM_{2.5}$ and constituents. A 10 ug/mm3 increase in $PM_{2.5}$ was associated with a mortality hazard ratio of 2.05. The ranges of $PM_{2.5}$ in this study are similar to those observed in the Seattle area. (Ostro. B. et al. Long-term exposure to constituents of fine particulate air pollution and mortality: results from the California Teachers Study. *Environ Health Perspect* 118(3):363-

369.)

- Decreased life expectancy, of 0.7 to 1.6 years of life expectancy due to long-term exposure to $PM_{2.5}$ of 10 ug/mm^3. Accordingly, improving air quality can result in a measurable increase in life expectancy, demonstrating that public policy regarding protection of air quality can have a measurable impact on life expectancy. (Pope, C. A. et al. 2009. Fine-particulate matter air pollution and life expectancy in the United States. *New Engl J Med* 360(4):376-386.)

The conclusion that airborne pollutants pose a significant and measurable health risk was also found by the American Lung Association, in its review "State of the Air 2011". Specifically, they concluded that the data collectively shows increased risk of death from respiratory and cardiovascular causes, including strokes and lung cancer; increased mortality in infants and young children; increased numbers of heart attacks, especially among the elderly and in people with heart conditions; inflammation of lung tissue in young, healthy adults; increased hospitalization for cardiovascular disease, including strokes and congestive heart failure; increased emergency room visits for patients suffering from acute respiratory ailments; increased hospitalization for asthma among children, and increased severity of asthma attacks in children. According to the American Lung Association, "The evidence warns that the death toll is high. Although no national tally exists, California just completed an analysis that estimates that 9,200 people in California die annually from breathing particle pollution..." (http://www.stateoftheair.org/2011/assets/SOTA2011.pdf)

The EPA also conducted a thorough review of the current research on particle pollution in December 2009. The Clean Air Scientific Advisory Committee consisted of a panel of expert scientists, who concluded that particle pollution caused multiple, serious threats to health. They found that pollution causes early death (both short-term and long-term exposure), cardiovascular harm (heart attacks, strokes, heart disease, congestive heart failure), respiratory harm (worsened asthma, worsened COPD, inflammation), and may cause cancer and reproductive and developmental harm. (American Lung Association, State of the Air 2011)

Puget Sound is also in particular danger from airborne pollutants. The National-Scale Air Toxics Assessment (NATA), a study also by the EPA, indicated that the Puget Sound region ranks in the country's top 5% of risk for exposure to toxic air pollution, with risks including cancer, heart disease, lung damage, and nerve damage. "According to this study, diesel- and gasoline-powered engines account for over 90 percent of the risk from air toxics to Puget Sound residents," said Craig Kenworthy, Executive Director of the Puget Sound Clean Air Agency. "If we're serious about protecting public health, we must redouble our efforts as a region to reduce pollution from vehicles and diesel pollution in particular."http://www.pscleanair.org/news/newsroom/releases 2011/03_11_11_NATA.aspx

Consistent with this view, the Puget Sound Clean Air Agency (representing King, Kitsap, Pierce, and Snohomish Counties) assembled the Particle Matter Health Committee, which felt that federal standards were not sufficiently protective for human health, and set goals for $PM_{2.5}$ of 25ug/mm^3 daily, and 15ug/mm^3 annual average. (The 2006 EPA standards for $PM_{2.5}$ are 35ug/mm^3 daily, and 15ug/mm^3 annual average.) It is noted that of the four represented counties, two violate the federal standards, and three violate the goals of the Puget Sound Clean Air Agency. (http://www.pscleanair.org)

In summary, the adverse effects of air pollutants, which largely represent diesel combustion particular matter but would also include coal dust, are not hypothetical. A multitude of studies show real and measureable effects, not only in high exposure areas (such as coal mines) but also with normal routine environmental exposures (even within federal guidelines), and in the Puget Sound area. These effects can be measured in many ways, and include direct measurements of inflammation in the lungs and pulmonary function tests, increased asthma attacks, increased ER visits, increased hospital admissions, and even increased mortality rates (including by cardiopulmonary causes, lung cancer, and

remarkably, even overall mortality). The represented studies have statistically significant data, show a linear effect, and indicate that there is no purely safe threshold.

This is not a hypothetical issue. The data indicates that adding additional large sources of diesel and particulate matter pollution in the Puget Sound region would exacerbate human health problems that are already documented to be present.

References/Summaries of Studies: Mortality & Life Expectancy

Pope, C. A. et al. 2009. **Fine-particulate matter air pollution and life expectancy in the United States**. *New Engl J Med* 360(4):376-386.
The life expectancy of 51 metropolitan areas spread across the United States was compared from 1979-1983 and 1999-2000. During this time period, particle air pollution decreased by an average of 6.52 ug/mm^3, and life expectancy increased 2.72 years. Prior indirect calculations reportedly showed a loss of 0.7 to 1.6 years of life expectancy due to long-term exposure to $PM_{2.5}$ of 10 ug/mm^3. In this study, after adjustment for socioeconomic, demographic, and proxy variables for smoking, a decrease of $PM_{2.5}$ of 10ug/mm3 was associated with an increase in life expectancy of 0.61 years. This study shows that public policy (enforcement of clean air standards) can have a measurable impact in life expectancy.

Dockery, D. et al. 1993. **An association between air pollution and mortality in six U.S. cities**. *New Engl J Med* 329(24): 1753-1759.
8111 people living in 6 different cities were studied over a 14-16 year period (111,076 person-years). The 6 cities chosen have varying levels of pollution, which were stratified with 6 measurements (including particulate matter). Causes of death were analyzed. Increased mortality was associated with cigarette smoking (RR 1.59 for current smokers, 1.26 for a 25 pack-year history), obesity (RR 1.08), and ambient air pollution (RR 1.26 when comparing the most and least polluted cities, $p< 0.001$). The increased mortality was restricted to cardiopulmonary-related deaths (including lung cancer), persisted after controlling for hypertension, smoking, and occupational exposure, and showed a dose-response curve when examining the cities from least-polluted to most-polluted. There was not an increased risk of death due to non-cardiopulmonary causes. This study demonstrates that people living in more polluted cities have a significant mortality increase that is equivalent to a 25 pack-year smoking history.

Pope, C. A. III et al. 1995. **Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults**. *Am J Respir Crit Care Med* 151: 669-674.
Data from 552,138 people living in 151 US metropolitan areas was used to determine relative risk for death by living in more polluted cities (as measured by particulate air pollution, predominantly generated by burning fossil fuels). Increased mortality due to cardiopulmonary causes was associated with current smoking (RR 2.28) and living in cities with higher particulate matter (RR 1.26 when measured by sulfite particles, and 1.31 when measured by elevated fine particles, $p<0.001$). The association with air pollution was consistent among smokers and nonsmokers. This corresponds to an increase of 8 to 10 deaths/year/100,000 people. This study confirms Dockery's observations that deaths due to air pollution in US communities can be measured.

Ostro. B. et al. 2009. **Long-term exposure to constituents of fine particulate air pollution and mortality: results from the California Teachers Study**. *Environ Health Perspect* 118(3):363-369.
Data from the California Teachers Study (encompassing 45,000 active and former teachers, with 2600 deaths, over a 5 year period) was analyzed to examine correlates between air pollution (with monthly averages of $PM_{2.5}$ constituents) and mortality causes. Long term exposure to $PM_{2.5}$ and constituents was associated with increased risk of all-cause and cardiopulmonary mortality. A 10 ug/mm3 increase

in $PM_{2.5}$ was associated with a HR of 2.05. The ranges of $PM_{2.5}$ in this study are similar to those observed in the Seattle area.

Pope, C. A. III et al. 2002 **Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution**. *JAMA* 287: 1132-1141.
This is a very large study encompassing 500,000 adults in 51 metropolitan areas of the US over 16 years. Causes of death were compared with measures of pollution. Elevated all-cause mortality, cardiopulmonary mortality, and lung cancer mortality was observed with statistical significance in more polluted areas, even after extensively controlling for smoking, BMI, diet, education, occupational exposure, and regional differences. No association with non-cardiopulmonary mortality was observed. The increase in mortality was found to be linear with elevated pollution, with each 10 ug/m^3 increase in $PM_{2.5}$ (particulate matter <2.5 um) associated with a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality. The all-cause mortality risk was found to be comparable to moderate obesity. This study reaffirms prior findings of other studies that particulate matter is associated with a measureable increase in mortality in the U.S., and further defines a linear dose-response relationship.

References/Summaries of Studies: Pulmonary development & effects

Gauderman, W. et al. 2004. **The effect of air pollution on lung development from 10 to 18 years of age**. *New Engl J Med* 351(11):1057-1067
Children's Health Study: The lung function of 1759 adolescents (average age at start of study 10y) in 12 California communities was measured annually for eight years. This age is an important period of lung maturation, as measured by increases in FEV1 and FVC. Children living in the more polluted communities (as measured by particulate matter, O3, NO2, and airborne carbon) showed significant deficits in pulmonary development as compared to those living in less polluted communities (multiple parameters showed $p<0.05$). For example, children in the most polluted community had a 5x greater risk of having low FEV1 (using the clinical definition as < 80% predicted value) by the age of 18 (7.9% vs 1.6%). The effect was similar to exposure to passive smoking that was shown in prior studies, and less pronounced as a history of personal smoking. Exposure-response relationship nearly linear, with no discernable safe thresholds (review of study by Pope, NEJM 351(11):1132-1134.) This study indicates that current levels of pollution in some areas have a negative impact on lung development in adolescents.

Thaller, E. et al. 2008. **Moderate increases in ambient PM2.5 and ozone are associated with lung function decreases in beach lifeguards**. *J Occup Environ Med* 50:202-211.
The change in lung function (FVC and FEV1) in the morning vs afternoon was measured in 142 lifeguards, and correlated with daily pollution indices (primarily PM2.5 and ozone). Normally, pulmonary function increases throughout the day, but in this study the pulmonary indices declined with increasing pollution. The magnitude was not huge, but many measurements showed statistical significance. An important aspect of this study is that statistically significant decreases in pulmonary performance could be demonstrated in young healthy adults at exposures far below EPA Air Quality Standards. (EPA has an unhealthy level of PM2.5 at 35ug/mm3 for 24hr, and 15 ug/ml for annual exposure. The measurements in the study only exceeded 35ug/mm3 once over the three year study period, yet significant effects could be measured.)

Ghio, A. J et al. 2000. **Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers**. *Am J Respir Crit Care Med* 162: 981-2000.

38 healthy young volunteers (average age 18-40, no history of allergies, asthma, or other pulmonary disease) were exposed to ambient air (control; 8) or concentrated air particles from ambient Chapel Hill air (30) for 2 hours. Exposure to the concentrated air particles was associated with measureable increases in inflammation, as determined by neutrophils counts on BAL specimens obtained 18 h after exposure (8.44 vs 2.29% for the bronchial fraction, and 4.20 vs 0.75% in the alveolar fractions). The data is statistically significant. The increases in inflammation were despite no reported symptoms or changes in pulmonary function tests. Although the exposures were to higher concentrations that are typically found in US polluted areas, it is noted that the exposure was for only 2 hr rather than years. This study shows that particulate matter can induce measurable pulmonary inflammation which may be asymptomatic or undetectable by PFTs.

Slaughter, J. C. et al. 2003. **Effects of ambient air pollution on symptom severity and medication use in children with asthma**. *Ann Allergy Asthma & Immunol* 91:346-353.
133 children in the greater Seattle area with asthma were monitored for asthma attacks, which were correlated with daily pollution measurements over 28 to 122 days. Severity of attacks was recorded by subjective self report, as well as recording the dosage and puffs of medication. Pollution measurements consisted of particulate matter (PM) and carbon monoxide (CO) at 12 area stations. $PM_{2.5}$ was found to correlate more with time than locale. Of note, the Seattle area appears to vary between 10 and 60 ug/m3, with most measurements between 10 and 40. Each 10ug/m3 increase was associated with a 1.2 fold increase chance of having a severe attack (including a prolonged attack lasting >2 hr), with a 1.08 fold increase in rescue inhaler use. Time spent indoors vs outdoors was not recorded, and thus the true impacts may be greater than the observed effects.

References/Summaries of Studies: ER visits and hospitalization rates

Norris, G. et al. 1999. **An association between fine particles and asthma emergency department visits for children in Seattle**. *Environ Health Perspect*. 107:489-493.
The Seattle-King County Dept. of Public Health issued a report that showed that the hospitalization rate for children with asthma was >6x greater for children living in the inner city than in suburbs. Thus, this study was created to determine if an association with air pollution exists. Daily air pollution data was collected and correlated with data for ER visits in 6 Seattle area hospitals over 15 months. The majority of the ER visits were at Seattle Children's Hospital. Every increase in PM of 11 ug/mm^3 was associated with a relative rate of 1.15 for ER visits. These changes were seen even when $PM_{2.5}$ was below the National Ambient Air Quality Standards of $15ug/mm^3$.

Lin, S. et al. 2002. **Childhood asthma hospitalization and residential exposure to state route traffic**. *Environ Res* Sect A 88:73-81.
417 children (age 0-14) who were hospitalized for asthma exacerbations were compared to 461 controls who were admitted for other reasons. After controlling for age, education and poverty levels, home addresses were analyzed for area traffic information. Children hospitalized for asthma were more likely to live on roads in the highest tertile of vehicle miles traveled. An odds ratio of 1.93 was associated with living within 200m of roads traveled by trucks and trailers, as compared to control subjects. It is also noted in the paper that heavy duty diesel trucks emit as much as 100x as much particulate matter as gasoline powered vehicles (reference not reviewed; Hildemann L. M. et al. 1991. Environ Sci Technol 14:138-152).

Ostro, B. et al. **The effects of fine particle components on respiratory hospital admissions in children.** *Environ. Health Perspect*. 117(3):475-480.

ICD-9 codes for admissions for children < 19 and <5 (for hospital admissions in 6 California counties from 2000-2003, in which county air pollution statics were available) were correlated with multiple pollutant levels. Children <5 were found to be particularly susceptible. Increased risks of 4-7% were observed for admissions for pneumonia, acute bronchitis, and asthma for each interquartile range.

APPENDIX B: Health Impacts of Coal Dust

The mining, processing and transport of raw coal will result in a certain proportion of that coal fracturing into dust and becoming airborne. Coal dust can become airborne in particle sizes smaller than 500 microns, with the fraction smaller than 10 microns (PM10) being particularly important, as particles in this size range can be inhaled into the respiratory alveoli. Several health problems can result from respirable coal dust, the most severe of which is Coal Worker's Pneumoconiosis (CWP), commonly known as Black Lung Disease, a progressive, incurable, and often fatal disease (Hathaway et al 1991). Despite industry standards that have been in place since 1969, respirable coal dust from coal mining is currently responsible for the deaths of approximately 700 miners and ex-miners in the United States each year. To put this statistic in perspective, this is over *20 times* the number killed in last year's West Virginia coal mine explosion, a tragedy incidentally caused by the ignition of coal dust (Mine Safety and Health Administration briefing September 2010). Respirable coal dust can also exacerbate asthma and COPD, and cause chronic bronchitis even in non-smoking coal miners, at rates which approximate heavy smokers (Marine et al 1988).

The health impacts of respirable coal dust on underground coal miners, exposed to high levels of coal dust for extended periods, are well known and incontrovertible. There may also be severe risks of exposure to lower levels of coal dust. A recent study by researchers from the University of West Virginia examined a population of relatively young miners who developed the most severe form of CWP, even while exposed to currently legal and well-regulated levels of coal dust (Wade, et al 2010). Animal studies suggest reasons for why this is so. Vincent et al (1987), using a rat model, examined the pulmonary burden throughout a wide range of coal dust exposures, and found that pulmonary clearance mechanisms tend to sequester the dust in lymphatic tissue and the interstitial space between alveoli. This sequestration renders the further clearance mechanisms of the lung inoperable, and facilitates the inflammatory cascade, similar to the pathogenesis of silicosis. Studies such as this suggest that our current "threshold" model of allowing exposure up to a certain regulatory limit is likely to be in error, as pulmonary inflammation and the resultant fibrosis are found over the entire range of exposures. In addition, the synergy of respirable coal dust with other pollutants, such as diesel particulate matter, may accelerate the damage beyond what would be predicted by the epidemiological mine data (Karagianes 1981).

Less well studied are the epidemiological effects of respirable coal dust in lower concentrations, or exposure for shorter periods, as can occur for individuals living in proximity to transport lines and processing centers such as proposed Gateway Pacific Terminal. The Burlington Northern Santa Fe (BNSF) Railroad has performed studies of fugitive coal dust emissions along their own rail lines, but these data have not been made public (Cornell Hatch Queensland Rail Study 2008). There are data from other sources on fugitive emissions from open-topped coal cars, such as the cars currently used by BNSF. A 1993 study on a West Virginia rail line, transporting bituminous coal similar to the coal from the Powder River Basin, showed loss of coal dust of up to a pound of coal per mile per car (Simpson Weather Associates, 1993). This loss occurs throughout the entire transport, as the mechanical fracturing of the coal continuously produces fugitive dust as the coal settles. There are even substantial coal dust emissions on the

return trip, as the "empty" cars actually contain a significant quantity of fine particles known as "carry back" (Cornell Hatch 2008).

In addition to the dust emission from coal cars, the terminal processing, storage, and shipping of coal, such as is planned for the Gateway Pacific Terminal, can lead to even higher fugitive emissions, approximating those of an open pit coal mine (Ghose and Majee, 2007). In this study of airborne monitoring around an open pit mine in India, and in the attendant transport corridor, PM10 episodically approached levels that would be considered in violation of OSHA standards in the United States, and the residential areas up to 2.5 km away from the mine boundary showed PM10 above baseline for the region. In the absence of data from proprietary internal studies conducted by BNSF, as noted above, it is difficult to accurately predict the airborne respirable dust load for our specific community from the proposed transport of coal to and from the Gateway Pacific Terminal. Quite apart from the respirable fraction, however, fugitive coal dust emissions are an undeniable and costly nuisance pollutant to businesses and residences along a rail line, or near a coal terminal, with substantial economic impact simply due to the need for frequent cleaning (Cope et al 1994, from a British Columbia study). Finally, coal dust in all size fractions contains varying amounts of heavy metal contaminant such as Lead, Mercury, Chromium (Sharma and Singh 1991) and Uranium, particularly in coals from the Powder River Basin. Whether this contamination will lead to a substantial health impact deserves further study, in the form of a formal assessment by the Department of Health, or within the context of a comprehensive environmental impact study.

In summary, airborne fugitive coal dust emissions will occur from the transport of coal to and from the Gateway Pacific Terminal, the largest coal terminal ever proposed for the west coast of North America. These emissions will certainly result in nuisance pollution. The health effects for our community's citizens can be predicted, but not known, for many years to come.

Coal Dust References

Hathaway GJ, Proctor NH, Hughes JP 1991. **Proctor and Hughes' chemical hazards of the workplace, 3rd Edition**. New York, NY: Van Nostrand Reinhold

Marine WM, Gurr D, Jacobsen M 1988. **Clinically important respiratory effects of dust exposure and smoking in British coal miners**. *Am Rev Resp Dis.* 137:106-112.

Wade WA, Petsonk EL et al. 2010. **Severe occupational pneumoconiosis among West Virginia coal miners: 138 cases of progressive massive fibrosis compensated between 2000-2009**. *Chest* 139(6):1458-1463.

Vincent JH, Jones AD, Johnston AL et al. 1987. **Accumulation of inhaled mineral dust in the lungs and associated lymph nodes: implications for exposure and dose in occupational settings**. *Annals of Occupational Hygiene* 31(3):375 – 393.

Karagianes MT, Palmer RF, Busch RH 1981. **The effects of inhaled diesel emissions and coal dust in rats**. *American Industrial Hygiene Journal.* Volume 42(5):382 – 391

Queensland Government Environmental Protection Agency Report. 2008. **Environmental evaluation of fugitive coal dust emissions from coal trains Goonyella, Blackwater, and Moura coal rail systems, Queensland rail limited**. Connell Hatch

and Co. Final Report.

Simpson Weather Associates 1993. **Norfolk southern rail emission study: consulting report prepared for Norfolk Southern Corporation**. Charlottesville, VA

Ghose MK, Majee SR. 2007. **Characteristics of hazardous airborne dust around an Indian surface coal mining area.** *Environmental Monitoring and Assessment* 130:17-25.

Cope D, Wituschek W, Poon D et al. 1994. **Report on the emission and control of fugitive coal dust from coal trains**. Regional Program Report 86 – 11. Environmental Protection Service, Pacific Region British Columbia Canada.

Sharma PK, Singh G. 1991. **Distribution of suspended particulate matter with trace element composition and apportionment with possible sources in Raniganj coalfield India**. *Environmental Monitoring and Assessment* 22:237 - 244.

APPENDIX C: Cardiovascular Impacts of Airborne Pollutants (including particulate matter):

Review of the scientific literature indicates that the human body, in particular the cardiopulmonary system, is not equipped to safely process the toxic side effects of air pollution any better than it is able to process cigarette smoke. Almost all of the same physiologic reactions that occur in response to cigarette smoke occur in response to exposure to air pollution, in particular the fine particulate matter of diesel exhaust.

The cardiovascular impacts of airborne pollutants have been thoroughly documented in a recent comprehensive review by the American Heart Association, with 426 peer reviewed journal article references (Particulate Matter Air Pollution and Cardiovascular Disease: An update to the Scientific Statement from the American Heart Association. *Circulation* 121:2331-2378). The conclusions of the American Heart Association, which are based on numerous studies in major peer-reviewed journals, are summarized below:

- Short-term exposure to PM2.5 over a period of a few hours to weeks can trigger cardiovascular-related events and mortality, including myocardial infarction (heart attacks), heart failure, arrhythmias, and strokes.
- People particularly at risk include the elderly, patients with pre-existing coronary artery disease, those with diabetes or obesity, and perhaps women.
- Long-term exposure to PM2.5 appears to increase the risk even more than short-term exposure.
- Cardiovascular risk appears to extend below national standards, with no safe threshold (harmful effects extend to below the $PM_{2.5}$ 15ug/mm^3 standard).
- Long-term exposure to elevated concentrations of ambient $PM_{2.5}$ at levels encountered in the present day environment reduces life expectancy by several months to a few years.
- Most recent studies indicate that the absolute risk for mortality due to particulate matter is even greater for cardiovascular than for pulmonary diseases. (See Appendix A for the pulmonary impacts).

American Heart Association comprehensive review:
Particulate Matter Air Pollution and Cardiovascular Disease: An update to the Scientific Statement from the American Heart Association. *Circulation* 121:2331-2378
HYPERLINK "http://circ.ahajournals.org/content/121/21/2331.full.pdf"
http://circ.ahajournals.org/content/121/21/2331.full.pdf

Brook RD. 2008. **Cardiovascular effects of air pollution.** *Clin Sci (Lond)*.115:175–187.

Pope CA 3rd, Muhlestein JB, May HT, Renlund DG, Anderson JL, Horne BD. 2006. **Ischemic heart disease events triggered by short-term exposure to fine particulate air pollution.** *Circulation*.114:2443–2448.

Simkhovich BZ, Kleinman MT, Kloner RA. 2008. **Air pollution and cardio- vascular injury epidemiology, toxicology, and mechanisms**. *J Am Coll Cardiol*. 52:719–726.

APPENDIX D: Health Impacts of Noise Pollution

Noise pollution is a growing health concern in this country and around the world. The World Health Organization has recognized it as a major threat to human health and well-being. Some of the well-documented adverse health effects include:

I. Cardiovascular Disease: In adults, both short-term and long-term adverse health effects have been documented including increased blood pressure, increased heart rate, vasoconstriction, elevated stress hormones such as epinephrine and cortisol, arrhythmias, ischemic heart disease, and strokes.

In children, increased stress-related hormones and elevated blood pressures have especially been seen in children with lower academic achievement.

II. Cognitive Impairment in Children: Children exposed to increased noise have shown lower academic achievement in various forms including reading, learning, problem solving, concentration, social and emotional development, and motivation.

III. Sleep Disturbance: Noise can have both auditory and non-auditory deleterious effects on human health. Auditory effects include delay in falling asleep, frequent night time awakenings, alteration in sleep stages with reduction of REM sleep, and decreased depth of sleep.

Although there may be some acclimation to the auditory effects of noise over time, non-auditory effects including increased blood pressure, increased heart rate, vasoconstriction, changes in respiration, and arrhythmia continue to have delirious effects on human health even after the subject has 'gotten used' to the noise.

There are also 'after affects' of decreased alertness resulting in increased rate of accidents, injuries and premature death.

IV. Mental Health: Although not a causative agent, increased noise is known to accelerate and intensify development of latent mental health disorders including depression, mental instability, neurosis, hysteria, and psychosis. It is also a major environmental cause of annoyance leading to diminished quality of life.

Noise Pollution References:

Berglund B, Lindvall T. (eds.) **WHO Document on Guidelines for Community Noise**. 1999: 39-94.

Suter AH. **Noise and its effects**. Administrative Conference of the United States. 1991

Goines L, Hagler L. **Noise Pollution : A modern plague**. *South Med J*. 2007;100(3):287-294

Babisch W. **Noise and Health**. *Environ Health Perspect* 2005; 113: A14-15.

Ising H, Kruppa B. **Health effects caused by noise: evidence from the literature from the past 25 years**. *Noise Health* 2004; 6: 5-13.

Evans GW, Lepore SJ. **Non-auditory effects of noise on children: a critical review**. *Children's Environments* 1993; 10: 42-72.

Selander J, Milsson ME, Bluhm G, Rosenlund M, Lindqvist, M Nise G, Pershagen G. **Long-term exposure to road traffic noise and myocardial infarction.** *Epidemiology* 2009; 20(2): 272-279.
Willich SN, Wegscheider K, Stallmann M, et al. **Noise burden and the risk of myocardial infarction**. *Eur Heart J* 2006; 27: 276-282. .
Sørensen M, Hvidberg M, Andersen ZJ, Nordsborg RB, Lillelund KG, Jakobsen J, Tjønneland A, Overvad K, and Raaschou-Nielsen O. **Road traffic noise and stroke: a prospective cohort study.** *European Heart Journal* 2011; 32(6): 737-744.
Evans GW, Hygge S, Bullinger M. **Chronic noise and psychological stress**. *Psychol Sci* 1995; 6: 333–8
Haines MM, Stansfeld SA, Brentnall S, Head J, Berry B, Jiggins M, Hygge S. **The West London School Study: The effects of chronic aircraft noise exposure on child health**. *Psychol Med* 2001; 31: 1385–96
Evans GW. **Ambient noise and cognitive process among primary schoolchildren.** *Environment and Behavior* 2003, 35(6) 725-735
Cohen S, Evans GW, Krantz DS, Stokols D. **Physiological, motivational and cognitive effects of aircraft noise on children: Moving from the laboratory to the field**. *Am Psychol* 1980; 35: 231–43
Evans GW, Maxwell L. **Chronic noise exposure and reading deficits: The mediating effects of language acquisition**. *Environ Behav* 1997; 29: 638–56
Haines MM, Stansfeld SA, Job RFS, Berglund B, Head J. **Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children**. *Psychol Med* 2001; 31: 265–77
Hygge S, Evans GW, Bullinger M. **A prospective study of some effects of aircraft noise on cognitive performance in school children**. *Psychol Sci* 2002; 13: 469–74
Stansfeld SA, Matheson MP. **Noise pollution: non-auditory effects on health**. *Brit Med Bull* 2003; 68: 243-257.
Stansfeld SA, Berglund B, Clark C, et al. **Aircraft and road traffic noise and children's cognition and health: a cross national study**. *Lancet* 2005; 365: 1942-1949.
Ohrstrom E, Bjorkman M. **Effects of noise-disturbed sleep: A laboratory study on habituation and subjective noise sensitivity**. *J Sound Vibration* 1998; 122: 277-290.
Carter NL. **Transportation noise, sleep, and possible after-effects**. *Environ Int* 1996; 22: 105-116
Fidell S, Barber DS, and Schultz TJ. **Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise**. *J Acoust Soc Am*. 1991, 89: 221-233.
Hall F, Birnie S, Taylor SM, and Palmer J. **Direct comparison of community response to road traffic noise and to aircraft noise**. *J Acoust Soc Am* 1981, 70: 1690-1698.
Bronzaft AL, Dignan E, Bat-Chava Y, & Nadler NB. **Intrusive community noises yield more complaints**. *Noise Rehabilitation Quarterly* 2000, 25 : 16-22,34.

APPENDIX E: Anticipated Impacts of Frequent Long Trains on Emergency Medical Service Response Times and Risk of Injuries at Crossings

In the modern medical era, a five to ten minute delay in emergency medical service (EMS) response time can make the difference between life and death, particularly for cardiovascular events, respiratory emergencies, and trauma. The prospect of an additional eighteen trains per day – each 1.5 miles long—threatens to substantially increase the chances of critical delay in provision of emergency services to several areas in our county.

Among the locations where citizens are at greatest risk of EMS delays are the arterial roads in western Whatcom County—particularly Birch Bay-Lynden Road and Slater Road. These roads are highly traveled by EMS and other vehicles. Thus, frequent prolonged closures could have a life-threatening impact. While there are alternative routes around any one crossing at these locations, the detours themselves are long and would still result in significantly prolonged emergency response times.

Other affected locations include multiple highly visited areas along the Bellingham waterfront. Access to the downtown waterfront is significantly limited when D and F streets are simultaneously closed by rail traffic, as alternate routes are long and inconvenient. Boulevard Park, Fairhaven Harbor, and Marine Park are completely cut off when trains pass through the Fairhaven area. Similarly, several Chuckanut residential neighborhoods and parts of Larrabee Park are completely cut off from services while trains pass.

While the impact of EMS delays is of considerable concern in Whatcom County, it may be an even greater problem for neighboring Skagit and Snohomish Counties that have a greater number of arterials that will be interrupted by rail traffic.

Annually in the US, a train/vehicle collision occurs about every 90 minutes. Train/vehicle crashes are more likely than other crashes to be fatal because of the mass of the train. A 150 car freight train traveling at 50 miles per hour takes about 8,000 ft to stop (1.5 miles). Train/vehicle crashes also carry the risk of train derailment and, thus, risk to community and environment if hazardous materials are being transported.

In 2010 there were 739 fatalities, 8,167 injuries and 11,417 incidents at railroad crossings nationally according to the Federal Railroad Administration Office of Safety Analysis database.

Spaite D, Criss E, Valenzuela T, Meislin HW, and Ogden, R. 1988**. Railroad accidents: A metropolitan experience of death and injury.** *Annals of Emergency Medicine* **6: 620-625.**

Web searchable database at:
http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/statsSas.aspx

Jack Louws
Whatcom County Executive
311 Grand Avenue, Suite 108
Bellingham, WA 98225

Ted Sturdevant
Director, Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504

March 12, 2012

Dear Executive Louws and Director Sturdevant,

Whatcom Docs is a group of more than 180 physicians who live throughout Whatcom County, who coalesced to voice concern over the health impacts of the largest proposed coal shipping facility in North America. Additional **new research published in major medical journals** augments our concerns:

- A new study (Turner et al; see reference list at end of letter) published in a prominent medical journal showed a remarkable **15-27% increase in lung cancer deaths**, **in people that have never smoked**, for each increase of 10 ug/m^3 of particulate matter (PM2.5). This study examined 1100 cancer deaths of people living in normal conditions, and not industrial exposure.

- Another study (Wellenius et al) examined the impact of transportation-related particulate matter (PM2.5) on stroke risk. Overall, the **risk of ischemic stroke was 34% higher** with moderate exposures. This is an unprecedented finding, and points to the danger of even short term exposure to levels of particulate pollution previously thought safe. This is highly relevant to the coal shipment proposal, as hundreds of thousands of people live along the rail corridor, and would be exposed to bursts of diesel particulate matter by frequent trains.

- A third study, (Mustafic et al), represents a "meta-analysis," in which data from 34 prior studies was re-analyzed, and indicated that **short-term exposure** to air pollution is a **trigger of myocardial infarction (heart attack).** This data augments numerous prior studies, and has significant social implications, as unlike cigarette smoking, individuals exposed to air pollution have little control over their exposure.

- In another study (Wueve et al) exposure to particulate pollution was found to be a **strong predictor of cognitive decline**. Cognitive decline is one of the most significant and resource-intensive health issues facing our population, and few

modifiable risk factors have been identified, until now.

- A presentation at a national asthma and allergy meeting on March 4, 2012 (Bernstein, D.) described a new study that shows exposure to diesel particulate matter is associated with a **2-3 fold risk of wheezing in infants (an early measure of asthma).** Asthma is a common disease that presents significant costs to society.

- It has been emphasized (Bhatia, R.) that there is significant spatial disparity in pollution distribution. "Concentrations of PM2.5 are known to be much higher near busy highways, rail yards, and ports than at regional monitors, but inadequate intraregional assessment means that these higher levels are often not considered by regulators". Thus, for accurate assessment, **pollution needs to be measured adjacent to the source, where people work, live, and play**. Relying on measurements taken at a regional air station provides a false sense of security.

<u>The recent studies detailed above augment the concerns we previously outlined:</u>

1. **Diesel particulate matter,** which is associated with impaired pulmonary development in adolescents; increased cardiopulmonary mortality and all-cause mortality; measurable pulmonary inflammation; increased severity and frequency of asthma attacks, ER visits, and hospital admissions in children; increased rates of myocardial infarction (heart attack) in adults; increased risk of cancer.

2. **Coal dust,** which is associated with several chronic respiratory; and environmental contamination through the leaching of toxic heavy metals.

3. **Noise exposure,** which is associated with cardiovascular disease; cognitive impairment in children; sleep disturbance and resultant fatigue; exacerbation of mental health disorders such as depression and anxiety.

4. **Frequent long trains at rail crossings,** which would result in delayed emergency response times.

Our concerns are backed by statements from the **American Heart Association** and the **American Lung Association**.

On Feb 24, 2012, a survey funded by the American Heart Association was announced that showed **"a majority of Washington State voters favor current legislation requiring the state to consider impacts on people's health when planning new transportation projects"** (www.healthimpactproject.org/news/in/poll-washington-state-voters).

The adverse effects of air pollution are real and measurable, even when levels of pollutants are below U.S. Environment Protection Agency (EPA) standards. This is widely recognized by scientists within the EPA, who have proposed tighter guidelines. **Existing regulatory frameworks are insufficient to protect human health.**

There are now over 150 Health Impact Assessments (HIAs) across the United States, conducted for much smaller projects, such as casinos, bus transportation routes, and for rebuilding the Seattle 520 bridge. As such, it is imperative that a Health Impact Assessment (HIA) be done in considering the largest coal shipping terminal in North America.

Considering: 1) the published, publicly-available research that clearly links particulate and noise pollution with numerous adverse health effects, 2) that hundreds of thousands of people live along the rail corridor in Washington, Idaho, and Montana, and 3) the burgeoning costs of health care; it would be socially and economically irresponsible to not consider these impacts when evaluating the Gateway Pacific Terminal.

Our group of Whatcom physicians has now been joined by physicians in King County and Skagit County in calling for a **cumulative and comprehensive Health Impact Assessment (HIA)** along the entire transportation corridor.

Additional medical data is detailed in our statement and appendices that are available on coaltrainfacts.org. All references are cited and are based on published, publicly-available studies.

Sincerely,

Dale Abbott, MD
Camilla Allen, MD
Daniel Austin, MD
Diane Arvin, MD
Barbara Bachman, MD
Laura Backer, MD
Kristi Bailey, MD
Jeffrey B. Black, MD
Terri Blackburn, MD
Pete Beglin, MD
Claire Beiser, MD, MPH
Don Berry, MD
Richard Binder, MD
Nancy Bischoff, MD
Bruce Bowden, MD
Kirk Brownell, MD
Allan Buehler, MD
David Cahalan, MD
Soren Carlsen, MD
Erin Charles, MD
Michael Chmel, MD
Joshua Cohen, MD
Andrew Coletti, MD
Paul Conner, MD
Kirstin Curtis, ARNP
Jan Dank, MD
Marc Davis, MD
Joe Deck, MD
Katherine Dickinson, MD
Peter Dillon, MD
Thang Do, MD
Mark Doherty, MD
Kevin Dooms, MD
Jim Eggen, MD
Jerry Eisner, MD
David Elkayam, MD
Laurie Emert, MD
John Erbstoeszer, MD
Worth Everett, MD
Anneliese Floyd, MD
Ryan Fortna, MD, PhD
Dianne Foster, ARNP
Randy Frank, DO
Eric Frankenfeld, MD
Jonathan Franklin, MD
Anthony Gargano, MD
Ken Gass, MD, PhD
Jeremy Getz, MD
Robert Gibb, MD
Stan Gilbert, MD
Martha Gillham, MD

Corinne Gimbel-Levine, ARNP
Lorna Gober, MD
David Goldman, MD
Aaron Gonter, MD
Erin Griffith, MD
Deborah Hall, MD
Tom Hall, MD
William Hall, MD
David Hansen, MD
James Harle, MD
Emil Hecht, MD
Grayce Hein, ARNP
Michael Hejtmanek, MD
Harry Herdman, MD
David Hoeft, MD
Marcy Hipskind, MD
John Holroyd, MD
Jim Holstine, DO
Sherry Holtzman, MD
Will Hong, MD
John Hoyt, MD
Bao Huynh, MD
Kellie Jacobs, MD
Meg Jacobson, MD
Gertrude James, ARNP
Frank James, MD
Helen James, MD
Lisa Johnson, ARNP
David Jessup, MD
Mitchell Kahn, MD
Daniel Kim, MD
Annie Kiesau, MD
Carter Kiesau, MD
Gail Knops, MD
Joost Knops, MD
Ann Knowles, MD
Andrew Kominsky, MD
Pamela Laughlin, MD
Shawna Laursen, MD
George Lawrence, MD
Josie Lee, MD
Tyler Leedom, DO
Kathy Leone, MN, ARNP
Rick Leone, MD, PhD
Linda Leum, MD
Hank Levine, MD
Chris Lewis, DO
Serge Lindner, MD
Kelly Lloyd, MD
Bill Lombard, MD
Jena Lopez, MD
Jonathan Lowy, MD
Leasa Lowy, MD
Thomas Ludwig, MD
Bruce Mackay, MD
Margaret Mamolen, MD
Troy J. Markus, D.O.
Vincent Matteucci, MD
Dick McClenahan, MD
Marianne McElroy, PA
Monica Mahal, MD
Scott McGuinness, MD
Judson Moore, PA
David Morison, MD
Gib Morrow, MD
Larry Moss, MD
Sara Mostad, MD, PhD
Ward Naviaux, MD
John Neutzmann, DO
Deborah Oksenberg, MD
David Olson, MD
Rob Olson, MD
Patricia Otto, MD
Tracy Ouellette, MD
Mark Owings, MD, PhD
Evelyn Oxenford, ARNP
Clark Parrish, MD
Mike Pietro, MD
Trevor Pitsch, MD
Denise Plaisier, PA
Suneil Polley, ND, Lac
Ronda Pulse, MD
Gita Rabbani, MD
Andris Radvany, MD
Jon Ransom, MD
Christoph Reitz, MD
Niles Roberts, MD
April Sakahara, MD
W. Scott Sandeno, MD
Paul Sarvasy, MD
Neal Saxe, MD
James Schoenecker, MD
Julie Seavello, MD
R. Milton Schayes, MD
Barbara Schickler, ARNP
Melana Schimke, MD
Luther Schutz, MD
Miriam Shapiro, MD
Janine Shaw, MD
John Shaw, MD
Mary Ellen Shields, MD
Hannah Sheinin, MD
Russell Sheinkopf, MD
Lora Sherman, MD
Alan Shurman, MD
Don Slack, MD
Robert Slind, MD
Chris Spilker, MD
Bonnie Sprague, ARNP
Scott Stockburger, MD
Berle Stratton, MD
Jenny Sun, MD
Gregory Sund, MD
Mary Swanson, MD
Warren Taranow, DO
Michael Taylor, MD
Greg Thompson, MD, MPH
Stuart Thorson, MD
Teresa Thornberg, MD
Loch Trimingham, MD
Elizabeth Vennos, MD
Steve Wagoner, MD
April Wakefield Pagels, MD
Heather Whitaker, ARNP
Sara Wells, ARNP
Anne Welsh, MD
Greg Welsh, MD
Susan Willis, ARNP
David Wisner, MD
Steven Wisner, MD
Todd Witte, MD
Ginny Wolff, MD
Greg Wolgamot, MD, PhD
Stephen Woods, MD
Darla Woolman, PA
Chao-ying Wu, MD
Jessica Yoos, MD
Ellen Young, MD

cc:
Dow Constantine, King County Executive
Christine Gregoire, Governor of Washington State
Mayor Kelli Linville, City of Bellingham
Mayor Pete Lewis, City of Auburn
Mayor Suzette Cooke, City of Kent
Mayor Denis Law, City of Renton
Mayor Mike McGinn, City of Seattle
Mayor Keith McGlashan, City of Shoreline
Mayor David Condon, City of Spokane
Mayor Jim Haggerton, City of Tukwila
Peter Goldmark, Washington State Commissioner of Public Lands
Dennis McLerran, Regional Administrator, U.S. Environmental Protection Agency
Tay Yoshitani, CEO, Port of Seattle
Joni Earl, CEO, Sound Transit
Bob Drewell, Executive Director, Puget Sound Regional Council
Craig Kentworthy. Executive Director, Puget Sound Clean Air Agency
Christie True, Director, Dept. of Natural Resources and Parks
Ngozi Oleru, Director of Environmental Health, Dept of Public Health
Carrie Cihak, Director of Policy and Strategic Initiatives, King County Executive's Office
Megan Smith, Environmental Policy Advisor, KCEO
Greg Stern, Whatcom County Health Officer
Washington State Medical Association
Howard Frumkin, Dean, School of Public Health, University of Washington

Newest medical research, references:

Bernstein, D., of the University of Cincinnati. "How Do Traffic Pollutants Affect Childhood Wheezing and Asthma?" March 4, 2012 presentation at the annual meeting of the American Academy of Allergy, Asthma, and Immunology.

Bhatia, R 2012. Policy and Regulatory Action can Reduce Harms from Particulate Pollution. *Arch Intern Med* 172(3):227-228.

Mustafic, H. et al. 2012. Main Air Pollutants and Myocardial Infarction: A Systematic Review and Meta-Analysis. *JAMA* 307(7):713-721.

Turner, M. et al. 2011. Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers. *Am J Respir Crit Care Med.* 184(12):1374-81.

Wellenius, G. et al. 2012. Ambient Air Pollution and Risk of Acute Ischemic Stroke. *Arch Intern Med* 172(3):229-234.

Wueve, J. et al. 2012. Exposure to Particulate Air Pollution and Cognitive Decline in Older Women. *Arch Intern Med* 172(3):219-227.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D15305, doi:10.1029/2007JD009428, 2008

Click Here for Full Article

Trans-Pacific transport of mercury

Sarah A. Strode,[1] Lyatt Jaeglé,[1] Daniel A. Jaffe,[2] Philip C. Swartzendruber,[1,2] Noelle E. Selin,[3] Christopher Holmes,[3] and Robert M. Yantosca[3]

Received 27 September 2007; revised 24 December 2007; accepted 25 March 2008; published 7 August 2008.

[1] We examine the trans-Pacific transport of mercury with a global chemical transport model. Using existing anthropogenic inventories, the model underestimates the observed Hg/CO ratio in Asian long-range transport events observed at ground-based sites in Okinawa, Japan and Mount Bachelor, Oregon, by 18–26%. This is in contrast with previous studies that inferred a factor of two underestimate in Asian anthropogenic emissions. We find that mercury from land emissions and re-emissions, which are largely colocated with anthropogenic emissions, account for a significant fraction of the observed Hg/CO ratio. Increasing Asian anthropogenic Hg^0 emissions by 50% while holding land emissions constant, or further increasing anthropogenic emissions while decreasing land emissions, corrects the remaining model bias in the Hg/CO ratio. We thus find that a total Asian source of 1260–1470 Mg/a Hg^0 is consistent with observations. Hg^0 emissions from Asia are transported northeastward across the Pacific, similar to CO. Asian anthropogenic emissions of mercury contribute 18% to springtime Hg^0 concentrations at Mount Bachelor. Asian RGM is not directly transported to North America in the lower troposphere but contributes to a well-mixed pool at high altitude. Asian and North American sources each contribute approximately 25% to deposition to the United States, with Asian anthropogenic sources contributing 14% and North American anthropogenic sources contributing 16%.

Citation: Strode, S. A., L. Jaeglé, D. A. Jaffe, P. C. Swartzendruber, N. E. Selin, C. Holmes, and R. M. Yantosca (2008), Trans-Pacific transport of mercury, *J. Geophys. Res.*, *113*, D15305, doi:10.1029/2007JD009428.

1. Introduction

[2] Anthropogenic emissions have caused a factor of 3 increase in the atmospheric mercury burden since preindustrial times [*Mason and Sheu*, 2002], posing a threat to human health and wildlife. Asian emissions increased rapidly in the early 1990s, and in 2000 accounted for 54% of global anthropogenic emissions [*Pacyna et al.*, 2006]. European and North American emissions decreased over the same time period.

[3] With an atmospheric lifetime of several months, elemental mercury (Hg^0) undergoes global atmospheric transport. Global modeling studies indicate that 21–24% of mercury deposition to North America is of Asian origin, compared to 30–33% of North American origin [*Seigneur et al.*, 2004; *Travnikov*, 2005].

[4] Several observational studies have detected long-range transport of mercury from Asia. Aircraft measurements during the ACE-Asia campaign found mercury to be well correlated with other pollutants in plumes over the western Pacific Ocean [*Friedli et al.*, 2004]. At a ground-based site in Okinawa, Japan, *Jaffe et al.* [2005] measured elevated Hg^0 and CO concentrations during episodes of Asian outflow. During the INTEX-B campaign, *Talbot et al.* [2007] observed mercury in Asian plumes on flights over the Pacific. In North America, observations from Mount Bachelor Observatory, Oregon (MBO) identified episodes of Asian long-range transport with high Hg^0 concentrations [*Jaffe et al.*, 2005; *Weiss-Penzias et al.*, 2006]. The Hg^0/CO enhancement ratio during Asian transport events, which represents the relative increase of the two species over their respective background levels, is expected to reflect the relative emissions of Hg^0 and CO. However, the Okinawa Hg^0/CO enhancement ratio of 0.0056 ng/m^3/ppbv observed during Asian long-range transport events is almost twice the emission ratio from the current anthropogenic mercury and CO inventories [*Jaffe et al.*, 2005]. *Friedli et al.* [2004] and *Weiss-Penzias et al.* [2007] reported similarly enhanced ratios for long-range transport events observed during ACE-Asia and at MBO, respectively. *Jaffe et al.* [2005] proposed three possible explanations for this discrepancy: an underestimate of Asian anthropogenic Hg^0 emissions, a contribution from Asian land emissions, or production of Hg^0 from reactive gaseous mercury (RGM) emissions during transport.

[5] In this paper, we use the GEOS-Chem global chemical transport model to interpret mercury and CO observations at Okinawa, Japan and Mount Bachelor, Oregon. We

[1]Department of Atmospheric Sciences, University of Washington, Seattle, Washington, USA.
[2]Interdisciplinary Arts and Sciences Department, University of Washington, Bothell, Washington, USA.
[3]School of Engineering and Applied Sciences and Department of Earth and Planetary Sciences, Harvard University, Cambridge, Massachusetts, USA.

Copyright 2008 by the American Geophysical Union.
0148-0227/08/2007JD009428$09.00

use the model to improve constraints on the magnitude of Asian mercury emissions and their contribution to deposition over North America.

2. Observations and Model

[6] The Hedo Station, Okinawa (HSO) is located at 26.8°N, 128.2°E, 60 m above sea level. It is remote from any major cities and in the pathway of East Asian outflow. *Jaffe et al.* [2005] conducted a campaign at Okinawa from 23 March to 2 May 2004, measuring concentrations of mercury species (Hg^0, RGM, and particulate mercury) and CO.

[7] MBO is a mountain top site located at 44.0°N, 121.7°W, 2.8 km above sea level. It receives both free-tropospheric and boundary layer air masses and experiences a diurnal cycle of upslope and downslope flow [*Weiss-Penzias et al.*, 2006]. *Weiss-Penzias et al.* [2006, 2007] describe measurements of total airborne mercury (TAM = Hg^0 + RGM + particulate mercury), CO, and other species at MBO from 28 March 2004 until 30 September 2005. From 30 April to 31 August 2005, *Swartzendruber et al.* [2006] measured speciated mercury (Hg^0, RGM, and particulate mercury) at MBO.

[8] We analyze these observations with the GEOS-Chem global tropospheric chemistry model [*Bey et al.*, 2001] version 7-04-05 (http://www.as.harvard.edu/chemistry/trop/geos/). The model is driven by assimilated meteorology from the NASA Global Modeling and Assimilation Office (GMAO). After a spin-up period to reach steady state, we run the model for 2004 using the GEOS-4 meteorological fields. The model has 2° latitude by 2.5° longitude horizontal resolution and 30 hybrid pressure-sigma layers. For the grid boxes corresponding to Okinawa and MBO, we extract hourly output from the model.

[9] We perform a CO simulation [*Duncan et al.*, 2007], which includes emissions from fossil fuel, biofuel, and climatological biomass burning, as well as a photochemical source from oxidation of methane and biogenic volatile organic compounds (BVOCs). The CO simulation has been evaluated extensively in other studies [e.g., *Heald et al.*, 2003; *Palmer et al.*, 2003; *Liang et al.*, 2004; *Duncan et al.*, 2007].

[10] We also perform a mercury simulation, with tracers for Hg^0, divalent mercury (Hg^{II}), and particulate mercury (Hg^P) [*Selin et al.*, 2007]. We treat the Hg^{II} tracer as comparable to RGM measurements. In the atmosphere, Hg^0 is oxidized to Hg^{II} by ozone and OH, and in cloudy regions Hg^{II} can be reduced back to Hg^0. Hg^{II} is lost through wet and dry deposition. In the rest of the paper we will refer to RGM as Hg^{II}. The model includes emission, transport, and deposition of Hg^P, but does not currently include Hg^P chemistry. The atmospheric mercury model is fully coupled to a slab model of the ocean mixed layer [*Strode et al.*, 2007]. Mercury entering the ocean mixed layer through deposition or oceanic mixing can be converted in the ocean to elemental mercury and then emitted to the atmosphere through gas-exchange, or it can be lost to the deep ocean through mixing and sinking on particles.

[11] The mercury simulation includes emissions from anthropogenic sources [*Pacyna et al.*, 2006; *Wilson et al.*, 2006], biomass burning, and natural emissions plus re-emissions from land and ocean. Globally, the model includes 2200 Mg a^{-1} total mercury from anthropogenic sources, 2000 Mg a^{-1} from land emissions and re-emissions, 520 Mg a^{-1} from biomass burning, and 2970 Mg a^{-1} ocean emissions. Mercury from biomass burning is scaled to climatological biomass burning emissions of CO [*Duncan et al.*, 2003], using a Hg^0/CO emission ratio of 1.5×10^{-7} mol/mol [*Slemr et al.*, 2006b]. Land emissions are divided into a natural (geogenic) component of 500 Mg a^{-1}, distributed in regions with geologic deposits, and a re-emission component of 1500 Mg a^{-1}, distributed according to the pattern of deposition. Ocean emissions are a function of deposition, radiation, biological productivity, temperature, and wind speed. Land, biomass burning, and ocean emissions are all as Hg^0.

[12] Figure 1 shows the distribution of anthropogenic, land, and biomass burning emissions over Asia (defined here as 9°S–60°N, 65°–146°W). For this region, anthropogenic emissions are 610 Mg a^{-1} of Hg^0, 380 Mg a^{-1} of Hg^{II}, and 100 Mg a^{-1} of Hg^P. Geogenic emissions of 100 Mg a^{-1} Hg^0 are located primarily in southeast China. Land re-emissions of 310 Mg a^{-1} Hg^0 are distributed throughout the region, with large emissions from southeast China and India. Large anthropogenic emissions and high deposition rates drive the elevated re-emissions in China. India has lower anthropogenic emissions than China, but its land re-emissions are elevated because high precipitation combined with the elevated rate of Hg^{II} formation in the tropics causes high deposition to this area. Biomass burning accounts for 150 Mg a^{-1} Hg^0, with large emissions from Southeast Asia and India peaking in March and April and emissions from Siberian boreal forest fires peaking in July and August. This region also includes ocean emissions of 360 Mg a^{-1} Hg^0.

[13] Both CO and mercury tracers are tagged in the model according to their emission region and source. We consider four regions: Asia, North America, Europe, and the rest of the world. For mercury, we also tag emissions from biomass burning, land, and ocean sources. The regional land tracers include both geogenic land emissions and land re-emissions. Mercury emitted as Hg^0 that later oxidizes to Hg^{II} retains the tag of its original emission region. For example, the Asian Hg^{II} tracer contains both Hg^{II} directly emitted from Asia and Hg^{II} formed by oxidation of Asian Hg^0. Ocean emissions are tagged as primary ocean only if the mercury entered the mixed layer from the deep ocean; mercury of anthropogenic or land origin that is deposited to the ocean and then re-emitted retains its original tag. Our Asian anthropogenic mercury tracer thus includes both direct emissions from Asia and also ocean re-emission of previously deposited Asian anthropogenic mercury. We infer the contribution to each tracer from ocean re-emission by differencing our standard simulation with a model simulation with the net sea-air flux set to zero. For CO, we tag emissions from anthropogenic (fossil fuel plus biofuel) sources, biomass burning, and the photochemical oxidation of methane and BVOCs.

3. Results

3.1. Hg^0 and CO at Okinawa

[14] Figure 2 shows observed and modeled Hg^0 and CO at Okinawa during spring 2004. The frequent simultaneous increases in CO and Hg^0 concentrations reflect the influence

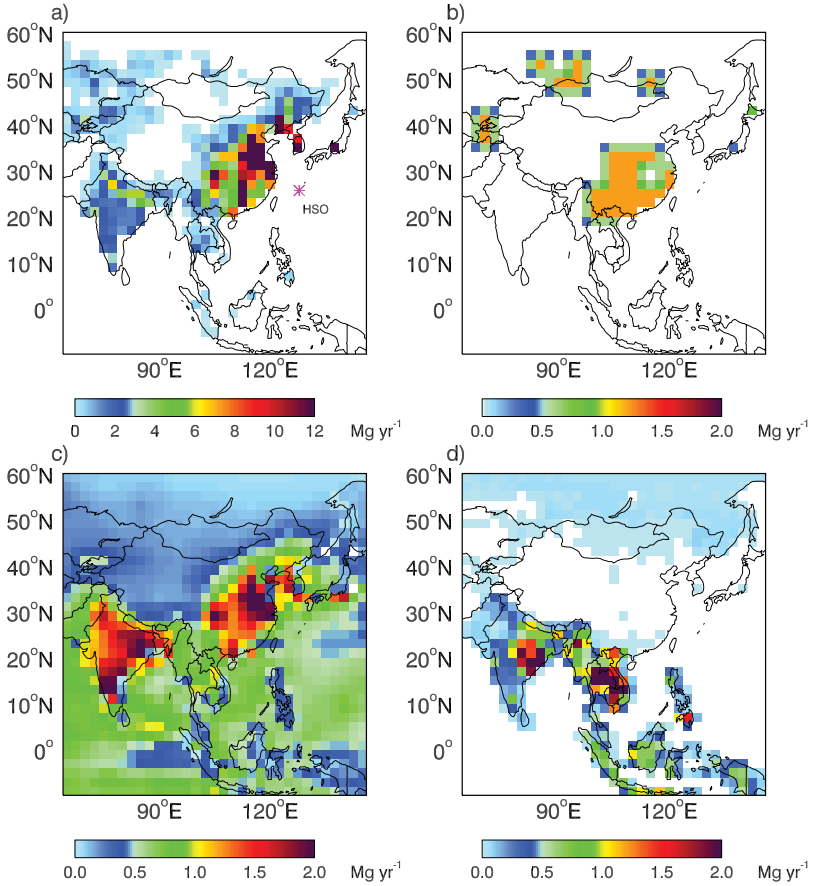


Figure 1. Distribution of annual Asian mercury emissions (Mg a^{-1}) from (a) anthropogenic, (b) geogenic, (c) land re-emission + ocean emission, and (d) biomass burning used in the GEOS-Chem model. The location of Okinawa is indicated by a star in Figure 1a.

of episodic outflow of polluted air from Asia reaching Okinawa [*Jaffe et al.*, 2005]. For CO, the mean observed value ± one standard deviation is 215 ± 65 ppbv compared to the modeled 209 ± 58 ppbv, while for Hg^0 the observed mean and standard deviation is 2.04 ± 0.38 ng m^{-3} standard air compared to the modeled 2.04 ± 0.25 ng m^{-3}. The model captures some of the observed temporal variability, with r^2 = 0.28 for CO and r^2 = 0.39 for Hg^0. The tagged simulations show that the variability in CO and Hg^0 is dominated by the variability in Asian tracers, as expected. For CO, the Asian anthropogenic tracer explains 97% of the variance in modeled total CO. Using multiple regression, we find that the Asian anthropogenic and land tracers together explain 97% of the variance in total Hg^0. Land emissions from Asia covary with the Asian anthropogenic tracer (r^2 = 0.87) due to the approximate colocation of the anthropogenic and land sources (Figure 1), which allows the tracers to be transported together.

[15] We used our tagged tracer simulation to divide the total CO and mercury concentrations over Okinawa into different source contributions for the 1 March to 31 May period (Table 1). Asian sources account for 44% of Hg^0 at Okinawa, with Asian anthropogenic, land, and biomass burning emissions contributing 26, 15, and 3%, respectively. The Asian anthropogenic contribution to Hg^{II} (45%) and particulate mercury (78%) over Okinawa is greater than the contribution to Hg^0 (Table 1) because the model shows Okinawa receiving direct transport of Asian Hg^{II} and particulate mercury emissions, but the short lifetimes of these species prevent them from reaching Okinawa by direct transport from other regions. For CO, the Asian anthropogenic contribution is 41%. During periods of enhanced outflow, the Asian anthropogenic contribution reaches up to 73% for CO and 43% for Hg^0 (Figure 2).

3.2. Hg^0 and CO at Mount Bachelor

[16] Figure 3 shows the time series of observed and modeled CO and TAM at MBO for 2004. At MBO, the mean model concentrations are 116 ± 20 ppbv and 1.61 ± 0.09 ng m^{-3} for CO and mercury, respectively, compared to observed means of 133 ± 28 ppbv and 1.53 ± 0.19 ng m^{-3}, yielding a mean model bias of −12% for CO and 5% for mercury. The CO bias is evident primarily in springtime. The r^2 value is 0.37 for CO and 0.34 for mercury. The model fails to reproduce the magnitude of the observed mercury peaks and has a standard deviation of only 0.09 ng m^{-3}. It also somewhat underestimates the standard deviation of CO. In contrast, the model better reproduces CO observations, including springtime long-range transport events, at the surface coastal site Cheeka Peak in Washington State [*Liang et al.*, 2004]. The difficulty at MBO is likely due to subgrid scale processes

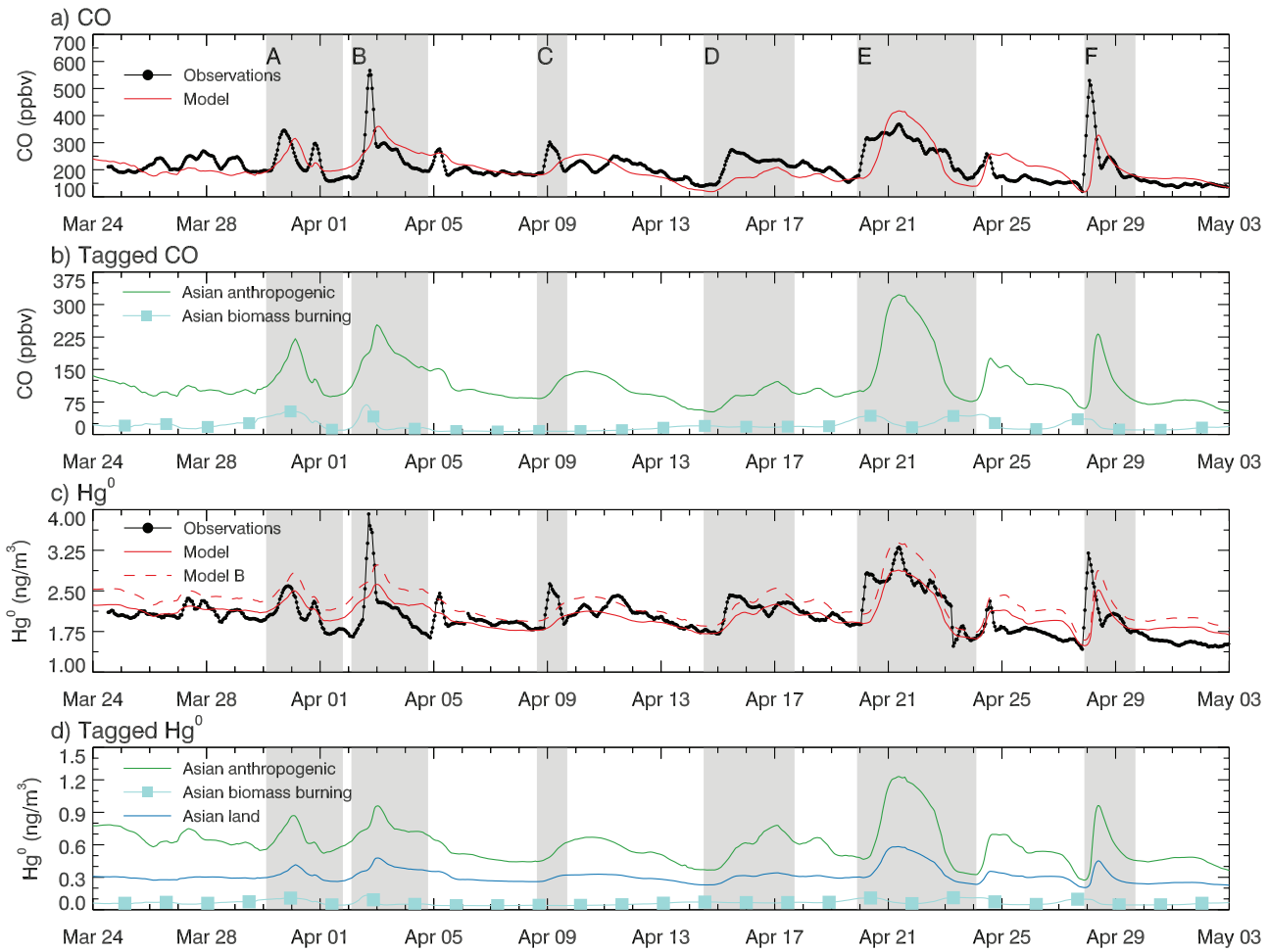


Figure 2. Time series of CO and Hg^0 at Okinawa for March–May 2004. (a) Observed (black) and modeled (red) CO. (b) Model CO tracers tagged by source. (c) Observed (black) and modeled (red) Hg^0. The dashed red line shows model simulation B (Asian Hg^0 emissions increased by 50%). (d) Hg^0 tracers tagged by source. The observations are averaged using a 6-h running mean. Asian transport events from *Jaffe et al.* [2005] are shaded in gray.

associated with the local mountainous terrain. The model grid box containing MBO has a surface altitude of 1.4 km above sea level. The model is sampled at the vertical level corresponding to the actual altitude of MBO (2.8 km above sea level), where the model captures the observed temperature. In the model, this level is usually above the boundary layer during spring. Springtime observations show that MBO experiences a mixture of boundary layer and free-tropospheric air, with a diurnal cycle in up-slope and downslope flow [*Weiss-Penzias et al.*, 2006]. Thus some of the model error is likely due to its inability to capture the transitions between boundary layer and free tropospheric air at the peak of Mount Bachelor.

[17] Unlike Okinawa, where enhancements are primarily driven by Asian transport, at MBO the tagged tracer simulations attribute the majority of the variability in CO to fluctuations in North American CO and CO from hydrocarbon oxidation, and much of the variability in mercury to variations in transport of regional land sources. During springtime, the North American land tracer explains 46% of the variability in TAM at MBO while the Asian tracers (anthropogenic + land + biomass burning) explain 42%. In the annual average, the North American land tracer explains only 29% of the TAM variability while the Asian tracers explain 57%. The large fraction of variability in the annual average explained by the Asian tracers is due partly to their effect on the seasonal cycle; the Asian tracers explain only 37% of the variance when monthly variability is removed by subtracting the 31-day running mean.

[18] *Weiss-Penzias et al.* [2007] discuss a number of Asian long-range transport events observed at MBO. The model captures some of these observed events (Figure 3). For the 9 and 10 April 2004 events (a, b), the model captures the timing of the events but greatly underestimates their magnitude. During the large 25 April event (c), the model shows a small enhancement in the Asian tracers for CO and mercury. However, the model predicts a larger Asian event 3 days later on 28 April. Our simulation captures the timing and duration of the 20 December event (h), and attributes it to concurrent increases in both the Asian and North American tracers. For several of the other observed events, there is a small increase in the Asian tracer corresponding to the timing of the event, but the model usually underestimates the magnitude of the events. This

Table 1. Average Springtime Contributions of Source Regions to Hg^0 (ng m^{-3}), Hg^{II} (pg m^{-3}), and CO (ppbv) at MBO, Okinawa, and the United States[a]

	Okinawa (26.8°N, 128.2°E, 60 m)			MBO (44.0°N, 121.7°W, 2.8 km)			USA (30°–46°N, 125°–65°W, Surf.)		
March 1–May 31	Hg^0	Hg^{II}	CO	Hg^0	Hg^{II}	CO	Hg^0	Hg^{II}	CO
Anthropogenic[b]									
Asia	0.48(26)	6.3(45)	73(41)	0.29(18)	15(18)	30(24)	0.26(16)	5.6(15)	25(16)
North America	0.03(2)	0.2(2)	11(6)	0.03(2)	2(2)	17(13)	0.07(4)	5.9(15)	53(31)
Europe	0.10(5)	0.5(4)	20(11)	0.10(6)	4.8(6)	19(15)	0.10(6)	1.9(5)	19(12)
Rest of world[c]	0.12(7)	0.7(5)	3(2)	0.12(7)	7.0(8)	4(3)	0.11(7)	2.7(7)	4(2)
Biomass Burning[b]									
Asia	0.06(3)	0.4(3)	19(12)	0.05(3)	2.5(3)	10(8)	0.04(3)	1.1(3)	8(5)
Rest of world[d]	0.09(5)	0.5(4)	5(3)	0.08(5)	5.1(6)	6(5)	0.08(5)	2(5)	8(5)
Land[b,e]									
Asia	0.27(15)	1.4(10)	-	0.21(13)	11.1(13)	-	0.20(12)	4.3(11)	-
North America	0.12(7)	0.7(5)	-	0.16(10)	6.7(8)	-	0.27(16)	3.4(9)	-
Rest of world[f]	0.34(18)	2.0(14)	-	0.34(21)	19(22)	-	0.33(20)	7.3(17)	-
Primary ocean[g]	0.22(12)	1.3(9)	-	0.21(13)	12.3(14)	-	0.21(13)	4.7(12)	-
CO: Oxidation of CH_4 and BVOC	-	-	42(26)	-	-	39(32)	-	-	44(28)
Total	1.8(100)	14(100)	173(100)	1.6(100)	86(100)	125(100)	1.7(100)	39(100)	171(100)

[a]Percent contributions are given in parentheses.
[b]Each tagged tracer includes ocean re-emission.
[c]Includes all anthropogenic emissions from regions other than Asia, North America, and Europe.
[d]Includes all biomass burning outside of Asia.
[e]Land tracer includes both geogenic emissions and re-emissions from land.
[f]Includes land emissions from all regions except Asia and North America.
[g]Oceanic mercury that originates below the mixed layer is considered primary ocean.

underestimate is likely due to model resolution and the inability to capture the high concentrations of a thin plume.

[19] The modeled lifetime of total gaseous mercury in the northern hemisphere spring, calculated as the TGM concentration divided by the loss to deposition, is approximately 9 months, so concentrations at both Okinawa and MBO are influenced by global sources. MBO, though more distant from Asia, nevertheless receives 34% of its Hg^0 from Asian sources during spring. On average, these Asian sources include 0.34 ng m^{-3} (20%) from the Asian background, 0.11 ng m^{-3} (7%) from ocean re-emission of Asian emissions, and 0.12 ng m^{-3} (7%) from direct transport from Asia. Non-Asian land and primary ocean emissions are also major contributors at MBO, accounting for 31% and 13%, respectively. The North American anthropogenic contribution is only 2%, reflecting MBO's location upwind from most North American sources. The Asian anthropogenic percent contribution to Hg^0 at MBO shows little variability between seasons, with an Asian anthropogenic contribution of 18% in spring and in the annual average. In the model, the largest Asian Hg^0 contribution occurred on 28 April, when the Asian sources accounted for 41% of Hg^0 (Figure 3 and event c). Since the model underestimates the magnitude of the events, this modeled Asian contribution is likely an underestimate. For CO, the percent contribution is 24% in spring compared to 20% in the annual average. The stronger seasonality in CO reflects its shorter lifetime (~2 months) compared to the 9-month lifetime of TGM.

[20] If we consider the entire continental United States, we find a springtime North American anthropogenic contribution to surface Hg^0 concentrations of 4%, a N. American land contribution of 16%, an Asian anthropogenic contribution of 16%, and an Asian land contribution of 12%. The remainder comes from anthropogenic and land emissions from other regions of the world, biomass burning, and ocean emissions (Table 1).

3.3. Hg^0/CO Ratios

[21] Mercury emissions inventories remain highly uncertain. For the global inventory, the uncertainty is estimated to be ±25% for fuel combustion sources, ±30% for industrial processes, and a factor of 2–5 for waste disposal [*Pacyna et al.*, 2006]. The uncertainty in anthropogenic emissions from China is ±44% [*Streets et al.*, 2005]. Uncertainties in natural mercury emissions, with estimates varying by a factor of 4 [*Gustin and Lindberg*, 2006], as well as re-emissions of previously deposited mercury further complicate these estimates. *Streets et al.* [2006] estimate the uncertainty in CO emissions from China to be ±68%. However, Asian CO emissions inventories have also been constrained by comparison to ground-based, aircraft, and satellite observations [e.g., *Heald et al.*, 2003, 2004; *Palmer et al.*, 2003].

[22] A common method for estimating emissions based on observed concentration data is to use the ratio of two observed compounds [*Hansen et al.*, 1989]. *Jaffe et al.* [2005] report an Hg^0/CO ratio at Okinawa of 0.0053 ng m^{-3} $ppbv^{-1}$ for the spring 2004 observations, as listed in Table 2. Ratios for individual Asian transport events range from 0.0036–0.0074 ng m^{-3} $ppbv^{-1}$, with a mean of 0.0056 ng m^{-3} $ppbv^{-1}$ during Asian transport episodes [*Jaffe et al.*, 2005]. This is similar to the TGM/CO ratio of 0.0074 ng m^{-3} $ppbv^{-1}$ found in a Shanghai plume during the ACE-Asia campaign by *Friedli et al.* [2004] and the TAM/CO ratio of 0.0046 ± 0.0013 ng m^{-3} $ppbv^{-1}$ (mean ± stddev) for Asian long-range transport events at MBO [*Weiss-Penzias et al.*, 2007]. In contrast, *Weiss-Penzias et al.* [2007] observed a TAM/CO enhancement ratio of

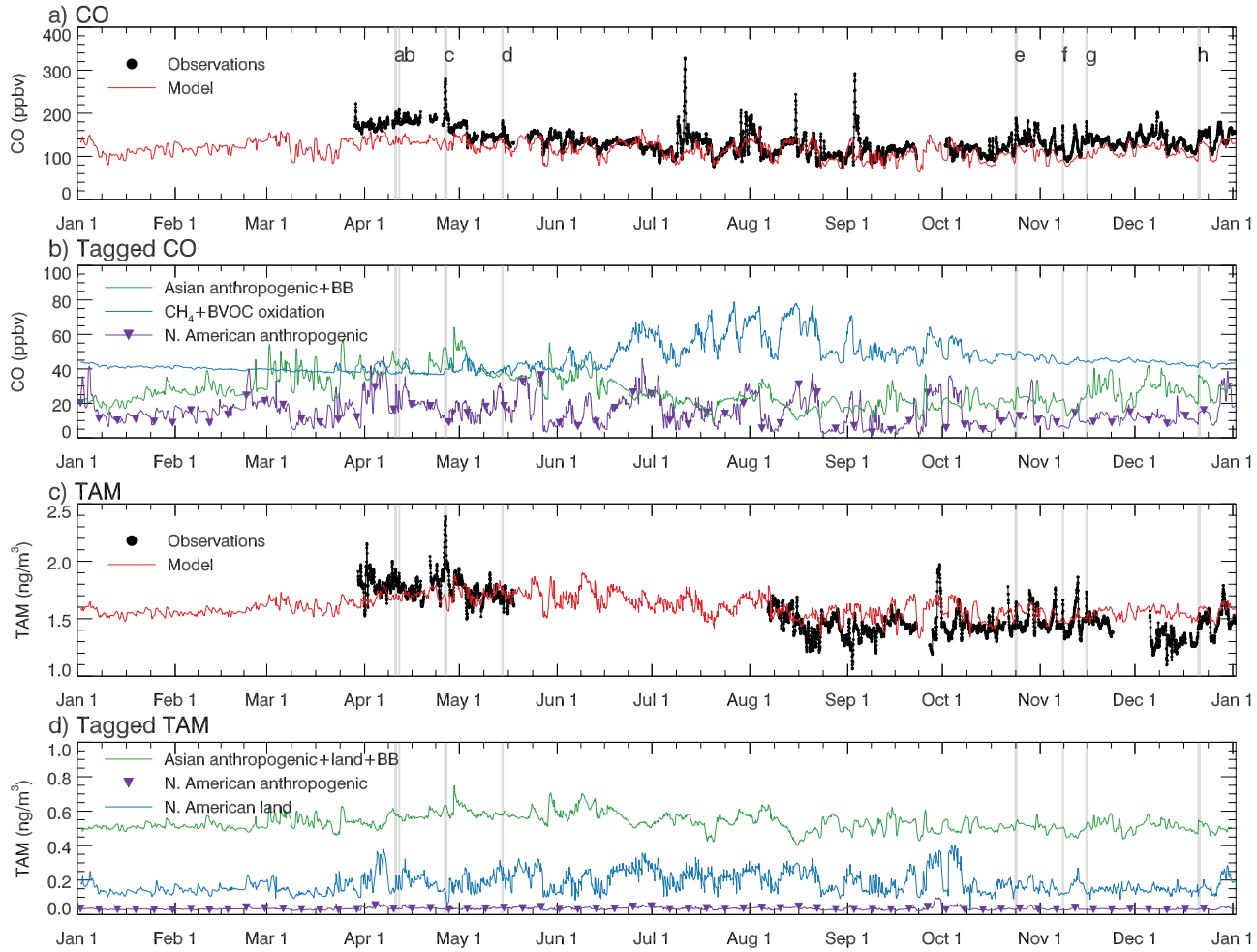


Figure 3. Time series of 6-h running mean observations and model at MBO for 2004. (a) Observed (black) and modeled (red) CO. (b) Model CO tracers tagged by source. (c) Observed (black) and modeled (red) total airborne mercury (TAM) from the standard simulation. (d) TAM tracers tagged by source. Asian long-range transport events from *Weiss-Penzias et al.* [2007] are shaded in gray and labeled Figures 3a–3h.

Table 2. Observed and Modeled Hg^0/CO Ratios (ng m^{-3} ppbv)

Location	Episode	Observations	Model	Model B[b]	Model C[c]	Model D[d]
Okinawa	spring 2004	0.0053	0.0039	0.0050	0.0062	0.0045
	A	0.0043	0.0044	0.0055	0.0066	0.0048
	B	0.0056	0.0029	0.0037	0.0045	0.0030
	C	0.0073	0.0045	0.0056	0.0068	0.0052
	D	0.0051	0.0065	0.0084	0.0103	0.0080
	E	0.0074	0.0044	0.0058	0.0072	0.0053
	F	0.0036	0.0050	0.0063	0.0076	0.0058
	HSO episode mean	0.0056	0.0046	0.0059	0.0072	0.0054
MBO	a	0.0032	0.0025	0.0024	0.0024	0.0026
	b	0.0035	0.0029	0.0029	0.0029	0.0032
	c	0.0042	0.0055	0.0057	0.0061	0.0063
	d	0.0048	0.0047	0.0044	0.0042	0.0045
	e	0.0026	0.0027	0.0033	0.0038	0.0030
	f	0.0044	0.0019	0.0032	0.0039	0.0030
	g	0.0051	0.0027	0.0033	0.0041	0.0029
	h	0.0051	0.0023	0.0034	0.0040	0.0031
	MBO 2004 Episode mean	0.0041	0.0031	0.0036	0.0039	0.0036
ACE-Asia[a]	04/30/01	0.0072	0.0061	0.0073	0.0087	0.0067

[a]The value is given for the Shanghai Plume in the ACE-Asia campaign [*Friedli et al.*, 2004].
[b]Model B has 280 Mg a^{-1} more Asian anthropogenic emissions and the same land emissions as the standard simulation.
[c]Model C has 610 Mg a^{-1} more Asian anthropogenic emissions and the same land emissions as the standard simulation.
[d]Model D repartitions the total emissions from the standard simulation with more anthropogenic emissions compensated by lower land emissions.

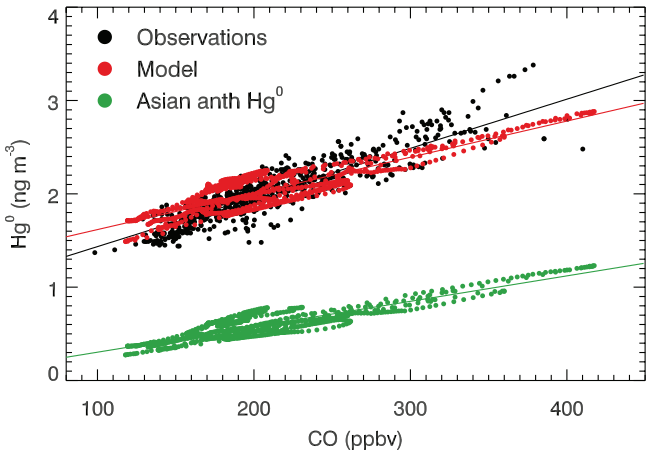


Figure 4. Scatterplot of Hg^0 (ng m^{-3}) versus CO (ppbv) concentrations for Okinawa 2004. Observations are in black, model in red, and model Asian tracer contribution in green. The mercury tracers are from the standard simulation.

0.0011 ng m^{-3} $ppbv^{-1}$ in U.S. industrial events and 0.0014 ng m^{-3} $ppbv^{-1}$ in biomass burning events.

[23] Using the observed ratio, *Jaffe et al.* [2005] calculated Asian Hg^0 emissions of 1460 Mg a^{-1} compared to 610 Mg a^{-1} Hg^0 in the anthropogenic inventory of *Pacyna et al.* [2006]. *Weiss-Penzias et al.* [2007] inferred Hg^0 emissions of 620 Mg a^{-1} from China, a factor of 2 larger than the recent anthropogenic inventory of 300 Mg a^{-1} from *Streets et al.* [2005] for China. The *Pacyna et al.* [2006] inventory for 2000 contains 360 Mg a^{-1} of Hg^0 emissions from China, 20% more than the *Streets et al.* [2005] inventory for 1999. *Pan et al.* [2006] compared a regional model with ACE-Asia data over the Yellow Sea and found that using Asian anthropogenic and biomass burning emissions of 1040 Mg a^{-1} total Hg with 830 Mg a^{-1} from Asian land, biogenic, and marine sources, their model underestimated mercury concentrations after subtracting background concentrations. They suggest that there may be an 80–200% underestimate in mercury emissions from China. Using 4D-Var to assimilate the ACE-Asia data, *Pan et al.* [2007] estimate Asian emissions of 1430–2270 Mg a^{-1} Hg^0, depending on their assumed boundary conditions.

[24] Here, we examine the ability of GEOS-Chem to reproduce observed Hg/CO ratios using the *Pacyna et al.* [2006] inventory. We sample the model hourly at Okinawa and find a slope of 0.0039 ng m^{-3} $ppbv^{-1}$, 26% lower than the observed slope of 0.0053 ng m^{-3} $ppbv^{-1}$ for the total data set (Table 2). Considering the ratios only during the Asian long-range transport events identified by *Jaffe et al.* [2005] yields a mean ratio of 0.0046 ng m^{-3} $ppbv^{-1}$, with a range of 0.0029–0.0065 ng m^{-3} $ppbv^{-1}$, 18% lower than the observed mean.

[25] In comparison to the previous studies described above, we find a smaller underestimate of Asian sources. The model's total Hg^0 tracer is able to capture the observed Hg^0/CO slope to within 30% because it includes a contribution from Asian land emissions and re-emissions. At Okinawa, these tracers covary in time with the Asian anthropogenic tracer and contribute to the magnitude of the observed events (Figure 2d). If we consider only the Asian anthropogenic tracer in the model, we get a slope of 0.0031 ng m^{-3} $ppbv^{-1}$, 42% lower than that observed (Figure 4). Anthropogenic emissions from other regions as well as Asian biomass burning also contribute to some of the events. However, since the model Hg^0/CO ratio is still lower than the observed ratio, we also examine the sensitivity of the model to higher Asian Hg^0 emissions.

[26] *Selin et al.* [2008] included a dry deposition sink for Hg^0 in the GEOS-Chem model and find that they need additional sources to balance this 1700 Mg a^{-1} loss. In particular, they increase the Asian anthropogenic Hg^0 source over the region 70°–152.5°E, 8°–45°N by 50% as well as increasing other anthropogenic sources and including artisanal mining. We conduct a simulation (Model B) by increasing the Asian anthropogenic source from 610 to 890 Mg a^{-1} Hg^0, but without including dry deposition of Hg^0 or increasing other sources. This simulation reproduces the observed Hg^0/CO slope for the total Okinawa data set (0.0050 ng m^{-3} $ppbv^{-1}$ modeled, 0.0053 ng m^{-3} $ppbv^{-1}$ observed) and the Asian transport events within 6%, but leads to a 13% positive bias in modeled Hg^0 for the total data set at Okinawa. Thus the Hg^0/CO ratio is consistent with a larger Asian anthropogenic source. However, lower background concentrations would be required to prevent model bias at Okinawa. Total Asian emissions of Hg^0 in this simulation are 1450 Mg a^{-1}. This estimate is smaller than the 2270 Mg a^{-1} of *Pan et al.* [2007] based on background concentrations of 1.2 ng m^{-3}, but agrees well with their estimate of 1430 Mg a^{-1} based on background concentrations of 1.5 ng m^{-3}. GEOS-Chem reproduces mean concentrations at nonurban land-based sites of 1.58 ng m^{-3} [*Selin et al.*, 2007]. Since the Hg^0/CO ratio at Okinawa is sensitive primarily to Hg^0 emissions, this improvement in the modeled ratio can be obtained either by increasing total emissions as described above, or by changing the speciation of the original emissions so that a larger fraction is emitted as Hg^0. *Edgerton et al.* [2006] found that 84% of the mercury in power plant plumes was Hg^0. Applying this speciation to the Asian emissions would lead to approximately a 50% increase in Asian Hg^0 (910 Mg a^{-1} Hg^0, 1470 Mg a^{-1} total Hg), leading to similar Asian Hg^0 emissions and a similar fit to observations compared with Model B.

[27] We conduct a third simulation (Model C) with Asian anthropogenic Hg^0 emissions over Asia doubled (1220 Mg a^{-1}) while other emissions are the same as in the base simulation. This yields a Hg^0/CO ratio of 0.0072 ng/m^3/ppbv for the Asian long-range transport events at Okinawa, a standard deviation above the observed mean (0.0056 ± 0.0016 ng m^{-3} $ppbv^{-1}$). For the total data set, we find a Hg^0/CO ratio of 0.0062 ng m^{-3} $ppbv^{-1}$ compared to the observed 0.0053 ng m^{-3} $ppbv^{-1}$. This simulation also leads to a 26% positive bias in Hg^0 concentrations at Okinawa, although this could potentially be reduced by inclusion of Hg^0 dry deposition. We therefore consider the doubling of Asian anthropogenic emissions an upper limit of the uncertainty.

[28] It is possible that an overestimate in the modeled land emissions could compensate for an underestimate in anthropogenic emissions. We examine this possibility with a model simulation (Model D) in which we decrease Asian

Table 3. Comparison of Asian and Chinese Hg^0 Emissions (Mg a^{-1}) From Several Studies[a]

Reference	Emissions: Asia	Emissions: China
Jaffe et al. [2005]	1460	
Pacyna et al. [2006]	(610)	(360)
Pan et al. [2007]	1430–2270	720–1140
Weiss-Penzias et al. [2007]		(620 ± 180)
Streets et al. [2005]		(300)
This study	1260–1450 (890–990)	680–800 (530–580)

[a]Values are given for emissions from all sources, while emissions from anthropogenic sources only are in parentheses.

Hg^0 land emissions and re-emissions by 70% (from 540 to 160 Mg a^{-1}) and increase Asian anthropogenic Hg^0 emissions by 62% (from 610 to 990 Mg a^{-1}) so that the total emissions are the same as the reference simulation. We do not alter the spatial distribution of the land or anthropogenic emissions. This simulation improves the agreement of the modeled and observed Hg^0/CO ratios for the total data set and agrees with the observed ratios during long-range transport events to within 2% (Table 2). It also increases the overall model Hg^0 bias at Okinawa from 2% to 7%.

[29] Mercury emitted from Asia as Hg^{II} and then reduced in the atmosphere can also contribute to the amount of Hg^0 reaching Okinawa during transport events. In-cloud reduction of Hg^{II} to Hg^0 in GEOS-Chem is scaled according to constraints on seasonal variability and TGM liftetime [*Selin et al.*, 2007]. Furthermore, *Edgerton et al.* [2006] suggest that in-plume reduction of RGM could explain their observations of RGM and Hg^0. To quantify the role of Hg^{II} emissions in our standard simulation, we conduct a model simulation without anthropogenic emissions of Hg^{II}. We find that removing direct Hg^{II} emissions decreases the model Hg^0/CO slope during Asian long-range transport events from 0.0046 ng m^{-3} $ppbv^{-1}$ to 0.0039 ng m^{-3} $ppbv^{-1}$ for Okinawa. This suggests that aqueous reduction of Hg^{II} emissions during transport contributes ~15% to the observed Hg^0/CO ratio at Okinawa.

[30] During the ACE-Asia campaign, *Friedli et al.* [2004] report a TGM/CO ratio of 6.4×10^{-6} w/w in a plume originating in Shanghai that they sampled on 30 April 2001. This is equivalent to 0.0072 ng m^{-3} $ppbv^{-1}$. We sample the model along the 30 April 2001 flight track and find a TGM/CO ratio of 0.0061 ng m^{-3} $ppbv^{-1}$, which would be 23% lower in the absence of Hg^{II} emissions. Increasing Asian emissions by 280 Mg a^{-1} (Simulation B) results in a TGM/CO ratio of 0.0073 ng m^{-3} $ppbv^{-1}$, in better agreement with the observed ratio (Table 2). *Friedli et al.* [2004] observed a peak in TGM concentrations between 6 and 7 km altitude, which they attribute to lofted pollution. Examining the vertical profile of Asian Hg^0 above Okinawa in the GEOS-Chem model, we also see episodic enhancements at this altitude.

[31] We also compare modeled and observed TAM/CO ratios at MBO during 8 Asian long-range transport events in 2004, as defined by *Weiss-Penzias et al.* [2007]. This leads to a modeled TAM/CO ratio of 0.0031 ng m^{-3} $ppbv^{-1}$ for the standard simulation, compared to the 2004 observed mean ratio of 0.0041 ng m^{-3} $ppbv^{-1}$ [*Weiss-Penzias et al.*, 2007]. Simulation B (50% increase in Asian anthropogenic Hg^0) yields an enhancement ratio of 0.0036 ng m^{-3} $ppbv^{-1}$ and an 11% positive model bias in Hg^0. Simulation C (doubled Asian anthropogenic Hg^0) results in a small underestimate of the enhancement ratio (0.0039 ng m^{-3} $ppbv^{-1}$) and a 20% positive model bias. Simulation D (62% higher Asian anthropogenic and 70% lower land emissions) similarly increases the modeled enhancement ratio to 0.0036 ng m^{-3} $ppbv^{-1}$ (Table 1) without changing the mean Hg^0 at MBO.

[32] We consider simulations B and D the best fit to the observations. This leads to an estimated range of Asian Hg^0 emission of 1260–1450 Mg a^{-1}, of which 890–990 is anthropogenic (Table 3). This represents approximately a 50% increase over the anthropogenic emissions estimate of *Pacyna et al.* [2006]. For China, we find Hg^0 emissions of 680–800 Mg a^{-1} of which 530–580 Mg a^{-1} is anthropogenic. This lies within the uncertainty given by *Weiss-Penzias et al.* [2007] and at the low end of the *Pan et al.* [2007] estimate, but our anthropogenic emissions are larger than the *Streets et al.* [2005] inventory (Table 3).

[33] We use GEOS-Chem at $4° \times 5°$ resolution to explore the effect of source regions on Hg^0/CO ratios globally. Figure 5 shows the Hg^0/CO regression slope for a 3-hourly time series in each model grid box at 930 hPa for April 2004. Slopes are only included where the Hg^0 versus CO regression yields $r^2 > 0.4$, and the standard deviation of CO exceeds 15% of mean CO. These criteria are met over and downwind of major source regions such as eastern China, Europe, and the eastern United States. In the southern hemisphere, South Africa and Australia are highlighted. We find large average Hg^0/CO ratios downwind of Asia (0.0040 ng m^{-3} $ppbv^{-1}$), and smaller ratios downwind of the eastern United States (0.0021 ng m^{-3} $ppbv^{-1}$) and Europe (0.0024 ng m^{-3} $ppbv^{-1}$). The highest Hg^0/CO ratio occurs near South Africa (0.0099 ng m^{-3} $ppbv^{-1}$), while outflow from Australia has a lower ratio of 0.0025 ng m^{-3} $ppbv^{-1}$. This supports the use of Hg^0/CO ratios as tracers of source regions. Care should be taken, however, in the interpretation of Hg/CO ratios as they reflect land as well as anthropogenic emissions of mercury. Furthermore,

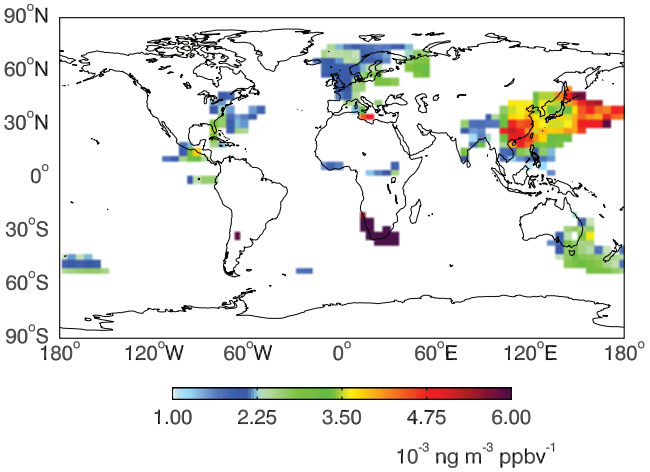


Figure 5. Hg^0/CO regression slopes for 3-hourly model output at 930 hPa for April 2004. Slopes are only given for grid boxes with a standard deviation of CO greater than 15% of mean CO and $r^2 > 0.4$ for the Hg^0/CO correlation.

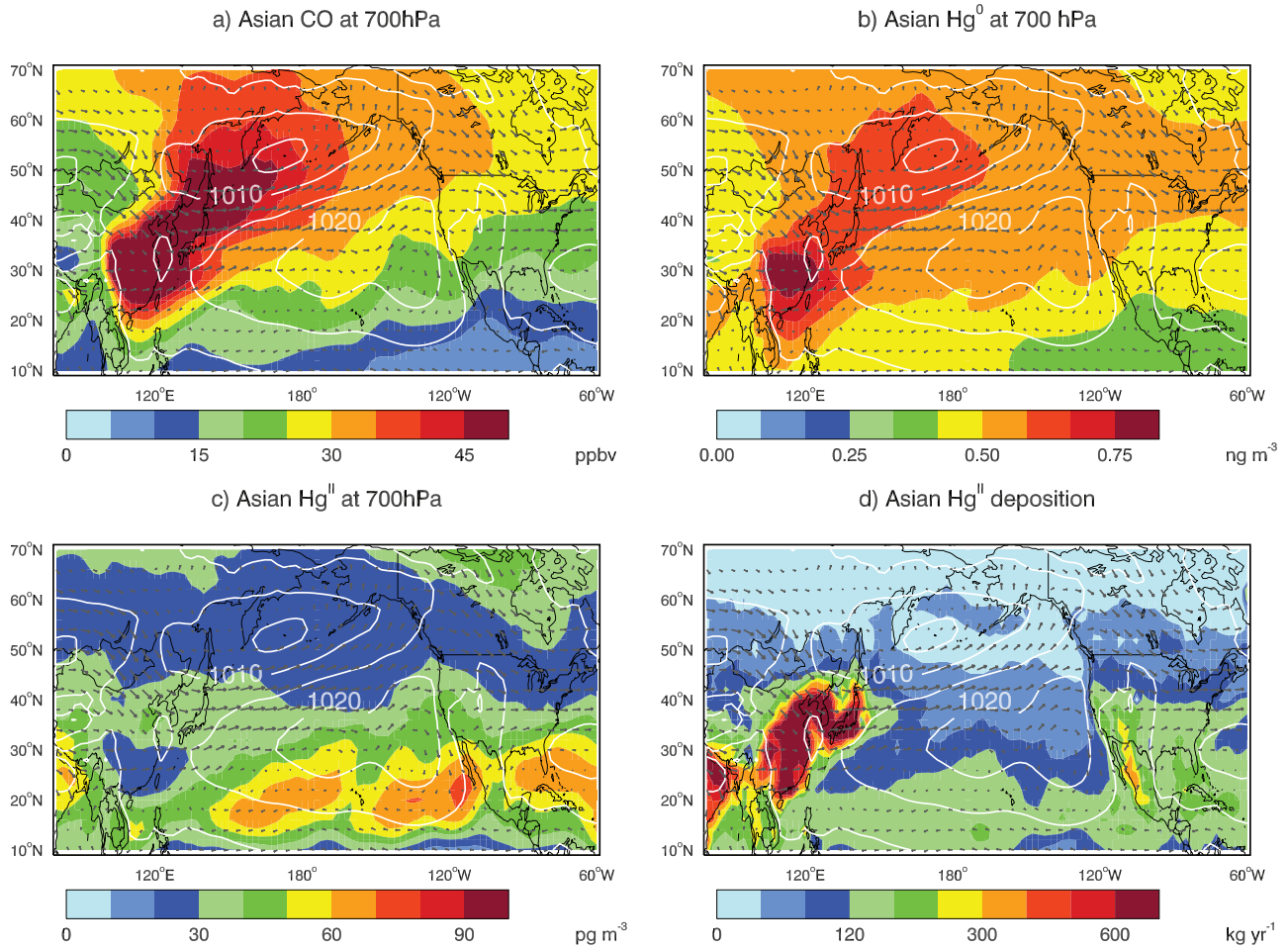


Figure 6. Map of March–May 2004 700 hPa concentrations of Asian (a) CO (ppbv), (b) Hg^0 (ng m^{-3}), and (c) Hg^{II} (pg m^{-3}) over the Pacific. Asian total deposition (kg a^{-1}) is shown in Figure 6d. Sea level pressure contours are overplotted in white, and gray arrows indicate wind at 700 hPa.

enhancement ratios may not be unique to a particular region. *Slemr et al.* [2006a] found TGM/CO ratios averaging 0.0050 ng m^{-3} $ppbv^{-1}$ at Mace Head, Ireland, similar to the ratios found in Asian outflow.

3.4. Trans-Pacific Transport of CO and Mercury

[34] The different mechanisms by which Asian Hg^0 and Hg^{II} reach North America affect the latitudinal distribution of their contributions (Figure 6). Hg^0, like CO, is transported to the northeast from Asia with the prevailing winds. Consequently, at 700 hPa the Asian influence is largest over Alaska, western Canada and the Northwestern United States (Figures 6a and 6b). In contrast, Asian emissions influence North American Hg^{II} concentrations through in situ oxidation of the global Asian Hg^0 pool rather than by direct advection of Hg^{II} from the emission source. The Asian Hg^{II} contribution is thus largest at low latitudes where high oxidant concentrations and descending dry air favor accumulation of Hg^{II} (Figure 6c). Total Hg^{II} concentrations are also high in this region for the same reason. Asian Hg^{II} deposition follows a similar pattern to Asian Hg^{II} concentration since both wet and dry deposition depend on Hg^{II} concentrations. Hg^{II} deposition is also larger over land, where dry deposition velocity is high (Figure 6d). In terms of percent contribution from Asian sources, the geographic distribution and the deposition of Hg^{II} are similar to that of Hg^0 and CO (Figure 7). This similarity occurs because Hg^{II} originates from oxidation of the Hg^0 pool and thus reflects regional percent contributions to that pool.

[35] Figure 8 shows a longitudinal cross-section of the contribution of CO, Hg^0, and Hg^{II} from Asian sources across the Pacific during spring. The contribution from Asian Hg^0 and CO decreases with distance from Asia, with Asian Hg^0 decreasing by 32% and CO decreasing by 56% at the surface between 140°E and 125°W. Both species show lower concentrations in the upper troposphere (Figures 8a and 8b). In contrast, Asian Hg^{II} increases at high altitudes, where it is not readily removed by wet or dry deposition or in-cloud reduction [*Selin et al.*, 2007]. Consequently, Asian Hg^{II} in the upper troposphere is due to oxidation of Asian Hg^0 emissions rather than to direct transport of Asian Hg^{II} emissions, which are mostly deposited close to their source (Figure 8c). The inverse altitude profiles of Hg^{II} and Hg^0 are consistent with observations at MBO [*Swartzendruber et al.*, 2006] and aircraft observations off the Florida coast [*Landis et al.*, 2005].

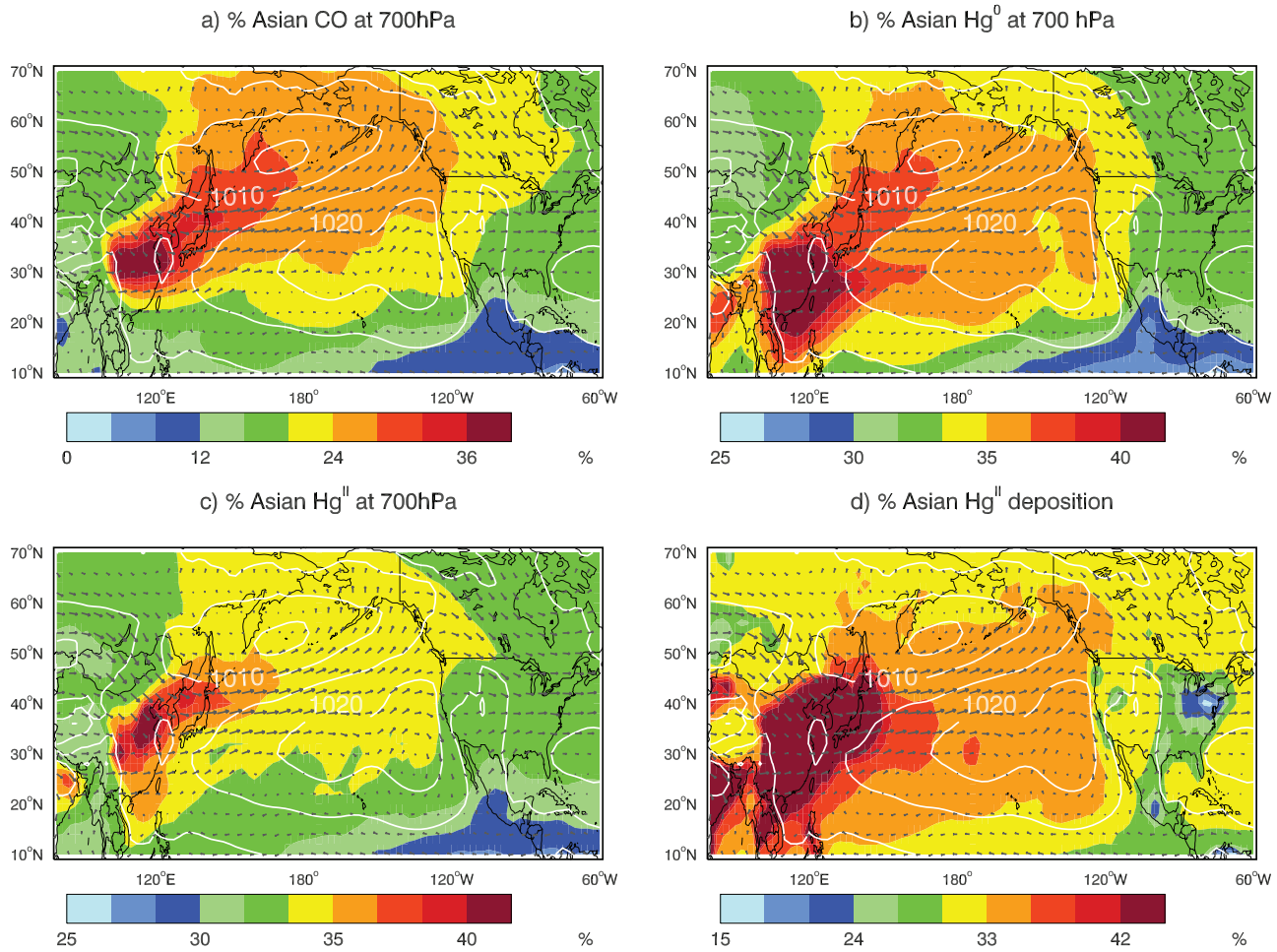


Figure 7. Map of March–May 2004 700 hPa percent contributions from the Asian tracers to (a) CO, (b) Hg^0, (c) Hg^{II}, and (d) total (wet + dry) deposition over the Pacific. Sea level pressure contours are overplotted in white, and gray arrows indicate wind direction.

[36] We consider the role Asian Hg^0 re-emitted from the ocean using a tagged simulation with ocean emissions turned off. We find that ocean re-emission increases the Asian contribution of Hg^0 over the west coast of North America by 29% (from 0.42 to 0.54 ng/m^3) (Figures 8b and 8d). Including Hg^0 ocean re-emissions increases the amount of Hg^0 available for oxidation and thus increases the background levels of Hg^{II} in the upper troposphere (Figures 8c and 8e).

3.5. Origin of Mercury Over the United States

[37] Table 4 shows regional contributions to Hg^{II} deposition (wet and dry) to Okinawa, MBO, and the United States. These contributions are based on the tagged tracer contributions in our standard simulation. Adding anthropogenic (including ocean re-emission) and land tracers together, we find a North American contribution to deposition over the continental United States of 26%, slightly lower than the 30% contribution of North American anthropogenic (direct + re-emission) to the US of *Seigneur et al.* [2004] and the 33% natural + anthropogenic North American contribution to deposition over North America of *Travnikov* [2005]. Our Asian land + anthropogenic deposition to the US is 25%, compared to 21% over the US [*Seigneur et al.*, 2004] and 24% over North America [*Travnikov*, 2005]. The Asian contribution in this study includes anthropogenic, geogenic, and land re-emission from Asia, as well as ocean re-emission of all those tracers. For comparison, *Seigneur et al.* [2004] include anthropogenic emissions from Asia and re-emission of those emissions from all regions, while *Travnikov* [2005] consider natural and anthropogenic emissions from Asia.

[38] The relative importance of Asian and North American sources to deposition over the U.S. varies geographically. We find that the average contribution to deposition in the western U.S. (125°–100°W) from the North American anthropogenic tracer is 11%, where as in the eastern U.S. (95°–75°W) the average contribution is 25% due to larger anthropogenic emissions in the eastern half of the country. This is similar to the results of *Selin et al.* [2007]. The Asian anthropogenic contribution to deposition is 15% over the western U.S. and 12% over the eastern U.S. For Hg^0 concentrations over the United States, the east-west gradient is smaller than for deposition, with approximately 15% coming from Asian anthropogenic sources in both the east and west of the country and the North American anthropogenic contribution increasing from 3% in the west to 6% in

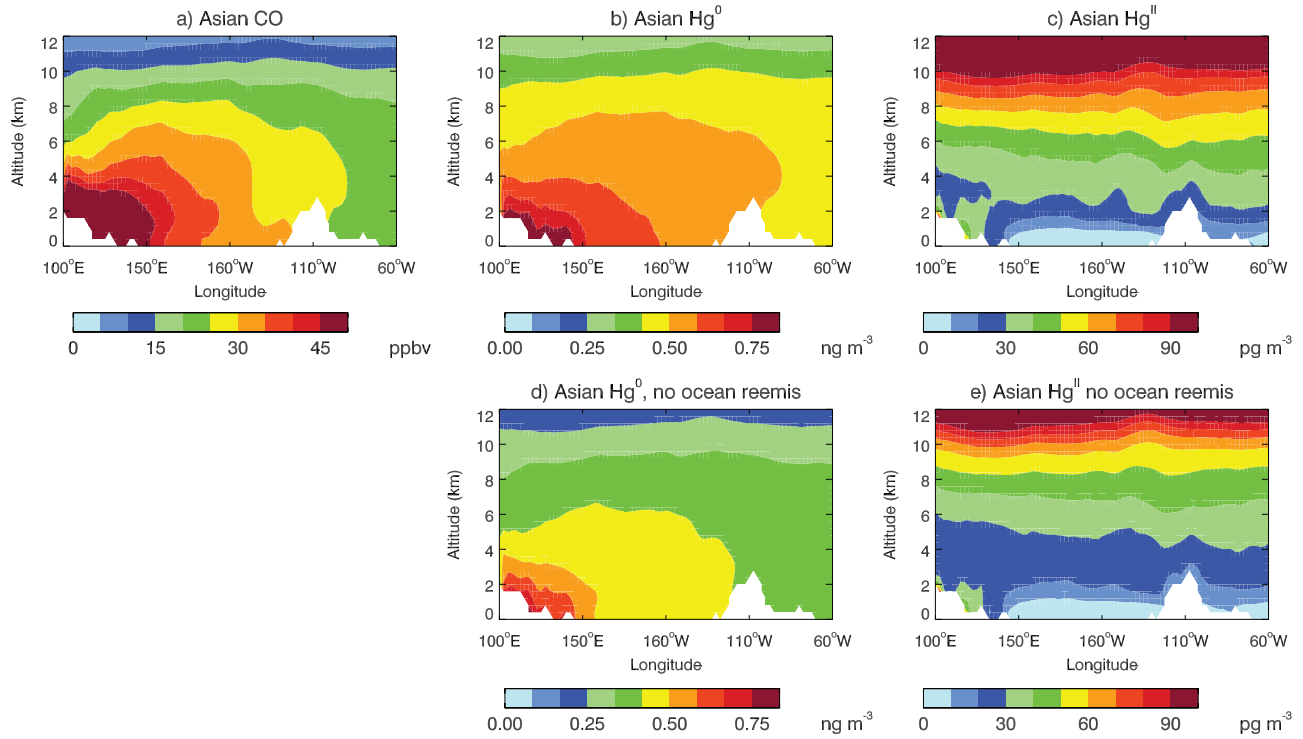


Figure 8. Longitude-altitude plot of Asian tracer concentrations averaged over 28°–60°N from 1 March to 31 May 2004 for (a) CO, (b) Hg^0 , and (c) Hg^{II}. Figures 8d and 8e show the Asian tracer concentrations excluding ocean re-emissions.

the east. The near-source deposition of Hg^{II} emissions drives the large east west gradient in deposition.

4. Conclusions

[39] We conducted a simulation of trans-Pacific transport of mercury including anthropogenic emissions tagged by region of origin as well as natural emissions and re-emissions from land and ocean. The simulation captures 39% of the observed variability in Hg^0 concentrations at Okinawa, Japan, and attributes the variability primarily to variability in the outflow of Asian anthropogenic and land emissions. At Mount Bachelor, Oregon, the model captures mean concentrations (1.53 ± 0.19 ng/m^3 observed, 1.61 ± 0.09 ng/m^3 modeled) of Hg^0, but underestimates the magnitude of the observed long-range transport events.

[40] We tested the model's ability to reproduce observed Hg/CO enhancement ratio during Asian long-range transport using the *Pacyna et al.* [2006] inventory for anthropogenic emissions. By including transport of Asian land emissions, which covary in time with transport of Asian anthropogenic emissions, the model reproduces the observed Hg/CO enhancement ratios to within approximately 30%. However, the ratio is underestimated, suggesting that Asian emissions in the inventory may also be underestimated. Increasing Asian anthropogenic Hg^0 emissions by 50% improves the ratio, but leads to a positive bias in the mean concentration. Altering the speciation of the emissions to increase Hg^0 yields a similar result. Increasing Asian anthropogenic Hg^0 emissions by 62% while reducing Asian land emissions so that total Asian emission is unchanged also improves the Hg/CO ratio. Doubling Asian anthropogenic emissions leads to a 29% overestimate of the Hg/CO ratio. We find that approximately 15% of the Hg/CO enhancement ratio at Okinawa is due to reduction of Hg^{II} emissions during transport. We cannot conclusively separate the effect of anthropogenic versus land emissions, but total Asian Hg^0 emissions of 1260–1470 Mg/a from anthropogenic, land, and biomass burning in the region 65°–146°W, 9°S–60°N are consistent with observations.

[41] Trans-Pacific transport of Hg^0 follows similar patterns to CO in both its latitudinal and vertical distribution. At MBO, we find a springtime Asian anthropogenic contribution to Hg^0 concentrations of 18% compared to a North American anthropogenic contribution of 2%. Including land emissions, these contributions increase to 31% and 12%, respectively. Ocean re-emission accounts for 22% of the Asian anthropogenic influence over the west coast of North America. Unlike Hg^0, Hg^{II} is not transported across the

Table 4. Annual Mean Percent Contribution to Wet and Dry Deposition of Hg^{II}

Annual Mean Deposition	%	Okinawa	MBO	USA
Anthropogenic	Asia	35	14	14
	N. America	1	19	16
	Europe	4	5	5
	rest of world	7	6	7
Biomass burning	Asia	2	2	2
	rest of world	5	5	5
Land	Asia	11	11	11
	N. America	6	9	10
	rest of world	17	17	18
Ocean	primary	12	12	12

Pacific in the lower troposphere due to its short lifetime, but the long lifetime of Hg^{II} in the upper troposphere allows global transport.

[42] **Acknowledgments.** This work was supported by funding from the National Science Foundation grant ATM 0238530.

References

Bey, I., D. J. Jacob, R. M. Yantosca, J. A. Logan, B. D. Field, A. M. Fiore, Q. Li, H. Y. Liu, L. J. Mickley, and M. G. Schultz (2001), Global modeling of tropospheric chemistry with assimilated meteorology: Model description and evaluation, *J. Geophys. Res.*, *106*, 23,073–23,095.

Duncan, B. N., R. V. Martin, A. C. Staudt, R. Yevich, and J. A. Logan (2003), Interannual and seasonal variability of biomass burning emissions constrained by satellite observations, *J. Geophys. Res.*, *108*(D2), 4100, doi:10.1029/2002JD002378.

Duncan, B. N., J. A. Logan, I. Bey, I. A. Megretskaia, R. M. Yantosca, P. C. Novelli, N. B. Jones, and C. P. Rinsland (2007), The global budget of CO, 1988–1997: Source estimates and validation with a global model, *J. Geophys. Res.*, *112*, D22301, doi:10.1029/2007JD008459.

Edgerton, E. S., B. E. Hartsell, and J. J. Jansen (2006), Mercury speciation in coal-fired power plant plumes observed at three surface sites in the southeastern U.S., *Environ. Sci. Technol.*, *40*, 4563–4570.

Friedli, H. R., L. F. Radke, and R. Prescott (2004), Mercury in the atmosphere around Japan, Korea, and China as observed during the 2001 ACE-Asia field campaign: Measurements, distributions, sources, and implications, *J. Geophys. Res.*, *109*, D19S25, doi:10.1029/2003JD004244.

Gustin, M. S., and S. E. Lindberg (2006), Terrestrial mercury fluxes: Is the net exchange up, down, or neither, in *Dynamics of Mercury Pollution on Regional and Global Scales: Atmospheric Processes and Human Exposures Around the World*, edited by N. Pirrone and K. R. Mahaffey, pp. 241–259, Springer, Norwell, Mass.

Hansen, A. D. A., T. J. Conway, L. P. Steele, B. A. Bodhaine, K. W. Thoning, P. Tans, and T. Novakov (1989), Correlations among combustion effluent species at Barrow, Alaska: Aerosol black carbon, carbon dioxide, and methane, *J. Atmos. Chem.*, *9*, 283–299.

Heald, C. L., et al. (2003), Asian outflow and trans-Pacific transport of carbon monoxide and ozone pollution: An integrated satellite, aircraft, and model perspective, *J. Geophys. Res.*, *108*(D24), 4804, doi:10.1029/2003JD003507.

Heald, C. L., D. J. Jacob, D. B. A. Jones, P. I. Palmer, J. A. Logan, D. G. Streets, G. W. Sachse, J. C. Gille, R. N. Hoffman, and T. Nehrkorn (2004), Comparative inverse analysis of satellite (MOPITT) and aircraft (TRACE-P) observations to estimate Asian sources of carbon monoxide, *J. Geophys. Res.*, *109*, D23306, doi:10.1029/2004JD005185.

Jaffe, D., E. Prestbo, P. Swartzendruber, P. Weiss-Penzias, S. Kato, A. Takami, S. Hatakeyama, and Y. Kajii (2005), Export of atmospheric mercury from Asia, *Atmos. Environ.*, *39*, 3029–3038.

Landis, M. S., M. M. Lynam, and R. K. Stevens (2005), The monitoring and modeling of mercury species in support of local, regional, and global modeling, in *Dynamics of Mercury Pollution on Regional and Global Scales*, edited by N. Pirrone and K. R. Mahaffy, Springer, New York.

Liang, Q., J. Jaeglé, D. A. Jaffe, P. Weiss-Penzias, A. Heckman, and J. A. Snow (2004), Long-range transport of Asian pollution to the northeast Pacific: Seasonal variations and transport pathways of carbon monoxide, *J. Geophys. Res.*, *109*, D23S07, doi:10.1029/2003JD004402.

Mason, R. P., and G.-R. Sheu (2002), Role of the ocean in the global mercury cycle, *Global Biogeochem. Cycles*, *16*(4), 1093, doi:10.1029/2001GB001440.

Pacyna, E., J. Pacyna, F. Steenhuisen, and S. Wilson (2006), Global anthropogenic mercury emission inventory for 2000, *Atmos. Environ.*, *40*, 4048–4063.

Palmer, P. I., D. J. Jacob, D. B. A. Jones, C. L. Heald, R. M. Yantosca, and J. A. Logan (2003), Inverting for emissions of carbon monoxide from Asia using aircraft observations over the western Pacific, *J. Geophys. Res.*, *108*(D21), 8828, doi:10.1029/2003JD003397.

Pan, L., J.-H. Woo, G. R. Carmichael, Y. Tang, H. R. Friedli, and L. F. Radke (2006), Regional distribution and emissions of mercury in east Asia: A modeling analysis of Asian Pacific Regional Aerosol Characterization Experiment (ACE-Asia) observations, *J. Geophys. Res.*, *111*, D07109, doi:10.1029/2005JD006381.

Pan, L., T. Chai, G. R. Carmichael, Y. Tang, D. Streets, J.-H. Woo, H. R. Friedli, and L. F. Radke (2007), Top-down estimate of mercury emissions in China using four-dimensional variational data assimilation, *Atmos. Environ.*, *41*, 2804–2819.

Seigneur, C., K. Vijayaraghavan, K. Lohman, P. Karamchandani, and C. Scott (2004), Global source attribution for mercury deposition in the United States, *Environ. Sci. Technol.*, *38*, 555–569.

Selin, N. E., D. J. Jacob, R. J. Park, R. M. Yantosca, S. Strode, L. Jaeglé, and D. Jaffe (2007), Chemical cycling and deposition of atmospheric mercury: Global constraints from observations, *J. Geophys. Res.*, *112*, D02308, doi:10.1029/2006JD007450.

Selin, N. E., D. J. Jacob, R. M. Yantosca, S. Strode, L. Jaeglé, and E. M. Sunderland (2008), Global 3-D land-ocean-atmosphere model for mercury: Present-day vs. preindustrial cycles and anthropogenic enrichment factors for deposition, *Global Biogeochem. Cycles*, *22*, GB2011, doi:10.1029/2007GB003040.

Slemr, F., R. Ebinghaus, P. G. Simmonds, and S. G. Jennings (2006a), European emissions of mercury derived from long-term observations at Mace Head, on the western Irish coast, *Atmos. Environ.*, *40*, 6966–6974.

Slemr, F., R. Ebinghaus, A. Zahn, and C. A. M. Brenninkmeijer (2006b), Distribution of gaseous mercury in the upper troposphere and lower dtratosphere as observed by CARIBIC flights, poster, EGU.

Streets, D. G., J. Hao, Y. Wu, J. Jiang, M. Chan, H. Tian, and X. Feng (2005), Anthropogenic mercury emissions in China, *Atmos. Environ.*, *39*, 7789–7806.

Streets, D. G., Q. Zhang, L. Wang, K. He, J. Hao, Y. Wu, Y. Tang, and G. R. Carmichael (2006), Revisiting China's CO emissions after the Transport and Chemical Evolution over the Pacific (TRACE-P) mission: Synthesis of inventories, atmospheric modeling, and observations, *J. Geophys. Res.*, *111*, D14306, doi:10.1029/2006JD007118.

Strode, S. A., L. Jaeglé, N. E. Selin, D. J. Jacob, R. J. Park, R. M. Yantosca, R. P. Mason, and F. Slemr (2007), Air-sea exchange in the global mercury cycle, *Global Biogeochem. Cycles*, *21*, GB1017, doi:10.1029/2006GB002766.

Swartzendruber, P. C., D. A. Jaffe, E. M. Prestbo, P. Weiss-Penzias, N. E. Selin, R. Park, D. J. Jacob, S. Strode, and L. Jaeglé (2006), Observations of reactive gaseous mercury in the free troposphere at the Mount Bachelor Observatory, *J. Geophys. Res.*, *111*, D24301, doi:10.1029/2006JD007415.

Talbot, R., et al. (2007), Factors influencing the large-scale distribution of Hg^0 in the Mexico City area and over the North Pacific, *Atmos. Chem. Phys. Discuss.*, *7*, 15,533–15,563.

Travnikov, O. (2005), Contribution of the intercontinental atmospheric transport to mercury pollution in the Northern Hemisphere, *Atmos. Environ.*, *39*, 7541–7548.

Weiss-Penzias, P., D. A. Jaffe, P. Swartzendruber, J. B. Dennison, D. Chand, W. Hafner, and E. Prestbo (2006), Observations of Asian air pollution in the free troposphere at Mount Bachelor Observatory during the spring of 2004, *J. Geophys. Res.*, *111*, D10304, doi:10.1029/2005JD006522.

Weiss-Penzias, P., D. Jaffe, P. Swartzendruber, W. Hafner, D. Chand, and E. Prestbo (2007), Quantifying Asian and biomass burning sources of mercury using the Hg/CO ratio in pollution plumes observed at the Mount Bachelor Observatory, *Atmos. Environ.*, *41*, 4366–4379.

Wilson, S., F. Steenhuisen, J. Pacyna, and E. Pacyna (2006), Mapping the spatial distribution of global anthropogenic mercury atmospheric emission inventories, *Atmos. Environ.*, *40*, 4621–4632.

C. Holmes, N. E. Selin, and R. M. Yantosca, School of Engineering and Applied Sciences and Department of Earth and Planetary Sciences, Harvard University, 29 Oxford St., Cambridge, MA 02138, USA.

L. Jaeglé, S. A. Strode, and P. C. Swartzendruber, Department of Atmospheric Sciences, University of Washington, 408 ATG Building, Box 351640, Seattle, WA 98195-1640, USA. (sstrode@atmos.washington.edu)

D. A. Jaffe, Interdisciplinary Arts and Sciences Department, University of Washington, Box 358530, Bothell, WA 98011, USA.

Protecting Nearshore Habitat and Functions in Puget Sound

October 2007

Revised June 2010

EnviroVision,
Herrera Environmental, and
Aquatic Habitat Guidelines Program[1]

[1] The Aquatic Habitat Guidelines Program is a multi-agency committee within Washington State that receives support and participation from the Departments of Fish and Wildlife, Ecology, Natural Resources, Transportation, Commerce; the Recreation and Conservation Office, and the Puget Sound Partnership.

TABLE OF CONTENTS

SECTION I 1

INTRODUCTION 1

Purpose and Need 1

Acknowledgements 5

Relationship to SMA and GMA Requirements 5

The Puget Sound Nearshore 8

SECTION II 1

SCIENCE BRIEFS: KEY NEARSHORE HABITATS 1

Beaches and Bluffs 2

Forage Fish Habitat 16

Kelp and Eelgrass Beds 28

Marine Riparian Vegetation 36

Juvenile Salmon Habitat 44

SECTION III RECOMMENDATIONS FOR REGULATING COMMON SHORELINE MODIFICATION ACTIVITIES 1

Using the SMP to Enhance Habitat Protection 1

Overwater Structures 3

Shoreline Armoring 20

Riparian Vegetation Alteration 33

LITERATURE CITED 1

GENERAL REFERENCE 1

APPENDIX A – SHORELINE MASTER PROGRAM PLANNING PROCESS 1

TABLE OF TABLES

SECTION I

Table 1.1 Link Between Topics Addressed in this Guidance and the SMA. 7

SECTION II

Table II.2: Common Impacts to Beaches and Bluffs and Key Regulatory and Design Considerations. .. 14

Table II.3: Common Impacts to Forage Fish Habitat and Key Regulatory and Design Considerations... 27

Table II.4: Common Impacts to Kelp and Eelgrass and Key Regulatory and Design Considerations. 36

Table II.5: Common Impacts to Marine Riparian Vegetation and Key Regulatory and Design Considerations. 43

Table II.6: Common Impacts to Juvenile Salmonids and Key Regulatory and Design Considerations. .. 48

SECTION III

Table III.1. Impacts from over-water structures (piers, docks and floats) and natural functions that may be affected. 4

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage..... 10

Table III.3. Mitigation strategies for habitat losses due to development of overwater structures, shoreline armoring, and riparian vegetation management. 16

Table III.4. Impacts from shoreline armoring and the natural functions that may be affected. 22

Table III.5. Recommendations for design and construction of shoreline armoring structures. 29

Table III.6. Impacts from marine riparian alterations and the natural functions that may be affected. 34

Table III.7. Marine riparian buffer functions and appropriate widths identified in the literature 39

Table III.8. Recommendations for riparian vegetation alteration. 44

TABLE OF FIGURES

SECTION II

Figure II.1. Diagram of Puget Sound nearshore terminology. 3

Figure II.2. Example of beach width loss through passive erosion. 4

Figure II.3. Change in sediment size between the upper slope and low tide terrace. 5

Figure II.4. Large grain sediment deposits from storm activity. 6

Figure II.5. Four examples of common bluff formations found throughout the Puget lowlands. 8

Figure II.6. Examples of natural erosion (left photo) and steep bluff vegetation on right (from Brennan 2007). 10

Figure II.7. Photos contrasting high-tide wind waves(top) versus low-tide wind waves (bottom). 12

Figure II.8. Illustration of frequent causes of bank stability failure as a result of alterations of hydrology and vegetation. 13

Figure II.9. Forage fish spawning habitats in the nearshore zone of Puget Sound. 17

Figure II.10. Intertidal algae bed with heavy herring spawn, S. Cherry Point, Whatcom County. 19

Figure II.11. Sand lance spawning beach with fresh spawn pits, S. Port Gamble Bay, Kitsap Co. 22

Figure II.12. Low-tide terrace eelgrass bed (*Zostera marina*). 29

Figure II.13. Underwater view of eelgrass. 32

Figure II.14. Example of shoreline prairie. 39

Figure II.15. Conceptual Model of Marine Riparian Functions. 40

Figure II.16. Unaltered riparian vegetation and example of bluff erosion following removal of riparian vegetation. 41

SECTION III

Figure III.1. Recommended Review Steps for Overwater Structures. 19

Figure III.2. Recommended Review Steps for Shoreline Armoring Projects. 28

TABLE OF FIGURES

Section III (CONTINUED)

Figure III.3. Recommended Review Steps in Riparian Vegetation Alteration/Clearing Projects. 43

SECTION I
INTRODUCTION

PURPOSE AND NEED

WHY PROVIDE THIS GUIDANCE?

Increasing human population growth combined with the desirability and high value of shoreline properties, means that shoreline modifications will continue to occur in the Puget Sound area. "Shoreline modification" is a broadly used term covering a variety of structures and activities intended to adapt the shoreline environment for human use. These activities can range from installing stairways across bluff faces, to building docks and bulkheads, to dredging. Shoreline modification has been accelerating significantly in recent decades in response to population growth and development of the shoreline for commercial, industrial, residential, and recreational uses. These activities have contributed to wide scale degradation and loss of important habitat in the nearshore environment. The remaining habitat is becoming increasingly fragmented and degraded by ongoing activities.

The Shoreline Management Act (SMA) provides the framework for protection of the nearshore. Adopted in 1971 from a citizen's initiative, the Act's purpose is to protect the state's shorelines from uncoordinated and piecemeal development. This is accomplished through locally prepared and administered Shoreline Master Programs (SMPs). SMPs are currently being updated statewide consistent with new guidelines (WAC 173-26, Part III). The SMP update process requires local governments to evaluate existing nearshore conditions and establish policies and regulations that will protect nearshore ecological functions. During this update process, local planners and officials have the opportunity to determine where, and under what conditions, certain shoreline uses and activities should be permitted or prohibited. In this way, inappropriate modification activities can be prohibited, thereby avoiding future impacts altogether. In those circumstances where modification activities are allowed, local governments have the authority to ensure that policies, regulations and specific standards of local master programs are being met. Shoreline protection is also integrated into many local critical areas ordinances under the Growth Management Act (GMA).

This guidance has been developed as a companion to the Department of Ecology's SMA Guidelines and critical areas protection guidance offered by the Department of Commerce.

This guidance provides a synthesis of current science on several important nearshore habitats and processes, and directions for where to find data and specific recommendations for moving through the mitigation sequence; from avoidance of new activities and reducing impacts from approved activities, to mitigating for cumulative impacts. In addition to helping local planners prepare SMP updates, this document will also assist Ecology in their review to ensure that SMP updates are based on good science.

The intent of this guidance is to:

- ◊ Provide basic information on key nearshore habitats and how they are impacted by shoreline modifications, in summary form.
- ◊ Provide useful approaches to protecting nearshore habitat that are supported by the prevailing science.
- ◊ Provide recommendations in a form that lays out a decision sequence that begins with avoiding impacts from these activities and moves through mitigating for cumulative impacts.
- ◊ Provide the information in the form of user-friendly text and graphics with reliance on tools such as flow charts and tables rather than extensive narrative.

WHAT IS THE SCOPE OF THIS GUIDANCE?

This Introduction (section I) includes a description of the relationship of this guidance to SMA and GMA requirements, and a definition of the importance of the Puget Sound nearshore zone. Section II, provides a brief description of some key nearshore habitats in Puget Sound that are often affected by shoreline modifications. These "science briefs" were summarized from recent scientific papers, and provide a framework to put the importance of nearshore habitats into perspective. The goal is to provide planners and regulators with condensed information that shows how shoreline modification can affect Puget Sound nearshore habitat and nearshore ecological functions. The science briefs include:

Beaches and Bluffs
Forage Fish Habitat
Kelp and Eelgrass Habitat

Marine Riparian Vegetation
Juvenile Salmon Habitat

Section III, contains recommendations associated with reviewing and permitting three common shoreline modifications. For each activity, an overview of impacts is provided along with recommendations for reducing the level of impact through planning and site specific designs. In this section, narrative and descriptive text were minimized in favor of flow charts, tables, and matrices that would serve as an easy-to-use reference for planners and decision-makers. The following shoreline modifications are addressed:

Overwater Structures
Shoreline Armoring
Riparian Vegetation Alteration

Throughout the document links to websites with supporting or more detailed information have been included. Scientific citations have been minimized within the text but are included as footnotes to tables and references.

In 2009, the Aquatic Habitat Guidelines Program endorsed the white paper, Protection of Marine Riparian Functions in Puget Sound, Washington. The purpose of this white paper is to provide shoreline planners and managers with a summary of current science and management recommendations to inform the protection of ecological functions of marine riparian areas. The scientific recommendations in the white paper complement the science briefs contained Section II and can be used to further support the management recommendations in Section III of this guidance. Minor amendments were made throughout this guidance in 2010 to reflect the updated science.

WHY IS THE SCOPE LIMITED?

Most local governments are, or will soon be, undertaking ordinance and comprehensive plan amendments and revising their SMPs to meet GMA and SMA requirements. In addition, scientific white papers, draft management recommendations and other science products related to the nearshore environment have recently been released. There was a need to compile this information and provide a portal to access more detailed information in a timely manner.

The recently released white papers (available at: http://www.pugetsoundnearshore.org/technical_reports.htm) and other documents cover

much more than the 5 habitat and 3 shoreline modification types addressed in this guidance. The scope of this guidance was limited to these topics because they represent some of the most common habitat concerns and frequently permitted activities in Puget Sound. Additional topics may be integrated into later versions of this guidance or supplemental documents may be developed to address other topics and particular areas of concern.

WHY PROVIDE NEARSHORE GUIDANCE?

The Washington Department of Fish and Wildlife (WDFW), along with other state agencies and others in the scientific community have been developing "best available science (BAS)" for the nearshore environment. This "BAS" for a variety of topics has been synthesized in recently released white papers. This guidance reflects the findings of these papers to assist local government updates of SMPs and local codes. Although BAS has been used to develop this guidance, full details regarding the science have not been included here. Instead, links to supporting information and citations are provided for those needing more detailed information.

WHO SHOULD USE THIS GUIDANCE?

This guidance was written to assist local planners involved with development of regulations to meet requirements of the GMA and SMA. In recent years many reports have addressed habitat loss and impacts from shoreline modifications. However, it is unrealistic to expect planners and decision-makers to review all of these technical documents. A reference document was needed that contained summary information of the ecological functions of the nearshore, as well as one that provided tools recommendations to inform nearshore management decisions.

HOW TO USE THIS GUIDANCE?

Local planners developing SMP's should review the appropriate scientific brief (Section II) for the habitats of interest. This review may assist planners with identifying where more shoreline inventory information is needed. In addition, the review may help planners better identify critical nearshore habitat and make more informed decisions about applying appropriate shoreline environment designations and activity standards. The recommendations section (Section III) can be used to develop policies for inclusion in revised SMP's and to guide decisions on specific permit requests.

ACKNOWLEDGEMENTS

The Washington State Department of Ecology and the Puget Sound Partnership provided funding for the production of this document.

RELATIONSHIP TO SMA AND GMA REQUIREMENTS

In Washington State, development activities in nearshore environments are regulated by the Shoreline Management Act (RCW 90.58) and the Growth Management Act (RCW 36.70A). Local governments are responsible for meeting the requirements of these Acts through development of SMPs, for SMA, and Comprehensive Plans and Critical Area Ordinances, for GMA.

ELEMENTS OF THE SMA RELATED TO THE NEARSHORE

Washington State's Shoreline Management Act was first adopted in 1971 "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines." The SMA has three broad policies that are implemented through administration of locally customized SMPs. These broad policies include: (1) protecting shoreline natural resources, (2) encouraging water-oriented uses, and (3) promoting public access. This guidance has been developed to assist with meeting the first policy of protecting shoreline natural resources.

SMPs include; policies, shoreline environment designations, specific regulations; and permit administration provisions. At the outset of the planning process for updating local SMPs, natural resources and related ecological processes and functions are identified for each stretch of shoreline through a required inventory and characterization process. (Appendix A is a summary of planning steps associated with SMP updates.) As stated in WAC 173-26-201(3)(c), an inventory of shoreline conditions is to be conducted by gathering and incorporating "all pertinent and available information, existing inventory data and materials." The rules clearly state that critical areas are to be included in the inventory as noted below:

> "Local government shall, at a minimum, and to the extent such information is relevant and reasonably available, collect the following information:
>
> (ii) Critical areas, including wetlands, aquifer recharge areas, fish and wildlife conservation areas, geologically hazardous areas, and frequently flooded

areas. See also WAC 173-26-221. " (WAC 173-26-201(3)(c))

Critical saltwater habitats are incorporated as critical areas and are defined in WAC 173-26-221 to include:

> "… all kelp beds, eelgrass beds, spawning and holding areas for forage fish, such as herring, smelt and sand lance; subsistence, commercial and recreational shellfish beds; mudflats, intertidal habitats with vascular plants, and areas with which priority species have a primary association. "(WAC 173-26-221(2)(iii)(A)
>
> When the inventory has been completed, the information is used to characterize shoreline functions and ecosystem-wide processes. This consists of three steps (WAC 173-26-201(3)):
>
> "(I) Identify the ecosystem-wide processes and ecological functions…
>
> (II) Assess the ecosystem-wide processes to determine their relationship to ecological functions present within the jurisdiction and identify which ecological functions are healthy, which have been significantly altered and/or adversely impacted and which functions may have previously existed and are missing based on the values identified in (d)(i)(D) of this subsection; and
>
> (III) Identify specific measures necessary to protect and/or restore the ecological functions and ecosystem-wide processes."

Jurisdictions that contain critical saltwater habitats should also implement the principles outlined in WAC 173-26-221(2)(c)(iii)(B).

When the shoreline inventory and characterization has been completed, local jurisdictions begin the planning phase of SMP updates. Each individual shoreline inventory and characterization provides the basis for determining environment designations and developing appropriate policies and regulations. Planning objectives under the SMA guidelines for critical areas state that SMP "regulatory provisions for critical areas shall protect existing ecological functions and ecosystem-wide processes" (WAC 173-26-221(2)(B)(iv). With regard to critical areas:

> "Critical saltwater habitats require a higher level of protection due to the important ecological functions they provide. Ecological functions of marine shorelands can affect the viability of critical saltwater habitats. Therefore,

> effective protection and restoration of critical saltwater habitats should integrate management of shorelands as well as submerged areas." (RCW 90.58.090(4) and WAC 173-26-221(2)(iii)(A).

Policies and regulations developed for SMPs are to "provide a level of protection to critical areas within the shoreline area that is at least equal to that provided by the local government's existing critical area regulations adopted pursuant to the GMA for comparable areas other than shorelines" (WAC 173-26-221(2)(a) and (c)).

The following table lists WAC section references that relate to the different habitat types and shoreline modifications that are addressed in this guidance document.

Table I.1 Link Between Topics Addressed in this Guidance and the SMA.

HABITAT OR SHORELINE MODIFICATION TYPE	SMA WAC REFERENCE
Forage Fish Habitat	WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Beaches and Bluffs	WAC 173-26-221(2)(c)(ii) Geologically Hazardous Areas WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Kelp and Eelgrass	WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Juvenile Salmon	WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Marine Riparian Vegetation	WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Over-Water Structures	WAC 173-26-231(3) (b) Piers and Docks WAC 173-26-231(3)(d) Breakwaters, Jetties, and Weirs WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats WAC 173-26-211(5)(c) Aquatic Environment Designation
Shoreline Armoring	WAC 173-26-231(3)(a) Shoreline Stabilization WAC 173-26-221(2)(c)(ii) Geologically Hazardous Areas WAC 173-26-221(2)(c)(iii) Critical Saltwater Habitats
Riparian Vegetation Alternation	WAC 173-26-221(5) Vegetation Conservation WAC 173-26-231(3)(a) Shoreline Stabilization WAC 173-26-241(3)(e) Forest Practices

ELEMENTS OF GMA RELATED TO THE NEARSHORE

The GMA requires all cities and counties throughout the State to designate and protect Critical Areas (RCW 36.70A.060 (2)). The five types of critical areas defined by GMA are: 1)

wetlands, 2) areas with a critical recharging effect on aquifers used for potable water, 3) fish and wildlife habitat conservation areas, 4) frequently flooded areas, and 5) geologically hazardous areas (RCW 36.70A.030). All, with the exception of critical aquifer recharge areas, relate directly to the Puget Sound nearshore.

The GMA requires that local governments use the best available science in developing policies and development regulations to protect the functions and values of critical areas" (RCW 36.70A.172(1)). GMA requires the use of "best available science" in designating critical areas, protecting their functions and values, preserving and enhancing anadromous fisheries, and identifying the risks associated with alternative approaches for accomplishing these goals. Until a local government updates its SMP to be consistent with Ecology guidelines, local governments must continue to regulate shoreline areas under critical areas ordinances, as well as SMPs'. After Ecology approves a new SMP, sole jurisdiction of critical areas within shoreline jurisdiction, which will typically include the nearshore environment, will "transfer" exclusively to the SMP. (See Ecology guidance: http://www.ecy.wa.gov/programs/sea/shorelines/smp/toolbox.html .

THE PUGET SOUND NEARSHORE

WHAT DO WE MEAN BY "NEARSHORE"?

The nearshore zone in Puget Sound is the aquatic interface between freshwater, air, land, and the marine waters of Puget Sound. It includes areas along the shore that are either influenced by or directly influence marine water. It extends waterward to the maximum depth offshore where sunlight is sufficient to support plant growth (i.e., the photic zone). The nearshore zone also includes upland and backshore areas that directly influence shoreline conditions. It also extends upstream in estuaries to the head of tidal influence. The offshore edge of the nearshore zone will vary depending upon water depth and clarity, and can reach depths of -30 meters. The nearshore zone includes areas commonly known as the shore, beach, intertidal and subtidal zones. For description of nearshore zone processes and the effect of development on those processes see: http://www.kingcounty.gov/environment/watersheds/central-puget-sound/nearshore-environments.aspx .

WHY IS THE NEARSHORE AREA SO IMPORTANT?

The nearshore zone is where the interplay of physical processes such as wave energy and sediment transport create and maintain shoreline physical features and habitats. It is where biological processes such as sunlight driven photosynthesis, primary productivity, and carbon cycling occur at rates important at a worldwide scale. Puget Sound's nearshore zone also represents three critical "edge" habitats; the edge between upland and aquatic environments, the edge between the shallow productive zone and deep water, and the edge between fresh and marine waters. Variations in wave energy, sediment movement, sunlight, water depth, salinity and location associated with "nearshore edges" creates a wide range of physical environments that support a wide diversity and abundance of life.

The nearshore zone also attracts a lot of human activity. Much of the northwest economy is tied to the Puget Sound and its nearshore environment, including shellfish and salmon industries, ports and refineries, and a variety of recreational activities.

SECTION II
SCIENCE BRIEFS: KEY NEARSHORE HABITATS

Section II provides science briefs that summarize nearshore zone elements important to the Puget Sound region. The five topics included in these briefs provide an overview of Puget Sound nearshore ecology and how it is commonly affected by shoreline modification activities.

- ◊ Beaches and Bluffs
- ◊ Forage Fish Habitat
- ◊ Kelp and Eelgrass Beds
- ◊ Marine Riparian Vegetation
- ◊ Juvenile Salmon Nearshore Habitat

BEACHES AND BLUFFS

The information in this brief is summarized from a Puget Sound Nearshore Partnership Report by Jim Johannessen and Andrea MacLennan (2007) entitled "Beaches and Bluffs of Puget Sound". The full report contains a detailed discussion of how beaches and bluffs are shaped and formed and how they are affected by shoreline activities. The full report can be viewed at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Beaches and bluffs are important geological features of the Puget Sound nearshore. In Puget Sound, bluff erosion is the primary source of material that replenishes beach substrate. Beaches and bluffs also provide important habitat to numerous species dependant on the nearshore zone of Puget Sound.

Shoreline modifications, including over-water structures, shoreline armoring, and marine riparian vegetation alteration can change natural processes such as erosion and sediment transport associated with beach and bluff formation. Recommendations for minimizing or mitigating impacts from these activities are provided in section five.

BEACHES

Beaches are comprised of materials that accumulate between an upland environment such as a bluff, dune, or bulkhead and a lower limit defined by the area where substrate is still active and mobile. This lower limit extends below the low tide line to depths of -10 feet Mean Lower Low Water (MLLW = 0.0 ft) or greater. Puget Sound beaches generally have two components; a beach face, sometimes called the high-tide beach, that has an abrupt decrease in slope at the waterward extent; and a low tide terrace, a more gently sloped beach extending seaward from the beach face. Some Puget Sound beaches also have a berm or series of berms above ordinary high water. These are formed when material is transported to the backshore during high water windstorms. Salt-tolerant plants such as dunegrass and marsh plants will often grow in sandy backshore areas between a bluff and beach berm. See Figure II.1 below for a cross-section of the nearshore zone.

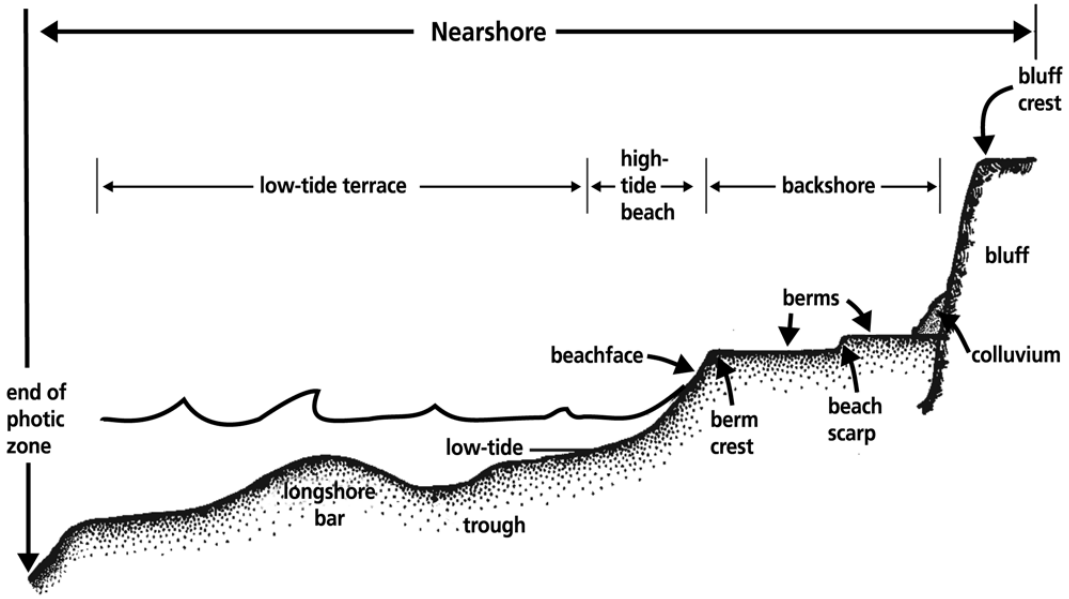


Figure II.1. Diagram of Puget Sound nearshore terminology (Johannessen and MacLennan 2007).

How are Beaches Formed and Maintained?

The source material for Puget Sound beaches is primarily derived from up-drift bluff erosion (e.g., feeder bluffs that supply sediment to the beach system). The composition of contributing bluffs and the amount of wave energy exposure determines the type and size of material that collects on the beach and forms the substrate. The material can be comprised of fine sand or mud or large boulders and woody debris. The size and shape of the beach is primarily a function of the beach substrate, the orientation of the beach in respect to wave energy and the rate of bluff erosion (see beach width examples in Figure II.2). For additional details, see http://www.kingcounty.gov/environment/watersheds/central-puget-sound/nearshore-environments/BeachTopics-Processes/accreting_beach.aspx.

The width and slope of the low-tide terrace affects the degree of wave energy dissipation that occurs along a beach. The large amount of gravel eroding from bluffs gives Puget Sound beach faces a much steeper slope than sandy beaches like those found on the outer coast of Washington. Because steeper sloped beaches do not dissipate wave energy as well as gradually sloped beaches, fine material is often moved away from the beach face and larger material is left in place (see Figure II.3 below). As waves transport fine materials away, the remaining boulders and large material can, over time, naturally armor the low tide terrace.

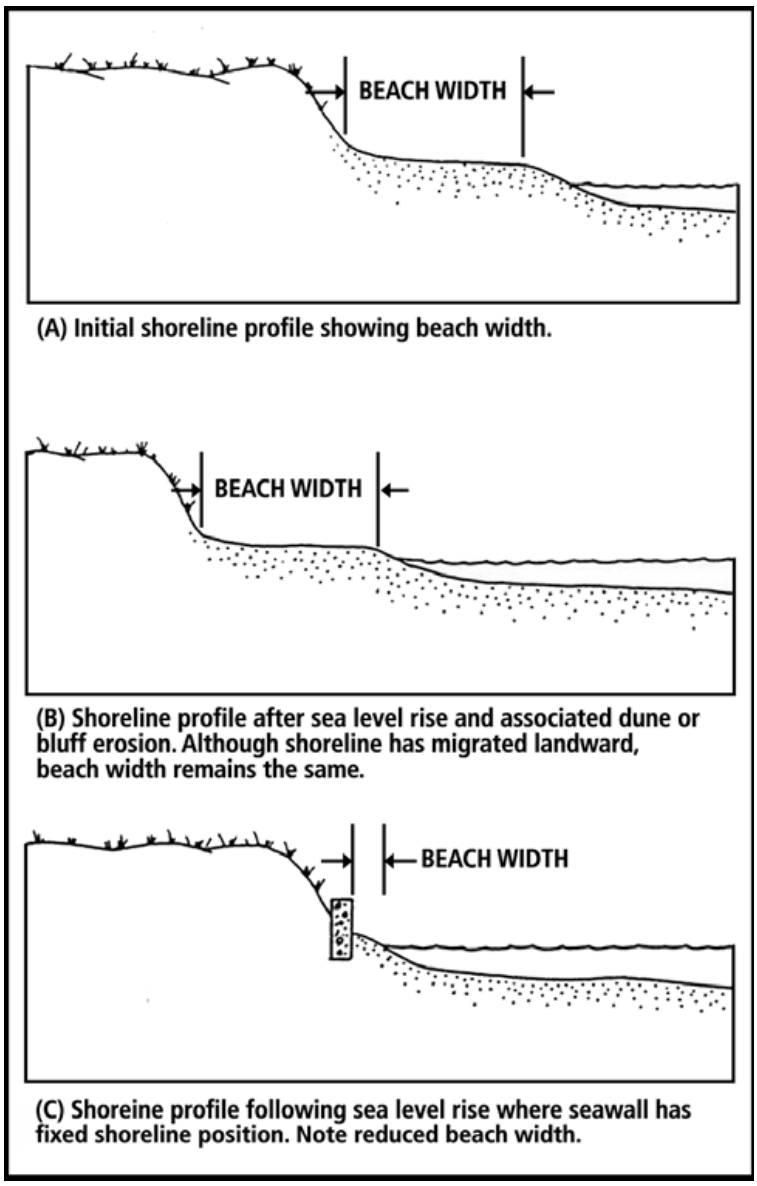


Figure II.2. Example of beach width loss through passive erosion (Griggs et al.1994). .

Figure II.3. Change in sediment size between the upper slope and low tide terrace (Finlayson 2006).

Low wave energy beaches are composed of poorly sorted (i.e., uniformly mixed) substrates with a relatively narrow backshore and intermittent intertidal vegetation. Higher wave energy beaches contain areas with well-sorted substrates forming distinct bands of different sized sediments distributed over a broad intertidal and backshore area, usually devoid of fringing vegetation.

Wave energy causes beaches to continually evolve by affecting sediment erosion, entrainment, and transport (see Figure II.4 below). This dynamic process, called "shore drift", is the combination of materials being transported landward and seaward (beach drift), as well as laterally along the coast (longshore drift). The movement can vary seasonally but, depending on the orientation of the beach to predominant winds and wave energy, sediment ultimately moves in one direction along the shore. Over time, this results in a gradual change in the beach size, shape, and structure.

Figure II.4. Large grain sediment deposits from storm activity caused buildup on the low energy side of this beach (Johannessen and MacLennan 2007).

Approximately 860 cells where net shore-drift occurs, and over 233 separate areas where there is essentially no net shore-drift have been identified within Puget Sound. While the average length of these drift cells[2] is just 1.5 miles, they vary broadly in length from as little as 46 feet to almost 19 miles. The recruitment and movement of sediments within these drift cells are largely responsible for the shoreline configuration we see today. Unique shoreline features, such as spits, are formed by the particular characteristics of individual drift cells and the interactions between them. Spits can be straight, curved, or a complex form of multiple spits. For example, cuspate spits are formed where two drift cells meet from opposite directions and deposit sediment in a formation extending away from the shore to a seaward point. Linear spits can be formed when sediment is carried away from easily eroded bluffs. Other landforms are created from sediment deposits as well; including tombolos, connecting two islands or an island to the mainland; and bars, which are subtidal deposits. These landforms, created by shore drift, are highly dynamic and continue to evolve through the continual deposition and erosion of sediments carried along the shoreline by these natural processes. As these features evolve, new habitats are formed and existing habitats mature and change. For example, two cuspate spits that form where the shore orientation changes at the narrowest part of an inlet or bay, as they often do, can

[2] "Drift cell," "drift sector," or "littoral cell" means a particular reach of marine shore in which littoral drift may occur without significant interruption and which contains any natural sources of such drift and also accretion shore forms created by such drift (WAC 173-26-020). Drift cell data is available through the Department of Ecology: http://www.ecy.wa.gov/programs/sea/sma/data/maps_table.htm.

converge to create a coastal wetland in the center. This wetland may persist for some time before the barrier features are naturally breached, forming a shallow marine embayment. Images of beaches, spits, and other habitat features formed by coastal processes can be viewed on the Department of Ecology's Shoreline Aerial Photos web site or Coastal Atlas.

WHY ARE BEACHES IMPORTANT TO THE NEARSHORE ZONE?

Beaches are the primary feature that defines the landward edge of the nearshore zone. They are variable in size, shape, and composition and are continually evolving in response to physical processes. These habitats, as well as their continual process of formation and change, provide important habitat for forage fish, juvenile salmon, shellfish, and aquatic vegetation such as eelgrass and kelp beds. Beach evolution also defines the structure and composition of the marine backshore where marine riparian vegetation grows, which in turn provides a separate unique range of habitat types for both aquatic and terrestrial species. The value of beaches to people for commercial and recreational uses, are also well known.

WHAT DATA ARE AVAILABLE?

The DNR Shorezone Inventory is a comprehensive source of information about Washington shorelines. It contains information on shoreline and substrate types, drift cell patterns and existing shoreline modifications, as well as other information. The Department of Ecology's Coastal Atlas also provides a delineation of drift cells and information on the direction of net shore drift as well as many other physical, biological, regulatory and landscape features.

Data or research reports on beach formation, including effects of shoreline modifications on beaches is provided as references in Section II of this guidance.

BLUFFS

A bluff is a steep-sloped landform that is similar to a cliff, except that there is soil and vegetation covering most of the underlying rock, whereas a cliff is mostly exposed. The movement of glaciers and the stabilization of sea levels following the end of the last ice age formed bluffs along much of Puget Sound's shorelines. The composition and shape of bluffs depends on how the glacial material was deposited in combination with the affects of ice melt and the resultant sea level rise and geologic uplift. Because conditions and events

affected areas on a local scale, bluffs have differing topographies and can be composed of diverse rock or sediment types and sizes.

The bluffs in the Puget Sound region are highly variable in terms of size, shape, and composition (see Figure II.5 below). Physical conditions such as geology, hydrology, orientation and exposure, erosion rates, and vegetation all play a role in determining a bluffs character. Depending on their composition they can be more or less resistant to erosion. Glacial till, for example, can be highly resistant to erosion, whereas bluffs comprised primarily of silt and clay are typically more susceptible to erosion. Glacial till is one of the most common bluff types in Puget Sound. While its resistance to erosion may seem a positive attribute, it can limit a bluff's capacity to replenish down-drift beaches.

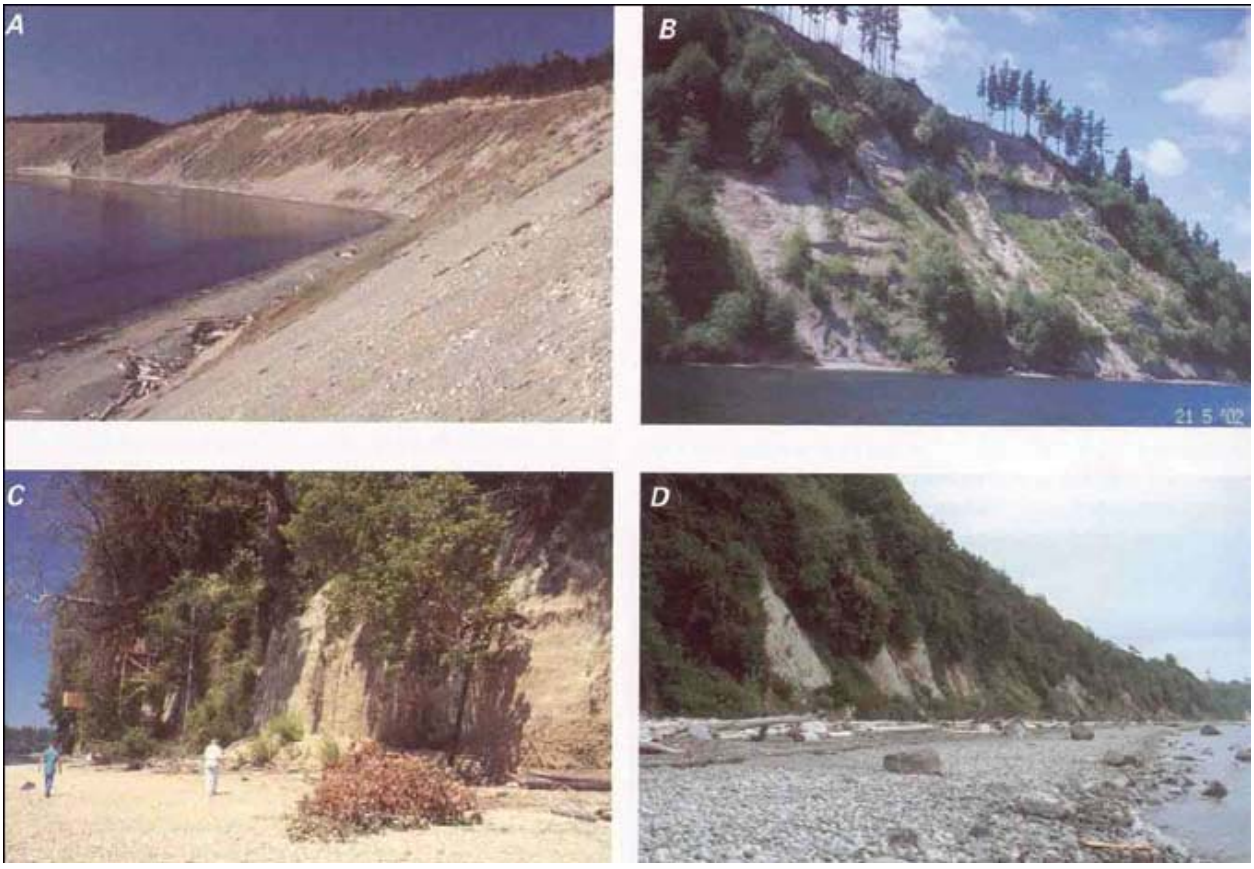


Figure II.5. Four examples of common bluff formations found throughout the Puget lowlands (from Shipman 2004).

How are Bluffs Formed and Maintained?

Puget Sound bluffs are formed by a combination of processes. Wave action at the base of

the bluff is an ongoing active process, overlaid upon a natural process of the bluffs receding or "laying back" to achieve a natural equilibrium slope. This process is very slow acting but it plays a dominant role in the evolution of bluffs along our shorelines. See Figure 5 in: "Beaches and Bluffs of Puget Sound" at http://www.pugetsoundnearshore.org/technical_reports.htm.

The effects of wave action are a more immediate and more visible component of this longer acting process. As wave action works at the base of the bluff it erodes, the face is undercut and material slides down to form colluvium; sediment, sand, rock, and slabs. The colluvial material collects at the base and protects the bluff from further erosion but over decades is gradually eroded and carried away. This leaves the base of the bluff exposed to wave action once more until the cycle repeats.

The combination of these processes causes the bluff to slowly recede over time and to develop a shallower slope. The rate of recession is dependant on a number of factors including; geology of the bluff, beach structure, and wave energy. Development impacts can further affect the rate of recession. Stormwater runoff and vegetation clearing or alteration (e.g., to create views) can have profound effects on bluff recession rates and stability.

WHY ARE BLUFFS IMPORTANT TO THE NEARSHORE ZONE?

These geological features are found along more than 60% of Puget Sound's shoreline and are the primary source of recruitment for the sand, gravel, and larger substrate that make up the region's beaches. Consequently, they have a significant influence on the region's nearshore environment. Bluff erosion plays an important role in shaping nearshore habitat (see Figure II.6 below).

Figure II.6 Example of natural erosion on left, and steep bluff vegetation on right (from Brennan 2007).

Variation in bluff topography, material composition, and orientation in relation to weather and waves can produce a diverse range of nearshore habitat types. The combination of these factors will determine the exposure to wave energy, the rate of erosion, the composition, volume, distance and direction these materials are transported by shore drift, and the type of riparian vegetation on the bluff face. The complex interactions between factors combine to provide the diversity of habitat types that characterize marine shorelines.

Many species that use the Puget Sound nearshore zone are dependent on a particular range of beach substrates. The size and composition of substrate are important factors determining the value of nearshore habitats for juvenile salmon rearing and forage fish spawning. These factors also determine the habitat suitability for the formation of kelp forests and eelgrass beds. These aquatic marine plants form dense canopies below the water surface that provide highly productive refuges for a broad range of species. Again, because bluffs are the primary source of material for replenishing beaches, they indirectly ensure that a variety of habitats continue to exist for species with diverse requirements. Bluffs are therefore vital to the overall health of these populations and, indirectly, to the health of Puget Sound.

WHAT DATA ARE AVAILABLE?

As with beach data, the DNR Shorezone Inventory is the most comprehensive source of information on shoreline types. The Department of Ecology's Coastal Atlas also contains data on slope stability along Puget Sound shorelines.

Data or research reports on bluffs, including effects of shoreline modifications on bluffs is provided as references in Section III of this guidance.

How do Common Shoreline Activities Impact these Features?

Direct and indirect impacts to beaches and bluffs can occur through any activities that alter erosion or wave energy or change the supply of sediments and other material along the shoreline. Shoreline modifications have been, and continue to be, widespread in Puget Sound. Approximately 34% of the shoreline in the Puget Sound region has been modified by structures such as bulkheads, riprap, dikes and other shoreline armoring.

Shoreline armoring or other energy attenuation devices (e.g., seawalls) are the most significant activity that impacts bluff erosion or more accurately, deters colluvium from being transported. Clearly, since there is a direct relationship between these bluffs and beaches, these activities also affect the size, shape, and substrate character of the down-drift beach (e.g., surf smelt spawning areas that may be present).

Shoreline armoring is also detrimental to the beach area immediately adjacent to the structure. For example, when bulkheads are constructed it causes greater wave energy at the bulkhead face (see Figure II.7 below). The excess turbulence causes downcutting (lowering) of the beach. Ultimately, the beach can cut below the base of the bulkhead causing failure of the bulkhead. Pilings, that support overwater structures, can also impact beach substrate because they attenuate waves energy, causing fine grains to fall out of the water column. In addition, barnacles and other organisms that colonize the pilings result in formation of a different beach substrate than normal, changing the character of the habitat. Groins and jetties also interrupt shore drift, causing sediment starvation that can alter habitat structure, and in turn the species composition.

Figure II.7. Photos contrasting high-tide wind waves (top) versus low-tide wind waves (bottom), from Finlayson 2006.

Riparian vegetation alteration and general shoreline development can result in increased erosion and an increase in the potential for landslides, particularly on steep bluffs. In addition to potentially damaging property and infrastructure, landslides can result in an oversupply of substrate to the beach, which can also alter habitat structure and species composition.

Activities that alter the composition and distribution of shoreline substrates or their contributing physical processes can adversely affect the productivity of spawning habitats for beach spawning forage fish (Pacific herring, sand lance, and surf smelt). These species are fundamental components of the marine foodweb supporting a number of highly valued species, including salmon, rockfish, flatfish, seabirds, and marine mammals.

Cumulative impacts from continued modification of the shoreline and resultant alternation of bluff erosion and beach formation are difficult to quantify. However, they are likely to be exacerbated over time because beaches and bluffs are so closely connected (see Figure II.8 below). For example, erosion caused by shoreline armoring at a specific beach can be accelerated when the bluffs supplying sediment to that beach are armored even though those bluffs may be miles away. The continued propagation of these armoring structures along the shoreline of Puget Sound will continue to adversely affect physical processes and shoreline configuration.

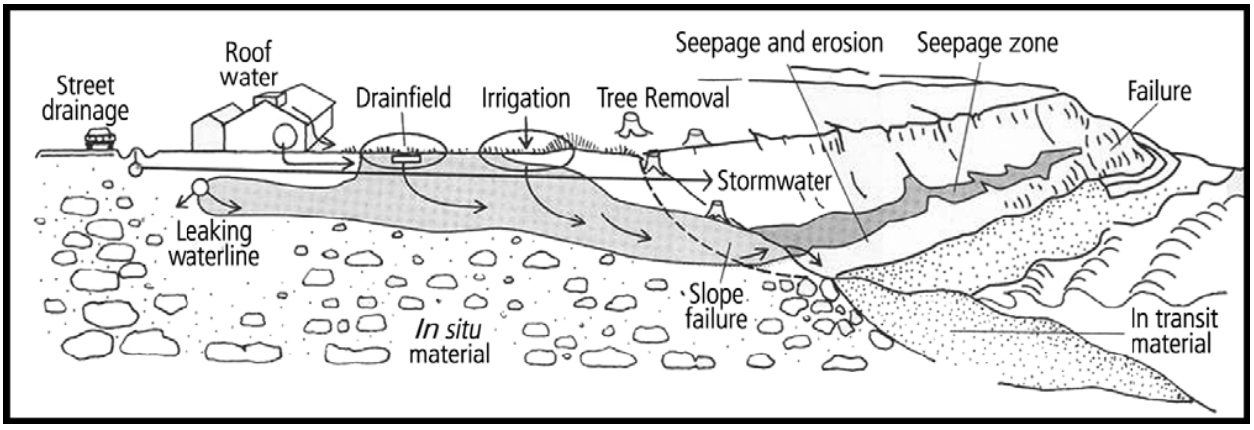


Figure II.8. Illustration of frequent causes of bank stability failure as a result of alterations of hydrology and vegetation (from Marsh 2005).

The cumulative impacts of shoreline modifications are expected to intensify with a rise in sea level associated with climate change. As sea levels rise, extreme storm surges become increasingly higher, exposing more beach and bluff area to erosive wave energy. This will promote a landward migration of beaches, increased coastal flooding, and the gradual loss of salt marshes, wetlands, and low-lying beaches or spits that form the Puget Sound nearshore habitat.

Beaches and bluffs contribute to Puget Sound's dynamic habitat through erosion and shore drift occurring on a landscape scale. As net shore-drift is significantly altered by shoreline modifications, these also affect Puget Sound on a landscape scale. Due to the complexity of

the natural process involved, mitigation is unlikely to be a viable solution to reduce impacts. Therefore, avoidance and minimization measures are essential, in addition to the need for restoration actions that remove impacting structures. These impacts and some planning and site design issues are summarized in Table II.2. Section III of this report contains detailed recommendations associated with planning and site design issues.

Table II.2: Common Impacts to Beaches and Bluffs and Key Regulatory and Design Considerations.

Direct/Indirect Impacts	◊ Any activity that alters erosion or wave energy and changes the supply or distribution of sediments along the shore can result in impacts such as; o Loss of backshore due to shoreline armoring o Direct loss of beach through downcutting (often caused by shoreline armoring) o Indirect loss of beach through armoring of updrift bluffs, the resultant loss of sediment supply followed by changes in beach substrate character and downcutting ◊ Loss of nearshore vegetation and shading ◊ Simplification of habitat structure due to removal of large wood, overhanging branches, and boulders ◊ Substrate modification due to piling placement (shellhash formation) and grounding of boats and/or structures ◊ Reduced bluff and beach stabilization, and increased erosion due to vegetation removal ◊ Loss or change to beach substrate and conditions that support aquatic and riparian vegetation and spawning habitat for forage fish
Cumulative Impacts	◊ Landscape scale changes in beach structure and habitat function due to changes in wave energy and geomorphic processes (erosion, transport, and accretion) ◊ Changed/reduced productivity of Puget Sound nearshore zone ◊ Loss of connection between aquatic and upland environment which impacts drainage, wildlife corridors, and loss of unique transitional areas across Puget Sound ◊ Decrease in habitat suitable for eelgrass, kelp and other plants and overall photosynthesis in intertidal and subtidal zones ◊ Landward migration of beaches and loss of some habitats due to sea level rise

Table II.2: Common Impacts to Beaches and Bluffs and Key Regulatory and Design Considerations.	
Regulatory and Design Considerations	◊ Identify feeder bluffs and protect them (and their functions) through appropriate shoreline designation and SMP regulations ◊ Identify intact beaches and protect them through appropriate shoreline designation and SMP regulations ◊ Avoid and minimize shoreline armoring projects, and require geotechnical assessments, reviewed by a qualified third party, to evaluate problems and analyze potential solutions, including the use of alternative designs ◊ Require proposed bulkhead rebuild projects to evaluate the effectiveness of alternative designs (e.g., soft-shore approaches) as opposed to in-kind replacement ◊ Promote retaining or establishing marine riparian vegetation including large trees by requiring a vegetation conservation plan for activities impacting marine riparian vegetation ◊ If tree removal is unavoidable, leave felled trees or create snags for wildlife habitat ◊ Avoid placement of shoreline armoring or other structures near the beach, especially waterward of OHWM ◊ Minimize displacement of beach area by pilings or other structures. Where such structures are unavoidably necessary, prohibit the use of treated wood in favor of concrete, steel, or recycled plastic ◊ Prohibit grounding of floats, rafts, docks and vessels ◊ Require replacement of all native riparian or aquatic vegetation that is directly or indirectly lost through shoreline activities

FORAGE FISH HABITAT

The following information on forage fish is summarized from a Puget Sound Nearshore Partnership report by Dan Penttila (2007) entitled "Marine Forage Fishes in Puget Sound". The full report contains maps and photos of spawning areas and details about spawning timing by location or stock, as well as status and trend information. The full report can be viewed at: http://www.pugetsoundnearshore.org/technical_reports.htm. Forage fish information is also available through WDFW's website.

Impacts on forage fish habitat from common shoreline modification activities (e.g., shoreline armoring, overwater structures, and riparian vegetation alteration) and recommendations for minimizing or mitigating impacts are provided in Section III.

WHAT ARE FORAGE FISH?

Forage fish is a loosely defined term for small, schooling fish that provide a critical food web link in marine environments; they prey upon zooplankton and are in turn preyed upon by larger predatory fish, birds and marine mammals. In addition to being considered a key component of the food base for economically and socially important species such as salmon, some forage fish species in Puget Sound have commercial and recreational importance.

Key forage fish species in Puget Sound include; Pacific herring (*Culpea pallasi*), surf smelt (*Hypomesus pretiosus*), Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), and longfin smelt (*Spirinchus thaleichthys*). Pacific herring, surf smelt, and Pacific sand lance are the most common in Puget Sound. For photos and additional information on forage fish see: http://www.wdfw.wa.gov/fish/forage/forage.htm.

WHY IS THE NEARSHORE ZONE CRITICAL TO FORAGE FISH?

Three of these forage fish species, Pacific herring, surf smelt, and Pacific sand lance, spawn in the nearshore (see Figure II.9). Their spawning habitat occupies many of the intertidal and shallow subtidal areas within the Puget Sound basin – areas most at risk from shoreline modification activities. Further, because these species congregate in large numbers at high densities during spawning they are particularly vulnerable to marine shoreline activities during this critical life history stage. While Northern anchovy and longfin smelt do not spawn in the nearshore, juveniles of these species use nearshore areas for rearing and are thus potentially vulnerable to disturbance of nearshore habitat. See

http://www.ecy.wa.gov/programs/sea/pugetsound/species/smelt.html for a description and locations of forage fish spawning habitat.

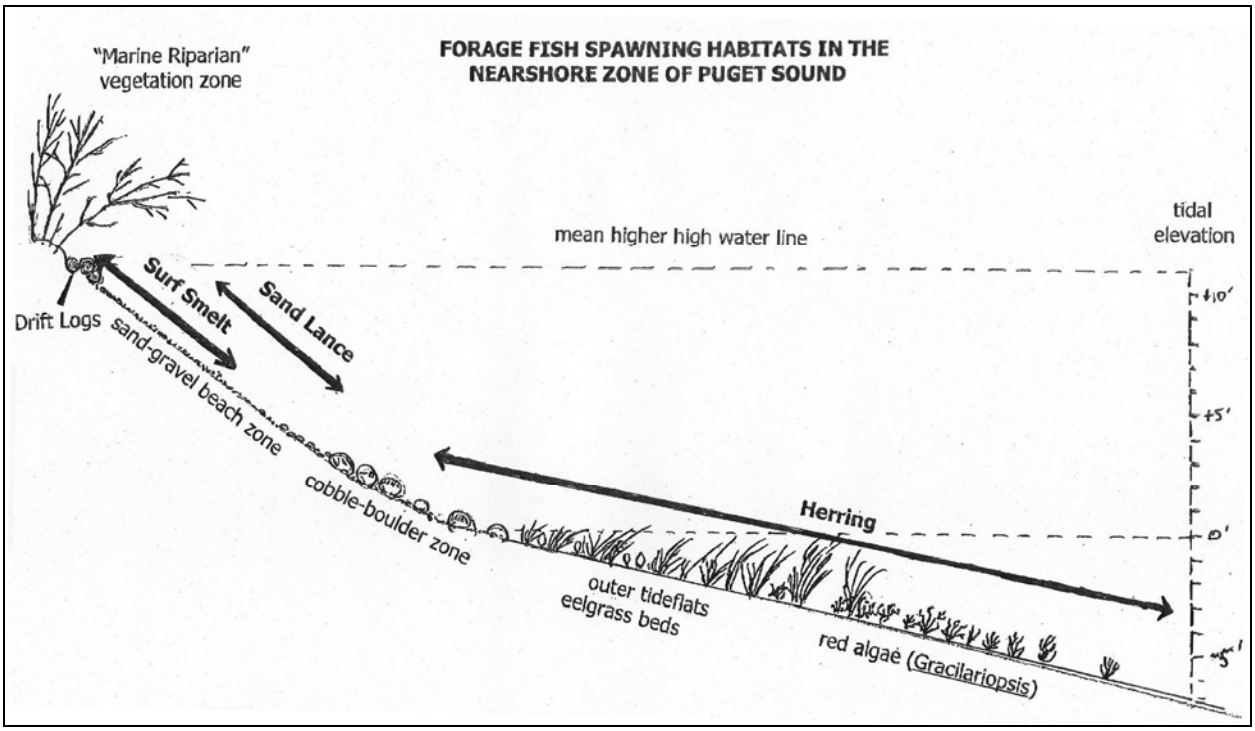


Figure II.9. Forage fish spawning habitats in the nearshore zone of Puget Sound (Penttila, 2005).

Because all forage fish species rely on nearshore habitats during at least some part of their life history, the protection of these habitats is critically important to their long-term sustainability. In addition, because forage fish are a critical prey resource for a number of species, including ESA listed salmon and marine mammals, the protection of forage fish habitat is important to the conservation of these ESA-listed species as well.

Pacific herring, surf smelt, sand lance, and longfin smelt spawning habitats and congregation areas are listed as "marine habitats of special concern". As such, they are considered to be "priority habitats" under WDFW's Priority Habitats and Species (PHS) program. Washington's Hydraulic Code (Chapter 220-110-250-WAC) that governs hydraulic project review and permitting by WDFW provides "no net loss" protection for spawning sites documented through on-site surveys. However, the Puget Sound Management Plan has a goal of "net gain in ecosystem function" to address past degradation of habitat. To meet this goal, beaches with spawning potential should also be identified and protected through local planning efforts. For the purpose of developing local regulations, WDFW forage fish

databases and Priority Habitat Species (PHS) maps are considered "best available science". The PHS maps are periodically updated and project proponents are expected to confirm that the information they are relying on is the most recent.

PACIFIC HERRING

The Pacific herring is a widespread, open-water (pelagic) species found throughout marine waters of Washington State. Approximately twenty herring stocks occupy the Puget Sound basin. Each stock is defined by a geographically distinct spawning area and season.

WHEN DO THEY USE THE NEARSHORE ZONE?

Pacific herring congregate offshore in the general area of their spawning grounds several weeks prior to spawning. Subgroups of herring within this larger congregation will mature at slightly different times, moving from deeper water into the shallow nearshore zone to deposit their spawn. The spawning season of any individual spawning ground may be staggered over 6 to 8 weeks, during which time a number of individual spawning events of varying magnitude may occur. While the Pacific herring spawning season in Puget Sound lasts from late January to early June, most spawning takes place in February and March.

Herring eggs take up to two weeks to hatch. After hatching, the free-floating larvae will remain in close to the spawning areas unless they are transported offshore by wind and current. Typically, juvenile herring inhabit nearshore waters of Puget Sound through their first several months of life, moving into deeper water during September-October. Thus, sensitive life history stages of Pacific herring may be found in nearshore areas from late January through October. Subadult herring will remain in open waters until they are ready to spawn, typically in their second or third year of life.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE IMPORTANT?

In Washington State, herring deposit their eggs almost exclusively on marine vegetation (see Figure II.10), and therefore spawning sites are limited to portions of the nearshore zone where there is adequate light for plant growth. The depth at which spawning can occur is largely controlled by water clarity, which in turn controls the maximum depth at which

vegetation will grow. This depth corresponds to the shallow subtidal and lower half of the intertidal zone. In areas with especially clear water, the zone where herring can spawn can extend to depths of -10 meters MLLW in tidal elevation.

Figure II.10. Intertidal algae bed with heavy herring spawn, S. Cherry Point, Whatcom County (Penttila 2007).

In Puget Sound the native eelgrass (*Zostera marina*) is the primary herring spawning substrate. In some areas, a combination of red, green, and brown alga referred to as "marine alga turf" is commonly used by spawning herring. In deeper water in areas where native eelgrass is uncommon, the red alga (Gracilariopsis or Gracilaria) is may be used for spawn deposition. Water depth and substrate composition (e.g., mud, gravel, cobble) are the most important factors that determine the composition of vegetation found in spawning ground. In a few of the known herring spawning areas, more unusual substrates are used, including; boulder/cobble rock surfaces, current-swept gravel beds, pilings, and amassed beds of tubes of polychaete worms.

In addition to physical habitat needs for spawning, the larval and juvenile life stages utilize the nearshore zone. Therefore water quality, as well as other conditions that affect food or predator abundance in the nearshore zone, are important.

WHAT DATA ARE AVAILABLE?

Spawning Pacific herring populations have been monitored with sufficient effort to provide annual estimates of relative abundance. Pacific herring information is available through WDFW's website. The locations and seasons of herring spawning in Puget Sound are relatively well known. However, no comprehensive survey of "likely looking" shorelines has been done and new spawning sites are still being discovered.

SURF SMELT

Surf smelt is a common and widespread forage fish species that spawns in the nearshore. However, this species is poorly studied and little is known about its distribution and movement or the number and distribution of distinct stocks.

WHEN DO THEY USE THE NEARSHORE ZONE?

The spawning season for surf smelt is widely variable; timing of spawning for various stocks includes summer (May – October), fall-winter (September – March) or year-around (January – December often with a seasonal peak). Spawning, which occurs at high tide, may occur at irregular, short intervals at any particular site. Once a spawning season begins, an individual beach is likely to experience a continuous deposit of eggs for several months.

The egg incubation period varies with seasonal temperatures. During summer incubation time is about 2 weeks, while during cold winter months it may be 4 to 8 weeks in length.

Little is known about the life history of surf smelt apart from its use of the intertidal areas for spawning. The species is not generally known to form large open-water schools. Surf smelt may reside near the shoreline in the general area of their spawning sites for their entire lives.

For those areas that experience year round spawning, surf smelt eggs may be found in the most vulnerable portion of the nearshore area (upper intertidal zone) during any month of the year.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE IMPORTANT?

Surf smelt require upper intertidal sand-gravel beaches for spawning. The specific mix of small gravel and coarse sand (commonly called "pea gravel") preferred by surf smelt for spawning is usually found in patches or bands along the upper third of the intertidal zone. The physical area of spawning substrate can vary from a discontinuous array of small patches around the high tide line, to broad bands of material several yards wide and several miles long. Within a typical sediment-transport drift cell, spawning habitat may be limited at the two ends of the drift cell where beach substrate is too coarse (upper end of cell) or too sandy (lower end).

Most known beach spawning sites are used annually with other areas only used only during in periods of high smelt abundance. According to WDFW surveys, the majority of Puget Sound beaches that appear to be suitable for spawning are not documented surf smelt spawning sites. This lack of documentation should be interpreted cautiously, due to limitations of the monitoring and the variable nature of spawn timing.

For summer spawning fish, the presence of over-hanging trees along the upper beach area is important for moderating/preventing wind and sun exposure, which can kill eggs. See Figure 13 in Valued Ecosystem Component (VEC) White Paper on Marine Forage Fishes in Puget Sound (Pentilla 2007): http://pugetsoundnearshore.org/technical_reports.htm .

In addition to physical habitat needs for spawning, all life stages utilize the nearshore zone. Therefore water quality and other conditions that may affect food or predator abundance in the nearshore zone are important.

WHAT DATA ARE AVAILABLE?

Spawning site inventories for surf smelt have been fairly extensive. WDFW can provide GIS-based charts of known spawning beaches and site-specific surf smelt spawning habitat. The mapped locations are available to those who receive PHS data.

PACIFIC SAND LANCE

Pacific sand lance are common and widespread forage fish in the nearshore marine waters throughout Puget Sound. However, there is little life history information or population data

available for this species.

WHEN DO THEY USE THE NEARSHORE ZONE?

Sand lance deposit their eggs in many small individual spawning events scattered over broad reaches of shoreline. Spawning occurs between November and February in Puget Sound, predominantly during the first half of that period. Sand lance spawn during high tides when the upper beach is covered by shallow water, and the spawn is often deposited at the bottom of scattered, shallow pits excavated in the beach (see Figure II.11). Incubation time is approximately one month. Repeated spawning episodes may occur throughout the spawning season.

Figure II.11. Sand lance spawning beach with fresh spawn pits, S. Port Gamble Bay, Kitsap Co. (Penttila 2007).

Planktonic sand lance larvae are common in nearshore waters of Puget Sound in late winter and juveniles are common there through the first summer of life. Sand lance dwell in the very nearshore area even as adults and spend part of their diurnal and seasonal cycles buried in the bottom substrate; probably as a means of avoiding predators and conserving energy. A broad array of marine bird, mammal and fish species feed on sand lance, especially when

they are in dense surface schools commonly called "bait balls" by anglers.

Sand lance eggs and larvae are found in the upper intertidal area of spawning beaches during winter; adults are found burrowed into the substrate in subtidal areas at all times of the year, and generally spend their lives in the nearshore zone.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE IMPORTANT?

The spawning habitat of the Pacific sand lance resembles that of surf smelt; they spawn in the upper third of the intertidal zone, in sand-sized substrate. As a result, these two species often use the same beaches and co-occurrence of eggs is common during winter when spawning seasons overlap. Depositional shoreforms such as beaches at the far ends of drift cells and sandy spits, supports sand lance spawning.

In addition to physical habitat needs for spawning, all life stages utilize the nearshore zone. Therefore water quality and other conditions that affect food or predator abundance in the nearshore zone are important to the long-term health of Pacific sand lance populations.

WHAT DATA ARE AVAILABLE?

WDFW, with the help of other entities (North Olympic Salmon Coalition, Friends of the San Juans, and recently the Nisqually Tribe and South Puget Sound Salmon Enhancement Group) has been documenting sand lance spawning sites since 1989, but new sites continue to be documented. WDFW can provide GIS-based charts of known spawning beaches and site-specific sand lance spawning habitat. The mapped locations are available to those who receive PHS data. Little or no stock assessment or population data are available on this species.

NORTHERN ANCHOVY

Northern anchovies commonly occur in Puget Sound and are considered to be a primarily pelagic (open-water) species.

WHEN DO THEY USE THE NEARSHORE ZONE?

Anchovy spawn away from shore, releasing their floating eggs into open water. The larvae are planktonic i.e., they drift freely with the current. Because waterways in Puget Sound are narrow and swept by currents, juvenile anchovy are often transported to nearshore environments. Young-of-the-year anchovies occur in the nearshore zone of Puget Sound during summer months and are also found at midwater depths throughout the Puget Sound basin. Spawning is known to occur in southern Puget Sound and the Strait of Georgia during summer months and anchovy are most likely to be in the nearshore zone during summer.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE IMPORTANT?

Spawning habitat for this species is not associated with the nearshore zone. However, anchovy do rear in the nearshore zone during summer. Therefore, summer period water quality and other conditions that affect food or predator abundance in the nearshore zone are important to this species.

WHAT DATA ARE AVAILABLE?

Northern anchovy populations have not been thoroughly monitored by WDFW and there are no assessments of abundance or population trends. Midwater trawl surveys targeting Pacific herring have contained incidental catches of anchovy, and those data are available by contacting the Marine Resources Division of the Fish Program at WDFW.

LONGFIN SMELT

Unlike the other forage fish species described here, longfin smelt are ananadromous species that spawn in rivers and rear mostly in marine waters. The only well-documented spawning population of longfin smelt in Puget Sound occurs in the Nooksack River. Another population may occur in the Duwamish River, but has not been documented.

WHEN DO THEY USE THE NEARSHORE ZONE?

Longfin smelt are an anadromous species that deposit their adhesive eggs on river-bottom

sediments near the upper ranges of tidal influence. After hatching, planktonic larvae are transported by river currents to estuarine waters. During the winter months, young of the year, maturing adults, and post-spawn females appear to occupy open water habitat. Although little is known about their larval/juvenile rearing requirements, it is likely that marine nearshore areas are important during this life stage. Longfin smelt are most likely to be in the nearshore zone during summer.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE IMPORTANT?

Longfin smelt may have the most geographically restricted and vulnerable spawning habitat of any marine/anadromous species in Puget Sound due to their specific association with only one or two rivers. As described previously, they spawn in the freshwater nearshore zone rather than marine waters.

Although longfin smelt do not have a marine nearshore spawning habitat requirement, they may rear in the nearshore zone in the vicinity of their spawning streams. Therefore, water quality and other conditions that affect food or predator abundance in the nearshore zone are important.

WHAT DATA ARE AVAILABLE?

No stock assessment or spawning habitat survey data exist for longfin smelt in Puget Sound. The species has been part of the incidental catch during midwater trawls in Bellingham Bay. They were also identified as a locally common nearshore fish along the Strait of Juan de Fuca, but no adjacent spawning streams have been identified. They have been only rarely encountered elsewhere in Puget Sound.

HOW DO COMMON SHORELINE ACTIVITIES IMPACT THIS HABITAT?

Activities that alter the beach, or the nearshore physical processes that form and maintain beaches, have the potential to impact the spawning habitat for Pacific herring, sand lance, and surf smelt. To adequately protect forage fish habitat requires protecting the beaches where spawning occurs in addition to protecting the physical processes that form and

maintain habitat conditions that support spawning.

Direct impacts to the beach substrate would include any activity that disturbs the substrate, from installation of footings for dock construction, to grounding a barge on the beach. Such activities can directly impact spawning adults and/or deposited eggs, or impact the substrate in such a way that reduces its suitability for spawning. These impacts can be minimized through avoiding these activities on spawning beaches, conducting activities to avoid the spawning period, and restoring/replacing impacted substrate.

Indirect impacts to the habitat can occur through activities that change the size and shape of the beach or the composition of beach substrate. These impacts can occur through a myriad of activities. Activities that affect the hydraulic character (energy and/or flow patterns) of the drift cell that feeds the beach will affect the beach form and substrate size. Shoreline armoring or other energy attenuation devices (e.g., jetties or seawalls) are the most significant cause of changes to beach size, shape, and substrate character.

Because Pacific herring rely on marine vegetation for spawning, activity that impacts plant growth in the intertidal and subtidal zone is likely to negatively affect habitat quality or quantity for this species. This may include changes to water quality that decrease water clarity and the depth at which plants can grow, changes in wave energy that make the environment less suitable for plant attachment, and shading from construction activities such as overwater structures.

Since some populations of surf smelt spawn high on the beach during summer, they are considered particularly vulnerable to loss of marine riparian vegetation, which provides shade to this region of the beach. These impacts and some planning and site design issues are summarized in Table II.3. Section III of this report contains detailed recommendations associated with planning and site design issues including marine riparian buffer recommendations from the white paper Protection of Marine Riparian Functions in Puget Sound, Washington.

Table II.3: Common Impacts to Forage Fish Habitat and Key Regulatory and Design Considerations.	
Direct/Indirect Impacts	◊ Alteration of wave energy or other shoreline processes that affect beach substrate or morphology through shoreline modification activities ◊ Decreases in terrestrial food supply, shading, and protection from overhead predators due to clearing of marine riparian vegetation ◊ Loss of marine vegetation from shade impacts of boats and floats, and scouring from buoy anchors causing reductions in spawning, rearing, and refugia habitat available to forage fish. Changes to substrate, increased egg mortality, and fish avoidance from prop wash and grounding of boats during low tides Changes to substrate structure/vegetation due to accumulation of shell fragments adjacent to pilings resulting in decreased habitat available for herring spawning ◊ Uptake of contaminants (leading to decreased survival) by herring eggs deposited on chemically treated wood pilings ◊ Decreased survival, due to desiccation, for herring eggs spawned on pilings at high tide elevations
Cumulative Impacts	◊ Changes in general pattern of upper intertidal sediment distribution and character ◊ Decrease in marine aquatic plant habitat and overall reduction in productivity of the nearshore zone ◊ Accumulation of shell fragments (long term impact from growth on pilings) and subsequent change to substrate structure and vegetation spawning substrate availability
Regulatory and Design Considerations	◊ Designate inventoried spawning areas as natural or conservancy shorelines ◊ Avoid and minimize new over-water structures in areas inventoried as forage fish spawning ◊ Minimize displacement of beach area by pilings ◊ Prohibit grounding of floats and rafts on the beach ◊ Promote overwater structure designs that result in improved light levels (e.g., minimize width, use grating, orient north-south to minimize shading resulting from new and rebuilt structures ◊ Minimize the footprint and number of pilings associated with overwater structures and do not allow use of treated wood ◊ Place structures to perpendicularly span the shoreline spawning habitat zone ◊ Do not allow construction activity during egg deposition and incubation periods ◊ Avoid placing docks or piers in tidal flats because these locations require very long structures

KELP AND EELGRASS BEDS

The information in this brief is summarized from a Puget Sound Nearshore Partnership White Paper by Thomas F. Mumford, Jr (2007) entitled "Kelp and Eelgrassin Puget Sound." The full report provides detailed information on the biology, distribution, and status of kelp and eelgrass populations in Puget Sound. The full report can be viewed at: http://www.pugetsoundnearshore.org/publications.htm.

Kelp and eelgrass are important marine plants that are dependant on specific environmental conditions found in the nearshore zone. Human activities and shoreline modification can adversely affect kelp and eelgrass through direct removal or degradation and indirectly through alteration of the environmental conditions that support them. Overwater structures, shoreline armoring, riparian vegetation alteration, boating, illegal harvesting, shellfish culturing, and water quality impairments all have the potential to affect the health of kelp and eelgrass beds. These activities can alter light and nutrient levels, alter substrate composition, increase toxics and suspended sediments, or cause physical disturbance of the species. Recommendations for minimizing or mitigating impacts are provided in Section III.

WHAT ARE KELP AND EELGRASS AND WHY ARE THEY IMPORTANT?

Kelp and eelgrass are marine aquatic plants that thrive in the nearshore zone. The term kelp refers to a particular group of multicellular marine algae, also known as brown algae, which attach themselves to the surface of marine substrates using a structure called a "holdfast". Puget Sound is home to 23 species of kelp, making it one of the most diverse kelp floras in the world. Kelps are believed to play as significant a role in the marine environment in terms of their forest-like productivity and contribution to carbon cycling.

Eelgrass, *Zostera marina*, and its introduced non-native relative *Z. japonica,* are vascular plants that root in the substrate like land plants. Like kelp, eelgrass is a carbon fixer that is important to nearshore primary production.

Figure II.12. Low-tide terrace eelgrass bed (*Zostera marina*) Photo by H. Shipman (from Finlayson 2006).

Kelp and eelgrass play a critical role in the marine ecosystem as primary producers, generating nutrients and substrate that form the base of the food chain. The dense and complex structure created by kelp and eelgrass beds also provide refuge and foraging habitat for a wide range of fish, invertebrates and other organisms, many of which are valued from a cultural and economic standpoint. For example, kelp forests and eelgrass meadows are critical to juvenile salmon as they prepare for life in the open ocean. Dense forests and meadows of vegetation provide refuge from current and wave energy, protect juvenile salmon from predation, and support and attract organisms that are important food sources for salmon and other species.

In addition to salmon, kelp and eelgrass in Puget Sound provide important spawning and rearing habitat for a variety of other species. Forage fish, crab, and a variety of other shellfish species are critically reliant on these important habitats. Lastly, kelp and eelgrass have historically supported a range of cultural uses, especially to Puget Sound Indian tribes.

WHY IS THE NEARSHORE ZONE CRITICAL TO KELP AND EELGRASS?

Since kelp and eelgrass are photosynthesizers and dependant on specific sediment types, they require a fairly well defined set of physical conditions; hard, relatively stable substrate in the case of kelp, and sandy substrate in the case of eelgrass (see Figure II.12 above), high ambient light, and clear water free of turbidity that can block light and bury or smother the plants. Since all kelp and eelgrass species begin life on the bottom and require sunlight to grow, they are limited to a relatively narrow band of shallow nearshore area that provides

the proper substrate and sufficient light penetration.

As these plants grow they form unique habitats within the nearshore zone that are used by many fish and invertebrate species, including four salmonid species that are currently listed as threatened under the Endangered Species Act (ESA). Due to their role in the health or recovery of these species, eelgrass and kelp are considered key elements of designated critical habitat for the purpose of ESA consultation and recovery planning. Kelp and eelgrass beds are also afforded regulatory protection at the local level through either local Critical Areas Ordinances or through Shoreline Master Programs. With the exception of giant kelp (*Macrocystis integrifolia*), once important to the commercial herring roe fishery in Puget Sound, commercial harvest of kelp and eelgrass is prohibited. Harvesting of kelp for personal use is currently permitted and is regulated jointly by the Washington Department of Natural Resources (WDNR) and Washington Department of Fish and Wildlife (WDFW).

KELP

Kelps' wide blades form dense canopies that shade the water and substrate. Depending upon the length of the kelp stems (actually known as "stipes") these canopies fall into three groups. There are those with long stipes and blades that float on or near the water surface, such as the familiar bull kelp, those that are raised off the bottom by short, rigid stems, and those that are prostrate and cover the substrate. Of the 23 kelp species found in Puget Sound, the majority (21 species) fall into the second two groups; they are either low growing or prostrate types and are therefore not often visible through boat and aerial surveys. These low growing and prostate types are limited to shallower portions of the nearshore zone than the much longer floating blade types. This is simply due to their inability to extend into the sunlit portion of the water column where light penetration is adequate to support growth and metabolism throughout the year.

Kelps are held to the bottom by holdfasts, which unlike roots do not penetrate the substrate or carry nutrients to the plant. This means the kelp must obtain nutrients directly from the water. This may be one of the reasons that most are found in areas with moderate wave energy or currents, since water movement is needed to keep nutrient rich water circulating past the plant. Because they lack a root system all kelps require a relatively stable solid substrate for attachment. Suitable substrates range from bedrock and boulders, to pebbles, to manmade structures such as sunken vessels, boat bottoms, pilings and docks.

WHERE DO THEY OCCUR IN THE NEARSHORE ZONE?

Floating kelps are found adjacent to approximately 11% of Washington's shoreline. The distribution of non-floating kelps is not as well quantified but they are generally more widely distributed and more abundant (~31%) than the floating varieties. Generally, kelps in Puget Sound prefer water with fairly high salinity (>25psu), low temperature (<15°C), high ambient light, hard substrate, and minimal sedimentation.

Because kelps are dependant on hard substrates and high ambient light levels for growth, areas providing these conditions are likely to support kelp habitat. The lower depth limits of kelp vary by species and by water clarity, but in Puget Sound most occur in the shallow subtidal zone from Mean Lower Low Water (MLLW) to about 20 meters below MLLW. Kelps also prefer high-energy environments in the lower intertidal or subtidal zone where tidal currents renew available nutrients and prevent sediment from covering young plants.

Non-floating species are abundant and cover large areas within the subtidal zone where substrate and water conditions such as temperature, light, and currents provide suitable habitat. These species, which are much less likely to be included in boat or aerial surveys, are those most likely to be impacted by changes to the condition of the nearshore area.

Kelps are vulnerable to a variety of competitor species including the invasive brown algae, *Sargassum muticum*, and are also vulnerable to herbivores like sea urchins and mollusks. An overabundance of urchins can result in barrens where kelp and other fleshy seaweeds have essentially been eradicated. Conversely, depressed abundance of urchins due to the presence of sea otters or human harvesters of sea urchins can greatly mediate their impact on kelp. Due to this vulnerability to grazing, kelps are more likely to become established in areas where sea urchin access is naturally limited, such as cobble beds surrounded by sand.

WHAT DATA ARE AVAILABLE?

Most of the data available on kelps pertains to the floating species as forests of floating kelp species can be easily mapped and monitored using aerial photographs. Data from aerial surveys is included in Ecology's Coastal Atlas, which includes aerial surveys from past years for comparison. The WDNR Puget Sound Assessment and Monitoring Program has been monitoring kelp beds since 1989, using data collected from aerial photographs. Maps produced with the ShoreZone Inventory database illustrate the distribution of floating kelp beds. These data are also available through Department of Ecology's Coastal Atlas. The

Coastal Atlas also contains links to county sites that may contain additional data layers of interest.

Because they are not readily visible in aerial photographs under all conditions, the smaller non-floating kelp species are not as easily monitored or mapped. They are expected to be more abundant and have more extensive distribution than floating kelps, meaning that they likely play a larger roll in primary production and carbon cycling in Puget Sound, and support habitat requirements for a broader range of species.

EELGRASS

Eelgrass grows in fine-grained substrates and forms a tangled mat of rhizomes that allow it to spread horizontally to produce new plants. The plant can also reproduce by pollination. Fertile seeds are broadcast into the current and those that are transported to suitable environments form new colonies. Flowering occurs in spring and seeds are broadcast in mid-summer. Germination occurs the following spring. Eelgrass blades are up to 2 meters in length and 2 centimeters wide, with the largest plants occurring in deeper intertidal or subtidal areas. The roots and rhizomes are a large component of the overall mass of the plant. The plant gets the majority of its nutrients through its root system, but adequate light exposure is also required for photosynthesis and growth.

Figure II.13. Underwater view of eelgrass. Photo by S. Simenstad.

WHERE DO THEY OCCUR IN THE NEARSHORE ZONE?

Eelgrass grows in low to moderately high-energy intertidal and shallow subtidal areas with mud/sandy substrate (see Figure II.13). It occurs along roughly 37% of Washington's shoreline. Eelgrass is limited to these substrate types, and is therefore highly sensitive to actions or activities that affect their distribution and availability. Eelgrass persistence is dependent on receiving sufficient light during summer to support growth and nutrient storage necessary for survival during winter when light levels are naturally low. Light attenuation due to propeller-derived bubbles, high turbidity, and sediment loading can limit photosynthesis by reducing the depth of light penetration and/or by settling material on the plant blades, limiting the amount of light available. Conditions that encourage eelgrass growth are often found near the margins of river deltas. These areas are close enough to the river mouths that nutrients are introduced to the tidal zone but they are far enough away that water turbidity is low. Extensive eelgrass beds are also found in large tidal flats. Smaller patches of eelgrass commonly occur in areas where conditions are not ideal, for example, where the substrate may have only small areas of sediment between rocks or where wave energy or other factors restrict growth. These fragmented beds are often located on the fringes of continuous beds and may vary in size and distribution from year to year.

Typically eelgrass beds form near Mean Lower Low Water (MLLW) and extend to depths from about 2 meters above MLLW to almost 9 meters below MLLW. The depth to which eelgrass grows is determined primarily by water clarity. However, factors such as extreme low or high nutrient levels, substrate composition, presence of other species, and toxic pollutants in the water can affect eelgrass abundance and distribution.

Eelgrass is found in all but the southernmost part of Puget Sound; it is not found south of Anderson Island and Carr Inlet. The lack of eelgrass presence in this southern part of the Sound is likely due to the timing of tidal events and to higher temperatures and low nutrient levels that can limit growth. Temperature limitations may also affect the upper depth at which eelgrass grows in other parts of the sound.

As a perennial plant, eelgrass beds form and reemerge in the spring, with bed areas varying only slightly (typically less than 10%) from year to year. However, impacts from human activities and shoreline modifications have contributed to loss of eelgrass beds.

Since the plants die back during the fall, for planning purposes it is important that inventory and survey work be done during summer months, including project specific surveys required for permit activities.

WHAT DATA ARE AVAILABLE?

WDNR and the Puget Sound Assessment and Monitoring Program have collected the most comprehensive data on eelgrass presence. Surveys began in 2000 and the agency continues to monitor eelgrass distribution and abundance on a regional scale. These data are part of WDNRs' ShoreZone Inventory datasets and maps can also be obtained through Department of Ecology's Coastal Atlas. WDFW has collected data on eelgrass presence while conducting herring roe surveys. Known eelgrass areas are mapped in the WDFW PHS data system. Eelgrass surveys are also conducted in the process of obtaining Hydraulic Project Approvals and Shoreline Permits and may be collected through other local programs, although most of this information is unpublished.

HOW DO COMMON SHORELINE ACTIVITIES IMPACT THIS HABITAT?

Kelp beds and eelgrass meadows can be adversely affected by a number of shoreline modifications. Direct impacts can occur on a local or site-specific scale through impacts to substrate and light levels. Dredging, filling, and grading, or otherwise altering the substrate can make a site uninhabitable for these plants and the numerous species dependent on them. Boat propellers and anchors can physically damage plants, disturb sediments, and alter the habitat by creating high-energy wakes. Overwater structures such as piers, docks, and floats, and moored boats decrease the amount of light available, and cause physical habitat changes that can result in a substantial reduction in the size and diversity of the plant community. Reduced light levels have been shown to be detrimental to eelgrass even during the winter dormant season.

Shoreline development can cause a multitude of indirect effects that can adversely impact kelp and eelgrass habitat. For example, shoreline armoring can alter wave energy patterns and change the composition of nearshore substrates. Removal of marine riparian vegetation can alter the temperature and nutrient regime of the nearshore environment, and increase the amount of sediments and pollutants entering the intertidal zone. Elevated nutrient levels associated with stormwater runoff and septic systems can cause excessive growth of macroalgae, phytoplankton, or invasive competitors that reduce the amount of light and substrate available. Increased boat use may affect eelgrass meadows through light attenuation caused by propeller-generated bubbles. Oil products, metals, and other pollutants from stormwater runoff and industrial or agricultural land uses can damage kelp and eelgrass or affect their growth and reproduction.

The broad patterns of development and shoreline modification around the Puget Sound basin have caused small, incremental effects that have become cumulatively significant. For example, there are areas that have experienced rapid reductions in the extent of eelgrass beds and where beds are now virtually eliminated. Significant losses have also occurred in major river deltas. Local observations indicate that the physical extent of kelp and eelgrass beds in the Puget Sound region is in decline, as is the amount of suitable habitat for these important marine plant communities. Successful eelgrass restoration has been difficult to achieve in Puget Sound, and costs associated with restoration have been uneconomical. Since they do represent a unique habitat that is critical to many species, their deterioration or loss is expected to affect the marine food web. Impacts to kelp and eelgrass and some planning and site design issues are summarized in Table II.4. Section III of this report contains detailed recommendations associated with regulation and design.

Table II.4: Common Impacts to Kelp and Eelgrass and Key Regulatory and Design Considerations.	
Direct/Indirect Impacts	◊ Reduction or loss of beds due to shading by over-water structures ◊ Loss of substrate appropriate for attachment or growth due to beach loss or substrate change from changes in wave energy and other physical processes ◊ Loss of appropriate habitat or direct vegetation impacts due to pilings (shellhash), dredging, prop wash, buoy anchor chain scour, and grounding of boats or structures ◊ Habitat reduction due to reduced light levels from short and long term increases in turbidity ◊ Loss of vegetation (eelgrass) due to increased shading from ulvoids and epiphytes (due to eutrophication)
Cumulative Impacts	◊ Puget Sound wide decrease in nearshore photosynthesis and productivity ◊ Puget Sound wide reduction in kelp and eelgrass and domino affect on numerous species that are directly and indirectly dependent upon them ◊ Increased release of carbon dioxide and potential climatic impacts ◊ Loss in nearshore habitat complexity
Regulatory and Site Design Considerations	◊ Identify all marine vegetation within intertidal and subtidal zones and protect them through appropriate shoreline designation and SMP regulations ◊ Require survey of intertidal and shallow subtidal areas prior to permitting any structures or activities that could impact existing beds ◊ Prohibit placement of overwater structures over marine vegetation ◊ Require structure designs that minimize shading and disturbance of the substrate including from prop wash ◊ Prohibit grounding of floats and rafts ◊ Avoid placement of shoreline armor or other structures that may result in downcutting of the beach, substrate change, or alteration of shoreline physical processes ◊ Require replacement or mitigation for all riparian or aquatic vegetation directly or indirectly lost through shoreline activities

MARINE RIPARIAN VEGETATION

"Marine riparian vegetation" includes both upland forested plant communities occurring on the Puget Sound shoreline that function similarly to freshwater riparian communities, as well as unique vegetation found only in the marine nearshore. Much of the information in this brief is summarized from a Puget Sound Nearshore Partnership Report by James S. Brennan titled "Marine Riparian Vegetation Communities". The full report contains a detailed discussion of how vegetation communities in the Puget Sound area evolve over long periods

of time, and how they are impacted by human activities. The full report can be viewed at: http://www.pugetsoundnearshore.org/publications.htm.

Riparian vegetation is an important aspect of nearshore habitat in Puget Sound. Riparian areas can be directly impacted by vegetation alteration (removal, topping, trimming), or indirectly impacted by changing the physical conditions required by plants that make up the community. For example, shoreline armoring, or other modification can impact natural erosion and soil composition. Development along the shoreline can change surface water runoff patterns, increasing soil erosion or risk of landslides. By disturbing riparian vegetation directly, or by altering the physical conditions that determine the type of plants that grow in the nearshore zone, shoreline modification can affect numerous culturally, commercially, and ecologically important species. Recommendations for minimizing or mitigating impacts are provided in Section III.

WHAT IS MARINE RIPARIAN VEGETATION?

The marine riparian area of Puget Sound's shoreline consists of many different plant community types. These communities vary in structure and composition, ranging from salt-tolerant vegetation on beaches or tidal flood plains, to forest communities that grow along the shoreline and on adjacent bluffs. Despite this variability, these communities share two common characteristics; they are directly influenced by the marine environment, and they directly or indirectly influence nearshore aquatic habitat. Specifically, tree and understory species are influenced by the specific microclimate produced by the nearshore environment. Riparian vegetation in turn influences the marine nearshore environment in ways similar to its function in freshwater environments- by stabilizing bluffs, filtering surface runoff, and providing shade, organic litter, and large woody debris. Upland marine riparian communities are often continuous with and closely linked to freshwater riparian communities where streams enter the sound and freshwater wetlands border estuarine marshlands. Maintaining the diversity of these communities and continuity between them is critical to species that depend on these areas. The diversity that exists today is in part due to environmental conditions but also reflects natural disturbance and succession processes.

VEGETATION IN THE NEARSHORE ZONE

Prior to European colonization, the Puget Sound lowlands and riparian forest communities were largely dense coniferous forests primarily of Douglas fir with a diverse understory that may include Oregon grape, salal, red huckleberry, trailing blackberry, and sword fern. However, natural and human alterations of the landscape have changed the vegetation in many areas. Natural disturbance of riparian vegetation includes episodic events such as fire, disease, seismic activity, and landslides. Human disturbance is generally more continuous over long periods of time and includes forest harvesting, agriculture, clearing and development. After a disturbance the area is first populated by plant species that are tolerant of the altered conditions. Disturbed areas may support shrubs and deciduous trees such as alder and maple. Conditions gradually change until the area is again capable of supporting climax forest communities that include Douglas fir, western hemlock and western red cedar.

There are other unique forest communities found throughout Puget Sound as well. Dry sunny locations with relatively nutrient-poor soils may support forest communities of madrone and associated plants. Aspen is a common species found on San Juan Island and Sucia Island that is relatively rare elsewhere in Puget Sound.

Forest and prairie communities have developed in the rain shadow of the Olympic Mountains. South facing slopes of islands can be uncommonly dry and exposed to heavy wind and salt spray. The conditions are the basis for unique vegetation communities including open forests comprised of Douglas fir, madrone, shore pine, and juniper; dense forests of Douglas fir, grand fir and western red cedar; or grass prairies with few trees (see Figure II.14 below).

Interspersed among the forested bluffs of Puget Sound are numerous plant communities associated with beaches, sand dunes, and salt marshes. These environments support plant communities that are tolerant of specific conditions. For example, marshes are

Common plant species of marine riparian areas:

- Vine maple
- Red alder
- Bigleaf maple
- Pacific madrone
- Western hemlock
- Western redcedar
- Douglas-fir
- Sword fern
- Salal
- Oregon grape
- Oceanspray
- Indian plum
- Salmonberry
- Huckleberry
- Snowberry
- Nootka rose
- Beach pea
- Shore lupine
- Tufted hairgrass
- Saltweed
- Saltgrass
- Fleshy jaumea
- Seaside arrowgrass
- Seaside plantain
- Pickleweed
- Dune wildrye
- Gumweed

composed of plants that are tolerant of saltwater inundation and soils with high organic matter. Beaches and dunes support salt tolerant plants that can also survive nutrient poor soils and exposure to waves. Unique communities occur on the narrow strip of the backshore or beach berms, on large spits, or in the lower portions of river estuaries. The type of soil, amount of sediment, local climate, and topography, degree of saltwater and salt spray exposure, and other factors determine the type of vegetation that grows in these areas.

Figure II.14. Example of shoreline prairie (from Brennan 2007)

As distance inland from the shore increases, tidal influence gradually decreases making the habitat suitable for plant species less tolerant of salt and tidal disturbance. Areas further from the open shoreline typically have more sediment accumulation and less wave energy. The vegetation communities that develop in flood plains or tidal surge plains closer to river mouths can be considerably different than those communities along open shorelines.

WHY IS RIPARIAN VEGETATION IMPORTANT TO THE NEARSHORE ZONE?

A diverse number of communities comprise the vegetated area around Puget Sound's marine waters. These plant communities create a gradient in environmental conditions and form transitional areas connecting aquatic and terrestrial habitat (see Figure II.15). This transitional habitat is important to the Puget Sound ecosystem and many species depend on its unique characteristics.

Riparian vegetation contributes to the foodweb by providing large woody debris and

organic matter, important to many species, and creates habitat for insects and marine invertebrates that are important food sources for fish and other aquatic life. Vegetation in tidal plains provides refuge for juvenile salmon and shades shallow water to maintain cooler temperatures that are necessary for the survival of salmon and other species. Large trees, which shade the upper intertidal zone is especially important for maintaining forage fish spawning habitat.

Marine riparian vegetation also protects water quality and reduces surface erosion by slowing run off. Terrestrial and shoreline vegetation acts as a filter for runoff, while submerged vegetation causes sediments to settle out of the water column. By slowing erosion and retaining sediments, riparian vegetation reduces pollutants including nitrogen, phosphorus, hydrocarbons, PCBs, metals, and pesticides. It also prevents excessive turbidity, which can smother eggs and aquatic vegetation.

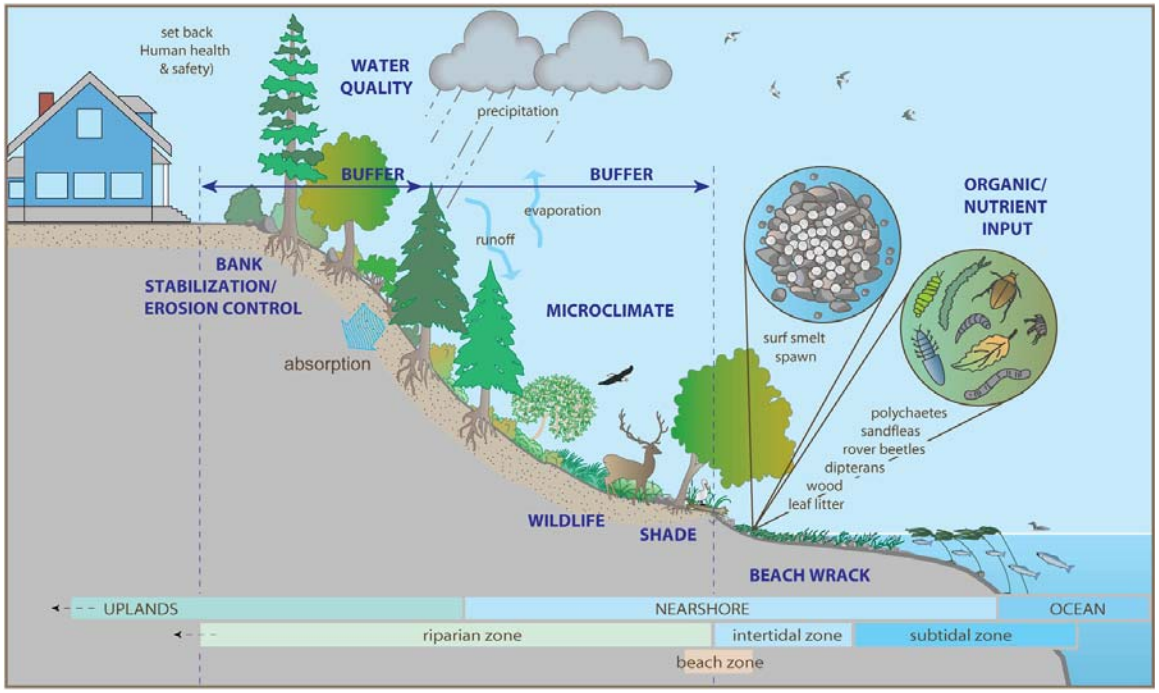


Figure II.15. Conceptual Model of Marine Riparian Functions (from Brennan and Culverwell 2004).

WHAT DATA ARE AVAILABLE?

Digital map data on important plant associations in Washington State have been developed by DNR's Natural Heritage Program (NHP). This information can be useful for understanding distribution, status, environmental characteristics, and succession patterns of vegetation

communities. However, the NHP is focused primarily on terrestrial plant species and does not characterize all communities found along Puget Sound shorelines. Wildlife species occurrence data for marine riparian areas is available from Washington Department of Fish and Wildlife's PHS program. The DNR Nearshore Habitat Program maintains the ShoreZone Inventory database, which provides information on the locations of saltmarsh vegetation and common nearshore vegetation such as surfgrass, seagrass, dune grass, kelp and eelgrass. It also provides data for geology, soils and forest disturbance, which can influence vegetation communities and habitat characteristics. Department of Ecology's Coastal Atlas also provides mapped information on vegetation and habitat types found along Puget Sound shorelines.

How do Common Shoreline Activities Impact this Habitat?

The composition of Puget Sound marine riparian communities is determined by environmental conditions specific to the nearshore area. Because of this, riparian vegetation is particularly susceptible to disturbance by common shoreline modifications.

Probably the most common activity that has directly impacted riparian vegetation along the shoreline is clearing. Historic forest harvesting and clearing of vegetation for agriculture, docks, roads, residential development and other uses has substantially altered the Puget Sound nearshore riparian zone. Many of these activities continue today.

Figure II.16. Unaltered riparian vegetation (left photo by R. Carman), and an example of bluff erosion following riparian vegetation removal (right photo, Brennan 2007).

Clearing vegetation can destabilize slopes (see Figure II.16). This leads to increased erosion, risk of landslides, and elevated levels of suspended sediments and turbidity in the nearshore environment. As a result, clearing vegetation reduces the amount of pollutants that are removed from the water and creates conditions harmful to aquatic species. Shade, organic litter, large woody debris and other benefits provided by riparian vegetation are also reduced.

Clearing is commonly followed by additional development or agricultural use of the land, which reduces and fragments available habitat. Even where cleared areas have been replanted, they were often replaced by single species stands that have little habitat diversity. Cleared areas are also much more vulnerable to colonization by invasive plant species. These plants do not provide the same habitat conditions that native species provide, and further contribute to the degradation of riparian conditions.

Nearshore riparian areas are transition zones between the aquatic environment and upland forest. These zones are characterized by sharp environmental gradients that tend to support relatively diverse plant and animal communities. Altering shorelines, beaches, and bluffs with armoring, over-water structures, fill, or other types of development typically results in the alteration or removal of vegetation. Shoreline alteration and vegetation removal can alter environmental gradients (e.g., by changing topography, soil composition, salt spray exposure, the amount of saltwater inundation, etc.). As a consequence, highly modified areas lose habitat diversity.

In the Puget Sound region, the cumulative impacts of human disturbance are the result of activity that has occurred over a relatively brief period since European settlement. The net result of these impacts is that tidal wetland and riparian habitat in Puget Sound has been reduced to less than 30% of its historic extent. Urban areas have less than 10% of their estuarine wetlands remaining. A DNR survey of Puget Sound (ShoreZone Inventory) showed that, currently, vegetation overhanging the intertidal zone covers less than 18% of the shoreline. The cumulative effects of shoreline modification and development have led to a reduction in riparian vegetation, habitat fragmentation, and simplification of vegetation communities on a landscape and regional scale. The functional vegetation that remains is threatened by human development. The effective management and conservation of remaining marine riparian vegetation is critical to a healthy Puget Sound. These impacts and some planning and site design issues are summarized in Table II.5. Section III of this report contains detailed recommendations associated with planning and site design issues. Additional science on the functions provided by riparian vegetation can be found in the white paper, Protection of Marine Riparian Functions in Puget Sound, Washington.

Table II.5: Common Impacts to Marine Riparian Vegetation and Key Regulatory and Design Considerations.	
Direct/Indirect Impacts	◊ Loss of function due to direct removal or disturbance during clearing and grading activities ◊ Reduction in functional value due to decreases in vegetated riparian area width and plant diversity or density ◊ Reduction or loss of riparian function through pruning overhanging pieces and/or removal of large trees ◊ Increased pollutant load due to change from established native community to non native landscaping requiring use of fertilizers and pesticides ◊ Increased incidence of invasive species due to site disruption ◊ Increased beach substrate temperatures during low tide in summer due to removal of overhanging vegetation ◊ Reduction or loss of localized terrestrial insect input from shoreline vegetation due to vegetation removal
Cumulative Impacts	◊ Loss of marine riparian area and associated ecological function throughout the Puget Sound basin due to vegetation removal and modification ◊ Fragmentation of remaining habitat and simplification of vegetation communities on a landscape and regional scale have resulted in greatly reduced functional value ◊ Loss of large tracts of shaded nearshore area throughout Puget Sound has reduced organic matter and large woody debris recruitment ◊ Reduced level of pollutant removal due to decreased riparian areas resulting in deteriorating water quality throughout Puget Sound ◊ Increased substrate temperatures at low tide due to loss of overhanging riparian vegetation
Regulatory and Design Considerations	◊ Require site surveys of existing conditions including vegetation function analysis ◊ Avoid and minimize area disturbed during nearshore construction activities by establishing standards for equipment use within riparian areas, and require replacement of damaged vegetation with native species, including long term maintenance provisions ◊ Identify marine riparian protection areas that support existing functions through no-touch buffers in undeveloped areas and enhancement and mitigation requirements related to expansions or redevelopment of developed areas ◊ Require development of vegetation conservation plans, including replanting and maintenance standards focused on native species, for any project that impacts marine riparian vegetation ◊ Promote off-site mitigation to address cumulative impacts using the restoration component of the shoreline master program

JUVENILE SALMON HABITAT

The information summarized below is from a Puget Sound Nearshore Partnership report by Kurt L. Fresh titled Juvenile Pacific Salmon and the Nearshore Ecosystem of Puget Sound. The full report provides detailed information on the nearshore habitat requirements of juvenile salmon, and the status, distribution and trends of the populations. The full report can be viewed at: http://www.pugetsoundnearshore.org/publications.htm

Juvenile salmon are dependent upon the nearshore estuarine and marine environments in Puget Sound. The nearshore area provides food, a migration corridor, protection from predators, and a transitional environment that supports the physiological changes that occur as they transition from a freshwater to a marine environment. Shoreline modification activities (e.g., shoreline armoring, placement of over-water structures, and riparian vegetation alteration) can degrade these nearshore habitats, reducing the quantity and quality of habitat available. Habitat impacts from common types of shoreline modification, the related effects on juvenile salmon from common types of shoreline modification, and recommendations for avoiding, minimizing, or mitigating these impacts are provided in Section III.

WHAT ARE JUVENILE SALMON?

Juvenile salmon in Puget Sound are young salmon that have migrated from their natal streams to the marine environment. Salmon migrating from fresh to salt water undergo a process called "smoltification," a physiological transformation that allows them to survive in the marine environment. This life history stage is particularly sensitive because these physiological changes are demanding, young salmon are small and vulnerable to predation, and their food requirements are large. These combined factors make juvenile salmon sensitive to even small changes in habitat condition.

There are eight species of salmonids that use Puget Sound during their juvenile life history stage: chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), sockeye (*O. nerka*), sea-run cutthroat trout (*O. clarkii*), steelhead trout (*O. mykiss*), and bull trout (*Salvelinus confluentus*).

Four salmonid species are currently listed as threatened under the Endangered Species Act in Puget Sound: Chinook, Hood Canal summer-run chum, steelhead, and coastal-Puget Sound bull trout. Puget Sound steelhead was recently listed as threatened, while Puget Sound-Strait of Georgia coho, is listed as a Species of Concern.

WHY IS THE NEARSHORE ZONE CRITICAL TO JUVENILE SALMON?

The range of unique habitat characteristics provided by the nearshore environment is critical to juvenile salmon development as they prepare for and undertake their migration to the open ocean. Nearshore habitat provides food, refuge from predation, a shallow water migration corridor, and the distinctive environmental conditions that support the physiological changes necessary to move from freshwater to saltwater as juveniles, and back to freshwater as mature adults. It is essential to the success and long term viability of the species that nearshore habitat in Puget Sound continues to provide the conditions necessary to support these needs.

The agencies responsible for recovery of ESA-listed populations recognize the critical role nearshore habitat will play in the recovery of listed populations. Critical Habitat designations for listed chinook, chum, steelhead, and bull trout stocks include the Puget Sound nearshore environment. Critical habitat designation incurs special management considerations and protections intended to ensure that the habitat will function as necessary to provide for the survival and recovery of listed populations in areas with a Federal nexus. However, these protections are limited in scope and many areas of the Puget Sound shoreline do not receive adequate protection under Section 7 of ESA (e.g., proposed new bulkheads most often do not undergo Section 7 review).

WHEN DO THEY USE THE NEARSHORE ZONE

The life histories of northwest salmon are widely diverse and complex. Spawn timing, migration timing, and utilization of different habitats vary greatly between species such as between Chinook and coho, as well as between stocks or subpopulations of the same species. For example, Chinook salmon originating from different rivers or from different segments of the same river may have very different life cycles in terms of when they spawn, when they migrate downstream, etc. The wide variations between species and populations equates to wide variations in habitat use within a population.

While the physical or behavioral traits of Puget Sound salmon populations can be generally summarized, variations within these populations make it difficult to predict how and when these fish use the nearshore zone. Factors such as spawning timing, variability in stream flows and temperatures, the distance upstream to where the fish were hatched, and the time spent rearing in their natal streams determine the timing, size and age at which juvenile salmon arrive in the nearshore environment. Age and size, food abundance, weather

conditions, and other factors determine how long they remain in the nearshore zone and the type of habitat they require. Ultimately these variations affect the overall success and abundance of a population on a seasonal or annual scale.

There is a high level of stock mixing that occurs in Puget Sound as juvenile salmon migrate through their natal estuaries and deltas to nearshore habitats. All of these fish are essentially heading toward the same place and along the same Puget Sound shoreline. They forage and grow as they move along the nearshore environment toward the open ocean. As they do so, their survival depends on connectivity among diverse habitats. This mixing and reliance on similar habitat ensures that juvenile salmon representing a number of species and stocks will be present in the Puget Sound nearshore throughout the year.

Salmonid use of the Puget Sound nearshore is not restricted to juvenile fish. Bull trout and sea-run cutthroat use nearshore marine habitats as both juveniles and foraging adults, and all species of salmonids forage along these nearshore environments as adults returning to freshwater systems to spawn.

WHAT CHARACTERISTICS OF THE NEARSHORE ARE MOST IMPORTANT?

The variations that occur between species and populations of salmon are complex and are not completely understood in relation to nearshore habitat characteristics. However, some fundamental characteristics have been identified.

Juvenile salmon typically utilize shallow water habitat with low wave energy and fine-grained silt or mud substrate. These characteristics are associated with marsh and wetland areas and pocket estuaries (connected lagoons and stream mouths). These areas can provide food and protection for juvenile salmon.

Food in the form of prey species is often abundant in vegetated shallow water areas such as eelgrass or macroalgae beds. The vegetation also provides cover and protection from predation.

As salmon feed and grow they are likely to utilize different habitats with different characteristics (deeper water, higher salinity, different food sources). Connectivity between these habitats is critical to foraging success, refuge from predation and successful physiological adaptation to the marine environment as fish grow and migrate towards the ocean. Connected habitats provide gradual transitions between estuarine and marine waters, along shallow water environments adjacent to the shoreline, and between shallow

and deeper water environments. Habitat fragmentation caused by shoreline modification limits the amount of suitable habitat available and creates unproductive zones where prey and cover are limited and exposure to predation, strong waves and currents, and other factors detrimental to survival is more likely.

Due to these diverse habitat requirements and the need for connectivity, it is essential to recognize that habitat protection cannot be considered solely at the project or site-specific scale. Effective habitat protection must be implemented at a landscape-scale that considers the broad range of habitat requirements necessary for survival and productivity, and recognizes the need for connectivity between the habitats that meet these requirements.

WHAT DATA ARE AVAILABLE?

Information has been collected on various Puget Sound salmon stocks over the past 40 years. Field surveys conducted by WDFW, tribes, and other agencies provide data on stock presence in Puget Sound streams. Priority Fish presence is included in WDFW Priority Habitats and Species maps. SalmonScape, a web-based mapping application, is a useful tool for identifying stock presence in specific streams. WDFW biologists can often provide more detailed information on a site-specific scale and should be contacted to confirm that the information is complete and accurate to the most recent surveys and available data.

Although there are still some gaps in the data available much has been learned through field research where migration and survival is monitored through the use of smolt traps and various tagging methods. Since 1992, WDFW has compiled data into the http://wdfw.wa.gov/fish/sasi/ (SaSI). This inventory provides a method for identifying and monitoring the status of salmonid stocks.

HOW DO COMMON SHORELINE ACTIVITIES IMPACT THIS HABITAT?

The habitat functions provided by the nearshore environment are defined by the specific physical, chemical, and biological conditions present. These conditions are not easily replicated, meaning that alterations cannot be readily mitigated. This makes the Puget Sound nearshore unique in the landscape and particularly susceptible to impacts by development and human activity.

Any activity that alters the wave energy along the shoreline or causes other physical changes will change habitat conditions for juvenile salmon. The most common causes for wave energy change are through shoreline armoring (e.g. bulkheads and riprap) and other energy attenuation devices (e.g., jetties or seawalls). However removal of marine or shoreline vegetation will also affect how wave energy is dissipated before it reaches the upper shore. These localized changes in wave energy alter the supply and movement of sediment and therefore can also impact downdrift shorelines that may be far removed from the site of a planned activity.

Another important area of impact is from overwater structures that create a "light barrier" to salmon. Juvenile salmon have been shown to avoid moving under a structure if there is insufficient light. Instead, they react by migrating into deeper water and around the offshore edge of the structure. This migration pathway is in a water depth zone where predators are more likely, travel distances are greater and currents are stronger. While one dock is not a significant obstacle, the cumulative effect of numerous structures along the Puget Sound shoreline can be significant in terms of the total distance a fish must travel and the additional time and energy it requires.

Other common impacts associated with human activities include alterations in erosion and sediment transport, and loss of riparian vegetation as well as increases in pollutants. These alterations may directly impact juvenile salmon or indirectly impact them by disturbing their habitat or prey. These impacts and some planning and site design issues are summarized in Table II.6. Section III of this report contains detailed recommendations associated with regulation and design issues. Model policy and regulatory language specific to salmonid habitat protection can be found in the Aquatic Habitat Guidelines publication, Land Use Planning for Salmon, Steelhead and Trout. This publication is written for local government Growth Management and Shoreline Management planning programs.

Table II.6: Common Impacts to Juvenile Salmonids and Key Regulatory and Design Considerations.

Direct/Indirect Impacts	◊ Decreases in terrestrial food source due to loss of nearshore vegetation ◊ Changes in prey diversity and abundance due to alterations in beach substrate and structure ◊ Disruption of nearshore migration and feeding areas due to noise and turbidity associated with construction activity ◊ Substrate change and fish use impacts (avoidance) during low tides from prop wash and grounding

Table II.6: Common Impacts to Juvenile Salmonids and Key Regulatory and Design Considerations.	
Direct/Indirect Impacts (cont.)	◊ Increased wave energy due to armoring modifies habitat form and function ◊ Loss of nearshore habitat structure and function due to removal or large wood, boulders, and vegetation ◊ Substrate modification due to accumulation of shell fragments adjacent to pilings ◊ Altered migration behavior and potentially increased predation due to shading from overwater structures ◊ Increased water temperatures and bird predation due to loss of overhanging riparian vegetation ◊ Increased injury risk (lesions, tumors) and reduced prey and habitat due to water quality degradation from increased stormwater runoff and wastewater discharges ◊ Reduced prey and habitat due to loss of marine vegetation
Cumulative Impacts	◊ Puget Sound wide increase in pollutant loading from stormwater and wastewater ◊ Increased travel distance and time, extended time in deeper water, and increased energy expenditures for juvenile salmon migrating around overwater structures and other obstacles (groins, breakwaters, moored vessels) ◊ Fragmentation and loss of connectivity between habitats reducing migration efficiency ◊ Alternation in prey base decreasing foraging efficiency ◊ Changes in wave energy, geomorphic processes, and nearshore habitat structure and function
Regulatory and Design Considerations[3]	◊ Provide protected shallow water migration corridors, especially between estuaries and marine waters through shoreline designations ◊ Minimize and limit over-water structures and improve light conditions under these structures through design specifications (width, grating, etc.) Minimize pilings, avoid use of treated wood, and eliminate grounding of boats and structures ◊ Protect marine riparian areas and require mitigation for lost habitat elements such as trees, logs, and boulders ◊ Protect all native marine vegetation, including kelp, eelgrass, and wetland plants ◊ Avoid and minimize shoreline armoring projects ◊ Require analysis of alternative approaches to shoreline protection when armoring projects are proposed

[3] See Land Use Planning for Salmon, Steelhead and Trout for additional regulatory and design considerations.

SECTION III RECOMMENDATIONS FOR REGULATING COMMON SHORELINE MODIFICATION ACTIVITIES

This guidance addresses three general categories of shoreline modification: overwater structures; shoreline armoring; and riparian vegetation alteration. While there are other types of potential shoreline modification, these three categories represent the most common types of activities and account for the vast majority of adverse environmental impacts.

The guidance provided in this Section is supported by the best available science (BAS) and current information for managing the shoreline modification activities. This Section is not intended to provide detailed information on the environmental impacts of shoreline modification activities. Instead, it provides planners responsible for regulating these activities with the tools and guidance necessary to avoid and minimize adverse impacts where possible, and to mitigate these impacts where necessary. Links to additional information on specific topics and citations for supporting scientific studies are provided for those desiring additional background.

Finally, projected changes in local sea levels are an important consideration for long term planning. Sea levels in Puget Sound are expected to change over the coming century as a result of global climate change. While this document does not provide explicit guidance on how to incorporate sea level rise into planning and permit review, planners and regulators should familiarize themselves with projected trends in their area and incorporate a long-term perspective into marine shoreline management decisions. For example, a proposed bulkhead above the current ordinary high water (OHW) may cause an increasing level of adverse effects if sea level rise brings the structure within OHW. Planners should take this into consideration now to avoid adverse impacts in the future. For more information on the predicted impacts of climate change in Washington state visit the University of Washington Climate Impacts Group: *http://cses.washington.edu/cig/fpt/planning.shtml*; State of Washington Department of Ecology: *http://www.ecy.wa.gov/climatechange/index.htm*; and Puget Sound Partnership: *http://www.psparchives.com/our_work/climate.htm*.

USING THE SMP TO ENHANCE HABITAT PROTECTION

The required updates to local SMPs provide a unique opportunity to plan for, anticipate, and manage, future shoreline development in a manner that avoids impacts from necessary shoreline modification activities. The development of an SMP requires obtaining and developing information necessary to protect important shoreline physical processes and the habitats that depend on them. SMP updates will include conducting or updating inventories of important habitat features and shoreline characteristics, such as:

- ◊ Known forage fish spawning habitat
- ◊ Beach area providing substrate and wave energy characteristics suitable for potential support of forage fish spawning habitat
- ◊ Aquatic vegetation communities
- ◊ Steep and/or eroding bluffs that recruit substrate and riparian vegetation to the beach
- ◊ Identified drift cells and their configuration
- ◊ Habitat types (e.g., protected embayment's, spits, etc.) that likely provide critical nearshore habitat for juvenile salmon
- ◊ Riparian vegetation communities that provide shade, large woody debris, and organic material recruitment to the nearshore environment

Where possible, the preferred management approach is to designate critical habitat features such as forage fish spawning habitat, aquatic vegetation communities, nearshore salmon habitat, and marine riparian communities under a Natural or other type of conservancy shoreline environment designation. Protected status designation provides some additional leverage to deny permits for projects that are unnecessary or to compel proponents to consider design alternatives that are less damaging to the environment.

Where protective shoreline designations cannot be applied or in cases where a project is deemed necessary to protect property or critical infrastructure, it may be necessary to permit activities that will cause unavoidable degradation. In such cases, planners and regulators should search for opportunities to minimize and mitigate both the site-specific and cumulative impacts that result. Jurisdictions should consider maintaining a database of mitigation opportunities from their shoreline restoration plan so that searching is easier, and highest priority mitigation opportunities are considered first.

In many areas the detailed information necessary to determine potential effects on shoreline processes and habitat types may not be readily available. In such cases, it is

incumbent on planners and regulators to require project proponents to conduct the surveys and studies necessary to support the permitting process. The guidance and recommendations provided in the following sections are consistent with this perspective.

This Section provides guidance for evaluating and permitting three types of shoreline modification activities: overwater structures, such as docks, piers, floats and mooring buoys; shoreline armoring, such as bulkheads, jetties, and seawalls; and riparian vegetation alterations, including the removal, alteration, or selective pruning of shoreline vegetation.

The following information and guidance are provided for each activity:

- ◊ A general description of the type of ecological impacts associated with the activity and links to, or citations for, additional sources of information
- ◊ A table describing direct, indirect, and cumulative impacts and their effects on the following key ecosystem components:
    - o Forage fish habitat
    - o Beaches and bluffs
    - o Kelp and eelgrass beds
    - o Marine riparian vegetation
    - o Nearshore habitat for juvenile salmon
- ◊ A "decision tree" flow chart to guide the permit review process
- ◊ A table providing design guidance and methods for avoiding and/or minimizing adverse impacts
- ◊ A table describing strategies for mitigating unavoidable impacts. (Due to the similarity in mitigation needs, one table is provided that addresses all three activities.)

This guidance is based to the greatest extent possible on the BAS for ecological impacts, design methods, and impact avoidance and mitigation strategies. For ease of use and reference, this document does not provide a detailed description of the BAS on each of these topics. Rather, it incorporates supporting BAS by reference and links to supporting documents.

OVERWATER STRUCTURES

HOW DO OVERWATER STRUCTURES IMPACT THE SHORELINE?

Piers, docks, mooring floats and other types of overwater structures have the potential to alter the physical characteristics of nearshore environments both at the site and beyond the footprint of the structure. By altering the physical processes that operate in the nearshore environment, such as light penetration, wave energy, and sediment transport, overwater structures can promote changes in habitats. Once habitats are altered, the species using those habitats and the way those habitats are used may also change, affecting the biological community in a number of ways. For example, the shaded, deep-water environment under piers can create a favorable habitat for predatory fish. Juvenile salmonids tend to migrate around structures that shade the water column and into deeper water where they can be exposed to predation as they migrate near the edges of the piers. Overwater structures can also impair habitat function. For example, by shading the nearshore environment and altering wave energy and sediment transport characteristics, overwater structures can degrade eelgrass habitat, which is an important refuge for a variety of important marine species. Table III.1 provides a summary of the impacts of overwater structures on a few key species or habitat types. Additional discussion on these key species or habitat types and how they can be impacted by shoreline modification activities was provided in the previous section of this document.

Table III.1. Impacts from over-water structures (piers, docks and floats) and natural functions that may be affected.

Impact	Supporting Technical Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Direct & Indirect Impacts						
Short-term (site-preparation and construction activities)						
Increased turbidity and possibly release of pollutants ◊ Reduced light and photosynthesis ◊ Fine sediment deposition/substrate change ◊ Increased contaminant levels in the water ◊ Avoidance by fish and other aquatic life	(Norris et al. 1997), (Thom et al. 2001), (Nightingale and Simenstad 2001)	X		X		X
Noise (especially from pile driving) ◊ Avoidance by fish and other aquatic life ◊ Fish mortality due to bladder eruption	(WSDOT 2006), (Hastings and Popper 2005), (Popper 2006)	X				X
Beach and nearshore disturbance from heavy equipment use, materials placement, etc. ◊ Avoidance by fish and other aquatic life ◊ Loss of fish eggs and other substrate dependent life ◊ Aquatic vegetation loss ◊ Riparian vegetation loss	(Kelty and Bliven 2003)	X	X	X	X	X

Table III.1. Impacts from over-water structures (piers, docks and floats) and natural functions that may be affected.

Impact	Supporting Technical Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Alteration of substrate characteristics ◊ Removal of existing habitat features such as large woody debris from the intertidal zone ◊ Loss of habitat features in the structural footprint ◊ Accumulation of shell hash underneath the structure, alteration of substrate characteristics	(Kelty and Bliven 2003), (Nightingale and Simenstad 2001), (Haas et al. 2002)	X	X	X		X
Shading from dock and adjacent area where boats and rafts may be tied ◊ Forced migration of juvenile salmon away from the intertidal zone and into deeper waters ◊ Loss of plants and the habitat they create ◊ Reduction in substrate cohesion ◊ Reduction in shoreline energy dissipation through plant loss	(Nightingale and Simenstad 2001), (Fresh et al. 2006), (Fresh 2006), (Williams et al. 2003)	X	X	X		X
Pilings impact on substrate and aquatic life ◊ Establishment of herring eggs on pilings and desiccation of eggs at low tides ◊ Uptake of contaminants and mortality for herring eggs deposited on treated wood pilings ◊ Development of "shellhash" and resultant substrate change ◊ Release of contaminants associated with wood piles or associated with piling maintenance	(Poston 2001), (Nightingale and Simenstad 2001), (Ecologic 2003)	X		X		X
Boat Operations Impacts	(Kelty and Bliven 2003), (Ecologic	X		X		X

Table III.1. Impacts from over-water structures (piers, docks and floats) and natural functions that may be affected.

Impact	Supporting Technical Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
◊ Prop wash impacts to substrate and substrate dependent life ◊ Petrochemical discharge and other maintenance related contaminants (e.g. zinc) ◊ Noise and lighting ◊ Possible continual impact to habitat during low and lowering tides from grounding, anchor chain scour, etc.	2003), (Nightingale and Simenstad 2001)					
Cumulative Impacts						
Increase in pollutants and habitat disturbance associated with boat operations and dock and piling maintenance	(Poston 2001), (Kelty and Bliven 2003), (Ecologic 2003), (Nightingale and Simenstad 2001), (Williams et al. 2003)	X		X		X
Increased travel distance and time for juvenile salmon and extended time in deeper water, increasing predation risk	(Redman et al. 2005), (Williams et al. 2003)					X
Decrease in eelgrass and plant habitat and overall photosynthesis in intertidal zone	(Nightingale and Simenstad 2001), (Kelty and Bliven 2003), (Haas et al. 2002), (Norris et al. 1997)	X		X		X
Alteration in juvenile salmon prey base and predation pressure	(Haas et al. 2002), (Williams et al. 2003), (Redman et al. 2005)	X				X
Change in wave energy and longshore drift patterns, and resulting changes in upper intertidal sediment distribution	(Kelty and Bliven 2003), (Nightingale and Simenstad 2001)	X	X	X	X	X

Over-water structures of any kind will result in loss of some habitat functions due to short-term (construction activities) and long-term (permanent structure features) impacts. Most, but not all, habitat impacts can be avoided or minimized through proper design, and compensated for through mitigation. However, small incremental impacts are essentially unavoidable where these types of projects are permitted. As a consequence, despite efforts to avoid, minimize, and mitigate ecological impacts, the cumulative effects of over-water structures will gradually increase over time. The ecological implications of this fact are potentially broad and have other regulatory implications. For example, juvenile salmonids from ESA listed populations are dependent on a variety of nearshore habitats that are broadly distributed throughout the Puget Sound nearshore. Permitting activities that will unavoidably cause cumulative incremental degradation of these habitats will ultimately have implications for the conservation and recovery of these highly valued species.

REGULATING OVERWATER STRUCTURES

Due to the clear adverse impacts on the nearshore environment from overwater structures, local planners and regulators must first manage the shoreline to avoid (not permit) the impacts and then to minimize impacts through careful review of permit applications. This guidance provides the tools and information necessary to determine if a proposed project avoids and minimizes ecological impacts to the greatest extent possible, and mitigates for unavoidable impacts consistent with regulatory standards.

The Shoreline Management Act (SMA) and related guidance for updating local Shoreline Master Programs (SMPs) provides a basis for developing more specific guidance for planning and permitting these activities. Because the SMA allows for the development of certain types of overwater structures to support water-dependent uses, it follows that permitting of some activities known to cause harm will take place. However, the SMA also mandates that permitted shoreline activities result in "no net loss" of habitats and habitat function. To remain consistent with this mandate, SMPs must provide a clear sequence of steps for avoiding and minimizing these impacts to the greatest extent possible, and for mitigating unavoidable impacts.

A key first step is to identify conditions when new structures should not be approved based on the potential to impact sensitive habitats. For example, Island County's' SMP prohibits new piers and docks on one of their bays in order to protect surf smelt spawning area. Because even carefully designed projects will produce some incremental loss of habitat functions, some limits on the total number of new structures allowed will be necessary to

control cumulative effects. The SMA provides useful guidance in this regard, recommending alternative approaches such as using moorage buoys and shared facilities that limit the number of new facilities while providing equivalent access. Useful elements of the broad regulatory guidance provided by the SMA include the development of local policies and requirements that:

a. State a clear preference for use of mooring buoys and shared facilities rather than individual private docks and piers. This policy addresses the potential cumulative impacts of multiple individual docks. If a shoreline inventory has already indicated that certain sensitive areas of the shoreline have a high number of overwater structures, a policy or regulation to restrict new structures in that area or require a higher level of scrutiny for those areas could also be adopted.

b. Regardless of shoreline designation, applicants must demonstrate conclusively that use of a moorage buoy, nearby marina, public boat ramp, or other existing shared facility is not possible. This includes providing evidence of contact with abutting property owners and evidence that they are not willing to share an existing dock or develop a shared moorage. For commercial/industrial facilities, this would include evidence that existing commercial facilities can't be shared or are inadequate for the proposed use.

c. New residential subdivisions must provide shared moorage if and when moorage is desired by the residents. A joint use agreement should be developed to ensure future shared use of the facility. If appropriate, an agreement to allow public use of the structure may be required. This information should be recorded on the face of the plat and/or as part of covenants.

d. Avoid locating docks, piers and mooring buoys, including those auxiliary to single family residences, in areas where they will adversely impact shoreline ecological functions or processes, including currents and littoral drift.

e. Docks, piers, and mooring buoys should not be located in areas containing sensitive, unique, or high-value fish and shellfish habitat.

f. When permitted, these structures must be the minimum size and length to accommodate the intended use.

g. Docks and piers should not be located on shallowly sloped beach areas because of

the large footprint required to attain adequate water depths for launching.

h. Prohibit new private or commercial docks in the Natural Shoreline Environment Designation, except as related to science and environmental education facilities that may be permitted in that designation. A conditional use permit should be required for docks in the conservancy environment.

A second key step in creating specific planning and permitting guidance is to employ innovative design standards for new and replacement structures. These design standards, which are based on BAS, are intended to produce overwater structures that avoid and minimize adverse impacts to the greatest extent possible. Finally, the guidance should also provide a means for determining when mitigation for unavoidable impacts should be required, and what form this mitigation should take.

The following "decision tree" tool has been developed with these key steps in mind. It is intended to guide local planners in making initial determinations about conditions where overwater structures should or should not be approved, providing design recommendations, and indicating situations where mitigation should be required. The decision tree is linked by reference to design standards and other recommendations for impact avoidance and mitigation provided in the following sections.

How to minimize impacts from approved Overwater Structures

Corps of Engineers permitting requirements and local shoreline management regulations provide extensive design guidance for overwater structures. This guidance has evolved from numerous studies of the effects of these structures on the nearshore environment, and experimental approaches for minimizing these impacts. A summary of this design guidance and the supporting environmental documentation this guidance is based upon is provided in Table III.2.

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
General	
Materials selection	Treated Wood: The use of treated wood should be avoided altogether; there are many alternative materials that can be used (i.e., concrete, steel, plastic, and in some cases, untreated wood). ◊ Regulatory requirements do not allow for creosote, pentachlorophenol, CCA, or comparably toxic compounds not approved for marine use, to be used on any component of the over water structure. ACZA treated wood must meet Post-Treatment Procedures (Poston 2001), (Nightingale and Simenstad 2001). Floatation: ◊ Enclose or contain floatation material within a durable shell to prevent disintegration (Corps 2006), (Ecology 1994). Transparent materials: ◊ Use transparent or partially transparent (e.g., grating) materials in ramp and pier/float decking (Shafer 2002). ◊ Corps of Engineers permitting requirements (Corps 2006) for functional grating used in docks, piers, floats and ramps state that the grating must have at least 60% open area, oriented to maximize light penetration and without any solid objects above or below the grating (Shafer 2002) (Fresh et al. 2006). ◊ Use transparent roofing materials where roofing is required (e.g., watercraft lifts).

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
Equipment operation	Site access: ◊ Confine equipment use to a single access point and limited to a 12-foot corridor on either side of the proposed work (Corps 2006). ◊ Operate equipment from the top of the bank, a temporary work platform, barge or similar out-of-water location to the maximum extent practicable (Corps 2006). Barges: ◊ When using barges, do not ground on the substrate at any time (Corps 2006). Water quality: ◊ Operate equipment in a manner that minimizes suspended particulates entering the water (Corps 2006).
Habitat and process protection	Watercraft moorage: ◊ Corps of Engineers permitting requirements state that structures must be designed to avoid watercraft resting on the substrate at all times (Corps 2006). Protection of geomorphic processes: ◊ Design for minimal interference with geomorphic and littoral drift processes (Ecology 1994). Habitat protection: ◊ Construction of new overwater structures within 25 feet (horizontally) of macroalgae or eelgrass beds is not allowed under Corps of Engineers permitting regulations (Corps 2006). ◊ For floats or support pilings for replacement structures installed where macroalgae or eelgrass beds and/or documented Pacific herring habitat are present within 25 feet of the float in any direction, allow a minimum of four feet depth between the top of the float stopper and the top of the habitat feature (Corps 2006). ◊ If piers and ramps need to be constructed over documented surf smelt and/or sand lance spawning habitat, they should span that habitat to the maximum extent practicable (Corps 2006).
Survey requirements	Eelgrass/macroalgae: ◊ Surveys are required for all new construction. Surveys are not required for replacement of existing structures within their original footprint (Corps 2006). Substrate types: ◊ Summary information about substrate types in project area must be submitted with Corps permit application. If undocumented Pacific herring, surf smelt, or sand lance spawning habitat is present, additional survey information may be requested from the applicant (Corps 2006). Surf smelt/sand lance habitat: ◊ If the project site contains documented surf smelt and/or sand lance habitat and there is no approved in-water work window for the site, obtain confirmation in writing from a WDFW certified biologist that these species are not spawning in the area when construction occurs. Once certification has been obtained, the permittee has 48 hours from the date of the inspection to begin and two weeks to complete all construction activities in contact with the substrate waterward of ordinary high water (Corps 2006).

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
Site restoration	Substrate disturbance: ◊ Restore depressions or trenches in beach substrate created by construction equipment waterward of OHW to pre-project conditions. Where beach hardpan or clay is exposed by construction activities, restore to pre-project conditions immediately upon completion of construction (Corps 2006). Vegetation disturbance: ◊ Develop a planting plan that provides for the replacement of disturbed vegetation with equivalent site-appropriate native species (Corps 2006). ◊ Do not remove existing habitat features (e.g., logs, aquatic vegetation) from the aquatic environment (Corps 2006). ◊ Limit disturbance of bank vegetation to a work area strip no wider than twice the width of the pier (Corps 2006). ◊ Obtain prior approval from the Corps before removing vegetation greater than 4 inches diameter at breast height within the work area strip (Corps 2006). ◊ Keep removed trees on site securely anchored on the beach (Corps 2006).
Piles	
Installation	Material selection: ◊ Replacement or proposed new piling can be steel, concrete, plastic or untreated wood (Corps 2006). ◊ When using existing treated wood pilings, incorporate design features like plastic rub strips or metal bands that minimize contact abrasion to limit the release of toxic chemicals into the environment (Corps 2006), (Poston 2001). Configuration and placement: ◊ Avoid placing pilings closer than 20 feet apart, or otherwise space to limit shading and dissipate wave energy and sediment transport (Corps 2006), (Shafer 2002), (Fresh et al. 1995). Minimizing construction related noise impacts: ◊ Steel pilings cannot exceed a 12-inch diameter for residential docks (Corps 2006), (WSDOT 2006). ◊ Vibratory hammers should be used for pile installation where possible (Corps 2006), (WSDOT 2006). Where impact hammers are necessary: ◊ Limit pile driving to periods when water depth is less than 3 feet (WSDOT 2006). ◊ Use approved sound attenuation devices (e.g., bubble curtains) per Corps of Engineers requirements as follows (Corps 2006): ▪ Piles 10 inches diameter or less, one approved device or measure ▪ Piles >10 to 12 inches diameter, two approved devices or measure
Habitat impact minimization	When piles must be placed in documented surf smelt and/or sand lance habitat (Corps 2006): ◊ Limit the number of piles to the minimum practicable

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
Habitat impact minimization (cont.)	◊ Use piles of 8 inches in diameter or less ◊ Do not use treated wood (Poston 2001)
Removal	Encourage complete removal of treated piles using the following methods of removal in preferred order (WDNR SPM 2005), (Poston 2001): ◊ Complete removal using vibratory extraction. ◊ If the use of vibratory extraction is not feasible, complete removal using puller buncher, choker cables, and/or lift bag extraction. Proponent should be required to demonstrate that use of vibratory extraction is not feasible. ◊ Complete removal by excavating a pit sufficiently large to grasp and extract the piling (potentially contaminated spoils must be disposed of at an approved hazardous waste handling facility; hydraulic jetting, which can suspend and scatter contaminated sediments, should not be permitted). ◊ If complete removal is not feasible, perform partial removal by breaking or cutting the piling at a minimum depth of 2 feet below the surface (sawdust and fragments should be collected and disposed of at an approved hazardous waste handling facility). Proponent should be required to demonstrate that complete removal is not feasible. ◊ Other removal methods evaluated on a case-by-case basis.
Piers and Docks	
Size and configuration	Configuration: ◊ The Corps of Engineers will only authorize linear configurations; finger, "T" or "L" piers are not permitted (Corps 2006), (Fresh et al.2006). ◊ Designs that allow the structure to move with tides (e.g., chained between pilings) are desirable over static structures (Corps 2006). Height: Recommend designing piers and docks for the maximum height practicable to maintain light transmission: ◊ Minimum height of 6 feet over the substrate bed is desirable to maintain light transmission (Nightingale and Simenstad 2001), (Shafer 2002). Length: Limit to the minimum length necessary, consistent with regulatory requirements: ◊ Whatcom County: Private docks up to 40 feet, shared moorage up to 80 feet (under special exceptions, docks up to 60 feet and 100 feet may be approved, respectively, where special conditions apply) (Whatcom SMP). Width: Limit to the minimum necessary consistent with regulatory requirements per jurisdiction: ◊ Corps of Engineers: Up to 6 feet width (Corps 2006), (Shafer 2002). ◊ Whatcom County: Up to 4 feet width, wider piers with functional grating may be allowable (Whatcom SMP). Railing: Limit to 36 inches in height with an open framework (Whatcom SMP).
Deck	Functional grating %: ◊ 30% of area along entire length for N/S oriented pier (338 to 22 north, or 158 to 202 south) greater than 4 feet in width (Fresh et al. 2006). ◊ 50% of area along entire length for NE/SW, NW/SE and E/W oriented piers (23 to 157 east,

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
Deck (cont.)	203 to 337 west) for all piers regardless of width (Fresh et al. 2006).
Ramps	Ramp width: ◊ Must not exceed 4 feet (Corps 2006), (Shafer 2002). Grating: ◊ Use functional grating (i.e., 60% minimum open area) for entire ramp surface (Corps 2006) (Fresh et al.2006).
Floats	
Size and configuration	Configuration: ◊ Use square or rectangular configuration (Corps 2006), (Fresh et al. 2006). Size limitations: ◊ Limit float size to the minimum width necessary as dictated by regulatory limits per jurisdiction. For example: Corps of Engineers: Up to 8 feet width and up to 20 feet length (Corps 2006). Siting: ◊ Do not build the structure in shallow areas such as tidal flats because the structure would need to be very long in order to reach a depth where boats can be moored. Orientation: ◊ Place float with largest dimension oriented north-south to the maximum extent practicable (Corps 2006), (Shafer 2002), (Nightingale and Simenstad 2001), (Fresh et al. 2006).
Design	Deck grating: ◊ Corps of Engineers: Functional grating over 30% of surface for floats up to 6 feet in width, and over 50% of surface for floats from 6 to 8 feet in width (Corps 2006), (Shafer 2002), (Fresh et al.2006). Suspension: ◊ Design float with stoppers or support pilings that keep the bottom of the floats at least 1 foot above the substrate so that the structure will not rest on the bottom (Corps 2006), (Shafer 2002), (Fresh et al.2006). Anchoring: ◊ Corps of Engineers: Limit floatation anchoring to a maximum of four helical screw anchors, piles, piling with stoppers, and/or float support/stub piles (Corps 2006).
Habitat impact minimization	◊ Per Corps of Engineers permitting restrictions, floats, float support piling, and helical anchors cannot be placed in documented Pacific herring, surf smelt and/or sand lance habitat (Corps 2006). ◊ Remove seasonal floats when not in use, ideally between October and April (Fresh et al. 2006).

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.

Regulatory issues	Recommendations
Water Craft Moorage and Lifts	
Permit limitations	Number of structures: ◊ Corps of Engineers permit applicants are limited to one uncovered watercraft grid or lift per single use overwater structure, and two uncovered watercraft grids or lifts per joint use structure (Corps 2006).
Design	Configuration: ◊ Design grid/lift so that the bottom of the grid rests at least 1 foot from the tidal substrate and does not rest on the substrate at any time (Corps 2006), (Shafer 2002), (Fresh et al.2006). Support piling: ◊ Use the minimum number of additional piles necessary to support the watercraft grid/lift (e.g., two additional piles per lift) (Corps 2006). Walls/roofing: ◊ Limit wall materials to the minimum open structural framework needed for roof support to limit shading effects (Whatcom SMP). ◊ Limit roof area to less than 200 square feet and 15 feet height above the ordinary high water mark (OHWM) (Whatcom SMP). ◊ Use translucent roofing materials, or use clear skylights covering at least 50% of roof area (Whatcom SMP).
Habitat protection	◊ Watercraft grids or lifts cannot be placed in documented Pacific herring, surf smelt and/or sand lance habitat (Corps 2006).
Mooring Buoys	
Equipment	Buoy size: ◊ Corps of Engineers: maximum 3- feet in diameter (Corps 2000). Materials: ◊ Hollow plastic, hard plastic-encapsulated styrofoam, aluminum kegs or other approved materials. Anchor: Helix or Manta Ray -style anchors: ◊ Nylon rope or chain and rope combination, with appropriate line "scope" (i.e. length to depth ratio) for location as per U.S. Coast Guard or local boating association guidance (typically 7:1 ratio of line length to depth) (Corps 2000), (Simenstad and Nightingale 2001). ◊ Chain with a mid-line float (no counterweight) that fully suspends the chain off the bottom at all tidal elevations (Simenstad and Nightingale 2001).
Configuration, placement and use	Placement: ◊ Corps of Engineers: Locate buoy so that anchor, buoy and moored vessels will not shade or otherwise impact vegetated shallows (Corps 2000).

Table III.2. Recommendations for construction, design, and operation of overwater structures, buoys, and other forms of watercraft moorage.	
Regulatory issues	**Recommendations**
Configuration, placement and use (cont.)	Vessel size: ◊ Corps of Engineers: Limit vessels using mooring buoys to less than 65 feet total length (Corps 2000) wrong bullet type here, match with above. Density of buoys: ◊ Corps of Engineers: Limit buoys to no more than four per acre (Corps 2000). Moorage limits: ◊ Corps of Engineers: Limit buoy use to 6 months/year or less to extent practicable and avoid use during winter months and stormy weather to avoid dragging anchors across substrate (Corps 2000).

STRATEGIES FOR MITIGATING UNAVOIDABLE IMPACTS

Construction of overwater structures will in many cases result in unavoidable environmental impacts, affecting a range of habitat types and ecological functions. Many of these impacts can be avoided or minimized with proper planning and design, and mitigation for several of the remaining impacts can be applied to compensate for impacts that are unavoidable. It should be recognized, however, that not all impacts can be adequately mitigated. Therefore, serious consideration should be given to denying such projects to avoid losses of habitat functions and continued cumulative impacts. Off site mitigation and restoration projects should also be considered to address unavoidable and cumulative impacts. Suggested impact avoidance and minimization measures, and various mitigation strategies are described in Table III.3.

Table III.3. Mitigation strategies for habitat losses due to development of overwater structures, shoreline armoring, and riparian vegetation management.	
Impact	**Mitigation Strategies**
General	Mitigation should emphasize on-site and in-kind rehabilitation or replacement of degraded habitats and ecological functions to the greatest extent possible. For example, loss of eelgrass habitat should be mitigated by the restoration of degraded eelgrass habitat in the immediate vicinity of the project, or the creation of new habitat. Replacement of lost eelgrass habitat by replanting marine riparian vegetation or by creating macroalgae habitat is not in-kind mitigation and would be inappropriate. Similarly, creation of new marine riparian vegetation in Hood Canal to mitigate for losses occurring on the east side of the Kitsap Peninsula would

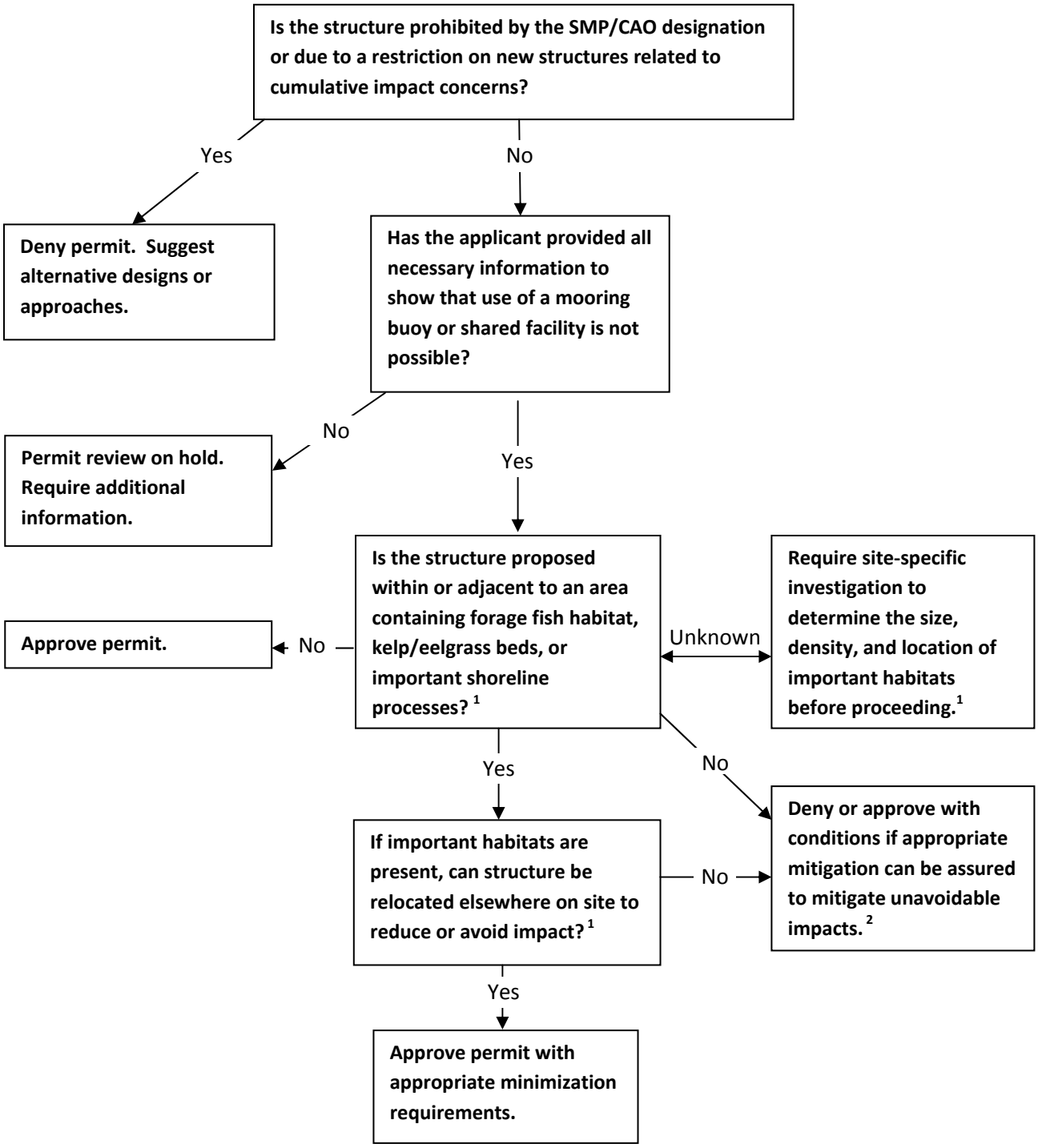
Table III.3. Mitigation strategies for habitat losses due to development of overwater structures, shoreline armoring, and riparian vegetation management.

Impact	Mitigation Strategies
	be considered off-site and thereby inappropriate. In some circumstances, however, off-site mitigation may be desirable and should be allowed, particularly as a way to mitigate for cumulative impacts. Mitigation plans should be developed and implemented by qualified professionals. Planners evaluating mitigation plans should consider the following: ◊ Is the mitigation plan sufficiently detailed to evaluate eventual success (e.g., does it include a plan view of the planting scheme, identify replacement species and methods, provide as built schematics, etc.)? ◊ Does the plan provide sufficient performance criteria and monitoring (a minimum of 5 years for most projects) to establish that mitigation was successful? Have sufficient reporting requirements been established? ◊ Does the mitigation site provide the ecological characteristics necessary to support the desired habitat? ◊ Does the proposed mitigation provide, at minimum, 1 to 1 replacement of the lost habitat area? ◊ Does the plan provide contingencies if performance criteria are not met?
Aquatic vegetation alteration	Impact avoidance and minimization is the most effective means of maintaining aquatic vegetation habitat functions. When unavoidable degradation occurs, mitigation of lost eelgrass and macroalgae habitat can sometimes be achieved by allowing for natural regrowth, or by using transplant methods (Thom et al. 2001). In addition to the general issues identified above, mitigation plans for aquatic vegetation losses should consider the following: ◊ Is there historical/baseline information indicating vegetation presence at the site before the disturbance or development? ◊ Does the proposed mitigation site provide suitable depth, substrate, wave energy, and water quality conditions to support the desired species? ◊ Does the plan provide clear performance criteria for vegetation establishment and survival? ◊ Does the plan include at least five years of monitoring, and contingency provisions if performance criteria are not met?
Riparian vegetation alteration **Riparian vegetation alteration (cont.)**	Disturbed marine riparian vegetation should be replaced with equivalent native species appropriate for the site. Mitigation should provide 100 % replacement of lost vegetation, and provide for an equal amount of vegetative function. The following factors should be considered when replacing lost ecological functions: ◊ Does the affected vegetation overhang the beach or provide organic litter and prey recruitment? ◊ Does the site contain large trees (>4" dbh) that provide shade and potential LWD recruitment? ◊ Would upland runoff from surface streets or residential properties run across exposed bluff areas (i.e., could reduced vegetative filtration negatively impact water quality)? In addition to the general issues identified above, mitigation plans for riparian vegetation alteration should consider the following: ◊ Does the mitigation plan replace the full range of vegetation types that were lost (e.g., trees, shrubs, understory)?

Table III.3. Mitigation strategies for habitat losses due to development of overwater structures, shoreline armoring, and riparian vegetation management.

Impact	Mitigation Strategies
	◊ Will the replaced vegetation provide equivalent functions? o Runoff filtration o LWD, prey and litter recruitment o Shade and microhabitat conditions o Terrestrial habitat functions ◊ Will revegetation occur during the appropriate time of year for the selected species? ◊ Have minimum survival criteria been established for all planting types? ◊ Does the plan include monitoring and maintenance, and contingency provisions if performance criteria are not met? The mitigation plan should provide clear performance criteria for survival of plantings until they are fully established.
Forage fish spawning habitat	Several aspects of mitigation for forage fish habitat are addressed by mitigation for degradation of aquatic vegetation (herring spawning substrate) and riparian vegetation (shade for surf smelt and sand lance spawning beaches). However, any project which results in the loss of suitable spawning substrate for surf smelt and sand lance (i.e., sand and fine gravel substrate high in the intertidal zone), either directly within the project footprint or through effects on sediment recruitment and longshore drift processes, has created an impact that should be mitigated. Mitigation plans for lost beach spawning habitat (e.g., substrate placement) should consider the following: ◊ Is placement of suitable substrate on the beach an adequate approach to mitigating project impacts? ◊ What is the appropriate location for substrate enhancement (on site, off site)? ◊ Does the mitigation site provide suitable wave energy and sediment transport characteristics to maintain the necessary substrate characteristics over time? ◊ Can spawning substrates be maintained at the correct intertidal elevation? ◊ Does the mitigation site provide sufficient spawning area and/or microhabitat characteristics to ensure equivalent spawning productivity?
Unavoidable impacts from approved structures	In certain cases, planners may have to approve overwater structures or shoreline armoring projects to support approved shoreline uses or to protect property, infrastructure, or public safety. In cases where these activities cause unavoidable degradation, appropriate mitigation may include the removal of an existing structure or structures followed by site restoration sufficient to replace lost habitats and ecological functions. These types of mitigation activities are complex and qualified professionals should develop the related plans.

Figure III.1. Recommended Review Steps for Overwater Structures.



1 See design and impact avoidance recommendations, Table III.2
2 See mitigation recommendations, Table III.3

SHORELINE ARMORING

HOW DOES SHORELINE ARMORING IMPACT THE SHORELINE?

Riprap, retaining walls (i.e., bulkheads), and other forms of shoreline armoring structures can have a number of adverse impacts on the marine shoreline environment. The adverse effects of these structures can occur through a variety of mechanisms that have been well documented. These adverse effects are particularly evident in areas where these structures have been constructed below the OHW elevation.

The construction of these types of structures promotes loss of terrestrial, shallow-water, and benthic habitat. The physical disturbance and damage to fish and wildlife habitat caused by the construction of bulkheads can vary, and is dependent on several factors including:

- ◊ type of habitat present prior to construction;
- ◊ location and elevation of the structure on the shoreline;
- ◊ size and configuration of the structure;
- ◊ construction methods used to create it;
- ◊ geomorphic setting;
- ◊ exposure and orientation to waves, and;
- ◊ erosion rates.

The construction of bulkheads and associated activities also cause local erosion, new sediment deposits in the vicinity of the structure, turbidity, and hence water quality degradation. New sediment deposits are often silty and thus can degrade forage fish spawning areas, smother benthic organisms and vegetation, and reduce bottom habitat diversity

Bulkheads promote erosion of the foreshore because waves can reflect off the face of these structures with sufficient energy to transport fine sediments along the shoreline or offshore. This erosion can be severe in many cases, leading to downcutting (lowering) of the beach and the eventual loss of the higher elevation portion of the intertidal zone. Downcutting may eventually undermine the bulkhead itself, leading to its eventual failure. Bulkheads can

also interfere with the recruitment of sediment from bluffs and the transport of sediment within drift cells, starving adjacent beaches of sediment. These two mechanisms can lead to the gradual loss of fine sediments in the nearshore environment and lowering of the beach profile, leading to a loss of shallow water habitat. The recent development of "soft" erosion protection techniques, such as vegetated berms and natural wood structures designed to emulate natural drift wood accumulations are preferable to vertical bulkheads because they effectively attenuate wave energy and reduce beach erosion. But even soft structures can reduce sediment recruitment by limiting feeder bluff erosion. Over time, decreased inputs of sand and gravel size sediment within an active drift cell can result in coarsening of nearshore substrate, potentially degrading forage fish spawning habitat.

There are several additional mechanisms through which shoreline armoring can impact the nearshore environment, and they can be complex in nature. Many of these impacts can be minimized through proper design, but they cannot be avoided entirely. As with overwater structures, the cumulative impacts from multiple shoreline armoring projects are potentially significant. Where extensive shoreline armoring has resulted in significant cumulative impacts, it may be difficult or impossible to maintain desirable ecological functions. These factors must be considered when reviewing proposed projects, and when developing mitigation requirements.

Table III.4 provides a summary of the impacts from shoreline armoring and some of the habitats that may be affected. Additional discussion of the environmental impacts on these components is provided in Section II.

Table III.4. Impacts from shoreline armoring and the natural functions that may be affected.

Impact	Supporting Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Direct and Indirect						
Short-term site preparation and construction activities)						
Increased turbidity and possible release of pollutants ◊ Reduced light and photosynthesis ◊ Fine sediment deposition/substrate change ◊ Possible spills from construction equipment, aquatic habitat and species exposure ◊ Noise and activity related disturbance, avoidance by fish and other aquatic life	(Norris et al. 1997), (Williams and Thom 2001)	X		X		X
Beach disruption from equipment access, materials staging and placement, etc ◊ Avoidance by fish and other aquatic life ◊ Loss of fish eggs and other substrate dependent life ◊ Vegetation loss	(Kelty and Bliven 2003), (Williams and Thom 2001)	X	X	X	X	X

Table III.4. Impacts from shoreline armoring and the natural functions that may be affected.

Impact	Supporting Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Long-term (ongoing impacts from permanent features)						
Morphologic alteration of shoreline ◊ Changes in wave energy and longshore drift patterns ◊ Change in beach profile ◊ Direct burial of the upper beach	(MacDonald et al. 1994), (Williams and Thom 2001)	X	X	X	X	X
Substrate alteration (sediment/wood) ◊ Coarsening of substrate (vertical bulkheads) ◊ Accumulation of fines (jetties or other structures that block longshore drift) ◊ Loss of sediment supply on downdrift side of jetties and groins	(Erstad 2006), (MacDonald et al. 1994), (Williams and Thom 2001), (Mulvihill et al. 1980), (Herrara 2005)	X	X	X		X
Aquatic vegetation alteration ◊ Loss of substrate cohesion ◊ Loss of fine substrate recruitment, coarsening of substrate, and change in beach profile ◊ Loss of habitat complexity ◊ Shifts in vegetation community types	(Erstad 2006), (MacDonald et al. 1994), (Williams and Thom 2001), (Williams and Thom 2001), (Mulvihill et al. 1980)	X		X		X
Riparian vegetation alteration	See Table III.6	X	X		X	X

Table III.4. Impacts from shoreline armoring and the natural functions that may be affected.

Impact	Supporting Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
◊ Removal of riparian vegetation within structure footprint						
Cumulative						
Change in wave energy and longshore drift patterns, resulting in changes to upper intertidal sediment characteristics	(Williams and Thom 2001)	X	X	X	X	X
Reduced nearshore habitat suitability for juvenile salmonids	(Redman et al. 2005), (Fresh 2006), (Williams and Thom 2001)		X			X

REGULATING SHORELINE ARMORING ACTIVITIES

As described above, shoreline armoring projects will often produce unavoidable adverse impacts, and numerous, small, incremental impacts can produce significant cumulative effects over time. Therefore, a logical first step toward meeting the SMAs "no net loss" mandate is to avoid permitting new shoreline armoring, in cases where it is not necessary. In many cases a structural approach may not be necessary for property or infrastructure protection, and may cause unacceptable environmental impacts. In such cases, alternative means of achieving the desired goal should be recommended. Where shoreline armoring is necessary for erosion control, planners should enforce or encourage the use of alternative design methods that avoid and minimize environmental impacts to the greatest extent possible, and require that unavoidable impacts be fully mitigated. Planners should consider whether the source of the erosion is from a feeder bluff, supplying sediment to downdrift beaches. During SMP development, planners should require that traditional, hard armoring be placed landward of the OHWM elevation, except in special circumstances where this may not be possible. Planners should also consider the future impact of sea level rise on the OHWM when developing SMP regulations.

Recently released SMPs incorporate guidance for protecting habitat from loss through shoreline armoring. For example, the draft Whatcom County SMP includes the following language pertinent to regulating the development of shoreline stabilization structures (Section 23.100.13): (Whatcom SMP)

a. Alternatives to structures for shore protection should be used whenever possible. Such alternatives may include; no action (allow the shoreline to retreat naturally), increased building setbacks, building relocation, drainage controls, and bioengineering, including vegetative stabilization, and beach nourishment.

b. New or expanded structural shore stabilization for new primary structures should be avoided. Instead, structures should be located and designed to avoid the need for future shoreline stabilization where feasible. Land subdivisions should be designed to assure that future development of the created lots will not require structural shore stabilization for reasonable development to occur.

c. New or expanded structural shore stabilization should only be permitted where demonstrated to be necessary to protect an existing primary structure

that is in danger of loss or substantial damage, and where mitigation of impacts would not cause a net loss of shoreline ecological functions and processes.

d. New or expanded structural shore stabilization for enhancement, restoration, or hazardous substance remediation projects should only be allowed when non-structural measures, vegetation planting, or on-site drainage improvements would be insufficient to achieve enhancement, restoration or remediation objectives.

e. Shore stabilization should be developed in a coordinated manner among affected property owners and public agencies for a whole drift sector (net shore-drift cell) or reach where feasible, particularly those that cross jurisdictional boundaries, to address ecological and geo-hydraulic processes, sediment conveyance and beach management issues. Where beach erosion threatens existing development, a comprehensive program for shoreline management should be established.

f. In addition to conformance with the regulations in this section, non-regulatory methods to protect, enhance, and restore shoreline ecological functions and other shoreline resources should be encouraged for shore stabilization. Non-regulatory methods may include public facility and resource planning, technical assistance, education, voluntary enhancement and restoration projects, or other incentive programs.

g. Shore stabilization should be located, designed, and maintained to protect and maintain shoreline ecological functions, ongoing shore processes, and the integrity of shore features. Ongoing stream, lake or marine processes and the probable effects of proposed shore stabilization on other properties and shore features should be considered. Shore stabilization should not be developed for the purpose of filling shorelines.

h. Failing, harmful, unnecessary, or ineffective structures should be removed, and shoreline ecological functions and processes should be restored using non-structural methods or less harmful long-term stabilization measures.

i. Structural shoreline stabilization measures should only be used when more natural, flexible, non-structural methods such as vegetative stabilization,

beach nourishment and bioengineering have been determined infeasible. Alternatives for shoreline stabilization should be based on the following hierarchy of preference:

1) No action (allow the shoreline to retreat naturally), increase building setbacks, and relocate structures.

2) Flexible defense works[4] constructed of natural materials including soft shore protection, bioengineering, including beach nourishment, protective berms, or vegetative stabilization.

3) Rigid works [structures] constructed of artificial materials such as riprap or concrete. Materials used for construction of shoreline stabilization should be selected for long-term durability, ease of maintenance, compatibility with local shore features, including aesthetic values and flexibility for future uses.

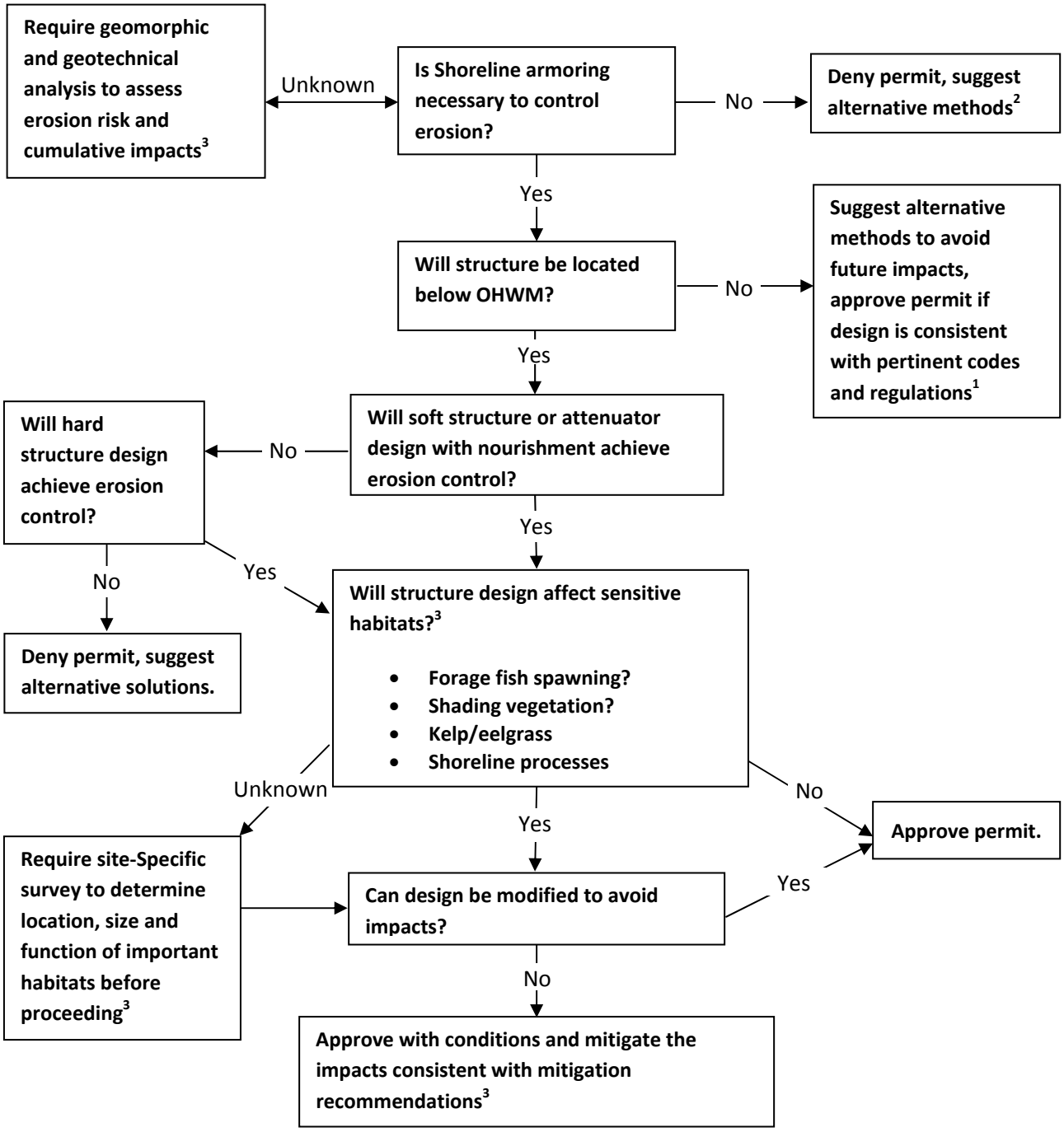
4) Larger works such as jetties, breakwaters, weirs or groin systems should be permitted only for water-dependent uses when the benefits to the region outweigh resource losses from such works, and only where mitigated to provide no net loss of shoreline ecological functions and processes.

5) Alternative structures, including floating, portable or submerged breakwater structures, or several smaller discontinuous structures, should be considered where physical conditions make such alternatives with less impact feasible.

The following decision tree tool is consistent with these directives. It provides guidance for determining whether a proposed activity is necessary to protect property and infrastructure, describes design recommendations for avoiding and minimizing ecological impacts, and discusses the need for environmental mitigation. The decision tree is linked by reference to design standards and other recommendations for impact avoidance and mitigation provided in the following sections.

[4] E.g.; bulkheads or other shoreline armoring.

Figure III.2. Recommended Review Steps for Shoreline Armoring Projects.



1 Suggest using alternative methods such as soft shore or wave attenuator designs, unless the structure is also intended to provide foundation support or some other function subject to separate design codes and regulations
2 See design and impact avoidance recommendations, Table III.4
3 See mitigation recommendations, Table III.5

How to Minimize Impacts of Shoreline Armoring

Currently there is little explicit guidance on which type of shoreline armoring is "best" in any given situation. Recent research has shown the value of "soft shore" designs that deform naturally and attenuate wave energy, in comparison to hard vertical structures that cause fragmentation of the intertidal environment. Attenuator designs, which incorporate features like large rock and/or logs that dissipate wave energy, are also preferable to hard vertical bulkheads in many cases. However, these designs require a larger area of beach and may not be suitable in cases where the construction footprint would displace sensitive habitats. As a general rule, planners should require project applicants to provide the site-specific surveys and information necessary to determine the most appropriate design to lessen impacts. This information should be produced by qualified experts, and should be used as a basis for design and for identifying mitigation requirements. Design guidance recommendations and survey requirements are presented in Table III.5.

Table III.5. Recommendations for design and construction of shoreline armoring structures.

Regulatory issues	Recommendations
Need for erosion control	Has geomorphic/geotechnical analysis established that shoreline armoring is needed for erosion control? No - Use alternative methods where hardened structures are not necessary to achieve erosion control Yes – Evaluate shoreline armoring design using criteria listed below
Design to avoid/minimize impact	Use alternatives to hard vertical structures wherever possible. Consider the following design approaches in descending order of preference (Williams and Thom 2001): Non-structural alternatives: Alternative methods applicable for areas where shoreline armoring is not necessary to achieve erosion control or provide property/infrastructure protection. Pros: Relatively minimal environmental impacts on the shoreline environment Cons: Applicable only in limited circumstances Examples include: ◊ Building setbacks: Require placement of new homes or other structures at a safe distance from erodable bluffs or shorelines to reduce/eliminate the need for shoreline armoring. ◊ Surface and groundwater drainage management (where applicable) (Ecology 2007a): o Direct surface drainage to the toe of bluff slopes as appropriate, design discharge to avoid point erosion. o Limit excessive irrigation or other sources of excessive runoff and/or infiltration. o Direct sanitary drain fields away from bluffs to the greatest extent possible. ◊ Improve vegetation management (where applicable): Encourage growth/regrowth of site appropriate native vegetation to increase shoreline stability (Ecology 2007b), (Ecology 1993).

Table III.5. Recommendations for design and construction of shoreline armoring structures.

Regulatory issues	Recommendations
Design to avoid/minimize impact (cont.)	Soft shore designs: Shoreline armoring that relies on natural materials in configurations that deform and adjust over time. A more desirable method for providing erosion protection where sufficient footprint area is available without damaging sensitive habitats (Williams and Thom 2001), (Johannesen 2001), (Gerstel and Brown 2006), (Shipman 2001), (Zelo et al. 2000). Pros: Provide erosion protection while minimizing ecological impacts. Cons: Require larger footprints than hard vertical structures leading to more extensive construction impacts and permanent habitat modification (therefore less desirable if sensitive habitats will be impacted). Require ongoing maintenance to maintain function (e.g., replacement of eroded beach nourishment, vegetation management). Examples include: ◊ Anchoring of untreated logs and large woody material to the shoreline to mimic the natural accumulation of downed and drift wood. ◊ Biotechnical approaches using the root cohesion provided by native vegetation to stabilize shorelines. ◊ Beach nourishment with sand and gravel substrates. ◊ Combinations of the above designs. Bulkheads, Seawalls and Revetments: Hard structures placed at the toe of bluff slopes or erodable shorelines to deflect wave energy. In general, these are less desirable design options that should only be permitted where erosion protection is absolutely essential and other methods are not applicable. Structures must be designed to allow groundwater drainage to prevent saturation induced slope failures (Gerstel et al. 1997), (Williams and Thom 2001), (Gerstel and Brown 2006), (Erstad 2006). Pros: Relatively small footprint limits construction impacts and immediate loss of intertidal habitats. Effective erosion protection in high wave energy settings with limited available space for project footprint. Cons: Hard vertical structures fragment the beach from sediment source areas. Reflected wave energy transports fine substrates offshore, causing a change in intertidal elevation in front of the structure and armoring of the nearshore substrate. Examples include: ◊ Concrete bulkheads ◊ Vertical log or pile bulkheads ◊ Rock bulkheads/seawalls (vertical and sloping) Jetties and groins: Hard structures placed perpendicular to the shoreline to trap sediments and create wave shadows protected from storm energy. Pros: None obvious. Cons: Depending on configuration, these types of structures can effectively block or alter longshore transport of sediments along the shoreline. This leads to sediment starvation on the downdrift side of the structure over time, coarsening of substrates, and alteration of beach profile and habitat structure. Jetties also alter circulation patterns, affecting water quality in the project vicinity. Examples include: Riprap jetties and groins
Equipment operation	Site access: ◊ Operate equipment from the top of the bank, a temporary work platform, barge or similar out-of-water location to the maximum extent practicable to avoid beach impacts (Corps 2006).

Table III.5. Recommendations for design and construction of shoreline armoring structures.

Regulatory issues	Recommendations
	◊ Where equipment use on the beach is required, confine the project to a single access point with a 12 foot wide work corridor on the seaward side of the structure (Corps 2006). Barges: ◊ When using barges, do not ground on the substrate at any time (Corps 2006). Water quality: ◊ Operate equipment in a manner that minimizes suspended particulates entering the water (Corps 2006).
Survey requirements for impact avoidance	Geomorphic/geotechnical analysis (Erstad 2006): ◊ Require surveys/analyses of beach geomorphology and geotechnical conditions (slope stability) for all shoreline armoring projects. These analyses are critical for determining the causes of shoreline erosion and the potential need for shoreline armoring to control this erosion, and provide critical information for selecting the most appropriate design for a site. Eelgrass/macroalgae (Erstad 2006): ◊ Require surveys for all new and replacement construction to support environmental design. ◊ Select design footprint that avoids or minimizes eelgrass impacts. ◊ Require post-construction monitoring of vegetation for up to 10 years to investigate potential project impacts. Surf smelt/sand lance habitat (Erstad 2006), (Penttila 2007): ◊ Select design that limits short-term and long-term impacts on beach profile and substrate characteristics in documented or potential forage fish spawning areas. ◊ Avoid removal of riparian vegetation that provides shade or overhanging cover for forage fish spawning beds. ◊ If the project site contains documented surf smelt and/or sand lance habitat and there is no approved in-water work window for the site, obtain confirmation in writing from a WDFW certified biologist that these species are not spawning in the area when construction occurs. Once certification has been obtained, the permittee has 48 hours from the date of the inspection to begin and two weeks to complete all construction activities in contact with the substrate waterward of OHW.
Site restoration	Substrate disturbance: ◊ Immediately restore depressions or trenches in beach substrate created by construction equipment waterward of OHW to pre-project conditions (e.g., elevation and substrate material type). ◊ Where beach hardpan or clay is exposed by construction activities, restore to pre-project conditions immediately upon completion of construction (e.g., elevation and substrate material type) (Corps 2006). Vegetation disturbance: ◊ Develop a planting plan that provides for the replacement of disturbed vegetation with equivalent site-appropriate native species (Corps 2006). ◊ Do not remove existing habitat features (e.g., logs, aquatic vegetation) from the aquatic environment (Corps 2006). ◊ Limit disturbance of bank vegetation to as small a work area as practicable (Corps 2006). ◊ Obtain prior approval from the Corps before removing vegetation greater than 4 inches diameter at breast height within the work area (Corps 2006).

Table III.5. Recommendations for design and construction of shoreline armoring structures.

Regulatory issues	Recommendations
Site restoration (cont.)	◊ Anchor removed trees to the beach onsite (Corps 2006).
Removal and/or replacement	Replacement structures: Permitting approval for replacement structures should consider the following recommendations (Penttila 2007): ◊ Replacement structures for shoreline armoring should be placed landward of existing structures. ◊ Existing structures should be completely removed. ◊ Emphasize replacement of existing hard structures with soft shore designs. Removal of treated pile revetments: Encourage complete removal of treated piles using the following methods of removal in preferred order (WDNR SPM 2005) (Poston 2001): ◊ Complete removal using vibratory extraction (first priority). ◊ Complete removal using puller buncher, choker cables, and/or lift bag extraction. ◊ Complete removal by excavating a pit sufficiently large to grasp and extract the piling (potentially contaminated spoils must be disposed of at an approved hazardous waste handling facility; hydraulic jetting, which can suspend and scatter contaminated sediments, should not be permitted). ◊ Partial removal by breaking or cutting the piling at a minimum depth of 2 feet below the surface (sawdust and fragments should be collected and disposed of at an approved hazardous waste handling facility). ◊ Other removal methods evaluated on a case by case basis.

STRATEGIES FOR MITIGATING UNAVOIDABLE IMPACTS

Where shoreline-armoring activities are determined to be necessary and will result in unavoidable adverse impacts, project applicants should be required to develop a mitigation plan. The mitigation plan should compensate for the types of habitats impacted and the ecological processes that have been affected. The same survey data and planning information used to avoid and minimize impacts should be used to assess the nature and extent of unavoidable habitat impacts. Off site mitigation and restoration projects should also be considered to address unavoidable and cumulative impacts. Mitigation strategies for potentially affected habitat types are described in Table III.3.

RIPARIAN VEGETATION ALTERATION

HOW DOES MARINE RIPARIAN VEGETATION ALTERATION IMPACT THE SHORELINE?

Marine riparian vegetation plays a number of important roles in the nearshore environment, including providing habitat structure, shade, and cover for intertidal habitats; fish prey; large wood and organic debris recruitment; habitat for numerous riparian dependent species; and corridors for wildlife movement and migration. Riparian vegetation also provides a number of well-documented ecological benefits, including the filtering of surface water runoff and associated sediments, nutrients and other pollutants, and providing soil stability and stabilization of erosion prone bluffs and shorelines. Removal or modification of riparian vegetation can result in both short and long-term impacts on nearshore processes. These impacts are summarized in Table III.6.

Table III.6. Impacts from marine riparian alterations and the natural functions that may be affected.

Impact	Supporting Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Short-term (site preparation and construction activities)						
Increased turbidity and possibly release of pollutants ◊ Reduced light and photosynthesis ◊ Deposition of fine sediment /substrate change ◊ Increased contaminant levels in the water ◊ Avoidance by fish and other aquatic life	(Desbonnet et al. 1994), (Brennan and Culverwell 2004), (Lemieux et al. 2004)	X		X	X	
Disruption of beach from tree felling, anchoring on beach, etc ◊ Avoidance by fish and other aquatic life ◊ Loss of fish eggs and other substrate dependent life	(Williams and Thom 2001)	X			X	X
Long-term (ongoing impacts from permanent features)						
Vegetation clearing ◊ Loss of soil cohesion, increased erosion, related turbidity	(Penttila 2007), (Penttila 2001), (Ecology 2007b), (Ecology 1993), (Lemieux et al. 2004), (Brennan and Culverwell 2004), (Romanuk and Levings 2006)	X	X	X	X	X

Table III.6. Impacts from marine riparian alterations and the natural functions that may be affected.

Impact	Supporting Studies	Forage fish habitat	Beaches and bluffs	Kelp and eelgrass beds	Marine riparian vegetation	Juvenile salmon nearshore habitat
Vegetation clearing (cont.) ◊ Loss of organic debris and large woody debris recruitment ◊ Increased surface runoff and turbidity ◊ Loss of fish habitat						
Alteration of microhabitat conditions ◊ Increased temperature ◊ Decreased humidity ◊ Increased solar exposure	(Rice 2006), (Penttila 2001), (Penttila 2007)	X		X	X	X
Loss of slope stability ◊ Increased landslide risk	(Gerstel et al. 1997)	X	X		X	
Loss of food source for fish	(Brennan and Culverwell 2004), (Sobocinski et al. 2004), (Romanuk and Levings 2006)	X			X	X

PROTECTING MARINE RIPARIAN VEGETATION

Many impacts associated with alterations to marine riparian vegetation can be avoided or minimized through careful planning (e.g., applying appropriate shoreline environment designations and use standards), and some lost habitat functions can be recovered through mitigation or restoration actions. However, even with these measures, the removal or substantial modification of riparian vegetation is likely to result in the temporal loss of some level of habitat function. This is particularly true at restoration or mitigation sites before vegetation can (re)grow to the point where it provides a full suite of ecological functions. Consequently, permitting multiple vegetation alteration or clearing activities within a given area will result in incremental cumulative effects that may increase over time. Therefore, it is important that planners and regulators establish clear, protective standards, and work with project applicants to avoid and minimize adverse impacts to the greatest extent possible.

MARINE RIPARIAN PROTECTED AREAS

Establishing "marine riparian protection areas" is an important regulatory mechanism that can help minimize the impact of development and re-development and trigger mitigation sequencing when projects impact riparian vegetation. Marine riparian protected areas are different from buffers and may be applied in different circumstances. The term "buffer" is typically used to denote a border set aside and managed to protect a relatively sensitive area from the effects of surrounding land-use or human activities. Buffers may work best when applied to undeveloped or partially undeveloped areas (e.g., where homes or other human activities uses are already set sufficiently back from the shoreline).

On more developed shorelines, or shorelines designated for future development under the SMP, buffers become less effective as the sole mechanism to protect the nearshore, and other strategies need to be employed to protect functions . Placing buffers on the landscape can create situations where existing landowners become immediately noncompliant, which often results in local resistance to the whole idea of regulation. Local ordinances provide variances and exemptions to deal with noncompliance but this is often done without considering impacts to marine riparian vegetation functions. Further, these exemptions often exclude enhancement (e.g., replanting denuded areas with native vegetation) or mitigation that implements the local shoreline restoration plan. The result is ongoing, incremental degradation of

the nearshore, even though buffers have been "theoretically" applied.

Marine riparian protected areas, however, can be effectively applied as a regulatory overlay even on developed shorelines. Buffers have a role to play within these protected areas, but are not the only mechanism to protect marine riparian functions. A variety of location-appropriate habitat protection regulations can be implemented, including function- and area-specific buffers, structural setbacks, riparian enhancement requirements (e.g., native vegetation replanting) and on-site or off-site mitigation requirements triggered when those areas redevelop, expand, or intensify over time. Landscape-based planning (e.g., the shoreline inventory and analysis component of an SMP) should dictate what protections are triggered within the marine riparian protected area overlay. For example, off-site mitigation can be linked to the SMP restoration plan. Variances and exemptions should be limited and tied to mitigation and enhancement, including implementation of the restoration plan.

RECOMMENDED WIDTHS FOR PROTECTED AREAS AND BUFFERS

Most of the current science on riparian management areas and buffers comes from studies of freshwater systems. Attention to marine riparian processes and functions has only emerged in the literature during the past decade, and research in this area is increasing (WDFW 2009). However, where the freshwater riparian area function is similar to functions in the marine system (e.g., large woody debris recruitment, shade, nesting and migration habitat for wildlife) these studies are appropriate to apply to planning and regulatory decisions and reflect BAS.

Because much of the literature is related to freshwater riparian systems, an interdisciplinary science panel was assembled to inform the process of adapting fresh water studies to marine nearshore environments for the white paper, Protection of Marine Riparian Habitat Functions in Puget Sound, Washington. The consensus of the science panel is that freshwater riparian buffer research as generally depicted in Table III.7 is applicable to the marine environment. This is supported by a number of publications (e.g. Desbonnet et al. 1994, 1995; NRC 1996; NRC 2002; Brennan and Culverwell 2004) that find riparian areas provide ecological functions regardless of whether they are adjacent to freshwater or marine water bodies.

There is no consensus in the literature recommending a single vegetated buffer width to protect a particular function or to protect all functions. Table III.7

summarizes recent findings from work in the freshwater and marine environment on the relationship of habitat functions to buffer widths based on the literature review and science panel findings in Protection of Marine Riparian Habitat Functions in Puget Sound, Washington. The narrowest and widest buffer widths recommended in the literature that achieved a minimum of 80% effectiveness for that function are summarized. The description of effectiveness at the 80% level does not imply a recommendation for adopting that level of effectiveness, however, this was used because most of the studies could be summarized at this level.

In applying buffers as part of a marine riparian habitat protection strategy, shoreline managers should consider what functions need protection in their shoreline areas (based on existing or anticipated threats), what level of protection is appropriate for those functions, how the protective goals of using a buffer can actually be achieved on the land given existing and planned development, and what functions will *not* be protected by choosing particular buffer widths. The science summarized in Table III.7 provides the information and context for these decisions. It does not dictate a single approach. Protection of Marine Riparian Habitat Functions in Puget Sound, Washington provides function curve tables depicting what level of protection is being achieved, or lost, based what buffer width is chosen for different marine riparian area functions. This is useful information for decision-makers and citizens, as well as planners, to understand the implications of policy choices around buffers that are established at the local level.

Table III.7. Marine riparian buffer functions and width recommendations identified in the literature (WDFW 2009)[5].

Riparian function	Range of buffer widths (feet) to achieve ≥ 80% effectiveness[6]	Literature cited	Average of all literature (to achieve ≥ 80% effectiveness)	Minimum buffer width (approximate) based on FEMAT curve to achieve ≥ 80% effectiveness
Water quality	5-600 m (16 – 1,968 ft)[7]	5 m (16 ft): Schooner and Williard (2003) for 98% removal of nitrate in a pine forest buffer 600 m (1969 ft): Desbonnet et al (1994/1995) for 99% removal	109 m (358 ft)	25 m (82 ft) sediment 60 m (197 ft) TSS 60 m (197 ft) nitrogen 85 m (279 ft) phosphorus
Fine sediment control	25-91 m (92 – 299 ft)	25 m (82 ft): Desbonnet et al (1994/1995) for 80% removal 91 m (299 ft): Pentec Environmental (2001) for 80% removal	58 m (190 ft)	25 m (82 ft) (sediment) 60 m (197 ft) (TSS)
Shade	17-38 m (56 – 125 ft)	17 m (56 ft): Belt et al 1992 *IN* Eastern Canada Soil and Water Conservation Centre (2002) for 90% 38 m (125 ft): Christensen (2000) for 80% temperature moderation	24 m (79 ft)	37 m (121 ft) (.6 SPTH*)
LWD	10-100 m (33 – 328 ft)	10 m (33 ft): Christensen (2000) for 80-90% effectiveness 100 m (328 ft): Christensen (2000) for 80-90% effectiveness	55 m (180 ft)	40 m (131 ft) (.65 SPTH*)
Wildlife	73-275 m (240 – 902 ft)	73 m (240 ft): Goates (2006) for 90% of hibernation and nesting 275 m (902 ft): Burke and Gibbons 1995 *IN* Goates 2006 for 100% of hibernation and nesting	174 m (571 ft)	N/A

[5] Table III-7 is a direct copy of Appendix G in Protection of Marine Riparian Functions in Puget Sound, Washington (WDFW 2009).
[6] The description of effectiveness at the 80% level does not imply a recommendation for adopting that level of effectiveness. This value of effectiveness is reported because most of the studies could be summarized at this level. Please see the function curves provided in Protection of Marine Riparian Functions in Puget Sound, Washington (WDFW 2009) for more information about function related to level of effectiveness.
[7] Appendix C in Protection of Marine Riparian Functions in Puget Sound, Washington (WDFW 2009) contains specific buffer widths for different water quality parameters.

Variable width buffer approaches are used in many jurisdictions to account for site-specific conditions, and are also discussed in the literature (Forman 1995). Variable width buffers can allow for greater flexibility, account for variation in site conditions and land management practices, and potentially achieve desired ecological goals while minimizing undue losses to landowners.Levings and Jamieson (2001) proposed the use of an interim measure consisting of site-specific buffer zones to protect nearshore ecological functions such as food production, temperature regulation, wave energy absorption, and provision of structure as well as indirect ecological value.

When applied properly, variable width buffers can be more ecologically sound because they have the potential to reflect the true complexity of the environment and management goals (Haberstock et al. 2000; IMST 2002). However, there are no generally accepted criteria for the establishment of variable width buffers. To ensure no net loss of function, variable buffers must be closely linked to the shoreline inventory and an analysis so that the most important shoreline processes and habitat areas receive the greatest protection via buffers. Where buffers will be smaller, other enhancements may be necessary to avoid cumulative loss of function. Monitoring over time is recommended to track whether variable width buffers are achieving protection goals across the landscape.

There is consensus in the literature that buffers or protected riparian areas are critical to sustaining many ecological functions. A precautionary approach toward regulating tmarine riparian habitat areas is recommended. A precautionary approach would rely on using the high end of the ranges required to protect specific functions, where those widths are achievable. Where there is opportunity (e.g., in areas of undeveloped or low-density shorelines with high habitat value), maximum protection will help compensate for unavoidable and cumulative impacts from development and redevelopment elsewhere in the landscape.

CONSISTENCY WITH OTHER REGULATIONS

Planners should ensure that the SMP standards for protecting marine riparian vegetation link to other regulatory mechanisms. For example, the Growth Management Act requires protection of the following types of critical areas that are pertinent to the management of the marine riparian zone:

- Landslide hazard zones

- Steep slope/erosion hazard zones
- Fish and wildlife habitat conservation areas, including:
  - Kelp and eelgrass beds
  - Commercial and recreational shellfish beds
  - Herring, sand lance, and surf smelt spawning areas
  - Endangered, threatened, and sensitive species
  - Locally important habitats and species (e.g., Great blue heron rookeries)
- Wetlands

Plans to modify vegetation should be supported by appropriate surveys and assessments. It is important to consider the types of habitat areas and hazard zones that could be affected by an activity, and to prevent activities that would be destructive of marine riparian habitat in high priority areas, and minimize the impacts of otherwise allowed activities in or near the marine riparian area. Evolving SMPs have recognized the importance of these habitats and incorporate guidance for protecting these habitats. For example, the Whatcom County SMP includes the following language pertinent to regulating marine riparian vegetation (Whatcom County 2007).

Under the section on policies for Vegetation Conservation (section 23.90.06.A):

1. Where new developments and/or uses are proposed, native shoreline vegetation should be conserved to maintain shoreline ecological functions and/or processes and mitigate the direct, indirect and/or cumulative impacts of shoreline development, wherever feasible. Important functions of shoreline vegetation include, but are not limited to:

   a) Providing shade necessary to maintain water temperatures required by salmonids, forage fish, and other aquatic biota.

   b) Regulating microclimate in riparian and nearshore areas.

   c) Providing organic inputs necessary for aquatic life, including providing food in the form of various insects and other benthic macroinvertebrates.

   d) Stabilizing banks, minimizing erosion and sedimentation, and reducing the occurrence/severity of landslides.

   e) Reducing fine sediment input into the aquatic environment by minimizing erosion, aiding infiltration, and retaining runoff.

f) Improving water quality through filtration and vegetative uptake of nutrients and pollutants.

g) Providing a source of large woody debris to moderate flows, create hydraulic roughness, form pools, and increase aquatic diversity for salmonids and other species. Providing habitat for wildlife, including connectivity for travel and migration corridors.

Under the section on Location and Design of new residential development (section 23.100.11.B.1 in part):

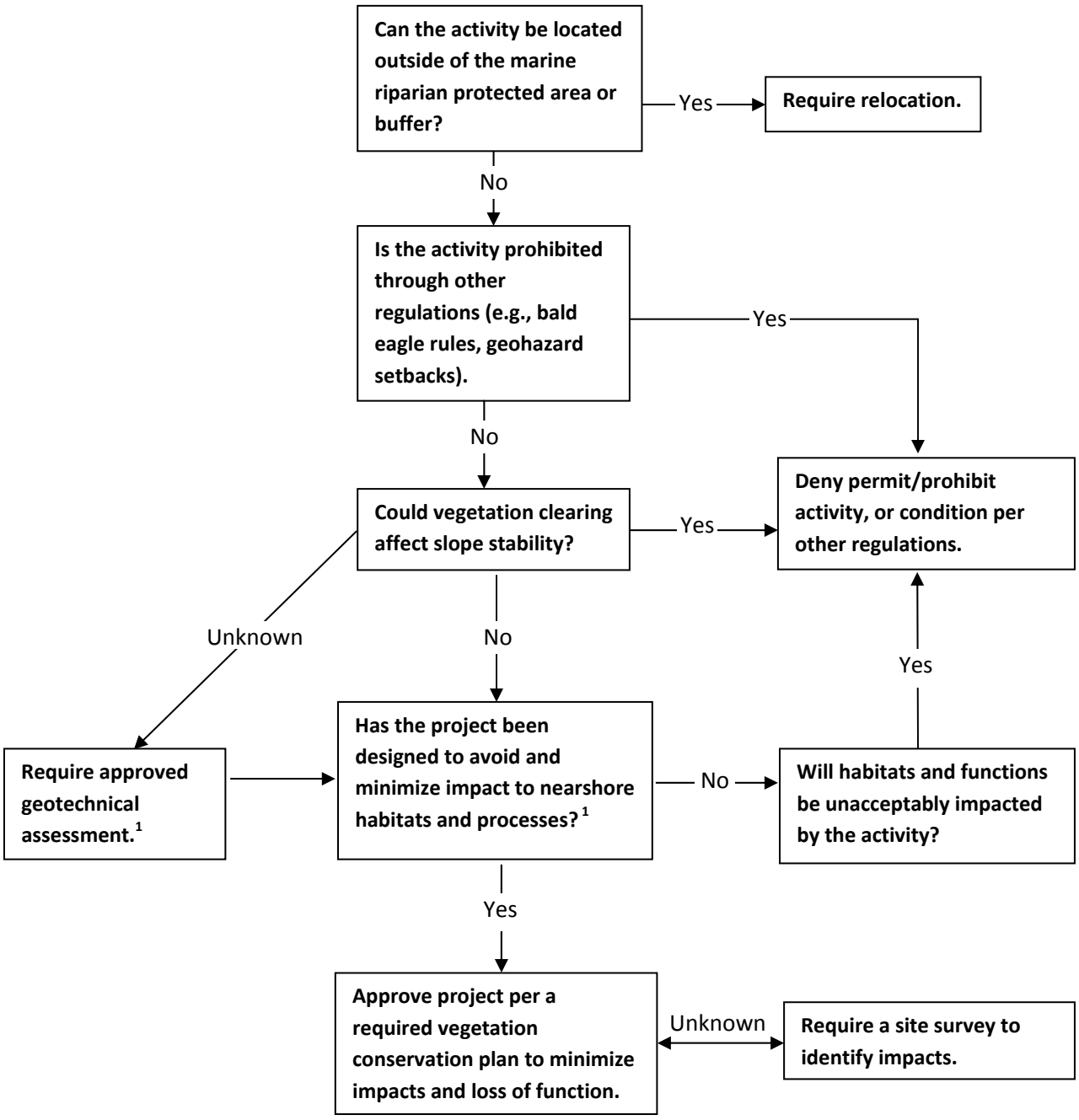
b) New residential development shall assure that the development will not require shoreline stabilization. Prior to approval, geotechnical analysis of the site and shoreline characteristics shall demonstrate that shoreline stabilization is unlikely to be necessary during the life of the structure; setbacks from steep slopes, bluffs, landslide hazard areas, seismic hazard areas, riparian and marine shoreline erosion areas shall be sufficient to protect structures during the life of the structure (100 years); and impacts to adjacent, downslope or down current properties are not likely to occur.

c) All new subdivisions shall provide for vegetation conservation to mitigate cumulative impacts of intensification of use within or adjacent to the shoreline that shall include compliance with vegetation conservation requirements of SMP 23.90.06, together with replanting and control of invasive species within setbacks and open space to assure establishment and continuation of a vegetation community characteristic of a native climax community.

REVIEWING PROJECTS THAT AFFECT MARINE RIPARIAN VEGETATION

The following decision tree provides guidance for regulating riparian vegetation that is consistent with SMP regulatory language. The decision tree links to regulatory guidance, vegetation management practices, and other recommendations for impact avoidance and mitigation provided in the following sections.

Figure III.3. Recommended Review Steps in Riparian Vegetation Alteration/Clearing Projects.



1 See design and impact avoidance recommendations, Table III.4

MINIMIZING IMPACTS OF MARINE RIPARIAN VEGETATION ALTERATIONS

Establishing local land use regulations for marine riparian protection, should begin with formation of development regulations linked to "marine riparian protection areas". During the permit application process, project proponents should be asked to produce a vegetation conservation plan and supporting surveys that provide sufficient information to guide the approval process. Planners should use this information to assess and approve permissible projects, deny approval for projects that have unacceptable impacts, and to provide recommendations for alternative approaches where such approaches can achieve desired results with less impact. As always, the goal should be to avoid or minimize the impacts of these activities on the nearshore environment to the greatest extent possible. Design guidance recommendations are presented in Table III.10.

Table III.8. Recommendations for riparian vegetation alteration.[8]

Regulatory issue	Recommendations
Site-specific limitations	Require surveys of the existing site and a description of functions the vegetation is providing. Identify minimum widths for marine riparian management areas that support the existing functions. Determine effect on bank stability: ◊ Require geotechnical assessment for vegetation clearing and removal projects to determine if planned activity will negatively affect slope stability (Ecology 2007b). Require maximum protection to existing marine riparian area: ◊ Disallow clearing and other vegetation management activities that could lead to increased instability. ◊ Avoid and minimize area disturbed during nearshore construction activities. ◊ Require development of vegetation management and replanting plans for any project that impacts marine riparian vegetation. Any management strategy should aim at maintaining all natural processes and functions, determined by an evaluation of the specific requirements for maintaining individual and collective functions over space and time (e.g., LWD recruitment; life history requirements of multiple species of fishes and wildlife) (Brennan and Culverwell 2004). ◊ Use a multidisciplinary approach to develop riparian management strategy. Promote off-site mitigation to address cumulative impacts. Increase public education and outreach.
Riparian protection area (buffer) requirements	The marine riparian protection area should include a "no-touch zone" or buffer tailored to protect the ecological processes and nearshore habitats. For developed areas, a protection area should act as an overlay that also requires habitat enhancement and mitigation as sites redevelop or intensify.

[8] See Protection of Marine Riparian Functions in Puget Sound for more information.

Table III.8. Recommendations for riparian vegetation alteration.[8]

Regulatory issue	Recommendations
Riparian protection area (buffer) requirements (cont.)	Administrative variances and exemptions should be strictly limited, and be evaluated for cumulative impacts. If building must occur, minimize the footprint, site disturbance and locate structures far enough back from the water's edge to ensure maintenance of functional riparian areas. Avoid land use practices in riparian areas that involve the use or generation of nutrients, pathogens, and toxics. Avoid locating septic and waste water systems in the riparian area. If they must be located in the riparian area, then they should be designed, maintained, and operated in such a way that human waste and nutrients are prevented from leaching into local water bodies. Avoid locating impervious surfaces in riparian buffers. If impervious surfaces must be located in riparian areas, minimize footprint,and mitigate impacts through techniques including pervious surfaces such as pervious pavers and concrete; bioretention facilities such as rain gardens; green roofs, cisterns, etc. Promote infiltration and implement approved methods/designs for controlling rates of surface runoff and pollutant loading. Caution should be taken when designing and installing bioretention and other facilities that infiltrate water along slopes and bluffs so as to not increase the likelihood of mass failures or erosion. Enforce requirements codified in local CAOs (Ecology 1994). Pertinent CAO ordinance categories include: ◊ Landslide hazard areas ◊ Steep slope/erosion hazard areas ◊ Fish and wildlife habitat conservation areas ◊ Wetlands ◊ Frequently flooded areas
Structural setback requirements	Enforce building setback requirements codified in local CAOs (Ecology 1994). Structure setbacks provide protection to aquatic area processes and riparian functions and values by increasing the distance between human activities and riparian areas. Riparian protection areas (buffers) sustain riparian functions and nearshore processes while the structural setbacks protect buffers from urban encroachment. Structure setbacks are areas adjacent to buffers where buildings and other facilities are not constructed; however, these areas may allow low impact activities such as gardening and lawns.
Impact minimization through a vegetation conservation plan	Recommend project applicants to consult with a qualified professional arborist to develop a vegetation management plan will provide desired outcomes while promoting desired ecological functions (Ecology 1993). Tree pruning and thinning: Discourage "topping" of conifers and broadleaf deciduous trees, which may lead to illness and eventual tree death. Instead, encourage alternative methods such as: ◊ Windowing ◊ Interlimbing ◊ Skirting-up Retain a minimum of 60% of the original crown to maintain tree health and vigor. Thinning and pruning activities should be conducted during the late fall to early spring dormant season. Limit pruning activities to a frequency of once every five years or less. Avoid vegetation removal on shorelines and bluffs. If vegetation must be removed, minimize the area and amount removed and locate the disturbed area as far from the water as possible. Minimize ground disturbance, removal of mature trees, and introduction of nonnative vegetation, especially invasive species. Purple Loosestrife, Himalayan blackberry, English Ivy and other invasive plants compete with native species, particularly in disturbed sites along marine bluffs and shorelines.

Table III.8. Recommendations for riparian vegetation alteration.[8]	
Regulatory issue	**Recommendations**
Impact minimization through a vegetation conservation plan (cont.)	Tree removal: Where tree removal is absolutely necessary, encourage leaving the stump or snag in place to maintain ground stability and reduce erosion. If removed trees are a potential source of LWD recruitment, they should be anchored on the beach on site. Shrub and understory: Promote retention of native understory within and adjacent to riparian buffer areas to control erosion, maintain slope stability, and provide water quality protection. Ensure that replanted marine riparian areas are properly maintained to improve plant survival. Maintain vegetation communities that are resilient to disturbance from surrounding land uses and able to regenerate with minimal human intervention. (See sidebar under Vegetation in the Nearshore zone for a native plant list.)

Table III.10 identifies survey and planning requirements and provides design considerations to assist planners in this regard. The information in this table is organized for consistency with the decision tree in Figure III.3.

The vegetation conservation plan and supporting professional surveys/assessments submitted by the project applicant should address the following information needs:

- Geotechnical and slope stability conditions
- Presence of hazard zones and habitat types protected under CAOs
- Shoreline characteristics (natural or developed)
- Beach substrate characteristics, presence of forage fish spawning habitat
- Presence of eelgrass or macroalgae in adjacent nearshore habitat
- Wildlife use and identified wildlife corridors
- Beach aspect and shading provided by affected vegetation
- Amount of affected vegetation overhanging the beach, providing litter and prey recruitment
- Number of affected trees greater than 4 inches in diameter at breast height that could reach the beach when downed
- Topography and relationship of the site to streets and developed properties and potential for stormwater input

The first logical step towards avoiding impacts to marine riparian habitats is to determine if the proposed vegetation alteration activity is allowable under current regulations or otherwise undesirable. If so, the project should not proceed. The following key questions should be posed:

- Are there hazard areas, critical habitat features, or priority species present that qualify for protection under local CAOs?
- Would the proposed activity affect slope stability or create an erosion hazard?

In general, CAOs and SMPs provide planners with a basis for denying large-scale alteration of vegetation within defined critical areas or shorelines, particularly where such activities would impact protected critical habitats or increase potential landslide or erosion hazards. Landowners should be dissuaded from proceeding with the activity if the geotechnical analysis indicates that a vegetation-clearing project would decrease slope stability. It is expected that most landowners will not wish to proceed with an activity that might lead to future property loss.

If the planned activity is permissible, planners should review the vegetation conservation plan, related surveys, and geotechnical analyses to determine if the activity has the potential to adversely impact sensitive habitats. If such impacts are identified, the planner should direct the applicant towards alternative approaches for achieving the desired results that avoid or minimize these impacts. Finally, if a permitted project will produce unavoidable impacts, appropriate mitigation should be identified.

STRATEGIES FOR MITIGATING UNAVOIDABLE IMPACTS

Mitigation strategies for addressing unavoidable impacts on marine riparian vegetation are identified in Table III.3.

LITERATURE CITED

Brennan, J.S. 2007. Marine Riparian Vegetation Communitiesof Puget Sound. Puget Sound Nearshore PartnershipReport No. 2007-02. Published by Seattle District, U.S.Army Corps of Engineers, Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Brennan, J. S. and H. Culverwell. 2004. Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Published by Washington Sea Grant Program. Copyright 2005, UW Board of Regents. Seattle, WA. 34 p.

Desbonnet, A, P. Pogue, V. Lee, and N. Wolff. 1994. Vegetated buffers in the coastal zone – A summary review and bibliography. Coastal Resources Center Technical Report No. 2064. University of Rhode Island Graduate School of Oceanography. Narragansett, Rhode Island.

EcoLogic, LLC. 2003. Ecological effects of overwater structures: literature review and annotated bibliography. 132 ½ Albany Street, Atwell Mill Annex, S-2, Cazenovia, NY 13035.

Ecology. 1993. Vegetation management: A guide for Puget Sound bluff property owners. Shorelands Environmental Assistance Program. Available at: http://www.ecy.wa.gov/programs/sea/publications.htm#property.

Ecology. 1994. Shoreline management guidebook, second edition. Washington Department of Ecology, Olympia Washington. Publication No. 93-104a.

Ecology. 2007a. Surface water and groundwater on coastal bluffs. Shorelands Environmental Assistance Program. Available at: http://www.ecy.wa.gov/programs/sea/publications.htm#property.

Ecology. 2007b. Slope stabilization and erosion control using vegetation. Shorelands Environmental Assistance Program. Available at: http://www.ecy.wa.gov/programs/sea/publications.htm#property.

Erstad, P. 2006. Draft Priority Habitats and Species recommendations: Bulkheads and shoreline armoring. Washington Department of Fish and Wildlife, Olympia, Washington.

Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant

Program, University of Washington, Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Forest Ecosystem Management Assessment Team. Forest Ecosystem Management: an ecological, economic and social assessment. Report of the Forest Ecosystem Management Assessment Team. 1993-793-071. United States Government Printing Office.

Franklin, J. and S. Thomas. 1983. Characteristics of Old-Growth Douglas-fir Forest. In: New Forest for a Changing World. Proceedings of the 1983 Society of American Forests' National Convention.

Fresh, K.L., B.W. Williams, and D. Penttila. 1995. Overwater structures and impacts on eelgrass (*Zostera marina*) in Puget Sound, Washington. In: Proceedings of 1995 Puget Sound Research Conference.

Fresh, K.L. 2006. Juvenile Pacific Salmon and the Nearshore Ecosystem of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers,Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Fresh, K.L., T. Wyllie-Echeverria, S. Wyllie-Echeverria, B.W. Williams. 2006. Using light-permeable grating to mitigate impacts of residential floats on eelgrass *Zostera marina* L. in Puget Sound, Washington. Ecological Engineering 28:354-362.

Gerstel, W.J., M.J. Brunengo, W.S. Lingley, Jr., R.L. Logan, H. Shipman, and T.J. Walsh. 1997. Puget Sound Bluffs: The Where, Why, and When of Landslides Following the Holiday 1996/97 Storms. Washington Geology 25(1).

Gerstel, W. J. and J. F. Brown. 2006. Alternative Shoreline Stabilization Evaluation Project; Final Report September 15, 2006. Prepared for: Puget Sound Action Team. Olympia, WA.

Haas, M.E., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, Washington. Prepared by the University of Washington, Research Project Agreement T1803, Task 30. Prepared for the Washington State Transportation Commission and U.S. Department of Transportation.

Haberstock, A.E., H.G. Nichols, M.P. DesMeules, J. Wright, J.M. Christensen, and D.H. Hudnut, 2000. Method to identify effective riparian buffer widths for Atlantic salmon habitat protection. J. Amer. Water Res. Assoc. 36(6): 1271-1286.

Hastings, M.C. and A.N. Popper. 2005. Effects of sound of fish. Prepared for Jones and Stokes and the California Department of Transportation. Sacramento, California.

Independent Multidisciplinary Science Team. 2002. Recovery of wild salmonids in western Oregon lowlands. Technical report 2002-1 to the Oregon plan for salmon and watersheds, Governor's Natural Resources Office, Salem, Oregon.

Johannessen, J. and A. MacLennan. 2007. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore PartnershipReport No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Kelty, R.A. and S. Bliven. 2003. Environmental and Aesthetic Impacts of Small Docks and Piers, Workshop Report: Developing a Science-Based Decision Support Tool for Small Dock Management, Phase 1: Status of the Science. NOAA Coastal Ocean Program Decision Analysis Series No. 22. National Centers for Coastal Ocean Science, Silver Spring, MD. 69 pp.

Knight, K. 2009. Land Use Planning for Salmon, Steelhead and Trout. Washington Department of Fish and Wildlife, Olympia, Washington. 96 pp. Available at: http://wdfw.wa.gov/hab/ahg/.

Knutson, K.C. and V.L. Naef. 1997. Management Recommendations for Washington's Priority Habitats: Riparian. Washington Department of Fish and Wildlife, Olympia, Washington.

Lemieux, J.P., J. Brennan, M. Farrell, C.D. Levings, and D. Myers. 2004. Proceedings of the DFO/PSAT Sponsored Marine Riparian Experts Workshop, Tsawwassen, BC., February 17-18, 2004. Can. Manuscript Report No. 2680. 92 p.

Levings, C.D. and G. Jamieson. 2001. Marine and estuarine riparian habitats and their role in coastal ecosystems, Pacific Region. Canadian Science Advisory Secretariat Research document 2001/109.

Marsh, W.M. 2005. Landscape Planning; environmental applications. John Wiley and Sons, Inc. 472 p.

Macdonald, K., Simpson, D., Paulsen, B., Cox, J., and Gendron, J., 1994. Shoreline armoring effects on physical coastal processes in Puget Sound, Washington. Coastal Erosion Management Studies, Volume 5. Shorelands and Water Resources Program, Washington Department of Ecology, Olympia, Washington. Publication 94-078.

May, C.W. 2003. Stream-Riparian Ecosystems in the Puget Sound Lowland Eco-Region: a review of best available science. Office of Natural Resources Coordinator, Kitsap County, Washington.

Mulvihill, E.L., C.A. Francisco, J.B. Glad, K.B. Kaster, and R.E. Wilson. 1980. Biological impacts of minor shoreline structures on the coastal environment: State of the art review, Volume II, data printout. FWS/OBS-77/51. Prepared by Beak Consultants, Inc., Portland, Oregon, with O. Beeman, for National Coastal Ecosystems Team, Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior.

Mumford, T.F. 2007. Kelp and Eelgrass in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-05. Published by Seattle District, U.S. Army Corps of Engineers,Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Nightingale, B. and C. Simenstad. 2001. Overwater Structures: Marine Issues. White Paper prepared for Washington Depts. of Fish and Wildlife, Ecology, and Transportation. Available at: http://wdfw.wa.gov/hab/ahg/finalmar.pdf.

Norris et al. 997. Norris, J.G., S. Wyllie-Echeverria, R. Thom, and J. Schafer. 1997. "Keep off the eelgrass!" Protecting a vital Puget Sound Habitat. GPS World 8(2):38-45.

Penttila, D. E. 2001. Effects of shading upland vegetation on egg survival for summer-spawning surf smelt on upper intertidal beaches in Puget Sound. Puget Sound Research 2001 Conference Proceedings.

Penttila, D.E. 2005. Coastal Planners Workshop, Padilla Bay National Estuarine Research Reserve, June 23, 2005.

Penttila, D. 2007. Marine Forage Fishes in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-03. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available at: http://www.pugetsoundnearshore.org/technical_reports.htm.

Penttila, D.E. 2007. Draft Washington Department of Fish and Wildlife Priority Habitats and Species recommendations: Forage fish. Washington Department of Fish and Wildlife, Olympia, Washington.

Popper, A.N., T.J. Carlson, A.D. Hawkins, B.L. Southall, and R.L. Gentry. 2006. Interim criteria for injury of fish exposed to pile driving operations: a white paper. Available at: http://www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6-750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf.

Poston, T. 2001. Treated wood issues associated with over-water structures in marine and freshwater environments. White Paper prepared for Washington Depts. of Fish and Wildlife, Ecology, and Transportation. Battelle Marine Sciences Laboratory, Pacific Northwest National Laboratory. 90 pp. Available at: http://wdfw.wa.gov/hab/ahg/finaltw.pdf.

Redman, S., D. Myers, D. Averill, K. Fresh and B. Graeber. 2005. Regional Nearshore and Marine Aspects of Salmon Recovery in Puget Sound. Prepared by the Puget Sound Action Team and NOAA Fisheries. Prepared for the Shared Strategy for Puget Sound.

Rice, C. 2006. Effects of Shoreline Modification on a Northern Puget Sound Beach: Microclimate and Embryo Mortality in Surf Smelt (*Hypomesus pretiosus*). Estuaries and Coasts Vol. 29, No. 1, p. 63–71.

Romanuk T.N. and C.D. Levings. 2006. Relationships between fish and supralittoral vegetation in nearshore marine habitats. Aquatic Conservation: Marine and Freshwater Ecosystems Vol. 16, p. 115-132.

Sedell, J.R., P.A. Bisson, F.J. Swanson, and S.V. Gregory. 1993. What we know about large trees that fall into streams and rivers. Pages 47-82 in Maser et al. editors. From "The Forest to the Sea: a story of fallen trees." General Technical Report, PNW-GTR-299. Pacific Northwest Research Station, United States Department of Agriculture, Forest Service, Portland, Oregon.

Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. Prepared for U.S. Army Corps of Engineers, Seattle District. 28p.

Shipman, H. 2004. Coastal bluffs and sea cliffs on Puget Sound, Washington, in Hampton, M.A., and Griggs, G.B., eds., Formation, Evolution, and Stability of Coastal Cliffs -- Status and Trends: Professional Paper 1693, U.S. Geological Survey, p. 81-94.

Shipman, H. 2001. Beach nourishment on Puget Sound: A review of existing projects and potential applications. Proceedings of the 2001 Puget Sound Research Conference.

Sobocinski et al. in Lemieux et al. 2004. Lemieux, J.P., J. Brennan, M. Farrell, C.D. Levings, and D. Myers. 2004. Proceedings of the DFO/PSAT Sponsored Marine Riparian Experts Workshop, Tsawwassen, BC., February 17-18, 2004. Can Manuscript Report No. 2680. 92 p.

Thom, R.M., Bourne, A.B. Borde, G.D. Williams, J.A. Southard, S.L. Blanton, D.L. Woodruff. 2001. Effects of Environmental Stressors on Eelgrass Restoration Projects. Proceedings of the 2001 Puget Sound Research Conference.

U.S. Army Corps of Engineers (Corps). 2000. Programmatic Biological Evaluation for the State of Washington for Salmonid Species Listed or Proposed by the National Marine Fisheries Service and U.S. Fish and Wildlife Service under the Endangered Species Act. Mooring buoys. Seattle District Corps of Engineers, Regulatory Branch, Seattle, WA 98124-375.

Washington Department of Fish and Wildlife. 2009. Protection of Marine Riparian Functions in Puget Sound, Washington. Olympia, Washington. 40 pp. Available at: http://wdfw.wa.gov/hab/ahg/ahgwhite.htm.

Whatcom County . 2007. Whatcom County Shoreline Management Program, Title 23., Bellingham, WA. February 27, 2007.

Williams, G. D. and Thom, R. M. 2001. Marine and estuarine shoreline modification issues. White Paper prepared for Wash. Depts. of Fish and Wildlife, Ecology, and Transportation. Battelle Marine Sciences Laboratory, Pacific Northwest National Laboratory. 121 pp. Available at: http://wdfw.wa.gov/hab/ahg/finalsl.pdf.

Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J.P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pederson, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, including Vashon and Maury Islands (WRIAS 8 and 9). J.S. Brennan, editor. Report prepared for King County Department of Natural Resources, Seattle, Washington.

Williams G.D., R.M. Thom, D.K. Shreffler, J.A. Southard, L.K. O'Rourke, S.L. Sargeant, V.I. Cullinan, R.A. Moursund, and M. Stamey. 2003. Assessing overwater structure-related predation risk on juvenile salmon: Field observations and recommended protocols. PNNL-14435. Prepared for the Washington State Department of Transportation. Prepared by the Pacific Northwest National Laboratory's Marine Sciences Laboratory, Sequim, Washington, in collaboration with Shreffler Environmental, Sequim, Washington, and the University of Washington, Seattle, Washington.

WSDOT. 2006. Noise impact assessment. Chapter 7 In: Biological Assessment Preparation for Transportation Projects - Advanced Training Manual. Washington State Department of Transportation, Environmental Affairs Office, Olympia, Washington. October 2006.

Zelo, I., H. Shipman, and J. Brennan. 2000. Alternative bank protection methods for Puget Sound shorelines. Shorelands and Environmental Assistance Program Washington Department of Ecology, Olympia, Washington. Publication # 00-06-012.

GENERAL REFERENCE

Canning, D.J. 2001. Climate variability, climate change and sea level rise in Puget Sound: Possibilities for the future. Proceedings, 2001 Puget Sound Research Conference.

Herrera. 2005. Marine shoreline sediment survey and assessment, Thurston County, Washington. Prepared for the Thurston Regional Planning Council by Herrera Environmental Consultants.

Johannessen, J., 2000. Alternatives To Bulkheads In The Puget Sound Region: What Is Soft Shore Protection? What Is Not? Proceedings of the 17th International Conference of the Coastal Society. p. 134-142.

McDade, M.H., F.J. Swanson, W.A. McKee, J.F. Franklin, and J. Van Sickle. 1990. Source Distances for Coarse Woody Debris entering Small Streams in Western Oregon and Washington. Canadian Journal Forest Resources 20:326-330.

Montgomery, D., B. Collins, J. Buffington, and T. Abbe. 2003. Geomorphic Effects of Wood in Rivers. American Fisheries Society Symposium 37 pg. 21-47.

Pollock, M.M. and P.M. Kennard. 1998. A Low-risk Strategy for Preserving Riparian Buffers Needed to Protect and Restore Salmonid Habitat in Forested Watersheds of Washington State. 1,000 Years Institute, Bainbridge Island, Washington.

Thom, R., Shreffler D., Macdonald, Keith, 1994, Shoreline armoring effects on coastal ecology and biological resources in Puget Sound, Washington. Coastal Erosion Management Studies, Volume 7**.** Washington Department of Ecology, Pub. No. 94-80.

U.S. Army Corps of Engineers. 2006. Regional General Permit No. 6. Maintenance, modification and construction of overwater structures in inland marine waters in the State of Washington. U.S. Army Corps of Engineers, Seattle District. Effective February 14, 2005. Available at: http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/REG/RGP6FinalText(7-13-05).pdf.

Van Sickle, J. and S.V. Gregory. 1990. Modeling Inputs of Large Woody Debris to Streams from Falling Trees. Canadian Journal Forest Resource 20:1593-1601.

WDFW. Undated. Draft Management Recommendations – Migratory corridors for juvenile salmon. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Natural Resources. 2005. Standard practice for the use and removal of treated wood pilings on and from State-owned aquatic lands. Standard practice memorandum SMP02-07.

APPENDIX A – SHORELINE MASTER PROGRAM PLANNING PROCESS

SMP UPDATE PROCESS	SPECIFIC PLANNING TASKS	PRODUCTS
Phase 1: Preliminary Shoreline Jurisdiction and Public Participation Plan	Task 1.1: Identify preliminary shoreline jurisdiction - shorelines & shorelands Task 1.2: Develop public participation plan (citizen, technical, Ecology, other stakeholders) Task 1.3: Demonstrate how Phase 1 complies with Guidelines	Product 1.1: Preliminary map of local shorelines & shorelands subject to the SMP Product 1.2: Public participation plan Product 1.3 Documentation in SMP submittal checklist
Phase 2: Shoreline Inventory &Shoreline Analysis & Characterization	Task 2.1: Complete shoreline inventory Task 2.2 Conduct shoreline analysis Task 2.2.1: Characterize ecosystem-wide processes Task 2.2.2: Characterize shoreline functions Task 2.2.3: Conduct shoreline use analysis, analyze public access opportunities Task 2.3: Prepare shoreline inventory and characterization report Task 2.4: Demonstrate how Phase 2 complies with Guidelines	Product 2.1: Draft list of inventory data sources, digital maps of inventory information Product 2.3: Shoreline inventory and characterization report with, map portfolio & GIS data, including: • Characterization of ecosystem-wide processes • Characterization of shoreline functions • Identification of potential protection and restoration areas • Shoreline use & public access analyses • Shoreline management recommendations Product 2.4: Documentation in SMP submittal checklist
Phase 3: Shoreline Environment Designation, Policy & Regulation Development; Cumulative Impacts Analysis	Task 3.1: Conduct community visioning process Task 3.2: Develop general goals, policies & regulations Task 3.3: Develop environment designations Task 3.4: Develop shoreline use & modifications policies, regulations & standards	Product 3.1: Shoreline management strategy Product 3.2-3.5: Complete Draft SMP, including: • Draft general goals, policies & regulations • Draft environment designations • Draft shoreline use & modifications policies, regulations & standards

SMP UPDATE PROCESS	SPECIFIC PLANNING TASKS	PRODUCTS
	Task 3.5: Develop administrative provisions Task 3.6: Prepare preliminary cumulative impacts analysis Task 3.7: Demonstrate how Phase 3 complies with the Guidelines	• Draft administrative provisions Product 3.6: Preliminary cumulative impacts analysis Product 3.7: Documentation in SMP submittal checklist
Phase 4: Restoration Plan; Revisiting Phase 3 Products as Necessary	Task 4.1: Prepare restoration plan Task 4.2: Revisit environment designations, policies and regulations; finalize jurisdiction maps Task 4.3: Demonstrate how NNL is achieved Task 4.4: Demonstrate how Phase 4 complies with Guidelines	Product 4.1: Restoration plan Product 4.2 Revised SMP, cumulative impacts analysis & jurisdiction maps Product 4.3 No net loss report Product 4.4: Documentation in SMP submittal checklist
Phase 5: Local Approval	Task 5.1: Assemble complete draft SMP and submit to Ecology for informal review Task 5.2: Complete SEPA review, documentation Task 5.3: Provide GMA 60-day notice of intent to adopt Task 5.4: Hold public hearing Task 5.5: Prepare responsiveness summary and respond to public comments Task 5.6: Adopt SMP and submit to Ecology Task 5.7: Demonstrate how Phase 5 complies with Guidelines	Product 5.1: Final draft SMP Product 5.2: SEPA products (checklist, MDNS/EIS; SEPA notice) Product 5.3: Evidence of compliance with GMA notice requirements Product 5.4: Public hearing record Product 5.5: Responsiveness summary Product 5.6: Complete SMP submittal package Product 5.7: Documentation in SMP submittal checklist
Phase 6: State Approval	Task 6.1: Provide public notice & opportunity for comment; respond to comments received Task 6.2: Prepare decision packet including findings & conclusions, transmittal letter, conditions of approval (if any), & responsiveness summary Task 6.3: Work with local government to finalize local adoption	Product 6.1: Responsiveness summary Product 6.2: Decision package submitted to local government Product 6.3: Final SMP adoption incorporating any Ecology conditions of approval; SMP takes effect

A REVIEW OF ENVIRONMENTAL AND SAFETY IMPACT DOCUMENTS FOR THE PROPOSED GATEWAY PACIFIC TERMINAL

By

John R. Harrald, Ph.D.
Decision Support Associates, L.L.C.
3124 Sleepy Hollow Road
Falls Church, VA. 22042

and

James R. Townley
Performance Improvement Enterprises, L. L. C.
14720 NW Forrestel Loop
Beaverton, OR 97006

August 1997

INTRODUCTION

The purpose of this document is to describe the results of a review, requested by the firm of Ziontz, Chestnut, Varnell, Berley, & Slonim, of the following documents:

- *Gateway Pacific Terminal Analysis of Vessel Traffic Issues*, Shapiro and Associates, November 19, 1996
- *Gateway Pacific Terminal Transportation Impact Study*, KJS Associates, December 17, 1996.
- *Gateway Pacific Terminal Draft EIS*, Section I (Summary) and Section III (Review of comments by Ocean Advocates)

The objective of the review was to identify and describe areas where safety and environmental issues related to the proposed GPT terminal are not adequately analyzed by these documents.

The review of the GPT impact assessment documents focuses on the following four issues:

1. A traffic analysis should estimate the potential impact of increased traffic on the potential for collisions and groundings in Georgia Strait, Rosario Strait, and Haro Strait
2. A traffic management analysis should describe the impact of the increased traffic on anchorage areas and regulated navigation areas.
3. A spill risk analysis should estimate both the potential impact for large accident related spills (determined through an analysis of traffic density and traffic patterns) and smaller transfer related spills (determined by the frequency of liquid cargo transfers and bunkering). While it is noted that bunkering transfers will not be permitted at the GPT facility, it should be expected that some vessels waiting at anchor to dock at the facility will bunker from barges.
4. A facility hazard analysis should contain a description of the types of cargoes transferred and stored on the facility, the types and sizes of vessels calling at the terminal, and a description of facility risk management requirements for preventing a concentration of multi-hazard commercial vessels from contributing to the potential accident risk at the facility.

TRAFFIC SAFETY ANALYSIS

The traffic analyses presented in the Gateway Pacific Terminal Impact Study prepared by KJS Associates (12/17/96) and in the Analysis of Vessel Traffic Issues prepared by Shapiro and Associates (11/19/96) are misleading due to the use of aggregated and average values. The reports use, as their basis for comparison, the total traffic flow of all self propelled vessels aggregated for all traffic channels in Georgia Strait. Desegregation of the traffic totals and attention to variations in traffic patterns would allow the identification and analysis of specific issues related to vessel traffic and would lead to answers to significant questions such as:

- How will GPT affect the density of deep draft traffic in Rosario Strait and other sensitive, constrained waterways?

- What is the volume and type of conflicting shallow draft traffic which could impede and interfere with the navigation and maneuvering of these deep draft vessels?
- What are the anticipated peak traffic levels in critical waterways, anchorage approaches, and turning points?
- How will the traffic densities and patterns generated by the GPT facility affect the expected incidence of collisions, powered groundings, and drift groundings in Georgia Strait, Rosario Strait, and Haro Strait?
- How will these potential accident frequencies be affected by the traffic densities and patterns generated by the GPT facility, the CPIP facility, and the proposed Delta Port, assuming all are operational.

The projected traffic impacts are described by KJS Associates (p.19) as follows,

> "the resulting daily shipping activity generated by the proposed Gateway Pacific Terminal in the Georgia Strait would be approximately one vessel movement per day, on average. Recent historical marine movements of large commercial vessels in Georgia Strait have averaged 15 shipping movements per day. New shipping activity associated with the Gateway Pacific Terminal increase shipping activities in the Georgia Strait by only 5 per cent per day."

Shapiro and Associates (p.11) state that ,

> "As of 1992 the existing terminals at Cherry Point received an estimated average of 28 entering transit per month (Collins, 1993), equivalent to approximately two one way transit per day, or 730 per year. Recent compilations for the entire Strait of Georgia indicate an average of 15 large commercial vessel transits per day, or about 5,500 movements per year.
>
> A mixture of sizes and types of marine vessels will transport bulk goods to and from the propose project site, but would average 60,000 metric tons capacity per vessel. The proposed project is expected to generate 140 entering transit (i.e. about 280 movements) annually (KJS, 196). This would results in a 38% average increase at Cherry Point, and approximately 5% for the study area as a whole. The transits would not be evenly distributed through the year."

The additional deep draft traffic anticipated from the GPT is apparently between 280 to 365 deep draft vessels per year. These vessels would be bulk carriers (dry or liquid), would average 60,000 metric tons cargo, but could be as large as 250,000 DWT (bulk vessels calling on the Port of Bellingham average 161,000 mt). If the CPIP facility is also operational, an additional 300 deep draft vessels could be added (although it is not clear from the reports if the creation of two facilities would double the anticipated throughput, or whether the two competing facilities would share the potential cargo represented by 140 port calls.)

As shown in Table 1 below, taken from the Volpe Transportation Systems Center's Puget Sound Maritime Safety Evaluation (1997), the 5,500 transit number used by Shapiro and KJS represents the total Strait of Georgia self propelled traffic (upper Rosario Strait + Haro Strait). However, a more meaningful comparison is the impact on the density of deep draft traffic in the constrained areas of Rosario Strait. Since Rosario Strait is the most direct and economical

approach to the GPT (the alternative is Haro Strait), an assumption that most vessels will elect to transit the Rosario Strait is reasonable. This will result in an increase of approximately 60% in the deep draft ship traffic in the upper Rosario Strait and an increase of approximately 45%. increase in the deep draft ship traffic in the lower Rosario Strait.. The inclusion of the transits of small self propelled vessels in the impact statements masks this significant increase.

TABLE 1
Annual Vessel Transits by Vessel Type and Waterway

AREA	TOTAL VESSEL TRANSITS	SELF PROPELLED VESSELS (TOTAL)	SELF PROPELLED VESSELS (DRAFT>19')	TANK VESSELS (TOTAL)	TANK VESSELS (DRAFT >19')	TUS WITH TANK BARGES
ROSARIO STRAIT (ABOVE GUEMES)	4000	1400	500	400	390	400
ROSARIO STRAIT (BELOW GUEMES)	7000	1350	650	600	550	1200
HARO STRAIT	8000	4200	4150	300	270	1000
NUMBER OF FERRY TRANSITS CROSSING ROSARIO STRAIT						9.000
NUMBER OF FERRY TRANSITS CROSSING HARO STRAIT						1.000

Source: Puget Sound Maritime Safety Evaluation: Segment Commodity Tables. Volpe Trans. Systems Center (1997)

The 9,000 ferry vessel transits that cross the deep draft traffic lane are State of Washington Ferries serving the San Juan Islands and Vancouver Island. The Tank Barge tows represent approximately 1/3 of the tug/barge traffic north of Guemes Channel and about 1/2 of the tug Barge traffic south of Guemes channel.

The potential impact of an increase in deep draft traffic on the risk of collisions and powered groundings in Rosario Strait is not adequately addressed by either Shapiro and Associates of by KJS and Associates.

Collisions: The expected frequency of collisions is highly dependent upon traffic density and environmental conditions. (KJS indicates that the waterway is "commonly affected by land fog from September through February, p. 9.). The reports do not attempt to estimate peak traffic volumes. Periods of high traffic density relatively high risk periods for collisions, particularly if they occur during adverse conditions and contribute most of the collision risk in a waterway system. Risk assessments of the Lower Mississippi River (Harrald et al. 1995) and Prince William Sound, Alaska (Harrald et al. 1997) have found that the average traffic density is a misleading indicator of risk. Peak traffic densities vary significantly from the average. For example, an average of 1.8 tankers per day calls at the Alyeska Terminal in Valdez. However, some days have no arrivals and it is not unusual to have 6 or more tankers arrive during one day. Similarly, the Port of New Orleans peak traffic levels are more than 10 times the average traffic levels. Feed grain cargoes will undoubtedly draw a significant number of bulk carriers to the GPT facility. The seasonality of the grain trade will further skew these peak traffic volumes, and will result in an increase in the number of vessels at anchor or moving on or off berth at the GTP waiting for cargo.

The impact of a collision includes the potential impact of both vessels. The reports are silent on the fact that the most likely collision "targets" in Rosario Strait are passenger ferries, tank barges, and tank vessels. The impact of a collision of a large bulk carrier and any one of these vessel types could be catastrophic.

Groundings: The Shapiro Report does not explicitly address the risk of powered or drift grounding of large bulk carriers. The potential for pollution in a grounding is significant; bulk carriers can carry thousands of tons of bunkers in single bottom tanks. The most likely cause of a powered grounding is maneuvering in restricted waters due to other vessel traffic or other floating hazards (maneuvering in ice was the proximate cause of the Exxon Valdez grounding, maneuvering around a fishing vessel led to the recent tanker grounding in Tokyo Bay. The density of small recreational and fishing vessel traffic in Georgia, Rosario, and Haro Straits are not described in the reports. Drift groundings occur when a vessel loses its ability to maneuver by losing power and/or steering and drifts onshore. The vessel risk study performed by the George Washington University for the State of Washington Office of Marine Safety found that foreign flag bulk carriers were the vessel type most likely to experience mechanical failures (Harrald et. al 1994). The USCG Captain of the Port for New Orleans has been tracking propulsion failures in the Mississippi River for several years; approximately 1% of all bulk carriers transiting the lower Mississippi experience a propulsion failure. The interventions that prevent a drift grounding are self repair (average self repair time for US Flag tankers studied in the Alaska risk assessment was 1/2 hour) or intervention by a tug. Bulk carriers are not escorted by tugs, as are Tankers in Rosario Strait, but could use the resources of the International Tug of Opportunity System. The reports do not attempt to calculate the time before a drifting tanker would ground in any area of the waterway, nor does it indicate that expected response time for any assist tug.

The primary cause of collisions is human error, the primary causes of groundings are human error and mechanical failures. Both the USCG and the State of Washington have developed vessel inspection programs that target vessels of certain flags, classification societies, and ownership that are believed to present a higher than normal risk based on their historical frequency of incidents, accidents, and violations (OMS, 1997). These targeted vessels are frequently ships engaged in the international bulk cargo trade. The impact statements should address the procedures that will be followed by the facility to ensure that sub standard vessels will not load or discharge cargoes.

TRAFFIC MANAGEMENT ANALYSIS

The Shapiro report states (p 11) that "The increase in shipping activity is not expected to have any impact on existing monitoring of vessel traffic control by the USCG (KJS 1996). Although the increase in traffic will not impact on the resources, policies, or procedures required for vessel traffic management, it may have a significant impact on the actual management of traffic. Rosario Strait is a one way zone for deep draft vessels. The increase in vessel traffic could cause an increase in the delays of vessels entering Rosario Strait causing vessels to slow down, drift, or anchor or to use Haro Strait. Any of these alternatives increase the amount of time that a vessel is underway in this sensitive area and therefore increases risk exposure. If

significant delays are encountered, vessels will elect to anchor potentially causing congestion at existing anchorage areas. Traffic delays would be experienced by all vessels, not just users of the GPT terminal, causing a potential economic impact on operators currently calling at the ports of Vancouver, Anacortes, Cherry Point, and Bellingham. A traffic management analysis should answer the following questions:

- What existing pressure will be put on existing anchorage areas for handling bulk vessels waiting for, or shifting to and from berth?
- What impact will the increased traffic density in Rosario Strait have on the flow of traffic through the regulated navigation area, and will laden vessels be required to wait or anchor, increasing their risk exposure in the system?
- What additional or revised U.S. Coast Guard vessel traffic management protocols will be required to minimize the risk of collisions or groundings during peak traffic periods? Should these protocols be independent of cargoes or should they be cargo specific?
- Would changes to existing anchorage regulations or the creation of new anchorage areas contribute substantially to reducing the risk of groundings or collisions?
- Would the implementation of new vessel traffic management or vessel anchorage protocols create significant land side traffic management problems?
- Is there significant land side transportation capacity to handle peak demand associated with feed grain shipments?

SPILL RISK ANALYSIS

The discussion of past risk of vessel incidents in the study area used by Shapiro and Associates (p.11-13) to infer a spill risk of 2.5 incidents per year is overly simplistic and misleading. Again, the faulty analysis is based on aggregation and averages. The report provides a spills/transit ratio as the predictor of potential spills. The vast majority of vessel related incidents are small and are related to transferring of cargo or bunkering. The meaningful predictor of the number of these types of incidents is the frequency of bunkering and liquid cargo transfer operations, not the number of port calls. The reports are silent on the anticipated bunkering demand and on the location and type of bunkering operations that will be generated by the deep draft traffic to either the GPT or CPIP terminals. The reports also do not indicate what percentage of the vessels calling at these terminals will be transferring petro-chemical liquid bulk cargoes. If the proposed terminals are in the bunkering business, the projection of small spills is understated. If no bunkering or transfers of liquid bulk cargoes is anticipated, the projection of 2.5 spills per year is probably overstated.

An attempt to predict the risk of large, accident related, oil spills is an essential element of any spill risk analysis. The use of historical spill statistics over a short time period to predict these low probability-high impact future events is invalid. Shapiro and Associates uses three years of spill statistics for Northern Puget Sound (1993-1995). During this period, only one spill greater than 1,500 gallons occurred: the grounding of the Crowley barge101 with the loss of 26,936 gallons of diesel fuel in Rosario Strait in December of 1994 (Washington DOE, April 1997). The probable cause of the grounding was the improper navigation in strong tidal currents by the tug Mercury (Washington OMS, 1996). The probability of occurrence of a

future incident of this type or a spill due to a collision or grounding of a bulk carrier is unrelated to the historical analysis of small facility related spills presented in the report.

In summary, a reasonable spill risk analysis should include the following:

- The probability and impact of transfer related spills during bunkering or cargo transfer operations should be estimated.
- The probability and impact of spills caused by collisions, allisions, and/or groundings should be assessed.

BUNKERING OPERATIONS

As stated above, the most frequent cause of small operational spills is the transfer of petroleum cargoes or fueling (bunkering). Where and when a vessel bunker depends upon the relative price of bunker fuel, the availability and convenience of bunkering facilities, and the itinerary of the vessel. Washington State has identified bunkering operations as a significant source of marine pollution and has instituted a bunkering inspection program (OMS, 1997). The state reports that cargo ship bunker spills occurred in Washington State waters between 1993-1995, resulting in 11,802 gallons of oil spilled (OMS, 1997). The KJS and Shapiro impact studies do not discuss bunkering at the GPT. The analysis should answer the following questions:

- While it is noted that bunkering will not occur at the GPT facility, does the same policy apply to the CPIP?
- Will vessels waiting to berth at GPT and/or CPIP bunker elsewhere in Puget Sound or the Strait of Juan de Fuca? If yes, what is the anticipated increase in bunker volume and frequency?

FACILTY HAZARD ANALYSIS

General cargo facilities are a potential site for fires, explosions, and toxic releases. The most serious industrial accident in U.S. history occurred in 1947 at Texas City, Texas, when two vessels, the *Grandcamp and the High Flyer*, laden with ammonium nitrate fertilizer caught fire and exploded. The explosion demolished everything within a mile of the docks, killing almost 600 people and injuring more than 3,000 (Stephens and Harrald, 1993) The level of hazard present at a marine terminal depends upon the types of cargoes shipped through the terminal, the types and amounts of cargoes stored on the facility, and the size, types and cargoes of vessels docked at the terminal.

The KJS study (p.19) states that the typical vessel will be a 60,000 metric ton bulk cargo vessel but will be capable of handling vessels with drafts up to 80 ft. The facility will be able to handle both liquid bulk and dry bulk cargo The draft GTP Environmental Impact Statement (p I-2) states that the projected cargoes are feed grains, petroleum coke, iron ore sulfur (prilled), potash, and woodchips. The economic viability studies that led to the design of the terminal undoubtedly contain more complete (albeit proprietary) description of projected cargo flows. The terminal hazard analysis should, without revealing proprietary economic projections, answer the following questions:

- What types and projected volumes of cargoes will be shipped through and/or stored at the GPT?
- What size vessels will be carrying these cargoes?
- What types of cargoes will be present at the same time, either stored at the facility or in vessels calling at the terminal? What hazards are associated with these potential combinations?
- What are the related fire, explosion, toxic hazards related to these cargoes?

Hazards are also presented by weather in the vicinity of the GPT facility or in anchorage areas where vessels wit to berth at the facility: The following questions relating to these hazards should be answered:

- What are the prevailing seasonal winds and tidal current patterns in the vicinity of the GPT? What special navigational, cargo loading, or anchorage management problems will be created by stronger than normal currents or winds (particularly during strong North Westerly winds produced by winter storms)?
- What are the holding characteristics of existing anchorage grounds and what has been the past vessel experience on these ground under different weather conditions?
- Will special anchorage rules or procedures be instituted to minimize risk of drift groundings or collisions in and around the anchorages? If not, why not? If yes, what will those measures be?

SUMMARY

The three documents describing the impact of the Gateway Pacific Terminal do not adequately describe the impacts and proposed mitigation measures in the several areas described in this report. The area that could have the greatest impact on the environment and maritime safety is, in our opinion, the affect of increased deep draft traffic in and around Rosario Strait. A more detailed modeling and analysis of the projected traffic patterns should be part of the impact statements. A second area of significant concern is the probable seasonal concentration of the large multi- cargo vessels calling at the GTP terminal, the resulting increase in peak deep draft traffic congestion, and the related increase in vessel support activities (bunkering, launch service, etc.) in anchorage areas as vessel wait for berth openings at the facility. The hazards associated with this peak period operation should be identified and mitigating measures described.

REFERENCES

Harrald, J.R., Saebo, E., and Grabowski, M., December 1996. *Prince William Sound Risk Assessment Final Report.* Washington, D.C.

Harrald, J.R. , Mazzuchi, T., and Grabowski, M. July 1995. *Evaluating and Monitoring Risk in the Lower Mississippi River* Washington, D.C.

Stephens, Hugh W. and J.R. Harrald. 1993. "From Texas City to the EXXON VALDEZ: What Have We Learned about Managing Disasters"? American Political Science Association 1993 Annual Meeting.

Washington State, Office of Marine Safety, Dec. 1996. *The Barge 101. Prevention Bulletin 96-02.* Olympia, Washington.

Washington State, Department of Ecology, April 1977. *Oil Spills in Washington State: A Historical Analysis. Publication 97-252.* Olympia, Washington.

Washington State. Office of Marine Safety. February, 1977. *Field Operations Report.* Olympia, WA.

Volpe National Transportation Systems Center. May 1997. *Puget Sound Maritime Safety Evaluation: Segment Commodity Tables.* Cambridge, MA.

SETTLEMENT AGREEMENT

Pacific International Terminals
Shoreline Substantial Permit SHS 92-0020
and
SHB Appeals Numbers 97-22 and 97-23

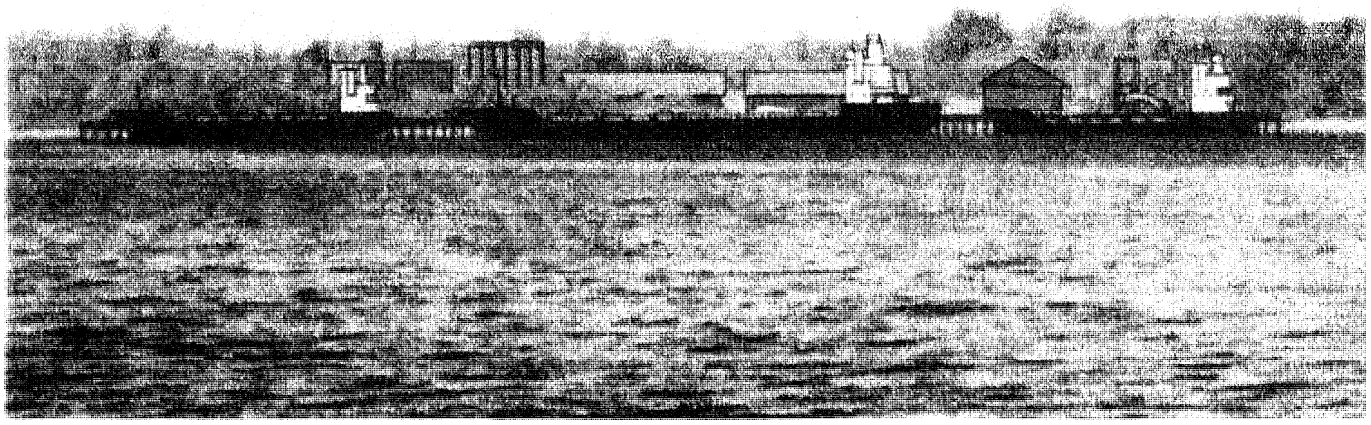


TABLE OF CONTENTS

Settlement Agreement

Appendix A: Preliminary Wetland Mitigation Plan

Appendix B: Macroalgae Mitigation Plan

Appendix C: Herring Monitoring Program

Appendix D: Gateway Pacific Terminal Ballast Water Exchange Requirements

Appendix E: Sediment Parameters for Baseline Testing in Vicinity of Smelter and Petroleum Processors

Appendix F: Stormwater

Appendix G: Proposed Analysis of Selected Vessel Safety and Environmental Impacts of the Gateway Pacific Terminals

Appendix H: Agreement for Gift Conveyance and Public Access

Appendix I: Proposed Amendments to Shoreline Program

Appendix J: Proposed Amendments to Whatcom County Comprehensive Plan

Appendix K: Timeline for Proposed Amendments to Whatcom County Shoreline Program and Comprehensive Plan

Appendix L: DNR Letter Regarding Proposed Additional Studies for Impacts to Herring

APPENDIX A

Preliminary Wetland Mitigation Plan for the Gateway Pacific Terminal Project

Prepared for:

Pacific International Terminals
1801 Roeder Avenue, Suite 156
Bellingham, WA 98225

Prepared by:

Aqua-Terr Systems, Inc.
1999 Gripp Road
Sedro Woolley, WA 98216

March, 1996

1.0 EXECUTIVE SUMMARY

The subject parcel is located within unincorporated Whatcom County, east of the City of Ferndale (within Sections 17, 18, and 19 of Township 39 North, Range 1 East of the Willamette Meridian) (Figure 1). The total acreage of the Gateway Pacific Terminal (GPT) property is 1,092, but only the 60 acre area south of Henry Road and a 65 foot wide proposed rail connection was investigated (totaling approximately 100 acres). This is the area that will be impacted by the project and was the original area reviewed by Aqua-Terr Systems, Inc. (ATSI) (ATSI 1995). Additional areas were investigated for mitigation of impacted wetlands.

The proposed project calls for the construction of a deep-water, multi-use, bulk and other cargoes, import and export facility. This property is one of only a few locations along the west coast of the United States where large transport ships can easily maneuver close to shore and is adjacent to a shoreline that can accommodate dry bulk storage and rail loops for ship to rail transport.

The entire area is a mix of forest, abandoned shrub dominated fields, and agricultural fields still in use. The terrain ranges from flat to gently rolling, except a ravine on the southeast portion of the site with moderate slopes, and moderate to steep bluffs along the shoreline. An unnamed seasonal stream is associated with the ravine.

Palustrine emergent, scrub-shrub, and forested wetlands are located in the proposed impact area for this project (ATSI 1995). The wetlands meet all three wetland parameters, but by differing degrees. In general, all on-site wetlands display a predominance of hydric vegetation, hydric soils displaying low chromas and mottling, and soils with wetland hydrology field indicators such as oxidized root channels. The proposed project plan requires filling 5.85 acres of wetlands on this parcel. Of the 5.85 acres proposed to be filled, 4.30 acres are farmed seasonally saturated palustrine emergent wetlands, 1.45 acres are seasonally saturated palustrine scrub-shrub wetlands, and 0.1 acres are seasonally saturated palustrine forested wetlands.

This mitigation project will directly and indirectly compensate for lost wetland acreage and function. **Five goals** have been established for the mitigation project. The **first** goal is to create 5.9 acres of seasonally saturated palustrine forested/scrub-shrub wetland to provide a 1:1 areal replacement ratio with greater functional value for wetlands filled. The **second** goal is to enhance a 16.2 acre monotypic stand of reed canarygrass into a diverse palustrine forested wetland habitat. The **third** goal is to assure the protection of the on-site stream corridor by placing the stream channel and the associated riparian area in a conservation easement recorded on the property deed (this encompasses approximately 50 acres). The **fourth** goal is to conduct a study on a designated 1.5 acre plot researching the natural regeneration of vegetation within seasonally saturated, palustrine emergent agricultural fields and also investigating the success of selected facultative upland and facultative wetland plants planted over a range of hydrogeomorphic regimes. The **fifth** goal is not directly related to wetland disturbance but addresses cultural functions lost on a regional basis. This goal will provide compensation for the local loss of natural resources, in this case western red cedar trees, important to the Lummi Indian Tribe's culture heritage.

In summary, compensation for filling 5.85 acres of predominately farmed palustrine emergent wetlands, 5.9 acres of palustrine scrub-shrub and palustrine forested wetland will be created, 16.2 acres of low grade palustrine emergent wetland will be enhanced, a 50 acre riparian corridor will be placed in a conservation easement, a research project on wetland ecology will be funded, and cultural resources important to the Lummi Indian Tribe will be provided.

2.0 PROJECT DESCRIPTION

2.1 Project Location

The total acreage of the Gateway Pacific Terminal (GPT) property is 1,092 (+/–), but only the 60 (+/–) acre area south of Henry Road and a 65 foot wide proposed rail connection (totaling approximately 100 acres) was investigated. This is the area that would be impacted by the project and was the original area reviewed by ATSI. Additional areas were investigated for mitigation of impacted wetlands.

The parcel lies within unincorporated Whatcom County, east of the City of Ferndale (within Sections 17, 18, and 19 of Township 39 North, Range 1 East of the Willamette Meridian) (Figure 1). Figure 2, a 1987 aerial photograph, and Figure 3, a map of the delineated wetlands within the impact area, show the size and location of the project site. The site is bordered on the north and west by the ARCO oil refinery, to the east by farms, wooded acreage and State of Washington Department of Natural Resources Trust Lands, and to the south by the Strait of Georgia. This portion of the County, including the subject parcel, is zoned Heavy Industrial. Surrounding land uses include: ARCO and TOSCO oil refineries, INTALCO's aluminum plant, rural residential, agricultural, and wooded tracts used for timber. Several roads border or pass through the property including: Aldergrove Road to the north, Gulf (Powder Plant) Road to the east, and Henry Road through portions of the south. Lonseth Road also passes east–west near the center of the property. Several decaying sheds, old foundations from farm houses and outbuildings are located south of Henry Road and near the intersection of Aldergrove and Gulf Roads.

The entire area is a mix of forest, abandoned shrub dominated fields and agricultural fields still in use. The terrain ranges from flat to gently rolling, except a ravine on the southeast portion of the site with moderate slopes, and moderate to steep bluffs along the shoreline. An unnamed seasonal stream is associated with the ravine.

2.2 Responsible Parties

Jeff Kaspar
Gateway Pacific Terminal
1801 Roeder Avenue, Suite 156
Bellingham, Washington 98225

2.3 Description of Project and History

The proposed project is for the construction of a deep–water, multi–use, bulk and other cargoes, import and export facility. This property is one of only a few locations along the west coast of the United States where large transport ships can easily maneuver close to shore and is adjacent to a shoreline that can accommodate dry bulk storage and rail loops for ship to rail transport. The southerly 60 acre portion of the subject parcel will be the most heavily impacted. The other areas in Figures 2 and 3 will be impacted by the rail line only.

The proposed project site has been under various ownership and was actively farmed up until the late 1960s. Farming included commodity crops such as rye, potatoes, and hay, as well as dairy and chicken farms, and scattered woodlots for firewood and logging. The present condition, with open fields and wood lots, has been stable for at least 50 years as indicated by a 1950 aerial photograph (ATSI 1995) (indicating the southerly parcel). Discussions with retired neighbors that have lived and worked in the Cherry Point area for most of their lives confirm past and current land uses (ATSI 1995).

When the Cherry Point area was rezoned from rural in the early 1970's to Heavy Industrial, various entities began to collect the farmlands into larger blocks of land as speculative ventures. Many of the farms have not actively produced commodity crops since that time, but cattle, hay and limited commodity crops are grown on most fields. The subject parcel has been compiled from two separate owners.

The proposed project plan requires filling 5.85 acres of wetlands on this parcel. Of the 5.85 acres proposed to be filled, 4.30 acres are farmed seasonally saturated palustrine emergent wetlands, 1.45 acres are seasonally saturated palustrine scrub–shrub wetlands, and 0.1 acres are seasonally saturated palustrine forested wetlands.

This mitigation plan will directly and indirectly compensate for lost wetland acreage and function. **Five goals** have been established for the mitigation project. The **first** goal is to create 5.9 acres of seasonally saturated palustrine forested/scrub–shrub wetland to provide a 1:1 areal replacement ratio with greater functional value for wetlands filled. The **second** goal is to enhance a 16.2 acre monotypic stand of reed canarygrass into a diverse palustrine forested wetland habitat. The **third** goal is to assure the protection of the on–site stream corridor by placing the stream channel and the associated riparian area in a conservation easement recorded on the property deed (this encompasses approximately 50 acres). The **fourth** goal is to conduct a study on a designated 1.5 acre plot researching the natural regeneration of vegetation within seasonally saturated, palustrine emergent agricultural fields and also investigates the success of selected facultative upland and facultative wetland plants planted over a range of hydrogeomorphic regimes. The **fifth** goal is not directly related to wetland disturbance but addresses cultural functions lost on a regional basis. This goal attempts to provide a compensation for the regional loss of natural resources, in this case western red cedar trees, important to the Lummi Indian Tribe's culture heritage.

Table 1 compares acres of wetland lost from proposed impacts with acres of wetland created, enhanced, and protected as part of the proposed mitigation. A total of 5.85 acres of wetlands are proposed to be filled for this project, most of which are low value, seasonally saturated agricultural palustrine emergent wetlands, that are cut for hay on a yearly basis. Compensation for this disturbance will include replacement of the 5.85 acres of palustrine emergent wetlands with 5.9 acres of palustrine forested/scrub–shrub wetlands (seasonally flooded/saturated). In addition, enhancement of 16.2 acres of low value wetland, protection of a high value riparian corridor and its headwaters, and provide funding for a research project on local wetland ecology will also occur. In summary, in compensation for filling 5.85 acres of mostly low value wetland, 73.6 acres of wetlands and uplands will be protected, enhanced, and created.

Table 1. Total area and classes of wetlands to be impacted and proposed compensation for mitigation

Impacts	**Compensation**			
Filled	Created	Enhanced	Protected	Research
4.30 acres seasonally saturated isolated ag. PEM. **1.45** seasonally saturated isolated PSS **0.1** seasonally saturated isolated PFO	**5.9** acres seasonally saturated PSS/PFO connected to riparian corridor	**16.2** ac. seasonally saturated, seasonally flooded PSS/PFO Meanders added to stream channel	100 feet on each side of stream channel in a native growth protection easement recorded on the plat Created wetlands, enhanced wetlands, buffers and research area in a native growth protection easement	Funding for a wetland ecology research project on a **1.5** acre area near the enhancement and creation area
Total wetland acres to be filled: **5.85**	Total wetland acres created: **5.9**	Total enhanced wetland acres: **16.2**	Total acres protected: **50**	Total acres dedicated to research: **1.5**
Total acres of wetland disturbed: **5.85**	Total acreage provided in compensation: **73.6**			

2.4 Wetland Delineation

The project site includes palustrine emergent (PEM), palustrine scrub–shrub (PSS), and palustrine forested (PFO) wetlands (ATSI 1995). The wetlands meet all three wetland parameters, but by differing degrees. In general, all on–site wetlands display a predominance of hydric vegetation, hydric soils with low chromas and mottles, and soils displaying wetland hydrology field indicators such as oxidized root channels.

Most of the wetlands impacted by this project (4.30 out of a total 5.85 acres) are seasonally saturated palustrine emergent wetlands are used as hayfields or pasture for cattle. Of the remaining 1.55 acres of wetlands, 1.45 acres are seasonally saturated palustrine scrub–shrub and 0.1 acre are seasonally saturated palustrine forested.

The wetlands were categorized using both the Whatcom County and the Washington Department of Ecology (DOE) Wetland Rating Systems (ATSI 1995). Using the Whatcom County Wetland Rating Category System (Note: the project is vested with the Whatcom County Critical Areas Ordinance) the PEM wetlands south of Henry Road are unregulated by Whatcom County, but are categorized as Category IV wetlands by the DOE. The remaining PEM wetlands are Category IV wetlands using either system. Both the PSS and PFO wetlands are Category III wetlands using either system.

Using the DOE wetland characterization sheets, identified important wetland functions include: water quality in the palustrine emergent wetlands; human impacts to wetlands, buffer structure and function, breeding, rearing, feeding, and wintering habitat for fish and/or wildlife, water quality, flood and storm drainage protection, and support of baseflow in the palustrine scrub–shrub wetlands; and human impacts to wetlands, buffer structure and function, water quality, and flood and storm drainage protection functions in the palustrine forested wetlands (ATSI 1995).

3.0 ECOLOGICAL ASSESSMENT OF IMPACT SITE

3.1 Vegetation

This parcel includes a variety of vegetation communities including upland forest, upland fields, upland shrub, palustrine emergent wetlands, and palustrine forested/scrub–shrub wetlands. Historically, the large parcels making up the project area were cleared and converted to agricultural fields and pasture. Today, fields south of Henry Road and along Aldergrove Road continue to be farmed in forage crops, but others have been abandoned and support forested and shrub vegetation. Some fields have been used intermittently as pasture for cattle, but the fields south of Henry Road have never been used for livestock grazing.

Seasonally saturated palustrine emergent wetlands are located in minor depressions and along drainages in fields and are dominated by non–native and invasive herbaceous plant species. Seasonally saturated palustrine forested and scrub–shrub wetlands are located within upland forests and shrub habitats and are dominated by native plant species. Below is a description of the on–site plant communities:

Upland Forest – Upland forest occupies the northwestern one–third of the property, as well as patches within fields and along the seasonal drainage. Most of the upland forest is a deciduous forest dominated by red alder (*Alnus rubra*) intermixed with paper birch (*Betula papyrifera*), western red cedar (*Thuja plicata*), and Douglas fir (*Pseudotsuga menziesii*). Understory species include: vine maple (*Acer circinatum*), snowberry (*Symphoricarpos albus*), Indian plum (*Oemleria cerasiformis*), red elderberry (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), sword fern (*Polystichum munitum*), and trailing blackberry (*Rubus ursinus*). The herbaceous layer is heavily shaded and sparse in most areas.

Upland Shrub – Upland shrub dominates logged areas and abandoned agricultural fields. This habitat type is most prominent at the southeast corner of Aldergrove and Gulf Roads, in the logged areas north of Lonseth Road and in isolated patches on the north and south sides of Henry Road. This habitat is typified by a regenerating canopy 15 to 20 feet high of red alder and paper birch. A dense shrub layer with Himalayan and evergreen blackberries (*Rubus discolor* and *R. laciniatus*), salmonberry, red elderberry, snowberry, thimbleberry (*Rubus parviflorus*), trailing blackberry and bracken fern (*Pteridium aquilinum*) standing 6 to 10 feet high. Except for exceptionally tall species (e.g. bracken fern), the herbaceous layer has been shaded out.

Upland Fields – Upland fields dominate along Aldergrove Road, the southwest ridge from Aldergrove Road towards Lonseth Road, and fields south of Henry Road. The fields are dominated by a facultative community of non–native pasture grasses and herbs. Representative species include red fescue (*Festuca rubra*), vernal sweetgrass (*Anthoxanthum odoratum*), meadow foxtail (*Alopecurus pratensis*), velvet grass (*Holocus lanatus*), redtop (*Agrostis alba*), hop clover (*Trifolium dubium*), Canadian thistle (*Cirsium arvense*), oxeye daisy (*Chrysanthemum leucanthemum),* reed canarygrass (*Phalaris arundinacea*), English and common plantains (*Plantago lanceolata* and *P. major*), and white clover (*Trifolium repens*).

Palustrine Emergent Wetlands (PEM) – PEM wetlands are located within depressions and shallow swales in the upland fields and along the northern portion of the seasonal drainage (Figure 3). The wetlands are composed of a single vegetation layer (herbaceous) with little complexity. They support non–native and invasive plant species dominated by, reed canary grass, meadow foxtail, red fescue, soft rush (*Juncus effusus*), and velvet grass. Additional species include: sawbeak sedge (*Carex stipata*), hare's–foot sedge (*Carex leporina*), slough sedge (*Carex obnupta*), bird's–foot trefoil (*Lotus corniculatus*), white clover (*Trifolium repens*), redtop, and Pacific silverweed (*Potentilla anserina*).

Palustrine Forested/Scrub–Shrub Wetland (PFO/SS) – Very few true forested wetlands are located within the study area. In most cases, the wetlands are dominated by shrubs, but have an upland canopy that extends over the wetland (Figure 3). The actual wetland plants include: salmonberry, black twinberry (*Lonicera involucrata*), hardhack (*Spiraea douglasii*), Nootka rose (*Rosa nootkana*), Hooker's willow (*Salix hookeriana*), Pacific willow (*S. lasiandra*), and slough sedge. The over reaching canopy is predominately red alder.

3.2 Water Regime

The topography within the study area is generally as flat to gently rolling terrain with shallow swales and small ridges. Moderate to steep bluffs are located along the marine shoreline and within the ravine located in the southeast corner of the study site. Site surface and subsurface drainage is directed towards the south. The majority of site surface drainage, either directly or indirectly, drains into the unnamed seasonal stream that flows into the Strait of Georgia approximately one–quarter mile west of Gulf Road. However, numerous ditches and roads intercept the natural hydrology of some wetlands.

The primary factors influencing the hydrology on this property are direct precipitation, stratigraphy, topography, soil texture, and a seasonally high perched water table. The average annual precipitation is 30 to 40 inches, with most falling in the months of November, December, January, February, and March. The average growing season is about 180 days, and begins mid–March and ends the first part of November. The stratigraphy of Whitehorn silt loams is a series of slowly permeable soil horizons that are composed of layers of silt loams, loams, and sandy loams. Typically, subsoils underlying the wetlands have a silty clay subsoil, but some are very sandy. Dense silty clay prevents surface water collected from direct precipitation from percolating downward, resulting in saturated or inundated surficial conditions whereas sandy subsoils allow surface water to percolate faster, not allowing wetland hydrology to accumulate. The majority of the site wetlands are underlain by Whitehorn silt loam, which technically,

has a seasonal perched high water table at a depth of 0 to 12 inches from the surface November through May. Although, ATSI (1995) data show the high water table varies on this site from 0 to 20 inches from the surface.

Hydrology within the agricultural fields is not well defined and the fields are saturated only on a seasonal basis. No primary field indicators of wetland hydrology were observed in many of the PEM wetlands, but secondary indicators included oxidized root channels in the upper 2 to 3 inches of the soil and local soil survey data indicating the presence of a seasonally high perched water table early in the growing season. Interviews with local farmers suggest that the agricultural fields can be farmed (plowed) late in the season (October and November) and as early as late April in most years, indicating that wetland hydrology is absent in the later growing season and present only very early in the growing season.

The National Wetland Inventory (NWI) indicates both seasonally saturated and seasonally flooded hydrologic conditions within the on-site wetlands. However, on-site data indicates that the majority of the on-site wetlands are seasonally saturated during the growing season and inundation is rare. Within these soil types, seasonally flooded wetlands generally display low matrix chromas and mottling to the surface demonstrating fluctuating water levels near and at the soil surface. However, data collected from some sample plots had matrix chromas between 2 and 3 with no mottles in the upper 12 inches of the soil surface. Chromas were not low enough to indicate prolonged saturation near the surface and the lack of mottles implies a stable water table below the major root zone during the growing season.

3.3 Soils

The Soil Conservation Service (SCS) indicates the presence of five soil series within the study area. The dominant soil series is Whitehorn silt loam, which occupies approximately 90 percent of the site. Whitehorn silt loam is listed as hydric on the local Hydric Soils List (SCS 1991). A ridge of non-hydric Birchbay silt loam extends from the corner of Aldergrove and Gulf Roads southwest to the west end of Henry Road. A ribbon of non-hydric Kickerville silt loam parallels the southwestern Birchbay soil on the west portion of the site, but most of this has been extensively disturbed by borrow pit activities. Non-hydric Whatcom silt loams are found on the western portion of the property between Aldergrove and Henry Roads as well as within the ravine on the eastern side of the parcel. Non-hydric Neptune very gravelly sandy loam occurs along the marine shoreline.

Indicators of wetland hydrology and vegetation were often difficult to distinguish within the agricultural fields. In those cases, the hydric soil criteria was used as the primary indicator for wetland determination in combination with any wetland hydrology or vegetation indicators available. Most on-site agricultural fields are underlain by Whitehorn silt loam. Although this soil series is indicated as hydric, hydric indicators were not located at all sample plots. Plots that displayed a topsoil color of 10 YR 3/2 or 3/3 with no evidence of mottling were designated as uplands: whereas soils within plots with topsoil colors of 10YR 2/1, 2/2 or 3/2 with mottles were considered hydric. The depth of the topsoil in the uplands exceeded 12 inches, but was usually less than 12 inches in the wetland soils. The subsoil was similar throughout the Whitehorn series, with a matrix color of 10YR 5/1-5/3 with distinct to prominent mottles. In some cases the matrix had a chroma of 3; not typically considered an indicator chroma, in others the matrix chroma was 2 without mottles.

3.4 Fauna

Wildlife utilizing this parcel are typical of species found in agricultural and deciduous forested areas in the marine shoreline areas of Whatcom County. In-depth studies have been performed on terrestrial birds and amphibians on the site, and other studies have included additional data on mammals, fish and invertebrate populations (ATSI 1995, Shapiro and Associates 1994).

A study was conducted by ATSI of the inland bird populations on this site in 1995 (ATSI 1995). The results of the study indicate the parcel supports birds typical of the local area. A total of 564 birds of 44 different species were observed during the spring of 1995 (ATSI 1995). The greatest numbers of birds were observed in the field habitats and the lowest numbers in the forests. The greatest species diversity was observed in the field and edge habitats, however other habitats had only slightly lower diversity.

The only priority bird species observed during the ATSI bird survey were bald eagles (*Haliaeetus leucocephalus*), great blue herons (*Ardea herodias*) and pileated woodpeckers (*Dryocopus pileatus*) (ATSI 1995). Bald eagles are a federal and state listed threatened species (WDFW 1995). Bald eagles were observed flying over the parcel in three instances. One mature and one immature eagle were observed, at separate times, flying parallel to the shoreline. In a third observation, a mature bald eagle was observed on the north side of the parcel. During another observation period in the Fall of 1995, two mature bald eagles were observed perched in a cottonwood tree at the mouth of the ravine and an immature eagle was observed flying from this location northwest, along the shoreline (ATSI staff, Nov. 1995).

Pileated woodpeckers are a state listed Candidate Species (WDFW 1995). Two observations of a single pileated woodpecker were made on different days along the shoreline. Because these observations were made on different days, it was not determined whether this was the same individual or if two birds utilize the site. Within the areas the pileated woodpeckers were observed, no trees were observed large enough to serve as nesting sites, but these habitats may serve as forage areas.

A great blue heron rookery is located northwest of the site on ARCO property (Norman per. comm.). Approximately 200 nests are present within this rookery. A regular flight pattern of great blue herons occurs near the seasonal stream corridor. The birds appeared to be flying to and from the rookery and shallows near Sandy Point during low tides (ATSI 1995). The great blue heron is listed as a State Monitor species and their breeding areas are listed as priority areas by the Washington Department of Fish and Wildlife (WDFW 1995, WDW 1994).

A large concentration of surf scoters (*Melanitta perspicillata*) was observed off-shore on May 9. Large concentrations of this species are known to congregate in this area to feed on herring spawn (Wahl 1994).

An amphibian and reptile survey was conducted by Shapiro and Associates, Inc. in 1993 (Shapiro 1994). Two frog species, two salamander species, and one reptile species were observed on the property. Red-legged frogs (*Rana aurora)* and Pacific chorus frogs (*Pseudacris regilla),* adults and tadpoles, were observed on the property. Tadpoles were observed in stagnant water pools and the brackish marsh. Northwestern salamander (*Ambystoma gracile*) and long-toed salamander (*A. macrodactylum*) were encountered under woody debris. A dead rough skinned newt (*Taricha granulosa*) was observed by ATSI staff on Gulf Road. According to distribution maps, five other amphibian species may occur in the vicinity of the project area (Leonard, et. al. 1993) including the Pacific giant salamander (*Dicamptodon tenebrosus*), western redback salamander (*Plethodon vehiculum*), ensatina (*Ensatina eschscholtzii*), western toad (*Bufo boreas*), and the non-native bullfrog (*Rana catesbeiana*).

Evidence of the following mammal use on the site has been documented: black-tailed deer (*Odocoileus hemionus*), coyote (*Canis latrans*), raccoon (*Procyon lotor),* opossum (*Didelphis marsupialis*) and mink (*Mustela vison*) (ATSI 1995 and Shapiro 1994). Other species may include: shrews, voles, deer mice, weasel, and skunk (Shapiro 1994).

Little information is available concerning fish populations on the parcel. The only possible fish habitat observed on the site are portions of the seasonal stream. The Shapiro Stream Habitat Survey (1994) indicates the possibility of chum (*Oncorhynchus keta)* or cutthroat trout (*O. clarkii)* use of the stream, but this was not confirmed and is doubtful. The Shapiro report goes on to state (ATSI staff concurs) the

hydroperiod of flow within the stream is not sufficient to provide habitat for these species. Other possible resident fish may include three-spine stickleback (*Gasterosteus aculeatus*) and sculpin (*Cottus sp.*). The only fish species observed during stream surveys performed by Shapiro staff was three-spine stickleback. To summarize, this is a seasonal stream that will not support fish from mid-Spring to mid-Fall due to absence of water. A large log and debris pile at the mouth of the stream also limits access to the stream to high tides only.

3.5 Functions and Values of Impacted Wetlands

Wetland Characterization sheets developed by the Washington Department of Ecology were used to assess the functional values of the on-site wetlands that would be impacted as the result of this project. Wetland functions have been divided into primary categories of wetland condition, buffers, wildlife habitat, fisheries habitat, hydrology, cultural values, shoreline stabilization, and heritage value. Within these primary categories individual functions are assessed point values of 1-3. Functions having values of 1 are considered low value; functions with values of 2 have moderate value; and functions with 3 points have high values.

Table 2 indicates the functions addressed for the PEM wetlands south of Henry Road and their associated values (Figure 3). Only water quality functions received values "moderate" or greater. The remaining functions received "low" values.

The overall wetland condition has a moderate to low value. The wetlands have been extensively impacted by past agricultural practices. The acreage south of Henry Road has been actively farmed for over 50 years. The wetlands and surrounding uplands are fields dominated by non-native pasture grasses that are presently mowed for hay. Each PEM wetland within this area is under one-half acre in size and is hydrologically isolated. Hydrological alterations include ditches within the fields and along Henry Road. The ditches along Henry Road may have had the greatest impact by separating wetlands in the southern fields from upgradient surface and subsurface drainage from wetlands on the north side of Henry Road.

The buffer surrounding these wetlands is mowed agricultural upland fields dominated by non-native grasses with small areas of forested/shrub habitat. The wetlands are greater than 100 feet from any other habitat type, but marine, forest, and shrub habitats are located within one-quarter mile. The vegetation cover between the wetlands and other habitats is mowed grass, providing low cover values.

Table 2. Palustrine Emergent Wetlands Functions and Values south of Henry Road

FUNCTION	VALUE
Human impacts to wetlands	1.5
Buffer structure and function	1.5
Breeding, rearing, feeding, and wintering habitat for fish and/or wildlife	1
Water quality	2
Flood and storm drainage protection	1
Support of baseflow	1
Shoreline stabilization	N/A
Sea level rise	N/A
Groundwater exchange	1
Cultural values	0
Heritage value	0

Habitat value within these wetlands is low. The low value is associated with their small size, isolated nature, and lack of structural diversity. As mentioned previously, the PEM wetlands are all under one-half acre in size and are hydrologically isolated. The buffer area is predominately mowed agricultural fields. Vegetation within the wetlands is dominated by non-native plant species consisting of a single vegetation class. The wetlands have a simple shape and no interspersion of wetland classes, resulting in reduced edge habitat. No significant habitat structures (e.g. downed logs, snags and/or perches) were observed within these wetlands or their associated buffers. The only connection to other habitat types is via mowed open fields. There is no connection to fish habitat.

The PEM wetlands serve "low" to "moderate" hydrological functions. The wetlands are located in shallow depressions underlain with silt and clay. The average surrounding slope is low (<3%). There is no apparent inlet or outlet to the wetlands. The wetlands are isolated and water is removed primarily through direct evaporation and evapotranspiration. The ditches have altered the natural hydrology of the wetlands, separating them from upgradient drainage. The wetlands are vegetated with pasture grasses, that may aid water quality during the growing season.

Cultural and Heritage values of these wetlands are "low". This is based on the small size, dominance by non-native and invasive plant species, disturbance, location on private property, and because the parcel is not known to be listed as a local, State, or Federal heritage site.

Table 3 indicates the functions addressed for the palustrine scrub-shrub wetlands (immediately north and south of Henry Road) and their associated values. Functions with the highest values are: human impact, buffer structure and function, wildlife habitat, water quality, flood and stormwater protection, and support of baseflow. The remaining functions received "low" values.

Human impact to these wetlands has been moderate. The wetlands have experienced alterations resulting from past logging, agriculture, and livestock grazing, but are now regenerating. Based on aerial photographs and interviews with local farmers, most of these fields were cleared and used in the past for agricultural crops and livestock grazing. The fields are now abandoned and support dense shrub communities. Other disturbances include logging within wetlands and ditches that have interrupted the natural hydrology to the wetlands. The wetlands are dominated by non-native vegetation, but also include native plants. Probable pollutants could include sedimentation and nutrient inputs from past agricultural and logging activities.

Table 3. Palustrine Scrub-Shrub Wetland Functions and Values.

FUNCTION	VALUE
Human impacts to wetlands	2
Buffer structure and function	2.5
Breeding, rearing, feeding, and wintering habitat for fish and/or wildlife	2
Water quality	3
Flood and storm drainage protection	2
Support of baseflow	2
Shoreline stabilization	N/A
Sea level rise	N/A
Groundwater exchange	1
Cultural values	0
Heritage value	0

The wetlands are buffered by a mix of forested/shrub, mowed agricultural fields and roads. The buffer is greater than 100 feet where forest, shrub and fields occur.

These wetlands have moderate wildlife habitat values. The wetlands include both palustrine emergent and palustrine scrub-shrub wetland classes with moderate interspersion and shape. Although open water is present and the wetlands are dry during the summer. Clumps of willows and small trees serve as perches for raptors in these fields. No other habitat features were identified. The wetlands are connected to other habitats via the on-site seasonal stream, but much of the riparian vegetation is limited to reed canarygrass. Fish do not inhabit these wetlands.

Water quality functions have "high" values. The wetlands have a combined large size, moderate level of disturbance, slow rate of water movement, and dense vegetation combined to provide significant water quality functions. These same features combined with the wetlands direct and indirect association with the on-site stream, allowing them to provide moderate values in flood and stormwater abatement, and support of the base flow of the stream. There is little data associated with the wetlands interaction with groundwater, but some on-site wetlands have a sandy subsoil indicating a possible interaction.

Cultural and Heritage values of these wetlands are "low". This is based on the disturbance, location on private property, and because the parcel is not known to be listed as a local, State, or Federal heritage site.

Table 4 indicates the functions addressed for the palustrine forested/scrub-shrub wetlands, located immediately north and south of Lonseth Road, and their associated values. Functions that have the highest values are: the overall wetland condition, buffer structure and function, water quality and flood and stormwater abatement. The remaining functions received "low" values.

Human impacts to these wetlands have been moderate. Logging has occurred in the past which has reduced the total canopy cover and allowed non-native blackberries to invade in some and in others the wetlands have recovered from logging that occurred more than 10 years ago. Peripheral ditches along the roads may have altered the original hydrology, but sufficient hydrology remains to support these communities. Past logging may have temporarily increased sediment loads, but no pollutants are currently apparent.

Table 4. Palustrine Forested/Scrub-Shrub Wetland Functions and Values.

FUNCTION	VALUE
Human impacts to wetlands	3
Buffer structure and function	2.5
Breeding, rearing, feeding, and wintering habitat for fish and/or wildlife.	1.5
Water quality	3
Flood and storm drainage protection	2
Support of baseflow	1
Shoreline stabilization	N/A
Sea level rise	N/A
Groundwater exchange	1
Cultural values	0
Heritage value	0

Buffers around the wetlands are composed of forest and shrub vegetation greater than 100 feet wide. These wetlands have low to moderate wildlife habitat functions. No open water component is present. Palustrine forested and scrub-shrub wetland classes are both present. Emergent vegetation is present, but makes up less than 10 percent of the community. Simple interspersion occurs between the wetland classes with moderate to complex wetland shapes. Habitat features include fallen logs, small snags and perches. There are narrow corridors with forested to herbaceous vegetation cover to other habitats. There is no documentation that these wetlands are connected to a fish habitat.

Water quality functions have "high" values. The wetlands are moderately (30 to 75% areal cover) vegetated with persistent and non-persistent vegetation. Because the wetlands are located in isolated depressions, water movement is slow to non-existent. The surrounding area around the wetlands has low (3% to 8%) slopes. These features provide the wetlands with high nutrient trapping features.

Cultural and Heritage values of these wetlands are "low". This is based on the disturbance, location on private property, and because the parcel is not known to be listed as a local, State, or Federal heritage site.

3.6 Water Quality

No surface water observed.

3.7 Buffers

Buffers surrounding the palustrine emergent wetlands are predominately closely mowed agricultural upland fields dominated by non-native grasses, with small areas of forested/shrub habitat. The wetlands are greater than 100 feet from any other habitat type, but marine, forest, and shrub habitats are located within one-quarter mile. The vegetation cover between the wetlands and other habitats is mowed grass, providing little cover for wildlife.

The palustrine forested and scrub-shrub wetlands are buffered by a mix of forested/shrub, mowed agricultural fields and roads. The buffers are greater than 100 feet where forest, shrub and fields occur.

3.8 Wetland Rating

Based on the Whatcom County and the DOE Wetland Rating System, the PEM wetlands (south of Henry Rd and on the west edge of the site) are unregulated Category IV wetlands; the remaining PEM wetlands (to the north and extreme east) are regulated Category IV wetlands. The DOE four tiered rating system designates these wetlands as Category IV wetlands. These ratings are based on small size (less than one-half acre in size), isolation, hydrological alteration, and the presence of a single wetland class dominated by vegetation that is primarily non-native, invasive wetland species.

The Whatcom County Wetland Rating System indicates the palustrine scrub-shrub wetlands are Category III wetlands. The DOE four tiered rating system designates these wetlands as Category III wetlands. These ratings are based on combined size of greater than 5 acres, hydrological connection to a seasonal stream, and the presence of two wetland classes dominated by both non-native and native vegetation.

The Whatcom County Wetland Rating System places the palustrine forested/scrub-shrub wetlands (predominately north of Lonseth Road) in Category III. The DOE four tiered rating system designates these wetlands as Category III wetlands. These ratings are based on a total size greater than 5 acres, hydrological isolation, moderate complexity, forested class and vegetation dominated by a mix of native and non-native plant species.

Based on the Whatcom County Water Categories rating system, the on-site stream is a Type 4 Water below Henry Road and a Type 5 Water above. This rating is based on the streams seasonal nature, no records of use by anadromous fish or game fish, and no domestic use. The average channel width is between 2 and 3 feet in most areas and 3 to 6 feet south of Henry Road, although some areas of the channel have been widened by ditching in the fields on the north part of the site near Aldergrove Road.

3.9 Position and Function of Wetlands in Landscape

The proposed impact area lies within the watershed of the on-site stream. This unnamed stream is a small, seasonal drainage that flows into the Strait of Georgia. The stream is approximately 1.25 miles long and has a drainage area of approximately 800 acres (Shapiro 1994). The headwaters of the stream are located on a relatively flat terrace, most of which is ditched. The lower reaches of the stream flows through a ravine into the Strait of Georgia.

A forested and shrub dominated riparian corridor is present along most of the stream, except near its headwaters. Vegetation in the headwaters vicinity is predominately reed canarygrass.

4.0 MITIGATION GOALS, OBJECTIVES AND PERFORMANCE STANDARDS

4.1 Goals

This mitigation plan will directly and indirectly compensate for lost wetland acreage and functions. **Five goals** have been established for the mitigation project. The **first** goal is to create 5.9 acres of seasonally saturated palustrine forested/scrub-shrub wetland to provide a 1:1 areal replacement ratio with greater functional value for wetlands filled. This 5.9 acres of seasonally saturated palustrine forested/scrub-shrub wetlands will be created to compensate for filling 4.30 acres of seasonally saturated farmed palustrine emergent wetland, 1.45 acres of seasonally saturated scrub-shrub wetland and 0.10 acre of seasonally saturated forested wetland.

The **second** goal is to enhance a 16.2 acre monotypic stand of reed canarygrass into a diverse forested wetland habitat. In order to meet this goal, the dominance of reed canarygrass in 16.2 acres of the field in the southwest corner of Aldergrove and Gulf Roads will be reduced. Native tree, shrub, and herbaceous plants will be planted and large organic debris (logs and root masses) placed, to diversify the community and provide habitat and food chain support for native mammals, birds, amphibians and aquatic macroinvertebrates. A complex hydrologic regime of seasonally flooded to seasonally saturated wetlands will be created.

The **third** goal is to assure the protection of the on-site stream corridor. The stream channel and the associated riparian area (100 feet on both sides of channel) would be placed in a conservation easement recorded on the property deed (encompassing approximately 50 acres).

The **fourth** goal is to conduct a study on a designated 1.5 acre plot. The study will research the natural regeneration of vegetation within seasonally saturated, palustrine emergent agricultural fields. It addition the study will investigate the success of selected upland, facultative upland, and facultative wetland plants planted over a range of hydrogeomorphic regimes.

The **fifth** goal is not directly related to wetland disturbance but addresses cultural functions lost on a regional basis. This goal will provide compensation for the local loss of natural resources (specifically western red cedar) important to the Lummi Indian Tribe's culture heritage.

4.2 Objectives and Performance Standards

To achieve the above goals the following objectives have been defined. Performance standards have been included to provide measurable values of specific variables to establish that objectives have been met.

Goal 1: Create 5.9 acres of seasonally saturated palustrine forested/scrub-shrub wetland to provide a 1:1 areal replacement ratio with greater functional value for wetlands filled.

Water Regime

A. A seasonally saturated hydrologic regime will be present within the created wetland areas.

> Performance Standard: A minimum of 5.9 acres will be saturated within the upper 12 inches of the soil horizon for at least 21 days during the early growing season (March/April) (Figure 5).

Vegetation Structure

A. The created wetland areas will be vegetated with a minimum of 5.9 acres of palustrine forested/scrub-shrub vegetation class with canopy, shrub, and herbaceous vegetation layers. Partial planting of the plants will occur one year after construction to allow confirmation of the hydrological regime. Monitoring will occur over a ten year period on a seasonal basis with reports written the 1st, 3rd, 5th, 7th, and 10th years post construction/planting.

> **First year monitoring.** Performance Standard: Native plant species will have a minimum cover of 15% after the first year.
>
> **Third year monitoring.** Performance Standard: Native plant species will have a minimum cover of 25% after the third year.
>
> **Fifth year monitoring.** Performance Standard: Native plant species will have a minimum cover of 50% after the fifth year.
>
> **Seventh year monitoring.** Performance Standard: Native plant species will have a minimum cover of 75% after the seventh year.
>
> **Tenth year monitoring.** Performance Standard: Native wetland forest vegetation will cover the 5.9 acre site with 50% canopy cover, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Goal 2: Enhance a 16.2 acre monotypic stand of reed canarygrass into a diverse palustrine forested wetland habitat.

Water Regime

A. Both seasonally saturated and seasonally flooded hydrologic regimes will be present within the enhancement area.

> Performance Standard: A minimum of 16.2 acres will be a complex (an approximate 8.1 acres of each) of seasonally saturated and seasonally flooded soils. The saturated zone will occur within the upper 12 inches of the soil horizon for at least 21 days during the early growing season

(March/April). The flooded zone will also occur for 21 days during the growing season with an approximate depth of 24 inches.

Vegetation Structure

A. The dominance of reed canarygrass will be reduced within the mitigation area within ten years.

Performance Standard: Less than a 25% cover of reed canarygrass, measured along permanent transects with at least 20X50 cm rectangular quadrats systematically placed along transects, will be present after ten years.

B. The wetland will be vegetated with a minimum of 16.2 acres of palustrine forested, scrub–shrub and emergent vegetation classes composed of native plant species. Percent cover of the vegetation and number of live and dead plants (by species) will be measured along permanent transects using at least 20X50 cm quadrats. Partial planting of the plants will occur one year after construction to allow confirmation of the hydrological regime. Monitoring will occur over a ten year period on a seasonal basis with reports written the 1st, 3rd, 5th, 7th, and 10th years post construction/planting.

First year monitoring. Performance Standard: Native plant species will have a minimum cover of 15% after the first year.

Third year monitoring. Performance Standard: Native plant species will have a minimum cover of 25% after the third year.

Fifth year monitoring. Performance Standard: Native plant species will have a minimum cover of 50% after the fifth year.

Seventh year monitoring. Performance Standard: Native plant species will have a minimum cover of 75% after the seventh year.

Tenth year monitoring. Performance Standard: Native wetland forest vegetation will cover the 16.2 acre site with 50% canopy cover, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Habitat Attributes

A. The enhancement area will provide habitat for at least four species of **amphibians** within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for both terrestrial and aquatic amphibian species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present within the enhancement area early in the growing season (Feb.–July). To restrict occupation by bullfrogs (*Rana catesbeiana*) year–long inundation within the enhancement area will be avoided.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

B. The enhancement area will provide habitat for at least four species of **aquatic insects** within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for aquatic invertebrates. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present within the enhancement area early in the growing season (Feb.–July).

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

C. The enhancement area will provide habitat for at least three **waterfowl** species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide nesting sites, cover and forage areas for waterfowl species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present within the enhancement area early in the growing season (Feb.–July).

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Performance Standard: A minimum of 5 temporary nesting boxes suitable for cavity nesting waterfowl (e.g. wood duck, hooded merganser) will be placed around the mitigation area.

D. The enhancement area will provide habitat for at least two **mammal** species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for mammal species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years to provide cover and forage for mammal species.

E. The enhancement area will provide habitat for at least five **passerine** bird species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide nesting sites, cover and forage areas for passerine species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present within the enhancement area early in the growing season (Feb.–July).

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Performance Standard: A minimum of 5 temporary nesting boxes suitable for passerine species will be placed around the mitigation area (e.g. tree and violet green swallows, black-capped chickadee, Bewick's wren).

Goal 3: Assure the protection of the on-site stream corridor. The stream channel and the associated riparian area (100 feet on both sides of channel) will be placed in a conservation easement recorded on the property deed (total area encompasses approximately 50 acres).

Goal 4: Conduct a study on a designated 1.5 acre plot researching the natural regeneration of vegetation over time of a seasonally saturated, palustrine emergent agricultural field and investigate the success of selected upland, facultative upland, and facultative wetland plants planted over a range of hydrogeomorphic regimes within this field.

A. Record the natural successive changes over time in an agricultural palustrine emergent wetland over a range of hydrogeomorphic regimes.

B. Investigate the success of selected upland, facultative upland, and facultative wetland plant species planted over a range of hydrogeomorphic regimes.

Goal 5: This goal is not directly related to wetland disturbance, but addresses cultural functions lost on a regional basis. This goal will provide compensation for the local loss of natural resources important to the Lummi Indian Tribe's culture heritage.

A. Natural resources available for harvest by the Lummi Indian Tribe will be established to provide totem pole stock and cedar bark for future cultural uses by the Lummi Indian Tribe.

5.0 PROPOSED MITIGATION SITE

5.1 Site Description

The proposed mitigation areas are located on the parcel and within the on-site watershed. The parcel lies within unincorporated Whatcom County, east of the City of Ferndale (within the northeast quarter of Section 18, Township 39 North, Range 1 East of the Willamette Meridian) (Figure 1). The subject area is located in a farmed 40 acre field in the southwest corner of Aldergrove and Gulf Roads and along the riparian corridor (Figure 4). This plan includes creation of 5.9 acres of palustrine forested/scrub-shrub wetland, enhancement of 16.2 acres of a reed canarygrass dominated palustrine emergent wetland, protection of a high quality riparian corridor, and funding for a research project on wetland ecology.

5.2 Ownership

Jeff Kaspar (contact person)
Pacific International Terminals
Gateway Pacific Terminal
1801 Roeder Avenue, Suite 156
Bellingham, Washington 98225

5.3 Rational for Choice

The entire parcel (1,092 acres) was searched for potential mitigation sites. The final site selection was based on future protection, connection to an existing riparian corridor, degraded conditions of existing wetlands, access for heavy equipment, and ownership. Since much of the immediate area is presently designated as wetland palustrine forested (PFO), palustrine scrub-shrub (PSS), palustrine emergent (PEM), or high quality upland, a degraded 16.2 acre, low value PEM wetland and ditched stream channel were chosen for enhancement. In addition, 5.9 acres of PFO/PSS will be created in the same area, further enhancing this area.

Water regime

The site currently supports wetlands and the upland soils have a silty/clay subsoil that is suitable for wetland creation. The primary factors influencing the hydrology in the mitigation area are seasonal flooding, direct precipitation, and topography. Seasonal flooding from the on-site seasonal stream and upgradient runoff appear to be the forces driving on-site's wetland hydrology. In addition, a seasonal perched high water table may contribute to the hydrology in the late winter and early growing season. The wetland area is underlain by Whitehorn silt loam, that technically has a seasonal perched high water table at a depth of 0 to 1 foot from the surface November through May.

The National Wetland Inventory map indicates seasonally flooded hydrologic conditions within the chosen mitigation area. Typically, on-site wetland soils display low matrix chromas and mottling to the surface demonstrating fluctuating water levels near and at the soil surface.

A hydrology study was conducted in the area of the proposed mitigation, and other areas of the site by Shapiro and Associates, Inc. from November 1994 through October 1995 (Shapiro and Associates 1995. Their monitoring data indicate soils within the enhancement area are saturated to the surface or flooded with up to 6 inches of water from December until mid-May. After May the water table quickly drops and remains at 2 feet or below the surface throughout the summer.

Buffers

The proposed mitigation site is currently buffered by field and forest vegetation. The buffer within 100 feet of the existing wetland is dominated by non-native grasses on the northwest side, Gulf Road on the east, and regenerating shrub and forest vegetation on the south. Beyond the immediate buffer, forest and shrub vegetation dominate on the east side of Gulf Road and to the south and west of the mitigation area: the ARCO Refinery is located on the north side of Aldergrove Road. A shrub and forested community forms a dense riparian system up and down gradient of the on-site stream. The on-site reach of the seasonal stream lays within a ditch choked with reed canarygrass. Prior to ditching, the stream was probably a headwaters wetland with no channel. The ditch was presumably dug to facilitate drainage for agricultural use.

Surrounding land uses include: fallow fields to the east, forested tracts to the west and south, and Heavy Industry with rail to the north. The immediate use of the land for the selected mitigation site is a seasonally mowed hay field.

Soils

The silty Whitehorn silt loam soils on this site are suitable for wetland enhancement as is the neighboring Kickerville silt loam. They will provide sufficient hydrology as evidenced by the existing wetland. A silty-clay subsoil, found in both soil series, ensures slow percolation rates.

Reed canarygrass currently dominates the site and will require treatment. Because reed canarygrass occurs upstream and cannot be controlled, fumigation or importation of "clean" soils is not cost effective. The money saved will be used in a regular maintenance program. Site soils are also discussed in detail in Section 4.2 of this document.

Zoning

Current zoning for this site and the immediate area is Heavy Industrial.

6.0 Ecological Assessment of Mitigation Site

6.1 Vegetation

Vegetation within the proposed mitigation site is predominately agricultural palustrine emergent wetlands, but also includes agricultural upland fields. This site is currently farmed for forage crops. Seasonally saturated palustrine emergent wetlands are located in a flat depression southeast of a prominent upland ridge. The vegetation within the uplands and wetlands is dominated by non-native herbaceous plant species. Seasonally saturated and flooded scrub-shrub wetlands are located south and east of the mitigation site and are dominated by both non-native and native plant species. A ditched seasonal stream passes through the wetland, but is choked with reed canarygrass (Figure 4). Below is a description of the vegetation communities within the mitigation (creation, enhancement, and study) areas:

Upland Fields – Upland fields dominate the ridge running from Aldergrove Road towards Lonseth Road. Approximately 13 acres of upland field are located within the proposed mitigation area. The fields are dominated by a facultative community of non-native pasture grasses that is mowed annually. Representative species include: red fescue (*Festuca rubra*), vernal sweetgrass (*Anthoxanthum odoratum*), meadow foxtail (*Alopecurus pratensis*), velvet grass (*Holocus lanatus*), redtop (*Agrostis alba*), hop clover (*Trifolium dubium*), Canadian thistle (*Cirsium arvense*), oxeye daisy (*Chrysanthemum leucanthemum),* reed

canarygrass (*Phalaris arundinacea*), English and common plantains (*Plantago lanceolata* and *P. major*), and white clover (*Trifolium repens*).

Palustrine Emergent Wetlands (PEM) – PEM wetlands are located within a flat depression at the headwaters of the seasonal stream corridor. Approximately 16.2 acres of PEM wetlands are located within the immediate proposed mitigation area. The wetlands are composed of a single vegetation class (herbaceous) with little complexity and is mowed annually. These wetlands support non-native and invasive plant species, predominately reed canarygrass, but meadow foxtail, red fescue, soft rush (*Juncus effusus*), velvet grass, sawbeak sedge (*Carex stipata*), bird's-foot trefoil (*Lotus corniculatus*), white clover (*Trifolium repens*), and redtop (*Agrostis alba*) are also present.

6.2 Water Regime

The topography within the mitigation area can be generally defined as flat to gently rolling terrain with a prominent ridge along the northwest side. Site surface and subsurface drainage is directed towards the south, off the adjacent ridge. A ditched seasonal stream crosses the subject area, although the ditch has not been maintained and is choked with reed canarygrass. The majority of the surface drainage either directly or indirectly drains into the unnamed seasonal stream, which flows into the Strait of Georgia approximately one mile south of the mitigation site.

A significant portion of the hydrology supporting this wetland originates from seasonal flooding of the site stream and poor soil percolation. Other factors influencing the hydrology within this wetland are direct

precipitation, stratigraphy, topography and soil texture. The average annual precipitation is 30 to 40 inches, with most falling in the months of November, December, January, February, and March. The average growing season is about 180 days and begins mid-March and ends the first part of November. The majority of the site wetland is underlain by Whitehorn silt loam, that, for this location, has a seasonal perched high water table at a depth of 0 to 12 inches from the surface November through May. The stratigraphy of Whitehorn silt loams is a series of slowly permeable soil horizons that are composed of layers of silt loams, loams, and sandy loams. Typically, subsoils underlying the wetlands have a silty clay subsoil. Dense silty clay prevents surface water collected from direct precipitation from percolating downward, resulting in saturated or inundated soil conditions, forming a perched high water table.

6.3 Soils

The Soil Conservation Service (SCS) indicates the presence of two soil series within the mitigation area. The dominant soil series is Whitehorn silt loam, which occupies the low areas within the site. Whitehorn silt loam is listed as hydric on the local Hydric Soils List (SCS 1991). A ridge of non-hydric Birchbay silt loam extends from the corner of Aldergrove and Gulf Roads southwest to the end of Lonseth Road.

6.4 Fauna

Although no sample plot was located in the mitigation area during bird surveys, notes were kept during site visits to this area (ATSI 1995). Birds observed included marsh wren, northern shrike, song sparrow, Savannah sparrow, common yellowthroat, barn and cliff swallows, northern harrier, and red-tailed hawk. Pacific chorus frogs were heard calling in the area and one dead rough-skinned newt was collected from the adjacent road (Gulf Road). No mammals were observed within the mitigation area, but frequent observation of coyote and deer, scat and prints, indicates these species commonly use the area. Refer to Section 3.4 for further information.

6.5 Existing Functions and Values

The Wetland Characterization system developed by the Washington Department of Ecology was used to assess the functional values of the wetland currently located within the proposed mitigation site. Wetland functions are divided into primary categories of wetland condition, buffers, wildlife habitat, fisheries habitat, hydrology, cultural values, shoreline stabilization, and heritage value. Within these primary categories individual functions are assessed point values of 1-3. Functions having values of 1 are considered low value; functions with values of 2 have moderate value; and functions with 3 points have high values. Below is a summary for the palustrine emergent, reed canarygrass wetland proposed for enhancement.

Table 5 indicates the functions and associated values for the wetland currently present in the proposed mitigation area. Functions which serve "moderate to high" values are: human impact, water quality, flood and storm drainage protection, and support of baseflow. The remaining functions received "low" values.

Table 5. Wetland Functions Currently Present at Mitigation Site.

FUNCTION	VALUE
Human Impact	2
Buffer structure and function	1.5
Breeding, rearing, feeding, and wintering habitat for fish and/or wildlife.	1
Water quality	3
Flood and storm drainage protection	2
Support of baseflow	3
Shoreline stabilization	N/A
Sealevel rise	N/A
Ground water exchange	1
Cultural values	1
Heritage value	1

Several sources of human impact to this wetland have been observed. The surrounding land uses include regenerating forested tracts that were logged approximately 5 years ago, mowed agricultural land, and the ARCO refinery across Aldergrove Road. Gulf Road abuts the eastern side of the wetland. The headwaters to the on-site seasonal stream are the ditches along Gulf Road. Runoff from the roads may be a potential source of moderate pollutants entering the system. Other impacts include past ditching of the on-site seasonal stream and yearly mowing of the surrounding fields and wetland vegetation. The wetland is currently dominated by invasive plant species (reed canarygrass). The immediate buffers around the wetland are a mix of regenerating forest, mowed hay fields, and Gulf Road.

The current habitat value within this wetland is low. The wetland is composed of a single vegetation class dominated by non-native and invasive herbaceous plant species. No open water is present. The wetland has a moderate percentage of edge area for its shape. Habitat features such as snags, logs, or perches are absent from the wetland or the immediate buffer, except to the south, where low perches are present. Due to it's seasonal nature, the wetland and stream do not provide habitat for fish, but downstream the stream flows into a brackish marsh (one mile south) that may support fish. No fish have been found and are not considered to be present within the wetland.

Based on the Wetland Characterization forms, the wetland serves high water quality functions. This value is based on a relatively large size (> 10 acres, including off-site), moderate pollution inputs, slow water movement within the wetland, dense emergent vegetative cover, and moderately low slopes surrounding the wetland. Water movement is slow during flood periods to non-existent outside the flood season. The rate of movement within the wetland is slowed by low gradients and dense emergent vegetation.

The wetland serves moderate flood and stormwater abatement functions. The wetland is adjacent to a seasonal stream and is located at the headwaters of the stream. The wetland is located in a slight depression, providing low to moderate storage capacity. The dense emergent vegetation aids in reducing velocities and settling suspended sediment.

Because the wetland is adjacent to a seasonal stream, upgradient from a brackish marsh system, it has significant value in supporting the baseflow for the stream.

The wetland is not associated with any large body of water (lake, river, marine system), so does not serve functions associated with shoreline stabilization or sea level rise.

Heritage and Cultural values associated with this wetland are low. The wetland does not provide any apparent aesthetic value. It is a reed canarygrass dominated agricultural field. The wetland is not of a sensitive class and is not documented by the Natural Heritage Society as a high quality wetland. The site is not known to be on the National or State Register of Archaeological and Historic Sites and is not known to support any endangered, threatened, sensitive, or priority plant or animal species. The site is not identified in the any local Parks or Recreation Plans.

6.6 Expected Wetland Functions Post-Creation and Enhancement

Functional value will increase with most functions and at a minimum remain the same as a result of the proposed enhancement activities (Table 6). The only functions not expected to increase in value after enhancement are groundwater exchange and heritage value (heritage should however increase significantly as the created and enhanced wetlands mature). The soils underlying the wetland have a dense silt-clay layer restricting interaction with groundwater, enhancement activities would not change this. Heritage values are base on the presence of rare wetland communities and/or the presence of rare or sensitive plants or animals. Although the mitigation project will create palustrine forested wetlands, it will take many decades before the site would fit the description of a mature forested wetland.

Table 6. Expected Changes in Wetland Functional Values within Enhanced Wetlands.

Function	Current Value	Post-Enhancement Value
Human Impact	2	3
Buffer structure and function	1.5	3
Breeding, rearing, feeding, and wintering habitat for fish and/or wildlife	1	3
Water quality	3	3
Flood and storm drainage protection	2	2
Support of baseflow	3	3
Shoreline stabilization	2	3
Sea level rise	N/A	N/A
Ground water exchange	1	1
Cultural value	1	2
Heritage value	1	1

Surrounding landscapes will include forested and shrub habitat to the south and west and a connection to the protected stream corridor. This adjoining stream corridor is a naturally vegetated corridor that extends from the mitigation site to the marine environment. This mitigation proposal places the stream corridor (100 feet on both sides of stream high water mark) in a conservation easement recorded on the property deed.

A rail line will be located approximately 50 feet west of the enhancement area and will lie between the creation areas. The area surrounding the rail line will be planted with native upland shrubs and trees to provide sound and visual buffers. Gulf Road is adjacent to the east side of the project with no upland buffer per se, however the current emergent vegetation will be enhanced with native tree and shrub species, providing a buffer with more diversity and structure.

The wetland lies at the headwaters of the seasonal stream. Wetland hydrology is currently provided by a straight ditch surrounded by non-native, herbaceous vegetation. The ditch will be rerouted to flow through

a series of seasonal pools and re-vegetated with native herbaceous, shrub, and tree species. Water movement through the existing wetland is slow and passes through dense emergent vegetation. Water movement through the mitigation area would continue to be slow and pass through a dense combination of herbaceous and woody vegetation. Although the wetland currently provides significant water quality functions, addition of woody plant species and increased structural diversity of the topography and vegetation will further increase water quality functions.

Current human impacts to the on-site wetland include ditching, road run-off, seasonal mowing, and past logging in the forested buffer to the south. Much of the water entering the wetland originates from road side ditches along Gulf Road. This water may contain some pollutants typical of road runoff (e.g. petroleum products and heavy metals). Increased channel area and floral diversity would increase the mechanical and biological treatment of pollutants within the mitigation area.

Habitat value within the mitigation area will increase in functional value. The wetlands are currently dominated by a single vegetation class (dominated by an invasive plant species) with no interspersion between wetland classes. No significant habitat features currently exist within the wetland. Enhancement of this area would increase the number of wetland classes from one to four and increase the percentage of native wetland plants. Habitat features (e.g. snags, logs, perches, islands) will be added during the construction and also will naturally form as the community matures. As mentioned previously, the mitigation area is connected to a larger riparian-marine corridor that will be protected under a conservation easement.

At present there is little cover over the stream channel other than reed canarygrass. Plantings of dense woody plant species will provide a canopy that will shade the water to maintain low water temperatures. Large organic matter (e.g. logs and root masses) will provide shelter for invertebrates and amphibians, add structural diversity, and will act as nurse logs.

6.7 Functions Summary

Table 7 provides a comparison of the existing wetlands to be filled with the changes in functions and values as the result of this project. A total of 5.85 acres of existing wetlands and their associated functions will be lost due to fill. The lost wetland acreage will be replaced by creating an equal area of wetlands within the proposed mitigation area. In addition, the values of all the functions found in the filled wetlands will be replaced and increased. The increase in value will be associated with a greater floral, faunal, and structural diversity; association with a seasonal stream and a riparian corridor; and placed in a native growth protection area.

Proposed enhancement of a wetland that is currently of low value will increase in value in most functions (Table 7). The vegetation diversity, both in species and structure will be increased, improving wildlife and water quality and quantity functions. The resultant project will also provide more diverse scenic opportunities therefore increasing the culture functions.

Table 7. Summary of the functions and values for the impacted and mitigated wetlands.

Functions	Existing PEM Wetlands (4.3 acres)	Existing PSS Wetlands (1.45 acres)	Existing PFO Wetlands (0.1 acres)	Created PSS/PFO Wetlands (5.9 acres)	Enhanced Wetlands (16.2 acres)
Wetland Condition	1.5	2	3	3	3
Buffer Structure and Function	1.5	2.5	2.5	3	3
Wildlife Habitat	1	2	1.5	3	3
Water Quality	2	2	3	3	3
Flood and Stormwater Protection	1	2	2	2	2
Support of Baseflow	1	2	1	3	3
Shoreline Stabilization	n/a	n/a	n/a	n/a	n/a
Groundwater Exchange	1	1	1	1	1
Cultural Value	0	0	0	2	2
Heritage Value	0	0	0	1	1

6.8 Existing Water Quality

No water quality data has been collected to date.

6.9 Existing Buffers

The proposed mitigation site is currently buffered by field and forest vegetation. The buffer within 100 feet of the existing wetland is dominated by non-native grasses on the north and west side, Gulf Road on the east, and regenerating shrub and forest vegetation on the south. Beyond the immediate buffer, forested and shrub vegetation dominate on the east side of Gulf Road and to the south and west of the mitigation area, the ARCO refinery is located on the north side of Aldergrove Road.

Surrounding land uses include: fallow fields to the east, forested tracts to the west and south, and Heavy Industry with rail to the north.

6.10 Wetland Rating and Water Type

Based on the Whatcom County Wetland Rating System, this palustrine emergent wetland is a Category III wetland. The DOE four tiered rating system also designates this wetland as a Category III wetland. These ratings are based on a size of greater than 5 acres, hydrological connection to a seasonal stream, and the presence of one wetland class dominated by non-native and invasive vegetation (ATSI 1995).

Based on the Whatcom County Water Categories Rating System, the on-site stream is a Type 5 Water within the reach on the mitigation site. This rating is based on the streams seasonal nature, no records of use by anadromous fish or game fish, and no domestic use. The average channel width is between two and three feet in most areas. Within the reach on the mitigation site, the stream has been ditched and is currently choked with reed canarygrass.

6.11 Position and Function of Wetland in Landscape

The proposed mitigation enhancement site is located at the headwaters of an unnamed seasonal stream. Water collects from upstream ditches and flows southwest across the subject area. The stream flows within a ditch across the subject field and enters a braided channel south of the mitigation area. The stream flows through a large ravine, approximately 1/2 mile down gradient from the proposed mitigation area.

6.12 Site Constraints

None identified.

7.0 FINAL SITE PLAN

7.1 Methods

Goal 1: Create 5.9 acres of seasonally saturated palustrine forested/scrub-shrub wetland to provide a 1:1 areal replacement ratio for wetlands filled.

Water Regime

A. A seasonally saturated hydrologic regime will be present within the created wetland areas.

Performance Standard: A minimum of 5.9 acres will be saturated within the upper 12 inches of the soil horizon for at least 21 days during the early growing season (March/April).

Method for Performance Standard: Seasonally saturated wetlands will be created by removing the top 12 to 24 inches of topsoil to expose the perched water table from a total of 5.9 acres of upland (hydrology data from Shapiro 1995).

Vegetation Structure

A. The created wetland areas will be vegetated with a minimum of 5.9 acres of palustrine forested/scrub-shrub vegetation class with canopy, shrub, and herbaceous vegetation layers Partial planting of the plants will begin one year after construction to allow confirmation of the hydrological regime. Monitoring will occur over a ten year period on a seasonal basis with reports written the 1st, 3rd, 5th, 7th, and 10th years post construction/planting.

First year monitoring. Performance Standard: Native plant species will have a minimum cover of 15% after the first year.

Third year monitoring. Performance Standard: Native plant species will have a minimum cover of 25% after the third year.

Fifth year monitoring. Performance Standard: Native plant species will have a minimum cover of 50% after the fifth year.

Seventh year monitoring. Performance Standard: Native plant species will have a minimum cover of 75% after the seventh year.

Tenth year monitoring. Performance Standard: Native wetland forest vegetation will cover the 5.9 acre site with 50% canopy cover, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Methods for Performance Standard: Native emergent, shrub, and tree plant species from the list in Appendix C will be planted in random groupings of species. Plant sources will be from local nurseries using plants from the local gene pool. A combination of sprigs and seeds will be used in planting herbaceous plants. Plant material will be installed according to the specifications in Appendix C.

Goal 2: Enhance a 16.2 acre monotypic stand of reed canarygrass into a diverse forested wetland habitat.

Water Regime

A. Both seasonally saturated and seasonally flooded hydrologic regimes will be present within the enhancement area.

Performance Standard: A minimum of 16.2 acres will be a complex (an approximate 8.1 acres of each) of seasonally saturated and seasonally flooded soils. The saturated zone will occur within the upper 12 inches of the soil horizon for at least 21 days during the early growing season (March/April). The flooded zone will also occur for 21 days during the growing season with an approximate depth of 24 inches.

Methods for Performance Standard: Seasonally saturated and shallow seasonally flooded wetlands currently exist for the enhancement area. Additional deep (24 inches) flooded areas will be created by removing the top 6 to 12 inches of topsoil to expose the perched water table from approximately 1/2 of the area. In addition, small "islands" approximately 6 to 12 inches in height, using clean upland soil from adjacent areas, will be deposited within the flooded area. An excavator will be used to add meanders to the current straight, ditched stream channel. Soils removed for adding depth to the mitigation site will be transported off-site.

Vegetation Structure

A. The dominance of reed canarygrass will be reduced within the mitigation area within ten years.

Performance Standard: Less than a 25% cover of reed canarygrass, measured along permanent transects with 20X50 cm rectangular quadrats, will be present after ten years.

Method for Performance Standard: Reed canarygrass will be sprayed with glyphosate in the Spring. Several weeks after glyphosate application the field will be plowed, disked, and planted with a cover crop (Appendix C, such as annual rye). The field will be either entirely or spot sprayed between 30 to 45 days later and replanted with a cover crop. All spraying will be performed by a certified pesticide–herbicide applicator and monitored by a qualified biologist. If the reed canarygrass is greater than 24 inches high, it will be cut and bailed and will be allowed to grow approximately 2 inches prior to spraying.

B. The wetland will be vegetated with a minimum of 16.2 acres of palustrine forested, palustrine scrub–shrub and palustrine emergent vegetation classes composed of native plant species. Percent cover of the vegetation and number of live and dead plants (by species) will be measured along permanent transects using 20X50 cm quadrats. Partial planting of the plants will occur one year after construction to allow confirmation of the hydrological regime. Monitoring will occur over a ten year period on a seasonal basis with reports written the 1st, 3rd, 5th, 7th, and 10th years.

First year monitoring. Performance Standard: Native plant species will have a minimum cover of 15% after the first year.

Third year monitoring. Performance Standard: Native plant species will have a minimum cover of 25% after the third year.

Fifth year monitoring. Performance Standard: Native plant species will have a minimum cover of 50% after the fifth year.

Seventh year monitoring. Performance Standard: Native plant species will have a minimum cover of 75% after the seventh year.

Tenth year monitoring. Performance Standard: Native wetland forest vegetation will cover the 16.2 acre site with 50% canopy cover, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Methods for Performance Standard: Entire area will be planted with a representative sampling of the listed tree and shrub species (Figure 5 and Appendix C), bare root or 1 gallon containers, within groups of 5 to 10 plants spaced 20 to 100 feet apart, one year post excavation. The entire area will also be planted with a representative sampling of the below listed herbaceous species (herbs), bare root or seeds, within groups of 10 to 20 plants spaced 20 to 50 feet apart, two years post excavation. The herbaceous species will also be seeded (with seed hand collected locally), if practicable, randomly along the entire perimeter of the seasonally flooded areas, additional native plants may be included. The buffer and remaining area will be planted with annual rye. These plants and seeds will be planted in late winter (assume late February or mid March at the latest). This lapse of time will allow for a complete and thorough understanding of the seasonal variation within the water table, therefore increasing the success rate of the plantings. If natural recruitment of desired plants occurs prior to two years, planting will discontinue. Actual monitoring will begin the following summer (approximately one year after excavation) to allow time to observe natural vegetation recruitment and success of seed stock, bare root, and container plantings. It is the belief of the designer that natural recruitment of many plants will occur within one to two years of construction. It is therefore our intent to allow all natural non–invasive plants to become established and document their presence. Measurement of re–vegetation success will follow the first two years of construction and will consist of 50% cover (or one healthy plant per square meter of entire site). Success following three years post construction will be 100% cover of native and/or non–invasive species. If after the first two years following construction the goal

of one healthy plant per square meter is not obtained, the bare areas will be planted. Two as-built reports will be written, one post construction in the fall and the second post planting in early spring. All subsequent monitoring will occur on an annual basis during the fall (prior to the first killing frost) and reports the 1st, 3rd, 5th, 7th, and 10th year.

Habitat Attributes

A. The enhancement area will provide habitat for at least four species of **amphibians** within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for both terrestrial and aquatic amphibian species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present throughout the enhancement area early in the growing season (Feb.-July). To restrict occupation by bullfrogs (*Rana catesbeiana*) year-long inundation within the enhancement area will be avoided.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Methods for Performance Standards: Amphibian breeding habitat will be created by excavating pools with a variety of depths and sizes to maximize the potential breeding areas for a number of amphibian species (Figure 5). A variety of emergent plant species will be planted to provide support for amphibian egg masses. Pools will be excavated with low slopes and seasonal, but long duration standing water to provide breeding areas of northwestern salamanders, rough-skinned newts, red-legged frogs, Pacific chorus frogs, and long-toed salamanders that have long maturation rates. Pools with short inundation periods (3 to 5 weeks) will be created to facilitate Pacific chorus frogs and long-toed salamanders that utilize temporary pools. Approximately 200 each of logs and root masses will be spread throughout wetland areas to provide cover for amphibians.

B. The enhancement area will provide habitat for at least four species of **aquatic insects** within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for aquatic invertebrates. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present throughout the enhancement area early in the growing season (Feb.-July).

Method for Performance Standard: Snags will be installed at a variety of heights and angles. Root masses and logs in various stages of decay will be scattered randomly throughout the enhancement area. Logs or root masses located within 25 feet of the stream channel will be partially buried to prevent movement.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Method for Performance Standard: See above under Section A.

C. The enhancement area will provide habitat for at least three **waterfowl** species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide nesting sites, cover and forage areas for waterfowl species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present throughout the enhancement area early in the growing season (Feb.–July).

Method for Performance Standard: Snags will be installed at a variety of heights and angles. Root masses and logs in various stages of decay will be scattered randomly throughout the enhancement area.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Method for Performance Standard: Native emergent, shrub, and tree plant species from the list in Appendix C will be planted in random groupings of species. Plant sources will be from local nurseries using plants from the local gene pool. A combination of sprigs and seeds will be used in planting herbaceous plants. Plant material will be installed according to the specifications in Appendix C.

Performance Standard: A minimum of 5 temporary nesting boxes suitable for cavity nesting waterfowl (e.g. wood duck, hooded merganser) will be placed around the mitigation area.

Method for Performance Standard: Boxes will be constructed of cedar and measure 12" wide by 24" high. They will be installed on posts or snags throughout the enhancement area.

D. The enhancement area will provide habitat for at least two **mammal** species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide cover and forage areas for mammal species. Woody material will be > 12 inches in diameter and > 15 feet long.

Method for Performance Standard: Snags will be installed at a variety of heights and angles. Root masses and logs in various stages of decay will be scattered randomly throughout the enhancement area.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years to provide cover and forage for mammal species.

Method for Performance Standard: Native emergent, shrub and tree plant species from the list in Appendix C will be planted in random groupings of species. Plant sources will be from local nurseries using plants from the local gene pool. A combination of sprigs and seeds will be used

in planting herbaceous plants. Plant material will be installed according to the specifications in Appendix C.

E. The enhancement area will provide habitat for at least five **passerine bird** species within five years.

Performance Standard: A minimum of 50 snags, 200 logs, and 200 root masses will be randomly placed throughout the wetlands to provide nesting sites, cover and forage areas for passerine species. Woody material will be > 12 inches in diameter and > 15 feet long.

Performance Standard: Multiple areas (1 to 2 acres) of standing water with maximum depths of 24 inches shall be present within the enhancement area early in the growing season (Feb.–July).

Method for Performance Standard: Snags will be installed at a variety of heights and angles. Root masses and logs in various stages of decay will be scattered randomly throughout the enhancement area. Logs or root masses located within 25 feet of the stream channel will be partially buried to prevent movement.

Performance Standard: Three vegetation classes, dominated by native wetland forest vegetation, will cover at least 16.2 acres with a minimum canopy closure of 50%, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Method for Performance Standard: Native emergent, shrub, and tree plant species from the list in Appendix C will be planted in random groupings of species. Plant sources will be from local nurseries using plants from the local gene pool. A combination of sprigs and seeds will be used in planting herbaceous plants. Plant material will be installed according to the specifications in Appendix C.

Performance Standard: A minimum of 5 temporary nesting boxes suitable for passerine species will be placed around the mitigation area (e.g. tree and violet green swallows, black–capped chickadee, Bewick's wren).

Method for Performance Standard: Boxes will be constructed of cedar and measure 4" wide by 5" high. They will be installed on posts or snags throughout the enhancement area.

Goal 3: Assure the protection of the on–site stream corridor.

A. A sufficient buffer shall remain to maintain the current riparian corridor and habitat attributes.

Performance Standard: A 100 foot corridor on both sides of the on–site stream will be placed in a Native Growth Protection Area and protected.

Method for Performance Standard: Stream side buffer shall be field flagged prior to any nearby construction.

Goal 4: Conduct a study on a designated 1.5 acre plot researching the natural regeneration of vegetation over time within a seasonally saturated, palustrine emergent agricultural field, and investigate the success of selected upland, facultative upland, and facultative wetland plants planted over a range of hydrogeomorphic regimes within this field.

A. Record the natural successive changes over time in an agricultural palustrine emergent wetland over a range of hydrogeomorphic regimes.

Performance Standard: A minimum of 3 permanent transects will be established perpendicular to the water gradient within the 0.75 acre (1/2 of the 1.5 acre area) agricultural field (Figure 5).

Method for Performance Standard: Transects will be marked with rebar in the field. Data will be collected on numbers and types of species present, their percent cover, and their heights will be recorded from representative sample plots along the transects over a period of ten years. Statistical analysis will be performed to compare the above mentioned data between and among hydrological regimes.

B. Investigate the success of selected upland, facultative upland, and facultative wetland plant species planted over a range of hydrogeomorphic regimes.

Method for Performance Standard: The following plants will be planted approximately 1 meter apart in rows spaced approximately 2 meters apart: *Abies grandis, Acer circinatum, Acer macrophyllum, Betula papyrifera, Crataegus douglasii, Cornus stolonifera, Holodiscus discolor, Lonicera involucrata, Oemleria cerasiformis, Physocarpus capitatus, Picea sitchensis, Pinus contorta, Prunus emarginata, Pseudotsuga menziesii, Pyrus fusca, Rosa gymnocarpa, Rosa nutkana, Rubus spectabilis, Rhamnus purshiana, Sambucus racemosa, Spiraea douglasii, Symphoricarpos albus, and Tsuga heterophylla.*

Method for Performance Standard: Data will be collected on numbers and types of species present, their percent cover, and their heights will be recorded from representative sample plots along the transects over a period of ten years. Statistical analysis will be performed to compare the above mentioned data between and among species.

Goal 5: This goal is not directly related to wetland disturbance, but addresses cultural functions lost on a regional basis. This goal attempts to provide compensation for the regional loss of natural resources important to the Lummi Indian Tribe's culture heritage.

A. Natural resources available for harvest by the Lummi Indian Tribe will be established to provide totem pole stock and cedar bark for future cultural uses by the Lummi Indian Tribe.

Method for Performance Standard: Specific locations and numbers of trees outside the mitigation areas will be determined in a joint planning effort between the proponent and the Lummi Indian Tribe.

7.2 Soil Amendments

Although reed canarygrass is present, the original wetland soil will be used with minor modifications in topography. Treatment of the soil will include spraying with glyphosate, plowing, and planting with cover crops and native vegetation.

Approximately nine (9) acres of (clean, no invasive plants present) soil from the forest to the west, within the proposed rail loop, will be transferred and placed in approximately 200, 50 foot diameter seasonally saturated islands. These islands will be randomly scattered throughout the seasonally flooded area within the enhancement and creation site to create seasonally saturated zones in existing and created flooded areas (Figure 5). These soils are Birchbay silt loam with a loamy texture. The donor areas are dominated by native forest plant species such as red alder, paper birch, vine maple, red elderberry, western snowberry, and baldhip rose. No non-native or invasive plant species were observed in these areas during site visits (ATSI 1995).

7.3 Plant Material

Plantings in the enhancement area are categorized according to four broad water regimes: upland, forested, scrub-shrub, and emergent. The species included in each of these water regimes are listed in Appendix C.

This water regime system allows plant species to be chosen that take advantage of select but different hydrologic conditions, assuring a diversity of species and a successful project. Plant species and density of planting described in Appendix C will be followed.

All excavation, woody material placement, and planting of all wetland areas will be done **in the presence of a wetlands biologist familiar with the project according to the drawings and plan**. Soil quality will be one of the major determinants of the success of the project, therefore excavation may deviate slightly from the construction drawing at the discretion of the biologist.

Planting will take place in the late winter or early spring as indicated above (7.1, Goal 2, Section C, item B, **Methods for Performance Standard** (page 27). Plant stock will primarily come from off-site sources for quantities sufficient for adequate cover. A contract will be made with a local nursery for plant materials. Appendix C indicates the condition (e.g. bare-root, balled-and-burlapped, cutting, seed) of the plant material for each species and the water regime it will be placed. Additional species noted at the bottom of Appendix C will likely be introduced by wind and waterfowl.

7.4 Habitat Features

Snags and downed logs will be added at a densities discussed above (7.1, Goal 2, pg. 26). Snags provide a variety of wildlife with food, habitat, and substrate. Cavity nesting species such as woodpeckers, chickadees, wrens, some owls, wood ducks, and hooded mergansers use snags for nesting sites. Insects inhabiting decaying wood in snags and downed logs provide food for a number of species including, woodpeckers, squirrels, rough skinned newts, northwestern salamander, and western red-backed salamander. Logs within the wetland provide pathways through the wetlands and substrate for wetland vegetation.

Inundated areas within the wetland increase the value of the wetland to wildlife by providing potential breeding and rearing areas for amphibian species such as western red-backed salamander, northwestern salamander, rough skinned newts, red-legged frogs, and Pacific chorus frogs. These species require a diversity of terrestrial and aquatic habitats that do not currently exist in this area.

No habitat features are suggested for the riparian corridor. Sufficient material occurs within the corridor and natural vegetation will continue to add to the number of downed woody material and snags over time. Significant damage to existing vegetation may occur from heavy equipment if additional woody material were to be added.

7.6 Erosion Control

In order to rapidly establish ground cover, bare ground within mitigation areas will be planted with a mix of the following species (*Lolium multiflorum, Alopecurus geniculatus, Agrostis stolonifera, Holcus lanatus, or Lotus corniculatus)* at a minimum rate of 50 lbs/acre. This will inhibit invasion by weedy exotic species, reduce erosion, and improve the quality of the soil.

8.0 MONITORING PLAN

Monitoring will occur on a seasonal basis for 10 years post construction/planting. However, monitoring reports written specifically for the regulatory agencies will be performed by a qualified wetland biologist at the peak of the growing season for 10 years (years 1, 3, 5, 7, 10) after the wetland construction and planting is completed. A quantitative analysis of biotic and abiotic conditions will be made in July/August during years 1, 3, 5, 7 and 10. The written report will summarize the findings and will be provided to the Army Corps of Engineers and other relevant agencies after each monitoring session. These reports will include an assessment of plant survival and percent cover, conditions of plants, natural plant recruitment, soil conditions, hydrology, invasion by exotic plant species and percent cover, observations of fauna, and an overall project description and suggested maintenance procedures.

Any changes that occur in this mitigation shall first be reviewed by a qualified wetlands biologist and if the change/s are/is considered significant, the U.S. Army Corps of Engineers will be contacted.

8.1 Vegetation

Permanent transects and photo points will be established for data collection. Percent cover of vegetation, survivorship of planted material, height of trees and shrubs, and total canopy cover will be tabulated at the peak of the growing season (July/August). Mitigation success will be staged as follows:

First year monitoring. Performance Standard: Native plant species will have a minimum cover of 15% after the first year.

Third year monitoring. Performance Standard: Native plant species will have a minimum cover of 25% after the third year.

Fifth year monitoring. Performance Standard: Native plant species will have a minimum cover of 50% after the fifth year.

Seventh year monitoring. Performance Standard: Native plant species will have a minimum cover of 75% after the seventh year.

Tenth year monitoring. Performance Standard: Native wetland forest vegetation will cover the mitigation site with 50% canopy cover, an 80% cover of native shrubs, and 25% cover of native herbaceous plants within ten years.

Planted and natural recruitment of plants will be noted and discussed. If a performance standard is not met within the time specified in the mitigation plan an analysis of the cause of failure will be determined, proposed corrective action will be made, and a time frame for implementing these actions will be presented. Minor corrective measures will be included in routine maintenance and will be identified in the subsequent monitoring report.

8.2 Water Regime

The water table will be measured during the beginning of the growing season (April) and once in the summer (August) for the entire monitoring period during the 1st, 3rd, 5th, 7th, and 10 year.

8.3 Development of Habitat Structure

Habitat variables of plant species present and percent cover (plus height for shrubs and trees), total canopy cover, density of dead wood, and vertical vegetation density will be measured along 3 permanent transects. Permanent photo points will be established along each transect and photographs will be taken at the peak of each growing season (July/August).

8.4 Fauna

Aquatic macro-invertebrates will be sampled by dip net in the spring and late summer during the monitoring years. Insects will be keyed to genus. Records of taxa observed will be kept.

Amphibians will be sampled by visual observation in the spring and fall of each monitoring year. Counts will be made of amphibian egg masses in the spring of each year. Records of observations will be maintained of species observed and egg masses.

Birds will be identified by call, song, pecking and drumming patterns, and visual sighting during 15 minute observations at two permanent census stations during April/May and December/January of the monitoring years.

9.0 SITE PROTECTION

9.1 Legal protection

The mitigation site, study site, and riparian buffer will be designated as a Native Growth Protection Area recorded on the property deed and will read as follows:

All land within the Native Growth Protection Area shall remain in a natural state. There shall be no clearing, vegetation removal, grading, filling, or construction of any kind within this area without the written approval of Whatcom County or responsible agency. The only exception to this requirement shall be in the case of emergencies for the protection of private property and public health, safety, and resources, such as for the removal of diseased or hazardous trees, or maintenance of existing roads, or installation of utilities, or transportation corridors that "may" be required to cross the seasonal stream, only. Any disturbance of vegetation that may occur through such emergency activities shall be repaired. For possible permanent damage to this area, a permit from the relevant agencies shall be obtained. The mitigation site, study site, and riparian buffer will be protected in perpetuity.

10.0 MAINTENANCE AND CONTINGENCY PLANS

10.1 Maintenance schedule

The following maintenance activities will be funded for this site for ten years after construction and planting: site inspection and reports, weed control, plant replacement, erosion control, and protection from herbivores.

Weed control will begin immediately after planting and will occur monthly if necessary during the growing season for the first two years and yearly after that. Plants will be replaced if a survival rate of less than 80 percent of a given species is observed and if natural recruitment has not occurred. Plants will be inspected during seasonal visits for significant damage from herbivores. Spot spraying of glyphosate for control of reed canarygrass will occur on the same regime. If predation of young plants becomes a

problem (reduction of greater than 50% of plantings), animal repellents such as METHOCARB® for geese or ROPEL® for deer may be used.

10.2 Contingency Plan

If a performance standard is not met within the time specified in the mitigation plan an analysis of the cause of failure will be determined, proposed corrective action will be made, and a time frame for implementing these actions will be presented. Minor corrective measures will be included in routine maintenance and will be identified in the subsequent monitoring report.

If significant reduction of reed canarygrass cannot be accomplished through herbicide application, plowing and planting with a competitive cover crop, flooding of the field will occur. Flooding can be accomplished by use of the installed weir. With the presence of the berm and weir most of the field can be flooded to depths of between three to six feet.

11.0 IMPLEMENTATION SCHEDULE

11.1 Construction Schedule

Initial spraying of glyphosate for control of reed canarygrass will occur in the early Spring, followed by plowing and disking (if practicable), and application of an erosion/competitive cover crop (Appendix C). An additional application of glyphosate will occur in 30 to 45 days following the initial spraying, if required, and the site will again be seeded with an annual cover crop. Excavation will be in the dryer summer months (July/August/September). **If practicable, all spraying and plowing will occur the first year prior to the construction of the terminal.**

11.2 Monitoring Schedule

An "as-built" report will be provided upon completion of construction and planting, and updated as both progress if extended over a one year period. This site will be monitored on a seasonal basis for 10 years following construction and planting. These seasonal site visits are intended to be qualitative and will give the assigned biologist the necessary information to understand the subtle changes (hydrological, flora, and faunal use) of the site. A more intensive monitoring will occur on the 1st, 3rd, 5th, 7th, and 10 year post planting. A report will be written as discussed in the above sections to be provided to the relevant agencies (U.S. Army Corps of Engineers, etc.)

12.0 PERFORMANCE BOND

A bond will be purchased before construction begins. A total construction bond of $509,620.00 based on $2.00 a square foot of wetland disturbed. The bond will be divided into three phases: construction, planting, and maintenance and monitoring. Two-thirds ($339,938.00) of the bond will be placed in the construction phase and will be released upon completion of construction and submittal of and approval of the as-built report, by U.S. Army Corps of Engineers. One-sixth ($84,857.00) will be held until planting has been completed and will be released with the submittal of the first year monitoring report with approval by the U.S. Army Corps of Engineers. The remaining one-sixth ($84,857.00) will be applied towards maintenance and monitoring and will be released at the end of the monitoring period (10 years research and monitoring for the creation, enhancement, and study sites).

The bond figures mentioned above are not the anticipated costs, but are for the assurance that the project will be completed. If at any time a portion of said work is completed, that relative portion of the bond will be released.

REFERENCES

Aqua-Terr Systems, Inc. 1995. *Pacific International Terminal Wetland Report.* Bellingham, WA.

Aqua-Terr Systems, Inc. 1995. *Pacific International Terminals Bird Survey.* Bellingham, WA.

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, M. Bentley, D. Shelton, and D. Dole. 1992. *Wetland Mitigation Replacement Ratio: Defining Equivalency.* Adolfson Associates, Inc. for Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, WA. Publication # 92-10.

Cowardin, L.M. V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States*, FWS/OBS-79/31, U.S. Fish and Wildlife Service, Washington, D.C.

Department of Natural Resources. 1993. *Washington Forest Practices.* Department of Natural Resources, Forest Practices Division.

Environmental Laboratory. 1987. *Corps of Engineers Wetlands Delineation Manual*, Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Goldin, A., 1992. *Soil Survey of Whatcom County Area, Washington.* U.S.D.A. Soil Conservation Service, Washington State Department of Natural Resources, and Washington State University, Agriculture Research Center.

Hitchcock, C.L. and A. Cronquist. 1973. *Flora of the Pacific Northwest.* University of Washington Press. Seattle, Washington.

Hruby, T. and C. Brower. 1994. *Guidelines for Developing Freshwater Wetlands Mitigation Plans and Proposals.* Washington State Department of Ecology. Olympia, WA. Pub. #94-29.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. *American Wildlife and Plants: A guide to wildlife food habits.* Dover Press, New York, N.Y.

Norman, D. 1995. Personal communication.

Reed, P.B., Jr. , 1988. *National List of Plant Species that occur in Wetlands: 1988 Northwest*, Biological Report 88 (26.9), U.S. Fish and Wildlife Service, St. Petersburg, Florida.

Reed, P.B., Jr. 1993. *1993 Supplement to the List of Plant Species That Occur in Wetlands: Northwest.* in cooperation with U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Soil Conservation Service, and the U.S. Environmental Protection Agency.

Shapiro and Associates, Inc. 1994. *Cherry Point Natural Resources Studies: Technical Reports.* Seattle, WA.

Shapiro and Associates, Inc. 1995. *Cherry Point Water Depth Studies: Technical Reports, unpublished.* Seattle, WA.

United States Department of the Interior, Fish and Wildlife Service. 1977. "National Wetlands Inventory Maps," Scale 1:24,000. Office of Biological Services.

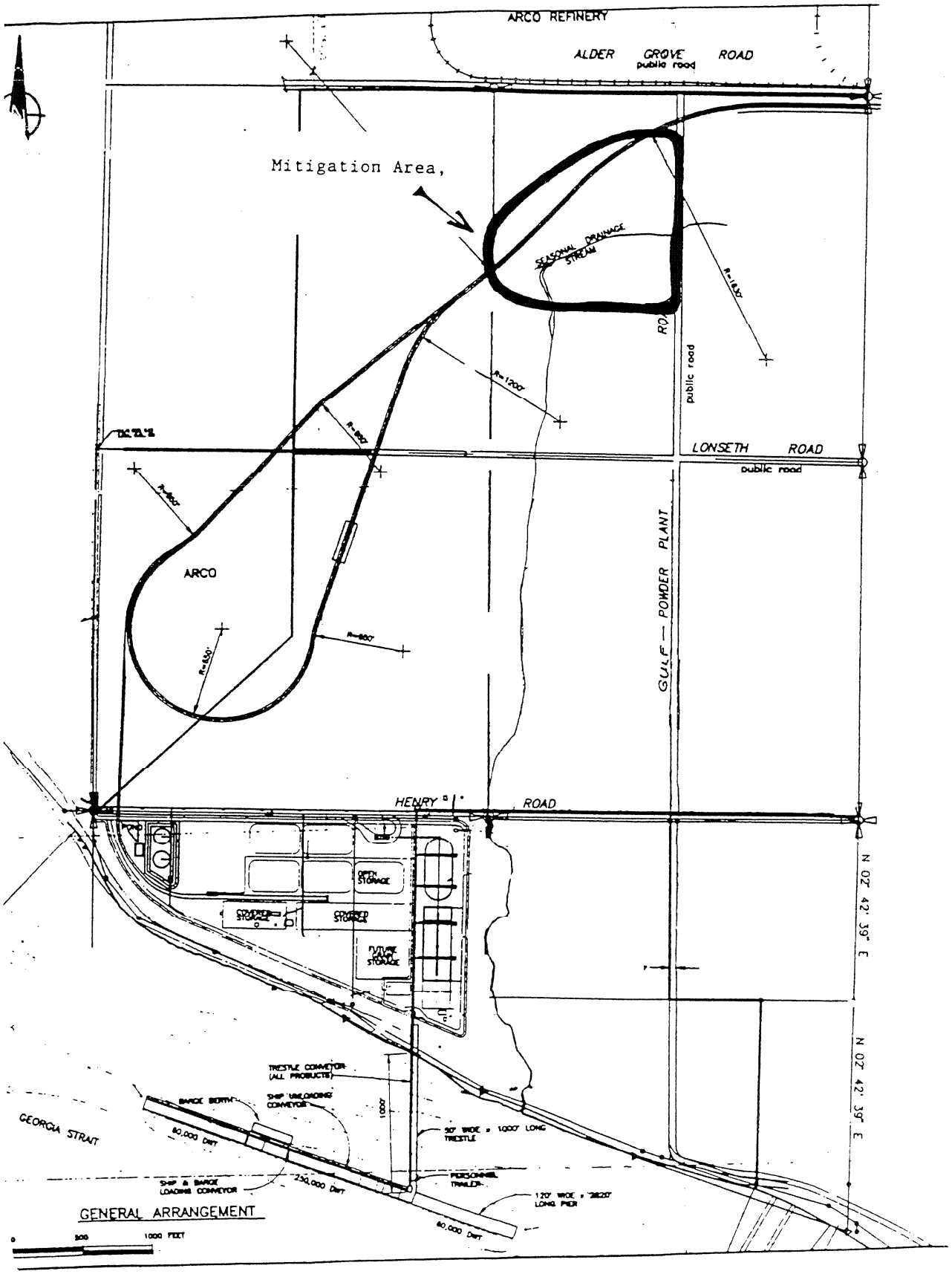
Wahl, T. 1995. Personal communication.

Washington Department of Ecology. 1991. *Washington State Wetlands Rating System for Western Washington.* Publication #91-57.

Washington State Department of Ecology. 1993. *Restoring Wetlands in Washington* . Olympia Washington.

Whatcom County Planning Department. July 15, 1992. *Temporary Critical Areas Ordinance.* Whatcom County, Washington.

Zim H.S, A.C. Martin and A.L. Nelson. 1952. *American Wildlife an Plants: A Guide to Wildlife Food Habits.* Dover Publications. New York.


ARCO REFINERY
ALDER GROVE ROAD
public road
Mitigation Area,
SEASONAL DRAINAGE STREAM
R=1500'
R=1200'
R=900'
R=900'
R=450'
R=600'
ROAD
public road
LONSETH ROAD
public road
GULF — POWDER PLANT
ARCO
HENRY ROAD
N 02° 42' 39" E
N 02° 42' 39" E
OPEN STORAGE
ENCLOSED STORAGE
ENCLOSED STORAGE
TRESTLE CONVEYOR (ALL PRODUCTS)
SHIP UNLOADING CONVEYOR
BARGE BERTH
1000'
90' WIDE x 1,000' LONG TRESTLE
GEORGIA STRAIT
60,000 DWT
PERSONNEL TRAILER
SHIP & BARGE LOADING CONVEYOR
230,000 DWT
120' WIDE x 3825' LONG PIER
60,000 DWT
GENERAL ARRANGEMENT
0
500
1000 FEET

APPENDIX C

Proposed planting schedule for wetland mitigation. This schedule includes plant species, condition (bare–root, balled–and burlapped, container, sprig, rhizome, cutting, seed), plant spacing, water regime (**PF**–permanently flooded; **SF**–seasonally flooded; **PS**–permanently saturated; **SS**–seasonally saturated), and wildlife values (Washington Department of Ecology, 1993 and Martin et al., 1952).

TREES

Species	Condition	Spacing	Water Regime	Wildlife Values
Abies grandis, grand fir	bare–root or balled–and–burlapped	groups of 5, 100' o.c.	upland	Provides nesting, roosting, and winter cover for birds; food for grouse, passerine birds, and deer.
Picea sitchensis, Sitka spruce	bare–root or balled–and–burlapped	groups of 5, 100' o.c.	SF PS SS	Provides nesting, roosting, and winter cover for birds; food for grouse, passerine birds, and deer.
Pseudotsuga menziessii, Douglas fir	bare–root or balled–and–burlapped	groups of 5, 100' o.c.	upland	Provides nesting, roosting, and winter cover for birds; food for grouse, passerine birds, and deer.
Thuja plicata, western red cedar	bare–root or balled–and–burlapped	groups of 5, 100' o.c.	SF PS SS	Provides nesting, roosting, and winter cover for birds; food for grouse, passerine birds, and deer.

SHRUBS

Species	Condition	Spacing	Water Regime	Wildlife Values
Lonicera involucrata, black twinberry	bare–root or container	groups of 5, 50'o.c.	SF PS SS	Fruits eaten by passerine birds.
Physocarpus capitatus, Pacific ninebark	bare–root or container	groups of 5, 50'o.c.	PS SS	Not determined.
Pyrus fusca, western crabapple	bare–root or container	groups of 5, 50'o.c.	PS SS	Fruits and seeds eaten by birds and mammals.
Rubus spectabilis, salmonberry	bare–root or container	groups of 5, 50'o.c.	SF PS SS upland	Nectar an important food for hummingbirds and bees; fruits eaten by many bird and mammal species.
Salix lasiandra, Pacific willow	bare–root or cutting	groups of 5, 50'o.c.	SF PS SS	Provides food, cover, and nesting habitat to fish, insect, mammal, and bird species.
Salix sitchensis, Sitka willow	bare–root or cutting	groups of 5, 50'o.c.	PS SS	Provides food, cover, and nesting habitat to fish, insect, mammal, and bird species.

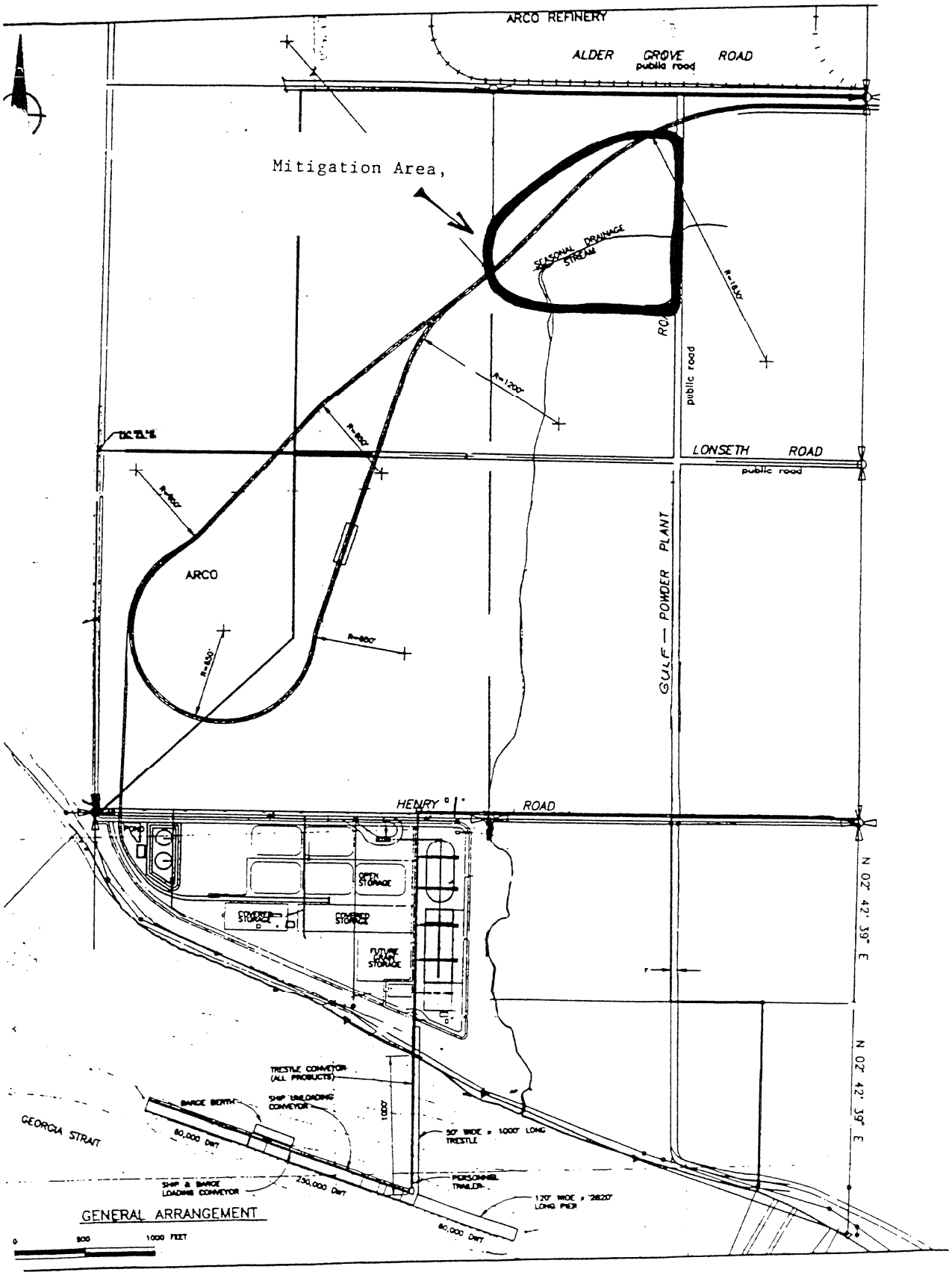
IERBS

pecies	Condition	Spacing	Water Regime	Wildlife Values
Alisma plantago–aquatica, water plantain	sprig or rhizome	groups or 10, 20' o.c.	SF PS	Not determined.
Carex obnupta, slough sedge	sprigs and seed	groups of 20, 20' o.c.	SF PS	Seeds eaten by waterfowl, sora, snipe, grouse, junco, and sparrows.
Carex stipata, sawbeak sedge	sprigs and seed	groups of 20, 20' o.c.	SF PS	Seeds eaten by waterfowl, sora, snipe, grouse, junco, and sparrows.
Glyceria spp., manna grass	seed	scattered	PF SF PS	Shoots and seeds eaten by waterfowl, marshbirds, and shorebirds.
Hippuris vulgaris, common mare's tail	sprigs	groups of 20, 20' o.c.	PS PF	Not determined.
Polygonum spp., smartweed	seed	scattered	PF	Food for at least 32 western Wash. species (including waterfowl and passerine birds).
cirpus acutus/validus, hardstem bulrush	rhizomes	groups of 20, 20' o.c.	PF	Seeds and rhizomes eaten by waterfowl, marshbirds, and shorebirds.
Scirpus microcarpus, small–fruited bulrush	seed	scattered	SF PS	Cover for small birds and small mammals; food for waterfowl.
Sparganium eurycarpum, broad–fruited burreed	rhizome	groups of 20, 20' o.c.	PF	Provides food and cover for waterfowl.

EXPECTED VOLUNTEER SPECIES

Species	Water Regime	Wildlife Values
Alnus rubra, red alder	SS upland	Provides food for grouse and small seed and insect eating passerine birds.
Juncus effusus, soft rush	PS SF SS	Not determined.
Juncus ensifolius, dagger–leaf rush	PS SF SS	Not determined.
Juncus tenuis, slender rush	PS SF SS	Not determined.
Populus balsamifera, black cottonwood	PS SS upland	Provides food for beaver and deer; harbors insects that are food for many bird species.
Spirea douglasii, hardhack	PS SF SS	Not determined.
Typha latifolia, common cattail	PS SF SS	Provides food for muskrat, beaver, and geese; nesting habitat for waterfowl and passerine birds.

* For erosion control and typical cover of bare ground, use annual rye (*Lolium multiflorum*) at 50 pounds per acre. Other grasses may be used as listed in the text or at the discretion of a wetlands biologist.


ARCO REFINERY
ALDER GROVE ROAD
public road
Mitigation Area,
SEASONAL DRAINAGE STREAM
R=1200'
R=800'
R=1800'
public road
LONSETH ROAD
public road
R=800'
ARCO
R=550'
R=800'
GULF — POWDER PLANT
HENRY ROAD
OPEN STORAGE
COVERED STORAGE
COVERED STORAGE
FUTURE COVER STORAGE
N 02° 42' 39" E
N 02° 42' 39" E
TRESTLE CONVEYOR (ALL PRODUCTS)
SHIP UNLOADING CONVEYOR
BARGE BERTH
GEORGIA STRAIT
80,000 DWT
50' WIDE x 1000' LONG TRESTLE
1000'
SHIP & BARGE LOADING CONVEYOR
250,000 DWT
PERSONNEL TRAILER
120' WIDE x 2820' LONG PIER
80,000 DWT
GENERAL ARRANGEMENT
0
500
1000 FEET

CELTIC SPIRAL

* ENHANCEMENT
* CREATION
* STUDY

A.T.S.I.

AQUA-TERR SYSTEMS, INC.

GATEWAY SITE

ALDERGROVE ROAD

ACRES
16.2 ENHANCEMENT
5.9 CREATION
1.5 STUDY
23.6 TOTAL

STUDY SITE

EXISTING

EXISTING PEMB WETLAND

WETLAND CREATION PFO/SS

100' R.R. ROW w/20' BUFFER BOTH SIDES

REDUCE GRADE FOR WETLAND CREATION PFO/SS

GULF ROAD

DOUBLE 24" CULVERT INLET

A'

A

LOGS & ROOT MASSES THROUGHOUT 250 EACH (NTS)

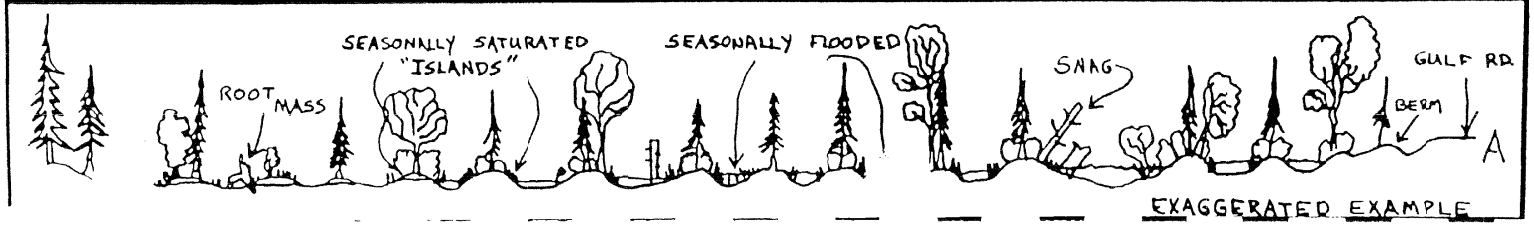
OUTLET WIER

6' TALL x 18' WIDE BERM

SEASONALLY SATURATED "ISLANDS" THROUGH OUT FOR CONIFER & DECIDUOUS TREES

THE REMAINING AREA WILL BE SEASONALLY FLOODED/SATURATED

150'



EXAGGERATED EXAMPLE

HABITAT FEATURES AND CONDITIONS

* Construction will occur during the late summer months.
* At least 50 snags, > 12" diameter, > 15 ' tall, will be randomly placed.
* At least 200 floating logs, > 12" diameter, > 15 ' long, will be randomly placed.
* At least 200 root masses (from trees greater than 6 feet diameter) will be randomly placed.
* Annual rye (*Lolium multiflorum*) will be seeded @ 50 lbs/acre on all bare ground, post construction.
* All contractor selection, construction, planting, maintenance, and monitoring will be supervised by a qualified wetlands biologist familiar with the site and plans. Any and all changes to this plan need to be approved by the qualified wetlands biologist prior to implementation.
* Ten temporary cardboard bird boxes of varying sizes will be placed randomly on the snags and surrounding trees.
* Entire area will be planted with a representative sampling of the below listed tree and shrub species, bare root or 1 gallon containers, within groups of 5 to 10 plants spaced 20 to 100 feet apart, one year post excavation. Entire area will also be planted with a representative sampling of the below listed herbaceous species (herbs), bare root or seeds, within groups of 10 to 20 plants spaced 20 to 50 feet apart, two years post excavation. The herbaceous species will also be seeded (with seed hand collected locally), if practical, randomly along the entire perimeter of the openwater areas, additional native plants may be included. The buffer and remaining area will be planted with annual rye. These plants and seeds will be planted in late winter (assume late February or mid March at the latest). This lapse of time will allow for a complete and thorough understanding of the seasonal variation within the water table, therefore increasing the success of the plantings. If natural recruitment of desired plants occurs prior to two years, planting will discontinue. Actual monitoring will begin the following summer (approximately one year after excavation) to allow time to observe natural vegetation recruitment and success of seed stock, bare root, and container plantings. It is the belief of the designer that natural recruitment of many plants will occur within one to two years of construction. It is therefore our intent to allow all natural non-invasive plants to become established and document their presence. Measurement of re-vegetation success will follow the first two years of construction and will consist of 50% cover (or one healthy plant per square meter of entire site). Success following three years post construction will be 100% cover of native and/or non-invasive species. If after the first two years following construction the goal of one healthy plant per square meter is not obtained, the bare areas will be planted. Two as-built reports will be written, one post construction in the fall and the second post planting in early spring. All subsequent monitoring reports will occur on an annual basis during the fall (prior to the first killing frost).
* Ten year maintenance schedule for invasive species and planting success will occur. Ten years of monitoring post construction to describe all construction, human manipulation (planting, snag and log placement, etc.) and natural recruitment of vegetation will occur. All amphibians, birds, aquatic insects, and mammal usage observed, water level, and percent cover of all plants will be recorded on a seasonal basis. Permanent photograph plots will be established and taken on a seasonal basis. Both natural plant recruitment and planted stock will be noted for growth and viability. A comparison of both for success will be discussed in the annual reports.
* Glyphosate will be used to maintain reed canarygrass and himalayan and evergreen blackberries if they occur. If either red alder or black cottonwood trees become established greater than one plant per square meter, they will be hand thinned. To initially rid the area of reed canarygrass (pre construction) the site will be sprayed with glyphosate (or approved herbicide) in the early spring, followed by plowing, disking, and planting with a cover crop to compete with the reed canarygrass. An additional application of glyphosate will occur in 60 to 90 days following plowing, and the site will again be seeded with an annual cover crop.
* Seasonally saturated islands (approximately 200, about 12 inches above existing grade, 50 feet in diameter) constructed with clean topsoil that contains shrubs, herbaceous plants, root stock, and seeds taken from the adjacent forested area where the railroad will be constructed, will be placed in the seasonally saturated area.

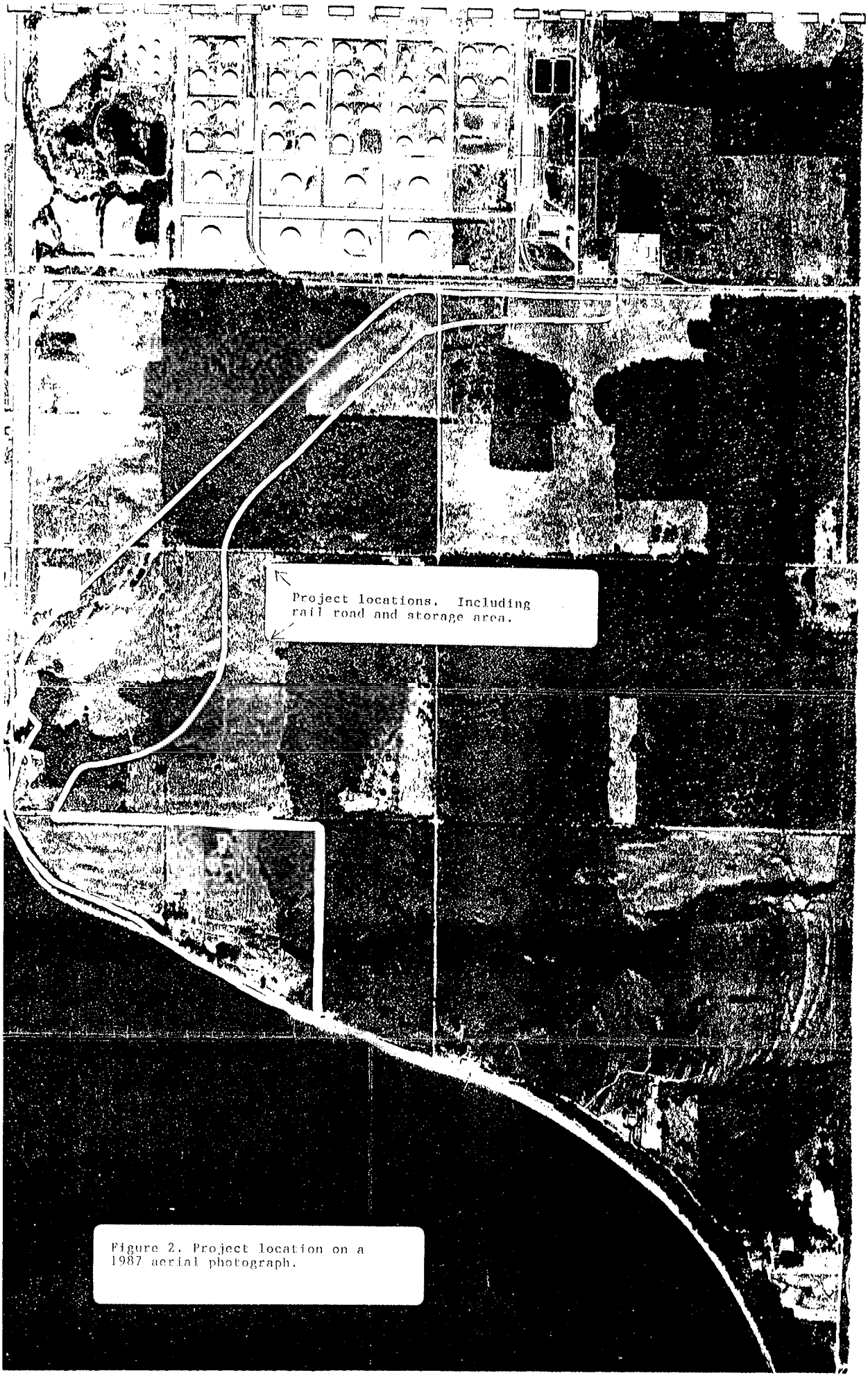


Figure 2. Project location on a 1987 aerial photograph.

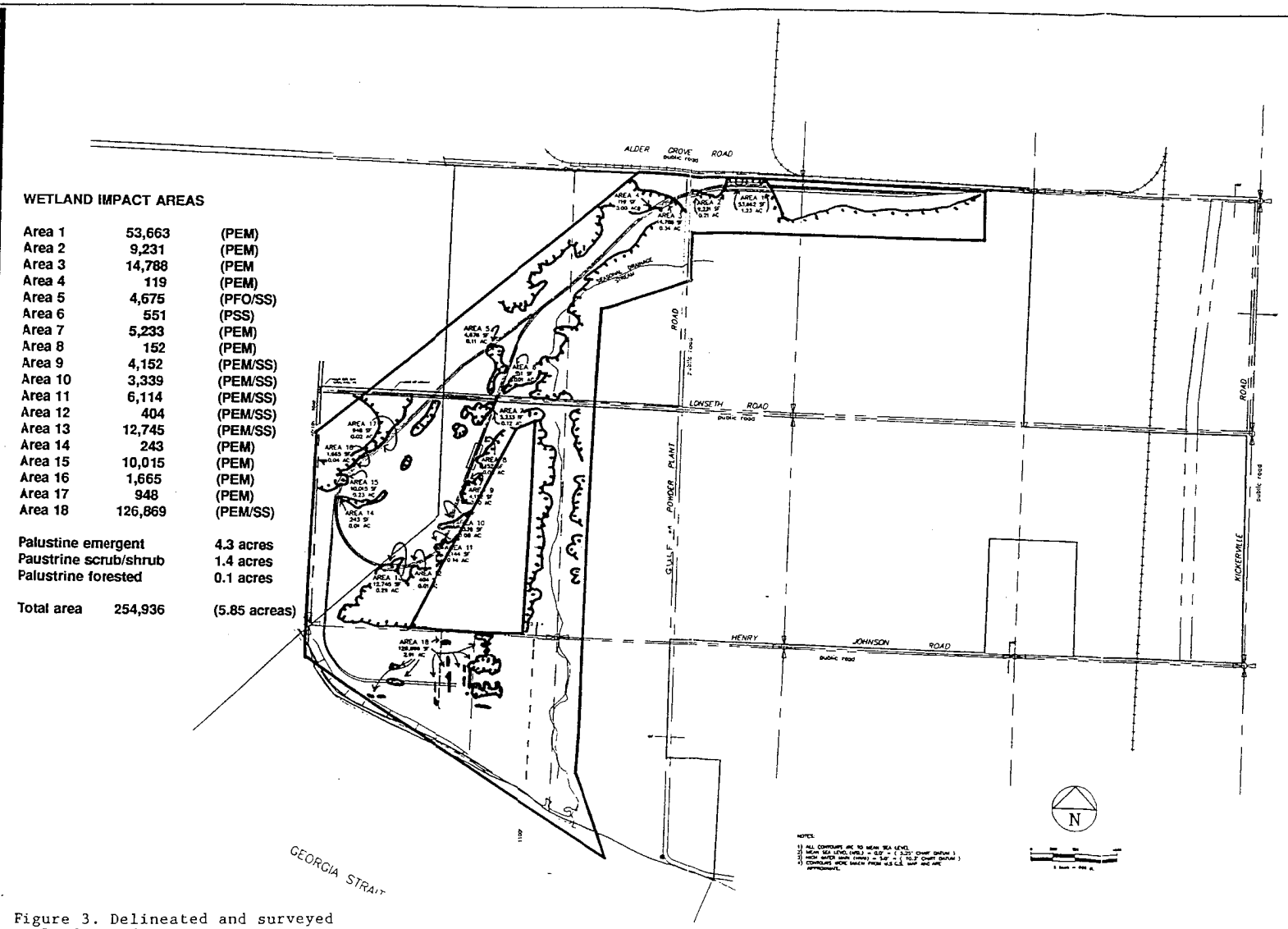


Figure 3. Delineated and surveyed wetlands, indicating fill areas. Total disturbance 5.85 acres.

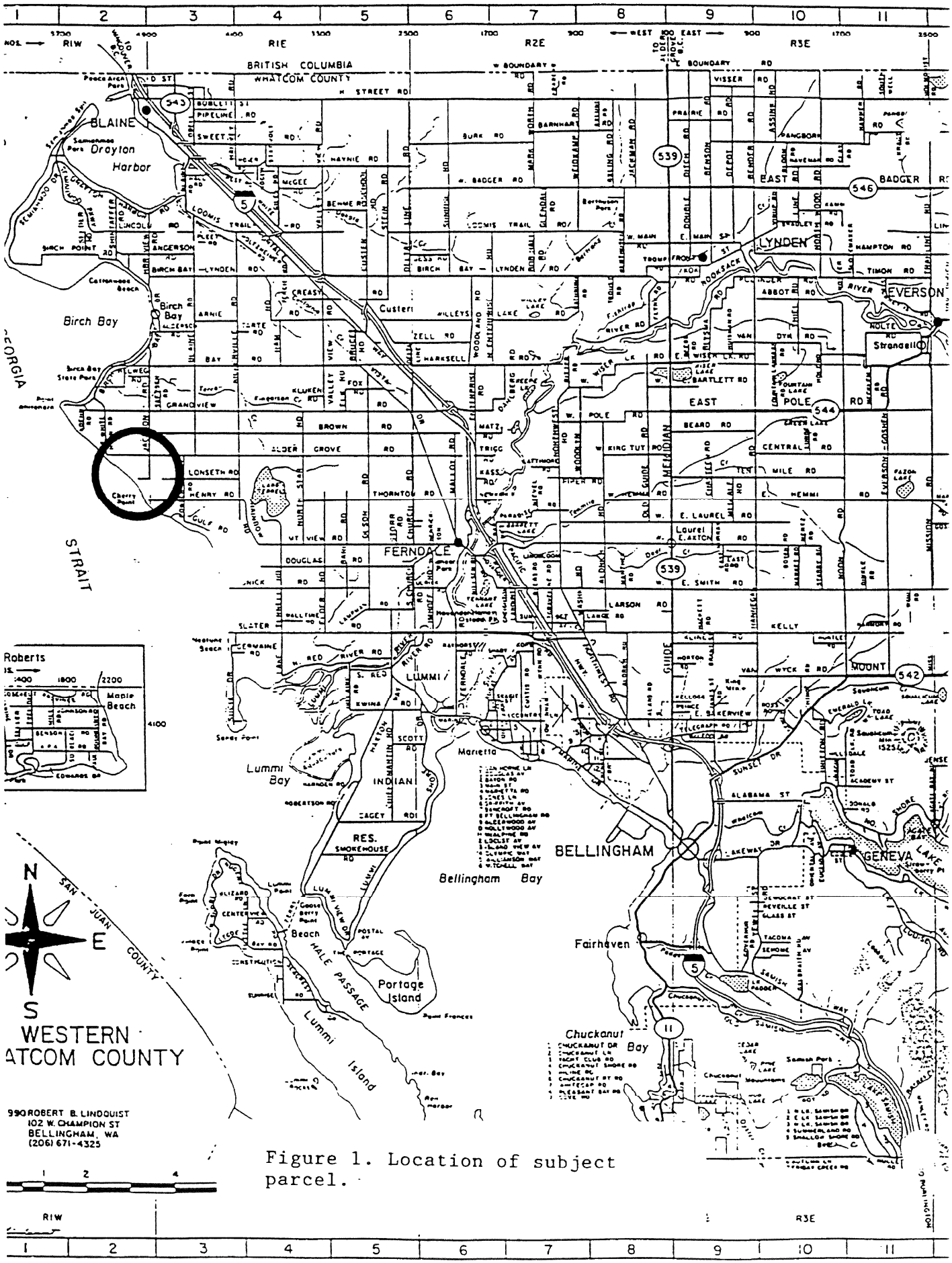
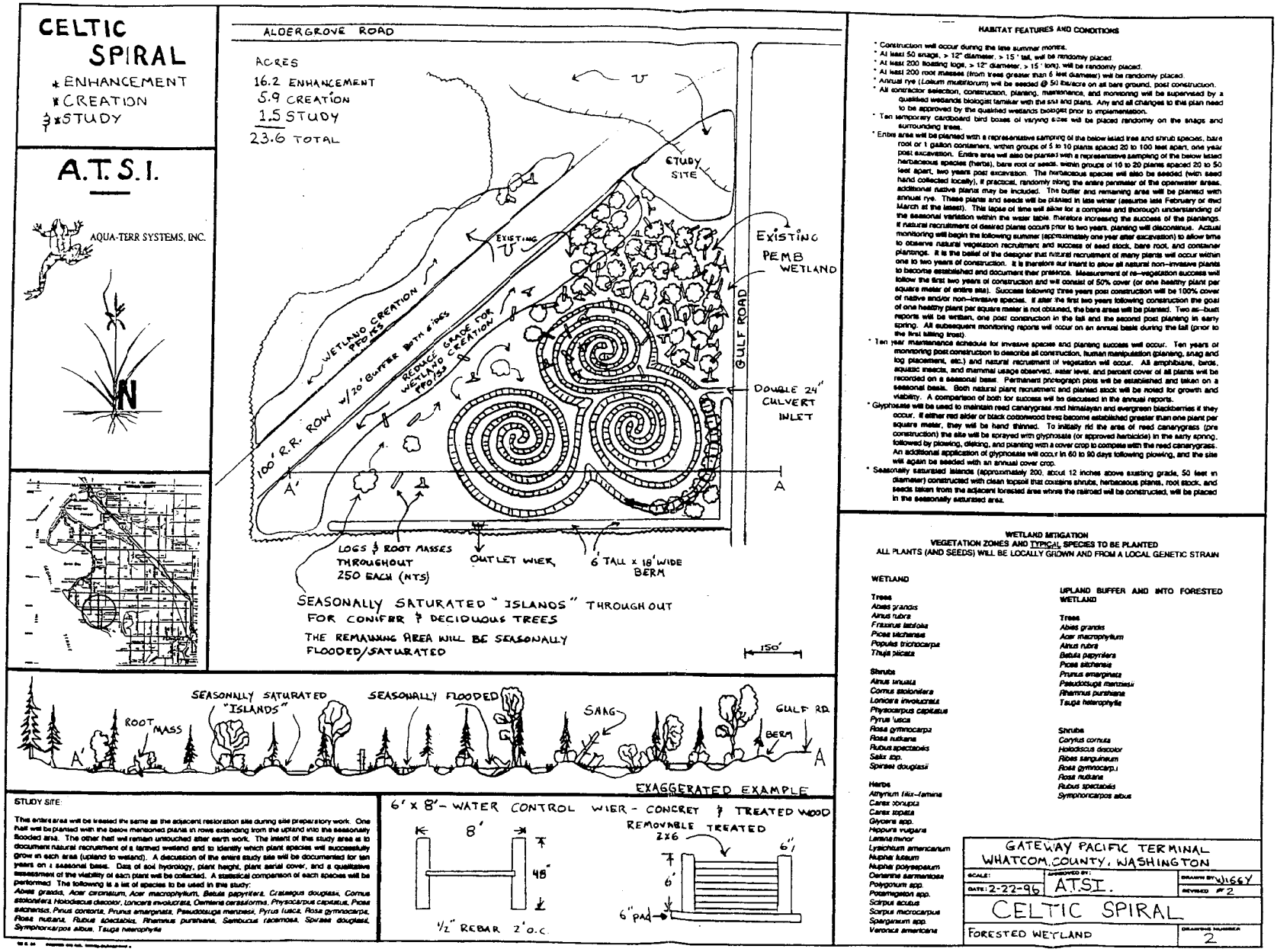


Figure 1. Location of subject parcel.

Figure 4. Native Growth Protection areas. Including mitigation site and creek channel area.



HABITAT FEATURES AND CONDITIONS

- Construction will occur during the late summer months.
- At least 50 snags, > 12" diameter, > 15 ' tall, will be randomly placed.
- At least 200 basking logs, > 12" diameter, > 15 ' long, will be randomly placed.
- At least 200 root masses (from trees greater than 6 feet diameter) will be randomly placed.
- Annual rye (*Lolium multiflorum*) will be seeded @ 50 lbs/acre on all bare ground, post construction.
- All contractor selection, construction, planting, maintenance, and monitoring will be supervised by a qualified wetlands biologist familiar with the soil and plants. Any and all changes to this plan need to be approved by the qualified wetlands biologist prior to implementation.
- Ten temporary cardboard bird boxes of varying sizes will be placed randomly on the snags and surrounding trees.
- Entire area will be planted with a representative sampling of the below listed tree and shrub species, bare root or 1 gallon containers, within groups of 5 to 10 plants spaced 20 to 100 feet apart, one year post excavation. Entire area will also be planted with a representative sampling of the below listed herbaceous species (herbs), bare root or seeds, within groups of 10 to 20 plants spaced 20 to 50 feet apart, two years post excavation. The herbaceous species will also be seeded (with seed hand collected locally), if practical, randomly along the entire perimeter of the open water areas, additional native plants may be included. The buffer and remaining area will be planted with annual rye. These plants and seeds will be planted in late winter (assume late February or mid March at the latest). This lapse of time will allow for a complete and thorough understanding of the seasonal variation within the water table, therefore increasing the success of the plantings. If natural recruitment of desired plants occurs prior to two years, planting will discontinue. Actual monitoring will begin the following summer (approximately one year after excavation) to allow time to observe natural vegetation recruitment and success of seed stock, bare root, and container plantings. It is the belief of the designer that natural recruitment of many plants will occur within one to two years of construction. It is therefore our intent to allow all natural non-invasive plants to become established and document their presence. Measurement of re-vegetation success will follow the first two years of construction and will consist of 50% cover (or one healthy plant per square meter of entire area). Success following three years post construction will be 100% cover of native and/or non-invasive species. If after the first two years following construction the goal of one healthy plant per square meter is not obtained, the bare areas will be planted. Two as-built reports will be written, one post construction in the fall and the second post planting in early spring. All subsequent monitoring reports will occur on an annual basis during the fall (prior to the first killing frost).
- Ten year maintenance schedule for invasive species and planting success will occur. Ten years of monitoring post construction to describe all construction, human manipulation (planting, snag and log placement, etc.) and natural recruitment of vegetation will occur. All amphibians, birds, aquatic insects, and mammal usage observed, water level, and percent cover of all plants will be recorded on a seasonal basis. Permanent photograph plots will be established and taken on a seasonal basis. Both natural plant recruitment and planted stock will be noted for growth and viability. A comparison of both for success will be discussed in the annual reports.
- Glyphosate will be used to maintain reed canarygrass and himalayan and evergreen blackberries if they occur. If either red alder or black cottonwood trees become established greater than one plant per square meter, they will be hand thinned. To initially rid the area of reed canarygrass (pre construction) the site will be sprayed with glyphosate (or approved herbicide) in the early spring, followed by plowing, disking, and planting with a cover crop to compete with the reed canarygrass. An additional application of glyphosate will occur in 60 to 90 days following plowing, and the site will again be seeded with an annual cover crop.
- Seasonally saturated islands (approximately 200, about 12 inches above existing grade, 50 feet in diameter) constructed with clean topsoil that contains shrubs, herbaceous plants, root stock, and seeds taken from the adjacent forested area where the railroad will be constructed, will be placed in the seasonally saturated area.

WETLAND MITIGATION
VEGETATION ZONES AND TYPICAL SPECIES TO BE PLANTED
ALL PLANTS (AND SEEDS) WILL BE LOCALLY GROWN AND FROM A LOCAL GENETIC STRAIN

WETLAND

Trees
Abies grandis
Alnus rubra
Fraxinus latifolia
Picea sitchensis
Populus trichocarpa
Thuja plicata

Shrubs
Alnus sinuata
Cornus stolonifera
Lonicera involucrata
Physocarpus capitatus
Pyrus fusca
Rosa gymnocarpa
Rosa nutkana
Rubus spectabilis
Salix spp.
Spiraea douglasii

Herbs
Athyrium filix-femina
Carex sonupta
Carex spp.
Glyceria spp.
Hippuris vulgaris
Lemna minor
Lysichium americanum
Mupha luteum
Mupha polyspepsum
Oenanthe sarmentosa
Polygonum spp.
Potamogeton spp.
Scirpus acutus
Scirpus microcarpus
Sparganium spp.
Veronica americana

UPLAND BUFFER AND INTO FORESTED WETLAND

Trees
Abies grandis
Acer macrophyllum
Alnus rubra
Betula papyrifera
Picea sitchensis
Prunus emarginata
Pseudotsuga menziesii
Rhamnus purshiana
Tsuga heterophylla

Shrubs
Corylus cornuta
Holodiscus discolor
Ribes sanguineum
Rosa gymnocarpa
Rosa nutkana
Rubus spectabilis
Symphoricarpos albus

STUDY SITE:

This entire area will be treated the same as the adjacent restoration site during site preparatory work. One half will be planted with the below mentioned plants in rows extending from the upland into the seasonally flooded area. The other half will remain untouched after earth work. The intent of this study area is to document natural recruitment of a farmed wetland and to identify which plant species will successfully grow in each area (upland to wetland). A discussion of the entire study site will be documented for ten years on a seasonal basis. Data of soil hydrology, plant height, plant aerial cover, and a qualitative assessment of the viability of each plant will be collected. A statistical comparison of each species will be performed. The following is a list of species to be used in this study:

Abies grandis, Acer circinatum, Acer macrophyllum, Betula papyrifera, Crataegus douglasii, Cornus stolonifera, Holodiscus discolor, Lonicera involucrata, Oemleria cerasiformis, Physocarpus capitatus, Picea sitchensis, Pinus contorta, Prunus emarginata, Pseudotsuga menziesii, Pyrus fusca, Rosa gymnocarpa, Rosa nutkana, Rubus spectabilis, Rhamnus purshiana, Sambucus racemosa, Spiraea douglasii, Symphoricarpos albus, Tsuga heterophylla

GATEWAY PACIFIC TERMINAL
WHATCOM COUNTY, WASHINGTON

SCALE:	APPROVED BY:	DRAWN BY:	WJGGY
DATE: 2-22-96	ATSI.	REVISED	#2

CELTIC SPIRAL

FORESTED WETLAND — DRAWING NUMBER 2

Figure 5. Mitigation drawing.

APPENDIX B: MACROALGAE MITIGATION PLAN

Mitigation Need

The majority of the Shade Model Group has acknowledged that changes to the macroalgae community as a result of altering the available light, coupled with non shade environmental factors, can not be predicted with certainty. To offset this uncertainty, the construction of a macroalgae mitigation site (Phase 1) shall be initiated prior to the commencement of pier construction. Construction of the mitigation site shall be completed before at least March 1 of the year in which construction of the pier is scheduled. Pier construction shall not be initiated until after June 15 following completion of construction of the mitigation site. This allows for a minimum of one macroalgae colonization cycle following the construction of the Phase 1 macroalgae Mitigation site. To the extent that Post-Project Monitoring identifies the need for additional mitigation, a Phase 2 mitigation site shall be provided.

Macroalgae colonization of the Phase 1 macroalgae Mitigation Site shall not be used as a criterion that limits or restricts commencement of pier construction.

Mitigation Goal and Objectives

PIT will construct a Phase 1 macroalgae mitigation site in the immediate vicinity of the proposed pier to offset anticipated impacts to the macroalgae community that may occur as a result of the construction and operation of the proposed pier structure, and to offset anticipated impacts to the epibenthic invertebrate community at the mitigation site associated with mitigation construction. In the event that post project monitoring demonstrates unexpected impacts that exceed the mitigation credit available at the Phase 1 Macroalgae Mitigation site, PIT shall construct a Phase 2 Mitigation Site.

The objectives of the mitigation will be to create an area of macroalgae community that is:

1. At least three times the macroalgae coverage area impacted by the project;

2. Similar in species composition to the impacted area; and

3. Compensates for existing epibenthic invertebrate production displaced by the mitigation site construction.

It is assumed that the mitigation sites will be constructed on an existing un-vegetated, soft substrate site, and it is anticipated that the mitigation construction will displace existing epibenthic invertebrate production. The Phase 1 macroalgae mitigation area required for pier related impacts will be increased by 25% to account for this loss and this mitigation area shall not be counted as mitigation credit available at the mitigation sites.

The macroalgae habitat mitigation sites shall be created by the placement of appropriate sized natural cobble substrate material within the immediate vicinity of the project site and at tidal elevations appropriate for macroalgae colonization.

The location and design for the macroalgae mitigation sites as well as the control sites shall be subject to state agencies' and WEC approval. The site locations will be surveyed by GPS or other suitable means to allow for future monitoring.

Implementation

The results of the Shade Model application suggests that an area up to 4,250 square feet of macroalgae could be affected in two ways by the proposed pier: (1) the relative species composition ratios could be changed; and (2) the amount of macroalgae biomass habitat could be reduced.

The Phase 1 Macroalgae Mitigation site shall be constructed with a minimum area of three times the maximum impact area predicted by the Shade Model (4,250 square feet) or 12,750 square feet, plus 25% (3,187 square feet) to offset epibenthic invertebrate production that will be displaced at the Phase 1 mitigation site. The Phase 1 mitigation site will include a minimum of 15,937 square feet.

Macroalgae control sites will be identified in the immediate vicinity of the proposed pier element. Control sites shall each equal the size of the pre-construction footprint vegetative zone of the proposed pier structure. One control site will be located at least 75 feet northwest of the pre-construction footprint of the proposed pier, and the other control site will be located at least 75 feet to the southeast of the proposed pier footprint. In addition, the control sites will have a macroalgae species composition and distribution similar to the macroalgae community within the pre-construction footprint of the proposed pier structure. The macroalgae composition and distribution similarity in the control sites shall be about 75% species overlap and within 25% of the average vegetative cover of the pre-construction project footprint. The control sites will be surveyed concurrently with the post construction surveys at the project site. The control site surveys will be used to calibrate the project site impacts for natural variation.

Impact Assessment

Pre-construction and post construction surveys of the macro algae distribution, species composition and percent cover at the pier site will be evaluated for pier structure, pier construction and pier operation related impacts. The macro algae distribution, species composition and percent cover will be surveyed at the control sites concurrently with the surveys at the project site. The control sites will serve as indicators of natural variation, and will be used to determine if natural variation "explains" variation in coverage seen at the project site (For example, if there is a 50% reduction in algae cover following construction, then this will be assessed against any declines or increased in cover at the control sites over the same period). The estimated net impact area and percent cover calibrated for natural variation and equivalent to 100% cover will be used to establish the area of mitigation that is required. (Example of 100% Equivalent: 100 square feet at 100% cover = 200 square feet at 50% cover)

Performance Criteria

The Phase 1 mitigation will be determined successful when the proponent provides an area of macro algae that is equivalent to 3 times the area impacted by the pier structure, pier construction and pier operation as determined by the year 3 post construction survey and calibrated for natural variation by the control site surveys equivalent to 100% macro algae coverage.

In addition, the area and % cover required for pier related impacts at a 3:1 mitigation ratio will be increased by 25% to account for the existing epibenthic invertebrate production that will be displaced at the mitigation site.

At the end of year 3 post construction, the macroalgae species composition at the mitigation sites will be similar to the same species composition present at the pre-construction project site as calibrated by natural annual changes to the macroalgae species composition observed at the control sites. The determination of species similarity will be made by applying the method noted in Thom and Widdowson (1978).

Contingencies

If the Phase 1 mitigation site does not provide sufficient mitigation to replace the macroalgae habitat impacted (performance criteria) as identified during year 3 post construction monitoring, then PIT will construct a Phase 2 mitigation site not later than one year following determination of a need for additional mitigation. The Phase 2 mitigation site will be of sufficient size to fully mitigate the macroalgae habitat impacts that are not mitigated by the Phase 1 mitigation site. The performance criteria noted above for phase 1 mitigation shall apply.

The project proponent will take reasonable and appropriate actions necessary to assure the mitigation site achieves the species composition performance criteria, and prevent the mitigation sites from being dominated by Sargassum. Such actions may include mechanical removal of Sargassum or anchoring kelp sporophylls onto the rocks to assure settlement of preferred species.

Mitigation credits available at the Phase 1 and Phase 2 mitigation sites shall only be available for impacts related to the GPT pier structure, pier construction, and pier operation.

Monitoring

The project site, the control site, and the mitigation sites shall be monitored as set forth below, during years 1,2,3,5,7, and 10 following construction of the pier.

<u>Pre-Project Baseline Study:</u>

Within 2 years prior to project construction, PIT shall submit for the State Agencies' review and approval a study describing and identifying the existing eelgrass and attachment macroalgae at the project site. The study shall provide baseline data for post-construction monitoring of the impacts of the project. The study shall also characterize the configuration and composition of the bed under and around the trestle and pier in a form usable for assessing impacts due to prop wash, which is further discussed below in the section labeled "Prop Wash Impacts".

Macroalgae:

The macroalgae in the immediate vicinity of the pier shall be monitored for impacts using methods employed during the 1996 baseline survey.

PIT will contract with a consultant approved by WDFW to conduct intensive level macroalgae surveys of the pier site and control sites between June 1 and 15 of each monitoring year according to protocols of the WDFW. The transects will begin at approximately 5.0 feet (1.5 meter (m)) MLLW and extend seaward parallel to the centerline of the proposed pier through the vegetated zone. Lead lines will be used to establish the subtidal transects. The seaward end of each lead line will be attached to an anchor with a float marking its location at the water surface. At the pier site, five transects will be established at 15-foot (4.6m) intervals along the beach, with the middle transect at the centerline of the proposed pier.

For the control sites, five transects will be established at 15-foot intervals along the beach, with the transect closest to the outside transect of the proposed pier survey site at least 75 feet (22.9 m) away. Transects will be surveyed by GPS or other means to assure continuity between monitoring years.

SCUBA divers will record data along each transect. Plant species will be identified as to genus, total vegetative cover of each species encountered within square meter quadrants centered at 20-foot (6.1m) intervals. Also recorded for each quadrant will be the elevation (recorded depth adjusted to MLLW) at the center of the quadrant and a description of the substrate. In addition, any eelgrass observed in the survey area will be identified as to location, size, and plant density. Plant density will be determined by counting eelgrass shoots within the square meter quadrant. Observations will be recorded to depths where macroalgae is no longer apparent and the substrate becomes consistently sand or mud.

PIT will contract with a consultant approved by WDFW to conduct intensive level macroalgae surveys of the mitigation site between June 1 and 15 of each monitoring year according to protocols of the WDFW. The number and orientation of the transects will be established after the location and configuration of each site has been chosen. Lead lines will be used to establish the transects in a pattern similar to that used at the pier and control sites. Transects will be surveyed by GPS or other means to assure continuity between monitoring years. Data will be recorded in a manner similar to that used in surveys of the project site and control sites.

Monitoring reports shall be submitted to the agencies and WEC during the same years that they are conducted.

Eelgrass:

Based on the last marine vegetation survey in 1996, no eelgrass was observed within 50 feet (15.2 m) of the centerline of the proposed trestle, and then, only to the northwest. Impacts to eelgrass in the vicinity are not expected. PIT shall monitor for unpredicted impacts to Zostera marina. Monitoring shall take place between June 1 and June 15, utilizing the same comparison protocols between the pier and control sites established for monitoring impacts to macroalgae. If monitoring reveals loss of Z. marina at the project site that is different than pre-construction abundance, as calibrated by the control site, PIT shall consult with WDFW and determine if a

study is necessary to determine a cause of additional loss. . The study shall employ consultants selected with the approval of the State Agencies. If the study reveals that the additional loss is due to the construction of the pier or activities at PIT's site or facilities, then additional mitigation shall be required as set forth in below in the section "Additional Mitigation Measures".

If the pre-project baseline study shows eelgrass (less than 100 shoots) within the footprint of the proposed trestle, PIT will transplant the eelgrass to a WDFW approved site adjacent to an existing eelgrass bed using state-of-the-art techniques. If the pre-project baseline study shows more than 100 shoots, PIT will develop jointly with WDFW an approved eelgrass mitigation plan. Implementation of the plan will involve state-of-the-art transplant techniques, monitoring, and success criteria.

Prop Wash Impacts:

During Construction: PIT will conduct construction such that tug prop wash will be directed offshore and to the south as much as practical. PIT will monitor the immediate areas of construction by using periodic diver surveys during construction operation. This will be intended to detect prop wash impacts early, and take measures to minimize additional damage to marine vegetation.

Post Construction: During the June macroalgae survey conducted immediately following construction of the pier, PIT's consultants shall conduct two additional dive transects to monitor impacts that may be associated with tugs and barges used during construction. One transect will be 50 feet (15.2 m) northwest of the edge of the footprint of the trestle and one will be 50 feet (15.2 m) southeast from the edge of the footprint of the trestle, or as adjusted by observations made during construction. Construction related impacts shall be determined during the year 1 post-construction survey. The survey shall be repeated during year 3, at which time impacted areas identified during the year 1 post-construction survey that have not recovered will be quantified. Mitigation (based on 100% vegetative cover equivalence) will be required for construction related impacts per the following criteria:

a. Area impacted and recovered by year 3 shall be mitigated at a 0.5:1 area ratio (to compensate for temporal losses between construction and year 3)
b. Area impacted and not recovered by year 3 shall be mitigated at a 3:1 area ratio.

The percent cover and species composition performance criteria noted for the Phase 1 mitigation shall apply.

The results of monitoring shall be reported at the same time as other monitoring reports.

Operational: In conjunction with the eelgrass and attachment macroalgae monitoring, PIT will monitor the aquatic land under and around the pier and trestle for prop wash scouring of the bed. The results of monitoring shall be reported at the same time as other monitoring reports.

If scour impacts are noted, PIT shall institute the following mitigation requirements as needed to eliminate the impacts:

1. Restrict the use of the pier for vessel maneuvering to periods of high tide.

2. Require the use of tug assistance for approaching or departing vessels.

Monitoring for prop wash impacts will continue for a period of 2 years following implementation of mitigation requirements 1 and 2 above. If at the end of the second year of survey following the implementation of mitigation requirements 1 and 2 above, operation prop scour impacts persist, the impacts will be quantified and mitigation required at a 3:1 area ratio. The percent cover and species composition performance criteria noted for the Phase 1 mitigation shall apply.

Herring Monitoring:

For a period of 5 years following the construction of the Phase 1 Macroalgae Mitigation Site, PIT will monitor the mitigation site for herring spawn during those years that WDFW surveys identify herring spawn south of the mitigation site. This monitoring will be coordinated with the herring spawning ground monitoring discussed in the Herring Monitoring Plan (Appendix C).

Additional Mitigation Measures

If post construction monitoring establishes that the project has created unanticipated impacts to macro algae or eelgrass, PIT shall institute the following requirements as may be required by the State Agencies to mitigate the impacts. Measures shall be considered by the State Agencies in the following order of preference:

1. Reasonable project modifications to avoid the impacts shall be instituted.

2. Reasonable project modifications to minimize the impacts that are unavoidable shall be instituted.

3. Replacement of lost habitat and natural resource values by PIT at a site approved by the state agencies.

4. If replacement and avoidance are not possible or do not succeed, payment of natural resource damages, as determined by the State Agencies, that are associated with the loss shall be made to the State Agencies, in addition to any minimization efforts that are instituted.

Additional mitigation shall be subject to the same monitoring and reporting requirements as the original mitigation.

Anticipated Time Line

The time line for design, permitting, construction, and monitoring is estimated as follows:

July 1999 - Settlement Agreement signed, and forwarded to SHB and Corps of Engineers.

August 1999 - Field and aerial photo study and decision on location of mitigation and control sites.

October 1999 - Preliminary design of mitigation site and next stage of design of facility.

November 15, 1999 - Lease commitment with DNR.

Summer 1999 - Obtain 404 permit from Corps; final negotiation of lease with DNR.

Fall 1999 - Next stage of design for facility.

December 1999 - Construction of mitigation site.

May 2000 Baseline macroalgae surveys of the pier site and control site.

Summer 2000 - All remaining local permits and approvals obtained.

September 1, 2000 - Begin construction of pier.

May 2001 - First post construction macroalgae surveys of the pier, control, and mitigation sites.

May 2002 - Second post construction macroalgae surveys of the pier, control, and mitigation sites.

May 2003 - Third post construction macroalgae surveys of the pier, control, and mitigation sites.

May 2005 - Fifth post construction macroalgae surveys of the pier, control, and mitigation sites.

May 2007 - Seventh post construction macroalgae surveys of the pier, control, and mitigation sites.

May 2010 - Tenth post construction macroalgae surveys of the pier, control, and mitigation sites.

Appendix C
Herring Monitoring Program

To Evaluate the Effects Of The Pacific International Terminal Trestle/Wharf Structure and Shipping Activity on the Behavior of Herring at Cherry Point

by
Hap Leon, North Coast Resources
for the Washington Environmental Council

and
Brian Williams, Norm Lemberg, Mark O'Toole, Jack Tagart
Washington Department of Fish and Wildlife

and
Mark Pedersen and Lorraine Read
Shapiro and Associates, Inc.

May 5, 1999

INTRODUCTION

The site proposed by Pacific International Terminal (PIT) for the Gateway Pacific Terminal (GPT) project is within the documented spawning habitat for the Cherry Point herring stock. The proposed trestle and wharf structures and/or the operation of the bulk terminal facility could disrupt the nearshore movement and spawning of the Cherry Point herring stock near the proposed GPT bulk terminal facility. The monitoring surveys proposed in this program are designed to study the interaction of the Cherry Point herring stock with the GPT bulk terminal facility and identify structural and operational contingencies in the event that significant disturbances are discovered.

Cherry Point is the spawning area for what was, until recently, the largest herring stock in Washington. The spawner biomass for this stock has been estimated as high as almost 15,000 tons (in 1973) but has declined considerably in recent years, averaging less than 6,000 tons in the 1980's, and less than 5,000 tons in the 1990s. Most recently, the spawning biomass has dropped to about 1,500 tons in 1998. Increasing adult herring mortality coupled with poor recruitment appears to be the primary reasons for the declining stock size. The dangerously low population level has resulted in the closure of the commercial herring fishery, and led to concerns about the future of this herring stock.

It is well documented that Pacific herring, among other schooling pelagic fish, are highly sensitive to noise and disturbance (Mitson, 1995; Schwartz and Greer, 1984). This sensitivity serves the herring well to help them detect and avoid predators, but it also causes them to avoid some disturbances caused by human activities. Pacific herring held in net pens have been documented to be sensitive to recorded sounds of some commercial fishing vessels (Canadian purse seiners) at a distance of up to one mile (Schwartz and Greer, 1984). On Annette Island, Alaska, ripe spawner herring have been observed leaving their usual spawning grounds before spawning. In addition to weather and other factors, it appears that exposure to activity by commercial gill-netters and seiners affected the movement of the herring (Leon, 1993; Leon, 1997 field observations).

The significance and duration of herring response to human activity, however, are not well understood. For example, herring regularly spawn on pilings and the bottoms of ships along the waterfront in downtown San Francisco (Watters, 1998), have spawned on the inside of the harbor breakwater in Sitka, Alaska (Gordon, 1998), and even on macroalgae attached to pilings of the Arco Pier at Cherry Point (O'Toole, 1998). These observations suggest that schools of herring may acclimate to human activity after a short behavioral response.

The Washington Department of Fish and Wildlife (WDFW) and the Washington Environmental Council (WEC) have concerns regarding development of the proposed trestle/wharf structures and/or the operation of the PIT bulk terminal facility. Operation of such a facility could disrupt the nearshore movement, schooling, and spawning of the Cherry Point herring stock in the immediate vicinity, and this may affect herring spawning and recruitment success. Although it is not always certain why herring select certain spawning grounds, the fact that most return to the same spawning grounds year after year (Hourston, 1982), reproduce more successfully in these locations than in other nearby locations (Robinson, 1988) and relocate to other places only under

duress (Leon, 1993) implies that these traditional spawning grounds are valuable, and perhaps necessary, for maintaining herring populations. Thus, any disturbance that can be shown to disrupt access to the spawning habitat or displace the spawning to a different location could be detrimental to the survival of the stock.

Although questions remain about the response of herring to noise and other disturbance in the water, the precarious status of the Cherry Point herring stock points toward a cautious approach to any development that might affect this population. The parties to this agreement have agreed on this monitoring program to document any potential adverse affects of the terminal and its operations on the herring, and have developed the contingency measures described in this document to mitigate those impacts.

MONITORING PROGRAM OBJECTIVES

This monitoring program is designed to study the potential impacts of the proposed GPT project on the Cherry Point herring stock and to answer the following questions:

1. Nearshore migration corridors/schooling areas:
   - 1.1 Are there preferred nearshore migration corridors/schooling areas at or near the GPT project site?
   - 1.2 Does the ship activity at the GPT site disrupt the use of a preferred nearshore migration corridor/schooling area?
2. Nearshore lateral migration: Does the trestle/wharf structure, ship activity, and bulk terminal operations at the GPT site disrupt the nearshore lateral migration and concentration of the herring?
3. Spawning behavior: Does the trestle and ship activity at the GPT site displace the herring from using the spawning habitat in the immediate vicinity of the trestle?

Objective 1.1: Determine whether there are preferred nearshore herring migration corridors/schooling areas at or near the GPT project site.

WDFW staff have observed that herring fishing activity is typically concentrated near a bathymetric trench located along the southern boundary of the GPT site suggesting that the fishers commonly find the highest concentrations of herring at that Cherry Point location.

Although the fishing observations suggest that the trench is a preferred nearshore migration corridor/schooling area, herring nearshore behavior has not been studied at the site. WDFW hydroacoustic surveys are focused on stock assessment rather than on monitoring herring behavior.

Survey Methods

A pre-project hydroacoustic survey was conducted in 1998 and another will be conducted during 2000 to determine the existence of a preferred nearshore herring migration corridor/schooling area near the proposed GPT project. Each survey will be conducted from a small research vessel in the nearshore area. The research vessel will survey two (2) northwest/southeast transects.

One transect will follow the 10-fathom (18.3 meter MLLW) depth contour. The second transect will parallel the 10-fathom contour approximately 500 meters seaward. Each of the transects will extend from one half mile north of Point Whitehorn to the south end of Sandy Point. The survey area will be divided into 28 segments, each 500 meters in length. The border between Segments 12 and 13 shall coincide with the midpoint of the proposed GPT wharf.

For the best coverage of the pre-spawning activity, surveys will be conducted from April 26 through May 17. The surveys will alternate between day and night sampling. Each survey will be conducted for a minimum of three hours. Day surveys will be conducted from 12 noon to 3:00 p.m. Night surveys will be conducted from 12 midnight to 3:00 am. For logistical reasons and to spread the surveys over different tidal phases, they will be conducted on Mondays, Wednesdays, and Fridays.

During each survey, the time, tidal stage, location, and relative size of pelagic fish schools will be recorded and plotted on a chart. School location will be determined from a differentially corrected global positioning system (DGPS) to within 1-10 meter.

An American Pioneer "Fishscanner Model 201" sonar system meeting these requirements was used during the 1998 monitoring program and will be used during the survey in 2000. This system operates at a frequency of 160 kHz, allowing relatively high target resolution. It incorporates a 6.5 degree nominal beamwidth transducer, which can be hydraulically aimed in the X (up-down) and Y (left-right) quadrants, allowing 90 degree sampling around the vessel, if desired. In "fast-scan" mode, the system automatically scans a repetitive sequential sweep over a user-defined area, allowing identification of individual fish targets and schools surrounding any part of the vessel. The acoustic signal is displayed on a 16-color video monitor for visual interpretation. Echo amplitudes, or signal strength, are shown on the video display as specific colors indicative of general target size or position in the acoustic beam. Small amplitude echoes appear as blue or green, medium echoes as yellow or red, and the largest amplitude echoes as purple or white. A detailed description of the operation and specifications of the "American Pioneer Fishscanner 201" is presented in the equipment manual (Roundy, 1988), available from American Pioneer and on file at HTI.

For the purposes of this study, the scanner will be operated in "fast-scan" mode repetitively sweeping a 180-degree swath centered on the bow of the vessel. System gain should be fixed (at +12) and total sampling range at 64 meters during the study period to maintain consistent system sensitivity and sampled volume between transects and surveys. Transects will be surveyed at a boat speed of approximately 5-6 knots.

The transducer is aimed at a slight vertical tilt angle toward the bottom. This allows sampling of the entire water column ahead of the boat, i.e. allows the bottom to be resolved at maximum sampling range. Based on the mean observed depth along each transect and the set 64 m maximum sampling range of the system, fixed tilt angles are chosen for each of the two transects. These should be 17 degrees (down from horizontal) for the inshore transect following the 10-fm contour (Transect 1) and 25 degrees for Transect 2 (500-m offshore of the 10 fm contour). With brief exceptions, these transducer aiming angles will be maintained for each of the transect locations over the study period. Once initially set, none of the selectable user parameters of the

sector-scanning sonar will be changed over the course of the study, such as gain, range, ping rate, etc.

To verify the stability and consistent response of the system, it is "calibrated" against a known target either before or after each survey. A 20-cm aluminum air-filled sphere is used as the acoustic reference target. The sphere is secured to a 20-m long rope at a distance of 5 m above a 25-lb lead downrigger ball, which serves as an anchor. This arrangement suspends the target sphere 5-m above the bottom when deployed. The rope and sphere are cast overboard in about 10 fm of water. The boat is positioned approximately 32-48 m away, and the scanner transducer is manually aimed at the float. The system gain is set to +12, as used during the surveys. The transducer aiming angle is then adjusted until maximum amplitude (peak color) is obtained.

In addition, an HTI Model 241 Portable Split-Beam System will be used for data collection and processing during 2000. This scientific echo sounder system will provide more accurate, quantifiable density estimates not available with the American Pioneer "Fishscanner Model 201" commercial sector-scanning sonar.

Data collected with the HTI Model 241 Portable Split-Beam System will be used to interpret the weighted values of school sizes determined from the data collected with the American Pioneer "Fishscanner Model 201" sector-scanning sonar as follows. Each year, the HTI system will be used to measure length, depth, and density of the schools. Simultaneously, the American Pioneer system will be used to measure the length, depth, density, and width of the schools. The final measurement for each school will be a function of length, width, depth, and density. The measurements from the HTI system will be compared with the measurements taken from the American Pioneer sonar each year, and the comparison may be used to adjust the data from the American Pioneer sonar in 1998

The HTI scientific system will be stable, reliable, calibrated, and will produce data comparable over time and range. The Model 241 System will use a down-looking 15 degree conical beam transducer to maximize sample coverage. The operation of the Model 241 System is described by HTI (1994a, 1994b), and detailed specification will be provided on request.

Absolute fish density estimated with the HTI Model 241 will be generated at 30-second intervals as fish/m^2. (Pings will occur at more than one per second.) At a boat speed of 4 knots, this equated to a density estimate approximately every 60 m. These individual density estimates will be combined within each of the 28 geographical areas of interest. Herring school data will be pooled by depth and day/night period for each of the twenty-eight sectors. Estimates of fish density (expressed in fish/m^2), associated variance, and 95% confidence intervals will be calculated for each of the 28 sectors.

All hydroacoustic data will be interpreted visually from the echo sounder video displays and entered into the electronic navigation and charting software program. The full video output of the sector-scanning sonar will be recorded to VHS videotape during all surveys. The taped data will provide a permanent record of the surveys for later review, if desired. Videotape fish school events will be recorded regularly to log sheets and the computer record during data collection to facilitate location of school events on tape at a later date.

Fish schools observed on the sector-scanning sonar will be classified into three qualitative "size" types, based on the intensity (color), area (number of pixels on the display), and duration (number of repetitive sampling sweeps over which the school is observed). These will be classified as Type 1 (small), Type 2 (medium) and Type 3 (large). Type 1 schools will be mainly blue, green and/or yellow in color, relatively small (6-25 pixels), and only observed during one sweep of the scanning transducer. Type 2 schools will be of higher amplitude, usually yellow, orange, red, purple or white in color, larger in area (15-80 pixels) and more persistent (observed over two sampling sweeps). Type 3 schools will be expected to be very large, long-lasting and of high echo amplitude. These schools will normally be red, purple, or white in intensity, observed over 3 or more sampling sweeps, and 80 to several hundred pixels in size. They should frequently obscure a large part of the video screen over an extended period. All counted schools will be required to be relatively compact and a minimum of 15 pixels in size. Small aggregations of dispersed fish and individual or paired targets will not be plotted, although their presence will be noted in the field logs.

The three recorded school size types will be indicated on the NOAA survey charts by specific marks or icons. School type 1's (small) will be designated with a green "X", type 2's (medium) with a red "X" and type 3's (large) with a large purple dot. The actual vessel survey track will also be plotted on each map.

Each school will be assigned a unique chart mark name describing the survey number, transect number, school type, and time position in the survey. For example, the first size 1 school in Transect 1 of Survey 7 will be designated as mark 7-1-1A and the last Survey 7 school, occurring in Transect 3 will be 7-3-1AZ. The naming convention will be *Survey # - Transect # - School Type – Sequential Alpha Character Designator*, where the sequential alpha character string flags the place of the school in the entire survey. (For example, 7-1-1D would be the 4th school in the survey and 7-3-1AZ the 52nd school.)

The charts with observed fish school data will be presented each year on a survey basis, plus a summary for all nine surveys as a whole (10 chart sets in total). Each survey map set includes three charts, one encompassing the entire survey area between Sandy Point and Point Whitehorn (1:32,000 scale) and two higher-resolution charts displaying the northern and southern halves of the area in greater detail (1:16,000 scale). These charts will be printed in color at 360 dots per inch (dpi) resolution.

The survey text logs will include all real-time observations from each survey, including a description of each observed school, environmental data, vessel traffic, and other ancillary information.

Changes in the above referenced survey methods will be subject to prior WDFW and WEC approval. WDFW and WEC representatives will be permitted access to the survey vessel upon request. Annual survey reports will be submitted to WDFW, WEC, and DOE by August 30 of the sampling year.

Analysis/Threshold Determination

A location will be considered a preferred nearshore migration corridor/schooling area if more of what are considered to be pre-spawning herring are observed for that particular site compared with other sites during either survey year.

For each transect during the surveys, the location and size of each school recorded with the American Pioneer "Fishscanner Model 201" sector-scanning sonar will be plotted on a chart. This information will be analyzed by examining data for each date and depth, data pooled for all daytime surveys, and data pooled for all nighttime surveys, and data pooled for all surveys day or night.

Since there is no concurrent net sampling on the hydroacoustic surveys, only the larger, denser fish schools that are most likely pre-spawner herring will be considered as such. The following school characteristics will be classified as spawner herring: amplitude high, primarily red, purple or white in color; screen size 20 pixels or greater; visible for at least two sweeps.

Each school that fits the above spawner herring criteria will be given a weighted score based on size and amplitude. For a given school, the number of pixels on the screen for a sweep will be counted and each pixel assigned a value. Red pixels will have a value of one, purple pixels a value of two, and white pixels a value of three. The score for that sweep will be summed. Each successive sweep for that school will be scored in the same manner. The scores from each sweep will then be summed to give a total weighted score for that school. This scoring method may be adjusted as agreed by technical staffs of WDFW, WEC, and PIT.

The assumptions implied in the analyses of data collected by the sector-scanning sonar are:

1. The combination of the number of pixels on the sonar screen and the number of sweeps in which a school is visible is a linear function of the volume of the school. For example, all other things being equal, a school visible in two sweeps is twice as large as a school visible in one sweep. And, all other things being equal, a school represented by 750 pixels is three times as large as a school represented by 250 pixels.
2. The pixel color of a school is linearly related to the density of the school and, therefore, to the strength of the signal returning to the sonar as described in the previous paragraph, subject to review by the Parties.
3. The abundance scores generated from this approach are not estimates of biomass.

A second set of charts with the abundance score data will be presented each year as a summary for all nine surveys as a whole. The survey map set will include three charts, one encompassing the entire survey area between Sandy Point and Point Whitehorn (1:32,000 scale), and two higher resolution charts displaying the northern and southern halves of the area in greater detail (1:16,000 scale). These charts will be printed in color at 360 dots per inch (dpi) resolution. The schools classified to be spawner herring will be indicated on the NOAA survey charts by specific marks or icons. Schools with scores below 250 will be designated with a green "X," schools with scores from 250 to 1,000 will be designated with a red "X," and schools with scores greater

than 1,000 will have a large purple dot. These scoring categories may be adjusted as agreed by technical staffs of WDFW, WEC, and PIT.

In addition, the densities recorded with the HTI Model 241 Portable Split-Beam System will be analyzed. The HTI Model 241 Portable Split-Beam System data will be used to check the data generated from the American Pioneer System, may be used to fine tune the weighted values of school size, and will be used in comparing data from the two post-construction surveys, if performed. Modifications to the weighting factors based on HTI Model 241 Portable Split-Beam System data analysis will be selected and approved by scientific representatives of WDFW, WEC and the proponent.

WDFW, WEC, and PIT technical staffs will examine the results visually (geographic analysis). Geographic analysis may clearly indicate existence of a preferred inshore migration corridor/schooling area, or it may indicate no particular pattern. After the results of the geographic analysis are known, if there is consensus among WDFW, WEC, and the proponent that no preferred nearshore migration corridor/schooling area exists, no additional analysis or surveys under Objective 1.1 and 1.2 will be required.

If there is consensus among WDFW, WEC, and the proponent that a preferred migration corridor/schooling area exists, then Contingencies 1, 2, and 3 will apply.

If there is no consensus regarding the existence or location of nearshore migration corridor/schooling areas, a statistical analysis of the data will be used. The fish school data will be assigned to one of 28 predetermined sectors. These sectors will be of equal length, spanning the 14-km shoreline within the herring spawning area. For each sector, the total weighted school scores described earlier will be summed over the survey period to produce a total abundance score for each sector. Any data comparisons and/or statistical analysis of the hypotheses for Objective 1 will use the abundance scores.

The abundance score data will be stratified according to year and period (day and night) and will be pooled across transects. The transects will be divided into 28 sectors, each of 0.5 km length, with the proposed GPT pier site as the dividing line between two adjacent sectors, (e.g., between Sectors 12 and 13). Observations taken on nine non-consecutive dates (alternating between day and night) constitute the replicates.

The residual and total degrees of freedom shown in Table 1 assume that there will be four and five replicates within each year, period, and sector.

Table 1: EXPECTED ANOVA TABLE FOR OBJECTIVE 1.1

Sources of Error	Degrees of Freedom
Main effects	
Year (1998, 1999) (Y)	1
Period (day/night) (P)	1
Sector (1 through 28) (S)	27
Interactions	

Year: Period	1
Year: Sector	27
Period: Sector	27
Year: Period: Sector	27
Residual	392
Total	503

All of the factors (year, period, and sector) are fixed and will be dealt with appropriately when calculating the error terms and the variance ratios in the generalized linear model (GLM). The abundance scores – which are essentially count data – are expected to follow a Poisson distribution, hence these data will be modeled using a Poisson error distribution and a log-link function. This is the most common model for count data (e.g., McCullagh and Nelder, 1989). Diagnostics on the residuals will be conducted to confirm the appropriateness of this model.

The model described in Table 1 will be used to test the following sets of hypotheses.

Hypothesis set 1.1:
Testing the null hypothesis:

The annual mean abundance scores in Sector 12 and Sector 13 are less than or equal to the annual abundance scores averaged across all the sectors that are not adjacent to the GPT site.

$$H_{01}: (\mu_{\text{Sector 12, 1998}} \leq \mu_{\text{Sectors 1-11 and 14-28, 1998}} \text{ and } \mu_{\text{Sector 12, 2000}} \leq \mu_{\text{Sectors 1-11 and 14-28 2000}})$$
$$H_{02}: (\mu_{\text{Sector 13, 1998}} \leq \mu_{\text{Sectors 1-11 and 14-28, 1998}} \text{ and } \mu_{\text{Sector 13, 2000}} \leq \mu_{\text{Sectors 1-11 and 14-28, 2000}})$$

versus the alternative hypothesis:

The annual mean abundance scores in either Sector 12 or Sector 13, in either 1998 or 2000, are greater than the annual abundance scores averaged across all the sectors that are not adjacent to the GPT site.

$$H_{a1}: (\mu_{\text{Sector 12, 1998}} > \mu_{\text{Sectors 1-11 and 14-28, 1998}} \text{ or } \mu_{\text{Sector 12, 2000}} > \mu_{\text{Sectors 1-11 and 14-28, 2000}})$$
$$H_{a2}: (\mu_{\text{Sector 13, 1998}} > \mu_{\text{Sectors 1-11 and 14-28, 1998}} \text{ or } \mu_{\text{Sector 13, 2000}} > \mu_{\text{Sectors 1-11 and 14-28, 2000}})$$

Where $\mu_{\text{Sector 12, 1998}}$ is the mean in 1998 for Sector 12 pooled across all transects and periods, and $\mu_{\text{Sectors 1-11 and 14-28, 1998}}$ is the grand mean in 1998 pooled across all sectors (except the two GPT-adjacent sectors), all transects and all periods. If Sector 12 or 13 has greater than average abundance scores in either year that sector will be interpreted to be among the preferred locations for herring migration/schooling, where preferred is interpreted as anything greater than average. If either of these sectors is found to be preferred by rejection of the null hypothesis, Contingencies 1, 2, and 3 will be implemented.

Statistical testing of this hypothesis set will be performed at a significance level (alpha) of 0.05. Failure to reject null hypothesis 1.1 indicates insufficient evidence to statistically show that the two GPT-adjacent sectors have greater abundance scores on average than the other sectors. (Note: The proposed design results in a test that should be relatively powerful. A powerful test is more likely to lead to rejection of the null hypothesis.) A power analysis will be performed to determine the level of sensitivity of this test. If it is found that the test has sufficient power (>80%) to detect an *a priori* stated effect size and the null hypothesis is not rejected, then it will have been effectively shown that the GPT site is not a preferred corridor and Contingencies 1, 2, and 3 will not be implemented. If the null hypotheses is rejected, then Contingencies 1, 2, and 3 will be implemented.

If there is insufficient power and the test fails to reject the null hypothesis, then the results are statistically inconclusive. Statistically inconclusive results will lead to modification of the sampling design to improve the power in subsequent sampling events (i.e., for Objective 1.2). In the event that the results from Objective 1.1 are inconclusive, Contingencies 1, 2, and 3 will be implemented.

Objective 1.2. Assess whether the ship activity at the GPT site disrupts the use of preferred nearshore migration corridors/schooling areas.

Post-construction hydroacoustic surveys of the study area will be required only if results of pre-construction surveys described above in Objective 1.1 conclude that there are preferred nearshore migration corridors/schooling areas within 500 meters of the footprint of the project (Sectors 12 or 13).

The question of whether vessel operations will affect pre-spawner herring use of preferred nearshore migration corridors/schooling areas will be assessed by repeating the survey methods outlined above in Objective 1.1 for a period of at least two operational years immediately following trestle/wharf construction and the initiation of bulk terminal operations. Post-construction surveys will be analyzed in relation to pre-construction survey results for measurable changes in pre-spawner herring presence in the preferred nearshore migration corridors/schooling areas.

Survey Methods

Same methodology outlined above in Objective 1.1.

Analysis/Threshold Determination

For each survey date, the location and size of each school will be plotted on a NOAA chart. The charts will analyze data for each date and depth, data pooled for all daytime surveys, data pooled for all nighttime surveys, and data pooled for all surveys day or night. Geographic analysis may clearly indicate a change of occurrence in a preferred inshore migration corridor/schooling area or it may clearly show no change.

If there is no consensus regarding a change in herring use of the nearshore migration corridor/schooling areas, then a statistical analysis will be used. The analysis will be similar to that used in testing Objective 1.1, except that the herring abundance scores (including the 1998 and 2000 data) will be transformed to proportions that account for annual differences in inshore survey area pre-spawner herring abundance. The proportions will be calculated as the abundance score in each category (year, sector, and period) divided by the total annual survey area abundance–score (where the total is calculated by summing school scores across all sectors, transects and periods within a year). The data will be analyzed using an ANOVA to determine the significance of year (comparing pre- vs. post-construction years) on the proportion, with the ANOVA accounting for the effects of sector and period separately.

A model similar to that outlined for Objective 1.1 will be used. All data treatment and evaluation of the model assumptions will be identical to that described for Objective 1.1. The ANOVA table for this objective (Table 2) will be similar to that detailed for Objective 1.1, but there are now four years of observations. Replication occurs on different dates throughout each year. For example, if there are four day and five night observations in 1998 and five day and four night observations in 2000, then there are nine replicates within each period and sector for the two years of the pre-construction phase. This same distribution of day and night observations in the post-construction years will be used to ensure a balanced design with nine replicates in each sector and year, with equal representation of day and night observations. The residual and total degrees of freedom shown in Table 2 assume four and five replicates for the two periods within each sector and year. Including data from all sectors in this model will provide a better estimate of the residual error, as well as the ability to define additional hypotheses regarding the sectors neighboring the GPT-adjacent sectors.

The model described in Table 2 will be used to test the following hypothesis, which is presented as one interpretation of the narrative Objective 1.2. Only the preferred corridor will be the focus of study for this objective, although this corridor might encompass more than one sector.

Hypothesis Set 1.2:

Testing of the null hypothesis: (Vessel traffic does not disrupt herring)

> The mean proportional abundance score observed in the preferred corridor during the pre-construction phase (1998 and 2000) is less than or equal to the mean score observed in the preferred corridor during the post-construction phase (2001 and 2002).

$$H_0: \mu_{\text{Preferred corridor, pre-construction}} \leq \mu_{\text{Preferred corridor, post-construction}}$$

The alternative hypothesis: (Vessel traffic disrupts herring)

> The mean proportional abundance score observed in the preferred corridor during the pre-construction phase (1998 and 2000) exceeds the mean score observed in the preferred corridor during the post-construction phase (2001 and 2002).

$$H_a: \mu_{\text{Preferred corridor, pre-construction}} > \mu_{\text{Preferred corridor, post-construction}}$$

Where $\mu_{\text{Preferred corridor, pre-construction}}$ is the mean proportion of the total annual survey area herring abundance score using the preferred sectors for the years 1998 and 2000, and $\mu_{\text{Preferred corridor, post-}}$

$_{construction}$ is the mean proportion of the total annual survey area herring abundance score using the preferred sectors for the years 2001 and 2002. Regardless of whether the ANOVA indicates a significant year effect, all hypotheses will average results for the years 1998 and 2000 to describe the pre-construction phase and the years 2001 and 2002 to describe the post-construction phase.

Table 2: EXPECTED ANOVA TABLE FOR OBJECTIVE 1.2

Sources of Error	Degrees of Freedom
Main effects	
Year (1998, 2000, 2001, 2002)	3
Period (day /night)	1
Sector (1 through 28)	27
Interactions	
Year:Period	3
Year:Sector	81
Period:Sector	27
Year:Period:Sector	81
Residual	784
Total	1007

Statistical testing of null Hypothesis Set 1.2 will be performed at a significance level (alpha) of 0.05. If the null hypothesis is rejected, Contingency 4 will be implemented. If the null hypothesis is not rejected, a power analysis will be performed to determine the level of sensitivity of this test. If it is found that the test has sufficient power (>80%) to detect an *a priori* stated effect size, and the null hypothesis is not rejected, then it will have been effectively shown that the ship activity at the GPT site does not disrupt the use of the preferred corridor, and Contingency 4 will not be implemented.

If there is insufficient power and the statistical tests fail to reject the null hypothesis, then the results are statistically inconclusive. In that event (low statistical power and there is failure to reject the null hypothesis), Contingency 4 will be implemented if the proportional abundance scores for the corridor (Sectors 12 and 13) decrease 10% or greater from the pre-construction phase to the post-construction phase.

The *Period* effect will be evaluated to determine if Contingency 4 needs to be implemented only during the day or night periods. Contingency 4 will be implemented as written or may be modified to account for the *Period* effect based on the results of the period effect analysis. Modification of Contingency 4 based on *Period* effect analysis will be subject to WDFW and WEC approval. Contingency 4 will be implemented during the appropriate day-time or night-time period.

Objective 2: Assess whether the trestle/wharf structure, ship activity, and/or bulk terminal operations disrupt the lateral nearshore migration and concentration of herring.

The question of whether the trestle/wharf structures, ship activity, and the bulk terminal operations will affect the lateral nearshore migration and/or concentration of herring will be explored through hydrophone and hydroacoustic monitoring. This monitoring will be conducted during the time of peak herring spawning activity (April 26 through May 17) for a period of two years when the terminal is in operation.

Because this monitoring involves methods and technologies that have not been used in this context, a pilot study will be conducted first to provide information on the feasibility of measuring herring behavior using fixed hydroacoustic transducers. This pilot study and the subsequent monitoring will have two parts. In the first part, hydrophone surveys will be "passive" surveys, using devices similar to underwater microphones to listen to the sounds in the water. The second part will consist of active hydroacoustic herring surveys using transducers that "ping" into the water and record the return signal from the ping.

As details of the pilot study are finalized, questions to be addressed regarding the hydrophones will include:

1) How much variability is there in the observable noise levels at different locations on the pier/trestle? 2) How many hydrophones does it take to adequately sample for the variability? 3) How can the noise readings from multiple hydrophones be integrated into a single sample interval datum? 4) What noise characteristic (frequency, amplitude, or both) provokes the observable herring response?

The following similar sets of questions will be evaluated for deployment of the hydroacoustic transducers. 1) Can a fixed transducer, facing outward from its stationary position, observe discrete schools of herring? 2) What is the range of detectability for the fixed transducer? 3) How many transducers will be necessary to effectively monitor herring near the pier and trestle? 4) How will the size of observed herring schools be determined? 5) How will observations of herring behavior be recorded and/or integrated into appropriate data for the sample interval? 6) What should be the duration of the sample interval?

Proposed Pilot Study Field Work Approach:

Hydrophone Monitoring

The project site will be surveyed using a broadband hydrophone, which is capable of picking up multiple frequencies. The signal from the hydrophone will be recorded and digitized for later analysis.

To begin the pilot study, two hydrophones will be fixed to the GPT trestle. One hydrophone will be fixed near the wharf and the second hydrophone will be fixed at approximately the location along the trestle where the bottom depth is 8.0 feet MLLW tide elevation (MLLW = 0.0). The exact placement of the hydrophones will be subject to WDFW and WEC consultation and approval. Hydrophone data will be collected during two consecutive years immediately following project construction. Hydrophone data will be collected during the April 26 to May 17

time period and when there is vessel activity at the wharf. The dates and times of vessel activity at the wharf will also be logged. As a control, data will be collected every sixth hour during one day each week when there is no activity.

The data collected with the hydrophones will document the frequency range associated with vessel activities and wharf operations, and provide a basis for comparison with the ambient sound conditions in the Cherry Point area. The analysis will also compare the frequencies and amplitudes of sound in the water at the project facility, with those frequencies that have been documented in the literature (e.g. Schwartz and Greer, 1984) as disturbing herring. In addition, the analysis will compare the frequencies and amplitudes from the wharf and at the 8 feet MLLW station. Annual reports will be submitted to WDFW, WEC, and Washington Department of Ecology (Ecology) by August 30 of each sampling year.

Hydroacoustic Monitoring

Because the monitoring is intended to determine if vessel traffic, the trestle/wharf structure, and facility operations affect herring behavior, the monitoring should not be conducted from a moving vessel, which itself makes noise and might disturb the herring. Instead, fixed location multi-beam transducers will be mounted on the pier to minimize disturbance to the fish from the monitoring activity. To begin the pilot study, two transducers will be fixed to the GPT trestle.

Hydroacoustic data will be collected during two consecutive years immediately following project construction. For the best coverage of the herring activity, hydroacoustic data will be collected on Mondays, Wednesdays, and Fridays from April 26 through May 17. Data collection will alternate between day and night sampling. During each sampling event, data will be collected for a minimum of six hours. For each sampling event, hydroacoustic data will be collected during the last half of the flood tide and the first half of the ebb tide. Two hydroacoustic transducers will be fixed to the trestle structure. The exact location and direction of the hydroacoustic transducers during each sampling year will be determined based on analysis of the Objective 1.1 and/or Objective 1.2 monitoring data and through consultation with WDFW and WEC technical representatives. The final placement of the hydroacoustic transducers will be subject to WDFW and WEC approval.

The hydroacoustic transducer arrays will record the abundance (relative backscattering or sv), location, and direction of movement of herring schools near the trestle. Hydroacoustic data should include periods of vessel activity at the wharf during the data collection period. The dates and times of vessel operations at the wharf and wharf activities including commencement and termination of lighting, loading and unloading, will also be logged. Based on historical WDFW hydroacoustic surveys and commercial fisher observations, it is assumed that any large fish schools in the area at this time are likely to be herring. Changes in the above referenced survey methods will be subject to prior WDFW and WEC approval. Annual reports will be submitted to WDFW, WEC, and Ecology by August 30 of each sampling year.

Exploratory and graphical data analysis will be used to investigate the relationship between herring behavior and concentration and noise. A description of the specific statistical tests that

could be used in this analysis will be provided after sample data from the pilot study are available and have been evaluated for their usefulness by participating scientists.

A complete experimental design to address Objective 2 will be forthcoming when the pilot study is completed.

Analysis/Threshold Determination

If results of the statistical analysis demonstrate there is a clear association between the onset of vessel or operation noise and an instantaneous change in herring migration direction, then one or more of Contingencies 2 and 5 through 8 will be implemented, depending on which type of noise or activity is shown to cause the disturbance.

Objective 3. Assess whether ship activity and bulk terminal operations displace herring from using the spawning habitat in the immediate vicinity of the trestle.

While it has been documented that Pacific herring are highly sensitive to noise and disturbance at a considerable distance (Mitson, 1995; Schwartz and Greer, 1984), they are also known to spawn in areas of concentrated human activity in the marine environment (San Francisco and Sitka). The effect of vessel and port bulk terminal operations at Cherry Point in relation to herring use of the spawning habitat near the dock structures has not been studied. The survey methods that follow are designed to evaluate the relationship between vessel activity/port bulk terminal operations and herring use of spawning habitat in the immediate vicinity of the trestle structures.

The spatial distribution of spawn for the Cherry Point herring stock has been highly variable over the past 28 years, during which the WDFW has conducted its grappling rake surveys in the herring spawning grounds. It is expected that the presence of spawn in a particular location is determined, in part, by the habitat quality in that location, but also by the total spawning stock size. When stock sizes are large, the herring will expand their spawning into areas that might not be used during periods of low spawning biomass. To assess whether the spawning preference for the GPT site has changed because of the presence of the trestle and its associated activities, a relatively long data series with sufficient contrast in spawning biomass levels both before and after construction is needed. The 28-year data series from the WDFW grappling rake surveys, conducted from 1972 through 1999, will be used to construct a model describing the use of the GPT site as a function of biomass. One or more environmental variables (e.g., water temperature) also may be considered. Observations taken at the GPT site following construction will be compared with predictions from the regression model based on the historical data for the site.

A survey, conducted by SCUBA divers, is proposed to validate that the WDFW estimates are providing a reasonably accurate representation of the spatial distribution of herring spawn and to quantify the error associated with the rake sample density estimates.

Survey Methods

Five locations determined to contain herring spawn will be selected for sampling by both the grappling rake and SCUBA methods. A WDFW sampling team will conduct grappling rake surveys at these locations using the same methods that have been used historically by WDFW. At the same five locations, SCUBA divers will collect egg spawn for estimating the error associated with the single rake sample estimates. If WDFW sampling indicates spawning at the GPT site, then it will be one of the experimental sites. The rake sampling and SCUBA sampling at each location will occur on the same day. The SCUBA survey will sample from an area approximately 100 meters in length (parallel to the shore) by the width of vegetated zone, with the rake sample estimate taken from one point in the center of the SCUBA sampling area. A systematic random sampling scheme will be used by the divers to record their observations along each transect. Transects will be placed perpendicular to the shore with one transect line intersecting the location where the rake sample was taken, and the other two placed approximately 50 meters north and south of the first transect line. The bounds of the vegetated zone will be identified for each transect line. The first interval on each transect will be randomly placed by the divers within the first five meters of visible vegetation. All subsequent 5-meter intervals will be measured from this first random start. Observations along the transect will be made at each 5-meter interval within the vegetated zone and within the width of the quadrat sampler (31.6 cm).

The divers will start at the shoreward end of the transect and will record their observations, including estimated spawn intensity (as egg layers), spawning substrate, percent cover, and water depth, at the 5-meter intervals within the vegetated zone. These observations will provide a general map of the spawn intensity and substrate along each transect and will identify all intervals at which spawn was present. Those intervals with no apparent herring spawn will be assigned an egg density of zero. Using a random number table, five intervals containing spawn will be randomly selected for quadrat sampling. Egg deposition within quadrats will be collected using square quadrat samplers with sides of 31.6 cm, for a total sampling area of 0.1 m^2. The position of the quadrat sampler relative to each station marker will be consistently applied (e.g., if the diver is facing away from shore, the bottom left corner of the quadrat sampler will be placed on the interval marker). All vegetation and eggs within the quadrat area will be removed for enumeration in the laboratory. The process will be repeated for each transect.

Eggs per *Sample*

In the laboratory, the samples taken by the SCUBA divers will be processed as follows. The samples will be soaked in water overnight, then eggs will be removed from the vegetation by soaking for 45 to 90 minutes in a 1N solution of potassium hydroxide (KOH). The eggs will then be gently separated from the vegetation by hand. Next, the size and shape of the eggs will be standardized by soaking for at least 24 hours in a 1N saline solution with 10% formalin, buffered with sodium bicarbonate to a pH of 6.5. Finally, the eggs will be enumerated using volumetric displacement techniques. Because the thoroughness of egg removal may vary with different vegetation types, separate standards will be used for the displacement of 1,000 eggs from each major vegetation type sampled (e.g., foliose red, filamentous red, eelgrass, etc.). Egg numbers in the samples will be estimated using the following formula:

$$E_{ij} = 1000\,(D_{ij}/V_j)$$

where:

E_{ij} = Estimate of total eggs in sample *i* in vegetation type *j*

D_{ij} = Volumetric displacement of eggs in sample *i*, vegetation type *j*

V_j = Volumetric displacement of 1,000 eggs, standard for vegetation type *j* (taken as the mean of at least three samples)

The total egg count per sample will be the egg count per vegetation type summed across all vegetation types present in the sample. Total egg count divided by 0.1 m^2 (the size of the quadrant sampler) will estimate egg density per sample – these density estimates will be converted to eggs per in^2 for the regression comparison to the rake sample estimates. The potential will also be examined for adjusting egg numbers to account for losses due to predation, storm damage or during the sampling procedures. Mean density for each transect will be computed using the following formula:

$$\bar{d}_{ij} = \frac{n - x}{n}\left(\frac{1}{k}\sum_{k} d_{ijk}\right)$$

Where:

$\bar{d}_{ij}$ = the mean density for transect *j* at site *i*

d_{ijk} = the density of eggs in the kth random sample interval (k = 1, …, 5)

n = the number of 5-meter intervals within the vegetated zone

x = the number of intervals without visible spawn.

The mean of the three transect density estimates for each site will provide an estimate of the total mean density for the site.

Analysis/Threshold Determination

The decision based on this analysis should reflect both the effects of the project and the natural variability in herring spawn deposition. Herring spawning biomass on any spawning ground varies a great deal from year to year, even under undisturbed and unfished conditions. Therefore, it is necessary to evaluate the post-construction use of the GPT site in light of the long-term average use of the site prior to construction and to condition the expectation of site use on estimates of spawning stock biomass (and possibly on other influential environmental variables). The GPT site is the sector of primary interest, but it may be necessary to expand the target site for this analysis to encompass several rake sampling locations for each year. The width of the GPT site will be one km in length, centered around the proposed trestle.

The WDFW historical data series will be reviewed and the data summarized to provide a measure of herring spawn deposition in the target sector in each year. The spawn deposition intensity categories will first be converted to the median number of eggs per square inch in that intensity category (Table 3).

At each sampling site, these values will be summed over all observations within the target site for that season, to produce an estimate of total spawn deposition at that site. For example, if the rake sampling provided three observations for an area which were Light, Medium, and Heavy, then there is an estimated total of (125 + 350 + 750) = 1,225 eggs per square inch in the area for that season.

Table 3: HERRING SPAWN DEPOSITION INTENSITY SCALE USED BY WDFW

	Very Light	Light	Medium	Heavy	Very Heavy
Eggs per square inch	1-50	50-200	200-500	500-1,000	>1,000
Factor applied to intensity category to estimate spawn density for regression analysis	25	125	350	750	1,000

Two regressions will be used, the first to predict the estimation error associated with the rake sample estimates and the second to predict the expected spawn intensity at the site. The first regression analysis relates the two estimates of egg density within each area (i.e., the point estimate from the single rake sample and the mean of the SCUBA samples from each sampling area). The emphasis in this analysis is on the relationship between our respective "best estimates" from the two sampling methods. For this reason, the mean of the SCUBA samples will be used rather than each individual SCUBA sample result. Using all of the individual results would inflate the error estimate to include the small-scale spatial variability (i.e., the variability among samples within each sampling area). While this spatial variability could be quite interesting to investigate, it is of secondary importance in the primary regression relationship addressed through equation [2].

The first regression model will use the five pairs of observations from the synoptic sampling using rake and SCUBA sampling techniques (equation [1]).

$$Y_i = \beta_0 + \beta_1 \overline{X}_i + \varepsilon_y \qquad [1]$$

Where:

Y_i = single rake estimate of spawn density from site i (i = 1 to 5)

$\overline{X}_i$ = mean of the SCUBA sample estimates of spawn density from site i (i = 1 to 5)

ε_y = residual error for the regression, this will be used as the estimation error for the rake observations

β_0 and β_1 = intercept and slope to be estimated from the regression analysis

The second regression model will be used to investigate the relationship between the total density of herring spawn in the target sector and the total spawning biomass estimate for that year, and possibly other factors important to herring spawn for which information is available (e.g., water temperature). The suggested regression model is shown in equation [2].

$$Y_i = \beta_0 + \beta_1 \text{Biomass}_i + \beta_2 \text{Temperature}_i + \beta_3 \text{Biomass}_i\text{:Temperature}_i + \varepsilon_i \quad [2]$$

Where:

Y_1	= estimate of total spawn density from all rake samples within the site for year i (i = 1 to 28)
Biomass_1	= annual WDFW spawn deposition estimate of total spawning biomass at Cherry Point (Point Whitehorn to Sandy Point)
Temperature_i	= water temperature at the site during spawning season
$\text{Biomass}_1\text{:Temperature}_i$	= term expressing the interaction between biomass and temperature
ε_1	= random process error
β_0, β_1, β_2, and β_3	= the parameters to be estimated by the regression analysis

In the years immediately following construction, this historical regression relationship will be used to generate prediction intervals around the level of herring spawn expected at the target site for the biomass and temperature values observed in that year. The prediction interval will incorporate the prediction error from the regression model (equation [2]) plus the estimation error associated with the rake samples (ε_y from equation [1]). If the observed herring spawn density is within the prediction intervals, then it could be inferred that the presence of the pier has not adversely affected the herring preference for the site. Details regarding this model and the decision criteria (e.g., confidence level for the prediction intervals and number of years following construction in which comparisons will be made) will be provided following discussions with WDFW and review of the WDFW historical data series.

For Contingency 9 to be implemented, a significant effect must be detected from the above tests and the results of Objective 2.

CONTINGENCIES

The following contingency measures may be necessary to mitigate disturbances to herring nearshore migration, schooling, and/or spawning as identified by the results of the monitoring surveys described above in Objectives 1, 2, and 3.

1. If the results of Objective 1.1 monitoring demonstrate that the proposed wharf element will overlap with a preferred nearshore migration corridor/schooling area, the project proponent will develop and implement an operational plan, subject to WDFW and WEC review and approval. The plan would provide specific pilot berthing instructions that avoid activity and disturbance to the area of concern from April 10 through May 20.

2. If the results of Objective 1.1 monitoring demonstrate that the proposed wharf element will overlap with a preferred nearshore migration corridor/schooling area, the berthing activity will be prohibited from one hour after the beginning of flood tide to one hour after the beginning of the ebb tide during the herring spawning period (April 10 through May 20).

3. If the results of Objective 1.1 monitoring demonstrate that the proposed wharf element will overlap with a preferred nearshore migration corridor/schooling area, then Objective 1.2 monitoring/sampling will be implemented.

4. If the results of Objective 1.2 monitoring and analysis demonstrate that PIT vessel movements to and from the wharf disrupt the use of the nearshore herring migration corridor or schooling area identified through Objective 1.1 analysis, the following procedures will be implemented. For those time periods during which berthing activities are not specifically prohibited under Contingency 2, PIT will implement the following Vessel Movement-Herring Interaction (VMHI) protocol. The VHMI protocol will be implemented for those years that, during the previous year, the WDFW Cherry Point spawning biomass estimate is less than 3,200 tons. If the Cherry Point herring stock declines to a cumulative spawning biomass of less than 100 tons in three consecutive years, the parties will discuss whether the continuation of the VMHI protocol is appropriate..

   The VMHI protocol shall include the following actions:

   PIT shall contract with a charter vessel that will be approved by WDFW and WEC. The charter vessel shall be equipped with the American Pioneer Fishscanner 201system capability to detect and record herring schools in the project area. The charter vessel will be on 24-hour call from April 26 through May17. PIT, WDFW, and WEC observers will be allowed on board, given reasonable notice to the contractor. The contractor will maintain all electronic data and paper chart records of the surveys. PIT will maintain all corresponding PIT vessel's pilothouse logs. WDFW and WEC will be provided access in order to compare the two sets of records so that they can clearly determine compliance with the VMHI protocol.

   The charter vessel will survey a corridor, for presence of pre-spawner herring schools. The corridor is defined as the rectangular area (two thousand meters by one thousand meters) in front of the GPT Wharf. The northerly two thousand meter side is parallel to the waterward edge of the wharf, and centered at the midpoint of the wharf. Presence of pre-spawner herring shall be based on the criteria for pre-spawner herring schools under Objective 1.1 (Amplitude high; primarily red, purple, and white colored pixels; a minimum of 20 pixels; and two sweeps of the American Pioneer system). The charter operator shall use a plastic grid overlay on the scanner display to estimate if the criteria for pre-spawner herring schools have been met. WDFW and WEC will approve this procedure.

   The survey shall be on a zigzag pattern at 90 degree angles (or other pattern approved by

WDFW and WEC) covering the corridor to be described above.

If pre-spawner herring are detected, the vessel shall wait, until chartered vessel makes another survey. The protocol will be repeated until herring have not been detected in the corridor. When the corridor is clear of pre-spawner herring, the vessel may approach or depart the wharf. The only exception will be in emergency situations authorized verbally or in writing in advance by Department of Ecology. This will avoid potential catastrophic spills due to vessel grounding or collision.

The parties will meet annually to review the results of this protocol and to evaluate its effectiveness. This protocol will be subject to further modification by the parties prior to its implementation and following each annual review. Further implementation of this protocol will be subject to approval by WDFW and WEC.

5. If the results of Objective 2 monitoring indicate that the trestle and/or wharf lighting adversely disrupts the onshore and/or lateral nearshore migration or concentration of herring, the trestle and/or wharf lighting shall be modified to minimize the light cast onto the water surface during the herring spawning period (April 10 through May 20).

6. If the results of Objective 2 monitoring indicate that the loading and off loading operations of the trestle and/or wharf adversely disrupt the onshore and/or lateral nearshore migration of herring, the project proponent shall minimize loading activities during the herring spawning period (April 10 through May 20).

7. If the results of Objective 2 monitoring indicate that the noise of loading and off loading operations of the trestle and/or wharf adversely disrupt the onshore and/or lateral nearshore migration of herring, the project proponent shall restrict loading and off loading operations to eight-hour periods during the herring spawning period (April 10 through May 20) followed by eight-hour periods when no loading and off loading activities occur. (Changing the schedule to minimize impacts due to union labor work shift agreements must be approved by WDFW and WEC.)

8. If the results of Objective 2 monitoring indicate that the vessel noise adversely disrupts the onshore and/or lateral nearshore migration of herring, the project proponent shall require that all non critical mechanical equipment on the vessel is turned off while moored at the wharf during the herring spawning period (April 10 through May 20).

9. If the results of the surveys and analysis in Objective 3 (with inferences from Objective 2) show a significant impact on herring spawn deposition, then hydroacoustic monitoring will be continued for up to two additional years to determine which aspect of vessel or bulk terminal operations (vessel noise, conveyor noise, lighting, prop-wash, etc.) are affecting the spawn deposition. In addition, Contingencies 2 and 5 through 8 will be implemented during that period to allow the study team time to determine from the monitoring what is disturbing the herring and causing them to avoid the spawning habitat at the GPT site. Herring biologists from California and Alaska will be consulted regarding their most recent research of herring spawning at harbors and marinas.

REFERENCES

Gordon, Dave, January 22, 1998. Herring Biologist, Alaska Department of Fish and Game, Sitka, Alaska. Personal communication.

HTI, 1994a. "Model 240 Digital Echo Sounder Operator's Manual. Part No. 012-0240-02." HTI, Seattle, Washington.

HTI, 1994b. "Model 340 Digital Echo Processor (Split-Beam) Operator's Manual. Part No. 012-0340-02." HTI, Seattle, Washington.

Hourston, A.H., 1982. Homing by Canada's west coast herring to management units and divisions as indicated by tag recoveries. Canada Journal of Fisheries and Aquatic Sciences 39: 1414-1422.

Leon, H., 1993. Stock discreteness of Pacific herring (*Clupea harengus pallasi*) in southeast Alaska. M.S. Thesis, University of Washington. Seattle, Washington. 128 p.

McCullagh, P. and J.A. Nelder, 1989. Generalized Linear Models, 2nd ed. London: Chapman and Hall.

Mitson, R.B., 1995. "Underwater noise of research vessels." Int. Council for the Exploration of the Sea. Cooperative Research Report No. 209.

O'Toole, M., 1998. Herring Biologist, Washington Department of Fish and Wildlife, Mount Vernon, Washington. Personal communication.

Robinson, S.M.C., 1988. Early life history characteristics of Pacific herring (*Clupea harengus pallasi* Valenciennees 1847) in the Strait of Georgia, British Columbia: hydrodynamics, dispersal, and analysis of growth rates. PhD Thesis. Zoology Department. University of British Columbia, Vancouver. 141 p.

Roundy, N., 1988. "Owner's Manual for the American Pioneer Fishscanner 201." American Pioneer, Inc. 4775 Ballard Avenue North, Seattle, Washington.

Schwartz, A.L. and G.L. Greer, 1984. "Responses of Pacific herring (*Clupea harengus pallasi*) to some underwater sounds." Canada Journal of Fisheries and Aquatic Sciences, 41: 1183-1192.

Watters, Diane, January 1998. Herring Biologist, California Department of Fish and Game, San Francisco, California. Personal communication.

APPENDIX D

Gateway Pacific Terminal Ballast Water Exchange Requirements

This memo serves to outline the approach, objectives and requirements regarding ballast water for the Gateway Pacific Terminal project at Cherry Point west of Ferndale, Washington. The agreed upon objectives are as follows:

1) **Non-indigenous Species**

To the greatest extent practicable, prevent the introduction of non-indigenous species into the waters of the state, including through the pathways of ballast water exchange and/or contained within related sediments, and the physical transport of organisms within cargo holds or attached to vessels. All vessels and barges using the terminal shall comply with the intent and requirements of these provisions.

2) **Mandatory Ballast Water Testing**

Salinity - All vessels shall be tested for ballast water salinity prior to being allowed to transfer materials at the terminal in accordance with the following Ballast Water Testing Protocol. Said testing may occur upon entering the Strait of Juan de Fuca, at anchorage, or docked at the terminal.

In instances where a vessel fails the initial salinity test, said vessel shall be escorted by tug, at the shipper's expense, to the state-designated ocean discharge area to flush all ballast tanks of their contents until meeting the monitoring requirements referenced herein.

Waiver Request - Upon failure of a salinity test, the vessel's captain may request of Ecology, or its designee, a one-time waiver of the open ocean discharge requirement provided further testing may be required and alternative treatment of specified ballast tanks completed, all at the shipper's expense. Ships previously taking on ballast at ports determined by Ecology to contain significant biological risk i.e. hot spots and/or Captains having been identified with a prior violation of this settlement requirement may at Ecology's discretion be ordered to meet the ocean discharge requirement without the benefit of the above one-time waiver provision.

Biological Indicators - Vessels which pass the salinity test shall be sampled for planktonic indicators of estuarine water and open ocean water. If estuarine indicators are determined to be present at significant levels as established by the state agencies, the subject vessel will be required to purge it's ballast tanks at the state-designated ocean discharge area.

Accredited Testing - Physical and biological sampling shall be accomplished in accordance with the following Ballast Water Testing Protocol by an Ecology-approved laboratory or entity, and as unanimously amended by the parties hereafter.

Notice - GPT shall include these provisions in the terminal's "Regulations and Notice to Ships and General Information" to be sent to all future clients in advance of engaging in business with them. Said "Regulations and Notice to Ships and General Information" shall be approved by Ecology prior to distribution.

Amendments - Amendments or revisions to these ballast water exchange provisions may be proposed by any party to the settlement and evaluated by an ad hoc ballast water committee ("Committee") appointed by Ecology. Membership on the Committee will be open to at least one representative from each of the parties to this settlement agreement as well as other interested parties selected by Ecology.

Ballast Water Testing Protocol

PIT shall follow the procedure and key outlined on the attached and as amended by Ecology. The required sampling gear includes the following:

✓ Well purging pump (12 volt, 1.5 inch o.d., intended to go down ballast tank sounding tube) with attached 0.5 inch i.d. plastic tubing, powered by a small 12 volt, 7 amp-hour battery
✓ Small plankton net
✓ Microscope for viewing the sample
✓ Buffered formalin, various jars and pipets for sample collection and handling
Refractometer reading in salinity, 0 to100 ppt

The sampling crew will test for salinity first. Anything below 31 ppt will be assumed to be estuarine water and will fail. Ballast waters with higher salinities will require plankton sampling. On the understanding that calanoids are by far the most common blue water copapods, followed by cyclopoid and then by a very few harpacticoid copepods, samples containing cyclopoid and especially harpacticoid copepods will also be assumed to be estuarine and will fail the test. These samples will be preserved and retained for future reference. Estuarine waters will not be permitted to be discharged within State of Washington jurisdiction. Ships who have failed a ballast water test and who do not subsequently follow the prescribed discharge procedure may be fined or otherwise penalized, including total prohibition of use of PIT facilities.

Gateway Pacific Terminal Port Corporation
Harbor Master Department Standing Order

1) Topic
Ballast Water Exchange Program

2) Statement
All vessels destined to arrive at the PIT in ballast water condition will be required to carry out a mid–ocean ballast water exchange prior to arriving in U.S. waters. The purpose of this exchange is to limit the possibility of transferring non-indigenous species into U.S. waters

3) Procedures
3.1 All vessels shall be boarded by Harbor Master's representatives to conduct ballast water inspections which will require examination of one or more of the following:

1) log book entry (in English)
2) abstract of the log book entry
3) company or other administration form

The examination must provide details of the mid-ocean exchange of ballast water including, at a minimum, the following information:

Position of exchange (latitude and longitude)
Place where ballast water was originally taken
Amount of ballast water
Ballast tanks which have had water exchanged
Details if ballast not exchanged

A copy of the above may be faxed to the Harbor Master's office.

3.2 In the event that the vessel is unable to supply the above information in the prescribed manner, then no ballast water will be allowed to be discharged until the following procedures have been completed.

1) Samples of ballast water will be drawn and analyzed by a Harbor Master representative
2) Failure of a ballast water test will require the vessel to depart the vicinity and exchange ballast water in the outgoing current of the designated state ballast discharge area.

All charges for the movement and delay of the vessel will be accrued to the vessel's account.

3.3 Vessels which do not contain ballast water from other foreign ports and which are arriving from ports on the west coast of the United States of America (North of Cape Mendocino) , British Columbia, and Alaska wishing to discharge ballast water may be determined by the Harbor Master's representative to be exempt from these regulations if the ballast water to be discharged is documented to originate from these west coast waters and free of non-indigenous biota. The Harbor Master's representative conducting the ballast inspection will require to see a log book entry showing where the ballast water originated and related documentation.

3.4 Upon approval by the committee, these regulations will not be applied to vessels wishing to discharge less than 1000 tons of ballast water, provided, a Harbor Master representative must confirm the origin and characteristics (salinity, qualitative observation) of the ballast water and be in attendance prior to and during the discharge.

3.5 The following circumstances may be considered by the committee as a basis for a variance from these regulations, on case by case basis, for a vessel not performing the required mid-ocean ballast water exchange:

1) documented extremes of weather resulting in unsafe conditions

2) stability or hull stress concerns – safety is paramount and the Master will only be required to carry out the exchange if it is safe to proceed. Vessels receiving a variance under this provision shall be required to demonstrate the safety concern and may not be allowed to use the GPT facilities in the future.

Wenger, Barry

From: Adolphson, Peter
Sent: Thursday, August 13, 1998 10:02 AM
To: Wenger, Barry
Cc: Turvey, Martha
Subject: Sediment Parameters for baseline testing in vicinity of Smelter and Petroleum processors

http://www.wa.gov/ecology/sea/smu/sapa/ch2.doc

TABLE 1. NUMERICAL CRITERIA FOR PUGET SOUND MARINE SEDIMENTS

Chemical Parameter / Analysis Program	Sediment Management Standards			Puget Sound Dredged Disposal	
	SQS	SIZ_{max}, CSL, MCUL	SL	ML	
Metals	(mg/kg dry weight, ppm)			(mg/kg dry weight, ppm)	
	Antimony	--	--	20	200
	Arsenic	57	93	57	700
	Cadmium	5.1	6.7	0.96	9.6
	Chromium	260	270	--	--
	Copper	390	390	81	810
	Lead	450	530	66	660
	Mercury	0.41	0.59	0.21	2.1
	Nickel	--	--	140	--
	Silver	6.1	6.1	1.2	6.1
	Zinc	410	960	160	1,600
Nonionizable Organic Compounds	(mg/kg organic carbon[a], ppm OC)		(µg/kg dry weight, ppb)		
	Aromatic Hydrocarbons				
	Total LPAH[b]	370	780		610 0,100
	Naphthalene	99	170		210 2,100
	Acenaphthylene	66	66		64 640
	Acenaphthene	16	57		63 630
	Fluorene	23	79		64 640
	Phenanthrene	100	480		320 3,200
	Anthracene	220	1,200		130 1,300
	2-Methylnaphthalene	38	64		67 670
	Total HPAH[c]	960	5,300		1,800 51,000
	Fluoranthene	160	1,200		630 6,300
	Pyrene	1,000		1,400	430 7,300
	Benz[a]anthracene	110	270		450 4,500
	Chrysene	110	460		670 6,700
	Total benzofluoranthenes[d]	230		450	800 8,000
	Benzo[a]pyrene	99	210		680 6,800
	Indeno[1,2,3-cd]pyrene		34	88	69 5,200
	Dibenz[a,h]anthracene		12	33	120 1,200
	Benzo[ghi]perylene	31	78		540 5,400
	Chlorinated Benzenes				
	1,2-Dichlorobenzene	2.3	2.3		19 350
	1,3-Dichlorbenzene	--	--		170 --
	1,4-Dichlorobenzene	3.1	9		26 260
	1,2,4-Trichlorobenzene		0.81	1.8	13 64
	Hexachlorobenzene	0.38	2.3		23 230
Nonionizable Organics (cont.)	(mg/kg organic carbon[a], ppm OC)		(µg/kg dry weight, ppb)		
	Phthalate Esters				
	Dimethyl phthalate	53	53		160 --
	Diethyl phthalate	61	110		97 --
	Di-n-butyl phthalate	220	1,700		1,400 --
	Butyl benzyl phthalate		4.9	64	470 --

	Bis[2-ethylhexyl]phthalate	47		78		3,100	--
	Di-n-octyl phthalate	58	4,500			6,200	--
Miscellaneous							
	Dibenzofuran	15	58			54	540
	Hexachlorobutadiene	3.9	6.2			29	290
	Hexachloroethane	--	--			1,400	14,000
	N-nitrosodiphenylamine	11		11		28	220
Total PCBs	12	65		130		2,500	
Chlorinated Pesticides*							
	Total DDT	--	--			6.9	69
	Aldrin	--	--			10	--
	Chlordane	--	--			10	--
	Dieldrin	--	--			10	--
	Heptachlor	--	--			10	--
	Lindane	--	--			10	--
Volatile Organic Compounds*							
	Ethylbenzene	--	--			10	50
	Tetrachloroethene	--	--			14	210
	Total xylene	--	--			12	160
	Trichloroethene	--	--			160	1,600
Ionizable Organic Compounds	(µg/kg dry weight, ppb)			(µg/kg dry weight, ppb)			
	Phenol	420	1,200			120	1,200
	2-Methylphenol	63	63		20	72	
	4-Methylphenol	670	670		120	1,200	
	2,4-Dimethylphenol	29	29		29	50	
	Pentachlorophenol	360	690		100	690	
	Benzyl alcohol	57	73		25	73	
	Benzoic acid	650	650		400	690	

Notes on next page. * Denotes not initially included in sampling unless indicated through results of other testing

Note:
- -- - no numerical criterion of this type for this chemical
- AET - apparent effects threshold
- CSL - cleanup screening level
- HPAH - high molecular weight polycyclic aromatic hydrocarbon
- LPAH - low molecular weight polycyclic aromatic hydrocarbon
- MCUL - minimum cleanup level
- ML - maximum level
- PCB - polychlorinated biphenyl
- SIZ_{max} - Sediment Impact Zone maximum allowable contamination level (WAC 173-204-420)
- SL - screening level
- SMS - Sediment Management Standards (WAC 173-204)
- SQS - Sediment Quality Standards (WAC 173-204-320)

Where laboratory analysis indicates a chemical is not detected in a sediment sample, the detection limit should be reported. Where chemical criteria in this table represent the sums of individual compounds (e.g., total LPAHs and total HPAHs), isomers (e.g., total benzofluoranthenes), or groups of congeners (e.g., total PCBs), and a chemical analysis identifies an undetected value for one or more individual compounds, isomers, or groups of congeners, the SMS require that the detection limit should be used for calculat-ing the sum of the respective compounds or groups of isomers or congeners. However, under the PSDDA program, only the highest individual chemical detection limit in a group is reported when all chemicals in that group are undetected: when any chemicals in a group are detected, only the detected concentrations are included in the sum. Consideration is being given to adopting the PSDDA summation method under the SMS [Contact: Rachel Friedman-Thomas, (360) 407-6909].

Both the SMS and PSDDA numerical criteria are based on Puget Sound apparent effects threshold (AET) values (Barrick et al. 1988). Conceptually, the SMS and PSDDA numerical criteria each provide two regulatory levels for the evaluation of sediment contaminant concentrations. The SQS under the SMS and the SL under the PSDDA program represent concentrations below which adverse biological effects are considered to be unlikely. The SIZ_{max}, CSL, and MCUL under the SMS and the ML under the PSDDA program represent concentrations above which adverse biological effects are considered to be significant. The derivation of these numerical criteria from the AET values is somewhat different because of the different regulatory uses of these criteria in the two applications. In addition, the fact that the concentrations of nonionizable organic compounds are expressed on a TOC-normalized basis under the SMS but on a dry-weight basis under the PSDDA program means that direct comparison of these two sets of numerical criteria is not possible.

[a] The listed values represent concentrations in parts per million "normalized" on a total organic carbon basis. To normalize to total organic carbon, the dry-weight concentration for each parameter is divided by the decimal fraction representing the percent total organic carbon content of the sediment.

[b] The total LPAH criteria are to be compared to the sum of the concentrations of the following LPAH compounds: naphthalene, acenaphthylene, acenaph-thene, fluorene, phenanthrene, and anthracene. 2-Methylnaphthalene is not included in the LPAH definition under the SMS, but is included in the LPAH definition under the PSDDA program. Consideration is being given to including 2-methyl-

naphthalene in the LPAH definition under the SMS [Contact: Rachel Friedman Thomas, (360) 407-6909]. The total LPAH criteria are not the sums of the cor-responding criteria listed for the individual LPAH com-pounds.

[c] The total HPAH criteria are to be compared to the sum of the concentrations of the following HPAH com-pounds: fluoranthene, pyrene, benz[a]-anthracene, chrysene, total benzo-fluoranthenes, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, and benzo-[ghi]-perylene. The total HPAH criteria are not the sums of the correspond-ing criteria listed for the individual HPAH com-pounds.

[d] The total benzofluoranthenes criteria are to be compared to the sums of the concentrations of the b, j, and k isomers of benzofluoranthene.

APPENDIX F

Stormwater

This memo serves to outline the stormwater requirements and objectives regarding the Gateway Pacific Terminal property at Cherry Point west of Ferndale, Washington as described in letters dated 9/26/97 and 10/29/97 from David Evans & Associates, Inc. to Ecology. The agreed upon objectives are as follows:

1) The conceptual stormwater management plan as described in the above letters shall address the entire 1,100 acre site and shall provide two independent systems - one for industrial stormwater, and one for uncontaminated stormwater, hereafter referred to as natural stormwater. Industrial process wastewater shall not enter either system and shall be recycled and/or discharged to an approved treatment facility. Requirements cited below make reference to the Stormwater Management Manual for the Puget Sound Basin (The Technical Manual), Ecology Publication 91-75, February 1992, hereafter referred to as the "Stormwater Manual".

2) All process wastewater generators shall comply with the permitting requirements of WACs 173-216 & 173-220 and with the engineering and design requirements of WAC 173-240. All industries subject to Title 40 of the Code of Federal Regulations Effluent Guidelines (e.g. electroplating, organic chemical manufacturers, etc.) shall be prohibited from tenancy at this facility unless specifically authorized and permitted by Department of Ecology. General Industrial Stormwater NPDES permits and associated Stormwater Pollution Prevention Plans shall be required for all industrial facilities within the 1,100 acre site (Vol. IV Urban Land Use BMPs - Stormwater Manual). General Construction Stormwater NPDES permits and associated Sediment and Erosion Control Plans shall be required for construction sites five acres and larger. Ecology reserves the right to require additional pollutant parameter targets for the aforementioned NPDES permits through Administrative Order on a case by case basis. All project proponents, regardless of the project size, shall develop and implement a Sediment and Erosion Control Plan prior to construction which is in strict conformity to the Stormwater Manual Vol II - Erosion and Sediment Control. For all projects less than five acres, the project proponent shall develop and implement a Sediment and Erosion Control Plan which shall be reviewed and coordinated with Ecology and approved by Whatcom County prior to construction.

3) All industrial stormwater shall be stored, monitored, and adequately treated to Ecology's standards (Vol. IV Urban Land Use BMPs - Stormwater Manual) prior to discharge through the pier diffuser unit. Pre-treated industrial stormwater may be authorized by Ecology on a case-by-case basis for direct discharge to the natural stormwater system during storm events (bypassing the pier diffuser) provided the bypass occurs outside the herring spawning season and other critical habitat periods and is thoroughly monitored. Determination by Ecology of whether perimeter, roadside and related drainage is considered industrial or natural stormwater shall be made on a case-by-case basis and incorporated into the stormwater plan for the 1,100 acre site.

4) Unless otherwise permitted, all natural stormwater shall be pretreated (Stormwater Manual Vol III - Runoff Control), if necessary, and routed to the existing natural drainageways, such as the seasonal streams, on the property and shall to the greatest extent practical be used to enhance wetland and riparian features and functions. The preliminary stormwater plan shall identify all wetland and connecting riparian corridors to be included in the natural stormwater system and shall include design parameters to maintain the quantity and quality of wetland and riparian features.

5) Areas of the facility which present the potential for contamination to stormwater, key locations at the facility for spill control and containment, and storage areas of solid, liquid or gaseous products or

waste that have a potential for accidental spill or release shall be designed for handling all contingencies, including all necessary ongoing and contingency monitoring efforts (Stormwater Manual Vol III - Runoff Control). The railroad loop and spur is an area which will need additional detention and treatment capability based on the potential for discharges exceeding water quality standards. Other areas may be identified as the conceptual plan evolves into a more definitive stormwater plan. All recovered material from spills and releases and any associated contaminated soils on the pier or uplands shall be immediately contained, captured, cleaned-up and disposed of in accordance to local, state and federal regulations.

6) The 180 acre terminal facility shall prevent the discharge of direct or indirect industrial stormwater to the marine waters during herring spawning season (approx. March 15-June 15) and other critical habitat periods, unless otherwise authorized by the Department of Ecology. Stormwater detention facilities shall be designed and constructed at the east edge of the facility to provide all sufficient storage and necessary treatment for all potential spills or releases within the facility or from the upland 1,100 acres. A sampling and monitoring program shall be implemented to determine a baseline, operation parameters, and if further treatment is necessary. No bilge water from visiting vessels will be accepted or handled except for treatment at an approved upland facility.

7) As the conceptual stormwater plan is refined and updated, all upland property development within the 1,100 acre site shall be undertaken in a manner which complies with the intent, objectives and provisions of the plan and shall obtain written approval by Ecology prior to construction. Prior to occupancy, all future tenants shall be evaluated by Ecology for baseline stormwater permit requirements and all revisions or changes shall be approved. The above stormwater plan conditions shall run with the land in perpetuity.

September 26, 1997

DAVID EVANS AND ASSOCIATES, INC.

119 Grand Avenue
Suite D
Bellingham,
Washington 98225
Tel: 360.647.7151
Fax: 360.647.7160

Mr. Barry Wenger
Shorelands Planner
Washington Department of Ecology
1616 Cornwall Ave., Suite 201
Bellingham, WA 98225

RE: Conceptual Stormwater Management Systems
Proposed Gateway Pacific Terminal

Dear Mr. Wenger:

Per your request, a site map of the proposed Gateway Pacific Terminal with **conceptual** stormwater management systems has been prepared to further address the Department of Ecology (DOE) questions related to stormwater management. This drawing is attached for your review, dated September 19, 1997. As you are aware, all stormwater management systems are conceptual and have not been engineered to manage stormwater from any specific rainfall event. It is still not possible at this time to engineer the stormwater management systems as no preliminary site plans have been developed.

PROCESS IMPACTED STORMWATER

Process impacted stormwater will be conveyed through catch basins and a pipe network to the pond within the GPT 180 acre facility labeled process stormwater treatment pond on the site map. A sampling program will be implemented to determine the appropriate treatment methods (if shown to be required) for the process impacted stormwater. The treated process impacted stormwater will be discharged via an engineered diffuser (if necessary) located at the face of the pier.

NON-PROCESS STORMWATER RUNOFF

Where possible, non-process stormwater from roof tops and other non-process areas within the GPT 180 acre facility will be conveyed by catch basin and pipe networks to the perimeter ditch displayed in the site map. This catch basin and pipe network will be independent from the process impacted stormwater catch basin and pipe network. The GPT 180 acre facility perimeter ditch will also serve to prevent run-on water from entering the facility. Non-process stormwater from the upland 1100 acres will be allowed to continue its current runoff patterns. If needed, benches and/or swales may be constructed on the upland 1100 acres to decrease runoff velocities and maximize infiltration rates. Construction of benches and swales will need to be coordinated with the management practices of existing wetlands and swales and proposed constructed wetlands. This drainage work will take place only as development occurs.

DEM INC.

RAILROAD LOOP AND SPUR STORMWATER RUNOFF

The railroad spur and loop will be paralleled on both sides with drainage swales. The inside swale will convey water toward the stormwater detention pond located near the southern end of the railroad loop. The swale lining the outside of the railroad loop will convey water toward the stormwater detention pond just to the south of the railroad loop (pond locations may change upon final site plan development). A drainage swale will direct water from the stormwater detention pond to the season stream. A sampling program will be implemented to determine if treatment of the stormwater within the ponds is required prior to discharge. Both detention ponds may serve as an emergency storage area in the event of a spill along the railroad loop.

HERRING SPAWNING SEASON

In order to minimize the discharge of process impacted stormwater to the bay during the herring spawning season of March through June, a stormwater detention pond may be placed to the east of the GPT 180 acre facility and the seasonal stream. A detention pond located near the outfall of the seasonal stream will allow additional storage, and a system to slowly meter water back to the diffuser at the end of the pier. This would also provide a possible storage area in the event of a spill within the facility or the upland 1100 acres. A sampling program will be implemented to determine if treatment of the stormwater within the pond is required prior to discharge.

SUMMARY

Our main goals with regard to managing stormwater on the GPT facility are:

1) To surround the rail spur and loop with a series of swales that will serve to capture and filter stormwater runoff from sidings and loading and unloading areas. The use of detention ponds will provide the detention times necessary to store and treat contaminated water in the event of a spill.

2) To collect all process stormwater from the 180 acre facility that would be most likely contaminated by oil and grease from paved areas and/or spill and releases as a result of commodity storage. All process stormwater will be stored, monitored, and treated (as necessary) prior to discharge through the diffuser. A monitoring and treatment plan for process stormwater will be submitted to DOE as part of the SWPPP.

3) To provide, if possible, final stormwater detention capabilities prior to discharge to the bay. For contaminated non-process runoff during lesser storm events, the stormwater

detention pond east of the 180 facility would allow a tertiary means of treating stormwater as well as the ability to slowly meter stormwater into the bay.

Again, we must stress that this proposed stormwater management system remains conceptual at this time. We look at the preparation of any final DOE approved SWPPP to involve many on-going discussions with you and your Department as well as a coordinated effort with GPT, the facility designers, wetland specialists, biologists, and other entities that will have input to the project.

It is our understanding that the submittal of this site map and information completes the information you have requested. We would appreciate a written acknowledgment of this at this time.

Please contact our office with any questions you may have.

Sincerely,
DAVID EVANS AND ASSOCIATES, INC.

Craig R. Parkinson, P.E.
Senior Associate / Office Manager

attachment

cc: Mr. Jeff Kaspar, Pacific International Terminals
Mr. George Holroyd, David Evans and Associates, Inc.

P:\PITI0003\WORD\70926LA.DOC

DAVID EVANS AND ASSOCIATES, INC.

119 Grand Avenue
Suite D
Bellingham,
Washington 98225
tel: 360.647.7151
fax: 360.647.7160

October 29, 1997

Mr. Barry Wenger
Shorelands Planner
Washington Department of Ecology
1616 Cornwall Ave., Suite 201
Bellingham, WA 98225

RE: Conceptual Stormwater Management Systems
Proposed Gateway Pacific Terminal

Dear Mr. Wenger:

Please find attached a revised copy of the site map of the proposed Gateway Pacific Terminal with conceptual stormwater management system. Review of the original version shown the southeastern most detention pond lying east of the existing drainage way. This revised copy has been changed to show the pond on the west side of the drainage.

Please replace that copy transmitted to you with our letter dated September 26, 1997. Also, within our previous letter we had stated that it is our understanding that the submittal of the information to date completes the information you have requested. We would appreciate a written acknowledgment of this, and as such request that you initial in the space provided below and mail or fax back your initialed copy. This will allow us to close our files for this phase of the work.

Please contact our office with any questions you may have.

Sincerely,
DAVID EVANS AND ASSOCIATES, INC.

Craig R. Parkinson, P.E.
Vice President / Office Manager

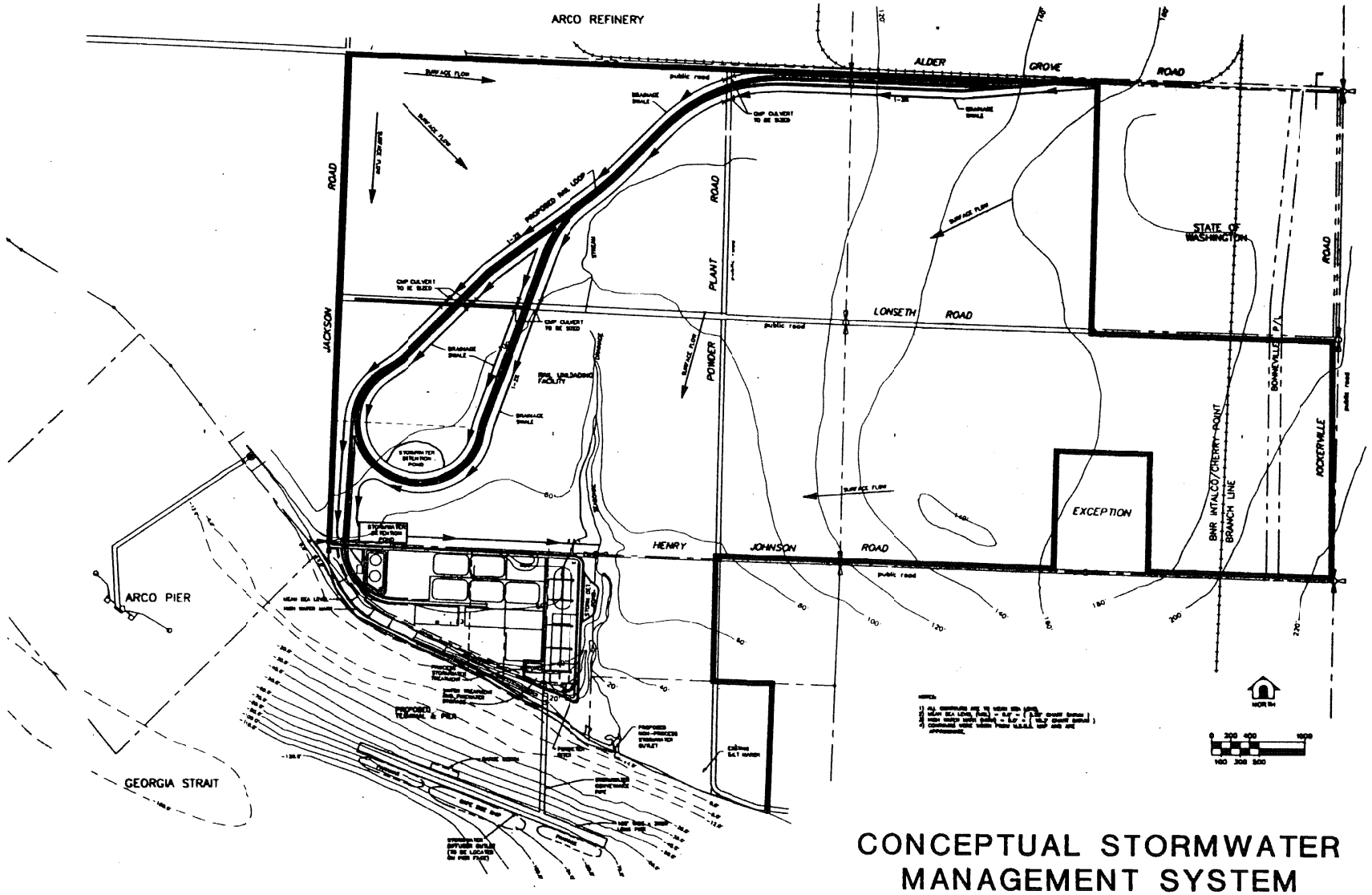
ACKNOWLEDGED

_____ _____
Mr. Barry Wenger Date

attachment

cc: Mr. Jeff Kaspar, Pacific International Terminals
Mr. George Holroyd, David Evans and Associates, Inc.

P:\PITI0003\WORD\71029LA.DOC



CONCEPTUAL STORMWATER MANAGEMENT SYSTEM

GATEWAY PACIFIC TERMINAL
Conceptual Stormwater Management System

DAVID EVANS AND ASSOCIATES, INC.

Appendix G

PROPOSED ANALYSIS OF SELECTED VESSEL SAFETY AND ENVIRONMENTAL IMPACTS OF THE GATEWAY PACIFIC TERNIINAL*

Submitted by

John R. Harrald, Ph.D.
Decisions Support Associates, L.L.C.
3124 Sleepy Hollow Road Falls Church, VA 22042 tel: (703) 237-8428 fax: (703) 237-8554

and

James R. Townley
Performance Improvement Enterprises, L.L.C.
14720 NW Forestel Loop
Beaverton, OR 97006
tel: (503) 645-4743 fax: (503) 614 9109

February 20, 1998

Changes from draft proposal in text indicated by italics.

INTRODUCTION

The purpose of this proposal is to identify work required to resolve the issues identified in the Harrald/Townley August 17, 1997 review of the Gateway Pacific Terminal impact documentation. The report identified unanswered questions in five areas: the analysis of the safety impacts of increased vessel traffic, the analysis of the impact on vessel traffic management, the analysis of spill risk, the potential for bunkering- operations, and the analysis of hazards at the facility. This proposal address all areas of concern in the maritime environment. It does not address the questions raised in the 17 August report about facility hazards or the impact on land side transportation.

The increased deep draft traffic in and around Rosario Strait was identified as the factor having the greatest potential impact on maritime safety and the environment. A second area of significant concern is the probable seasonal concentration of the large multi-cargo vessels calling

at the GPT terminal, the resulting increase in peak deep draft traffic congestion, traffic management problems, and the related increase in vessel support activities (bunkering-, launch service, etc.) in anchorage areas as vessel wait for berth openings at the facility. The potential for oil spills during bunkering and cargo transfer operations was also identified as an area requiring additional analysis. The specific questions raised in the report, and the proposed methods of answering these questions are described below.

TRAFFIC SAFETY AND TRAFFIC MANAGEMENT ANALYSIS

The questions raised in the report about vessel traffic safety and vessel traffic management are considered together since traffic management is a system intervention to ensure vessel safety.

Questions raised about vessel safety:

- How will GPT affect the density of deep draft traffic in Rosario Strait and other sensitive, constrained waterways?
- What is the volume and type of conflicting shallow draft traffic which could impede and interfere with the navigation and maneuvering of these deep draft vessels?
- What are the anticipated peak traffic levels in critical waterways, anchorage approaches, and turning points9
- How will the traffic densities and patterns generated by the GPT facility affect the expected incidence of collisions, powered Groundings and drift groundings in Georgia Strait, Rosario Strait, and Haro Strait?
- How will these potential accident frequencies be affected by the traffic densities and patterns generated by the GPT facility?

Questions raised about vessel traffic and anchorage management:

- What existing pressure will be put on existing anchorage areas for handling bulk vessels waiting for, or shifting to and from berth?
- What impact will the increased traffic density in Rosario Strait have on the flow of traffic through the regulated navigation area, and will laden vessels be required to wait or anchor, increasing their risk exposure in the system?
- What additional or revised U.S. Coast Guard vessel traffic management protocols will be required to minimize the risk of collisions or groundings during peak traffic periods? Should these protocols be independent of cargoes or should they be cargo specific?
- Would changes to existing anchorage regulations or the creation of new anchorage areas contribute substantially to reducing the risk of groundings or collisions?
- Would the implementation of new vessel traffic management or vessel anchorage protocols create significant land side traffic management problems? [not addressed in this proposal]
- Is there significant land side transportation capacity to handle peak demand associated with feed grain shipments? [not addressed in this proposal]
- What are the prevailing seasonal winds and tidal current patterns in the vicinity of the GPT? What special navigational cargo loading, or anchorage management problems will be created by stronger than normal currents or winds (particularly during strong North Westerly winds produced by winter storms)?

- What are the holding characteristics of existing anchorage grounds and what has been the past vessel experience on these ground under different weather conditions?
- Will special anchorage rules or procedures be instituted to minimize risk of drift groundings or collisions in and around the anchorages? If not, why not? If yes, what will those measures be?

Proposed work. The response to these questions will require the completion of three tasks.

Task 1: Build a traffic simulation

The calculation of changes in vessel traffic patterns and density in this well defined system will be determined through the creation and application of a relatively simple traffic simulation. The traffic simulation program is a computer based implementation of the traffic arrivals, traffic departures, traffic rules, and selected weather conditions (e.g., visibility). Maritime traffic in the following area will be simulated: the deep draft waterways around the San Juan Islands south of 49 degree and north of (and including) the traffic convergence zone around buoy "RA" and including the Strait of Georgia, Boundary Pass, Haro Strait, and Rosario Strait, and the approaches to the proposed GPT terminal (see attached chart), and all anchorage areas. The simulation will include commercial passenger vessel and fishing vessel traffic, but will not include recreational vessels. The traffic simulation will include projected traffic to the proposed GPT terminal and projected traffic increases at existing Cherry Point terminals.

Task 2: Simulate present and proposed conditions.

The output of the simulation calculation will show the change in occurrence of situations of relatively higher risk (e.g. traffic congestion, traffic in constrained waterways during periods of reduced visibility). The simulation will calculate the frequency of occurrence of these situations for both the current traffic levels and for the traffic levels projected post introduction of the GPT. The incremental relative risk produced by the introduction of the terminal will be identified. Risk will be computed relative to the base (existing) case. No attempt will be made to calculate absolute risk in order to compare the level of risk in the area under study with the level of risk in other ports or to the risk due to other hazards.

Task 3.- Analyze anchorage traffic and procedures.

The current and potential anchorage zones, anchorage conditions, and practices will be documented and the output of the simulation will be used to determine the changes in demand for anchorages. Pilots and other appropriate members of industry will be interviewed to collect past vessel anchorage experience for anchorage areas used and weather conditions experienced. Trends and patterns of weather at anchorage areas and accident and incident data for vessels at Puget Sound anchorages will be reviewed for trends and patterns. Using estimates of potential increases in anchorage utilization. an estimate will be made of the chan-e in relative risk or drift groundings and collisions involving vessels in anchorages. Alternative anchorage management procedures will be identified.

Task 4: Analyze traffic management and "save" alternatives.

The simulation program will be used to test alternative vessel traffic management rules and procedures that will minimize the occurrence of relatively high risk traffic situations. The simulation will also analyze the "save" potential for disabled vessels in the area of interest. The traffic simulation program is a project deliverable and may be re-used to analyze currently unanticipated changes in vessel traffic or vessel traffic management procedures.

The building of the simulation model is simplified by three factors. First, a significant amount of the data required to populate the model has been collected and is the public domain. Second, team members have extensive experience in port simulation. Merrick and Harrald have constructed similar traffic simulations for the Port of New Orleans and Prince William Sound, and Captain Townley helped construct traffic simulations of the Port of New, York, Baltimore, and Wilmington. Finally, answers to these questions only require the estimation of relative risk, not absolute risk. The goal is to maintain the level of safety in the system, not to precisely measure that level of safety .

Traffic data for all vessel types is collected by the Coast Guard and the State of Washington and the Volpe Transportation Systems Center reconciled this data for its recent Hazards Analysis study. Projections of GPT vessel traffic will be obtained from existing documentation and interviews with GPT officials. Coast Guard vessel traffic rules and industry practices (e.g. typical speeds, reduced visibility operations) will be verified. Visibility and weather projections will be adapted from the NOAA data used in the Volpe study. All portions of the transits of interest are in well defined waterways, greatly simplifying the modeling process.

Note that this proposal does not address the two question raised concerning the land side transportation impacts of vessel traffic changes.

BUNKERING OPERATIONS

Question raised:

- Will vessels waiting to berth at GPT bunker elsewhere in Puget Sound or the Strait of Juan de Fuca? If yes, what is the anticipated increase in bunker volume and frequency?

Proposed work: Adequate answers to these questions may be developed through projections based on local expertise and existing documentation. The following task is proposed:

Task 5: Develop and analyze bunkering scenarios.

Probable bunkering scenarios for vessels calling at the OPT terminal will be developed using the results of the vessel traffic analysis, documentation available from the GTP and interviews with industry personnel. These bunkering scenarios will be based on a review of current bunkering practices, frequency, and location. and will include an estimation of the number of vessels that will require bunkering in Washington State waters, the location of these bunkering operations. Although vessels are not anticipated to bunker at the GPT terminal, this analysis is intended to identify the proportion of vessels calling at GPT that will bunker in Washington State waters.

SPILL RISK ANALYSIS

Questions raised:

- The probability and impact of transfer related spills during bunkering or cargo transfer operations should be estimated.
- The probability and impact of spills caused by collisions, allisions, and/or Groundings should be assessed.

Proposed work: A determination of probability and impact of accident related spills implies a comprehensive risk analysis that is beyond the scope of this proposal. However, the results of the
prior task can be used to provide a more comprehensive and useful estimate than that contained in the GPT impact documents. The following specific tasks are proposed:

Task 6: Estimate operational (bunker) spill potential

Using the results of the estimates in changes in bunkering operations determined above, estimate the potential bunkering spill frequency based on USCG and State of Washington spill data specific to bunkering operations. Liquid bulk car-o transfer related operational spills at GPT will be considered if the GPT is projected to handle petrochemical cargoes.

Task 7: Estimate potential change in accident related spills.

Using, the results of the vessel traffic model, estimate the change in relative risk of accident related spills both with and without recommended traffic management interventions and procedures. Provide recommendations for mitigating the increase in relative risk determined to be due to the introduction of the GPT terminal.

F]INAL REPORT PREPARATION

Task 8: Prepare and deliver final report

A draft final report will be delivered and presented. Comments and corrections \ received will be incorporated in the final report.

PROJECT TEAM QUALIFICATI[ONS

The project team consists of principles from two small businesses: Dr. John R. Harrald and Dr. Jason Merrick are members of Decision Support Associates, a limited liability company organized in the State of Virginia. Captain James Townley is a member of Performance Improvement Enterprises, a limited liability company organized in the state of Oregon. As shown below, the team provides significant expertise in maritime operations safety and risk assessment.

John R. Harraid, Ph.D.

Dr. Harrald is the Director of the Institute for Crisis, Disaster, and Risk Management and a Professor of Engineering Management at The George Washington University, He is also the Associate Director of the Louisiana State University of the George Washington University Ports and Waterways Institute. During his prior career in the U.S. Coast Guard he served in marine safety, environmental protection, and Captain of the Port positions and attained the rank of Captain. He was the lead scientist in a National Research Council study of the Exxon Valdez - rounding and oil spill. He was the principal investigator in the project that developed vessel screening and risk management tools for the Washington Office of Marine Safety, and for risk assessment studies of the Port of New Orleans, and Prince William Sound. He is a founding member and officer of The International Emergency Management Society (TIEMS). He received his B.S. in Engineering from the U.S. Coast Guard Academy, a M.S. from M.I.T., where he was a Sloan Management Fellow, and his MBA and Ph.D. from Rensselaer Polytechnic Institute.

James Townley

Captain James Townley is the Executive Director of the Columbia River Steamship Operators Association (CRSOA) and President of PIE. L.L.C. Captain Townley's company developed the apprentice pilot selection, training, and qualification program used by the State of Oregon as adopted by the Oregon Board of Maritime Pilots. As Executive Director to CRSOA, Captain Townley has directed several government/industry task forces addressing anchorage practices, vessel navigation, and piloting procedures, and commercial asset coordination during major emergencies for vessels calling at Columbia River, Willamette River, and Oregon coastal ports. As USCG Captain of the Port ,he served as a member of the Northwest Area Committee responsible for developing the Northwest Area Contingency Plan and as a member of the State of Washington Advisory Groups that developed Best Achievable Protection Standards for Tank Vessels and Cargo and Passenger Vessel Standards. He received his B.S. in Engineering from the U.S. Coast Guard Academy, and MBA from New York University. and a M.S. in Ocean Transportation Systems from MIT.

Jason, Merrick, D.Sc.

Dr. Merrick received his B.A. and M.A. from Oxford University, Oxford, U..K. and his Doctor of Science in Operations Research from The George Washington University and is currently a Senior Research Scientist with The George Washington University Institute for Crisis, Disaster, and Risk Management. He worked as a systems analyst and systems programmer for a major U.K. consulting firm. He has developed graphical simulation models to support the assessment of risk in dynamic transportation systems and has developed forecasting and reliability tools to support risk management. He was a Senior Analyst on the recent Prince William Sound Risk Assessment project. He is a principal in DSA.

PROJECT BUDGET AND SCHEDULE

The project budget and schedule assumes that two trips will be made to the Seattle area by Dr. Harrald and Capt. Townley (one at the start of the project, and one to present preliminary results), and that the project will start in January or February of 1998 and will be completed in approximately 12 weeks. A draft report will be available 10 weeks after project start. The

budget below presents fully burdened personnel costs; including all overhead and miscellaneous costs except for travel.

PERSONNEL	
John R. Harrald 85 hours @ $ 90/hour	$ 7,650
James Townley 85 hours @ $ 90/hour	$ 7,650
Jason Merrick 200 hours C& $60/hour	$ 12,000
TRAVEL (2 trips to Seattle at $ 1,000 per trip--Harrald) (2 trips to Seattle at $300 per trip--Townley)	$ 2,600
PROJECT TOTAL	$29,900

APPENDIX H: AGREEMENT FOR GIFT CONVEYANCE AND PUBLIC ACCESS

COME NOW Pacific International Terminals ("PIT") and Whatcom County ("County") and by way of this Agreement for Gift Conveyance and Public Access ("Agreement") set out the terms for conveying certain property and access rights for public use. This Agreement is entered into under the following agreed facts:

A. PIT owns or has the rights to acquire that property legally described in Exhibit A ("The Property"), attached hereto and incorporated by reference, which is located at Cherry Point, Whatcom County, Washington. PIT proposes to construct a deep water pier and related upland facilities on the Property. Towards this end, PIT has obtained, or is in the process of obtaining, approval from local, state, federal, and other jurisdictions for construction of such a deep water pier and related upland development.

B. The County has, as part of its Comprehensive Park and Recreation Open Space Plan ("Plan"), proposed to establish public access and facilities in the Cherry Point area. Such opportunity for public access has been proposed in this Plan on portions of The Property.

C. Pursuant to this Agreement, the parties intend to define the areas, terms, and conditions for gifting portions of The Property in fee, and access rights and conservation protection through an easement or license, when PIT secures all approvals for construction of a deep water pier and upland development and following PIT's acquisition of all the property necessary to construct the project.

NOW, for valuable consideration, receipt of which is acknowledged herein, the parties agree as follows:

1. Conveyance of Certain Portions of The Property

Upon securing all local, state, and federal permits and for the construction of deepwater pier approvals, including, but not limited to, all building permits, and a lease agreement with the Department of Natural Resources for aquatic lands and tidelands, and following PIT's acquisition of all the property necessary to construct the project, but before commencement of any clearing or

construction, PIT shall convey to the County, by way of a statutory warranty deed, the saltwater marsh and adjacent uplands located on the southwest corner of The Property, all of which are generally shown in Exhibit B, which is attached hereto and incorporated by reference. The County shall pay all costs associated with such conveyance, including all excise taxes, closing costs, and attorneys' fees for preparation of necessary documents. The particular terms and conditions of the closing and conveyance shall be mutually agreed upon by the parties at such time that PIT notifies the County that it has secured all necessary permits, approvals, and leases and construction is to begin.

2. Easements or Licenses for Public Access

In addition to conveying that portion of The Property shown in Exhibit B, upon securing all local, state, and federal permits and approvals, including, but not limited to, all building permits, and following PIT's acquisition of all the property necessary to construct the project, and a lease agreement with the Department of Natural Resources for the aquatic lands and tidelands, but before commencement of any clearing or construction of the deepwater pier development, PIT shall grant, by way of an easement or license, public access to the following portion of the Property

> That beach area south of Gulf Road, including tidelands, from the eastern boundary of The Property south approximately 600 feet to the west, and which is generally shown in Exhibit C, attached hereto and incorporated by reference.

3. Parameters, Use and Conservation Protection

The scope and terms for public access and/or conservation protection to areas conveyed and over which an easement or license is granted shall be particularly determined and defined following a joint planning process between the County and PIT. At the very least, such shall include, the following particulars:

a. Above all else, the goal of the parties shall be to provide public access opportunities, while at the same time preventing any interference with PIT's use of The Property or operation of a deep water pier and upland

development, or any harm to the natural values of the property conveyed to the County.

b. The County shall pay, or otherwise obtain funding for, any and all improvements or other work to accommodate public access or conservation protection undertaken on those portions of The Property that are conveyed or upon which an easement or license is granted, unless the parties otherwise agree. This would include any and all costs for creating, cleaning, and maintaining a parking facility in that area shown in Exhibit B. Further, the County shall be responsible to maintain, police, and clean those areas conveyed or upon which an easement or license is granted. Notwithstanding the above, the County shall not be monetarily obligated, in any way, for any costs imposed upon PIT for reclamation, conservation, or environmental mitigation requirements which may be imposed by any federal, state, or local government as a condition precedent to the issuance of any permits, approvals, including, but not limited to, all building permits for improvements on property other than those conveyed herein, or the lease agreement with the Department of Natural Resources for aquatic lands and tidelands, needed for the construction of the deep water pier and upland development.

c. All improvements shall be located, sized, and constructed, and all public access and use opportunities limited, so as to avoid any conflict or interference with PIT's use of The Property, construction and operation of a deep water pier and upland development or any harm to the natural values of the property conveyed to the County.

d. A minimum of three public access signs approved by Whatcom County Planning and Development Services shall be posted adjacent to the public access areas. The locations of these signs shall be approved by Whatcom County Planning and Development Services.

e. At such time that the County determines that those areas upon which an easement or license is granted are no longer needed for public access or conservation, then the County shall convey its easement back to PIT at no cost, except no public access required by SHS 92-0020 may be relinquished unless said permit has been terminated.

f. Any easement granted by PIT for public access and conservation protection shall run with the land.

4. All Transfers Are a Gift

Notwithstanding any condition within any permit, approval, or lease that has been issued or will be issued, the conveyance by PIT of land in fee, easements and licenses as set forth in this Agreement shall be a gift from PIT. The County need not pay any consideration in exchange for such property, easements or license.

5. Severability

Should any provision of this Agreement be found to be void or otherwise unenforceable, all other provisions shall remain enforceable and binding.

6. Attorneys' Fees and Costs

In any proceeding brought to enforce this Agreement or to determine the rights of the parties under this Agreement, the prevailing party shall be entitled to collect damages, together with accrued interest, and in addition to any judgment awarded by a court, all attorneys' fees, costs, and expenses incurred in connection with such proceeding, including those incurred in any litigation, arbitration, mediation, and appeal. For purposes of this Agreement, the prevailing party shall be that party in whose favor final judgment or determination is rendered or who the court or decision maker determines substantially prevails, if both parties are awarded judgment. The term "proceeding" shall mean and include, but is not limited to, arbitration, administrative, bankruptcy, mediation, judicial proceedings, and appeals.

7. Notices

All notices to be given to any of the parties hereto shall be addressed to the respective party at the applicable address as follows:

Pacific International Terminals	Whatcom County
Wayne Schwandt	_____
Harbor Center Building, Suite 156	_____
1801 Roeder Avenue	_____
Bellingham, WA 98226	_____

8. Representations and Warranties

The parties represent that the person signing on behalf of each has full power and authority to execute this Agreement and perform the obligations hereunder.

EXECUTED this _____ day of _____, 1999.

PACIFIC INTERNATIONAL TERMINALS

_____

By: _____

Its: _____

WHATCOM COUNTY

_____

By: Pete Kremen
Whatcom County Executive

APPROVED AS TO FORM:

_____

David Grant, WSBA #15770
Whatcom County Assistant Civil
Prosecuting Attorney

AGREEMENT FOR GIFT CONVEYANCE AND PUBLIC ACCESS

STATE OF WASHINGTON)
) ss.
County of Whatcom)

On this day personally appeared before me _____, to me known to be the _____ [Title] of PACIFIC INTERNATIONAL TERMINALS, the joint venture that executed the foregoing instrument, and acknowledged the said instrument to be the free and voluntary act and deed of said joint venture, for the uses and purposes therein mentioned, and on oath stated that he/she was authorized to execute the said instrument.

GIVEN under my hand and official seal this ____ day of _____, 1999.

_____
NOTARY PUBLIC in and for the state of Washington, residing at _____ My commission expires:_____

STATE OF WASHINGTON)
) ss.
County of Whatcom)

On this day personally appeared before me PETE KREMEN, to me known to be the Executive of WHATCOM COUNTY, the municipal entity that executed the foregoing instrument, and acknowledged the said instrument to be the free and voluntary act and deed of said municipal entity, for the uses and purposes therein mentioned, and on oath stated that he was authorized to execute the said instrument.

GIVEN under my hand and official seal this ____ day of _____, 1999.

_____
NOTARY PUBLIC in and for the state of Washington, residing at _____ My commission expires:_____

Legal Description:

PARCEL A

THE EAST 1/3 OF THE WEST HALF OF GOVERNMENT LOT 4, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST OF W.M., WHATCOM COUNTY, WASHINGTON, TOGETHER WITH THE SECOND CLASS TIDELANDS ABUTTING THEREON. EXCEPT COUNTY ROAD #340 (GULF ROAD) AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY QUIT CLAIM DEED RECORDED UNDER AUDITOR'S FILE NOS. 510264 AND 510394.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL B

A TRACT OF LAND LOCATED IN THE WEST 2/3 OF THE WEST HALF OF GOVERNMENT LOT 4, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST OF W.M., WHATCOM COUNTY, WASHINGTON, DESCRIBED AS FOLLOWS:

BEGINNING AT THE INTERSECTION OF THE EAST LINE OF THE SAID WEST 2/3 OF THE WEST HALF OF GOVERNMENT LOT 4 AFORESAID AND THE SOUTHERLY LINE OF COUNTY ROAD NO. 340; THENCE NORTHWESTERLY ALONG THE SOUTHERLY LINE OF COUNTY ROAD NO. 340, A DISTANCE OF 138 FEET SIX INCHES; THENCE NORTHEASTERLY A DISTANCE OF 234 FEET ON A BEARING SO THAT THE NORTHERLY END OF SAID 234 FEET IS A POINT EXACTLY 67 FEET WEST OF THE EAST LINE OF THE WEST 2/3 OF THE WEST HALF OF SAID GOVERNMENT LOT AFORESAID; THENCE SOUTHEASTERLY TO A POINT ON SAID EAST LINE 246 FEET NORTH OF THE POINT OF BEGINNING; THENCE SOUTH ALONG SAID EAST LINE AFORESAID 246 FEET TO THE POINT OF BEGINNING. EXCEPT COUNTY ROAD #340 (GULF ROAD) AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY QUIT CLAIM DEED RECORDED UNDER AUDITOR'S FILE NO. 510394.

ALSO ALL UPLANDS LYING SOUTHERLY OF SAID COUNTY ROAD 340 AND WITHIN THE EAST AND WESTERLY LINES OF THE ABOVE DESCRIBED TRACT PROJECTED SOUTHERLY.

Initials _____ Initials _____

TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING UPON THE UPLANDS LAST HEREIN DESCRIBED SOUTHERLY OF SAID COUNTY ROAD NO. 340.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL C

THE WEST TWO-THIRDS OF THE WEST HALF OF GOVERNMENT LOT 4, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO. EXCEPT COUNTY ROAD NO. 573 (POWDER PLANT ROAD) ON THE WEST SIDE THEREOF AND EXCEPT COUNTY ROAD NO. 340 (GULF ROAD), AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEEDS RECORDED UNDER AUDITOR'S FILE NOS. 510394 AND 194273.

EXCEPT BEGINNING AT A POINT ON THE CENTER LINE OF WHATCOM COUNTY ROAD NO. 573, TWO THOUSAND THIRTY-SIX FEET SOUTH OF THE NORTHWEST CORNER OF THE NORTHEAST QUARTER OF THE NORTHEAST QUARTER OF SAID SECTION 19, THENCE SOUTH ALONG THE CENTER LINE OF ROAD NO. 573, ONE HUNDRED FIFTY FEET; THENCE EAST 175 FEET; THENE NORTH 150 FEET; THENCE WEST 175 FEET TO THE POINT OF BEGINNING.

AND EXCEPT BEGINNING AT THE INTERSECTION OF THE EAST LINE OF SAID WEST 2/3 OF THE WEST HALF OF GOVERNMENT LOT 4 AFORESAID AND THE SOUTHERLY LINE OF COUNTY ROAD NO. 340; THENCE NORTHWESTERLY ALONG THE SOUTHERLY LINE OF COUNTY ROAD NO. 340 A DISTANCE OF 138 FEET 6 INCHES; THENCE NORTHEASTERLY A DISTANCE OF 234 FEET ON A BEARING SO THAT THE NORTHERLY END OF SAID 234 FEET IS A POINT EXACTLY 67 FEET WEST OF THE EAST LINE OF THE WEST 2/3 OF THE WEST HALF OF SAID GOVERNMENT LOT 4 AFORESAID; THENCE SOUTHEASTERLY TO A POINT ON SAID EAST LINE 246 FEET NORTH OF THE POINT OF BEGINNING; THENCE SOUTH ALONG THE SAID EAST LINE AFORESAID 246 FEET TO THE POINT OF BEGINNING. ALSO ALL UPLANDS LYING SOUTHERLY OF SAID COUNTY ROAD NO. 340 AND WITHIN THE EAST AND WESTERLY LINES OF THE

Initials _____ Initials _____

ABOVE DESCRIBED TRACT PROJECTED SOUTHERLY, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL D

A TRACT OF LAND IN GOVERNMENT LOT 4, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, DESCRIBED AS FOLLOWS, TO-WIT:

BEGINNING AT A POINT ON THE CENTER LINE OF WHATCOM COUNTY ROAD NO. 573, TWO THOUSAND THIRTY-SIX FEET SOUTH ON THE NORTHWEST CORNER OF THE NORTHEAST QUARTER OF THE NORTHEAST QUARTER OF SECTION 19; THENCE SOUTH ALONG CENTER LINE OF ROAD NO. 573, ONE HUNDRED FIFTY FEET; THENCE EAST 175 FEET; THENCE NORTH 150 FEET; THENCE WEST 175 FEET TO THE POINT OF BEGINNING. EXCEPT COUNTY ROAD 573 (POWDER PLANT ROAD) ON THE WEST SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEED RECORDED UNDER AUDITOR'S FILE NO. 194273.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL E

THE EAST 32 RODS OF THE NORTHWEST QUARTER OF THE NORTHEAST QUARTER AND OF GOVERNMENT LOT 3, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO. EXCEPT COUNTY ROAD NO. 573 (POWDER PLANT ROAD) ON THE EAST SIDE THEREOF AND COUNTY ROAD NO. 495 (HENRY ROAD) OF THE NORTH SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEEDS RECORDED UNDER AUDITOR'S FILE NOS. 147105 AND 194272.

PARCEL F

THE WEST 14 RODS OF THE EAST 46 RODS OF THE NORTHWEST QUARTER OF THE NORTHEAST QUARTER AND OF GOVERNMENT LOT 3, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO. EXCEPT COUNTRY ROAD NO. 495 (HENRY ROAD) OFF THE NORTH SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEED RECORDED UNDER AUDITOR'S FILE NO. 147105.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL G

THE WEST 14 RODS OF THE EAST 60 RODS OF THE NORTHWEST QUARTER OF THE NORTHEAST QUARTER AND OF GOVERNMENT LOT 3, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, Q.M., WHATCOM COUNTY, WASHINGTON, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO. EXCEPT COUNTY ROAD NO. 495 (HENRY ROAD) OFF THE NORTH SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEED RECORDED UNDER AUDITOR'S FILE NO. 147105.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL H

THE NORTHWEST QUARTER OF THE NORTHEAST QUARTER AND GOVERNMENT LOT 3, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, EXCEPT THE EAST 60 RODS AND EXCEPT COUNTY ROAD NO. 495 (HENRY ROAD) OFF THE NORTH SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEED RECORDED UNDER AUDITOR'S FILE NO. 147105, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL I

GOVERNMENT LOT 2, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON, EXCEPT THE WEST 700 FEET THEREOF, TOGETHER WITH ALL TIDELANDS OF THE SECOND CLASS ABUTTING THERETO. EXCEPT COUNTY ROAD NO. 495 (HENRY ROAD) OFF THE NORTH SIDE THEREOF, AS CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEEDS RECORDED UNDER AUDITOR'S FILE NOS. 147111 AND 430524.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

PARCEL J

THE EAST 325 FEET OF THE WEST 700 FEET OF GOVERNMENT LOT 2, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST OF W.M., WHATCOM COUNTY, WASHINGTON, EXCEPT COUNTY RAOD NO. 495 (HENRY ROAD) OFF THE NORTH SIDE THEREOF, CONVEYED TO WHATCOM COUNTY FOR ROAD PURPOSES BY DEED RECORDED UNDER AUDITOR'S FILE NO. 147111.

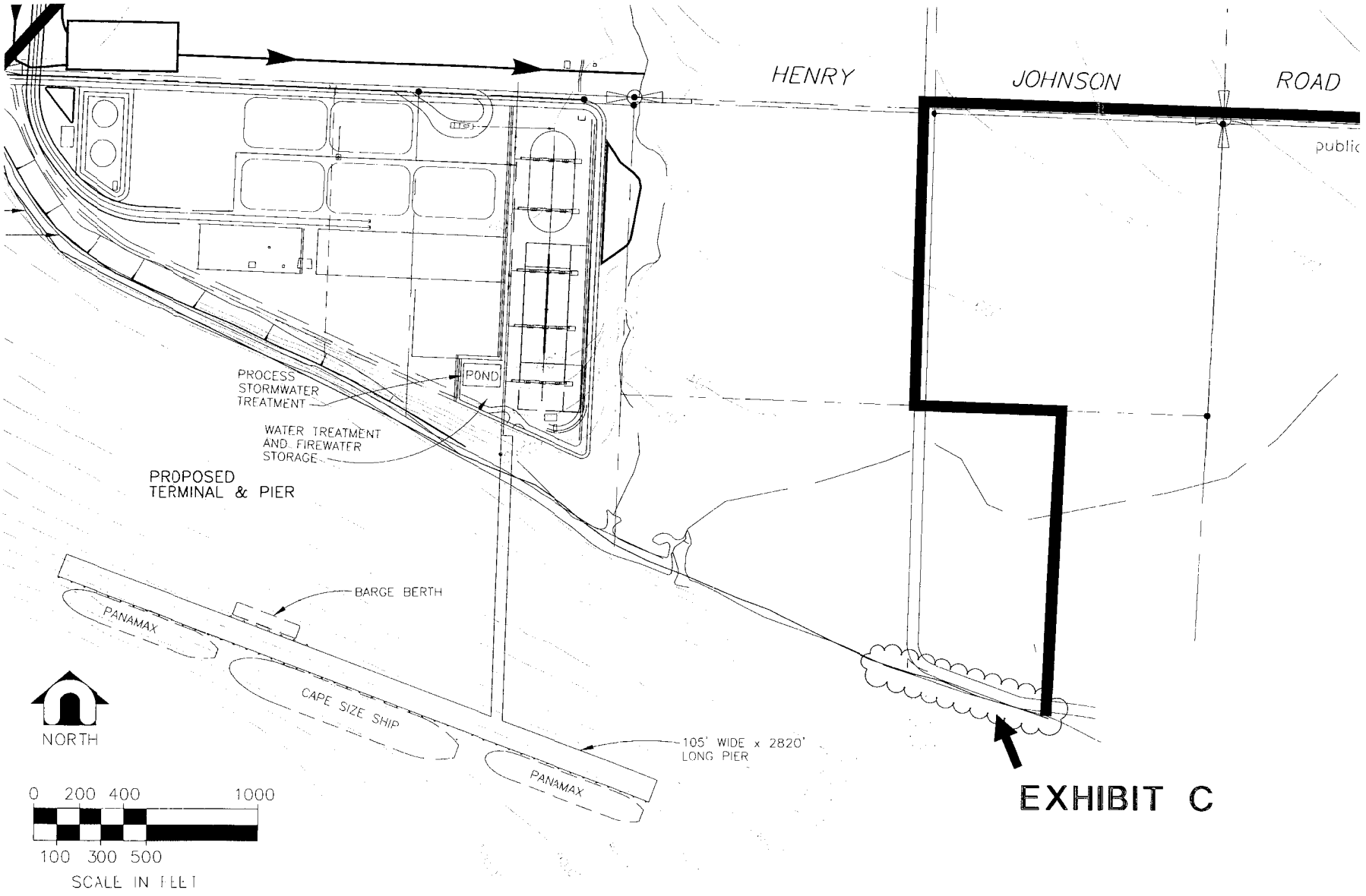
SITUATE IN WHATCOM COUNTY, WASHINGTON,

PARCEL K

ALL SECOND CLASS TIDELANDS ABUTTING THE EAST 325 FEET OF THE WEST 700 FEET OF GOVERNMENT LOT 2, SECTION 19, TOWNSHIP 39 NORTH, RANGE 1 EAST, W.M., WHATCOM COUNTY, WASHINGTON.

SITUATE IN WHATCOM COUNTY, WASHINGTON.

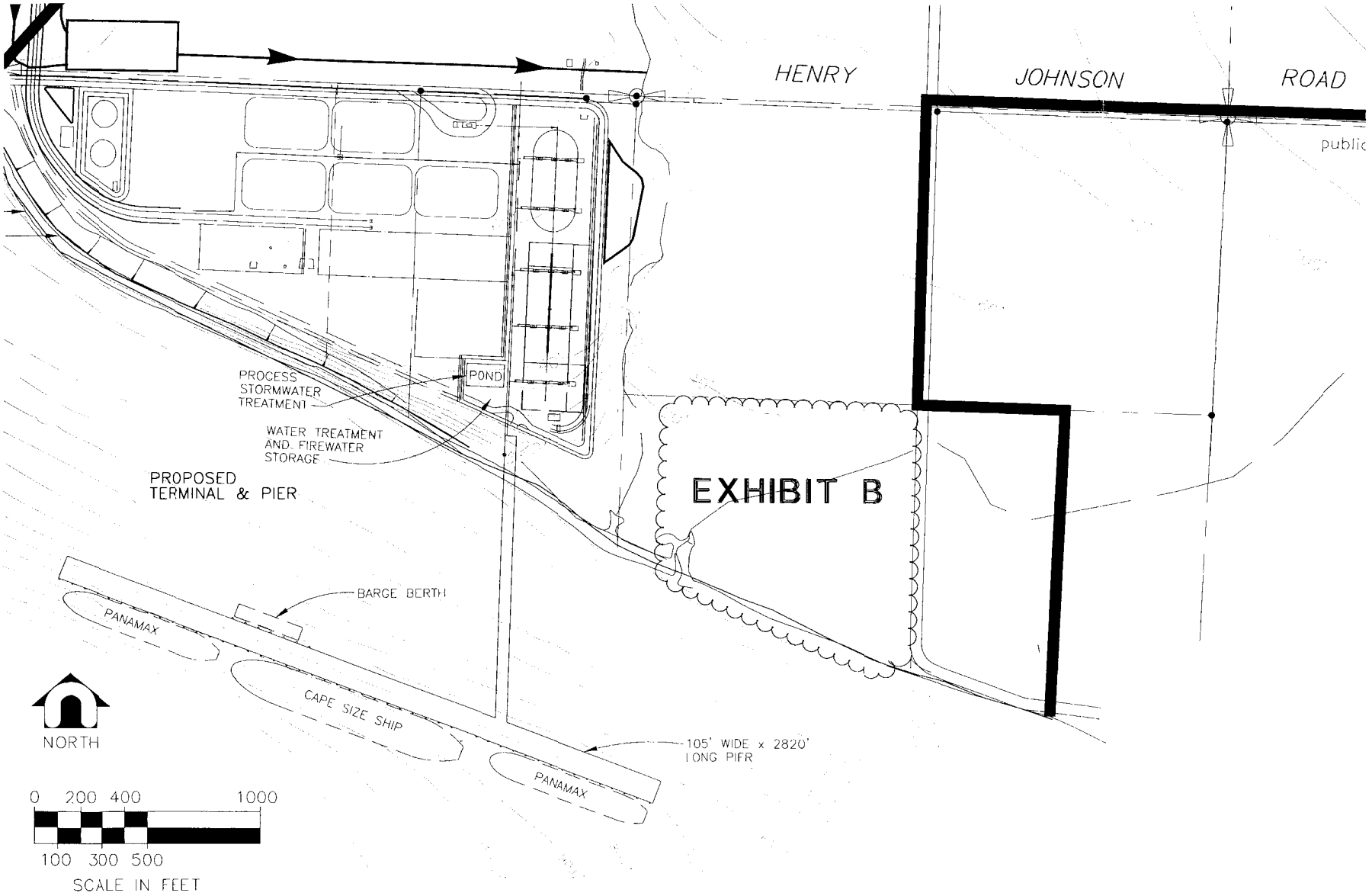
Initials _____ Initials RBB



GATEWAY PACIFIC TERMINAL
GENERALLY DEFINED SALT WATER MARSH AREA

DAVID EVANS AND ASSOCIATES, INC.
119 GRAND AVENUE, SUITE D
BELLINGHAM, WA 98225-4400 (360) 647-7151

SHEETS 1 OF 1
REVISIONS
DESIGN
DRAWN CMA
CHECKED
SCALE AS SHOWN
DATE 7-8-99
FILE DPT0003 / STORM3A.DWG



GATEWAY PACIFIC TERMINAL

GENERALLY DEFINED SALT WATER MARSH AREA

DAVID EVANS AND ASSOCIATES, INC
119 GRAND AVENUE, SUITE D
BELLINGHAM, WA 98225-4400 (800) 647-7151

1 1

SCALE AS SHOWN
DATE 7-6-93
FILE P11000.1 / STORMWA.DWG

Appendix I

PROPOSED AMENDMENTS TO SHORELINE PROGRAM

23.100.210.21 Port Development

(a) Development of a limited number of piers on piling and floating public and private marine cargo transfer terminal facilities is encouraged as the preferred use in the Cherry Point Management Unit. Port development that requires dredge and fill not associated with the construction and operation of the preferred uses has not been permitted in Cherry Point Management Unit due to its potentially adverse effects on the natural environment, including fish and shellfish habitat and geo-hydraulic processes. ~~Further,~~ However, Washington State natural resource agencies and Whatcom County have identified certain portions of the Cherry Point Management Unit as a herring spawning bed and have prohibited dredge and fill activities therein due to their potentially adverse effects on the natural environment, including fish and shellfish habitat and geo-hydraulic processes. Moreover, the State of Washington Department of Natural Resources has indicated that it will not consider issuance of more than one aquatic lands lease for port development in the Cherry Point Management Unit in addition to the three piers already in operation as of January 1, 1998.

(b) Consequently, it is the policy of Whatcom County that port facilities which require dredge and fill not associated with the construction and operation of the preferred uses should be prohibited until such time that it can be demonstrated that the impact of such development will avoid adverse effects to the shoreline environment.

(c) Consequently, it is the policy of Whatcom County to limit the number of piers at Cherry Point by establishing a development moratorium. The goal of the moratorium is to ensure that only one pier in addition to those in operation as of January 1, 1998, is constructed at the Cherry Point Management Unit. Notwithstanding the above, this moratorium shall not affect, nor otherwise apply to, any proposed pier that Whatcom County approved under its Shoreline Management Program prior to adoption of the moratorium.

23.100.210.31 Permitted Development

The following listed uses and activities are permitted within the Cherry Point Management Unit subject to the development standards contained in Section 23.100.213.

(a) Port development and shore-dependent or shore-related industrial development together with any or all of the following components and restrictions:

1. There is hereby established a moratorium precluding issuance of any shoreline permit allowing development of new pile supported or floating piers, except that this moratorium shall not have any application to those that have obtained shoreline approval from Whatcom County prior to adoption of this moratorium. If all of the unexercised shoreline approvals in existence at the time of imposition of this moratorium expire or are abandoned, a single exception to the moratorium may be granted and shoreline approval may be given for one additional pile, supported or floating pier.

2. Expansion of existing piers.

3. Landfill or excavation necessary to the access and construction of any pile supported or floating pier permitted following expiration or abandonment of the unexercised permits.

4. Dredging for maintenance or expansion of operations at existing piers.

5. Dredging necessary for the construction of new pile supported or floating piers.

6. Roads and railways.

7. Utilities.

8. Shore defense works: revetments, bulkheads, floating breakwaters and seawalls only.

9. Over-water structures and buildings that are intrinsic to the operation of the primary development, provided that they are elevated on pilings or on floating structures.

(b) Recreational development for public or quasi-public shoreline access.

(c) Archaeological excavation.

(d) Fish and wildlife habitat research and/or enhancement.

.32 Conditionally Permitted Development:

Port development and shore-dependent or shore-related industrial development which includes the following components may be considered under the Shoreline Conditional Use Permit process defined in WAC 173-14, except to the extent restricted in Section 23.100.210.31, and except where prohibited along the accretion shoreform and natural wetland areas described in Section 23.100.210.27(g) and Appendix E.

(a) Landfill or excavation associated with pier or floating structures which does not meet the development standards for such activities.

(b) Dredging for purposes associated with pier or floating structures which does not meet the development standards for such activities.

(c) Shore defense works, floating breakwaters and seawalls which do not meet the development standards for these structures.

Appendix J

PROPOSED AMENDMENTS TO WHATCOM COUNTY COMPREHENSIVE PLAN

1. The following paragraph should be inserted after the second paragraph on page 2-50:

   The Cherry Point shoreline also has great importance to the fisheries and ecology of Northern Puget Sound because it provides essential spawning habitat for the largest herring stock in Washington State. This herring stock has supported important commercial fisheries and provides forage for salmonids and other important marine resources.

2. Policy 2AA-10 should be amended to read:

   Consequently, it is the policy of Whatcom County to limit the number of piers at Cherry Point by establishing a development moratorium. Notwithstanding the above, this moratorium shall not affect, nor otherwise apply to, any proposed pier that Whatcom County approved under its Shoreline Management Program prior to adoption of the moratorium.

APPENDIX K TIMELINE FOR PROPOSED AMENDMENTS TO WHATCOM COUNTY SHORELINE PROGRAM AND COMPREHENSIVE PLAN

The County has currently scheduled a public hearing to review the proposed Comprehensive Plan and Shoreline Master Program amendments for May 27, 1999. The County plans to have the Shoreline Master Program amendment presented to the County Council by July 1999, subject to public participation and notice requirements and scheduling limitations. The County plans to have the Comprehensive Plan amendments to the County Council by November 1999, subject to public participation and notice requirements and scheduling limitations.

APPENDIX L

WASHINGTON STATE DEPARTMENT OF
Natural Resources

JENNIFER M. BELCHER
Commissioner of Public Lands

July 7, 1998

Mr. Jeff F. Kaspar
Pacific International Terminals
1801 Roeder Avenue, Suite 156
Bellingham WA 98225

Dear Mr. Kaspar:

This letter is to advise you that we would like to initiate further discussions with you regarding certain environmental issues that are not fully addressed in the proposed settlement agreement for the Shoreline Substantial Development Permit appeal (SHB Nos. 97-22 and 97-23). While it might be argued that the settlement agreement might meet Shoreline Master Plan requirements, we think the settlement does not yet fully address the intent of shoreline or aquatic resources protection. Specifically, the current draft proposal for settlement does not commit to avoid long-term cumulative impacts as they relate to the Cherry Point herring stock on a region-wide perspective.

In addition, because the state also has proprietary responsibility for state-owned aquatic lands our concern for natural resources amplify the regulatory concerns that have been in discussions in the negotiations. The regulatory and proprietary obligations of the state must be addressed in a complementary way in order to further an authentic and complete resolution of the permit appeal. For example, we propose some revisions to the draft settlement agreement to fully address resource concerns on state-owned aquatic lands.

We want to quickly commence and conclude these negotiations with you so that the settlement is complete and so that so we can ensure an integrated settlement package.

To this end, we offer the following to facilitate this process. The September hearing dates should be released and conclusion of the settlement put on hold while PIT participates in studies, assessments, and planning as outlined herein. In return, PIT can expect conclusion of the permit and related lease issues in one package, should risk assessment results demonstrate no unacceptable risks. This will help assure that there will not be a liability for "takings" under the Endangered Species Act (ESA). It also assures PIT that all conditions for the settlement, any anticipated future lease, and permits are complete and are consistent.

We have attached our request for involvement in the list of herring studies and regional risk analysis, as well as detailed information to substantiate the cost and the scope of that work. (See attachment A). We can send you a list of specific provisions in the current proposed settlement agreement that will need to be further discussed.

We look forward to working with you. Please contact me at (360) 902-1010 at your earliest convenience.

Sincerely,

Paul Silver
Deputy Supervisor
Resource Management

Attachment A

Outlined below are the issues which remain unresolved.

Preliminary, basic biological thresholds for describing a healthy herring stock, and long-term average and maximum measures for the herring stock have been developed. In developing these goals, it was realized that defining a threshold for a healthy population was necessary. Currently, the Cherry Point population does not meet these basic thresholds. The biological thresholds for Cherry Point herring are:

1. Biomass: 5,000 (tons) spawners which translates into 25% of average unfinished biomass; and/or the amount of shoreline utilized to spawn will double the amount used in 1996 & 1997.

2. Recruitment: At least 75% of long-term average recruitment.
   Note: The mean 20 yr recruitment is 2,200 tons.

3. Adult survival: Annual survival of adult herring to exceed 50% of total biomass.
   Note: The current annual adult herring survival is 30% of the biomass. The worldwide average survival is 60%.

An examination of Cherry Point herring issues must be made on a region wide basis in collaboration with federal agencies, and Cherry Point stakeholders, including Pacific International Terminals (PIT), in anticipation of the proposed listing of Chinook Salmon throughout Puget Sound under the federal Endangered Species Act.

To accomplish this, we have identified three separate components critical to the protection of Cherry Point herring: 1) initiate studies, as well as collect and analyze existing studies, to determine what stressors are influencing the herring decline; 2) develop a regional ecological risk assessment to determine what effect individual stressors have on herring/salmon for all of the existing stressors that may be influencing the herring stocks at Cherry Point; and 3) prepare an aquatic management landscape (aquascape) plan to address the proprietary decisions that need to be made by DNR, to ensure adequate protection/mitigation measures are taken for herring.

We seek PIT's participation in the studies, risk analysis and landscape efforts at Cherry Point, as further outlined below. PIT's contribution can take the form of a financial contribution and/or in-kind services toward the efforts identified.

Attached is a map that identifies the boundaries for the Cherry Point herring studies, aquatic management landscape plan, and regional ecological risk assessment.

1. Studies

Phase 1 — Literature searches to be accomplished during the period of June 1998 - June 1999.

Studies	Costs	Timeline	Study Areas
Literature search and annotated bibliography on disease, predation, food supply, larval and egg sensitivity to oil	$44,000	1 year	NA
Historical spawning distribution and changes	$20,000	1 year	2
Nearshore habitat changes since early 1950's	$75,000	1 year	1

139,000

Phase 2 — Herring related studies to be accomplished during the period of June 1998 - June 1999.

Studies	Costs	Timeline	Study Areas
Herring Embryo/Larval Viability Evaluation	$45,000	6 months to 1 year	3
Cherry Point Caged Mussel Study	$48,000	6 months to 1 year	1
Regional study of herring population behavior	$350,000	2 years	2
Chemical contamination in adult herring	$22,000	6 months to 1 year	3
Improvement of biomass estimation methodologies	$60,000	1 year	2
Wave dampening and longshore drift	$20,000	1 year	1

545,000 → 484,000

Phase 3 — Herring related studies as might be requested by the Department of Ecology/Office of Marine Safety, approximately during the period of April 1999 - April 2000.

Studies	Costs	Timeline	Study Areas
Oil Spill and stormwater effluent bioassays for Larval Herring	$120,000	1 year	1
Oil Spill and stormwater effluent bioassays for Juvenile Herring	$80,000	1 year	1
Participate in and assist in funding of a North Puget Sound vessel traffic safety study	To be determined	1 year	Outside of 3

200,000 → $84,000

2. Regional Ecological Risk Assessment.

We also ask that PIT participate in and contribute to a regional ecological risk assessment (ERA) to determine the risk that structures and operations pose to herring and salmon at Cherry Point, in the context of existing and proposed facilities.

Regional ecological risk assessment is a defined process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. We intend to use this analysis in assessing whether proposed construction and operation activities will pose an acceptable or unacceptable risk to the Cherry Point herring stock. A regional ecological risk assessment can accomplish four goals towards the purpose of analyzing decisions which might impact the Cherry Point herring stock:

1. It involves risk managers, risk assessors, and stakeholders;
2. It creates an agreed-upon set of endpoints, management goals, and understanding of the ecosystem and its interactions;
3. It addresses concerns about cumulative impacts; and
4. Risk to the herring resource can be communicated to the risk managers for decisions.

The risk assessment process does not make management decisions. The proposed short- term studies are important in the risk assessment process. The topics proposed for study have been identified as areas of high concern or lacking information. It is important to understand that results from the studies will not be used separately, but will be used to assess the overall risk to the resource on a regional ecosystem context.

The process will also allow identification of high risk activities and then devise appropriate adaptive management to minimize risk. It will also allow for examining various "what if" trade-off scenarios between different activities.

At a minimum, the following stressors to herring will be examined: 1) oil spill and vessel traffic safety; 2) sediment quality; 3) water quality; 4) nearshore littoral transport; 5) wave attenuation; 6) nearshore fills; and 7) supporting food web (predation).

3. Participate in a long-term Aquatic Landscape Management Plan. DNR is beginning to develop an aquatic landscape management plan in order to balance the ecological needs and the needs of the industrial facilities at Cherry Point. PIT's participation in the aquascape management plan can involve providing information to DNR on property ownership, mitigation/enhancement areas, land uses, etc. PIT will also be offered the opportunity to review and comment on the aquascape management plan.

We will allow the construction of the PIT proposed facility only if the completed regional ecological risk analysis shows that construction and operation activities will not pose an unacceptable risk to the Cherry Point herring stock. This risk will be reviewed in a regional context and will be reviewed to ensure that it does not constitute a "takings" under the proposed listing for chinook salmon under the ESA, as determined by the National Marine Fisheries Service.

(The department would also like to initiate discussions regarding additional Best Management Practices, Natural Resources and Water Quality Monitoring, and PIT's Implementation of Adaptive Management Strategies prior to completion of lease negotiations. However, these need not be resolved as part of the settlement of the permit appeal.)

Section B- Regional Ecological Risk Assessment

Introduction:

Ecological risk assessment is a defined process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. EPA has recently published guidelines for such as assessment[1]. (Pertinent sections from the introduction and a diagram showing the interactions between the participants and the three phases are attached.) DNR intends to use this analysis in assessing whether the proposed construction and operation activities will pose an acceptable or unacceptable risk to the Cherry Point herring stock.

Regional ecological risk assessment can accomplish four goals towards the purpose of analyzing decisions which might impact the Cherry Point herring stock:

1. It involves risk managers, risk assessors, and stakeholders,
2. It creates an agreed-upon set of endpoints, management goals, and understanding of the ecosystem and its interactions,
3. It addresses concerns about cumulative impacts, and
4. Risk to the herring resource can be communicated to the risk managers for decisions.

The risk assessment process does not make management decisions.

The proposed short-term studies are important in the risk assessment process. These topics proposed for study have been identified by state agency's resource managers as areas of high concern or lacking information. It is important to realize results from the studies will not be used separately, but will be used to assess the overall risk to the resource on a regional ecosystem context.

The process will also allow identification of high risk activities and then devise appropriate adaptive management to minimize risk. It will also allow for examining various "what if" trade-off scenarios between different activities.

Resources:

Project Management:

- Project Manager- full time position for 1 year within lead agency.
- Project Coordinator- full time position for 1 year within lead agency.

Teams

- Risk Manager Team, which will include representatives from the proprietary agency (WDNR), regulatory agencies, tribes, port, county, and industry.
- Risk Assessor Team, which will consist of technical staff with expertise in herring biology, marine/estuarine ecology,herring population modeling,contaminated sediments, shoreline geomorphology, stormwater and wastewater toxicology, and oil spill risks/ toxicology.
- Stakeholders Committee, which could include the proprietary agency (DNR), regulatory agencies, tribes, non-tribal commercial fishers, port, county(ies), industry, environmental groups (WEC, etc.), private property owners, and Canadian representation.

---

[1] EPA.*Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. February, 1998. Available as Acrobat® .pdf document at http://www.epa.gov/ncea/ecorsk.htm

Consulting

- It is highly recommended by those who have gone through the process to have a consultant facilitate/lead the Teams though the process and to provide technical assistance in modeling and risk assessment.

Timeline

It is assumed that the risk managers, in particular DNR, will have the results from the ecological risk assessment process by early 1998 in order to make DNR proprietary decisions by June 1999

Costs:

Staff:	
- Project Manager- full time for 1 year- DNR-	$75,000
- Project Coordinator- full time for 1 year- DNR-	$60,000
Consultant	$150,000
Studies (See section A-1,2)	
Short -term:	$684,000
Long-term less vessel traffic safety study	$200,000
Vessel traffic safety study	$2,000,000

Relationship to Herring Recovery Plan and ESA

The ecological risk assessment process is viewed as a part of or leading to an potential long-term herring recovery plan. As indicated in the NMFS criteria in the DRAFT State Salmon Strategy, (Joint Natural Resources Cabinet, 1/19/98) "Critical and substantive elements of a comprehensive salmon restoration plan...are:

1. Identify major limiting factors that have contributed to the decline.
2. Establish priorities for action.
3. Establish explicit objectives and timelines for correcting factors for decline and achieving desired population characteristics.
4. Establish quantifiable criteria and standards by which progress toward each objective will be measured.
5. Adopt measures/actions needed to achieve the explicit objectives. A plan should include measures to protect and restore habitat wherever habitat condition is a factor of decline, whether on private and public lands.
6. Provide high level of certainty that the identified measures and actions will be implemented, commitments, funding, staffing, and enforcement measures.
7. Establish a comprehensive monitoring and reporting program, including.methods that measure whether objectives are being met and detect subpopulation declines and increases in each ESU.
8. As much as possible integrate federal, state, tribal, local, corporate, and nongovernmental activities and projects that are designated to recover salmon populations and the habitat upon which they depend.
9. Utilize an adaptive management approach that actively shapes management actions to generate needed information."

The proposed ecological risk assessment process meets many of these criteria and it should be a logical next step to create a herring restoration plan from the process.The ecological risk assessment process for a fish stock also should also be useful in determining the risk of a chinook "taking" under ESA. A herring restoration plan would provide long-term certainty and protection under the ESA for activities in salmon and herring habitat.

From: Environmental Protection Agency. 1998. *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. (Available as Acrobat .pdf document at http://www.epa.gov/ncea/ecorsk.htm)

"**Ecological risk assessment** is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors The process is used to systematically evaluate and organize data, information, assumptions, and uncertainties in order to help understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision making. An assessment may involve chemical, physical, or biological stressors, and one stressor or many stressors may be considered.

Ecological risk assessments are developed within a risk management context to evaluate human-induced changes that are considered undesirable.

Ecological risk assessments can be used to predict the likelihood of future adverse effects (prospective) or evaluate the likelihood that effects are caused by past exposure to stressors (retrospective).

Ecological risk assessment includes three primary phases: problem formulation, analysis, and risk characterization.

In problem formulation, risk assessors evaluate goals and select assessment endpoints, prepare the conceptual model, and develop an analysis plan.

During the analysis phase, assessors evaluate exposure to stressors and the relationship between stressor levels and ecological effects.

In the third phase, risk characterization, assessors estimate risk through integration of exposure and stressor-response profiles, describe risk by discussing lines of evidence and determining ecological adversity, and prepare a report. The interface among risk assessors, risk managers, and interested parties during planning at the beginning and communication of risk at the end of the risk assessment is critical to ensure that the results of the assessment can be used to support a management decision. Because of the diverse expertise required (especially in complex ecological risk assessments), risk assessors and risk managers frequently work in multidisciplinary teams.

After completion of the risk assessment, risk managers may consider whether follow-up activities are required. They may decide on risk mitigation measures, then develop a monitoring plan to determine whether the procedures reduced risk or whether ecological recovery is occurring. Managers may also elect to conduct another planned tier or iteration of the risk assessment if necessary to support a management decision.

From: Environmental Protection Agency. 1998. *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. (Available as Acrobat .pdf document at http://www.epa.gov/ncea/ecorsk.htm)

Table of Contents

I. Introduction
- A. The Ecological Risk Assessment Process
- B. Ecological Risk Assessment in a Management Context
  - 1. Contributions of Ecological Risk Assessment to Environmental Decision Making
  - 2. Factors Affecting the Value of Ecological Risk Assessment for Environmental Decision Making
- C. Scope and Intended Audience

II. Planning the Risk Assessment
- A. The Roles of Risk Managers, Risk Assessors, and Interested Parties in Planning
- B. Products of Planning
  - 1. Management Goals
  - 2. Management Options to Achieve Goals .
  - 3. Scope and Complexity of the Risk Assessment .
- C. Planning Summary

III. Problem Formulation Phase
- A. Products of Problem Formulation
- B. Integration of Available Information
- C. Selecting Assessment Endpoints
  - 1. Criteria for Selection
    - a. Ecological Relevance
    - b. Susceptibility to Known or Potential Stressors
    - c. Relevance to Management Goals
  - 2. Defining Assessment Endpoints
- D. Conceptual Models
  - 1. Risk Hypotheses
  - 2. Conceptual Model Diagrams
  - 3. Uncertainty in Conceptual Models
- E. Analysis Plan
  - 1. Selecting Measures
  - 2. Ensuring That Planned Analyses Meet Risk Managers' Needs

IV. Analysis Phase
- A. Evaluating Data and Models for Analysis
  - 1. Strengths and Limitations of Different Types of Data
  - 2. Evaluating Measurement or Modeling Studies
    - a. Evaluating the Purpose and Scope of the Study
    - b. Evaluating the Design and Implementation of the Study
  - 3. Evaluating Uncertainty
- B. Characterization of Exposure
  - 1. Exposure Analyses
    - a. Describe the Source(s)
    - b. Describe the Distribution of the Stressors or Disturbed Environment
    - c. Describe Contact or Co-occurrence
  - 2. Exposure Profile
- C. Characterization of Ecological Effects

1. Ecological Response Analysis
    a. Stressor-Response Analysis
    b. Establishing Cause-and-Effect Relationships (Causality)
    c. Linking Measures of Effect to Assessment Endpoints
2. Stressor-Response Profile

V. Risk Characterization
A. Risk Estimation
1. Results of Field Observational Studies
2. Categories and Rankings
3. Single-Point Exposure and Effects Comparisons
4. Comparisons Incorporating the Entire Stressor-Response Relationship
5. Comparisons Incorporating Variability in Exposure and/or Effects
6. Application of Process Models
B. Risk Description
1. Lines of Evidence
2. Determining Ecological Adversity
C. Reporting Risks

VI. Relating ecological information to risk management decisions.

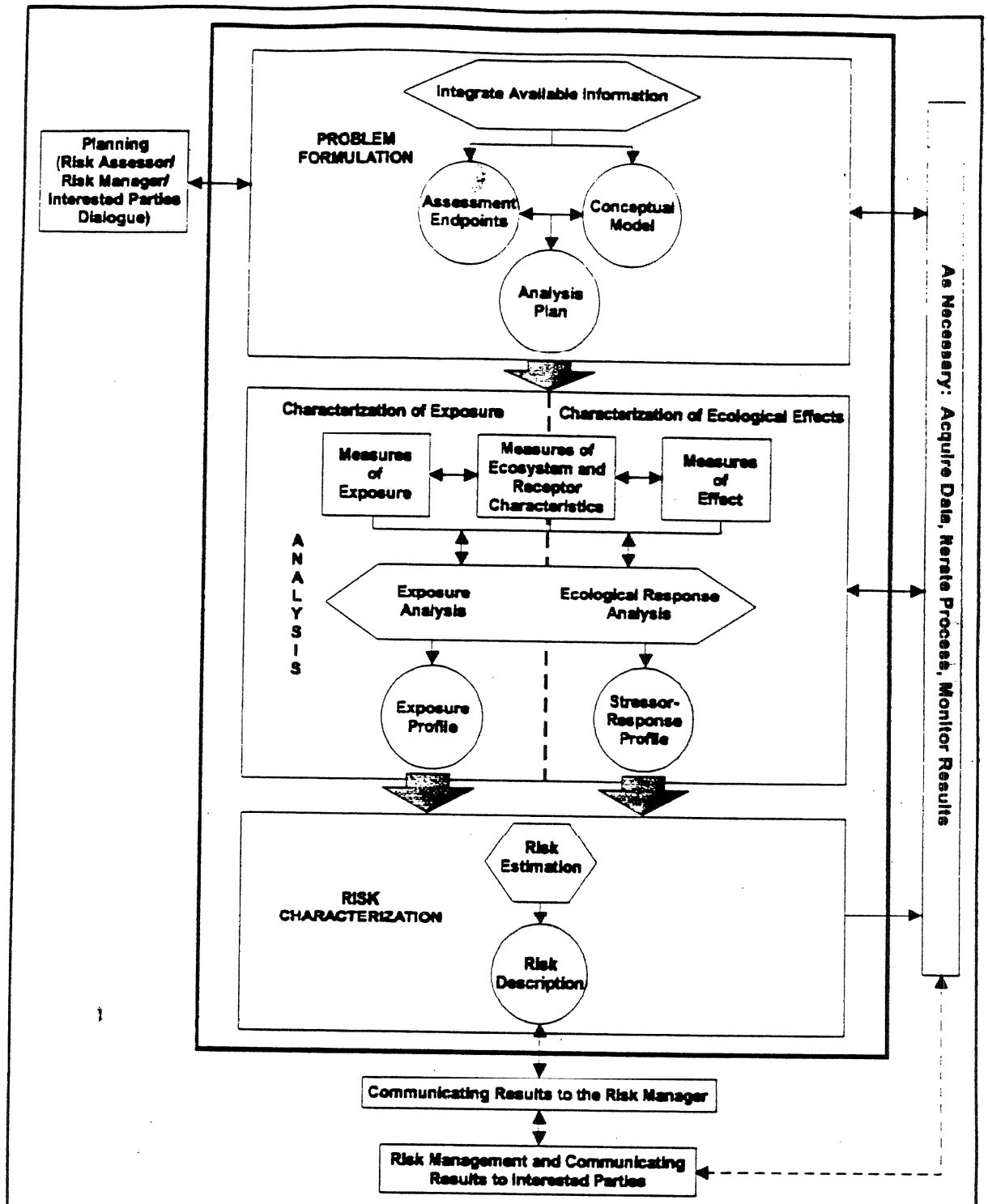


Figure 1-2. The ecological risk assessment framework, with an expanded view of each phase. Within each phase, rectangles designate inputs, hexagons indicate actions, and circles represent outputs. Problem formulation, analysis, and risk characterization are discussed in sections 3, 4, and 5, respectively. Sections 2 and 6 describe interactions between risk assessors and risk managers.

C. **Participate in a long-term ~~Aquatic Landscape~~ Aquascape Management Plan** — The DNR is beginning to develop an ~~aquatic landscape~~ aquascape management plan in order to balance the ecological needs and the needs of the industrial facilities at Cherry Point. Because ARCO is in essence also a land manger at Cherry Point, ARCO will be able to provide valuable information as to the management state-owned aquatic lands. ARCO's participation as a co-sponsor in the aquascape management plan can involve providing valuable information to DNR on property ownership, mitigation/enhancement areas, land uses, etc. ARCO will also be offered the opportunity to review and provide public support comment on the aquascape management plan.

Washington State
Transportation Commission
www.wstc.wa.gov

Statewide Rail Capacity and System Needs Study

Final Report

CAMBRIDGE SYSTEMATICS
Transportation leadership you can trust.

with

Berk & Associates, Inc.
Global Insight, Inc.
HDR, Inc.
Starboard Alliance Company
Transit Safety Management

December 2006

www.camsys.com

Washington State Transportation Commission

Richard Ford, Chair*

Elmira Forner, Vice Chair

Dan O'Neal*

Edward Barnes*

Bob Distler

Dale Stedman

Carol Moser*

*Member of the Rail Study Committee

STATE OF WASHINGTON

TRANSPORTATION COMMISSION

Transportation Building, PO Box 47308, Olympia, Washington 98504-7308 • (360) 705-7070
Fax: (360) 705-6802 • E-mail: transc@wsdot.wa.gov • http://www.wsdot.wa.gov/commission

January 5, 2007

The Honorable Christine Gregoire
Office of the Governor
P.O. Box 40002
Olympia, Washington 98504-0002

The Honorable Members
Washington State Senate
P.O. Box 40482
Olympia, Washington 98504-0482

The Honorable Members
Washington State House of Representatives
P.O. Box 40600
Olympia, Washington 98504-0600

Dear Governor Gregoire, Senators, and Representatives:

The Washington State Transportation Commission respectfully submits the enclosed *Statewide Rail Capacity and System Needs Study*, which was approved by the Commission at its meeting on December 12, 2006. Your interest in and attention to the need for policies to govern the State's participation in the rail transportation system is important to the mobility and commerce of the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity passenger rail service. In the last decade, it has also provided emergency funding to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature of this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The study concludes that the economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. However, it also concludes that the rail system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. The pressure on the rail system will increase as the Washington State economy

grows. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent between 2005 and 2025. The State's role is necessarily shaped by the fact that nearly all freight railroads are privately owned for profit companies.

The major freight railroads are investing to add capacity and improve service in Washington State, but their business practices and investment priorities are understandably driven primarily by the railroads' national-level needs and competition. The needs of Washington State businesses and communities are just one part of the railroads' considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets Washington State's economic needs, as well as the railroads' business needs.

A carefully planned program of state investments and other actions that are consistent with the policies recommended by the study will allow the State to realize a higher level of public benefits – in economic growth, jobs, tax revenues, and reduced community impacts – from the rail system than would be obtained without state participation. However, the State should invest only when it has been demonstrated that projects will deliver public benefits to the citizens and businesses of Washington State, and when it has been demonstrated that there is a low likelihood of obtaining those benefits without public involvement.

The study recommends policies, procedures, and approaches to governance and management of the State's rail programs and assets that will help the State make effective and responsible improvements to the rail system – improvements that will serve the economic development, transportation, social, and environmental goals of Washington State and its citizens.

The study points to but does not recommend specific improvements to the rail system. If the Legislature chooses to adopt the policies and procedures recommended by the study, it may wish to apply the policies and procedures to determine the high-priority projects.

We appreciate your support for transportation improvements statewide, and hope that these recommendations will help to expedite projects that will keep Washington moving and keep Washington's economy thriving.

Sincerely,

Richard Ford
Chairman
Washington State Transportation Commission

Enclosure

Table of Contents

1.0 Executive Summary 1
2.0 Introduction and Background..... 9
2.1 Purpose of the Study..... 9
2.2 Issues..... 9
2.3 Structure of the Report..... 10
3.0 Washington State Rail System, Rail Users, Capacity, and Issues 12
3.1 Washington State Rail System 12
3.2 Washington State Rail Users 15
3.2.1 Manufacturers/Industrial Carload Shippers 17
3.2.2 Ports and International Trade Sector/ Intermodal Container Shippers..... 18
3.2.3 Agriculture and Foods Products Industry/ Bulk and Specialized Carload Shippers..... 19
3.2.4 Passenger Rail Riders 20
3.4 Capacity of the Washington State Rail System and Implications for Rail Users 21
4.0 Washington State Powers, Authorities, and Interests... 30
4.1 Washington State Powers and Authorities in Freight and Passenger Rail..... 30
4.2 Washington State Investments in the Rail System.. 32
4.3 Washington State Governance of Rail..... 36
4.4 Using State Powers and Authorities to Further State Interests in the Rail System..... 37
5.0 Policy Recommendations 39
5.1 Policy Recommendation One 40
5.2 Policy Recommendation Two..... 44
5.3 Policy Recommendation Three..... 51
5.4 Policy Recommendation Four..... 52
5.5 Policy Recommendation Five 53
5.6 Policy Recommendation Six 54
Appendix A.
Benefit Assessment Illustrative Case Study – East-West Capacity Projects..... A-1
Appendix B.
Glossary..... B-1

Cover photographs of Amtrak *Cascades* service and BNSF 4937 courtesy of David Honan.

List of Tables

1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025 16

2. Rail Lines in Washington State Exceeding Capacity, 2015 and 2025 *Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains* 27

3. Recent and Ongoing Washington State Rail Investment Projects 34

4. Examples of Projects Addressing the Rail Service Needs of Washington State Rail Users 41

5. Major Choke Points in the Rail System and Potential Projects to Increase Capacity 43

6. Recommended Benefit and Cost Measures 46

7. Recommended Measures to Include in Estimating a Benefit-Cost Ratio 47

8. Sample Decision Matrix for Comparison of Alternative Rail Projects and Actions 48

9. Benefit Evaluation Cross-User Group Comparison 50

10. Freight Mobility Strategic Investment Board Evaluation Criteria and Weights 51

11. Asset Management Principles for State Rail Assets 55

List of Figures

1. Washington State Rail Network..... 13

2. Washington State Rail Tonnage by Commodity (2004) and Forecast Tonnage (2015 and 2025) 17

3. Washington State Rail System: Mainline Capacities, 2006 22

4. Washington State Rail Network: Rail Choke Points, 2006 24

1.0 Executive Summary

The Washington Rail Capacity and System Needs Study was requested by the Washington State Legislature to:

- Assess rail needs in the State;
- Determine the State's interest in the rail system;
- Develop policies to govern the State's participation in the rail system; and
- Develop a plan for managing the rail lines, railcars, and service rights owned by the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity rail service. In the last decade, it also has provided emergency relief to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature for this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The Economic Vitality of Washington State Requires a Robust Rail System

The economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. For example:

- Manufacturers, lumber and wood products producers, and central and eastern Washington agriculture and food products businesses rely on rail transportation to move heavy, bulky products to market cost effectively. These businesses generate 14 percent of the State's gross state product and 15.5 percent of its employment. If rail service deteriorates, these businesses may shift their freight to trucks, but this will increase their transportation costs and may increase the cost to state and

local government of maintaining roads. In some cases, the loss of rail service could drive businesses to relocate or close.

- The State's ports and international trade industry depend on rail to export grain and other agricultural products and to import intermodal containers of consumer goods. The ports generate more than 200,000 jobs directly and indirectly, and over $500 million in state and local tax revenues. If the rail system cannot deliver high-quality transportation services, especially for intermodal cargo that is not destined for Washington State, shippers will quickly shift to other ports. This could result in lower growth at Washington ports and a loss of port-related jobs. In addition, export trade plays a major role in the Washington economy, ranking it first among states in export value per capita. Without good rail connections to support both import and export trade, the Washington ports will become less attractive to ocean carriers, and ultimately, the State will become a less attractive location for export businesses.

- A high-quality intercity passenger rail service offers an alternative to automobile and air travel that can help reduce congestion, energy use, and environmental impacts of highways. If the rail system cannot accommodate frequent and reliable intercity passenger rail service, the State risks losing the benefits of passenger rail as an alternative to highway and air travel.

The System Is Nearing Capacity

The benefits that Washington State can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. For example:

- The Everett-Spokane line over Stevens Pass is the Burlington Northern Santa Fe Railway's (BNSF) major transcontinental route for double-stack intermodal trains. It operates today at about 123 percent of practical capacity.[1]

[1] Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is the point at which the system ceases to operate freely and reliably and begins to suffer slowdowns and congestion. At higher percentages, rail congestion increases and service reliability deteriorates quickly. For more information about how rail capacity is determined, see Technical Memorandum #3, *Rail Capacity Needs and Constraints*.

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the State's passenger-rail program. The cost of resolving the rail choke points in the I-5 corridor to meet passenger service and ridership goals is increasing, potentially reducing the cost-effectiveness of the passenger rail program. Without capacity improvements, rail will not maintain its share of the Washington State freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the State's industrial and agricultural shippers.

The Rail Industry Is Expanding Capacity, But May Not Meet All the State's Needs

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines. They are operating longer trains and maximizing the number of containers packed on intermodal cars; consolidating pick-up and delivery of railcars at central terminals; and eliminating mainline switching wherever possible (i.e., minimizing the number of times trains are 'parked' on the mainline while picking up cars from individual shippers). These changes favor a hook-and-haul operations strategy, where the railroads pick up a full train in Seattle or Tacoma and haul it directly to Chicago, or pick up a full grain train in the Midwest and haul it directly to a Columbia River port. Hook-and-haul operations allow the railroads to achieve economies of scale that keep costs down and services profitable. However, capacity will remain constrained in Washington even with these changes.

The move toward wholesale rail service helps meet the needs of Washington State's ports, which handle high volumes of imported intermodal containers and exported grain. But it is problematic for Washington State's manufacturers and agricultural shippers. They need low-cost, shorter-haul carload service and do not generate the high volumes attractive to the railroads. In general, international intermodal container traffic has been outbidding domestic carload traffic for space on the rail system, and the railroads have been pricing out lower-volume, lower-profit shippers to meet the demands of higher-volume, higher-profit freight.

The shift toward high-volume, hook-and-haul operations is also problematic for Washington State's short line railroads. They provide a link between smaller shippers and the Class I railroads. If they cannot generate enough volume to get service

commitments from the Class I railroads, they lose revenue and customers. This makes it difficult financially to maintain track and service quality, further undermining their ability to provide service to their customers and compete with trucking.

While the Class I railroads are investing in the Washington State rail system to increase capacity and improve service, their business practices and investment priorities are driven primarily by the railroads' national-level needs and competition. The needs of Washington State businesses and communities are just one part and not the largest part of the railroads' considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets Washington State's economic needs, as well as the railroads' business needs.

The State Should Participate in the Rail System in Partnership With the Private Sector to Increase Rail Capacity

A carefully planned program of state investments and other actions, consistent with the policies recommended by the study, will allow the State to realize a higher level of public benefits – in economic growth, jobs, tax revenues, and reduced community impacts – from its rail system than would be obtained without state participation.

The State should participate in the rail system through a mix of direct investment, financial incentives to private parties, and advocacy on behalf of Washington businesses and communities. However, the State should do so only when the projects or actions can be demonstrated to deliver public benefits to the citizens and businesses of the State of Washington, and when it has been demonstrated that there is a low likelihood of obtaining these benefits without public involvement.

The cost of state participation in the private rail system must be weighed against the benefits and costs of alternative modes. For example, in some cases, the costs of maintaining and improving rail service may be higher than the costs of maintaining and improving highways to accommodate added truck and automobile traffic. The cost of improving rail service must also take into account the cost of mitigating the impacts of increased rail traffic on communities near terminals and along mainlines. Finally, the cost of state participation should weigh Washington State benefits against national benefits. When a substantial share of the benefits of a project accrue to rail users outside of Washington State, the State's contribution should be limited. This study recommends an approach to evaluating costs and benefits to the State and other beneficiaries in a systematic decision-making framework.

Washington State is not alone in facing challenges in the rail system. The nation is entering the early stages of a freight transportation capacity crisis. The American Association of State Highway Officials (AASHTO), the congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, and Congress, as it takes up renewal of the national transportation program, are trying to establish forward-looking national policies and visions for the rail system. Washington State should take an active role in influencing the development of national policies and programs, and should look to multistate and Federal programs to help implement the recommendations of the report.

The Washington State Transportation Commission recommends six policies. They are summarized here and described in detail in Section 5.0, pages 38 to 53. The recommendations are as follows:

- **Policy Recommendation #1: Washington State should continue to participate in the preservation and improvement of both the freight and passenger rail transportation system where there are public benefits to Washington State, its businesses, and its communities.** The study provides guidance on how state actions can be used to address the needs of carload industrial shippers, agricultural shippers, ports and international trade industries, and the passenger-rail users. These include suggestions for mainline, terminal, and access improvements; development of consolidation facilities and shipper rail sidings; assistance to short line railroads; and mitigation of rail impacts on Washington communities.

- **Policy Recommendation #2: The State should base its decisions to participate in projects, programs, and other rail initiatives on a systematic assessment and comparison of benefits and costs across users and across modes.** The State should estimate quantifiable costs and benefits; economic impacts; and qualitative benefits for the State, rail users, the railroads and other carriers, and communities. Where appropriate, these benefits and impacts should be compared to the benefits and impacts of alternative investments in truck and barge services for freight, and the benefits and impacts of alternative investments in highway, bus, ferry, and air services for passengers.

- **Policy Recommendation #3: Where the State determines there are sufficient public benefits to justify public participation in the preservation and improvement of the rail transportation system, its actions should be guided by the following general principles:**

- Emphasize operations and nonfinancial participation in projects before capital investment;
- Preserve and encourage competition;
- Target actions to encourage private investment that advances Washington State economic development goals;
- Leverage state participation by allocating cost responsibility among beneficiaries; and
- Require projects to have viable business plans.

- **Policy Recommendation #4: The State should designate a single entity to coordinate and direct the State's participation in the preservation and improvement of the rail transportation system. This entity should have the authority to negotiate directly with the railroads.** The Class I railroads are large national corporations. The State can be an effective advocate for a multiplicity of state, business, and community interests, but cannot do so without a coordinated and unified vision and voice.

- **Policy Recommendation #5: The State should take an active role in influencing and shaping the development of national rail policies and programs. The State should also develop a multistate coalition to address rail system needs across the Pacific Northwest.** The Washington State rail system is an integral part of the national and Pacific Northwest rail systems. The State's rail needs transcend the State's boundaries. The congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, the American Association of State Highway and Transportation Officials, the Association of American Railroads, Congressional committees, and other groups are working to establish forward-looking national visions, policies, and programs for the rail system. Washington State should participate actively in these discussions. As part of this process, Washington State and its neighbors should also establish a multistate coalition to address rail system needs across the Pacific Northwest. Washington State and its neighbors should use the coalition as a forum to establish their common needs and work with the railroads to identify, prioritize, and implement the most cost-beneficial regional improvements.

- **Policy Recommendation #6: The State should implement the asset management plan developed as part of this study to govern investment and management decisions for state-owned rail assets.** The asset management plan sets objectives for the rail lines, specialized railcars, and service rights that the State owns; establishes performance measures to

determine if these objectives are being met; and describes management practices to ensure that the State's rail assets return maximum benefit to the public.

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic – most of which is associated with short- and medium-distance trips – on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 – Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

key rail users, summarizes the study findings about current and projected capacity, and discusses the implications of capacity and service shortfalls for rail users and Washington State;

- **Chapter 4.0 – Washington State Powers, Authorities, and Interests** summarizes the State's current rail policies and programs; lists the State's recent investments in rail lines, railcars, and other rail equipment; and identifies – in broad terms – the roles that the State can play to shape the future of the rail system; and

- **Chapter 5.0 – Policy Recommendations** details the six policy recommendations.

3.0 Washington State Rail System, Rail Users, Capacity, and Issues

3.1 Washington State Rail System

The Washington State rail system comprises mainlines, branch lines, industrial spurs and leads, and rail yards and terminals operated by a variety of public and private rail carriers. (See Figure 1.) The freight railroads operate 3,628 miles of rail service in Washington State over 2,523 miles of rail lines.[2]

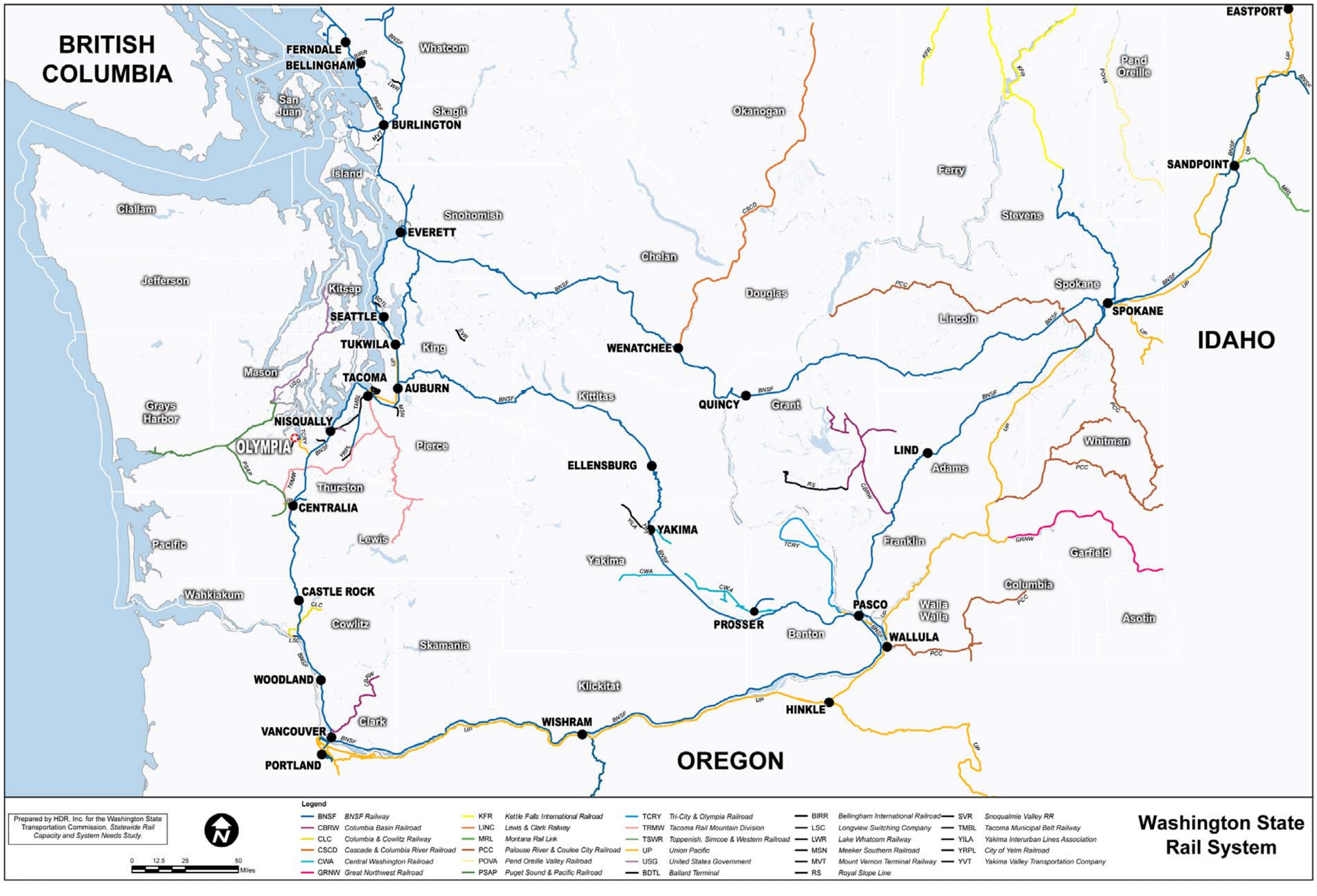
Who Operates the Rail System?

Railroad classification is determined by the Federal Surface Transportation Board. In 2004, Class I railroads were defined as railroads having $289.4 million or more in operating revenues. Class II railroads (referred to regional railroads) were defined as non-Class I line-haul railroads operating 350 miles or more with operating revenues of at least $40 million. Class III railroads (or short line railroads) were defined as all remaining non-Class I or II line-haul railroads. Switching or terminal railroads are railroads engaged primarily in switching and/or terminal services for other railroads.

Long-haul rail transportation is provided by two Class I railroads – BNSF and UPRR. The BNSF owns and operates the most mileage in the State – 1,572 in-state-operated miles, constituting 5 percent of the BNSF's total system mileage. The dominant position of the BNSF in many of the State's rail markets has significant implications for the degree of leverage that the State, rail shippers, and communities have in influencing its business decisions.

[2] Operated miles are greater than owned miles, because owning railroads lease operating rights over their lines to other railroads. And in a few areas, the U.S. Department of Transportation (DOT) Surface Transportation Board, which has economic regulatory oversight of the railroads, has mandated provision of operating rights to ensure competition between railroads.

Figure 1. Washington State Rail System



What Types of Services Do Freight Railroads Provide?

Intermodal services *receive fully-loaded and sealed truck trailers or containers from ships or trucks directly onto railcars for transport. Intermodal shipments are generally higher-value, lower-weight commodities than unit or carload trains.*

Carload services *are those that use a variety of railcar types to carry a range of commodities to a variety of customers. They generally carry lower-volume, higher-weight commodities than Intermodal trains. Examples of commodities shipped by carload include farm products, lumber, chemicals, and paper products.*

Unit carload trains *are those in which every car in the train is shipped from the same origin to the same destination. They are used for high-volume goods, such as coal, garbage, wheat, or any other suitable product gathered at one location for shipment.*

The BNSF System in Washington State

The BNSF owns and operates three east-west lines: The Everett to Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is BNSF's primary route for double-stack intermodal traffic. The Auburn to Pasco route crosses the mountains through the Stampede Pass tunnel. The ceiling of the Stampede Pass tunnel is too low for double-stack intermodal container trains, limiting the capacity of this route. The third route follows the north side of the Columbia River from Vancouver, Washington to Pasco. This is the primary route for export grain trains inbound to the Columbia River ports, but due to heavy traffic through Stevens Pass, this has become a reliever route for intermodal traffic moving from Seattle and Tacoma to Vancouver, Washington, and then east along the river.

These BNSF east-west corridors converge in Spokane to feed the two major BNSF routes providing access to grain producers in the Midwest and intermodal freight connections in Chicago.

The three east-west routes are linked by the north-south I-5 rail corridor. The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights over the line with the UPRR, Amtrak's intercity-rail services, and Sounder commuter-rail operations. (The UPRR also owns sections of rail line in the Auburn-Tacoma area that parallel the BNSF line.)

The UPRR System in Washington State

The UPRR's primary east-west corridor serving traffic in and out of Washington State is in Oregon, running between Portland and Hinkle on the south side of the Columbia River Gorge. At Hinkle, the line forks: one line runs northeast from Hinkle to Spokane, linking up with the Canadian Pacific near Eastport, Idaho; and the other line runs southeast from Hinkle to Pocatello, Idaho, connecting to the UPRR's Central Corridor and the heavily trafficked lines serving the Powder River Basin coal fields. This line is the UPRR's major connection between the grain producing regions of the Midwest and the Columbia River and Puget Sound ports. For the last 12 miles of the Hinkle to Spokane line (from Fish Lake to Spokane), the UPRR operates on the BNSF Lakeside Subdivision via trackage rights.

North of Vancouver, Washington, the UPRR has operating rights over the BNSF's I-5 rail line as far as Tacoma and Seattle. This is the UPRR's primary intermodal route connecting to the Ports of Seattle and Tacoma. South of Portland, the UPRR owns and operates the I-5 mainline, which is the major conduit for forest products from British Columbia, Washington, and Oregon to the growing population centers of Southern California and the Southwest. (The BNSF serves these markets using its line through Bend, Oregon, which parallels the UPRR line. The BNSF and the UPRR then share operating rights over the UPRR line through southern Oregon and Northern California.)

Short Lines

Each of the large Class I railroads is served by a number of smaller regional, short line and terminal railroads, which pick up and distribute railcars to individual industrial and agricultural shippers and receivers. These railroads provide critical services, particularly in lower-density rail corridors and markets where the Class I railroads cannot operate cost-effectively. In a number of cases, the short lines operate on branch lines that were previously owned and operated by the Class I railroads.

Intercity Passenger Rail

Intercity passenger rail service in Washington State is provided by Amtrak. The service with the highest ridership is the Amtrak *Cascades* service, operated by Amtrak in partnership with Washington State DOT. The Amtrak *Cascades* provides service along the I-5 rail corridor from Vancouver, British Columbia in the north through Everett, Seattle, Tacoma, and Olympia, and then south to Portland, Oregon. Oregon is a funding partner, underwriting Amtrak *Cascades* service to Eugene, Oregon. Amtrak also operates the Coast Starlight train between Seattle and Portland, and the Empire Builder train between Seattle and Spokane and between Portland and Spokane, with connections from Spokane east to Chicago.

3.2 Washington State Rail Users

Rail provides critical transportation for manufacturers, agricultural producers, lumber and wood products producers, the food products industry, and the ports and international trade sector – all important sectors of the Washington economy. Consider these statistics:

- Manufacturers, agricultural producers, and lumber and wood products producers generate 14 percent ($37 billion) of the State's $262 billion economic output value (gross state product) and 15.5 percent (425,700 jobs) of the State's employment.
- The Washington State ports generate between 200,000 and 300,000 direct, indirect, and trade-related jobs in the State. A portion of these jobs depend directly or indirectly on rail service.
- Sixteen percent of all freight tonnage moved in Washington State moves by rail.

Rail service is critical because it enables these Washington State industries to ship heavy or bulky commodities over long distances at low costs. Table 1 lists the top 10 outbound Washington State rail commodities by tonnage for 2004 and the forecast tonnages for 2015 and 2025. These are commodities that are shipped out of Washington State by rail. "Miscellaneous mixed shipments" are primarily merchandise and retail trade goods; many are moving in intermodal containers.

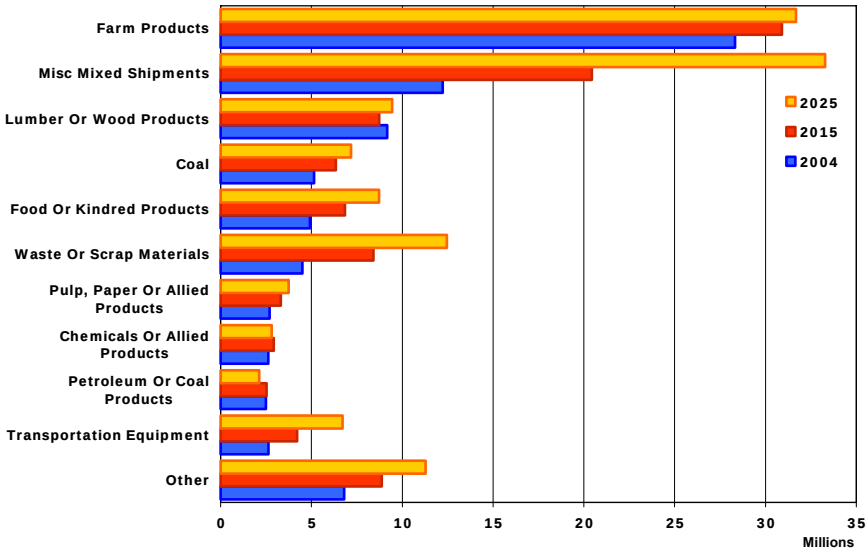
Table 1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025

		Rail Tonnage			Compound Annual Growth Rate		
STCC	Commodity	2004	2015	2025	2004-2015	2015-2026	2004-2025
46	Miscellaneous mixed shipments	6,516,304	11,309,371	19,060,968	5.1%	5.4%	5.2%
24	Lumber or wood products	4,506,679	4,072,939	4,183,956	-0.9%	0.3%	-0.4%
11	Coal	2,142,403	2,743,497	3,184,686	2.3%	1.5%	1.9%
40	Waste or scrap materials	1,543,296	2,377,099	3,260,635	4.0%	3.2%	3.6%
26	Pulp, paper, or allied products	1,231,469	1,556,870	1,752,517	2.2%	1.2%	1.7%
20	Food or kindred products	1,075,792	1,662,293	2,389,104	4.0%	3.7%	3.9%
37	Transportation equipment	826,102	2,090,719	4,523,959	8.8%	8.0%	8.4%
1	Farm products	700,653	997,648	1,385,204	3.3%	3.3%	3.3%
33	Primary metal products	606,415	677,274	597,161	1.0%	-1.3%	-0.1%
28	Chemicals or allied products	353,040	381,960	367,654	0.7%	-0.4%	0.2%

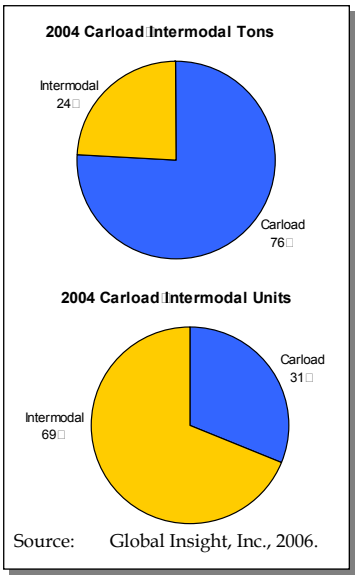
Source: Global Insight, Inc., 2006.

Figure 2 compares the 2004 tonnages to the forecast tonnages for 2015 and 2025. This figure includes commodities that are shipped into and out of Washington State; the previous figure showed only outbound commodities.

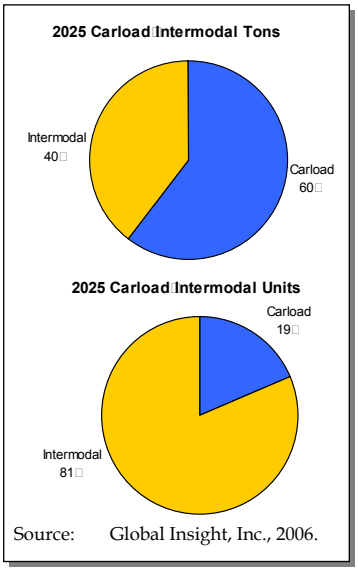
Figure 2. Washington State Rail Tonnage by Commodity (2004) and Forecast Tonnage (2015 and 2025)



Source: Global Insight, Inc., 2006.



Source: Global Insight, Inc., 2006.



Source: Global Insight, Inc., 2006.

Lighter commodities, such as merchandise and retail trade goods moving in intermodal containers, take up more railcar space and generate more trains than heavy, densely packed commodities, such as wheat or chemicals. While intermodal container shipments (a portion of miscellaneous mixed shipments) represent only 24 percent of tonnage in 2004, they represent 69 percent of railcar units. By 2025, intermodal container shipments will be 40 percent of tonnage and 81 percent of railcar units.

Without rail service, some of the Washington State businesses shipping by rail today would shift their rail freight to trucking, increasing their transportation costs and the cost to state and local government of highway maintenance; some would relocate to other states with the necessary rail service; and others might be forced out of business if higher transportation costs make them less competitive in global markets. This is of particular concern in the agricultural sector, where many traditional Washington crops are already under intense price competition in both domestic and international markets and where small increments of added cost can have significant impacts on competitive position.

3.2.1 Manufacturers/Industrial Carload Shippers

Manufacturing and industrial products industries are among the largest rail-using Washington State businesses, and they primarily

use rail carload services. Shippers include producers of metals, machinery, transportation equipment (including airplanes), wood and paper, and petroleum and plastic products. In 2004, the largest tonnage volumes of outbound shipments from these industries were waste and scrap materials; pulp, paper, and allied products; transportation equipment; primary metal products; and chemicals and allied products. Inbound manufactured or industrial products included coal; chemicals; clay, concrete, glass and stone; pulp and paper; and primary metal products.

Manufacturers interviewed for this study expect their volume of shipments to grow steadily, and economic forecasts show the demand for carload shipments growing at a compound rate of 1.8 percent per year for general manufacturing and 1.4 percent for lumber and wood products. However, many of the shippers reported that they were paying higher prices, were getting lower-quality service, and were often having business turned away by the railroads. These shippers will substitute truck for rail when they can, but for shippers of bulky, semifinished products or primary materials, trucking may not be feasible or cost-effective. In the longer term, there is a risk that Washington State will lose some of the businesses that depend on carload shipments to relocation or closure.

3.2.2 Ports and International Trade Sector/Intermodal Container Shippers

International trade generates huge flows of intermodal containers through the Ports of Seattle and Tacoma. Between 1994 and 2004, container traffic grew at an average annual rate of 3.7 percent at the Port of Tacoma, and 2.6 percent at the Port of Seattle. Much of the container traffic consists of merchandise and retail goods imported from Asia through the Ports, and then transferred to rail for shipment to Midwest and eastern U.S. markets. Intermodal rail traffic supporting the Ports and international trade is forecast to grow at a compound annual growth rate of 5.8 percent between 2005 and 2025.

Businesses and consumers across the U.S. benefit from this international trade, but healthy deepwater ports also provide benefits to Washington State. The Ports of Seattle, Tacoma, and Vancouver estimate that the total number of statewide jobs connected to each port are: 166,680 for the Port of Seattle; 113,000 for the Port of

Tacoma; and 15,500 for the Port of Vancouver.[3] The Ports also contribute over $500 million in state and local taxes associated with their maritime cargo operations. Washington State ranks third among all states in annual export value, and first in export value per capita. While many Washington State exporters do not use the rail system to deliver goods to the State's ports, the existence of a healthy rail system is important, because it brings more traffic to the ports and more shipping services that can be used by Washington State exporters. Ocean carriers make decisions about which ports to call, at what frequency, and with what services offered based on the overall market potential associated with the port. Strong long-haul rail services allow ocean carriers to access larger and more distant inland markets. Local export shipments help to balance import and export flows for the carrier. Thus, a strong rail system helps attract ocean carrier services to Washington State's ports and makes the State a more attractive location for national, regional, and local export businesses.

The ability of the Washington State trade sector to deliver these benefits to the economy is critically dependent on the ability of the Ports to compete with other North American ports. This is confirmed by experience of the last decade; first with loss of market share to Southern California ports, and then with gains as the California gateway experienced capacity problems. Looking forward, the Ports will face new competition from the Port of Vancouver, British Columbia; a new port being built specifically for North American inland container traffic at Prince Rupert, British Columbia; and "all-water" services that use the Panama Canal to reach East Coast ports. In this environment, an efficient rail system with good on-dock and near-dock connections is an important competitive advantage.

3.2.3 Agriculture and Foods Products Industry/Bulk and Specialized Carload Shippers

Agriculture and food products manufacturers are an important economic sector in the State, generating 3 percent of the gross state product and accounting for 6 percent of the employment. Washington State ranked 11th among states in agricultural

[3] These job estimates are self-reported by each port based on economic impact studies conducted by Martin Associates in 2001 (Vancouver), 2004 (Seattle), and 2005 (Tacoma). The Port of Seattle explains that their estimates include direct, indirect, and induced jobs related to marine cargo activities, as well as jobs with associated regional manufacturing and distributions firms moving cargo through the Port.

production in 2002, producing crops and livestock valued at over $5.3 billion. Agriculture is the major source of employment in many of the State's rural counties.

By tonnage, 36 percent of all Washington State agricultural shipments move by rail. Agricultural rail traffic outbound from Washington State is expected to grow at a compound annual growth rate of 3.3 percent over the next 20 years. Washington State also has a growing food products industry with particular strengths in frozen foods (7.3 percent of U.S. output) and wine production.

However, most of the agricultural tonnage moving on the Washington State rail system is Midwestern grain moving to the Lower Columbia River and Puget Sound ports for export. And because Midwestern grain is moving long distances by unit train, it is generally more profitable for the railroads than local Washington State agricultural shipments, which often are moving shorter distances for export or require specialized handling.

The Class I railroads are asking Washington agricultural shippers to consolidate their shipments at new facilities (such as the Ritzville loader), and this may prove economical for those shippers who can accommodate the changes. But these changes will affect the short lines, which may see declines in their markets; operators of small grain elevators along the short lines who also stand to lose business; and the remaining shippers on the short lines who could see reductions in service and increased costs.

The challenge faced by Washington State agriculture is to maintain competitive rail service as it focuses on higher-value added crops and produce that may not generate the volumes that are attractive to the Class I railroads.

How do Amtrak Cascades ridership forecasts compare with other intercity corridors?

Amtrak Cascades – ***In 2005, three round-trip trains between Seattle to Portland served 0.4 million riders. In 2023, 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) are forecast to serve 3.0 million riders.***

Capitol Corridor* **–** ***In 2003, 12 round-trip trains between San Francisco Bay Area and Sacramento served 1.14 million riders.***

Surfliner Corridor* **–** ***In 2003, 11 daily round-trip trains between San Diego, Los Angeles, and San Luis Obispo served 2.2 million riders.***

Northeast Corridor – ***In 2001, 42 round-trips trains between Boston to New York to Washington, D.C. served 10.9 million riders.***

*Source: *Amtrak Strategic Plan FY2005-2009, Amtrak, June 2004.*

3.2.4 Passenger Rail Riders

Washington State supports intercity passenger rail and commuter rail services. The major service is the Amtrak *Cascades* intercity rail program, which provides service from Vancouver, British Columbia through Everett, Seattle, Tacoma and Olympia, and then south to Vancouver, Washington and Portland and Eugene, Oregon. The program currently provides four round trips daily between Seattle and Portland, with one round trip daily between Seattle and Bellingham, and one round trip daily between Seattle and Vancouver, BC. Ridership in 2005 was about 421,000 on the

four trains that were supported financially by Washington State at that time, and about 637,000 on the entire *Cascades* service.[4] The State's passenger rail plans envision serving up to 3.0[5] million riders with 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) in 2023.

Sound Transit provides Sounder commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks. The *Cascades* service is operated by Amtrak; the Sounder commuter trains are operated by BNSF and maintained by Amtrak.

In the Puget Sound region, Sounder ridership is projected to grow from 1.2 million passenger trips in 2006 to 2.6 million passenger trips in 2011, a five-year increase of 117 percent.

Forecasts for both the Amtrak *Cascades* and the Sounder services are predicated on substantial investments to increase capacity and improve operations along the I-5 rail corridor. Full build out of the draft Long-Range Plan for the *Cascades* program calls for additional investments of $6.5 billion (in 2006 dollars) by 2023.

Rail Capacity *is calculated in a two-step process.*

First, a "theoretical capacity" is determined, assuming perfect conditions and operations.

Second, "practical capacity" is determined by considering factors, such as possible disruptions, signal needs, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand.

Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of "C." At higher percentages, rail congestion increases and service reliability deteriorates quickly.

3.4 Capacity of the Washington State Rail System and Implications for Rail Users

The Washington State rail system is nearing capacity; service quality is strained, and rates are going up.

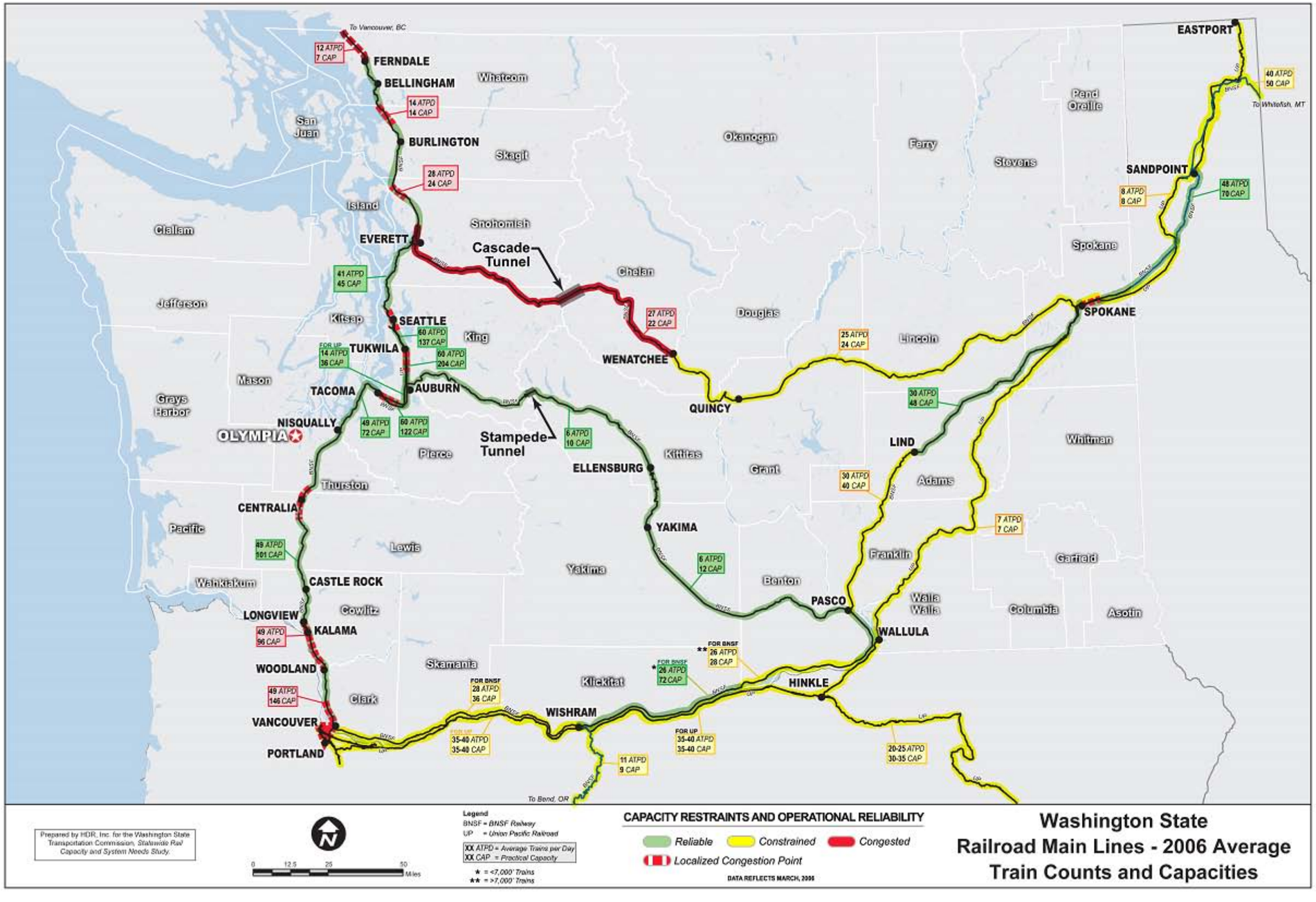
Figure 3 compares the average number of trains operated on each line to the practical capacity of the line.

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major transcontinental route for double-stack intermodal container trains. It is heavily used, operating today at about 123 percent of practical capacity.

[4] As of July 1, 2006, there are four round trips daily on the Seattle to Portland segment. Prior to this, there were only three round trips daily.

[5] A range of ridership projections were produced that varied based on fare structure and other variables. 3 million is a higher end projection.

Figure 3. Washington State Rail System: Mainline Capacities, 2006



The BNSF's Auburn-Pasco line, which passes through the Stampede Tunnel, operates today at about 60 percent of practical capacity. The line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains. Grades over Stampede Pass also make it difficult to haul heavy-loaded unit grain trains along this line.

The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Puget Sound and Columbia River ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity.

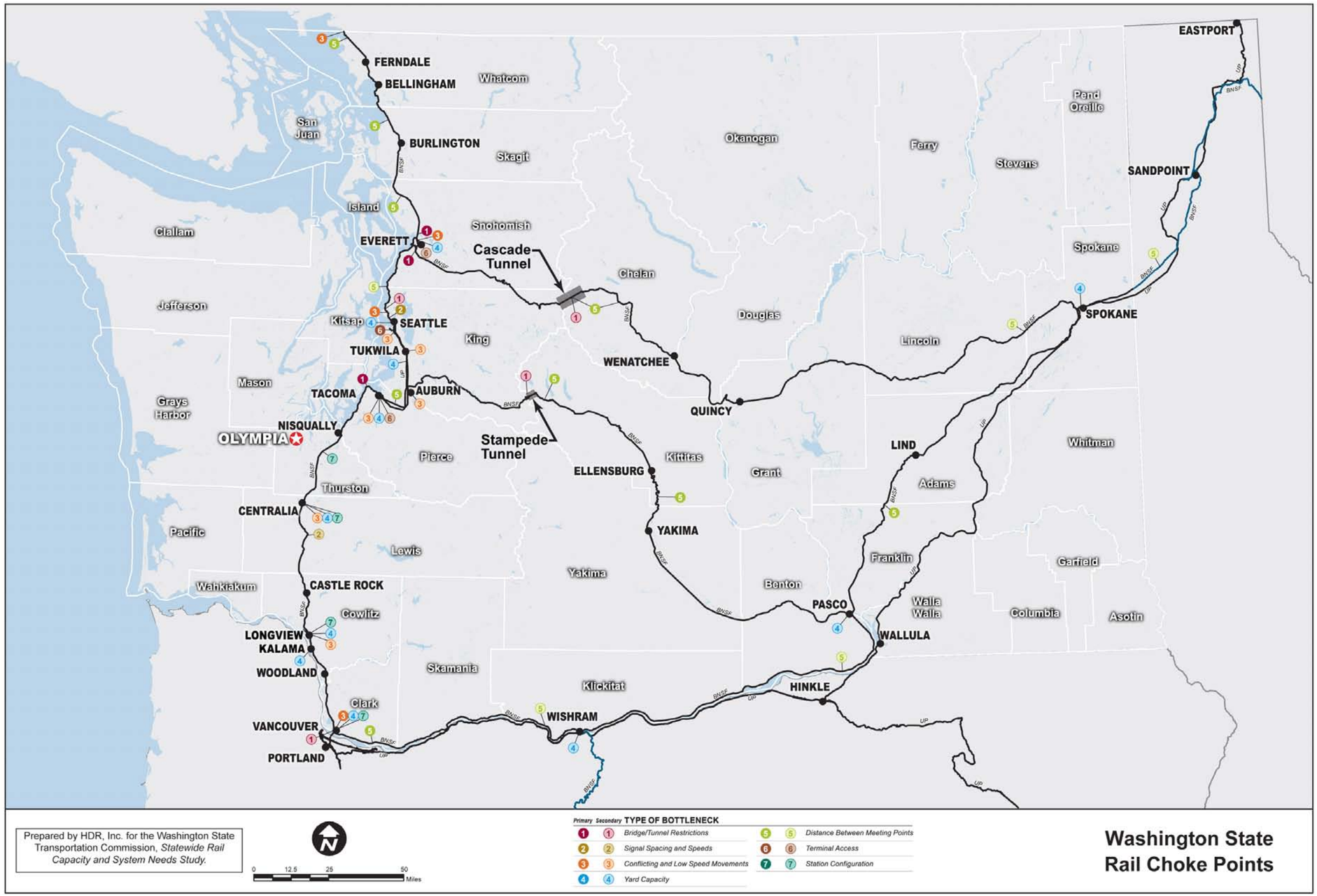
The I-5 corridor rail line runs the length of the State from the Canadian border, Bellingham and Everett through Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights over the line with the UPRR, Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

Rail Choke Points

Figure 4 locates the major rail choke points by type across the Washington State rail system.

With the Everett-Spokane line nearing its maximum capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line along the Columbia River Gorge, and made the scheduling of train moves through the Gorge and along the I-5 rail corridor more complex.

Figure 4. Washington State Rail System: Rail Choke Points, 2006



The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UPRR freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver area, where the railroads' north-south and east-west routes intersect. Rail simulation studies of grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[6]

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, but the operational changes may not be sufficient to satisfy the future needs of Washington shippers. The short-term operating strategies being pursued by the railroads include the following:

- Operating longer 8,000-foot trains and maximizing the number of containers packed on intermodal flat cars;
- Marketing and operating single origin and destination unit trains for carload traffic;
- Consolidating pick-up and delivery of railcars at central terminals operated by third parties (examples include new rail-served industrial parks, logistics hubs, and transload centers);
- Eliminating mainline switching whenever possible (i.e., picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity); and
- Transferring responsibility for branch-line switching from the Class I railroads to local short lines, wherever possible.

These strategies will help meet the needs of the ports and intermodal shippers, but will likely complicate the problem of

[6] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

industrial carload shippers who cannot take advantage of longer and better packed intermodal trains. The Class I railroads are asking shippers, wherever possible, to reorganize and upgrade their tracks and track layouts to improve switching efficiency and be more compatible with the railroads' hook-and-haul operations. The more track space within the shipper's property and the longer the entrance and exit tracks, the faster and more efficiently the railroad can pick up or set out cars. This saves time and labor costs for the railroads and keeps high-volume mainlines open more hours of the day for through train movements. But for low-volume shippers, the costs of these site improvements are usually prohibitive. The same problems apply to consolidating rail pick-up and delivery of railcars at central terminals operated by third parties; unless the consolidation centers are well located, designed, and financed, the financial risks to shippers and operators may be very high.

Consolidation and outsourcing of terminal operations to third parties and transfer of branch-line switching from Class I to short line railroads can result in the replacement of union rail jobs with lower-paying nonunion jobs. Unless offset by future growth in Class I business that generates new union jobs, the loss of union jobs can mean a lower income and standard of living for some Washington State residents with jobs in the rail industry.

The new operating strategies also impact the State's agricultural shippers. Low-cost rail service keeps product costs competitive, but the increasing cost of rail service and the Class I railroads' focus on higher-profit, hook-and-haul intermodal traffic has made it more costly and more difficult for some agricultural shippers to get service at acceptable prices. The Class I railroads also have been asking Washington State grain and other bulk agricultural shippers to consolidate shipping points so that the railroads can operate more unit trains. Notable examples of this trend are the Ritzville grain-loading facility and the new Railex produce service at Wallula.[7]

While these new rail operating strategies have the potential to partially address future capacity needs, the analysis conducted for this study suggests that they may not be sufficient in the longer term. Table 2 lists the lines where mainline practical capacity will be exceeded within 20 years even with the additional capacity gained by operating longer trains and implementing better scheduling. The existing choke points will persist and worsen, some more quickly than others.

[7] http://www.wsdot.wa.gov/Projects/Rail/Freight/PortWallaWalla/.

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[8]

Table 2. Rail Lines in Washington State Exceeding Practical Capacity, 2015 and 2025
Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains

2015	2025
Everett-Burlington	Everett-Burlington
Burlington-Ferndale	Burlington-Ferndale
Ferndale-New Westminster	Ferndale-New Westminster
Everett-Spokane, Washington (BNSF)	Everett-Spokane, Washington (BNSF)
Vancouver-Wishram	Vancouver-Wishram
Wishram-Roosevelt	Wishram-Roosevelt
Roosevelt-Pasco	Roosevelt-Pasco
	Pasco-Spokane, Washington (BNSF)
Pasco (Wallula)-Spokane, Washington (UP)	Pasco (Wallula)-Spokane, Washington (UP)
Spokane, Washington-Sandpoint, Idaho (UP)	Spokane, Washington-Sandpoint, Idaho (UP)
Auburn-Yakima	Auburn-Yakima
Yakima-Pasco	Yakima-Pasco

Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[8] See for example: AASHTO, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UPRR have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers. This is a painful change for all shippers, especially captive shippers, who are being forced to rethink their supply chains and markets.

The national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and Washington State. Continuing high levels of growth and the competition between the BNSF and the UPRR for the lucrative Southern California rail market have made Southern California the key focal point of investment for both railroads. This has shifted investment away from the Pacific Northwest and Washington State.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, Federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not

overtake and collide with slower-moving carload freight trains.[9] The freight railroads, who own the track, are focused on obtaining the maximum benefit from each available train slot and the revenue they receive for providing train slots to the passenger railroads is usually modest.

When the Amtrak *Cascades* program was initiated, the freight railroads were willing to sell slots to the State, especially in return for physical improvements to the rail lines that would benefit both the passenger and freight railroads. With capacity tightening and increasing shipper pressure to improve throughput and reliability, the freight railroads are less willing or able to accommodate expansion of the intercity rail program. As a result, passenger services are often asked to pay a premium when they purchase slots or contribute to mainline capacity improvements.

Amtrak *Cascades* ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases and the freight railroads give priority to freight trains. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. However, if congestion continues to build and the cost of improvements increases, on-time performance may deteriorate further, undermining ridership growth and reducing the cost-effectiveness of the program. Unless a coordinated solution is examined, the future cost of the Amtrak *Cascades* program may exceed the public benefits anticipated in the original plans, and the State may need to examine alternative strategies for the passenger rail program.

[9] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

4.0 Washington State Powers, Authorities, and Interests

Given the State's need for a robust rail system and the emerging capacity needs, what are the State's powers and authorities? What can the State do to address the capacity needs of the system?

4.1 Washington State Powers and Authorities in Freight and Passenger Rail

The State of Washington has a longstanding interest and involvement in both freight and passenger rail. Many of the needs of the Washington State rail system can be addressed by building on the existing freight and passenger rail policies in the Revised Code of Washington (RCW). The policy recommendations of this study build on this foundation, and in many instances, confirm existing policy. The existing statutes include the following:

The Essential Rail Assistance Account is a dedicated rail account created in the state treasury and governed by RCW 47.76.250. Money in the account can only be used for purposes specified in the RCW, including:

- *Acquiring, rebuilding, or rehabilitating rail lines;*
- *Purchasing or rehabilitating essential railroad equipment;*
- *Railroad improvements to mitigate port or mainline congestion;*
- *Construction of loading facilities; and*
- *Preservation of future rail corridors.*

- **RCW 47.76, Freight Rail Services –** This section, which reflects recommendations to the Legislature by the 1995 Washington State Freight Rail Policy Development Committee and others, spells out State policies and interests in freight rail. The statutes:
  - Recognize the critical role of a healthy freight-rail system in supporting the economic vitality of the State and key economic sectors;
  - Mandate continuing roles and responsibilities for the Washington State DOT and the Washington Utilities and Transportation Commission in administering the State's freight rail programs;
  - Provide for technical assistance in the establishment of county rail and port districts;
  - Create an Essential Rail Assistance Account to provide financial assistance for acquisition and improvements to rail lines, purchasing or rehabilitating rail equipment for essential services, and construction of loading facilities to increase business on light density lines or mitigate impacts of abandonment;

- Describe criteria for prioritizing projects that include cost-benefit analysis and cofunding from other beneficiaries; and
- Create a rail preservation program aimed at rail lines and rights-of-way abandoned by the Class I railroads.

- **RCW 47.79, High-Speed Ground Transportation –** This section establishes a program to promote a high-quality, high-speed, intercity rail system. The statute was enacted based on the Legislative recognition that major intercity transportation corridors in Washington are becoming increasingly congested; that high-speed ground transportation offers a safer, more efficient, and environmentally responsible alternative to increasing highway capacity; and that high-speed ground transportation can complement existing air transportation systems, as well as regional growth management plans. Some of the goals of this statute include the following:

  - Reduce travel time between downtown Portland and downtown Seattle to a maximum of two hours by 2010;
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Everett and Portland, Oregon by 2020;
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Everett and Vancouver, BC by 2025; and
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Seattle and Spokane by 2030.

  In addition, this statute recognizes the Legislature's intent to develop public support and awareness of the benefits of a high-speed ground transportation system through the incremental upgrading of existing service. The statute makes the Department of Transportation responsible for developing a prioritized list of projects to improve existing passenger rail service.

- **RCW 47.46 Public-Private Transportation Initiatives –** This section spells out the benefits, roles, and responsibilities of public-private partnerships as a means of developing innovatively financed transportation infrastructure projects. The statute was enacted to create incentives for private investment in road and bridge projects, but many of the policies and approaches specified in the statute could be applied to public-private financing of private rail projects, where the State can demonstrate a clear public interest and significant benefits.

These existing statutes define the State's interest in freight and passenger rail, assign roles and responsibilities for the oversight of the State's interest in rail, and establish a number of specific passenger and freight investment programs. The statutes provide a broad foundation for continued state participation in the preservation and improvement of the rail transportation system, where there are public benefits to Washington State, its businesses, and its communities.

Any rail improvement strategies suggested for State participation also must be consistent with the Washington State Constitution. There are a number of provisions in the Constitution that may limit the State's involvement in the private rail system. The guidelines outlined in Article VIII of the Constitution, "State, County and Municipal Indebtedness," limit the extent to which the State, counties, or cities can give or loan credit to corporations. The provisions of RCW 47.76 and 47.46 address this limitation by making it clear that the State may not participate in projects with private ownership unless there are clear and demonstrated public benefits. The policies recommended in this report also recognize this need to demonstrate public benefit before the State can invest in the private rail system. Nevertheless, before the Legislature enacts specific investment or financial assistance programs that are rooted in the policies proposed in this report, a thorough legal evaluation of the programs' compliance with the constitutional provisions should be undertaken.

4.2 Washington State Investments in the Rail System

Over the last 15 years, the State has used its powers and authorities to:

- Develop the Amtrak *Cascades* service as part of its high-speed intercity rail program;
- Acquire and preserve rail lines and rights-of-way abandoned by the Class I and other railroads;
- Provide assistance to short line railroads to maintain service for shippers and receivers who do not have access to mainline rail service; and
- Purchase specialized railcars (e.g., hopper cars for the Washington Grain Train, and refrigerated produce cars) to

ensure an adequate pool of equipment for Washington State growers.

The State has contributed consistently to both the passenger and freight rail systems. Table 3 lists the passenger and freight rail projects that the State has participated in since 2003. By 2005, the State had contributed a total of about $120 million to the Amtrak *Cascades* program capital budget (including the projects listed below). Freight rail investments by the State have totaled about $31.5[10] million since 1990, with 2003 to 2005 funding alone reaching $12.5 million.

All the State's investments were authorized – some with clear policy guidance and analysis of the public benefits, others with less clear guidance and more limited assessment of longer-term benefits. As a result of these investments and other prior investments, the State now owns a number of rail lines, specialized railcars, rail maintenance equipment, and rights to use privately owned rail lines. But the State does not have a centralized inventory of these assets, nor does it have a comprehensive plan for their use, maintenance, and eventual replacement or disposal.

[10]This number represents actual state expenditures and does not include money programmed or set aside for future use.

Table 3. Recent and Ongoing Washington State Rail Investment Projects

Project	Year Complete	State Contribution
Crossover Projects		
Woodland Crossover	2005	$4 million
Ruston Crossover	2005	$3.6 million
Titlow High Speed Crossovers	2005	$4 million
Felida Crossover	2005	$2.2 million
Tenino High-Speed Crossover	In progress	$3.8 million
Centennial High-Speed Crossovers (Leary, Pattison)	In progress	$3.4 million
Winlock High-Speed crossovers	In progress	$3.4 million
Track Rehabilitation, Construction, or Realignment Projects		
PA Junction Curve Realignments and Delta Yard Storage Tracks	2008	$14 million
Chehalis Junction to Blakeslee Junction Via Centralia	In progress	$7 million
King Street Station Track Improvements	In progress	$15 million
Columbia Basin Railroad Wheeler-Warden 286K	In progress	$400,000
Northern Columbia Basin Railroad Project	In progress	$2 million
Point Defiance Bypass	In progress	$59 million
Port of Pend Oreille 286K Upgrades	In progress	$695,000
Tacoma RMDRR Morton Line Repairs	2005	$3.18 million
Stanwood Siding Upgrade	In progress	$3 million
Kelso-Martin's Bluff Rail Project	In progress	$53 million
Bellingham Waterfront Redevelopment	In progress	$5 million
Bellingham GP Area Upgrades	In progress	$200,000
Lewis and Clark Railroad Rehabilitation	In progress	$300,000
Mt. Vernon Siding Upgrade	In progress	$3.8 million
Railroad Yard Reconfiguration or Expansion Projects		
Dayton Yard Rehabilitation	In progress	$270,000
Vancouver Rail Project	In progress	$100 million
Swift Customs Facility at Blaine/White Rock	In progress	$3 million

Table 3. Recent and Ongoing Washington State Rail Investment Projects (continued)

Project	Year Complete	State Contribution
Actions to Support Agricultural or Industrial Carload Shippers: Spur Track Construction or Improvement and Short Line Acquisition, Other		
Industrial Spur Track to Winlock Glass Manufacturing Plant	2006	$800,000
Geiger Spur Connection	In progress	$5 million
PCC Cheney-Coulee City-Pullman Acquisition and Upgrades	In progress	$28 million
Produce Railcar Pool	In progress	$2 million
TS and W Yakama Sawmill Traffic Upgrades	In progress	$640,000
Increased Passenger Service		
New Seattle to Portland Roundtrip	2006	$2.75 million
Sound Transit: Sounder Track Improvements	2003	$17 million
Equipment Purchase or Upgrade		
One Existing Train Set from Oregon	2003	$7.5 million
Cascades Trainsets Overhaul	In progress	$10 million
Port Access		
Port of Grays Harbor Grain Terminal Loop Track	2003	$2 million
Port of Olympia On-Dock Rail Spur	2006	$375 thousand
Port of Columbia Railroad Improvements	In progress	$5.3 million
Port of Pasco Intermodal Facility Improvements	In progress	$5.4 million
Port of Pend Orielle 286K Upgrades	In progress	$695,000
Port of Walla Walla Railex Project	In progress	2.5 million
Transload Facility		
Quincy Transload Facility	2005	$2 million
Quincy Short-Haul Intermodal Pilot Project	In progress	$900,000
Feasibility Studies		
BNSF Skagit River Bridge Replacement Study	In progress	$150,000
Eastern Skagit Rail Study	2006	$50,000

4.3 Washington State Governance of Rail

Four groups within the state government have legislatively mandated roles and responsibilities for oversight, management, and implementation of the State's interest in passenger and freight rail.

Washington State Utilities and Transportation Commission (WUTC)

The Washington Utilities and Transportation Commission (WUTC) is responsible for railroad safety. The rail group is part of the WUTC safety and consumer protection division, but separate from the transportation safety group, which covers persons and property traveling Washington State roads. A primary responsibility of the rail group is to work with the Federal Railroad Administration (FRA) to inspect rail shipments of hazardous materials. There are more than 300 inspection points throughout the State, including shippers' facilities, railroad yards, and terminals.

Washington State Department of Transportation

Washington State Department of Transportation (WSDOT) is charged with planning, funding, implementation, construction, and maintenance of the multimodal transportation system in Washington State. As such, it is the conduit for state and Federal transportation dollars. The WSDOT freight rail program is housed within the Office of Freight Strategy and Policy. The passenger program is housed within the Public Transportation and Rail Division.

Freight Mobility Strategic Investment Board (FMSIB)

The Freight Mobility Strategic Investment Board (FMSIB) was created by the Washington State Legislature in 1998 to administer projects and strategies to lessen the impacts of freight movement on local communities and to facilitate efficient and profitable freight movement in Washington State. The 10-member board has representatives from Washington ports, railroads, cities, counties, WSDOT, the governor's office, truckers, steamship operators, and private citizens. Periodically, FMSIB issues a call for projects in order to maintain a six-year list of active projects. Its past rail funding has gone primarily to grade separations and crossing improvements.

Washington Community Economic Revitalization Board (CERB)

Washington Community Economic Revitalization Board (CERB) issues grants and loans that will retain existing jobs and create new ones, boosting business growth across the State. CERB can provide funding for rail projects that promote industrial development and has done so in the past. An example of this type of project was its $1,000,000 low-interest loan to the Port of Longview to help construct a second rail line and rail spurs serving a planned new facility for processing newly imported cars.

Each of these groups has knowledgeable and effective staff, and each carries out its mandates effectively; however, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to deal with the State, and in some cases, weakens the State's negotiating position.

4.4 Using State Powers and Authorities to Further State Interests in the Rail System

Building on its existing powers and authorities, the State can:

- Influence the investment decisions of the Class I railroads to resolve rail choke points of critical importance to key rail user groups in the State and, thereby, provide more capacity for Washington State rail users. This will generally involve public-private partnerships in which the State is a minority partner, but the State's investment can influence the timing and priority of the Class I railroads' investment decisions.

- Increase its advocacy for a Federal program that addresses critical national rail capacity needs. Many of the key capacity choke points in the Washington rail system affect the national economy and shippers outside of the State. The State should look for Federal action and funding to address these choke points.

- Work with rail users in industrial and agricultural markets to assist in the transition to rail service models that preserve high quality, reasonably priced, rail service options. The State can help ensure that these transitions occur in a timely fashion before the lack of action has negative economic consequences for the State.

- Work with third-party service providers and advocate for innovative operations practices and services that support the economic development goals of the State and its communities.

- Establish local governance models that allow shippers and affected communities to be involved directly in the resolution of short line problems.

- Support cost-effective intercity passenger rail options that improve the overall balance and performance of the State's highway and air passenger systems.

- Create a more effective, centralized, rail management function within state government with authority to advocate and negotiate state interests with the railroads.

5.0 Policy Recommendations

This report makes six policy recommendations that address capacity issues and system needs in the Washington State rail system. The policy recommendations address the justification for continued action in the rail system (Policy Recommendation #1), provide a framework for determining if specific actions are appropriate for the State (Policy Recommendation #2), present guiding principles for action in the rail system (Policy Recommendation #3), offer a new governance framework (Policy Recommendation #4), recommend involvement in national and regional rail policy discussions (Policy Recommendation #5), and propose adoption of a rail asset management plan (Policy Recommendation #6). These policy recommendations are consistent with the five prioritized guidelines for future transportation investments set forth in the Washington Transportation Plan:

- **Preservation –** Preserve and extend prior investments in existing transportation facilities and the services they provide to people and commerce. The guiding principles contained in Policy Recommendation #3 below emphasize investment in operational improvements and use of existing rail infrastructure prior to investment in new capacity.

- **Safety –** Target construction projects, enforcement, and education to save lives, reduce injuries, and protect property. Policy Recommendation #2 below lays out a framework for evaluating the benefits and impacts of action in the rail system and calls for an evaluation of safety impacts as one of the benefit measures.

- **Economic Vitality –** Improve freight movement and support economic sectors that rely on the transportation system, such as agriculture, tourism, and manufacturing. Throughout this report it is argued that rail transportation is critical to the economic vitality of key industries in Washington State. This is emphasized in Policy Recommendation #1 below.

- **Mobility –** Facilitate movement of people and goods to contribute to a strong economy and a better quality of life for citizens. The framework for evaluating potential actions in the rail system includes assessment of mobility impacts for both passengers and freight.

- **Environmental Quality and Health –** Bring benefits to the environment and citizens' health by improving the existing transportation infrastructure. The evaluation of environmental impacts of actions in the rail system is an important aspect of the decision-making process laid out in Policy Recommendation #2.

5.1 Policy Recommendation One

Policy Recommendation #1: Washington State should continue to participate in the preservation and improvement of both the freight and passenger rail transportation system where there are public benefits to Washington State, its businesses, and its communities.

The freight rail system in Washington State provides critical transportation for major manufacturing and resource industries and rail links to the State's international trade ports. Key segments of the rail system are already operating at or near their practical capacity. Given the current investment priorities and new operating strategies of the Class I railroads, it is likely that capacity will continue to be constrained, that shippers within Washington State (particularly those in traditional industrial and agricultural carload markets) will see declines in service or price increases, that growth at the ports could be slowed, and that there will continue to be conflicts between passenger and freight trains. Without state action, the businesses and citizens of the State will not realize the potential benefits that rail transportation could provide.

Working with the railroads, rail users, and communities, Washington State should develop a description of the rail transportation system needed for the 21st Century as a framework for policy and investment. The description of the rail system and its evolution should address the rail transportation needs of the major rail user groups in Washington State, and should be focused on the high-priority problems identified in this study. The specific types of actions that could be supported will vary by user group.

Table 4 lists examples of the types of strategies that would address the rail service needs of Washington State rail users. For each strategy, examples also are provided of specific projects and actions that could be undertaken to implement the strategy.

Table 4. Examples of Projects Addressing the Rail Service Needs of Washington State Rail Users

Possible Strategies	Possible Projects/Actions
Industrial Manufacturers	
• Offer financial assistance and technical assistance to shippers for site improvements. Assistance can be in the form of tax-exempt bond financing repaid with user fees, industrial development tax credits, or CERB assistance. • Provide assistance for development of industrial carload transload/consolidation facilities, including financial assistance programs (similar programs to those described for site improvements), site identification; investments in supporting infrastructure (both through CERB and state DOT programs), and expedited permitting processes. • Develop rail improvement districts for service preservation on low density lines. This could include expansion of the existing Local Rail Assistance program or new financing programs targeted to these districts.	• New on-site storage track. • Site access improvements off mainline. • New loop tracks on-site. • Proposed carload consolidation facilities in the South Sound area – possibly a rail-served industrial park for carload consolidation to rationalize a dispersed, low-density system of carload shippers near Tacoma and provide more efficient rail service for these customers.
Ports and International Trade	
• Develop a comprehensive strategy to increase State's east-west rail capacity in partnership with Class I railroads, ports, and Federal government.	• Investments that resolve high priority east-west bottlenecks, such as crown cutting the Stampede Pass Tunnel to allow double-stack trains and providing supporting infrastructure and grade separations to allow for increased usage of this line. • Advocate for Federal funding of high priority east-west bottlenecks and designation as Corridors of National Significance. An example would be the development of a high capacity corridor over Stampede Pass with a new tunnel, lengthened sidings, construction of new track from Lind to Ellensburg, and other downstream capacity improvements. • Investments that resolve high priority north-south bottlenecks, such as completing the Vancouver Rail Project that provides access to east-west corridors for trade traffic. • Advocating to railroads and ports beneficial operating strategies such as directional running (e.g., running directionally on Stevens Pass line and Stampede Pass line after crown cutting Stampede Pass) and scheduling alternatives. • Expedited permitting processes for projects that eliminate high priority bottlenecks.
• Increase domestic and international intermodal terminal capacity through financial assistance, identification of and local advocacy for sites, and development of expedited permitting processes.	• Work with Port of Seattle and Port of Tacoma to investigate potentially feasible sites for new near-dock/off-dock intermodal terminals.

Table 4. Examples of Projects Addressing the Rail Service Needs of Washington State Rail Users (continued)

Type of Action	Illustrative Examples
Ports and International Trade (continued)	
• Partner with ports, Class I railroads, and third-party switchers to resolve critical port access bottlenecks.	• Port of Vancouver Rail Extension Project (providing direct access to the Port from the Columbia River Corridor eliminating mainline diamond crossings on the I-5 Rail Corridor). • Advocating to railroads and ports beneficial operating strategies. • Expedited permitting processes for projects that eliminate high priority bottlenecks.
• Partner in community impact mitigation to allow for higher rail traffic associated with international trade.	• Rail crossing grade separations along the Stampede Pass line to accommodate increased traffic associated with crown cutting the tunnel.
Agriculture and Food Products Businesses	
• Encourage formation of Railroad Transportation Improvement Districts (under existing or expanded TID authorities) to assist rail carriers and shippers in low density agricultural and industrial carload corridors. Districts should receive financial assistance through the Local Rail Assistance program.	• Track upgrades to meet specified service objectives; • Maintenance of rights-of-way and track owned by the State or district; and • Development of consolidation facilities, including collaborative work with multiple interested parties (such as the Railex project).
Passenger Rail Users	
• Continue to support incremental development of high-quality intercity passenger rail programs where documented demand exists and high levels of farebox recovery of operating and maintenance costs can be achieved.	• Partner with Class I railroads in mainline infrastructure improvements that provide positive benefit-cost tradeoffs. • Identify traffic thresholds and key track segments where separating passenger rail and freight rail on their own track is cost-beneficial. • Advocate alternative operating strategies to the Class I railroads that will increase combined operating efficiencies for passenger and freight rail. • Give priority to projects that provide benefits to freight and passenger rail service.

Source: Cambridge Systematics, Inc.; and HDR, Inc., 2006.

Table 5 lists some of the worst choke points in the system, which affect many Washington State rail users, and projects that could help relieve these strategic choke points.

The State should base its decisions to participate in these or similar projects, programs, and rail initiatives based on a systematic assessment and comparison of benefits and costs across users and across modes, as described further in the next policy recommendation.

Table 5. Major Choke Points in the Rail System and Potential Projects to Increase Capacity

Choke Points	Potential Projects
Port of Seattle Access and Argo Yard Operations	Duwamish Corridor and Second Lead Improvements
Mainline access to Port of Tacoma	Tacoma Tideflats Improvements: North Wye Connection, Puyallup River Crossing
Port of Vancouver access	Port of Vancouver Rail Extension Project
I-5 Corridor and access to Ports of Kalama and Longview	Kelso to Martins Bluff Third mainline
I-5 Corridor Centralia-Chehalis Segment	Centralia-Chehalis Rail Corridor Consolidation Project (Blakeslee Junction)
I-5 Corridor-Everett and Delta yard segments	Everett Passenger Rail Speed Improvements and Delta Yard Expansion
I-5 Corridor-Bellingham segment	Bellingham Mainline Track realignment
East-West Corridor: Stampede Pass	Stampede Pass High Capacity Rail Improvement Project (including Lind-Ellensburg connection)
East-West Corridor: Spokane Improvements and Spokane to Sandpoint Corridor	Bridging the Valley Projects, including improving mainline capacity, 72 grade crossings, additional trackage, etc.
Lack of yard capacity in South Sound Region	Proposed carload consolidation facilities in the South Sound area.
Congestion at Vancouver (WA) Yard, including safety concerns	Vancouver Rail Project
Seattle to Portland Freight/Passenger Train conflicts	WSDOT Point Defiance Bypass Phase 1 Project

Source: HDR, Inc., 2006.

5.2 Policy Recommendation Two

Policy Recommendation #2: The State should base its decisions to participate in projects, programs, and other rail initiatives on a systematic assessment and comparison of benefits and costs across users and across modes.

The assessment should:

- Assess the benefits and costs of the projects, programs, and other rail initiatives for each of four major groups: the State; rail users, including shippers and passengers; carriers, including railroads, ports, and truckers; and affected communities.
- Consider qualitative and nonmonetary benefits and costs, as well as quantifiable benefits and costs.
- Compare the benefits and costs for the project to the benefits and costs of taking no action.
- Where appropriate, also compare the benefits and costs of the project to investment in other transportation modes and service that might achieve the same goals.
- Use the assessment of benefits and cost to determine who the State should partner with and how the partnership should be structured so that project costs are allocated in accordance with benefits.

The assessment of benefits and costs should focus on the key measures listed in Table 6. Using a short list of measures helps to simplify the assessment process and focus on the benefits and costs that are most important to the affected groups. For the State, key measures would include jobs created or retained in the private and public sectors, and the impact on rail-related union jobs; tax benefits gained through the growth of new or retained businesses; contribution to transportation system efficiency and balance; and costs. Details on how the benefits and costs can be measured are provided in the technical memoranda prepared for the study.[11]

[11] See Interim Report 2 and Task 7 Technical Memorandum for background information on the selection and use of the benefit and cost measures. Task 8 Technical Memorandum also provides examples of how the assessment methodology can be applied to evaluation of a set of illustrative case examples.

One of the measures recommended for the State is a benefit-cost ratio. RCW 47.76 requires that freight-rail projects be subject to a benefit-cost analysis. Some states rely exclusively on a benefit-cost analysis, but this report recommends using a benefit-cost ratio as one of several measures. This allows decision-makers to consider specific benefit measures – such as jobs created by a project – independent of costs.

The measures typically included in formal benefit-cost analysis of rail projects are listed in Table 7. The technical memoranda accompanying this report describe the process for conducting a benefit-cost analysis using techniques recommended by the FRA and adopted by other states.[12] The specific techniques used to calculate the benefits and costs will vary depending on the type of project. WSDOT's recent analysis of the PCC short line acquisition provides a good case study on how to apply some of the cost analysis techniques to freight rail projects.

Benefit-cost analysis has not been required for Washington State passenger rail projects, although WSDOT has conducted cross-modal cost analyses of passenger-rail projects, comparing the total cost per passenger mile for rail, highway, and air modes. This report recommends conducting benefit-cost analysis for passenger-rail projects, as well as for freight-rail projects. The analysis should compare state benefits to state costs for passenger-rail projects and, where appropriate, alternative investments. On-time performance, which strongly affects intercity ridership, must be examined carefully when conducting benefit-cost analysis of passenger rail projects.

If a freight-rail project is expected to have significant national economic benefits that might justify Federal funding, an economic impact analysis should be conducted using the framework recommended by the U.S. DOT in its "Toolbox for Regional Policy Analysis."[13]

The results of the assessment of benefits and costs for all rail users should be summarized in a decision matrix. The format for the decision matrix is illustrated in Table 8. A decision matrix allows for direct comparisons among alternative rail project packages and, where appropriate, comparisons of the benefits and costs of alternative investments in truck and barge services for freight, and

[12]See Interim Report 2 and Technical Memorandum 7 for summary information on benefits and impacts used by other states and organizations.

[13]See "Toolbox for Regional Policy Analysis" at http://www.fhwa.dot.gov/Planning/toolbox/index.htm.

the benefits and costs of alternative investments in highway, bus, ferry, and air services for passengers.

Table 6. Recommended Benefit and Cost Measures

Rail User	Benefit and Cost Measures
State	• Jobs created/retained (private sector, public sector, and impact on rail-related union jobs) • Tax benefits (through new or retained businesses) • Contribution to transportation system efficiency/ balance (measured in terms of reduced travel delays, improved system reliability, or system redundancy, as appropriate) • Environmental benefits (air pollution and water quality impacts) • Safety benefits (reduced property damage, injuries, and fatalities) • Availability of partner funding • Cost to State • Benefit-cost ratio (using recommended benefit-cost analysis methodology)
Shippers	• Business cost impact (through impact on cost of service) • Access to service (does project increase rail/ transportation service options) • Service reliability (on-time performance) • Transit time
Passengers	• Rail capacity for passenger trains • Travel costs • Travel time • Increased modal choice/access
Railroads	• System velocity improvements • Hours of train delay • Yard dwell time • Increased revenue traffic • Equipment availability
Ports	• Throughput • Market share
Communities (Similar to State)	• Environmental benefits • Safety benefits • Reduced roadway delays and truck/auto delay at grade crossings • Local jobs created or retained

Source: Cambridge Systematics, Inc., 2006.

Table 7. Recommended Measures to Include in Estimating a Benefit-Cost Ratio

Measure	Explanation
Transportation and Economic Benefits	
Avoided maintenance costs	If the project preserves rail service, the no-action alternative may put more trucks on the highway. This may produce a net positive or negative benefit to be evaluated based on the type of road affected and the cost of maintaining the rail line.
Reduction in shipper costs (for shipments originating in State) – freight only	Benefits derived from lower logistic costs to the shippers, which ultimately can lead to lower consumer prices.
Reduction in automobile delays at grade crossings	Benefits resulting from improving grade crossing and decreasing automobile delays.
Economic Impacts	
New or retained jobs	Jobs that a particular project/action may keep from moving out of the State (e.g., by construction of a rail spur serving a factory or warehouse, etc.), or new jobs that are created within the State. Also to be considered are changes in job quality and pay levels (e.g., adding, losing, or changing union jobs).This measure accounts for both retained and new jobs.
Tax increases from industrial development	A rail action/project may foster industrial development that results ultimately in increased industrial property taxes to the State.
External Impacts	
Safety improvements	By diverting truck freight to rail, savings on highway safety improvements can occur.
Environmental benefits	Railroads are on average three or more times more fuel efficient than trucks. The State can benefit from savings due to environmental improvements.

Source: Cambridge Systematics, Inc., 2006.

Table 8. Sample Decision Matrix for Comparison of Alternative Rail Projects and Actions

	Measures	No Action	Alternative A	Alternative B
State	Jobs			
	Tax/Fee Benefits			
	System Efficiency			
	Environmental Benefits			
	Safety Benefits			
	Partner Funding			
	Cost to State			
	Benefit-Cost			
	Summary State			
Shippers	Business Cost Impacts			
	Access to Service			
	Service Reliability			
	Transit Time			
	Summary Shippers			
Passengers	Rail Capacity for Passenger Trains			
	Travel Costs			
	Travel Time			
	Increased Modal Choice/Access			
	Summary Passengers			
Railroads	System Velocity Improvements			
	Hours of Train Delay			
	Yard Dwell Time			
	Increased Revenue Traffic			
	Equipment Utilization			
	Summary Railroads			
Ports	Throughput			
	Market Share			
	Summary Ports			
Communities	Environmental Benefits			
	Safety Benefits			
	Reduced Roadway Delays			
	Local Jobs			
	Summary Communities			
National	Pct Benefits in WA State			
	Other States Benefiting			
	Summary National			

Source: Cambridge Systematics, Inc., 2006.

The decision matrix can accommodate quantitative measures, as well as qualitative measures. A simplified case study of how this framework can be used is provided in the appendix to this report.

Table 9 shows how the assessments of benefits and costs by affected group might be arrayed to determine who the State should partner with and how the partnership should be structured, so that project costs are allocated in accordance with benefits.

The assignment of an overall assessment of benefits and costs as "high," "medium," or "low" is a process of value judgment by the decision-maker. This study does not recommend a specific weighting scheme at this time, preferring that the initial applications of this process be as open and transparent as possible. As the State gains experience in assessing and weighting the benefits and costs of rail projects, the Legislature may wish to direct the WUTC and WSDOT to adopt a formal weighting procedure, such as that used by the FMSIB. The Board's weighting scheme is summarized in Table 10.

In states that conduct rail benefit-cost assessments and analyses, the technical work is done by a variety of different organizations that have responsibility for rail programs and policies. This may include state DOT rail offices, separate rail agencies or commissions, or policy offices at the secretarial level. For example, at Florida DOT, the Rail Office is responsible for rail investment benefit-cost assessment and analysis; in Virginia, it is the Rail Division of the Virginia Department of Rail and Public Transportation; at Pennsylvania DOT, it is the Bureau of Rail Freight Ports and Waterways; and at New Jersey DOT, it is the Bureau of Freight Services. At Louisiana DOTD, coordination is done through the secretarial Office of Intermodal Transportation, and at Maryland DOT, coordination is through the secretarial Office of Freight. In all cases, these offices draw on the technical and policy expertise and advice of other state and local agencies involved in rail-related finance, regulation, safety, environmental protection, and economic development.

Table 9. Benefit Evaluation Cross-User Group Comparison

Proposed Action	WA State	Shippers	Passengers	Railroads	Community	Likely Recommendation	Level of Action	Example
A	H	H	H	H	H	State should participate, but only if other beneficiaries contribute appropriate share	Consider direct investment and supporting legal and institutional mechanisms	Consider sources such as additional dedicated state freight rail funds, Federal funding sources through the Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), and other state matching sources
B	H	L	L	L	H	State should participate and be prepared to contribute more than other groups	Consider direct investment and supporting legal and institutional mechanisms	Consider sources such as additional dedicated state freight rail funds, Federal funding sources through SAFETEA-LU, and other state matching sources
C	M	M	M	M	M	State should participate with caution and only if costs to do so are low	Consider tax exempt financing loans or other methods that have limited costs to State, but benefit private industry	Consider public-private partnerships, tax credits, and other nonfinancing incentives
D	L	H	H	H	L	State should probably not participate	State should probably not participate with financial, institutional, or legal mechanisms	No state role is anticipated
E	L	L	L	L	L	State should probably not participate	State should probably not participate with financial, institutional, or legal mechanisms	No state role is anticipated

Source: Cambridge Systematics, Inc., 2006.

H = High; M = Medium; and L = Low.

Table 10. Freight Mobility Strategic Investment Board Evaluation Criteria and Weights

Evaluation Criteria Category	Weight
Freight Mobility for the Project Area	35 maximum
Freight Mobility for the Region, State, and Nation	35 maximum
General Mobility	25 maximum
Safety	20 maximum
Freight and Economic Value	15 maximum
Environment	10 maximum
Partnership	25 maximum
Consistency with Regional and State Plans	5 maximum
Cost	10 maximum
Special Issues	8 maximum
Total	**188 points**

Source: http://www.fmsib.wa.gov.

5.3 Policy Recommendation Three

Where the State determines there are sufficient public benefits to justify public participation in the preservation and improvement of the rail transportation system, its actions should be guided by the following general principles:

- **Emphasize operations and nonfinancial participation in projects before capital investment –** The State should give priority to preserving and improving rail transportation through leadership, planning, permitting, maintenance, and operations that leverage existing rail infrastructure and services rather than through capital investment.

- **Preserve and encourage competition –** Investment in one railroad's infrastructure can change the competitive balance among railroads to the detriment of the overall system. Before making an investment that directly benefits only one rail company, the State should conduct a comprehensive analysis of competitive impacts on other rail carriers and users.

- **Target actions to encourage private investment that advances Washington State economic development goals –** State

The State Can Promote Operational Strategies That Maximize Benefits for Washington Rail Users and Communities

- *Careful scheduling to avoid conflicts;*
- *Longer trains;*
- *Consolidating primary switching locations;*
- *Consolidated dispatch center;*
- *Carrier and routing alternatives;*
- *Scheduled point-to-point service;*
- *Improved intermodal terminal production;*
- *Reducing/eliminating main line work events;*
- *Co-production;*
- *Switching zone agreements; and*
- *Rationalizing carload network with regards to the truck/rail transloading facilities, new carload gathering/distribution centers, and remarketing of unprofitable traffic.*

actions should influence railroad investment decisions so that rail improvements generate greater benefits to Washington State than could be achieved if the State did not invest.

- **Leverage State participation by allocating cost responsibility among beneficiaries –** The State should not invest in the private rail system unless the railroads and other beneficiaries participate in proportion to their benefits and risks.

- **Require projects to have viable business plans –** Funding from the State should be contingent upon demonstration that the project proponent has rail service and customer agreements in place in order to make the project financially viable.

5.4 Policy Recommendation Four

Policy Recommendation #4: The State should designate a single entity to coordinate and direct the State's participation in the preservation and improvement of the rail transportation system. This entity should have the authority to negotiate directly with the railroads.

The responsibility for oversight and management of Washington State's rail programs and investments is divided among the WSDOT, the FMSIB, the Washington Community Economic Revitalization Board, and WUTC. Each has knowledgeable and effective staff, and each carries out its mandates effectively; however, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to deal with the State, and in some cases weakens the State's negotiating position.

This situation exists in many states and is only now becoming a significant problem as states move to deal with increasingly congested freight transportation systems and insistent demands from businesses and communities that they create more comprehensive policies and undertake larger investment programs.

Some states have moved to address the problem by organizing cross-agency policy committees or by designating a single entity or position, such as an undersecretary of transportation to coordinate state policies and programs and negotiate with shippers and carriers.

Having a single entity coordinate all Washington State's rail activities would give the State the ability to:

- Represent the interests of multiple stakeholders in negotiations with rail carriers more effectively than would individual stakeholders by themselves;

- Develop strategic packages of projects and actions across the State that would effectively promote state interests and be more attractive to the rail carriers than dealing with projects on a case-by–case basis;

- Represent the interests of multiple communities in resolving common rail issues; and

- Work more effectively with partners in other states and at the national level.

Washington State may wish to explore one or both of the approaches that are being taken by other states. Any approach taken by the Legislature should include oversight over freight and passenger rail systems, both public and private, and adequate authority to represent the interests of the State with the carriers, the Federal government, and other states.

5.5 Policy Recommendation Five

Policy Recommendation #5: The State should take an active role in influencing and shaping the development of national rail policies and programs. The State should also develop a multi-state coalition to address rail system needs across the Pacific Northwest.

The Washington State rail system is an integral part of the national and Pacific Northwest rail systems. The State's rail needs transcend the State's boundaries. The nation is entering the early stages of a freight transportation capacity crisis. The congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, the American Association of State Highway and Transportation Officials, the Association of American Railroads, the Congressional committee charged with reauthorization of the national transportation program, and other groups are working to address the emerging crisis and establish forward-looking national visions, policies, and programs for the rail system. Washington State should participate actively in these discussions.

As part of this process, Washington State and its neighbors should also establish a multistate coalition to address rail system needs

across the Pacific Northwest. Washington State and its neighbors should use the coalition as a forum to establish their common needs and work with the railroads to identify, prioritize, and implement the most cost-beneficial regional improvements. There is precedent for this in the I-95 Corridor Coalition and its Mid-Atlantic Rail Operations Program. The Pacific Northwest rail coalition could be formed as part of the newly established West Coast Corridor Coalition; as an independent coalition advising the Pacific Northwest states, the West Coast Corridor Coalition, and national groups; or as a formal multistate compact. There is existing legal precedent for multistate compacts, which are contracts among states that carry the force and effect of statutory law. A multistate compact could create the legal framework to develop policies, plans, and regulatory mechanisms for multistate rail programs in the Pacific Northwest.

The State should use the procedures recommended in this report to begin to identify projects of national and regional significance. And it should look to national and multistate programs to help fund and implement these projects.

5.6 Policy Recommendation Six

Policy Recommendation #6: The State should implement the asset management plan developed as part of this study to govern investment and management decisions for state-owned rail assets.

The guiding principles of the asset management plan are as follows:

- The asset management plan should be based on a business-case analysis of the goals and objectives for each class of assets;
- The plan should use clear performance measures and a monitoring system to determine how assets are performing;
- Benchmarks for each performance measure should be established based on industry standards; and
- An inventory management system (including information about condition and disposition of the assets) should be adopted.

The State currently owns the following classes of assets: freight rail lines, freight railcars (grain cars and refrigerated cars),

maintenance-of-way equipment, right-of-way, passenger train sets and passenger service agreements (train slots). A more complete inventory of these assets is provided in the full asset management plan. For each class of assets, the key features of the asset management strategy are summarized in Table 11.

Table 11. Asset Management Principles for State Rail Assets

Freight Rail Lines (Short Lines)	• State should be owner of last resort and should encourage private ownership and/or operation in conjunction with Rail Improvement Districts if public involvement is warranted. • Purchase decisions should be based on benefit-cost analysis. • Operate lines in conformance with business plan that specifies projected customer base and monitors performance measures (carloads carried, revenues earned, and return on invested capital) against specified benchmarks. • Implement inventory maintenance and monitoring system with periodic inspections and assessments of condition. Use annual and life-cycle costs as performance measures. • Third-party operating agreements should specify obligations of operator with respect to meeting specified performance benchmarks.
Freight Railcars	• Implement inventory and equipment tracking system. • Track location of each car (using global position systems where feasible). • Track usage by Washington State shippers, including level of revenue service. • Specify periodic condition inspections. • Adopt performance measures and benchmarks, including costs of operation and maintenance per revenue mile and life-cycle costs.
Miscellaneous Rail Equipment	• Develop inventory of equipment and conduct condition assessment. • Over longer term, consider disposal of the equipment and outsourcing the activity to the private sector.
Passenger Train Sets	• Continue with current Amtrak asset management program. • Investigate approaches to develop a sinking fund to cover depreciation of train sets that would be protected from use in meeting general fund current obligations.

Source: Cambridge Systematics Inc., and HDR Inc., 2006.

Appendix A. Benefit Assessment Illustrative Case Study – East-West Capacity Projects

As described in Section 3.4 of this report, constraints on the east-west lines of the Washington State rail system could inhibit future rail traffic growth, particularly intermodal growth through the ports. As an illustration of how the benefit assessment matrices can be used to evaluate strategic project packages, this case study presents an evaluation of a package to increase east-west capacity. A version of this case study that provides a detailed description of all of the calculation methodologies and data inputs, along with several other case studies, is included in Technical Memorandum 8.

The projects in this package include improving Stampede Pass to allow for double-stack containers, and incorporating "Bridging the Valley" improvements for the Spokane to Sandpoint, Idaho section. The State must decide if it should participate in this east-west rail capacity expansion program, and if so, at what level of involvement. There are two alternatives for Washington State to consider in this illustration:

- **Do Nothing –** Under this scenario, the State does not invest public funding to improve east-west capacity. Any investment is done by the railroads.

- **Alternative A: East-West Capacity Expansion Project –** A $350 million investment, shared between the State and the railroads, for selective capacity improvements. This will add approximately 50 percent more capacity (from 22 to 24 trains per day to 34 to 36 trains per day).

A summary of the improvements for Alternative A is contained in Table A.1. Table A.2 provides the results of the benefit/impact evaluation of Alternative A and a No Action case. Table A.3 provides a summary of the final assessment of benefits/impacts across all affected groups.

Table A.1 East-West Capacity Expansion: Summary of Alternative A

Project
Crown cut Stampede Pass
Construct Lind, WA to Ellensburg, WA connection
Install 8,000-ft siding tracks to provide 20-minute headways between Auburn, WA and Ellensburg, WA and between Lind, WA and Spokane, WA
Install CTC train control system overlaid with ETMS
Grade separated the corridor from Spokane, WA to Athol, ID as suggested in "Bridging the Valley"

Table A.2 East-West Capacity Expansion: Benefit/Impact Evaluation

	Measures	No Action	Alternative A: East-West Capacity Expansion Project
State	Jobs	Net New Jobs = 0	Net New Jobs = 500
	Tax/Fee Benefits	None	None
	System Efficiency	Congested	Reliable
	Environmental Benefits	Negative: emissions from YY trains x 400 mi x 12,000 tons	Negative: emissions from 12 trains x 300 mi x 6,480 tons
	Partner Funding	BNSF & UP make improvements	Expect railroad participation
	Benefit/Cost	n/a (Cost = $0)	B/C = 0.181
	Summary State	*LOW*	*MEDIUM*
Shippers	Business Cost Impacts	Increases due to increased rail cost, loss of service, and deteriorating reliability	Improvements to international intermodal traffic; little benefit to WA shippers
	Access to Service	Railroads disinvest from selected rail markets	Improved access for international shippers
	Service Reliability	Poor	Reliable in short term
	Summary Shippers	*LOW*	*MEDIUM*
Passengers	Rail Capacity for Passenger Trains	Limited to current services	Potential 1 or 2 train expansion
	Summary Passengers	*LOW*	*LOW*
Railroads	System Velocity Improvements	Further delays due to capacity issues	Crown cutting Stevens Pass, installing CTC, and eliminating grade crossings will increase velocity.
	Hours of Train Delay	Requires simulation analysis	Requires simulation analysis
	Yard Dwell Time	Requires simulation analysis	Requires simulation analysis

Table A.2 East-West Capacity Expansion: Benefit/Impact Evaluation (continued)

	Measures	No Action	Alternative A: East-West Capacity Expansion Project
	Increased Revenue Traffic	Yes	12 trains x 100 cars/train x $6000 car
	Equipment Utilization	Little change	Reduction in car cycle time; requires simulation analysis to quantify
	Summary Railroads	*LOW*	*MEDIUM*
Ports	Throughput	Current Capacity = XX	Additional 12 trains/day = 2400 containers per day
	Market Share	Decline	Requires complete analysis of West Coast Ports
	Summary Ports	*LOW*	*HIGH*
Communities	Environmental Benefits	Negative: emissions from YY trains x mileage x 12,000 tons/train	Negative: emissions from 12 trains x 300 miles x 6,480 tons/train
	Safety Benefits	More potential train incidents and grade crossing accidents due to increased trains	More potential train incidents; safety improvements from elimination of 20 grade crossing
	Reduced Roadway Delays	No change.	Elimination of 20 grade crossings
	Local Jobs	Mostly at the port; some increase in train crews	Mostly at the port; some increase in train crews
	Summary Communities	*LOW*	*MEDIUM*
National	Pct Benefits in WA State	Requires detailed economic analysis.	Requires detailed economic analysis
	Other States Benefiting	ID, IN, IL, MT, MN, NE, NJ, OH, PA, NY	ID, IN, IL, MT, MN, NE, NJ, OH, PA, NY
	Summary National	*LOW*	*MEDIUM*

Table A.3 Summary Decision Matrix

	No Action	Alternative A: East-West Capacity Expansion Project
State	Low	Medium
Shippers	Low	Medium
Passengers	Low	Low
Railroads	Low	Medium
Ports	Low	High
Communities	Low	Medium
National	Low	Medium

Appendix B. Glossary

A

Automatic Block Signaling (ABS) – An automatic system that prevents two trains moving in the same direction from occupying the same section of track simultaneously. As the lead train exits a section of track, it automatically triggers the signal to allow the following train to enter.

B

Branch Lines – A subsidiary, secondary, local, or feeder line of railway, which extends from the principal lines of rail traffic to connect to external shipping points.

C

Carload –

1. Carload services are those that use a variety of railcar types to carry a range of commodities to a variety of customers. They generally carry lower-volume, higher-weight commodities than Intermodal trains.

2. A rail-car loaded to its weight or space-carrying capacity.

Carload Manifest – Another name for mixed-carload shipments, or those that move a diverse range of commodities on a single train.

Centralized Traffic Control (CTC) – Train movements are controlled by signals, which are in turn controlled by dispatchers at a centralized location. The dispatchers will generally have a computerized graphical depiction of all or part of the railroad, allowing them to monitor train movements. Software prevents conflicting signal settings that could lead to an accident.

Class I – A railroad with average annual gross operating revenue of $250 million or more, in 1991 dollars. The threshold is adjusted every several years by the Surface Transportation Board to reflect

the effects of inflation and other factors. For example, in 2004, the threshold was $277.7 million.

Class II – A railroad with average annual gross operating revenue of between $20 million and $250 million, in 1991 dollars. In 2004, the lower and upper thresholds were $20.5 million and $277.7 million. Railroads considered by the Association of American Railroads (AAR) as "Regional Railroads" are typically Class II railroads

Class III – A railroad with average annual gross operating revenue of less than $20 million, in 1991 dollars. In 2004, the threshold was $20.5 million. Local short-line railroads typically fall under this category.

Commuter Rail – Urban passenger train service for local short-distance travel operating between a central city and adjacent suburbs. Service must be operated on a regular basis by or under contract with a transit operator for the purpose of transporting passengers within urbanized areas, or between urbanized areas and outlying areas. It does not include heavy rail rapid transit or light rail/street car transit service. Intercity rail service is excluded, except for that portion of such service that is operated by or under contract with a public transit agency for predominately commuter services.

Containers – Standard-sized rectangular box used to transport freight by ship, rail and highway. International shipping containers are 20 or 40 feet long, conform to International Standards Organization (ISO) standards and are designed to fit in ships' holds. Containers are transported on roads atop a container chassis towed by a tractor. Domestic containers, up to 53 feet long and of lighter construction, are designed for rail and highway use only.

D

Dark Territory – Unsignalized sections of the railroad.

Double-stack – The movement of containers on articulated rail cars which enable one container to be stacked on another container for better ride quality and car utilization.

Drayage – The movement of a container or trailer between an intermodal terminal and a customer's facility for loading or unloading. The vast majority of drayage takes place by truck.

Dynamic Capacity – The ability of a yard to receive, process, and dispatch traffic, generally described in trains per hour for receiving and dispatching, and cars per hour for switching.

Dynamic Track Occupancy – The density or spacing of moving trains.

H

Hopper Cars – A railroad freight car that can be either covered or uncovered, and has doors on its sides or undersides. Hopper cars are used to transport loose bulk commodities such as grain, ore, and coal.

G

Grade Crossing – A highway crossing that is at the same level (grade) as the rail.

Gross State Product (GSP) – The total market value of all final goods and services produced for money in a state within a given period of time, after deducting the cost of goods and services used in the process of production, but before depreciation.

I

Integrator – Marketing companies that assume the all-in organization and handling of complete shipping orders from the consignor to the consignee.

Interchange – A junction of highways on different levels that permits traffic to move from one to the other without crossing traffic streams.

Intermodal –

1. The use of two or more modes of transportation to complete a cargo move. For example, truck/rail or truck/ship.

2. Freight that is packed in an intermodal unit (trailer or container) and can therefore be transferred directly from the container ship to rail or truck for transportation. Intermodal shipments generally hold higher-value, lower-weight commodities than unit or carload trains.

Intermodal Units – Trailers and containers that can be transported, fully-loaded, from ship to rail or truck.

L

Line-haul – The movement of a railroad unit from origin to destination.

Long-haul – A freight shipment having a long distance between the origin and destination.

Logistics – Movement and supply of goods through the economy from raw materials, through all stages of the manufacturing process, to the final delivery of the finished product to companies and consumers.

M

Mainlines – A designation by each railroad of its own track signifying a line over which through-trains pass with relatively high frequency. Mainlines generally have heavier weight rail, more sophisticated signaling systems, and better maintenance than branchlines.

Multimodal – Representing more than one mode of transportation.

P

Practical Capacity – This is the capacity at which trains on the system are all moving without incurring significant delay or experiencing significant operational problems. Also defined as "The percentage of theoretical capacity that provides reliable and predictable train operation." The rail industry considers this to be between 50 and 60 percent of theoretical capacity.

R

Railcar – Double- stack railcars vary in length from 70 to 325 feet, with an industry average (for purposes of estimating capacity) of 305 feet. 270-foot railcars are better suited to the conveyance of international containers and are currently being developed by the major carriers to maximize the mainline capacity.

Rail Capacity – The number of trains that can occupy a given segment of track over a given period of time.

S

Short-haul – A freight shipment over a short distance between origin and destination.

Shortline – A switch carrier or roadhaul carrier that is not a Class I carrier. The carrier usually owns less than one hundred miles of track.

Sidings – A track parallel to a main track, having switches at both ends, used for meeting and passing trains.

Single-track – Rail right-of-way comprised of only one line of track, used by trains running in either direction.

Static Capacity – The ability of a yard to accommodate standing equipment (i.e., cars that are stored, awaiting movement, or awaiting processing).

Surface Transportation Board – The Surface Transportation Board (STB) is an economic regulatory agency created by Congress to resolve railroad rate and service disputes and review proposed railroad mergers. Although administratively affiliated with the U.S. Department of Transportation, it is decisionally independent. It serves as both an adjudicatory and a regulatory body.

Switch – A mechanical installation enabling trains to be guided from one line of rail tracks to another.

T

TEU – See Twenty-Foot Equivalent Unit.

Terminal – Area where docking and handling of freight takes place. In the case of intermodal shipping, it is the area where modal transfer of containers/trailers takes place.

Theoretical Capacity – The maximum amount of traffic that the infrastructure can accommodate.

Trackage Rights – The legal right to use a rail line.

Track Warrant Control (TWC) – A verbal authorization, usually with a radio, from a dispatcher to the train engineer permitting the train to occupy a specific section of the track. Used in unsignalized (dark territory) sections of the railroad.

Transload – To physically transfer commodity from one transportation vehicle to another, such as unloading freight from a rail car into a truck. This is a labor-intensive process that is usually performed manually.

Twenty-Foot Equivalent Unit (TEU) – The unit of measure for international container volumes. A 20-foot container is counted as one TEU, and a 40-foot container is counted as two TEUs. The 40-foot container is the most common type used in waterborne transportation.

U

Unit Train – A freight train composed of cars carrying a single type of commodity that are all bound for the same destination. By hauling only one kind of freight for one destination, a unit train does not need to switch cars at various intermediate junctions and so can make nonstop runs between two terminals. This reduces shipping time and shipping costs.

The Impact of the Development of the Gateway Pacific Terminal on the Whatcom County Economy

March 6, 2012

Prepared by

Public Financial Management, Inc.

for

Communitywise Bellingham

Table of Contents

I. EXECUTIVE SUMMARY 3

II. INTRODUCTION AND PROJECT OVERVIEW 5

III. GATEWAY PACIFIC TERMINAL 7

Overview 7
Proposed Phasing of Construction and Operations 7
Economic Impact Overview 8
Assumptions and the Impact of Projected Economic Benefits on Whatcom County 10

IV. POTENTIAL PUBLIC COSTS RELATED TO DEVELOPMENT AND OPERATION OF GATEWAY PACIFIC TERMINAL 14

V. GPT RELATED RISKS TO ECONOMIC DEVELOPMENT 16

Assessing Risks 17
Rail Traffic 17
Highest and Best Use of former Georgia Pacific site in Bellingham 19
Impact on Tourism and the Ability to Attract New Residents 26
Quantifying the Risk 27

VI. UNDERSTANDING AND MANAGING THE RISK 31

APPENDICES: WHATCOM COUNTY AND BELLINGHAM ECONOMY 33

Appendix A: Employment and Unemployment 33
Appendix B: Population Growth 37
Appendix C: Income and Wages 41
Appendix D: Underemployment and Poverty 49
Appendix E: Cost of Living 51
Appendix F: Bellingham's Importance as a Regional Economic Center 55
Appendix G: Projections for the Future – Population and Job Growth 58

I. Executive Summary

In November 2011, Communitywise Bellingham retained Public Financial Management, Inc. (PFM) to conduct an independent review of the potential economic impacts associated with the development of the Gateway Pacific Terminal (GPT) at Cherry Point.

A prior study by Martin Associates, conducted on behalf of the developers of GPT, projected the economic benefits that would result from the development and operation of the terminal. That study and a subsequent third party review of its results did not address either potential costs that could result from the development and operation of GPT or the degree to which the development of GPT could reduce potential benefits from other sources of economic development or job growth in Whatcom County.

Our analysis suggests that the potential for cost is real. To the extent that the development and operation of GPT would lead to an increase in rail traffic in Bellingham and other parts of Whatcom County, there would be costs to mitigate the impact particularly given the number of active rail crossings in the City.

The impact on other job growth and economic development strategies may be even more significant. To the extent that GPT s construction and operation could put other projected or planned growth at risk, it is possible that even if all of the projected employment benefits of GPT were achieved it could still have a net negative employment impact on Whatcom County s economy. If the development and operation of GPT led to the loss of more than 17 percent of projected job growth in Whatcom County between 2012 and 2021, or more than 13 percent in the ten year period after construction begins, the result would be a net loss in employment in the County.

Moreover, the planned development and operation of GPT could pose a specific risk to redevelopment plans for the Bellingham waterfront. State and local agencies have committed more than 40 million to the redevelopment of the former Georgia Pacific site in downtown Bellingham. The Port of Bellingham projects that over 25-30 years, redevelopment of the site could produce 1 billion in investment including a net increase of 5,600 direct jobs alone. To the extent that development and operation of GPT increases rail traffic, it could reduce the feasibility of redevelopment and projected resulting jobs.

The risk of offsetting reductions in projected job growth is largely due to train traffic. First, the operation of GPT would lead to a significant increase in rail traffic through Whatcom County especially through downtown Bellingham. Phase I operation would add five trains traveling to GPT through Bellingham on a daily basis. Each train would be between 7,000 and 8,500 feet 1.3 to 1.6 miles in length. Additional traffic is likely due to the return of rail cars from GPT.

Impacts to Bellingham positive and negative are significant for Whatcom County due to its role as the economic center of the County. Approximately 60 percent of all employment in the County is in Bellingham; Bellingham businesses generate more than three-quarters of all retail sales and more than half of all revenue related to accommodation and food services; in 2010, more than half of all residential home sales occurred in Bellingham; and, despite accounting for just 1.3 percent of total land in the County, 36 percent of total assessed county property value was in Bellingham.

Additional potential risks to growth beyond baseline projections are related to tourism and the in-migration of skilled workers and entrepreneurs to the region s economy. Again, these risks are related to both the projected increase in rail traffic and stigma associated with the transport of large amounts of coal through Whatcom County.

If the development of GPT proceeds, steps can be taken to reduce the impact of additional rail traffic through re-routing of rail traffic or new overpasses or changes to the street grid. Those steps could reduce potential risk and thereby increase the likelihood of net economic benefits for Whatcom County and Bellingham. Such steps, however, come at a cost that to date no party has assumed. To the extent that those costs are assumed by the public, it would reduce the net fiscal benefit of the GPT development to the public especially if local governments were asked to bear those costs.

In assessing the findings of this report, different decision makers may not view the risks imposed by the development and operation of GPT in the same way and reach dissimilar, yet valid conclusions. The purpose of the study is not to recommend a specific course of action. Instead, the purpose is to provide policymakers and the public with additional information about the potential economic impact to reach a better-informed decision. With that aim, other communities along the rail line may find the economic analyses and risk-based approach in this report to be a template for undertaking their own review of the economic impact of GPT.

II. Introduction and Project Overview

In November 2011, Communitywise Bellingham retained Public Financial Management, Inc. (PFM) to conduct an independent review of the potential economic impacts associated with the development of the Gateway Pacific Terminal (GPT) at Cherry Point. In particular, Communitywise Bellingham asked PFM to assess some impacts not considered in the report by Martin Associates (Martin) which projected employment and other economic benefits associated with the development and operation of GPT.

PFM is a national consulting and financial advisory firm, headquartered in Philadelphia, Pennsylvania, that serves public-sector clients. With 30 offices and over 450 professionals located across the country, PFM is the nation's leading provider of independent government financial advisory services. Throughout the remainder of this report, the professionals representing PFM in this engagement will be referred to as the project team or PFM.

To facilitate its work on this report, the project team spent four days in Washington conducting meetings in Bellingham, Olympia, and Bellevue. During this time, the project team met with over 50 people representing a diverse set of interests, viewpoints, and backgrounds – including representatives of SSA Marine (SSA), the State of Washington, Whatcom County, the City of Bellingham, the Port of Bellingham, the Whatcom County Chamber of Commerce, Northwest Washington Central Labor Council, not-for-profit entities, and local businesses. The meetings provided an opportunity for the project team to ask questions, receive information, seek clarification, and obtain verification of its approach, assumptions, and analysis.

The project team met with the SSA representative in Bellingham and a representative of SSA was invited to – and did – participate in the project team's meeting with state officials in Bellevue. The project team welcomed the opportunity to include SSA and saw two distinct benefits from their participation: 1) an opportunity to understand SSA's process and views; and 2) provide the opportunity for SSA to raise concerns with the project team's approach and methodologies. On more than one occasion, SSA offered to provide additional information to aid in the study. Unfortunately, SSA subsequently declined to provide information or additional input.

To supplement the meetings described above, the project team reviewed extensive documentation including documents regarding the development of GPT, demographics and economic data for the City of Bellingham, Whatcom County, and State of Washington, and academic and professional research pertinent to this report. Sources of data and information are cited throughout this report in footnotes.

The projected benefits of GPT have already been the subject of a prior study – the Martin study.[1] In addition, SSA retained Finance – Resource Management Consultants, Inc. (FRMC) to review methodologies used in the Martin analysis, and that review produced a different set of projected economic impacts. While our report includes a discussion of the findings and underlying assumptions in the Martin study and FRMC's review, it does not attempt to calculate – for a third time – projected job, economic activity and tax revenue benefits that might be realized from the completion of GPT.

A traditional economic impact analysis presents projections of benefits based on known or assumed inputs to an economic model. A cost-benefit analysis calculates offsetting costs that would be necessary to realize those benefits. In this report, we provide what we hope is a broader look at overall benefits and costs as well as a discussion of risk and uncertainty related to costs and benefits. In particular, we identify the degree to which proceeding with

1 The project team discloses that PFM has previously engaged in collaborative work with Martin Associates on behalf of other clients.

development and operation of GPT might impose risks to other potential economic growth in Bellingham and in Whatcom County. Understanding those risks and any uncertainty related to costs and benefits should allow policymakers and the public to make a more informed decision on the merits of the project.

Thus, this report attempts to answer the following questions:

- What are the projected economic benefits of GPT?
- Are there assumptions or other factors related to the development of GPT that should be considered in assessing the economic impact of GPT on Whatcom County?
- Are there potential costs that might be borne by the public in the development of GPT that could offset projected economic benefits?
- Would the development of GPT create a risk for other potential economic growth strategies in Whatcom County?
- What should the public and policymakers understand about the risks, the potential to mitigate those risks and uncertainty related to potential costs and benefits?

This study is presented to contribute to the public discourse by presenting additional information for consideration as policy makers and the public consider the development of GPT. With that goal in mind, other communities along affected rail lines may find it useful to build upon the work contained in this document or use a similar methodology to understand the specific potential risks to their respective communities and the resulting economic impacts due to the development of GPT.

This report should not, in any manner, be construed as taking the place of the scoping process of the Environmental Impact Study (EIS), the EIS itself, or any other formal review of the project. As such, the failure to consider certain issues as part of this report and analysis should not be inferred as dismissing the importance of those issues. As with any such review, individual components of our analysis rely on the validity, accuracy, and comprehensiveness of the information supplied to us, and projections of future events and outcome are inherently uncertain and subject to change. Similarly, time and resources limit the ability to consider all factors.

III. Gateway Pacific Terminal

Overview

SSA Marine (SSA) through one of its subsidiaries Pacific International Terminals, Inc. (PIT) is proposing to develop Gateway Pacific Terminal (GPT) in Whatcom County.[2] In February 2011, PIT submitted a Project Information Document (PID) to the State and Whatcom County to provide the public, the [multi-agency permitting team], decision-makers, and other stakeholders, including affected Native American Tribes, with a detailed description of the proposed project, the potential environmental effects of the project, and measures incorporated into the proposed project to reduce such effects.[3]

According to the project's website, the port is to be developed in a naturally occurring deep-water location and will be a full-service dry bulk commodity export-import facility on 1,092 acres in the Cherry Point Industrial Urban Growth Area. This area is zoned for heavy-impact industrial use and is located near the BP Refinery and INTALCO facility. The website indicates GPT would be the largest facility of its type on the west coast of the United States, capable of handling up to 54 million metric tons per year of dry bulk commodities.[4]

GPT is designed to accommodate "capesize" ships in order to allow for the movement of the forecasted volume of dry bulk commodities. Capesize ships, which take their name from the fact that they are physically too large to fit through locks of either the Panama or Suez Canals and therefore must travel via Cape Horn or Cape of Good Hope, are capable of carrying up to 250,000 dead weight tons of cargo. Due to the natural deep-water at Cherry Point, the development does not include the need for dredging.[5] The facility is being built to accommodate 1 to 9 loaded trains per day that will travel to Cherry Point on the Burlington Northern Santa Fe (BNSF) rail line.

In addition to deep water access and projected tonnage, the Cherry Point location provides an additional benefit to PIT due to its proximity to Asia and growing importers like China and India when compared to other US ports. The result is a shorter duration (and associated lower cost) to deliver "return cargo.

In February 2011, SSA and Peabody Energy (Peabody) announced an agreement to initially export up to 25 million metric tons of Powder River Basin (PRB) coal per year through GPT. Peabody, the world's largest private-sector coal company, is the leading coal producer in the PRB. The agreement provided Peabody with rights to throughput over the life of the operation of GPT and the ability to expand capacity in future years.[6]

Proposed Phasing of Construction and Operations

The PID outlines two construction development stages. According to the PID, SSA (PIT) projects construction of the first phase to begin in 2013 "when all required federal, state, and local permits and authorizations have been obtained and environmental review under the [National Environmental Policy Act (NEPA)] and [State Environmental Policy Act (SEPA)] has

2 SSA is a division of holding company Carrix, the largest US owned and privately held container terminal operator and cargo handling company in the world. In 2007, Goldman Sachs Infrastructure Partners acquired a 49 percent share of Carrix. The project team uses the abbreviations "SSA" and "PIT" throughout this report.

3 PID, p. 1-1.

4 Pacific International Terminals, Inc. Project Information Document, February 28, 2011, p. 4-1. The PID indicates GPT construction would occur in two phases. The first phase would allow for capacity of 25 million metric tons per year. At full build-out after phase 2 GPT would be designed to handle up to 54 million metric tons per year.

5 Http: www.gatewaypacificterminal.comH (accessed January 4, 2012).

6 Peabody Energy Press Release, February 29, 2011.

been completed.[7] SSA (PIT) estimates that the first construction phase will be complete by 2015 and the second phase complete by 2017. After the completion of the first phase, GPT would have capacity to handle 25 million metric tons of dry bulk commodities per year. The second phase would only begin if sufficient demand is present to handle an additional 29 million metric tons per year. If so, construction of phase two would begin after the first phase is completed and operational. After the completion of the second phase, GPT would be at its maximum throughput capacity of 54 million metric tons per year. PIT estimates that construction cost for both phases will total $665 million.

Economic Impact Overview

The project team reviewed the Martin study regarding the development of GPT[8] and the FRMC review of Martin's methodologies.[9] Martin and FRMC data were produced using input-output models, though the model types varied.

Martin Associates Analysis

Martin used the BEA's Regional Input-Output Modeling System (RIMS II) multiplier for construction activity in Whatcom County.[10] Martin arrived at an estimate of 7.4 million person hours supported by direct phase one construction (based upon input construction costs of $536 million) and 10.1 million person hours of indirect and induced activity.

The analysis estimated that the operation of the terminal upon completion of phase one would create 294 direct jobs and 569 induced and indirect jobs, for a total of 863 jobs. Among the 294 direct jobs, the report estimated 170 would be members of the International Longshore and Warehouse Union (ILWU), 46 would be railroad-related, 32 would be in maritime services, 29 would be terminal operators, and 17 would be for pilots and tugs. The Martin report also estimated that upon completion of phase one construction, GPT's operation would annually generate approximately $12.0 million of local purchases and the total state and local tax benefits associated with phase one operation would be approximately $8.1 million per year.

FRMC Review of Martin Methodology

FRMC used the Impact Analysis for Planning (IMPLAN) modeling system to generate its employment estimates. FRMC used this input-output model to assess the assumed economic impact of phase one construction costs of $536 million. The IMPLAN model yields a total that is reported in person hours, but also described person hours in worker years; FRMC assumed 2,080 hours worked as a worker-year.[11] IMPLAN calculations for phase one construction yielded an estimate of 6.85 million person hours of direct employment and 5.48 million hours of induced and indirect employment.

FRMC used Martin's estimate of direct jobs created by operation of the terminal and estimated that 576 induced and indirect jobs would result, for a total of 870 jobs. The FRMC and Martin analyses differ on the potential induced and indirect employment attributable to phase one

7 PID, p. 4-1. The US Army Corps of Engineers, the WA Department of Ecology, and Whatcom County will conduct a coordinated environmental review under the NEPA and SEPA. The US Army Corps of Engineers has determined that an EIS is required. Additional information regarding these processes may be obtained at:

Http: www.ecy.wa.gov geographic gatewaypacific

Http: www.co.whatcom.wa.us pds plan current gpt-ssa index.jsp

8 Martin Associates, The Projected Economic Impacts for the Development of a Bulk Terminal at Cherry Point. July 2011.

9 Finance Resource Management Consultants, Inc., Review of Martin Associates Economic Impact Study. October 2011.

10 The BEA indicates that, RIMS II provides users with five types of multipliers: final-demand multipliers for output, for earnings, and for employment and direct-effect multipliers for earnings and for employment.

11 A person working a 40 hour week for 52 weeks a year will work 2,080 hours.

construction. The FRMC estimate of indirect and induced jobs is 45.7 percent below that of Martin's assessment. Due to this difference, and a slightly smaller direct jobs estimate (7.5 percent less), the FRMC estimate for total person hours is 29.5 percent below the Martin assessment.[12] As FRMC notes, the variance could be due to classifications used as well as the different input-output models used in each analysis.

SSA (PIT) Projection

SSA (PIT) projects that during construction of the first phase, GPT would create approximately 3,600 job years per year and provide $74 million in tax revenue for state and local governments during the estimated two-year construction period.[13] This includes 1,700 direct job years[14] and 1,900 indirect[15] and induced job years annually.[16]

Once operating, after the first phase of construction, SSA (PIT) projects that GPT will provide over $8 million per year in state and local tax revenues as well as create 867 ongoing jobs (294 of which are direct jobs).[17]

If there is demand for additional capacity, SSA (PIT) projects that the second construction phase of GPT would create an approximate addition of 840 job years[18] annually and provide an additional $18 million in tax revenue for state and local governments during the estimated construction period. This phase would include approximately 400 direct job years[19] and 440 indirect and induced job years annually.[20]

At full operation upon completion of the second phase, SSA (PIT) estimates GPT would provide over $11 million per year in state and local tax revenues as well as create 1,250 ongoing jobs (430 of which are direct jobs – including the original 294 direct jobs from the operation of phase one).[21] SSA (PIT) projects the direct jobs to pay an annual average wage of $94,900.[22]

There is an important distinction to be made between the discussion of job years during the construction phases and permanent jobs projected to be created during operation of the terminal. Construction jobs are temporary in nature because once a structure or entity is built and operational, the construction ceases. On the other hand, jobs created during terminal operation are projected to be ongoing – and thus more likely to have a permanent impact on the local economy.

Martin and FRMC both discuss person-hours and do not convert the person-hours to "jobs" because the length of the construction period is uncertain. As FRMC notes, the person-hours

12 FRMC's review of phase two estimates of construction direct jobs and induced and indirect jobs resulted in similar divergences from Martin; most notably in induced and indirect jobs.

13 Job years includes direct, indirect and induced jobs. The information below sets forth the employment impact projections that appear on the GPT website: the employment impact is an average of the Martin and FRMC estimates. Where employment estimates, timing, or other details diverge from the PID, the project team represents the figures provided on the GPT website because those figures appear to have been more recently revised and the PID is a static document from February 2011.

14 SSA (PIT) defines direct jobs are those jobs directly generated by the construction of the terminal.

15 SSA (PIT) defines indirect jobs as those jobs that are created locally due to purchases of goods and services by firms for the construction of the Terminal.

16 SSA (PIT) defines induced jobs as those jobs that are created throughout the local economy because individuals directly employed by the activity at the terminal will spend their wages locally on goods and services (i.e. food, housing and clothing).

17 Includes direct, indirect, and induced jobs.

18 This figure is the average of the Martin and FRMC estimates.

19 This figure is the average of the Martin and FRMC estimates.

20 This is the average of the Martin and FRMC estimates.

21 These figures include the phase one job years (867) and revenues ($8 million).

22 Http://gatewaypacificterminal.com/economic-benefits/creating-new-jobs/ (accessed January 4, 2012).

number is difficult for a typical individual to interpret. FRMC suggests a conversion of person hours to job years (i.e. the number of workers it would take to build the project in one year), which can be used as well in place of the number of jobs and would make the findings generally more interpretable.[23] The project team uses job years to discuss potential employment during construction, not jobs.

One way to think about this is over a fixed period of time. Over a 10 year period, based on the projections provided by SSA (PIT), construction and operation of phase one would lead to:

- 3,400 direct job years and 3,800 induced and indirect job years during the two year construction phase
- 294 direct jobs per year and another 573 induced and indirect jobs per year a total of 2,352 direct job years and 4,584 indirect and induced job years during the first eight years of operation

Taken together, based on SSA's (PIT's) projections, GPT would produce the equivalent of an average of 575 direct jobs and 838 indirect and induced jobs per year during the first 10 years of construction and operation.

Assumptions and the Impact of Projected Economic Benefits on Whatcom County

The project team did not review and therefore has no basis for questioning the methodology utilized by Martin Associates or FMRC. Nor did we conduct our own independent impact analysis. In considering the projected economic benefits of the GPT project, however, it is important to understand some of the underlying assumptions of those projections and the resulting impact specifically on Whatcom County.

Phase I Construction Jobs are Unlikely to be Created Until 2016 and Permanent Jobs are Unlikely to be Created Until 2018

Critical data and assumptions were provided to Martin Associates by SSA (PIT) including the projected construction phasing, projected cost of construction, projected terminal employment, throughput assumptions, and salary ranges for select terminal employees.

SSA (PIT) provided Martin with a timeline that assumed terminal operations begin in 2015, with permitting completed in 2012 and construction beginning in 2013.[24] The timeline, however, is subject to change. First, representatives of SSA suggested that actual construction would depend on contractual guarantees for throughput. Second, the timing of construction depends on the completion of the EIS process. State officials told the project team that the scoping process for the EIS is likely to begin in the first or second quarter of 2012.

The scoping process and the final EIS must both be completed before the projected two-year construction timeline begins. While some officials estimated the EIS could be completed within two years, a greater number of parties suggested the process could take up to four years to complete. As a result, construction jobs would not be created until 2016 and permanent jobs would not be created until 2018.

23 FRMC, p.3.

24 Martin, p. 1.

Most, but not all, GPT Jobs Will Go to Whatcom County Residents

Even if all SSA (PIT) projected job gains are realized, not all jobs created as a result of the construction and operation of GPT will go to residents of Whatcom County.

During the construction of large scale projects, it is typical that a significant number of workers come from other parts of a region (or nationally) – on a temporary basis – to the project location for short-term work assignments. Our understanding is that construction of GPT would be the subject of a project labor agreement (PLA) with local labor unions, guaranteeing that all work on the site goes to a unionized labor force. PLAs appear to reduce the use of non-local labor on major construction projects, both through explicit local hiring requirements and by reducing the use of "independent contractors" as part of the labor force.[25]

The ability to staff the construction phase of the project will depend upon the capacity of the local construction workforce. Based on the number of job years and the projected construction period, phase one of GPT construction will require approximately 1,700 construction workers per year. Peak construction employment in the Bellingham MSA reached 6,310 in 2006 – some 1,900 more construction jobs than in 2010.[26] The combination of the PLA and existing capacity in the local construction workforce suggests that the majority of construction jobs during phase one will be held by local workers.

Yet, even if a PLA requires that all – or most – workers on the construction of GPT are local residents, it would have no effect on the share of induced and indirect jobs during construction, direct jobs during operation or induced and indirect jobs during operation going to non-Whatcom County residents.[27] Currently, among the general workforce, approximately 21.0 percent of jobs in Whatcom County are held by non-Whatcom County residents. This could suggest a similar percentage of induced and indirect jobs from GPT construction – as well as direct, induced, and indirect jobs from GPT operation – would go to non-Whatcom residents.[28]

Most GPT Tax Revenue Will Go to the State, Not Local Government

The Martin report defines the tax impact as "tax payments to the state and local governments by firms and by individuals whose jobs are directly dependent upon and supported by (induced jobs) activity at the bulk terminal."[29] Thus, projected tax benefits include taxes that are the direct result of the construction and operation of GPT – such as sales tax related to goods purchased during construction – and taxes that are the result of indirect and induced economic activity – such as property taxes paid by individuals who are employed as a result of jobs created by GPT's activity.

Martin used SSA's (PIT's) estimated phase one construction cost ($536 million) to project state and local tax impact of $74.4 million. Similarly, SSA's (PIT's) projected annual throughput of 25 million metric tons (upon completion of phase one construction) was used to project the

25 See, Uyen Le and Lauren Applebaum, "Project Labor Agreements in Los Angeles: The Example of the Los Angeles Unified School District," UCLA Institute for Research on Labor and Employment, December 2011 at Hhttp://www.irle.ucla.edu/publications/pdfs/ResearchBrief11.pdfH.

26 US BLS OES 2000-2010 data.

27 In understanding the effect of the project on local employment, it is worth noting that not all directly created jobs will go to individuals who are currently unemployed. In fact, as is the case with many new jobs, the likely beneficiaries are individuals who are already currently working. See: Geoffrey C. Ho, Todd L. Pittinsky, Margaret Shih, Daniel J. Walters. "The Stigma of Unemployment: When joblessness leads to being jobless." UCLA Institute for Research on Labor and Employment, December 2011. Thus, employment projections measure the net impact – i.e. by creating new vacancies in other positions, the effect will be to create a net increase in employment.

28 US Census Bureau 2009 OnTheMap data.

29 Martin, p. 3.

associated state and local tax impact of $8.1 million.[30] These tax revenue projections are based on both direct activity related to the terminal and related economic activity.

Most tax benefits from the project will likely go to the state, rather than to local governments. Every state has a different tax structure. Nationally, in 2009, state governments received 56.3 percent of general revenue tax dollars that were collected by state and local governments. In most states – all but five – state tax share exceeded local government share. In Washington, 60.8 percent of general tax revenue went to the state government.[31]

The precise division of revenue generated by GPT will depend, to a certain degree, on the types of tax revenue generated by the project.

Sales and property tax revenue are among the largest sources of revenue for both state and local governments in Washington. Washington does not have a state personal or corporate income tax.

According to the City of Bellingham – the largest city in the Whatcom County and the location of 60 percent of total jobs in the County – 75 percent of sales tax revenue collected in the Bellingham goes to the State of Washington; 10 percent goes to the City; 7 percent goes to the Whatcom Transportation Authority; 2 percent each goes to Whatcom County and the Transportation Benefit District; and 1 percent each goes to jail construction, the criminal justice fund, EMS, and the County mental health tax. Statewide, general sales tax revenue (not including taxes on alcohol, tobacco, gasoline or utilities) accounted for 21.7 percent of local government tax revenue in Washington in 2009.[32]

According to the Whatcom County 2011 Tax Book, approximately 33 percent of all property tax revenue goes to school districts; 24 percent goes to the State; 11 percent goes to both the City and the County; 7 percent goes to road districts; and 6 percent goes to fire districts. No other entity receives more than one percent of property tax revenue. Statewide, property tax revenue accounted for 59.8 percent of local government tax revenue in Washington in 2009.

Based on the above information, and accepting the SSA (PIT) tax revenue projections, it is possible to roughly model likely revenue flow during the first decade of construction and operation of Phase I:

30 Martin, p.3.

31 US Census Bureau, 2009 Annual Surveys of State and Local Government Finances.

32 City of Bellingham, obtained from: Hhttp: www.cob.org documents finance publications sales-tax-distribution.pdfH.

Ten-Year Revenue Projection (all dollars in millions)[33]

Year	1	2	3	4	5	6	7	8	9	10
Total State and Local Revenue	**37.0**	**37.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**
State Revenue	22.5	22.5	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Local Revenue	14.5	14.5	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Local Property Tax Revenue[34]	**8.7**	**8.7**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**
Schools	3.8	3.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
County Government	1.3	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
City Government	1.3	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Road District	0.8	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fire District	0.7	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Local Sales Tax Revenue	**3.1**	**3.1**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
City[35]	1.4	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
County (including WTA, Jail, Mental Health, CJ,EMS)	1.8	1.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

33 Just as not all employment will go to Whatcom County residents, at least some of the local tax revenue will likely go to cities, counties and districts outside of Whatcom County.

34 Does not include property tax revenues that go to support State entities.

35 Does not include Transportation Benefit District revenue.

IV. Potential Public Costs Related to Development and Operation of Gateway Pacific Terminal

The PID outlines infrastructure costs in the immediate area surrounding the GPT at Cherry Point. Issues such as at-grade rail crossings – meaning they are on the same level as vehicular traffic – and traffic congestion are detailed. The PID also suggests that the operational cost impacts in the immediate area of Cherry Point may be minimal – with greater instance during construction phases than operational phases.[36]

The PID does not address infrastructure-related costs along this rail line (either in Bellingham or other communities through which it travels) such as crossings, improvements, realignments, bypasses, overpasses, and separations. The PID mentions that the Bellingham Subdivision main line connects to the Cherry Point Line (Railway Custer Spur).[37] The Bellingham Subdivision main line is operated by BNSF and, as its name indicates, runs through Bellingham – much of the way along the waterfront.

Bellingham, as the hub of retail activity in the County, may have a greater use of its public infrastructure due to the development of GPT (roads, water and sewage systems, etc.) than other areas of the County. Without a consistent revenue stream to offset increased costs, the City, and potentially other communities along the BNSF railway, could face increased budget pressures in an already strained fiscal environment.

Rail crossing data from the Federal Rail Administration (FRA) indicate there are 29 active rail crossings in Bellingham on the BNSF rail line in question.[38] Of the 29 crossings, 2 are private crossings, 24 are public crossings, and 3 are pedestrian crossings. Of the public crossings, 16 are at-grade crossings and the other 7 are over-/underpasses.

According to a 2009 report prepared for the Washington Department of Transportation (DOT) and Washington Public Ports Association, in 2008, an average of 15 trains per day traveled north from Everett on the BNSF line.[39] The report indicates the line has a maximum capacity of 18 trains per day. By 2028, the report projects that maximum capacity would be 30 trains per day and traffic would be approximately 24 trains per day.

The PID indicates that upon completion of Phase I and operation of the GPT, an additional 5 loaded trains will travel to GPT along the train route through Bellingham on a daily basis. The PID states up to 9 loaded trains are projected to arrive on a daily basis upon completion of Phase II.[40] There may be additional rail traffic attributable to empty/unloaded trains returning from GPT.

SSA (PIT) anticipates servicing GPT using 7,000 foot-long trains (approximately 1.3 miles) and eventually 8,500 foot-long (approximately 1.6 miles) trains may be used.[41] The PID makes no mention of the potential infrastructure costs to remediate infrastructure and other service issues such as at-grade rail crossings, traffic congestion, access issues for business and commerce, access issues for recreational parks, or related issues. Similarly, the PID does not discuss additional operation costs such as maintenance, emergency management, and public safety along the rail line.

---

36 PID, pp. 5-91 – 5-130.

37 PID, p. 5-103.

38 FRA data available at: Hhttp://safetydata.fra.dot.gov/OfficeofSafety/publicsite/crossing/crossing.aspx

39 BST Associates, HIS Global Insight, and Mainline Management, Inc. "2009 Marine Cargo Forecast – Technical Report." March 23, 2009. A June 2011 study by Cascadia Center for Regional Development indicates that BNSF reports an average of 15 trains per day.

40 PID, p. 4-51.

41 PID, p. 4-31.

The project team met with Bellingham City officials and discussed the potential costs and challenges associated with increased rail traffic along the rail line. City officials identified three primary points of concern.

First, access to certain areas of the waterfront could be severely restricted or cut off. From a public use standpoint, this could be a concern as residents and tourists routinely use the City's parks and trails for recreational activities. Additionally, public safety and emergency service access to the waterfront could be jeopardized if a train was stopped or moving slowly through the rail line that separates some portions of the waterfront from the rest of the City.

A second concern was the safety of the rail crossings in the City. Many of the rail crossings in the City are "at-grade." Traffic delays, and increased traffic and use of side streets as a result of increased rail traffic (and longer trains) may cause greater wear and tear on main thoroughfares and alternate roads, a higher need for traffic management and direction activities, and overall challenges to move throughout the City (particularly in and around the waterfront area). Absent any mitigation, there is concern that the City's costs will increase and ease of transportation may suffer.

The third concern was noise impact for residents and businesses in Bellingham. Rail traffic results in two different types of noise. Some noise is experienced as a result of vibrations due to train movement and most greatly affects residents living close to the rail line. As trains pass through Bellingham, they are also required to use their horns as a safety precaution going through at-grade crossings.

Fully addressing these concerns would require infrastructure investments to eliminate at-grade crossings through the creation of either overpasses or re-routing of the rail line. Absent detailed engineering studies, the total cost of these investments is outside the scope of this report.

Noise reduction – related to train horn use – could be achieved through the creation of quiet zones pursuant to Federal Railroad Administration (FRA) rules. A September 2007 study prepared for the City of Bellingham notes that "[I]mplementing a quiet zone will not guarantee that the train will stop blowing its horn at all times and in all situations. A quiet zone will only reduce the train horn noise."

Quiet zones would require capital investments – gates and signage – and maintenance. The 2007 report evaluated the creation of two quiet zones in Bellingham – a Fairhaven zone (5 grade crossings) had a projected capital cost of $1.3 to $2 million. A waterfront zone (7grade crossings) had a projected capital cost of $1.4 to $3.5 million. At the time, there was also a projected annual maintenance cost of $5,500 per crossing, per year.

It remains unclear what party or parties would be responsible for bearing these costs – both in and around Cherry Point and in communities like Bellingham along the rail line that would require mitigation for commercial, public, or safety interests.

The project team spoke with County officials, who indicated the County would not pay for any mitigation-related expenses. SSA (PIT) does not address such costs in their PID outside of the immediate Cherry Point area. Thus, mitigation costs and/or the associated economic and quality of life losses likely to occur absent mitigation could be borne by the communities along the rail line and would reduce the net fiscal benefits – offsetting the projected local government tax revenue discussed in the prior section.

V. GPT Related Risks to Economic Development

To address the question of whether development and operation of GPT would put at risk other economic development, it is important to understand the recent economic history of Bellingham and Whatcom County.[42]

- Employment: From 2001 to 2010, the Bellingham MSA's rate of job growth was almost four times the state rate. The Bellingham MSA (Whatcom County) added 8,100 non-farm jobs – an 11.6 percent increase. Statewide, non-farm jobs grew by 3.0 percent. Compared to the state, the Bellingham MSA grew jobs at a greater percentage or shed jobs at a smaller percentage for every super-sector for which data were available.

- Population Growth: From 2000 to 2010, Bellingham and Whatcom County both grew in population by slightly more than 20 percent – greater than the State's growth rate of just over 14 percent. The US Census Bureau reported Bellingham's 2010 population as 80,885, an increase of 13,714 individuals from the 2000 Census. Whatcom County's 2010 population of 201,140 represented an increase of 34,326 from the 2000 Census. Migration played in important role in driving the increase. New residents – most from other parts of Washington, but significant numbers from other states as well – brought new income with them: IRS data suggest that Whatcom County realized a net growth of over $172.3 million in aggregate Adjusted Gross Income (AGI) from migration between 2004 and 2010.

- Income and Wages: Whatcom County's inflation adjusted per capita income has consistently been below both the State and US averages since 1969. Average earnings per job in Whatcom County have consistently lagged the Washington average since 1987 when the data set began; Whatcom County also remained below the State and US average earnings per job, while Washington has been largely been near or above the national average. Between 2000 and 2008, however, Whatcom County's per capita income grew at a compound annual growth rate (CAGR) of nearly double that of the nation and significantly greater than the State. Whatcom County's CAGR was 2.1 percent; US CAGR was 1.1 percent, and Washington's CAGR was 1.3 percent.

- Bellingham's Importance to the Regional Economy: Approximately 60 percent of jobs in Whatcom County are located in Bellingham and the City accounts for approximately 76 percent of all retail sales in Whatcom County. Bellingham – with just over 1 percent of the County's total square miles also accounts for nearly 36 percent of the County's total assessed value of real property.

The State of Washington currently projects that population will grow in Whatcom County at an average annual rate of 1.5 percent between now and 2030. Similarly, the State projects employment growth in Whatcom County at a rate that would lead to 15,000 new jobs in Whatcom County by 2021. These projections are based, in part, on the County's relative economic strength over the last decade.

42 The project team reviewed economic data for the State of Washington, Whatcom County, and Bellingham and analyzed the data to quantify several important economic factors. In certain instances, data are only available for Whatcom County and/or the Bellingham metropolitan statistical area (MSA) (the MSA is defined as Whatcom County) and not at the City level for Bellingham. In these cases, City-level data are not included. Additional detail and content are available in the appendices of this report and specific sources for the economic findings are detailed in footnotes to those appendices.

Assessing Risks

A more detailed analysis might identify other potential risks, but for the purposes of our analysis we focus on three possible GPT-related scenarios that would put economic growth in Bellingham and Whatcom County at risk:

- Development and operation of GPT could reduce the projected baseline growth in population and employment
- Development and operation of GPT could reduce the possibility of redevelopment of the Bellingham waterfront
- Development and operation of GPT could limit potential population and job growth related to tourism, in-migration of skilled workers and entrepreneurs

Rail Traffic

An increase in rail traffic through Bellingham resulting from the operation of GPT discussed above could increase the likelihood of all three of the risk scenarios. An increase in rail traffic could:

- Limit access to and redevelopment of the waterfront, its businesses, and recreational areas for residents and visitors
- Increase noise and nuisance making Bellingham less of a livable city and less attractive to tourists
- Reduce the capacity of existing rail infrastructure to provide service for residents and visitors

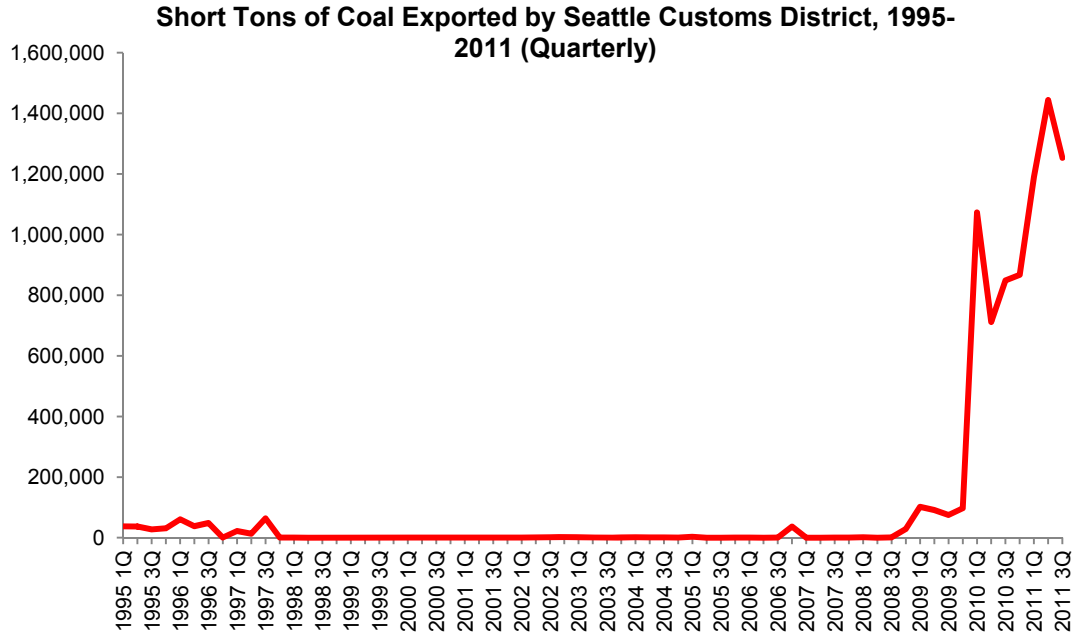
As noted above, rail traffic already travels through Bellingham on a daily basis. Rail traffic has recently increased due to the increase in transport of coal through Canadian ports. Statewide, DOT reported that as of 2007 10.6 million tons of coal was moved by train in Washington each year.[43] More recent data, however, suggest that amount has increased with a specific increase due to exports that affect the rail line through Bellingham.

The project team reviewed reports that indicate most, if not all, coal from the Seattle Customs District is transported to Canada, primarily on trains that run through Whatcom County and Bellingham.[44] US Customs and Border Patrol data indicate that the Seattle Customs District (which encompasses Northwest Washington including Whatcom County) experienced a significant increase in the amount of coal exported beginning in 2009 and 2010.[45] Prior to 2009, the annual volume of coal exported by the Seattle Customs District was often below 30,000 short tons per year in some instances below 5,000 short tons per year. From 2010 through the 3rd quarter of 2011, the average quarterly short tons exported by the Customs District was 1.1 million short tons; approximately 4.4 million short tons on an annual basis. The graph below displays the 1995-2011 quarterly short tons of coal exported by the Seattle Customs District.

43 WSDOT 2010-2030 Freight Rail Plan, p. 4-21. This data likely includes the coal consumed at the Centralia power plant. A recent agreement was reached to end the use of coal-fired generators (one in 2020 and the other in 2025). This may alter the amount of coal tonnage projected to move through Washington in the future and would not be included in the above projections.

44 PFM did not perform its own analysis of this statement.

45 US Customs and Border Patrol Quarterly and Annual Reports, 1995 to present.



Source: US Customs and Border Patrol Quarterly and Annual Report 1995-present

PIT projects the first phase of GPT to handle 25 million metric tons (approximately 27 million short tons) of throughput on an annual basis much of which would be coal.[46] This suggests that the amount of coal moving through Bellingham by rail could increase six-fold.

More and longer trains will increase the amount of time that rail crossings in Bellingham are blocked. This will impact businesses currently located on the waterfront side of the rail tracks that can only be accessed by at-grade crossings. More and longer trains also may result in greater noise both noise related to blowing of train whistles to comply with rail crossing rules and noise for property owners; including those immediately abutting the tracks and those nearby.

It is also likely that the additional rail traffic will have a negative impact on the property value of residential properties that abut the rail lines. A November 2011 study examined the impact of rail freight traffic on home values in Los Angeles after the Alameda Corridor, an urban infrastructure project in Los Angeles, consolidated most rail traffic into and out of San Pedro port facilities into one higher capacity rail line.[47] The study measured the impact of increased rail traffic along one corridor and the decreased traffic elsewhere. On average, the study found approximately a 2.0 percent decrease in average home value where rail traffic was more prevalent and approximately a 0.6 percent increase in home value where rail traffic was reduced.

Lower property values resulting from increased rail traffic could have an impact for all residents of Bellingham and Whatcom County not just the individual property owners. As noted earlier, sales price data suggest that properties in the Fairhaven, South Hill, and Edgemoor sections of Bellingham had among the highest values in the County. Thus, a loss in property value of these properties could also eventually lead to reductions in property tax revenue.

46 Upon completion of phase two, GPT's throughput is projected to be approximately 54 million metric tons per year.

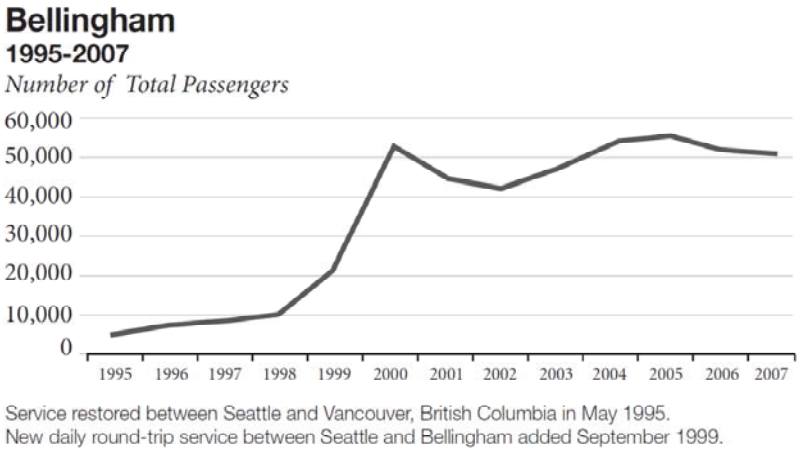
47 Michael Futch. "Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles, (November 2011).

Even those properties not directly affected by additional rail traffic could suffer from proximity to properties that are affected. Stigma associated with proximity to the increase in rail traffic or even resulting specifically from the fact that the rail was increasingly being used to transport coal could affect property value even if the properties would not be affected by additional noise.[48]

On the other hand, the negative impact on property value of properties near or abutting rail tracks could be offset by increased property values in Bellingham or Whatcom County that are not near the rail traffic. To the extent that demand would remain consistent for property in or near certain areas, the values of affected properties could bear a discount while other properties nearby enjoy a premium.

An increase in rail freight traffic could also limit the use of passenger rail in Bellingham and Whatcom County. In 2010, the Amtrak *Cascades* service had total passenger on-offs in Bellingham of 62,562, an increase of nearly 20,000 per year from 2002 levels.[49] Some of the County's tourism industry discussed in detail below is dependent on passenger rail. Increased use of tracks in and near Bellingham for freight access to GPT could limit passenger rail and impact tourism.

***Cascades* Total Passengers Bellingham**



Source: WSDOT, Amtrak *Cascades* Ridership and Station On-Off Information, March 2008

Highest and Best Use of former Georgia Pacific site in Bellingham

Redevelopment of the Bellingham waterfront has been the subject of significant planning and investment. Much of the proposed redevelopment activity centers on the former Georgia Pacific (GP) site.

From the early 1960s through the early 2000s, GP was the heart of the Bellingham waterfront, producing not only consumer and industrial goods, but also significant employment for the region employing as many as 1,200 workers in the late 1970s. By 2001, the company ended its pulp-mill operations, but continued its tissue-manufacturing operations through 2007, when it

48 Two example studies reviewed were:

Kevin J. Boyle, Nicolai V. Kuminoff, Congwen Zhang, Michael Devanney, and Kathleen P. Bell. "Does a Property-Specific Environmental Health Risk Create a "Neighborhood" Housing-Price Stigma? Arsenic in Private Well Water." September 2009.

Kai-yan Lee. Federal Reserve Bank of Boston. "Examining REO Sales and Price Discounts in Massachusetts." September 2010.

49 WSDOT, "Amtrak Cascades 2010 Performance Report", May 2011.

closed all operations at the site.[50] During its operational years, the site produced a myriad of products including tissue products, sulfuric acid, paperboard, chlorine, and sodium chlorate, among others. The manufacturing processes caused odors that led some to refer to the City as "Smellingham." In addition to the noticeable odor from the GP site, the site's operations also resulted in the introduction of harmful chemicals to the waterfront and Bellingham Bay.

Over the past decade, significant time, energy, and money have been contributed by the State, Port, City, and the City's Public Development Authority (PDA) in efforts to remediate the site and create a new game-changing redevelopment plan for the City and region. While the plans of the PDA and Port plans are not the same, they are complementary and both suggest the opportunity for significant private investment and economic opportunity.

In 2005, the Port of Bellingham (Port) purchased the property known as Georgia Pacific West as part of its long-term plan, in partnership with the City, to transform the larger 216.3 acre Waterfront District.[51] Part of this plan calls for the formulation and implementation of "a Master Development Plan for the Waterfront District that would gradually transform this historically industrial waterfront property into a new neighborhood with residences, shops, offices, marine and light industry, and institutional uses [e.g. Western Washington University], as well as parks, trails and shoreline improvement" along the Bellingham Bay.[52]

The Port's Final Environmental Impact Statement (FEIS) – submitted in July 2010 – indicates that "substantial new opportunities for public access to the waterfront that do not exist under current conditions" would be part of the project. The Port projects the full build out of the project – occurring over a 20 year period – to include "a diversity of uses that are complimentary to the downtown Bellingham [CBD], Old Town, and surrounding neighborhoods; an infrastructure network that integrates with and connects the waterfront to the surrounding area; and, a system of parks, trails and open space that opens up the waterfront to the community."[53] A map of the proposed preferred option follows:

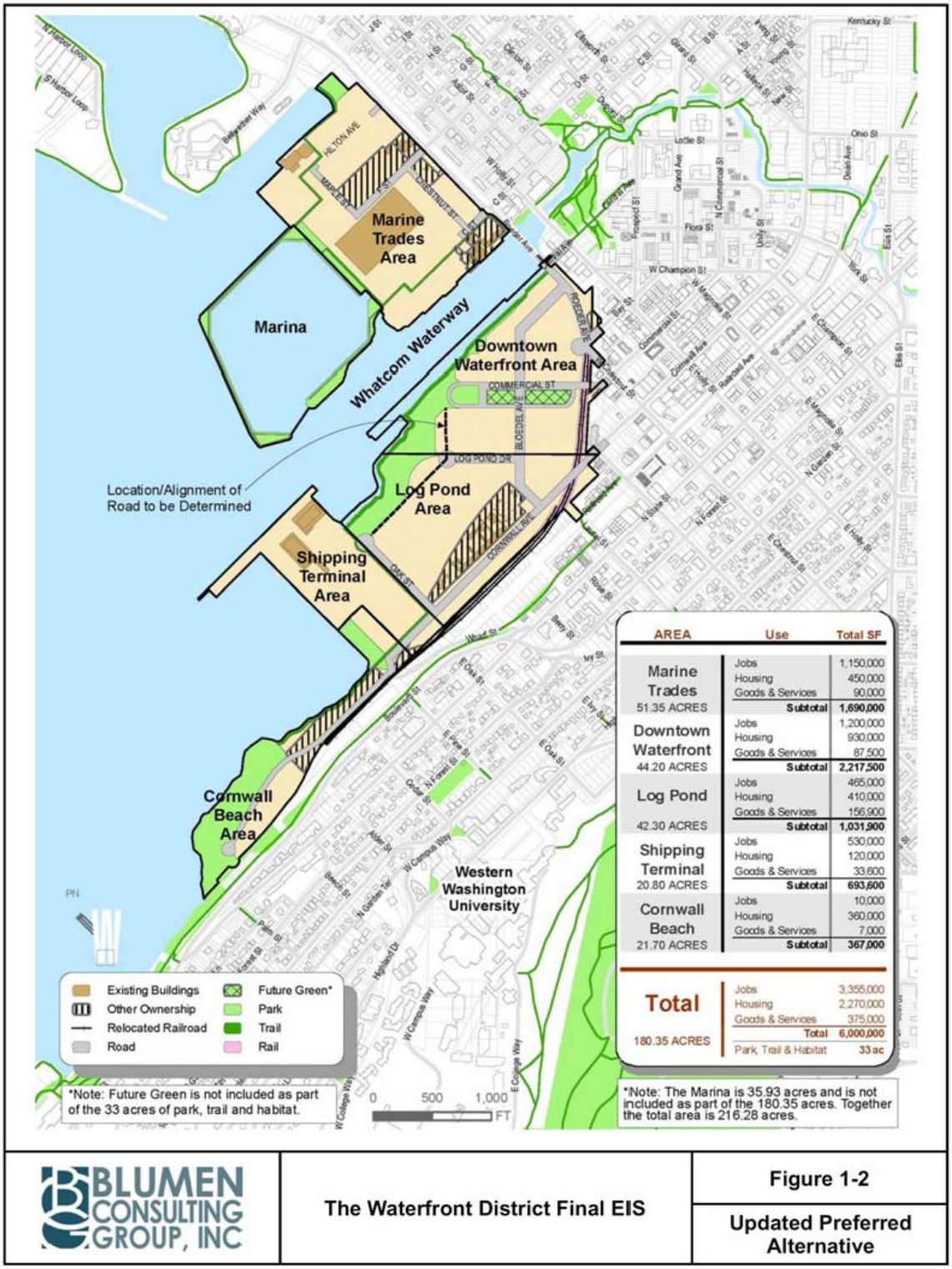
50 Port of Bellingham data.

51 The GP-West site required extensive environmental cleanup was necessary and as of December 2011, the first phase of interim cleanup was completed. This initial phase cost approximately $1 million and the State Department of Ecology is reimbursing all costs incurred by the Port for cleanup at the site. In the spring of 2012, it is anticipated a second phase – removing contaminated soils, debris and demolishing a building – will be completed.

52 Port of Bellingham (Port), The Waterfront District Redevelopment Project, Final Environmental Impact Statement (FEIS), July 2010.

53 Port, FEIS.

Port of Bellingham □Waterfront Redevelopment Preferred Alternative



BLUMEN CONSULTING GROUP, INC

The Waterfront District Final EIS

Figure 1-2

Updated Preferred Alternative

The Port of Bellingham's current plan calls for:[54]

- Redevelopment of 6 million square feet of office and commercial space
- 1,892 housing units
- Site population of 3,614 residents
- Up to 460 slips
- 33 acres of public parks and open space
- Maximum building heights

The redevelopment of the GP site is well beyond the planning phase. A September 2010 draft SubArea Plan estimates that the Port and City costs would be approximately $365 million for environmental remediation, streets, infrastructure, and parks to prepare the site for redevelopment.[55] At full build out, the Port suggests the project would potentially attract upwards of $1 billion in public (i.e. university) and private development. Some of this funding will come from other government sources (i.e. State grants, etc.). Combined, the Port and the City have received and authorized approximately $41 million of State grant funds and their own funds to remediate the waterfront and to plan for its future development.

State Grants Received by Port of Bellingham for Remedial Action

Description	Dates		Agency Funding
	Effective	Expires	
Current Ecology MTCA Grants			
Central Waterfront (2)	1/1/2009	12/31/2012	$2,604,057
Cornwall Avenue (2)	1/1/2009	12/31/2012	$3,166,650
GP Mill (1)	1/1/2004	12/31/2012	$5,681,472
Whatcom Waterway (2)	12/1/2006	12/31/2013	$26,047,141
Sub-total			***$37,499,320***
Closed Ecology MTCA Grants			
Central Waterfront (1)	4/1/1998	12/31/2010	$646,736
Cornwall Avenue (1)	1/1/2005	11/30/2009	$90,000
Whatcom Waterway (1)	5/1/2004	3/31/2008	$348,300
Sub-total			***$1,085,036***
Total			**$38,584,356**

54 Port, FEIS.

55 Port of Bellingham's Draft SubArea Plan, Chapter 8 – Capital Facilities, September 2010.

Authorized Joint City□Port Expenditures for New Master Plan for City Waterfront

Task	Total Cost	City share (50□)	Port share (50□)
Preliminary Design	□300,000	□150,000	□150,000
Outside funding	□250,000	□125,000	□125,000
Branding	□60,000	□30,000	□30,000
SEPA (EIS)	□854,174	□427,087	□427,087
Assumptions, market	□315,332	□157,666	□157,666
EIS data support	□655,626	□327,813	□327,813
Public Involvement	□118,256	□59,128	□59,128
Master Plan	□393,000	□196,500	□196,500
Devel. Regulations	□164,000	□82,000	□82,000
LEED ND	□20,000	□10,000	□10,000
Total Authorized Joint Expenditures	**□3,130,388**	**□1,565,194**	**□1,565,194**

Source: Port of Bellingham

In addition to the remediation efforts, the City□s PDA is moving forward with the first steps toward actual redevelopment.[56] As part of its October 2011 strategic plan, the PDA has identified five potential priority projects including four related to waterfront redevelopment.

The Army Street Project would serve as a jumping off point for waterfront redevelopment.[57] According to plans, the project "would span the BNSF railroad tracks and Chestnut Street□Roeder Avenue, including properties on both sides, providing a major urban plaza and pedestrian connection joining the Central Business District, Old Town District and the Waterfront District."[58] The project area would include two acres north of the BNSF rail tracks and 22 acres south of the tracks within the former GP West property.

As of 2011, PDA estimates that the waterfront□s "total build-out value could be in the realm of □350 million with public sector undertaking □120 million and the private sector...□230 million. [T]his public investment would yield benefits reflecting a 'whole greater than the sum of its parts' in terms of the multiplier effects of higher development feasibility and asset values in the CBD and Old Town."[59] The Strategic Plan estimates that earliest development and construction would be projected for 2015 or 2016.

PDA notes that "[a]n attractive, safe and convenient access way between the CBD□Old Town and the GP West property is considered a fundamental key to successful development of this portion of the waterfront and for the CBD (and Old Town) to accrue economic benefits from development of the Army Street Project."[60] The PDA indicates that without such an access way, the "barrier imposed by the inconvenience and hazard of an at-grade crossing of the combination of the trail tracks and Chestnut□Roeder will...negatively [impact] development feasibility...and would be aggravated by increased vehicular or rail traffic if not mitigated."[61] The

56 Bellingham Public Development Authority mission statement: □to maximize the public good by attracting sustainable development that generates capital investment, contributes to the vitality of the economy, and creates employment opportunities, while improving and preserving those historical and environmental assets that define the city's character.□ The PDA is an independent legal entity created by the City to develop public properties together with private investment, focusing on Bellingham□s Waterfront, Old Town, and Downtown districts.

57 Bellingham Public Development Authority (PDA) Strategic Plan CY2011-CY2015, adopted October 25, 2011.

58 PDA Strategic Plan, p. 6.

59 PDA Strategic Plan, p. 16.

60 PDA Strategic Plan, p. 15.

61 PDA Strategic Plan, p. 15.

Port's overall plan also recognizes that rail realignment will be necessary for full build out of the Georgia Pacific site. The site plan calls for relocation of the BNSF rail track to the east, allowing for passenger and freight trains to move through the area without bisecting the site.[62]

Both the Port and PDA waterfront development plans call for activity that could likely bring long-term construction, investment, and economic opportunity. Over the course of 25-30 years, the number of direct, induced and indirect jobs that would be created could serve as a significant economic opportunity for Bellingham and the region.

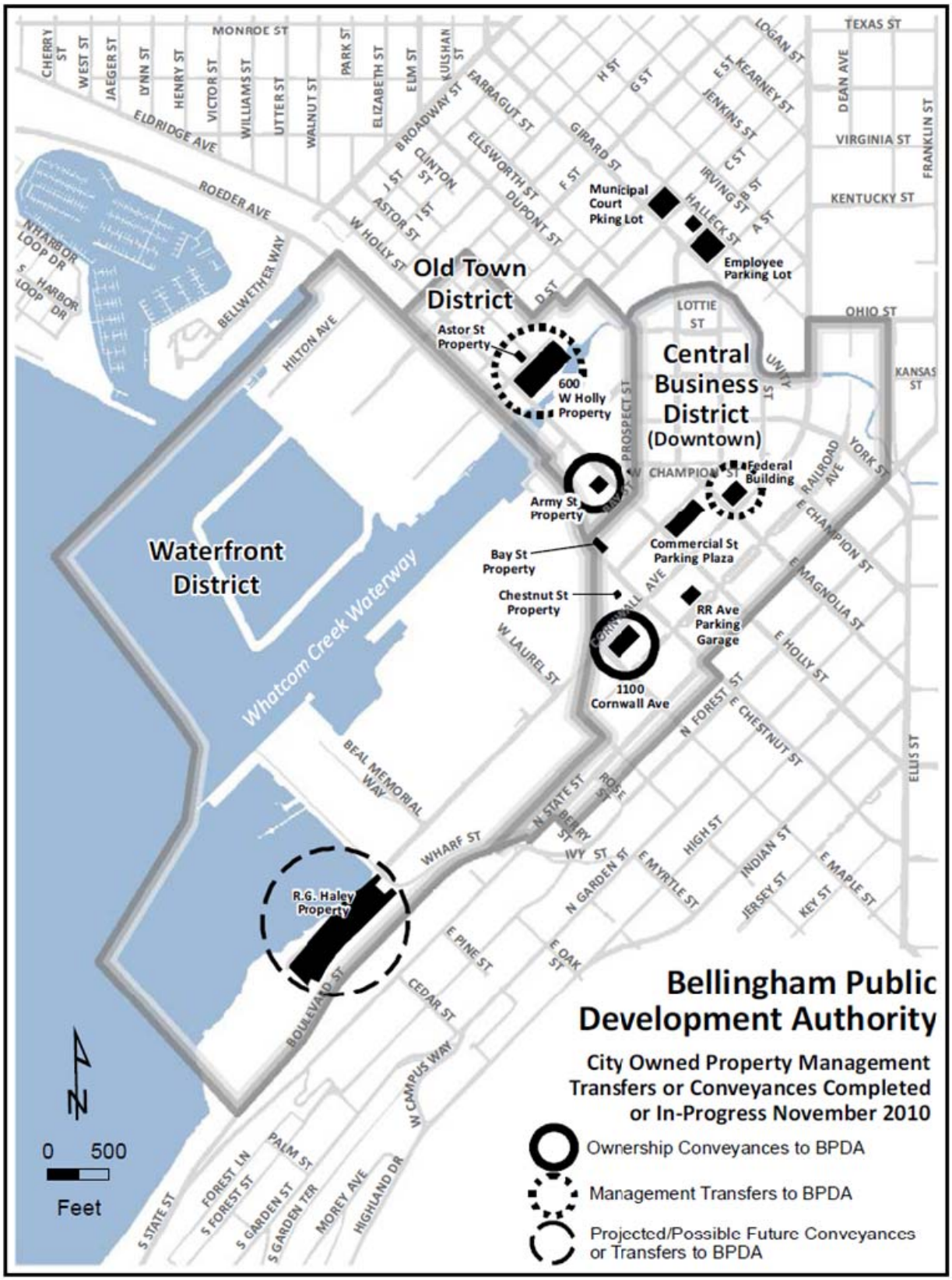
A 2007 analysis by Western Washington University estimated that full build out of the Georgia Pacific site – at a projected investment of $1 billion over 20 to 35 years – would result in between 17,250 and 23,000 job years of employment. The Port of Bellingham EIS for the Georgia Pacific site estimates that at full development, the site could be the home to as many as 7,200 jobs.[63]

To the extent that both the Port of Bellingham and PDA waterfront development projects hinge on access to the waterfront, increased train traffic that reduces access and/or safety (real or perceived) could reduce development potential if current access issues are not addressed. Prospective developers of the waterfront site – or investors – may be discouraged by the fact that there is even a pending proposal to increase rail traffic and further limit access.

62 It is important to note that the FEIS assumes the relocation, but the relocation itself would be subject to a separate permitting and environmental review process that would be undertaken by BNSF and Washington State DOT.

63 As is the case with the development of GPT, some of these jobs – as well as some of the resulting tax and other economic benefits – would go outside of Whatcom County.

Bellingham PDA City Project Map



Impact on Tourism and the Ability to Attract New Residents

In addition to the impact on baseline growth, GPT development and operation could also impose risk by reducing the likelihood of significant growth related to tourism opportunities, as well as the ability to attract new residents and jobs to Bellingham and Whatcom County.

Bellingham and Whatcom County Tourism (Tourism) actively markets the region's natural resources and amenities to attract visitors. According to a recent report commissioned by Tourism, total spending by visitors to the County increased each year since 2000, reaching $460 million in 2008.[64] The report also indicated that "the largest age segment of the primary market will continue to be relatively young people, indicating the importance of attracting families and young, active visitors."[65] Additionally, it suggested that Canadians are likely to continue to represent an important target market – dependent upon exchange rates and border crossing ability.

The study indicated that most visitors to Bellingham and Whatcom County fit the following categories:

- Return visitors
- Relatively high incomes (over 50 percent of all visitors have family incomes of at least $75,000)
- Almost 70 percent of visitors to Bellingham and Whatcom County possess a bachelor's degree or graduate degree

Four out of five visitors to Whatcom County traveled through Bellingham. While in and around Bellingham, visitors found Chuckanut Drive and Boulevard Park among the top attractions. Additionally, the study suggested that activities such as visiting downtown Bellingham (especially among first-time visitors), dining, shopping, hiking, and attending fairs are popular with visitors to the region. The highest rated quality of the County and City by visitors was its physical environment, as well as its parks, scenic areas, and recreational trails.[66]

The report concluded that the ambiance of downtown Bellingham and Fairhaven was a particularly important draw.[67] Similarly, the County's waterfront attractions and attributes, outdoor recreation activities, and natural beauty and environment were critical components of its tourism attraction.

The same attributes that appear to be driving increases in tourism may also be contributing to the attraction of Whatcom County and Bellingham to new residents who are bringing higher levels of education attainment and income. The County has attracted residents who migrate with higher AGIs than those who leave the County: migration between 2004 and 2010 resulted in an aggregate net increase of approximately $172.3 million in AGI. Similarly, the County has a higher number of residents who commute outside of the County and earn higher wages than those who commute into the County (and earn lower wages). Home prices remain high when compared to income, and individuals with higher education attainment levels are locating in Whatcom County despite lower wages and income. The choice of living in the County or City is worth something to individuals and they appear willing to pay for the region's location, lifestyle, and geography.

64 Dean Runyan Associates. Bellingham and Whatcom County Tourism Analysis, p. 14.

65 Runyan Associates, p. 11.

66 Runyan, p. 43.

67 Runyan, p. 53.

Beyond the risk of an impact on baseline growth, GPT's development and operation could have a risk of jeopardizing growth in tourism and in-migration of skilled workers and entrepreneurs because of its effect on the building brand of Whatcom County, particularly Bellingham. Both tourism and the in-migration attraction are based in part on the perception of the area as environmentally conscious. Currently, the region is seen as a green, clean, and socially responsible area. The region's view of itself as socially responsible and environmentally oriented is likely a leading reason why the Bellingham/Whatcom Chamber of Commerce will place an emphasis on the triple bottom line (TBL) with a focus on profit, people (i.e. social responsibility), and planet (environmental responsibility).[68] To the extent that GPT changes current residents' experiences with lifestyle characteristics they value, out-migration (particularly among those in the mobile class of skilled workers and entrepreneurs) could be a risk to the region.

The risk exists, in part, because the principal freight to be transported to GPT is coal. To the extent that the perception of Bellingham and Whatcom County as "clean and green" wanes, it could put potential gains in tourism and in-migration of skilled workers and entrepreneurs at risk.

Quantifying the Risk

Researchers suggest that "decisions are said to be risky because the outcome following a choice may result in a potential loss, including lost opportunities or sub-optimal outcomes."[69] Intuition and/or ad-hoc decisions where risk is present are unlikely to result in the best outcomes for decision makers; especially where decision makers hold the public trust. As a result, a focus on understanding the decision and its potential impacts – pro and con – is critical to develop a sophisticated understanding of the decision.

While it is possible that none of the risks identified in the prior section will be realized, a plausible case exists that the three scenarios outlined, in fact, pose some level of risk.

We do not attempt to quantify a specific level of risk. Instead, we know that if baseline growth rates are in fact reduced to a certain level as a result of GPT, the effect will be that the economic benefits of development and operation of the terminal will be more than offset by those lost opportunities. In other words, we can determine what level of risk would be sufficient to preclude any net economic benefit to Whatcom County.

Our analysis of risk makes a series of assumptions – each of which is uncertain. First, we assume that GPT will produce the level of economic benefits projected by PIT. Given the difference in projections from Martin Associates and FRMC, it is possible that those projections are too high or too low. Second, we assume that the baseline growth projections established by the state will be achieved. Again, these projections could be too low or too high. Third, we assume that project construction will not begin until 2015. As previously noted, it seems likely that the EIS process will not be concluded prior to 2016. Fourth, we base our analysis solely on the construction and operation of Phase I of the terminal. SSA (PIT) has indicated that they are prepared to proceed with construction of Phase I and Phase II would await additional throughput commitments. At this point, Phase II economic benefits seem more speculative. Finally, for purposes of this analysis, we assume that job years associated with construction will be equally divided over a two year period.

Our analysis examines two time horizons. The first is a 10 year time horizon beginning in 2012. Under this analysis, GPT development would not create any jobs until its fourth year. At the same time, while the proposal was pending, it could have an effect on other potential job

68 From discussions with Ken Oplinger, CEO/President – Bellingham/Whatcom Chamber of Commerce.

69 Martin T. Schultz, Kenneth N. Mitchell, Brian K. Harper, and Todd S. Bridges, "Decision Making Under Uncertainty, US Army Corps of Engineers", Washington, DC, November 2010, p. 1.

growth. The second analysis is a 10 year time horizon that begins in 2015, the assumed year that construction would begin.

Without the development of GPT, by 2021, the current projections indicate that Whatcom County's employment will increase from its 2010 level by 14,969, or 20.4 percent. By comparison, from 2000 to 2010, employment in the County grew by 11,510, or 18.6 percent. Over the next 10 years, total projected GPT related employment will equal 11,509 job years. Over the same period, the County's projected baseline employment gains (absent GPT) are equal to 67,653 job years. By comparison, from 2000-2010 factoring in both recessions, there was an increase of 86,630 jobs years in Whatcom County.[70]

The project team also compared the projected trajectory of Whatcom County's employment and that of GPT from 2015-2024 (assuming construction begins in 2015). In this time frame, without the development of GPT, it is projected that employment will grow in Whatcom County by 13,603, or 15.4 percent. Over the same period, the total projected GPT-related employment would equal 14,110 job years. By 2024, baseline employment gains in Whatcom County would equal 107,597 job years.

Thus, to the extent that development and operation of GPT would reduce baseline employment gains by less than 17 percent (between 2012 and 2021) or less than 13 percent (between 2015 and 2024), it would produce net gains in employment for Whatcom County. If, however, based on the scenarios outlined above – or for other reasons – development and operation of Phase I of GPT would result in the loss of more than 17 percent (between 2012 and 2021) or more than 13 percent (between 2015 and 2024) of baseline growth, it would have a net negative impact on the Whatcom County economy. Said another way, even if all of the PIT assumptions are accepted, there is a possibility that the development of GPT may have a negative net impact on the Whatcom County economy.

70 It is possible to have less job growth and more job years because growth focuses on point in time comparisons, while the job years analysis takes into account higher employment numbers during the period.

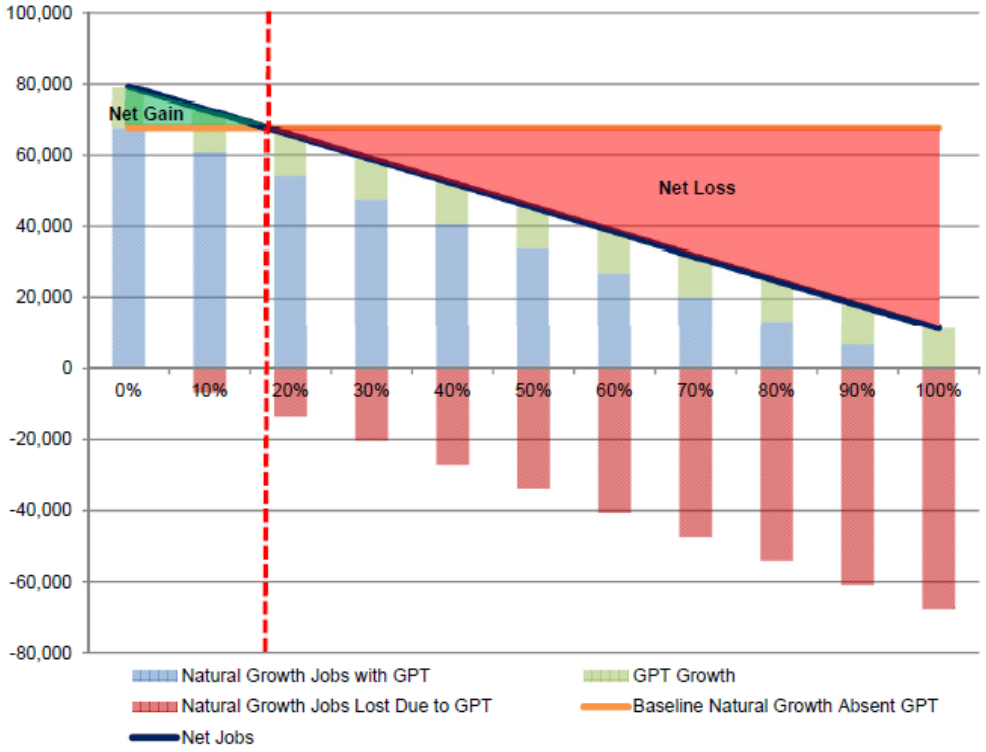
Whatcom County Natural Trajectory Job Years and GPT Projected Job Years (2012-2021)

GPT Jobs Years Created by 2021	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Direct Jobs											
Temporary Construction	0	0	0	1,715	1,715	0	0	0	0	0	**3,430**
Permanent Operations	0	0	0	0	0	294	294	294	294	294	**1,470**
Indirect Induced Jobs											
Temporary Construction	0	0	0	1,872	1,872	0	0	0	0	0	**3,744**
Permanent Operations	0	0	0	0	0	573	573	573	573	573	**2,865**
Total Direct, Indirect Induced Jobs											
Temporary Construction	0	0	0	3,587	3,587	0	0	0	0	0	**7,174**
Permanent Operations	0	0	0	0	0	867	867	867	867	867	**4,335**
Grand Total											**11,509**
Job Years Created Absent GPT	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
Whatcom County	1,135	2,286	3,455	4,721	6,006	7,313	8,640	9,988	11,359	12,750	**67,653**

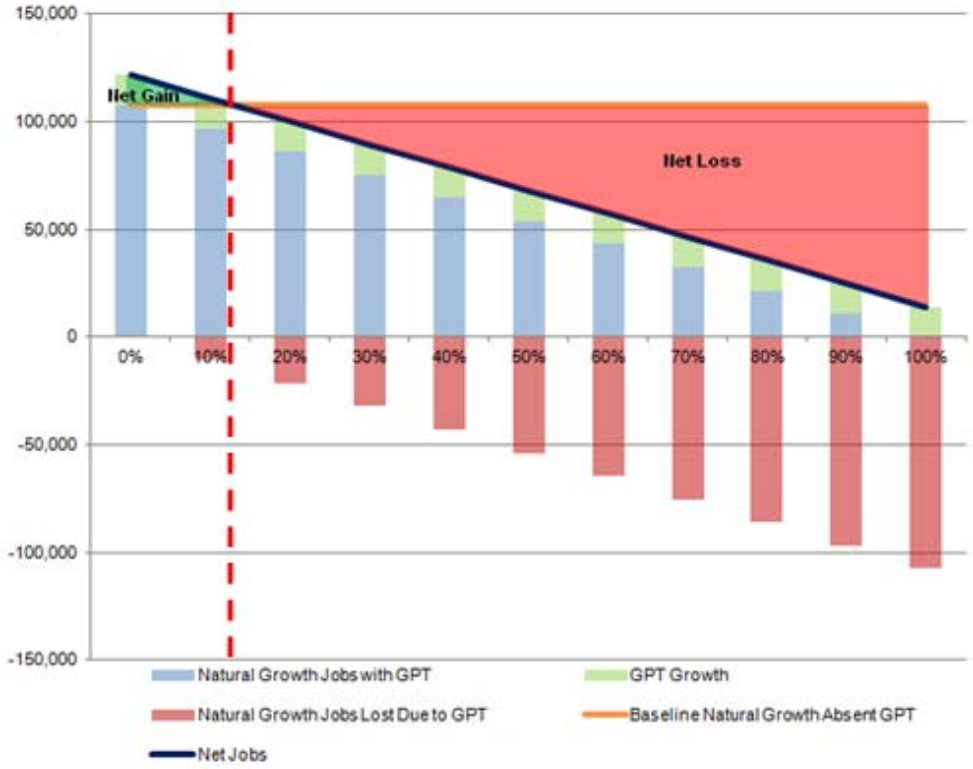
Whatcom County Natural Trajectory Job Years and GPT Projected Job Years (2015-2024)

GPT Job Years Created by 2024	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Jobs											
Temporary Construction	1,715	1,715	0	0	0	0	0	0	0	0	**3,430**
Permanent Operations	0	0	294	294	294	294	294	294	294	294	**2,352**
Indirect Induced Jobs											
Temporary Construction	1,872	1,872	0	0	0	0	0	0	0	0	**3,744**
Permanent Operations	0	0	573	573	573	573	573	573	573	573	**4,584**
Total Direct, Indirect Induced Jobs											
Temporary Construction	3,587	3,587	0	0	0	0	0	0	0	0	**7,174**
Permanent Operations	0	0	867	867	867	867	867	867	867	867	**6,936**
Grand Total											**14,110**
Job Years Created Absent GPT	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Whatcom County	4,721	6,006	7,313	8,640	9,988	11,359	12,750	14,163	15,599	17,058	**107,597**

From 2012-2021, if development of GPT reduces otherwise projected job growth by more than 17□, the project will be a net loss.



From 2015-2024, if development of GPT reduces otherwise projected job growth by more than 13□, the project will be a net loss.



VI. Understanding and Managing the Risk

Some have suggested, that to the extent most of the risk involved with the development of GPT is related to the increased rail traffic to the site, other developments could lead to the same level of risk without the same level of benefits.

The project team heard from several entities that indicated if GPT is not located at Cherry Point, coal could be shipped by rail through Whatcom County to ports in British Columbia. If this occurred, the region would still have the rail traffic, but none of the economic benefits associated with the development and operation of GPT. At this time, there is not sufficient evidence to support the claim that if GPT is not located at Cherry Point, the same magnitude of coal-related train traffic as caused by GPT would occur as a result of coal delivery to ports in British Columbia.[71]

In 2007, approximately 90 percent of Canada's coal exports were shipped through terminals in British Columbia.[72] The main coal export locations in British Columbia are Prince Rupert[73] (Ridley), which accounts for approximately 20 percent of all Canadian exported coal, and Port Metro Vancouver (Neptune and Westshore), which accounts for approximately 80 percent of all Canadian exported coal.[74] Prince Rupert is likely to receive some US coal in future years, adding to its larger Canadian-based demand, to increase annual coal export capacity; though there is some concern from at least one US coal company that shipping coal to Prince Rupert is uneconomic.[75]

Still, expansion of shipments of U.S. coal to Canada will depend upon the capacity of both the ports and rail. Westshore does not currently have plans to expand its physical footprint but has made operational and equipment adjustments to add incremental capacity. According to Washington DOT information and its Marine Cargo Forecast, rail capacity for the BNSF rail line along coastal Whatcom County (and Bellingham) has a capacity for 18 trains per day currently, and 30 trains per day by 2028. Additionally, a factor affecting capacity is that BNSF has performance and on-time agreements with Washington DOT (and Amtrak) to provide passenger rail service on the *Cascade* line.

While there is clearly an increase in demand for coal in Asia particularly China any additional cost related to transportation could tip the competitive advantage to other sources. More of China s demand for coal could be met domestically. According to the US Energy Information Administration's (EIA) 2011 International Energy Outlook, China has the ability to meet "substantial portions of their future coal demand with domestic production."[76] According to the EIA, China's domestic production of coal is expected to grow from 70.5 quadrillion Btu to 107.6 quadrillion Btu in 2035. Over the same time frame, US coal production is projected to increase from 22.6 quadrillion Btu to 26.5 quadrillion Btu.

Australia and New Zealand are both expected to become larger exporters of coal, increasing production from 10.1 quadrillion Btus in 2010 to 15.6 quadrillion Btus by 2035. Peabody, which has contracted with SSA for shipment of coal through GPT, has invested heavily in Australia - recently purchasing assets belong to Macarthur Coal for a reported 5.1 billion. Peabody

71 Requests for such information were made to SSA representatives.

72 British Columbia Ministry of Energy, Mines and Petroleum Resources. 2010 Coal Resources in British Columbia: Opportunities, Logistics and Infrastructure, p. 15.

73 Ridley Terminals Inc. is owned by the Canadian government.

74 Canadian Minerals Yearbook -- 2009.

75 Ridley Terminals, Inc. 2010 Annual Report: Building On A Strong Foundation, p. 9. In its 2011 Fourth Quarter and Full Year Highlights, Cloud Peak Energy, Inc. a large Powder River Basin coal producer indicated that it had no additional shipments planned through Ridley because it was uneconomic.

76 US Energy Information Administration (EIA), 2011 International Energy Outlook, p. 69.

executives recently indicated that Australian mines are expected to supply roughly half of the growth in global coal exports in 2012, driven by demand in China and India.[77]

It is also possible that some U.S. coal could be shipped through ports that would not affect rail traffic in Whatcom County such as ports on the Gulf of Mexico. For instance, Arch Coal recently signed a deal with Kinder Morgan Energy Partners LP to ship PRB coal from its Gulf ports and is in talks to ship additional coal from Kinder Morgan s east coast ports.[78]

Some of the risks to economic development posed by the development and operation of GPT can be managed. Plans for the redevelopment of the Georgia Pacific site already call for moving the existing BNSF tracks and for a series of projects that would eliminate grade crossings. The Army Street Project, the first step in the proposed redevelopment by PDA, calls for a design that specifically addresses the issue of rail traffic by bridging over existing tracks.

To the extent that noise and access issues are addressed,[79] the risks related to limitation on other economic growth can be reduced. It may not be possible to limit risks related to image or reputation and their potential impact on tourism and attraction of in-migration among the mobile class of skilled workers and entrepreneurs resulting from the proximity to GPT.

Risk management, however, comes at a cost. While some might argue that investments related to rail were already planned, the potential of the GPT development would clearly increase the need to act. The question then becomes who would pay and whether local governments and residents should be asked to bear the cost of risk management.

In the absence of risk management, decision makers need to determine how much risk they are willing to tolerate. If our analysis indicated that it would require the loss of 90 percent of projected baseline job growth for the GPT project to produce net negative employment impact, it would be relatively clear that the risk was relatively low. Similarly, if our analysis suggested that a loss of just 1 percent of projected baseline job growth would offset any benefits of GPT, it would be fairly clear that the risk was relatively high.

As noted earlier, different decision makers can look at our findings and reach different, yet valid conclusions. The important thing is that they weigh the risk and understand the need to manage it.

77 Steve James, Peabody profit misses estimate, sees U.S. coal slump. *Reuters*. January 24, 2012.

78 Jeremy Fugleberg, Powder River Basin coal to ship from Gulf Coast, Casper Star-Tribune. February 12, 2012.

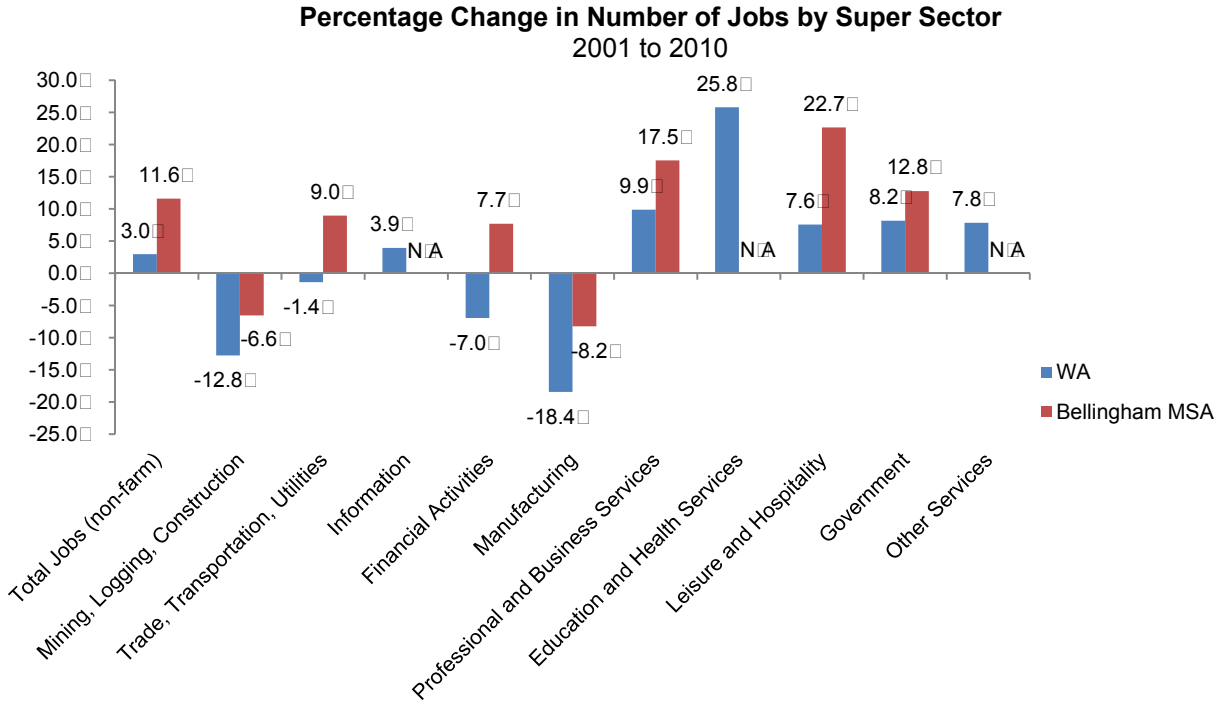
79 It should be noted that some noise problems can be mitigated (i.e. horn noise, crossings, etc.), but vibrations, rail screeches, and other likely occurrences of rail traffic cannot be fully mitigated.

Appendices: Whatcom County and Bellingham Economy

Appendix A: Employment and Unemployment

From 2001 to 2010, the Bellingham MSA's rate of job growth was almost four times the state rate. The Bellingham MSA (Whatcom County) added 8,100 non-farm jobs – an 11.6 percent increase. Statewide, non-farm jobs grew by 3.0 percent.

Compared to the state, the Bellingham MSA grew jobs at a greater percentage or shed jobs at a smaller percentage for every super-sector for which data were available.[80]



Source: BLS CES Data – Not Seasonally Adjusted

The super-sectors with the largest increase in number of jobs in the MSA were:

- Education and Health Services (1,900 jobs)[81]
- Government (1,800 jobs)[82]

80 Those super sectors for which data are available accounted for the growth of 4,800 of the 8,100 jobs from 2001 to 2010. While data from the CES database are not available individually for all super sectors, calculations indicate the missing super sectors accounted for 12,000 jobs in 2001 and 15,300 jobs in 2010. Given the composition of Bellingham and Whatcom County's economy, it could be argued that, of the super sectors that are not available at the Bellingham MSA level (and for the City of Bellingham in particular), education and health services sector was the most likely to be driving the significant increase in jobs during the 2001 to 2010 time period. The most recent BLS Occupational Employment Statistic (OES) data available for the Bellingham MSA estimated there were approximately 73,420 jobs in the Bellingham MSA. OES defined jobs of these types accounted for 14.8 percent of the MSA's total jobs. Applying that percentage to the total estimated number of jobs in 2010, yields 11,550 jobs, or 75.5 percent of the total jobs not included in a defined super sector. From 2001 to 2010, healthcare practitioner and technical operations occupations grew by 30.5 percent and healthcare support occupations grew by 52.6 percent. If applied to the CES data, it could be estimated that the health and education sector was responsible for job growth in the range of 1,900 jobs. While combining/comparing OES data and CES data is not a perfect or even ideal method for a variety of important reasons, the process suggests there is likely support to suggest that the education and healthcare sector (particularly healthcare) was an important driver of job growth in the Bellingham MSA over the last decade.

81 Estimated – see previous analysis. Education includes jobs in private higher education institutions. Government (specifically state government) includes jobs in public higher education institutions (i.e. WWU).

- Leisure and Hospitality (1,700 jobs)
- Trade, Transportation, Utilities (1,200 jobs).

Collectively, from 2001 to 2010, the four super-sectors above accounted for 81.5 percent of the total job growth in the Bellingham MSA. The education and health services super-sector grew at an estimated 20.5 percent from 2001 to 2010.

By comparison, the super-sectors with the largest increase in number of jobs at the state level were:

- Education and Health Services (76,900 jobs)
- Government (41,300 jobs)
- Professional and Business Services (29,300 jobs)
- Leisure and Hospitality (18,700 jobs).

The project team met with several individuals and groups that suggested public sector growth was responsible for the majority of the increase in jobs in Whatcom County. The data suggest that while local government in the MSA added a greater percentage of jobs than the state average for local government, the likely increase in education and health services, leisure and hospitality produced more total jobs than the growth in government. Similarly, job growth in the Bellingham MSA exceeded statewide growth across all super sectors. Even where it lost jobs, the Bellingham MSA losses were at a lower rate than statewide.

For example, Bellingham's role as the regional retail center for the MSA was likely a significant driver behind the MSA's retail trade job growth of 9.0 percent from 2001 to 2010 – significantly greater than the Statewide experience in which jobs declined by 1.3 percent over the same time period.

Given the overall trend for the Bellingham MSA as compared to the State, government employment contributed to the growth, but was among many drivers – and not the sole driver – to affect job increases in the region. Even if there had been no increase in government jobs from 2001 to 2010, the Bellingham MSA would have still added jobs and added them at a rate approaching three-times greater than the rate of statewide job growth.

82 The project team received information that suggested the 600 job increase in Federal government jobs was primarily due to increased border security post September 11, 2001.

Job Changes by Super Sector
2001 to 2010

Sector	WA			Bellingham MSA	
	Jobs	Jobs Chg		Jobs	Jobs Chg
Total Jobs (non-farm)	**80,400**	**3.0**		**8,100**	**11.6**
Mining, Logging, Construction	**(21,500)**	**-12.8**		**(400)**	**-6.6**
Mining and Logging	*(3,900)*	*-39.8%*			
Construction	*(17,600)*	*-11.1%*			
Trade, Transportation, Utilities	**(7,200)**	**-1.4**		**1,200**	**9.0**
Wholesale Trade	*1,200*	*1.0%*			
Retail Trade	*(4,200)*	*-1.3%*		*800*	*8.9%*
Transportation and Utilities	*(4,100)*	*-4.4%*			
Information	**3,900**	**3.9**			
Financial Activities	**(10,100)**	**-7.0**		**200**	**7.7**
Finance and Insurance	*(8,400)*	*-8.6%*			
Real Estate and Rental and Leasing	*(1,600)*	*-3.4%*			
Manufacturing	**(58,300)**	**-18.4**		**(700)**	**-8.2**
Professional and Business Services	**29,300**	**9.9**		**1,000**	**17.5**
Professional, Scientific, and Technical Services	*18,800*	*13.2%*			
Management of Companies and Enterprises	*1,900*	*6.4%*			
Administrative and Support and Waste Mgmt and Remediation Services	*8,500*	*6.8%*			
Education and Health Services	**76,900**	**25.8**			
Educational Services	*9,200*	*23.1%*			
Health Care and Social Assistance	*67,500*	*26.1%*			
Leisure and Hospitality	**18,700**	**7.6**		**1,700**	**22.7**
Arts, Entertainment, and Recreation	*4,300*	*10.6%*			
Accommodation and Food Services	*14,300*	*6.9%*			
Government	**41,300**	**8.2**		**1,800**	**12.8**
Federal Government	*7,600*	*11.2%*		*600*	*66.7%*
State Government	*4,500*	*3.1%*		*(200)*	*-3.8%*
Local Government	*29,200*	*9.9%*		*1,300*	*16.0%*
Other Services	**7,600**	**7.8**			

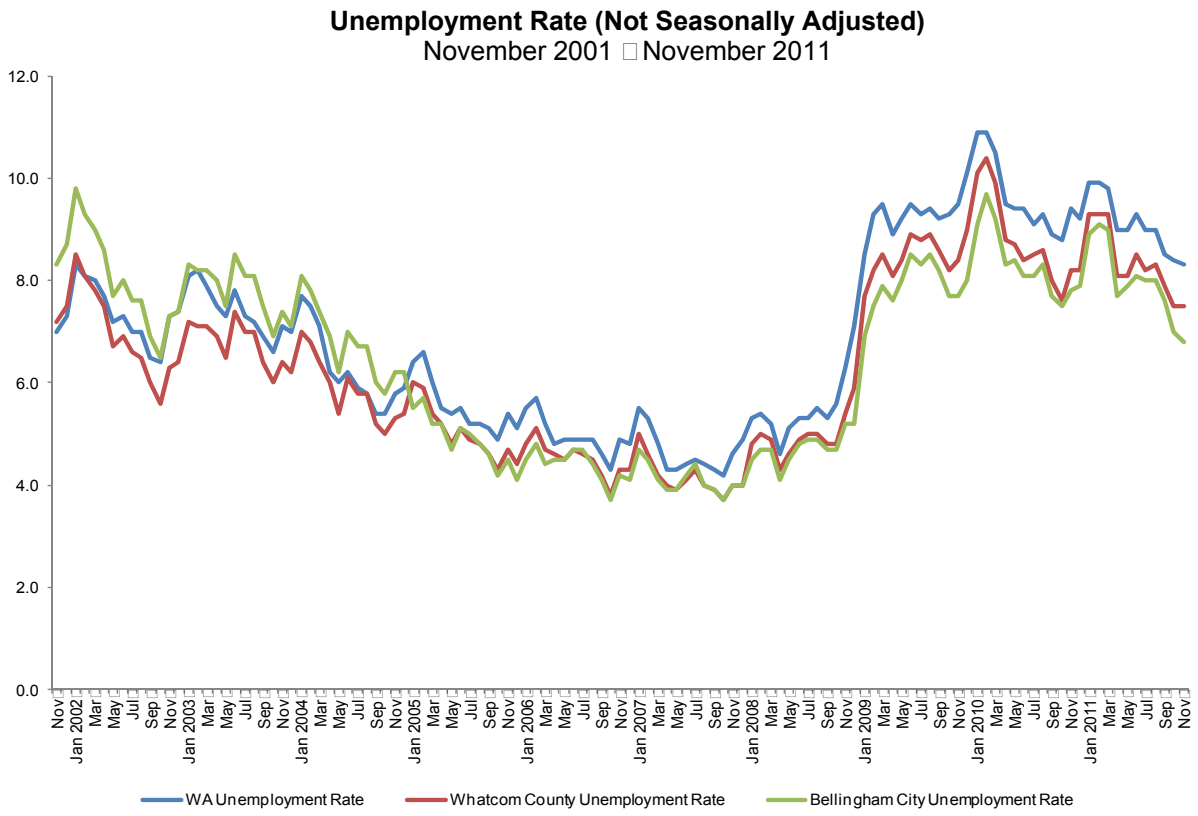
Note: totals may not sum due to rounding

Source: BLS - Current Employment Statistics - Not Seasonally Adjusted

Unemployment

As the graph below shows, since 2005, Bellingham's unemployment rate has been nearly equal or slightly less than Whatcom County's unemployment rate and consistently below the State's unemployment rate.[83]

83 US Bureau of Labor Statistics – Local Area Unemployment Statistics (LAUS), November 2001 – November 2011, Not seasonally adjusted data.


Unemployment Rate (Not Seasonally Adjusted)
November 2001 - November 2011
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Nov
Jan 2002
Mar
May
Jul
Sep
Nov
Jan 2003
Mar
May
Jul
Sep
Nov
Jan 2004
Mar
May
Jul
Sep
Nov
Jan 2005
Mar
May
Jul
Sep
Nov
Jan 2006
Mar
May
Jul
Sep
Nov
Jan 2007
Mar
May
Jul
Sep
Nov
Jan 2008
Mar
May
Jul
Sep
Nov
Jan 2009
Mar
May
Jul
Sep
Nov
Jan 2010
Mar
May
Jul
Sep
Nov
Jan 2011
Mar
May
Jul
Sep
Nov
WA Unemployment Rate
Whatcom County Unemployment Rate
Bellingham City Unemployment Rate

Appendix B: Population Growth

From 2000 to 2010, Bellingham and Whatcom County both grew in population by slightly more than 20 percent; greater than the State's growth rate of just over 14 percent.[84] The US Census Bureau reported Bellingham's 2010 population as 80,885, an increase of 13,714 individuals from the 2000 Census.[85] Whatcom County's 2010 population of 201,140 represented an increase of 34,326 from the 2000 Census.

Much of the population growth in both Bellingham and Whatcom County was attributable to increases in the number of residents between the ages of 20-39 and those between the ages of 50-69. These two age groups accounted for 84.0 percent of all population growth in Bellingham and 78.1 percent of all population growth in Whatcom County – statewide, these two age groups accounted for 86.9 percent of the State's net population growth.

Examining the data by 10-year age bands shows that there were several notable differences in the population changes experienced by Bellingham, Whatcom County, and Washington. For example, the number of residents between the ages 30 and 39 declined statewide by 2.1 percent and in the parts of Whatcom County outside of Bellingham by 0.3 percent: in Bellingham, the number of residents between 30 and 39 increased by 13.5 percent. While the number of 60-69 year old residents increased statewide by more than two-thirds, population in that age range nearly doubled in Bellingham and grew by more than 90 percent in the non-Bellingham parts of Whatcom County.

84 US Census Bureau 2000 and 2010 Decennial Census Data. Bellingham's population grew by 20.4 percent, Whatcom County's population grew by 20.6 percent, and Washington's population grew by 14.1 percent.

85 According to Bellingham's Planning – Community Development Department, annexations that occurred in Bellingham between 2000 and 2010 accounted for a population increase of 1,216 residents.

Population Change from 2000 to 2010

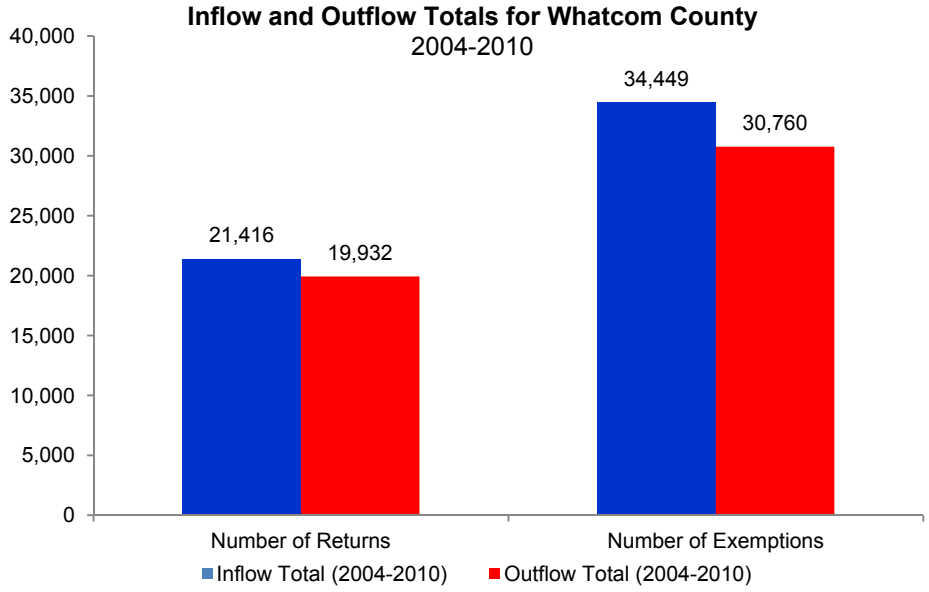
Total Population	WA 2010 vs 2000 (#)	WA 2010 vs 2000 (%)	Whatcom County 2010 vs 2000 (#)	Whatcom County 2010 vs 2000 (%)	Bellingham 2010 vs 2000 (#)	Bellingham 2010 vs 2000 (%)	Non-Bellingham 2010 vs 2000 (#)	Non-Bellingham 2010 vs 2000 (%)
Total Population	**830,419**	**14.1%**	**34,326**	**20.6%**	**13,714**	**20.4%**	**20,612**	**20.7%**
Total Population Under Age 10	49,319	6.0%	1,080	5.0%	482	7.2%	598	4.0%
Total Population Age 10-19	37,557	4.4%	2,311	9.0%	993	10.4%	1,318	8.2%
Total Population Age 20-29	148,073	18.7%	6,849	25.0%	4,256	25.1%	2,593	24.7%
Total Population Age 30-39	(19,438)	-2.1%	1,092	4.8%	1,133	13.5%	(41)	-0.3%
Total Population Age 40-49	7,247	0.8%	544	2.1%	(119)	-1.4%	663	4.0%
Total Population Age 50-59	271,120	40.0%	8,653	45.6%	2,548	38.6%	6,105	49.3%
Total Population Age 60-69	265,261	68.5%	10,212	93.8%	3,585	99.5%	6,627	91.0%
Total Population Age 70-79	25,165	8.3%	1,518	17.0%	67	1.8%	1,451	27.6%
Total Population Age 80 and Over	46,115	25.3%	2,067	38.7%	769	26.1%	1,298	54.1%
					0			
Population Age 60 and Over	336,541	38.5%	13,797	54.8%	4,421	43.2%	9,376	62.8%
Population Age 65 and Over	165,529	25.0%	7,240	37.3%	2,027	24.3%	5,213	47.2%
Population Age 70 and Over	71,280	14.7%	3,585	25.1%	836	12.6%	2,749	35.9%
Population Age 75 and Over	45,475	14.0%	2,405	25.1%	631	13.1%	1,774	37.4%

Working Age (25-64) Population Change from 2000 to 2010

Working Age Population	WA 2010 vs 2000 (#)	WA 2010 vs 2000 (%)	Whatcom County 2010 vs 2000 (#)	Whatcom County 2010 vs 2000 (%)	Bellingham 2010 vs 2000 (#)	Bellingham 2010 vs 2000 (%)	Non-Bellingham 2010 vs 2000 (#)	Non-Bellingham 2010 vs 2000 (%)
Total Population 25-64	506,687	16.0%	20,194	24.2%	7,880	25.5%	12,314	23.5%
Total Population Age 25-29	76,746	19.0%	3,348	31.4%	1,924	36.0%	1,424	26.7%
Total Population Age 30-34	15,905	3.6%	1,392	12.9%	853	20.0%	539	8.3%
Total Population Age 35-44	(66,782)	-6.8%	(423)	-1.7%	435	5.3%	(858)	-5.3%
Total Population Age 45-54	142,233	16.8%	3,311	13.8%	75	0.9%	3,236	21.1%
Total Population Age 55-59	167,573	58.7%	6,009	76.9%	2,199	85.1%	3,810	72.8%
Total Population Age 60-61	72,128	79.9%	2,783	114.9%	1,074	137.5%	1,709	104.1%
Total Population Age 62-64	98,884	81.9%	3,774	112.4%	1,320	120.0%	2,454	108.7%

Population Growth – Migration

IRS migration data for tax years 2004 through 2010 suggest the important role that migration played in the County's population growth.[86] The data show that Whatcom County experienced a greater amount of population inflow than population outflow during the years reviewed. The chart below displays the total number of income tax returns and the associated number of exemptions for those moving to and moving from Whatcom County.



The large majority of inflow to Whatcom County (68.7 percent) was from other Washington counties. Specifically, based upon the number of returns, King County (4,092 returns), Snohomish County (2,377 returns), and Skagit County (2,340 returns) accounted for 41.1 percent of all inflow, and 59.9 percent of all intra-state inflow, to Whatcom County from 2004-2010.

The remaining 31.3 percent of inflow was attributable to migration from 19 states and other countries. Former Californians represented 12.6 percent of total migration to Whatcom County (2,694 returns) and 40.2 percent of inflow from states excluding Washington. Within California, Los Angeles County (537 returns), San Diego County (435 returns), and Orange County (291 returns) represented 46.9 percent of all inflow from the State. Oregon was the next most popular previous state of residence for new Whatcom residents with 801 former citizens migrating to the County. Multnomah County (281 returns), Lane County (148 returns), and Washington County (134 returns) comprised the majority of the inflow from Oregon. Residents abroad—those moving from other countries (736 returns) and former Arizona residents (571 returns accounted for the next two most popular location of residence prior to moving to Whatcom County.[87]

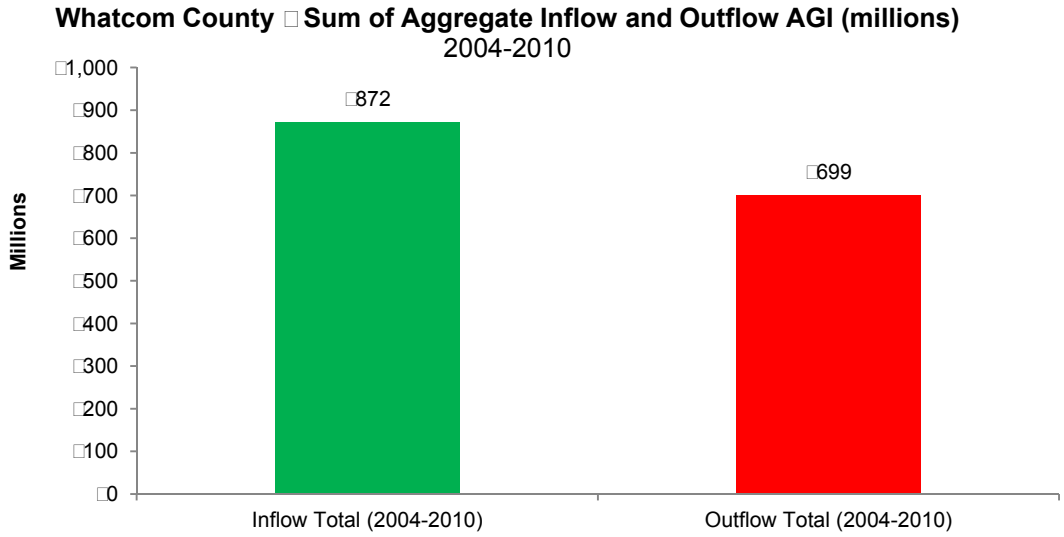
86 Bellingham and Whatcom County each experienced significant population growth from 2000 to 2010. The project team explored Internal Revenue Service (IRS) migration data to obtain a greater understanding of the previous location of newcomers to Whatcom County. IRS migration data is available on a County-to-County level and is based upon year-to-year address changes reported on individual income tax returns filed with the IRS. The data track inflows and outflows and where residents went.

The IRS defines inflows as "the number of new residents who move to a county or state." Outflows are defined as "the number of residents leaving a county or state." The IRS data report both the location of origin and the new location. The IRS notes that the data represent between 95 and 98 percent of total annual filings (those filed prior to late September of each calendar year).

87 172 returns listed AFO/AFP addresses as previous locations and are included within the "foreign' category.

Whatcom County outflow destinations were similar to its inflow patterns. From 2004-2010, the great majority (72.8 percent) of all outflow was to other Washington counties. Similar to inflow data, King County (4,820), Snohomish County (2,316), and Skagit County (2,275) had the most returns associated with outflow data and accounted for 64.8 percent of all outflow to other Washington counties and 47.2 percent of all outflow from Whatcom County.

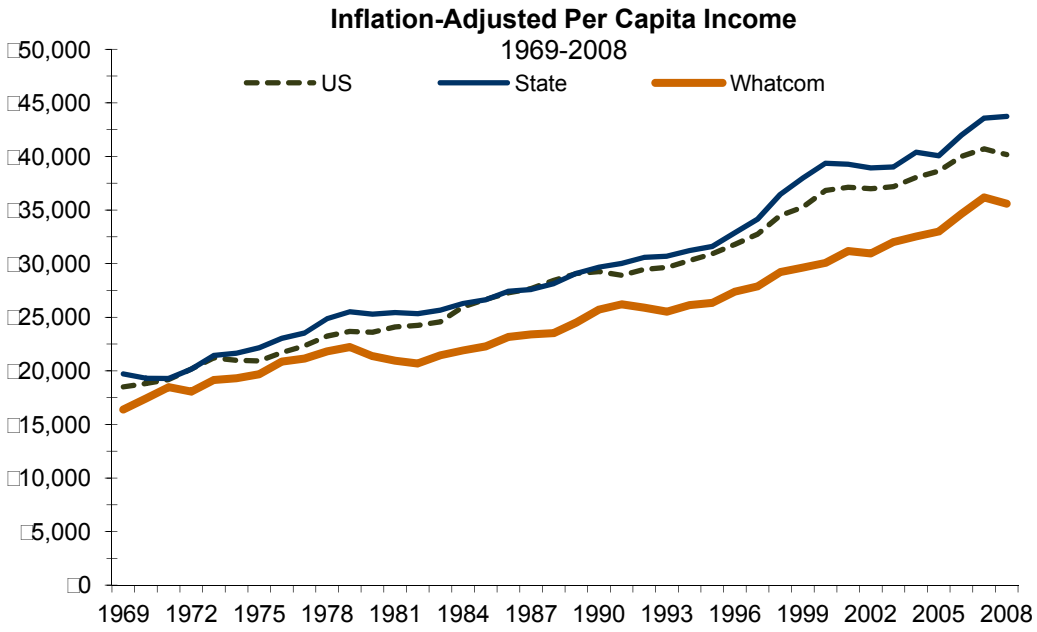
The IRS data also provide a summation of AGI from each of the jurisdictions from to which people migrated. The chart below shows that, on the whole, Whatcom County realized a net aggregate growth of over 172.3 million in AGI from migration between 2004 and 2010.



Appendix C: Income and Wages

Washington's Office of Financial Management (OFM) data indicate that Whatcom County's inflation adjusted per capita income has consistently been below both the State and US averages since 1969; the graph below shows this trend.[88] Analysis by the Washington Regional Economic Analysis Project (WA REAP), which used data published by the US Bureau of Economic Analysis (BEA), demonstrates that Whatcom County's per capita income has maintained its relative position below the State per capita income through 2009.[89]

Between 2000 and 2008, Whatcom County's per capita income grew at a compound annual growth rate (CAGR) of nearly double that of the nation and significantly greater than the State. Whatcom County's CAGR was 2.1%; US CAGR was 1.1%, and Washington's CAGR was 1.3%.



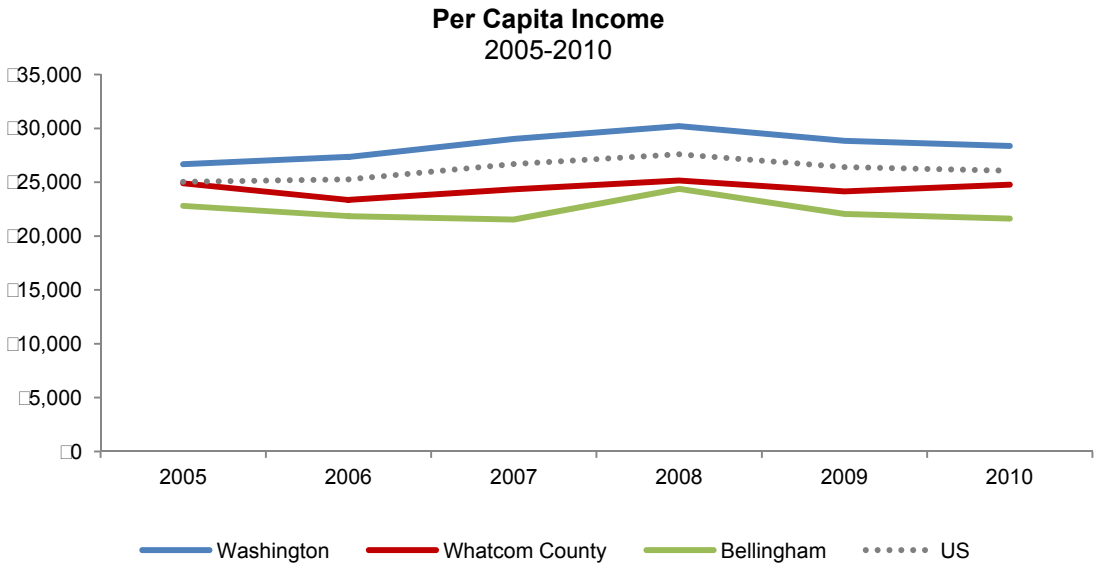
Source: WA Office of Financial Management (OFM)

Just as Whatcom County has consistently lagged the State and the national per capita income, Bellingham's per capita income has consistently lagged the per capita income of Whatcom County (and naturally the State and the nation). As of 2010, Bellingham's per capita income ($23,308) was 8.3 percent less than Whatcom County's per capita income ($25,429), 13.5 percent below US per capita income ($26,942), and 20.8 percent below the State's per capita income ($29,420).[90] Per capita income is sensitive to special populations (i.e. students, inmates, etc.) that can result in lower estimates than are experienced by the rest of the population.

88 OFM data are presented through 2007. Since 2008, Whatcom County has remained below both State and US per capita income levels according to the US Census Bureau's ACS 1-year Estimates in 2008, 2009, and 2010 and 2010 ACS 3-year Estimates data.

89 WA REAP data is available at: http://washington.reaproject.org.

90 US Census Bureau 2010 ACS 3-year Estimates data.



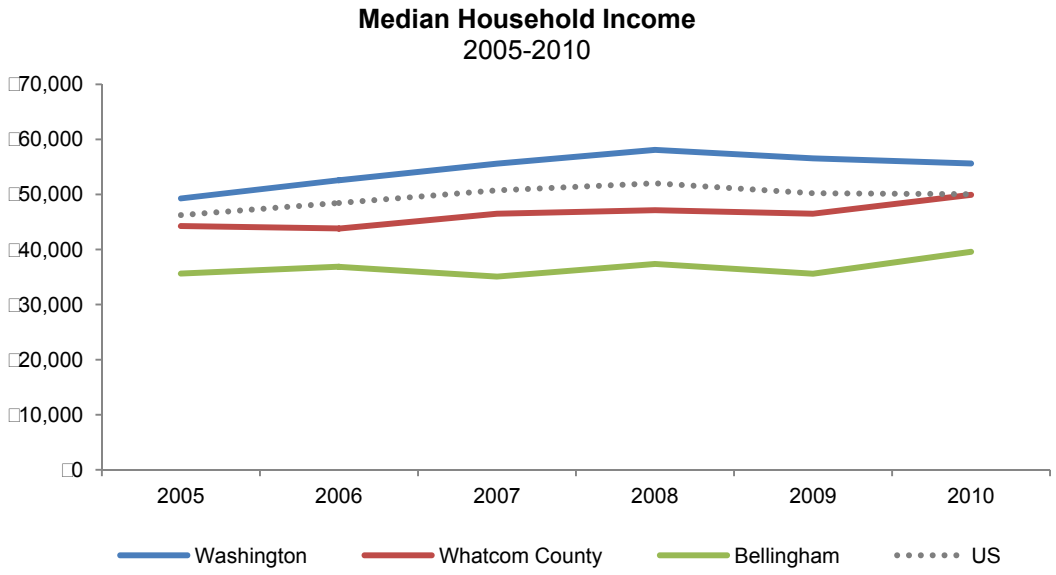
Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

Income may also be viewed at the household level.[91] Similar to per capita income, median household income can be sensitive to student-aged populations as several or many students residing in a household could lower the median household income below the experiences of the rest of the population. However, it provides a useful measure to assess the relative levels of incomes across jurisdictions.

The US Census Bureau's ACS 1-year data for 2010 indicated that Bellingham's median household income ($39,599) was less than that of Whatcom County, Washington, and the nation.[92] In 2010, Whatcom County's median household income of $49,938 was 3.3 percent above the US average ($50,046) and 7.7 percent below the State median household income ($55,631).

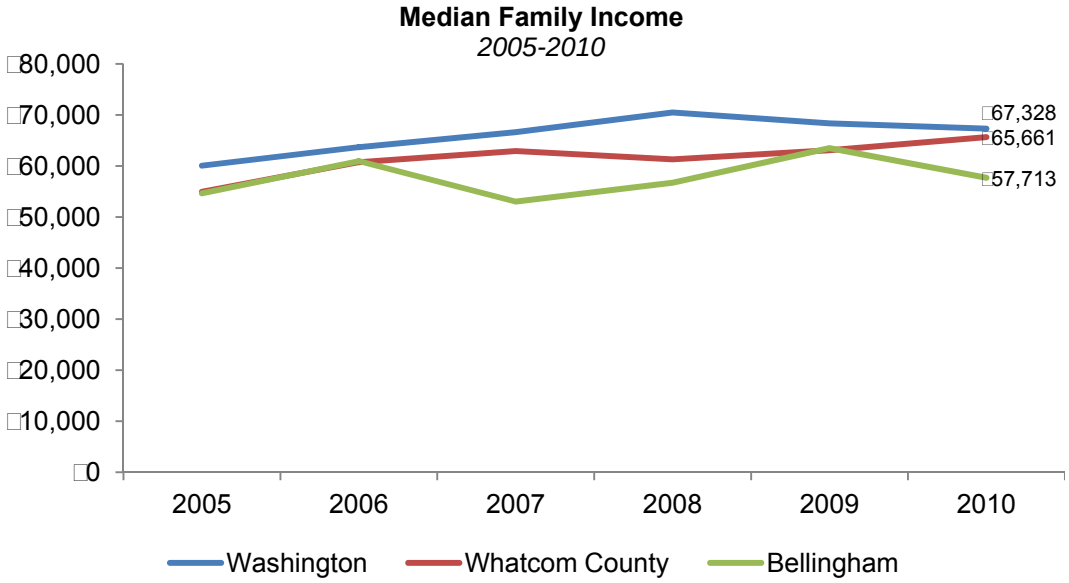
91 The US Census Bureau defines household income as including income of the householder and all other people 15 years and older in the household, whether or not they are related to the householder.

92 The project team endeavored to use US Census Bureau ACS 3-year Estimates data for the graphs on pages 23 through 25, but due to data issues experienced by the US Census Bureau, used ACS 1-year Estimates data for the charts on the aforementioned pages. The data are slightly different, but the patterns and relative rankings of the jurisdictions are largely unchanged. The primary objective of these graphs is to show relative relationships between jurisdictions and that is maintained by using the ACS 1-year Estimates data.



Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

Median family income data are less affected by student population data.[93] In four of the last six years, Bellingham's median family income was below that of Whatcom County, Washington, and the US. However, in 2006 and 2009, Bellingham's median family income was greater than both Whatcom County and the US average. Whatcom County's median family income was above the US average in four of the six years reviewed (2006-2007, 2009-2010), though it remained below the Washington state median household income in all six years.



Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

93 The US Census Bureau defines family household as a householder and one or more other people living in the same household who are related to the householder by birth, marriage, or adoption. All people in a household who are related to the householder are regarded as members of his or her family. A family household may contain people not related to the householder, but those people are not included as part of the householder's family in tabulations.

Wages

Overall, Whatcom County's average annual wage was below the State's average wage.[94] Similarly, in 18 of the 20 sectors reviewed, Whatcom County's average annual wage was below the State's average annual wage for the respective sector. In the two instances where Whatcom County had a higher average annual wage, both were less than 4.0 percent greater than the State average. In all 18 sectors where the County lagged the State average annual wage, all lagged the State average by more than 4.0 percent.

Growth industries in the Whatcom Bellingham region that were discussed earlier in this report included leisure and hospitality (accommodation and food services; arts, entertainment, and recreation), health care and social assistance, government, and retail trade. Among these growth sectors, all had an annual average wage in Whatcom County below their peers in similar sectors in the State.

94 Washington's OFM and the State's Employment Security Department (ESD) collaborate to compile median and hourly wage information for each County. Similar, but different, data are available from the BEA and WA REAP. While methodologies may vary slightly causing different results, both data sets provide quality data that are useful in reviewing income and wages. For the remainder of the income wages discussion, the project team will use data from Washington's ESD (in partnership with the BLS). Neither State nor BEA data for the full year 2011 are available as of January 10, 2012.

Whatcom County's Variance from State – 2010 Jobs and Wages by Occupation[95]

Sector	Whatcom County Percent of Total Jobs	WA Average Annual Wage	Whatcom County Average Annual Wage	2010 Difference in Average Annual Wage (–)	2010 Difference in Average Annual Wage (%)
All Industries	**100.0%**	**$48,521**	**$37,312**	**($11,209)**	**-23.1%**
Ag., forestry, fishing & hunting	3.9%	$24,034	$24,977	$943	3.9%
Mining	0.2%	$55,654	$51,050	($4,604)	-8.3%
Utilities	0.2%	$77,591	$73,842	($3,749)	-4.8%
Construction	6.2%	$51,127	$51,891	$764	1.5%
Manufacturing	9.8%	$64,925	$53,740	($11,185)	-17.2%
Wholesale trade	3.4%	$63,348	$47,072	($16,276)	-25.7%
Retail trade	12.5%	$30,021	$25,136	($4,885)	-16.3%
Transportation & warehousing	2.4%	$47,743	$37,127	($10,616)	-22.2%
Information	1.9%	$109,777	$42,615	($67,162)	-61.2%
Finance & insurance	2.4%	$70,137	$53,210	($16,927)	-24.1%
Real estate & rental & leasing	1.1%	$38,359	$27,494	($10,865)	-28.3%
Professional & technical services	3.8%	$75,376	$55,156	($20,220)	-26.8%
Mgmt. of companies & enterprises	0.6%	$95,731	$58,393	($37,338)	-39.0%
Administrative & waste services	3.8%	$41,466	$30,903	($10,563)	-25.5%
Educational services	0.9%	$35,158	$21,141	($14,017)	-39.9%
Health care & social assistance	12.4%	$44,673	$37,532	($7,141)	-16.0%
Arts, entertainment, & recreation	2.0%	$25,121	$16,078	($9,043)	-36.0%
Accommodation & food services	9.6%	$17,632	$14,482	($3,150)	-17.9%
Other services, ex. public admin.	4.4%	$24,227	$22,808	($1,419)	-5.9%
Government	18.4%	$51,394	$45,430	($5,964)	-11.6%

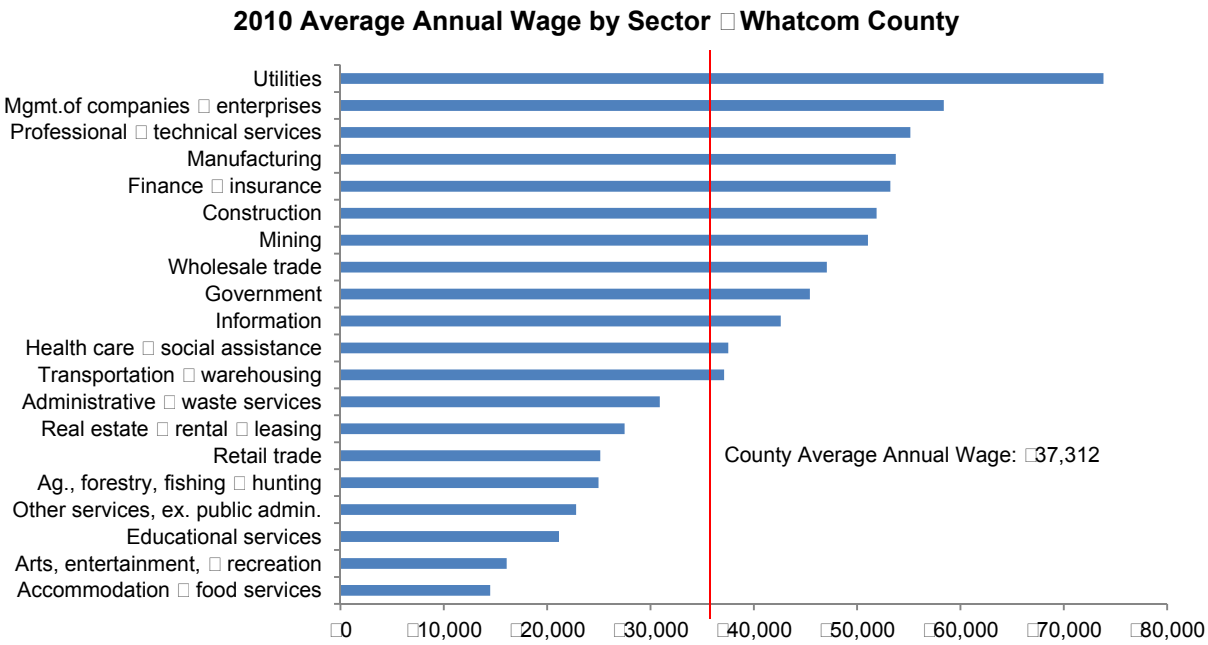
Source: WA ESD – Covered Employment Classified By Industry – Annual Averages 2010 (Revised)

One of the super-sectors that added the most jobs in Whatcom County since 2001 was leisure and hospitality (accommodation & food services and arts, entertainment & recreation sectors); which is also the sector with the lowest annual wage in Whatcom County. Similarly, the retail trade sector and education and health services sectors both experienced growth in Whatcom County and were comprised of industries that have average annual wages at or below the County's average annual wage. The only significant growth sectors in the County with wages above the County's average annual wage were Finance and Insurance and Government.

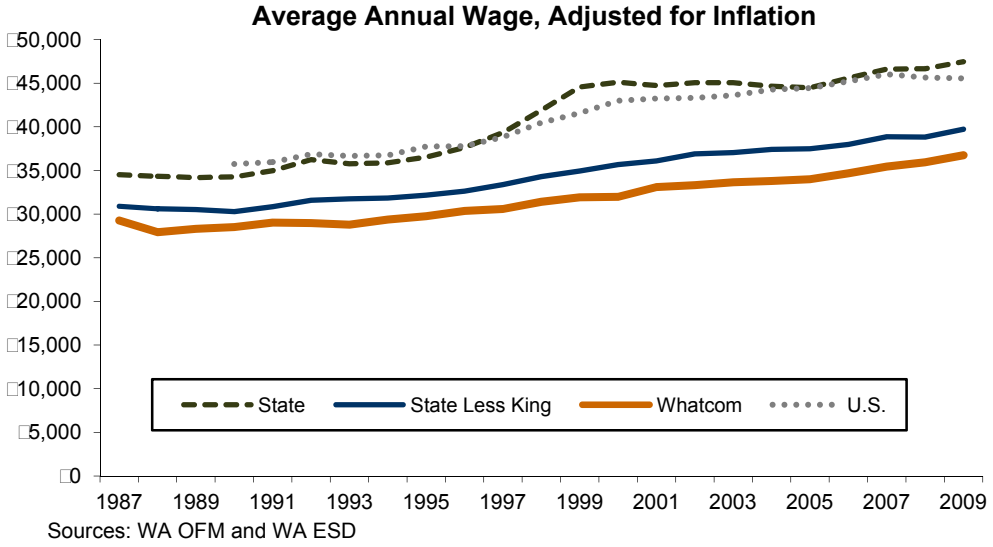
Taken together, this suggests that while the County added many good paying jobs relative to the annual average wage, it also added a significant number of jobs that provide annual wages at or below the County average.[96]

95 Washington ESD.

96 Additional information is available from the WA ESD. In July 2011, ESD published a 2011 Occupational Employment and Wage Estimates Guide that provides estimated employment, average wage and percentiles of wages for a multitude of professions. The data are presented for MSAs, regions, and Statewide. While a profession by profession comparison is beyond the scope of this report, a cursory review of the data seems to support the trend of Whatcom County (Bellingham MSA) having lower average wages than Statewide averages. The ESD publication is available at: Hhttps://fortress.wa.gov/esd/employmentdata/docs/occupational-reports/occupational-employment-wage-estimates-2011.pdfH.



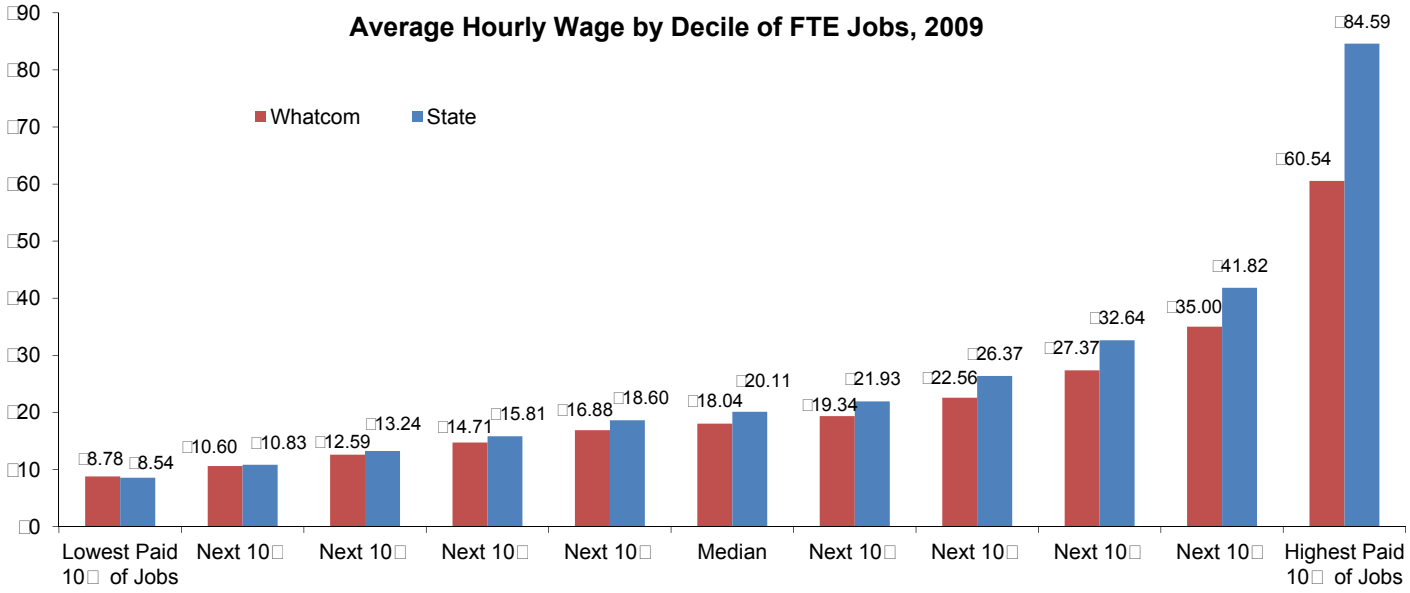
According to OFM and ESD data, the average earnings per job in Whatcom County have consistently lagged the Washington average since 1987 when the data set began; Whatcom County also remained below the State and US average earnings per job, while Washington has been largely been near or above the national average.



Sources: WA OFM and WA ESD

Whatcom County□s average hourly wages were closer to the State□s average hourly wages among those on the lower-end of the wage scale.[97] As hourly wages increased, the County□s lag significantly increased. In other words, the proverbial wage-floor to wage-ceiling was more compressed in Whatcom County than for the State.

97 The wage scale shown is for hourly wages by decile. This range begins with the lowest-paid 10 percent of jobs and increases by 10 percent intervals up to the highest paid 10 percent of jobs (based upon average hourly wage).

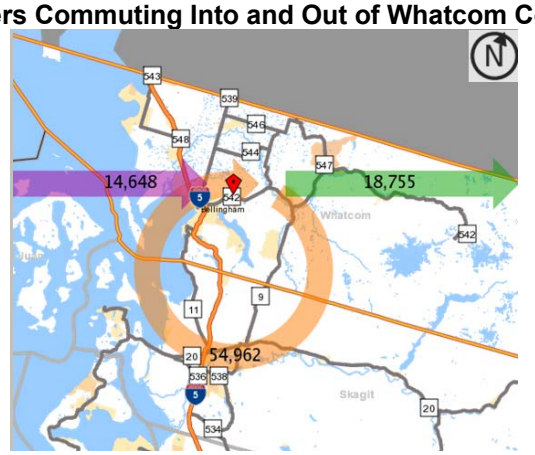


Wage data is based on location of employment. OFM and ESD historical data showed an important distinction that wages earned in Whatcom County are not equal to wages earned by Whatcom County residents. The data showed that the inflow of earnings from cross-county commuters was consistently greater than the outflow of earnings from cross-county commuters. This suggests that workers who resided in Whatcom County and commuted outside of the County for work earned higher wages than those who resided in other counties and commuted into Whatcom County.[98] Similarly, US Census OntheMap application data also showed that more Whatcom County residents commuted outside of the County for work than non-Whatcom residents who commuted into the County for work. In 2009, the difference was estimated to be 4,107 individuals; as shown in the below graphic.[99] Importantly, according to this data, 40.1 percent of those leaving Whatcom County earned more than $3,333 per month as compared with 32.8 percent of those who commuted into Whatcom County, and 34.6 percent of Whatcom residents who lived and worked in the County.

98 WA OFM and ESD personal income data.

99 It is possible that data from OnTheMap understates the effect of Whatcom residents who commute outside the County for work due to the Canadian border affecting its estimates.

Workers Commuting Into and Out of Whatcom County

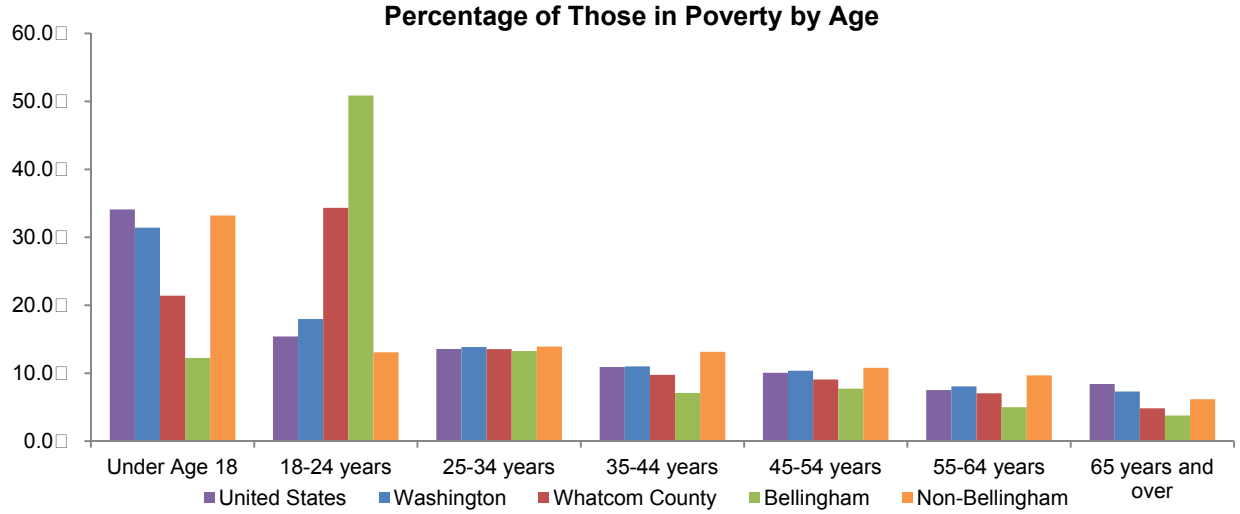


Further evidence that Whatcom County's labor market pays a lower wage in comparison to other regions is found in the County's trend of trailing the State average in wages for those with a Bachelor's degree or higher. Specifically, those with a Bachelor's degree or higher earned an average of $1,706 less per month than the State average for those with a Bachelor's degree or higher; equating to over $20,000 less per year.[100] This result suggests that in addition to being a lower-wage region than the State average – as mentioned previously – Whatcom County and Bellingham may have instances of underemployment among residents. Underemployment is discussed at greater length below.

100 US Census Bureau Quarterly Workforce Indicators (QWI) – 2010 Quarters 1-4.

Appendix D: Underemployment and Poverty

Bellingham's poverty rate of 21.0 percent was greater than the poverty rates for both Whatcom County (14.6 percent) and Washington (12.5 percent).[101] Bellingham accounted for 56.2 percent of Whatcom County's total population in poverty and 68.6 percent of those in poverty between the ages of 18-64. As shown in the chart below, much of Bellingham and Whatcom County's poverty was concentrated among those between the ages 18-24.[102] The City's poverty rate was likely impacted by the significant post-secondary student population in Bellingham; many of whom lived below the poverty line. Bellingham residents ages 18-24 with incomes below the poverty line accounted for 50.9 percent of the City's total and 83.3 percent of all age 18-24 County residents living in poverty.



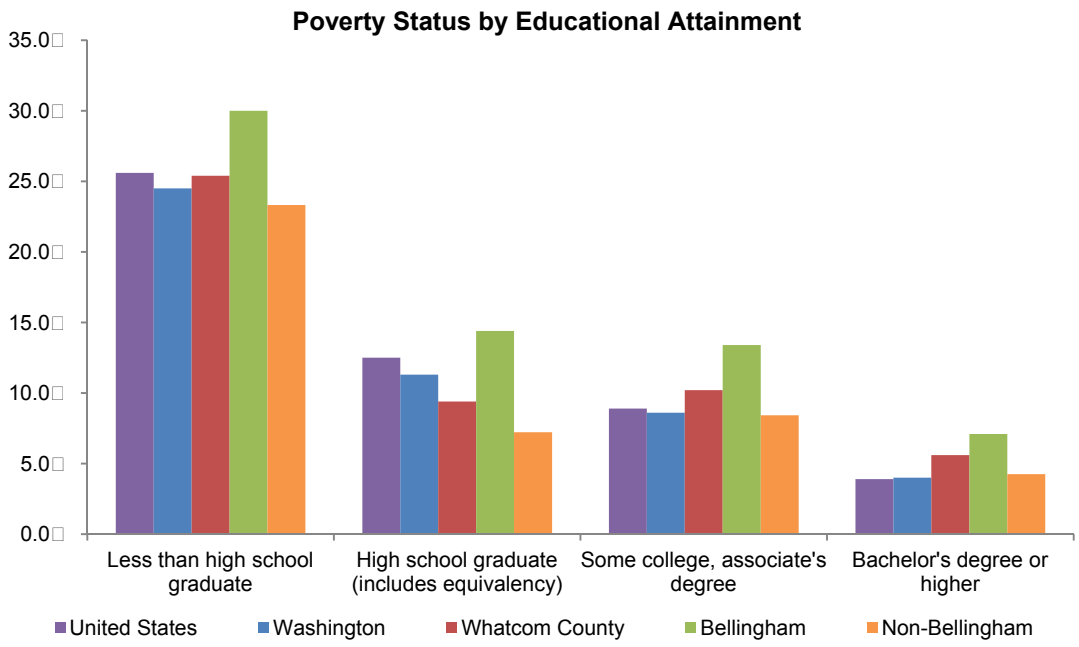
Source: US Census Bureau 2010 ACS 3-year Estimates

Across all educational attainment levels, Bellingham's poverty rate was greater than the remainder of the County, State, and national rates. Almost one-quarter (22.4 percent) of Bellingham residents age 25 and over who live in poverty possessed a Bachelor's degree or greater.[103] This percentage was significantly more than that seen in both the remainder of Whatcom County (13.4 percent) and Washington (13.3 percent) for the same population. The remainder of Whatcom County's poverty rate is generally below or on par with that of the State. The relative high level of poverty experienced by those in Bellingham with high educational attainment suggests there is some level of choice or desire to reside in Bellingham as opposed to other locations.

101 US Census Bureau 2010 ACS 3-year Estimates.

102 US Census Bureau 2010 ACS 3-year Estimates.

103 Source: US Census Bureau 2010 ACS 3-year Estimates.



Source: US Census Bureau 2010 ACS 3-year Estimates

Appendix E: Cost of Living

An important consideration to contextualize income and economic conditions independent of income is the associated cost of living for the region. One measure of this is the BLS Consumer Price Index (CPI) data.[104] The Bellingham MSA is not one of the local areas for which BLS produces an index.

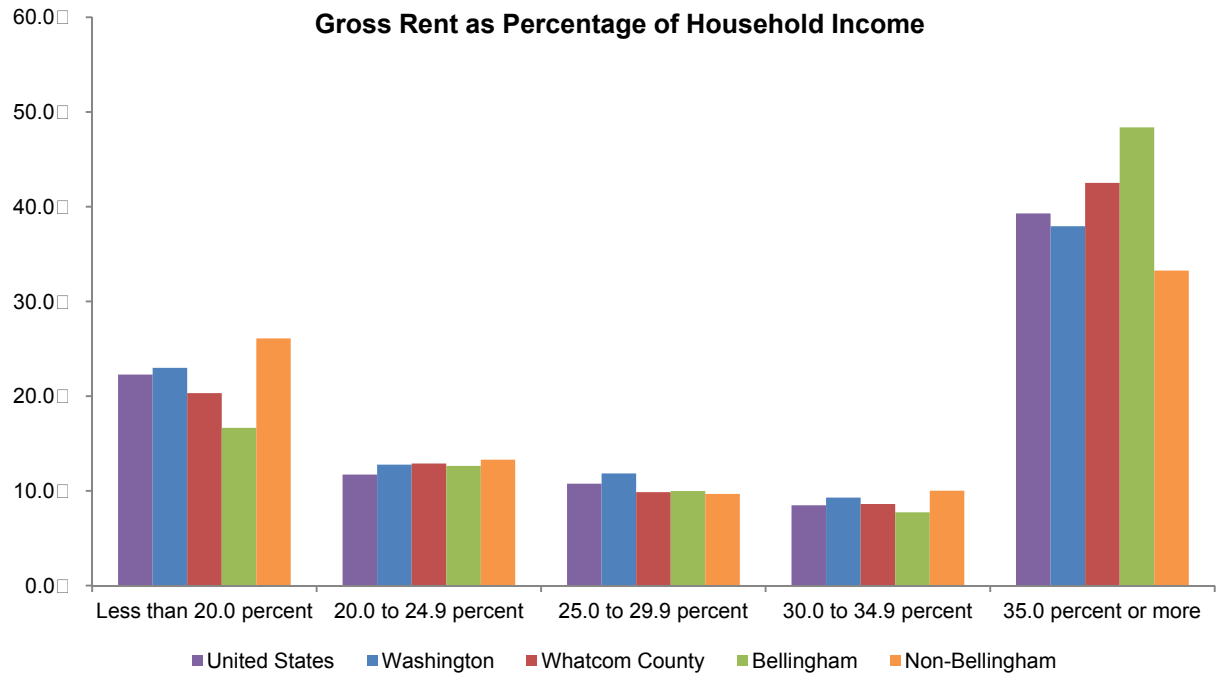
As CPI data are not available for Whatcom County or Bellingham, the project team reviewed the cost of housing to help inform discussions of the cost of living. Over half (51.1 percent) of Whatcom County households who rented their residence and 45.0 percent of those who owned their residence spent 30.0 percent or more of their income on housing compared with 47.2 percent of renters and 41.0 percent of homeowners in Washington.[105]

As shown in the following graphs, all jurisdictions had a significant portion of renters and home owners who paid 35 percent or more of household income for their residence. Bellingham had the highest percentage of households among renters and home owners who paid over 35 percent of household income toward their residence; 48.4 percent of all Bellingham renters and 35.3 percent of Bellingham home owners. A portion of Bellingham s high rent as a share of household income may have been attributable to the student population, many of whom may have rented apartments or homes.

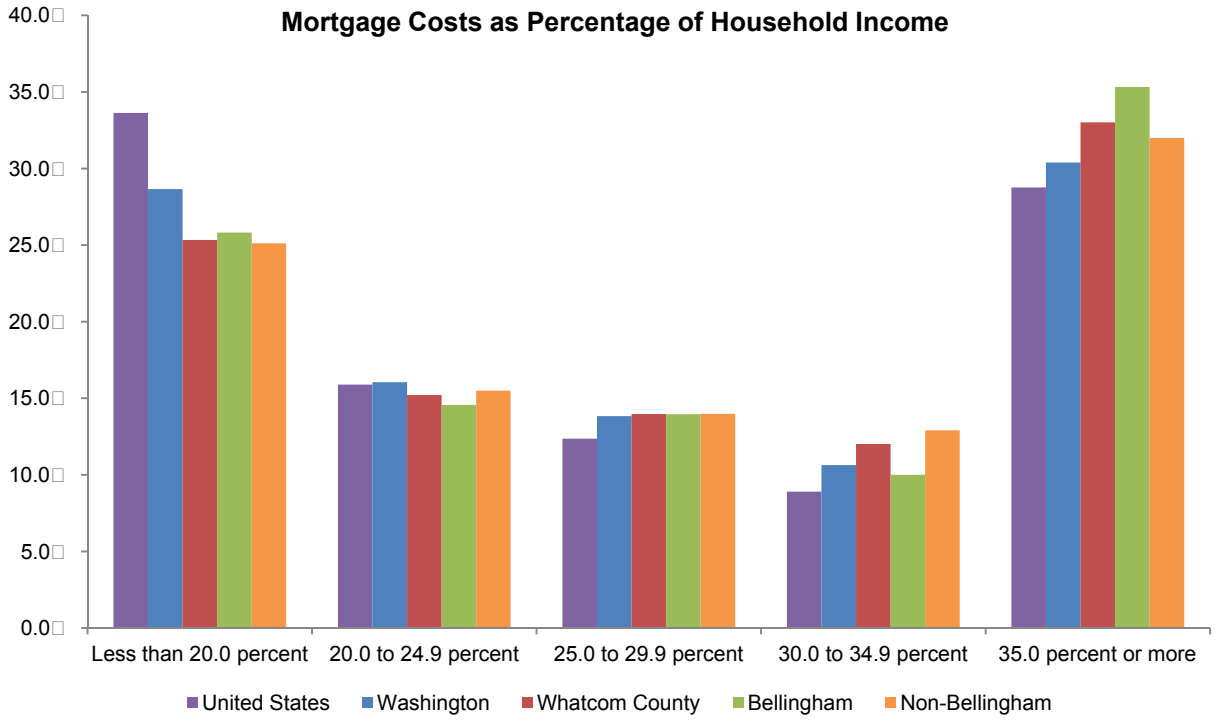
The remainder of the County tended to be more similar to the State than to Bellingham. However, rental and housing prices as a whole appeared to consume a greater percentage of total household income in Whatcom County and Bellingham as compared to the rest of the state. This could have been due to the jurisdictions lower wages, higher housing prices, or a combination of both.

104 The BLS publishes various CPI measures of market basket price changes as indicators of cost-of living. BLS cites the Chained CPI-U as its most accurate measure for cost-of-living. This index is produced on a national basis, and is available dating back to 1999. To provide insight into more localized changes, BLS also produces indexes for local areas covering all urban wage earners. While available for a longer duration and regionally focused, the BLS advises that such area series are less reliable due to sample size volatility.

105 OFM analyzes the cost-of-living by measuring housing costs (rent or mortgage) as a percent of household income. OFM considers households to be in distress when gross rent or mortgage costs are 30 percent or more of household income. OFM data use 2000 Census data as the base year and is current through 2009 ACS 1-year estimate data. In the data discussed, the project team used the 2010 ACS 3-year estimates. The project team examined mortgage costs as a percentage of household income for owner-occupied housing units in order to review housing costs as a percentage of household income without large potential for interference from the student population.



Source: US Census Bureau 2010 ACS 3-year Estimates.



Source: US Census Bureau 2010 ACS 3-year Estimates.

Washington State University's Washington Center for Real Estate Research (WCRER) publishes a myriad of housing-related data, including an affordability index and data on median sales prices. WCRER compiles an affordability index for home purchases that measures the ability of a typical family to make payments on a median price home. For example, if a jurisdiction had an affordability index of 110, it would mean that a family earning the median

income would have 10.0 percent more income than the bare minimum required to qualify to purchase a median-priced home with a 20.0 percent down payment and a 30-year mortgage.

Traditionally, Whatcom County's affordability index was slightly above the State's index until early 2004. Since that point, the County's index has generally remained below the State's index, meaning home purchases are slightly more affordable in the State as compared to Whatcom County. It is possible that Whatcom County's lower wages as compared to the State average (discussed above) contributed to this affordability lag, though the wage trend existed for a significant period prior to 2004.

The second chart below reviews the median home price for the State and County on a quarterly basis from 2004-2010.[106] Whatcom County's median home price was below the State's median home price until the middle of 2004. At this point, the County's median home price was nearly equal to the State's for the next 18 months; even briefly spiking above the State average. From early 2006 through early 2010, the County's median home price was lower than or nearly equaled that of the State.

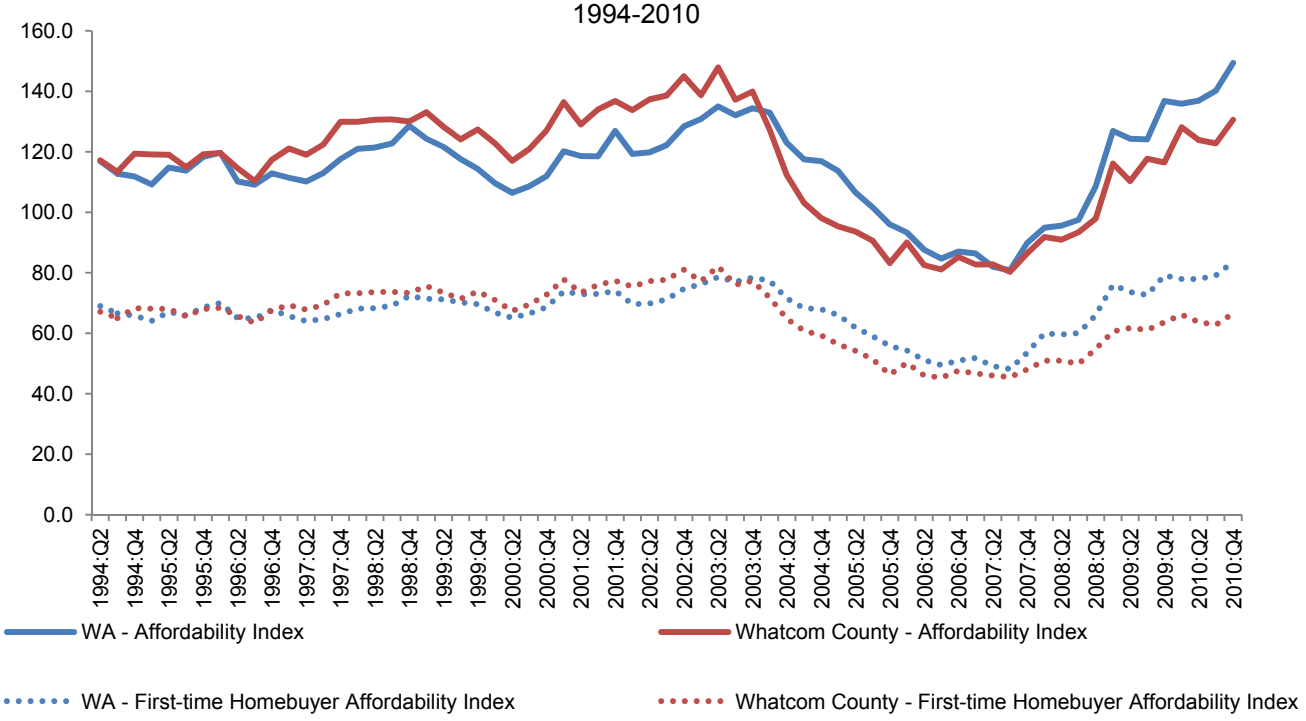
Since mid-2010, the County's median home price has been greater than the State's median home price. A portion of the County's increase could be due to the types of individuals migrating to the County from outside areas. These individuals (discussed in a previous section) have higher AGIs and may have helped sustain the housing prices by creating demand in the market whereas similar demand was not present in other markets. To the extent this supply-demand effect occurred, it increases the likelihood that people chose to move to Whatcom County and Bellingham because of the quality of life, quality of place, and/or amenities, as they were willing to pay more for a home in Whatcom County or Bellingham than other locations.

Considering both the affordability index data and median home price data, there may be two variables combining to create a lower affordability and higher median home price as compared with the State; this experience may even be potentially greater in Bellingham. The County and City's consistently lower wages coupled with the home prices that didn't fall as far from their peak as the State likely each play a role in the more expensive real estate (on an affordability measure and a median price measure) than the State average.

Given these facts, it could be argued that Whatcom County and Bellingham could be expected to have seen a small decrease in population as individuals and families seek more commensurate wages and home prices. However, this did not occur. In fact, the opposite occurred which again could suggest some level of desirability and choice associated with wanting to reside in Bellingham and or Whatcom County – even if it was less affordable.

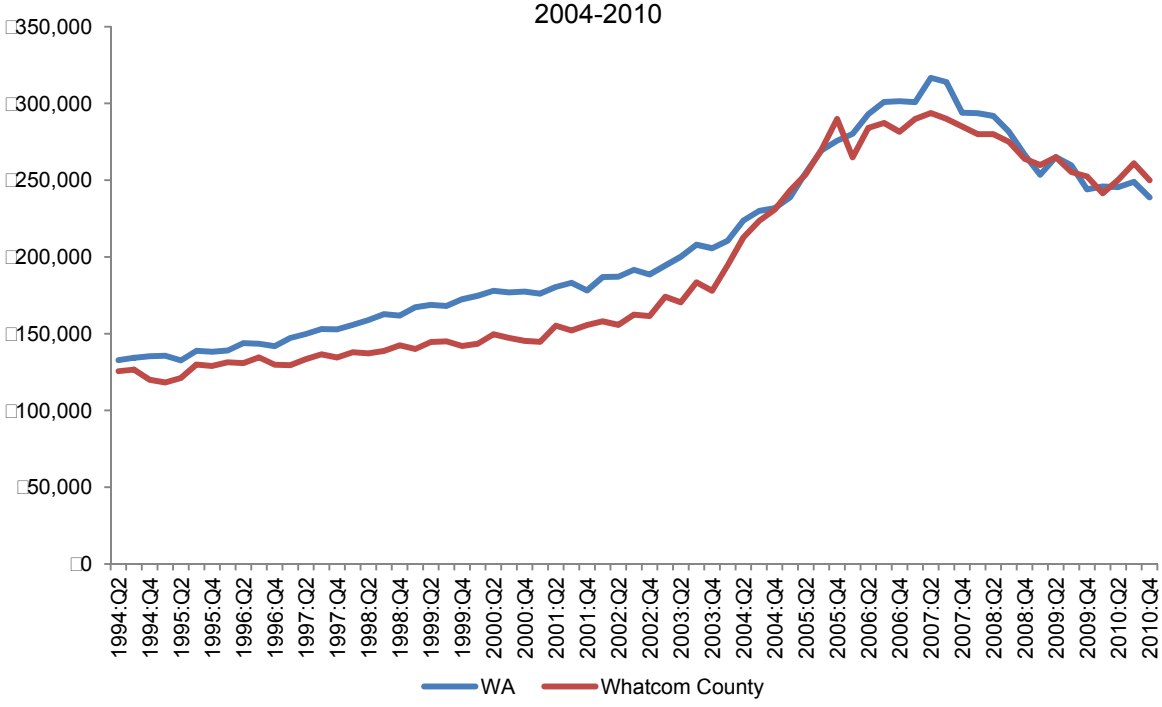
106 The Federal Housing Finance Agency (FHFA) House Price Index for the same period also reports similar data.

Washington State Affordability Index and First-time Homebuyer Affordability Index
1994-2010



Source: Washington Center for Real Estate Research

Median Home Price
2004-2010

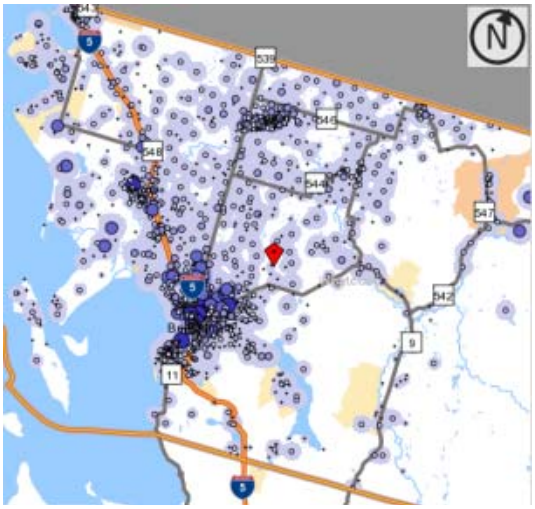


Source: Washington Center for Real Estate Research

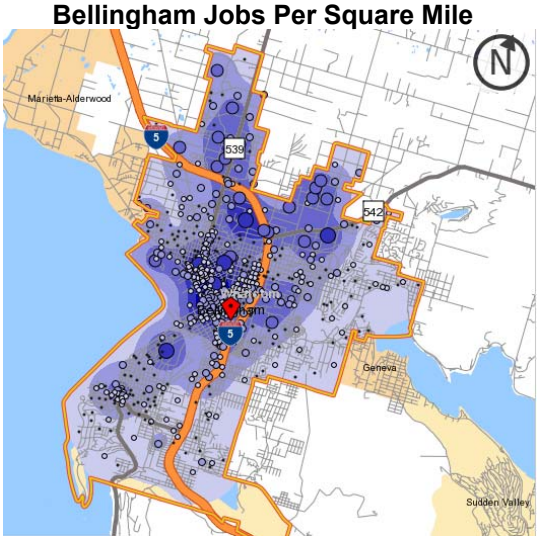
Appendix F: Bellingham's Importance as a Regional Economic Center

Approximately 60 percent of jobs in Whatcom County are located in Bellingham.[107] Countywide, jobs are concentrated in Bellingham and, within Bellingham, are concentrated west of Interstate 5 (I-5) and clustered near the Central Business District and within short distance to the waterfront.

Whatcom County Jobs Per Square Mile



Bellingham Jobs Per Square Mile



Source: US Census Bureau Local Employment Dynamics (LED), 2009.

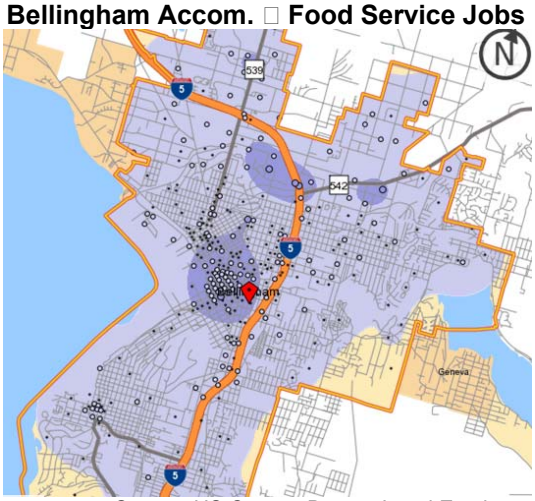
According to the US Census Bureau's 2007 Economic Census, the City also accounted for 76.1 percent of all retail sales in Whatcom County. In addition, Bellingham's retail sales per capita (□25,169) was nearly double the sales per capita of the County (□13,254). The City's accommodation and food services sales accounted for □226.6 million (55.6 percent) of the County's total accommodation and food services sales of □407.8 million.[108] The US Census Bureau's Local Employment Dynamics (LED) 2009 Work Area Comparison Report for Whatcom County indicates that the retail trade sector, as seen in other data earlier in this report, is one of, if not the largest industry sector in the County.

Specifically, as seen in the below maps, it appears that a significant portion of the City's retail, accommodation, and food services jobs are located in and around the waterfront area.

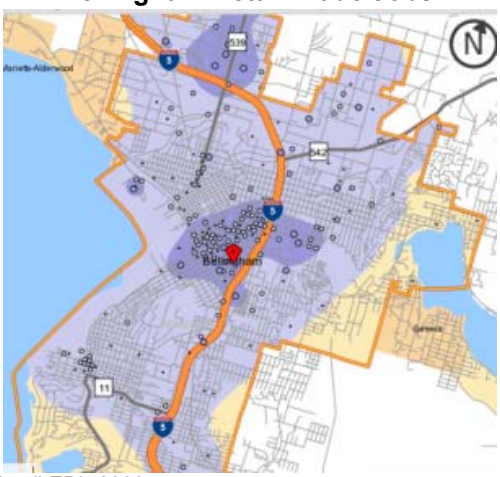
107 US Census Bureau Local Employment Dynamics (LED) 2002-2009 data.

108 US Census Bureau 2007 Economic Census.

Bellingham Accom. & Food Service Jobs



Bellingham Retail Trade Jobs



Source: US Census Bureau Local Employment Dynamics (LED), 2009.

Property Values

Just as Bellingham is the commercial center for Whatcom County, it also has a significant portion of the County's property value. As of 2010, Bellingham accounted for 35.8 percent of the County's total assessed value of real property. Bellingham achieved these results despite representing only 1.3 percent of the County's total square miles – further highlighting the importance of property value (for residential and commercial parcels) in the City for the rest of the County.[109]

In 2010, Bellingham accounted for 56.0 percent of the total residential sales volume in the County (in dollar amount) and 52.1 percent of total residential transactions in the County; suggesting the City's average house price is greater than the County's average price – a trend that has existed since the data set used began in 2006. Similarly, while Bellingham and the remainder of Whatcom County have both seen significant declines in residential sales volume (in dollars) since 2006, the City's decline is marginally slower than the decline experienced by the remainder of the County (-44.8 percent versus -47.1 percent).

Between 2005 and 2010, Bellingham's median and average home prices have been higher than the median and average prices for the County as a whole. It is important to note that the data for Whatcom County include the Bellingham data and are not presented in a disaggregated form. As a result, Bellingham's median and average home values are likely even greater than the non-Bellingham portion of the County.

During the peak of the housing bubble (2006-2008), Bellingham's home prices were not as far above the County's home prices as after the burst of the bubble (2009-2010), when the City's home prices appear to have increased the value difference with the County's home prices. This suggests that the Bellingham housing market did not decrease in value to the same extent as the remainder of the County (keeping in mind that County data are not disaggregated and include Bellingham's prices).

109 US Census Bureau, 2010 data.

Median and Average Prices of Houses Sold, 2005-2010

Median Sales Price	Bellingham	Whatcom County	Difference (□)	Difference (□)
2010 Median Sales Price	□264,950	□255,000	□9,950	3.9□
2009 Median Sales Price	□274,000	□259,990	□14,010	5.4□
2008 Median Sales Price	□285,000	□278,533	□6,467	2.3□
2007 Median Sales Price	□300,000	□290,725	□9,275	3.2□
2006 Median Sales Price	□295,000	□283,000	□12,000	4.2□
2005 Median Sales Price	□269,000	□259,900	□9,100	3.5□
Average Sales Price	**Bellingham**	**Whatcom County**	**Difference (□)**	**Difference (□)**
2010 Average Sales Price	□313,813	□291,985	□21,828	7.5□
2009 Average Sales Price	□320,767	□301,124	□19,643	6.5□
2008 Average Sales Price	□333,731	□323,172	□10,559	3.3□
2007 Average Sales Price	□351,063	□340,448	□10,615	3.1□
2006 Average Sales Price	□341,105	□324,852	□16,253	5.0□
2005 Average Sales Price	□302,749	□288,277	□14,472	5.0□

Most recently, the 2011 report reviews the differences in median sales price for new and existing homes in Whatcom County and Bellingham. In both 2009 and 2010, the City□s median sales prices for new and existing homes were greater than the County□s median sales prices for new and existing homes. New homes in Bellingham had a particularly higher median sales price than did new homes in Whatcom County (2009: □336,650 vs. □262,500; 2010: □313,500 vs. □256,750).

According to the report, in 2010, houses in Bellingham□s Census tracts had a higher average sales price for new homes than new homes sold in the rest of Whatcom County. In the nine Census tracts in Bellingham with new home sales in 2010, eight had an average sales price of over □300,000. Of the ten Census tracts in the remainder of the County with new homes sales in 2010, only one Census tract had an average sales price over □300,000.[110]

Among single family sales by Census tract in 2010, the properties in the Fairhaven, South Hill, and Edgemoor sections of the City had significantly higher sales prices than the rest of the City. The average sales price in the Fairhaven□South Hill section was □574,167 and the average sales price in Edgemoor was □555,433. Sales volumes were the highest in the Mount Baker, Alabama Hill□Silver Beach, North and South Shore□Lake Whatcom, and Puget□Whatcom Falls□Samish areas of the City.

110 Similar data for condominium sales are also included in the report. Bellingham accounted for 63.0 percent of condominium sales in Whatcom County during 2010 and had a higher average sales price than the remainder of the County.

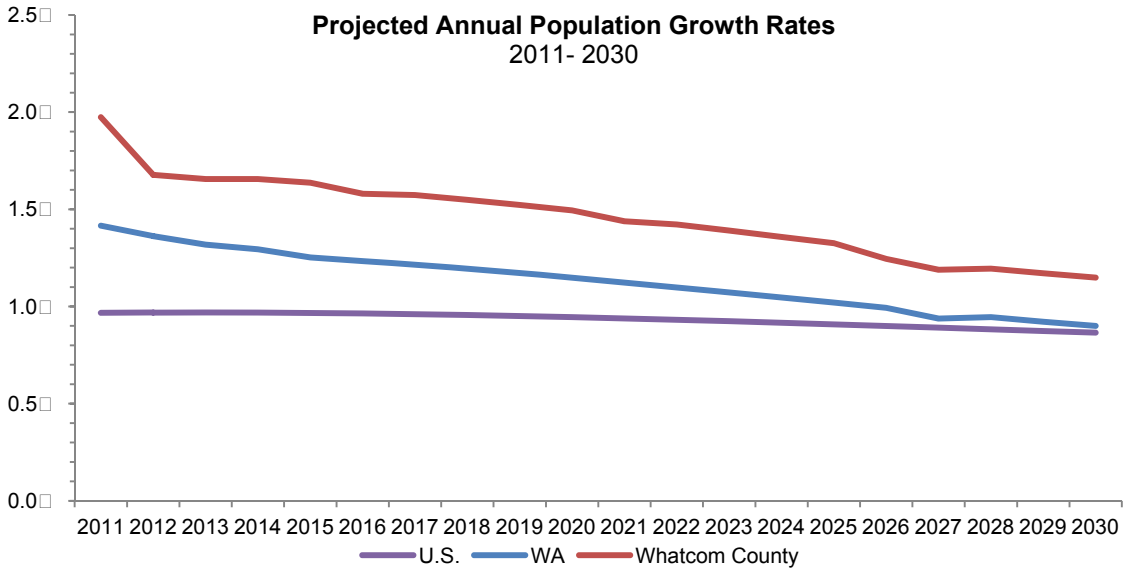
Appendix G: Projections for the Future – Population and Job Growth

Population Growth

WA OFM produces projections for future population growth on the State and County levels.[111] OFM projects the State's population growth rate from 2010 to 2030 to be 1.1 percent, just above the US rate of 0.9 percent. OFM projects Whatcom County's 2010-2030 population growth rate to be 1.5 percent.

Population growth forecasts for the City of Bellingham are not included in the OFM data. Bellingham's population growth rate is assumed to be similar, though not identical, in real experience to the County's population growth rate. It should be noted that Bellingham's CAGR for the most-recent 10 years (1.9 percent) is the same as Whatcom County's most-recent 10-year CAGR, for this reason, the project team used the same out-year CAGR for Bellingham as projected in OFM's estimates for Whatcom County.

For purposes of calculations later in this report, the project team used OFM's compound annual growth rate projections for Whatcom County for Bellingham; 1.6 percent through 2019 and 1.5 percent through 2030. This is in line with OFM's projections for a decreased rate of population growth for Whatcom County and the State in future years.



Source: WA OFM

OFM estimated that Whatcom County accounted for 2.9 percent of the State's total population.[112] By 2030, OFM projects the Whatcom County population to reach approximately 261,000 individuals and represent 3.1 percent of the State's population. Whatcom County's proportional increase in State population share occurs due to OFM's long-term forecasted population growth rate for Whatcom County being greater than the State's long-term forecasted population growth rate; this can be seen in the graph above.

111 OFM produces a *Forecast of State Population* (released in November 2011) that solely forecasts the population of Washington through 2040. OFM, as part of the Growth Management Act (GMA), produces population estimates every five years. New estimates are to be released in March of 2012 and were not available for use in this report. This report uses OFM 2007 Growth Management Projections through 2030. Historical differences between OFM projections and actual occurrences have been small. OFM's 2007 projections for 2010 were 97.3 percent of 2010 Census data. Similar or smaller margins were also seen in prior data.

112 OFM's estimates were made prior to the release of data from the 2010 Census. The 2010 Census suggested Whatcom County comprised 3.0 percent of the State's total population; up from 2.8 percent in 2000.

On a State level, it is worth noting that OFM's November 2011 *Forecast of State Population* (statewide projections) projects significant growth in the age 65 and over population from 2010 levels (24.2 percent) by 2040. Specifically, between 2010 and 2040, those age 65 and over account for 49.7 percent of OFM's projected total net population growth in the State. OFM's projections are consistent with growth in the population from the 2000 census to the 2010 census. OFM's projections likely account for baby boomers continuing to age and live longer, thus driving the increase in the population age 65 and over.

Job Growth

Washington's ESD produces Occupational Employment Projections for the State and its sub-regions that forecast the 2019 estimated levels of employment for over 800 occupation types.[113] Statewide, ESD projects an average annual growth rate of 1.4 percent for all occupations through 2019 resulting in an increase in employment of approximately 495,000 from 2009 levels. Over two-thirds of the State's projected increase is attributable to projected gains in nine occupational categories:

- Office and Administrative Support
- Sales Related
- Computer and Mathematical
- Computer Specialists
- Food Preparation and Serving Related
- Transportation and Material Moving
- Healthcare Practitioners Technical Related
- Personal Care and Service
- Building and Grounds Cleaning and Maintenance.

ESD projects the Northwest Washington region[114] (includes Whatcom County) to grow at a slightly greater average annual growth rate than the State estimate through 2014 (1.5 percent versus 1.4 percent). Thereafter, through 2019, it projects the region will grow at annual average rate of 1.6 percent and the State will remain at the same average annual growth rate of 1.4 percent. In total, ESD projects the Northwest region's 2019 employment level will be 16.6 percent greater than its 2009 employment level; higher than the Statewide projected 15.3 percent increase during the same time period. By 2019, Northwest Washington is projected to have estimated employment of 207,449; an increase of nearly 30,000 over 2009 levels. Similarly to the State, over two-thirds of the region's projected increase is attributable to projected gains in nine types of occupations:

- Office and Administrative Support (3,900 new jobs; accounts for over 13.2 percent of total increase)
- Sales Related (2,400 new jobs)
- Production (2,300 new jobs)
- Transportation and Material Moving (2,100 new jobs)
- Food Preparation and Serving Related (2,000 new jobs)
- Personal Care and Service (1,900 new jobs)
- Education, Training, and Library (1,900 new jobs)
- Building and Grounds Cleaning and Maintenance (1,800 new jobs)
- Construction and Extraction (1,700 new jobs).[115]

113 The project team reviewed ESD's May 2011 (most recently available) projections.

114 ESD indicates that Northwest Washington region is comprised of Island County, San Juan County, Skagit County, and Whatcom County.

115 ESD differentiates between Construction and Extraction occupations and Construction Trades Workers.

Baseline Growth for Whatcom County and Bellingham

Without the planned development of GPT, the State has already projected significant population and job growth for Whatcom County that build upon the County's historical growth trend. These projections are outlined above. Based on the state's projections, it is possible to state a baseline scenario for county population and job growth over a ten-year period.

Population Growth

The project team used OFM's projected annual growth rates from 2011 through 2030 to project the growth of the 2010 Census population data for Whatcom County and Bellingham.[116] By 2021, Whatcom County's projected population is approximately 240,000 and Bellingham's projected population is approximately 96,000. Through 2021, the OFM's projected average annual growth rate is approximately 1.6 percent, and 1.5 percent through 2030. Whatcom County's 2030 population is projected to be 269,000 and Bellingham's 2030 population is projected to be 108,000.

Projected Population Growth

	2010 Census Population	Average Annual Growth Rate Through 2021	Average Annual Growth Rate Though 2030	Proj. 2021 Population	Proj. 2030 Population
Whatcom County	201,140	1.6%	1.5%	240,000	269,000
Bellingham	80,885	1.6%	1.5%	96,000	108,000

Job Growth

In 2009, Washington's ESD projected that the northwest region of Washington (including Whatcom County) will see an average annual job growth of 1.5 percent from 2009-2014 and a 1.6 percent annual average job growth from 2014-2019.[117] At the projected rates, Whatcom County would have 88,389 jobs by 2021, an addition of almost 15,000 jobs from 2010. Similarly, Bellingham would have 53,034 jobs by 2021, an increase of almost 9,000 jobs from 2010.

116 The project team used Bellingham's 2010 population as a percentage of total Whatcom County population throughout the estimates. This ratio is used purely for the purposes of estimations; actual results will vary and are subject to tangible and intangible occurrences that cannot be incorporated in projections.

117 The project team used these annual average growth rates and applied them to the BLS OES data for 2010 jobs in Whatcom County. To calculate the number of Bellingham jobs, the project team used took 60 percent of all jobs in the County (per LED data suggesting an average of 60 percent of all jobs in the County exist in Bellingham). The calculation did not include the estimated job growth for 2009 as the OES figure is from 2010. However, the project team did apply the 2010 growth rate to this figure so as to ensure it captured the possible net increase and not artificially lower job growth. For 2020-2022, the project team used the projected 1.6 percent average annual growth rate to estimate the number of jobs.

Projected Job Growth[118]

	Growth Multiplier	Whatcom County Jobs	Net Increase	Growth Multiplier	Bellingham Jobs	Net Increase
May-10	-	73,420	-	-	44,052	
2010	1.015	74,521	1,101	1.015	44,713	661
2011	1.015	75,639	1,118	1.015	45,383	671
2012	1.015	76,774	1,135	1.015	46,064	681
2013	1.015	77,925	1,152	1.015	46,755	691
2014	1.015	79,094	1,169	1.015	47,457	701
2015	1.016	80,360	1,266	1.016	48,216	759
2016	1.016	81,645	1,286	1.016	48,987	771
2017	1.016	82,952	1,306	1.016	49,771	784
2018	1.016	84,279	1,327	1.016	50,567	796
2019	1.016	85,627	1,348	1.016	51,376	809
2020	1.016	86,998	1,370	1.016	52,199	822
2021	1.016	88,389	1,392	1.016	53,034	835
Total		**88,389**	**14,969**		**53,034**	**8,982**

118 The project team also assessed US Census Bureau LED data from 2009 for Bellingham and Whatcom County. The 2009 LED data indicated 69,610 jobs in the County and 41,613 jobs in the City. Applying an annual average growth rate of 1.015 percent for 2009-2014 and an annual average growth rate of 1.016 percent for 2015-2021, yielded a total job growth in the County of 14,193 and 8,484 in Bellingham. Ultimately, the project team used the OES data as it is more recent and showed a higher number of actual jobs than projection based upon the 2009 data. The OES data were used so as to not artificially discount "trajectory" growth when comparing to projected growth from GPT.

Washington State

2010-2030
Freight Rail Plan

December 2009

Washington State
Department of Transportation

For more information, contact:

- Call the WSDOT State Rail and Marine Office at (360) 705-7900;
- Write to the WSDOT State Rail and Marine Office at P.O. Box 47407, Olympia, WA 98504-7407;
- Fax your comments to (360) 705-6821; or
- E-mail your comments to rail@wsdot.wa.gov

Americans with Disabilities Act Information: Materials can be provided in alternative formats: large print, Braille, cassette tape, or on computer disk for people with disabilities by calling the Office of Equal Opportunity (OEO) at (360) 705-7097. Persons who are deaf or hard of hearing may contact OEO through the Washington Relay Service at 7-1-1.

Title VI Statement to Public: It is the Washington State Department of Transportation's (WSDOT) policy to assure that no person shall, on the grounds of race, color, national origin and sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated, may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For Title VI complaint forms and advice, please contact OEO's Title VI Coordinator at (360) 705-7098.

Washington State 2010-2030 Freight Rail Plan

Prepared by

Washington State Department of Transportation State Rail and Marine Office

December 2009

Washington State Department of Transportation

Washington State
Department of Transportation
Paula J. Hammond, P.E.
Secretary of Transportation

Transportation Building
310 Maple Park Avenue S.E.
P.O. Box 47300
Olympia, WA 98504-7300

360-705-7000
TTY: 1-800-833-6388
www.wsdot.wa.gov

Washington State requires a robust rail system that will provide effective and efficient transportation critical to maintaining our economy, environment and quality of life. Our vision for the future is to enhance our economic vitality and mobility while safeguarding the environment, by continually improving our transportation system.

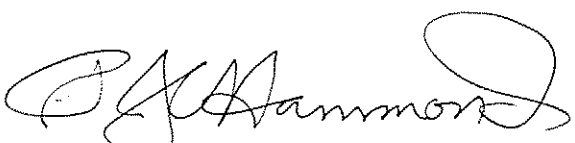
The *Washington State 2010-2030 Freight Rail Plan* is an update of the *Washington State Freight Rail Plan 1998 Update*. This plan will provide guidance for rail initiatives and investments in Washington State that will:

- Support Washington's economic competitiveness and economic viability.
- Preserve the ability of Washington's freight rail system to efficiently serve the needs of its customers.
- Facilitate freight system capacity increases to improve mobility and reduce congestion.
- Take advantage of freight rail's modal energy efficiency to reduce the negative environmental impact of freight movement in Washington.

The Washington State Freight Rail Plan complies with the Federal Railroad Administration (FRA) requirements that the state establishes, updates, and revises a rail plan in order to receive federal assistance. The Freight Rail Plan also fulfills state requirements, under the Revised Code of Washington (RCW) 47.76.220 and RCW 47.06.080, that the Washington State Department of Transportation (WSDOT) prepare and periodically revise a state rail plan that identifies, evaluates, and encourages essential rail services.

This plan is a product of broad participation from rail industries, ports, shippers, local entities, tribes, transportation communities, interest groups, and the general public. It develops the vision, goals, and strategies to provide reliable, accessible, cost-effective, energy efficient and environmentally friendly freight rail services. It presents a compilation of statewide freight rail needs. Currently a National Rail Policy is being developed by the FRA and is anticipated to be released in 2010. Washington's plan will be updated and revised as necessary to maintain consistency with the National Rail Plan.

The Washington State Freight Rail Plan is intended to serve as a blueprint for investment in our rail system and to prepare us to capture the emerging opportunities from economic recovery that is on the horizon. With effective and responsible improvements to our rail system we will serve the economic development, transportation, social and environmental goals of Washington State and its citizens.



Paula J. Hammond, P.E.
Secretary of Transportation

Washington State Department of Transportation

Table of Contents

Executive Summary

Introduction....ES-1
2030 Vision for Freight Rail in Washington State....ES-2
Rail Infrastructure Needs and Investment Program....ES-8
Preservation of At-Risk Railroads....ES-8
Freight System Issues and Needs....ES-14
Statewide Information and Data Needs....ES-17
The Partners....ES-18
Investment Prioritization and Project Evaluation....ES-18
Financing the Needs....ES-19
State Role....ES-19
Conclusion....ES-20

Chapter 1: Plan Purpose and Authority

Purpose of the State Freight Rail Plan....1-1
Washington State Department of Transportation....1-1
WSDOT's State Rail and Marine Office....1-1
State and Federal Legislative and Planning Requirements....1-2
Development of the State Freight Rail Plan....1-4
Plan Organization....1-9

Chapter 2: State Rail Vision

Introduction....2-1
Macroeconomic Environment....2-3
Changes in Transportation....2-4
Vision of Rail Transportation in Washington State....2-9
Goals, Objectives, Strategies, and Actions....2-9
Conclusion....2-16

Chapter 3: Rail System and Freight Rail Services in Washington State

Overview of Washington State Rail System Services....3-1
Washington State Freight Rail System Profiles....3-5
Capacity of the Washington State Rail System....3-20
Recent Major Policy Changes Impacting the Rail System in Washington State....3-29

Chapter 4: Freight Rail Services – Effects on the Economy and Society

Functions of Freight in Washington's Economy 4-1
Freight Rail in Washington's Economy 4-2
Major Drivers in Freight Rail Demand 4-13
Future Demand – Washington State Rail Forecast 4-18

Chapter 5: The Changing Rail System – Issue Discussion and Needs Assessment

Overview of Issues and Needs Assessment 5-1
Rail Abandonments: Recent, Proposed, and At-Risk Lines 5-3
Port Access 5-10
Intermodal Connectors 5-16
Rail Freight System Issues and Needs 5-20
New Services 5-29
Emerging Issues 5-29
Summary 5-44

Chapter 6: State Roles and Partners

Washington State's Current Roles 6-1
Washington's Strategic Partners 6-6
Strategic Planning 6-10
Future Roles 6-12
Continued Statewide Coordination and Partnerships 6-14
Conclusion 6-15

Chapter 7: Investment Prioritizing and Project Evaluation

Public and Private Benefits 7-1
Freight Rail Investment Analysis in Washington State 7-3
Rail Benefit/Impact Evaluation Methodology – Description 7-11
Limitations and Future Improvements 7-16

Chapter 8: Financing Washington's Freight Rail System

Needs for Investment 8-1
Funding for Freight Rail 8-10
Current Funding Sources 8-14
Strategies 8-28
Vision for Future Funding 8-30
Summary 8-32

Chapter 9: Challenges and Opportunities

Transportation Challenges 9-1
Transportation Opportunities: Implementation of the Plan 9-3
Conclusion 9-7

List of Exhibits

Exhibit ES-1: Washington State Rail Map ES-4
Exhibit ES-2: Washington State Rail Freight Directional Flows - 2007 .....ES-5
Exhibit ES-3: Top 10 Commodities Shipped by Rail Washington State 2007 .....ES-6
Exhibit ES-4: Freight-Dependent Sectors Employment Washington State 2008 First Quarter.....ES-7
Exhibit ES-5: Greenhouse Gas Emissions by Mode ES-7
Exhibit ES-6: Washington Rail Investments ES-9
Exhibit ES-7: Ports of Washington State.....ES-11
Exhibit ES-8: Intermodal Freight Connectors in Washington State...ES-13
Exhibit 2-1: Washington 2005 GHG Emissions 2-6
Exhibit 2-2: Greenhouse Gas Emissions by Mode 2-7
Exhibit 3-1: Washington State Rail System..... 3-2
Exhibit 3-2: Washington State Rail Freight 1991 to 2007..... 3-4
Exhibit 3-3: Rail Freight Flows in Washington State – 2007 3-5
Exhibit 3-4: Freight Rail Intermodal Traffic – Washington State 2007 3-5
Exhibit 3-5: Washington Freight Railroads, Mileage, and Class..... 3-7
Exhibit 3-6: Rail Service Corridors in Washington State 3-8
Exhibit 3-7: Rail Intermodal Facilities in Washington State 3-15
Exhibit 3-8: Railroad Terminals and Yards Impacting Washington State Rail Movements..... 3-16
Exhibit 3-9: 2008 Rail Line Capacity 3-21
Exhibit 3-10: 2028 Rail Line Capacity 3-22
Exhibit 3-11: Railroad Bottlenecks..... 3-23
Exhibit 3-12: Rail Lines in Washington State Exceeding Practical Capacity 2008 and 2028 3-28
Exhibit 4-1: Washington State Is a Global Gateway 4-2
Exhibit 4-2: Freight-Dependent Sectors GDP Washington State 2008 4-3
Exhibit 4-3: Business Incomes of Freight-Dependent Sectors Washington State 2008 4-3
Exhibit 4-4: Freight-Dependent Sectors Employment Washington State 2008 First Quarter..... 4-4
Exhibit 4-5: Freight by Mode – Washington State 2007 4-4
Exhibit 4-6: Rail Freight Flows – Washington State 2007 4-5

Exhibit 4-7: Growth of Rail Freight Flows Washington State 2007 versus 1996 4-5
Exhibit 4-8: Directional Rail Freight Flows Average of Other States in U.S. 2007 4-6
Exhibit 4-9: Top 10 Commodities Shipped by Rail Washington State 2007 4-7
Exhibit 4-10: Inbound Rail Freight Flows 4-8
Exhibit 4-11: Outbound Rail Freight Flows 4-9
Exhibit 4-12: Economic Output and Employment Supported by Produce Rail Car Program – Year 2008 4-10
Exhibit 4-13: Economic Impacts of Freight Rail Transportation – Washington State 2007 4-14
Exhibit 4-14: Population Growth – Washington State 2007-2030 4-15
Exhibit 4-15: U.S. Export and Import, 1992 to 2008 4-15
Exhibit 4-16: Top Ten Export States in the United States – 2008 4-16
Exhibit 4-17: Container Traffic Through Puget Sound Ports 1998-2008 4-16
Exhibit 4-18: GDP Growth of Freight-Dependent Sectors – Washington State vs. United States, 1997 to 2008 4-17
Exhibit 4-19: GDP Growth by Freight-Dependent Sectors – Washington State 1997 to 2008 4-18
Exhibit 4-20: Washington State Rail Freight 2007, 2020, and 2030 4-20
Exhibit 4-21: Rail Freight Distribution 4-20
Exhibit 4-22: Projected Rail Freight Growth of Top 10 Commodities – Washington 2007-2030 4-21
Exhibit 4-23: Marine Cargo Trends – Rail vs. Other Modes 2002 to 2030 4-22
Exhibit 4-24: Marine Cargo Port Modal Distribution Washington State 2007, 2020, and 2030 4-23
Exhibit 4-25: U.S. Shipments by Mode – 2006 and 2035 4-25
Exhibit 4-26: U.S. Freight Tons and Value by Mode, 2006 and 2035 4-25
Exhibit 4-27: Comparison of Total Rail Flow Railcars per Year – 2005 and 2035 4-28
Exhibit 4-28: Principle of With/Without Analysis 4-29
Exhibit 5-1: Procedure for Collecting Freight Rail Needs 5-3
Exhibit 5-2: Abandoned Rail Lines 5-4
Exhibit 5-3: Washington Rail Investments 5-5
Exhibit 5-4: Abandonment Survey List – Likely Abandonments 5-7
Exhibit 5-5: Palouse River and Coulee City Rail System 5-8
Exhibit 5-6: Washington State Ports 5-11
Exhibit 5-7: Seattle Freight Network 5-18
Exhibit 5-8: Tacoma Freight Network 5-19
Exhibit 5-9: All Intermodal Freight Connectors in Washington State 5-21

Exhibit 5-10: All Intermodal Freight Connectors in the Puget Sound Region 5-22
Exhibit 5-11: Rail Intermodal Freight Connectors in Washington State 5-23
Exhibit 6-1: Regional and Metropolitan Transportation Planning Organizations 6-8
Exhibit 7-1: Federal Requirements for Benefit Assessment and Documentation 7-2
Exhibit 7-2: Variables for the State Benefit/Cost Analysis 7-4
Exhibit 7-3: Benefit and Cost Measures 7-5
Exhibit 7-4: PRIIA-Defined Benefits and Evaluation Strategies 7-7
Exhibit 7-5: Possible Methodology to Measure Public Benefit in Washington State 7-10
Exhibit 7-6: Benefit Impact Evaluation Process 7-15
Exhibit 8-1: Needs Identification Process 8-2
Exhibit 8-2: Survey Respondents 8-4
Exhibit 8-3: Estimated Completion Dates 8-4
Exhibit 8-4: Project Types 8-5
Exhibit 8-5: Public Benefits 8-6
Exhibit 8-6: Private Benefits 8-6
Exhibit 8-7: Funding Needs by Commitment 8-7
Exhibit 8-8: Committed Funds by Source 8-8
Exhibit 8-9: Expected Funds by Source 8-9
Exhibit 8-10: Funding Needs by Area 8-9
Exhibit 8-11: Funding Needs by Phase 8-10
Exhibit 8-12: Governmental Transportation Expenditure by Mode 8-11

Washington State Department of Transportation

Executive Summary

Introduction

Washington State's (state) economy needs a vibrant, competitive rail network. This network must provide a reliable, accessible, and cost-effective freight service to shippers and customers across the state. At the same time, the freight rail system must co-exist with a high-quality, fast, frequent and reliable passenger rail service between major cities across the state that is competitive with automobile and air travel times. This plan focuses on the freight side of this equation. It must be recognized that both systems are interconnected and must be planned accordingly to meet both freight and passenger needs as an integrated rail network.

The future of the state freight rail system is envisioned by the State Freight Rail Plan Advisory Committee to meet the following six goals:

- **Economic Competitiveness and Viability:** Support the state's economic competitiveness and economic viability through strategic freight partnerships.
- **Preservation**: Preserve the ability of the state's freight rail system to efficiently serve the needs of its customers as well as preserve the potential of the system in the future.
- **Capacity**: Coordinate the freight rail system capacity increases to improve mobility, reduce congestion, and meet the growing needs of the state's freight rail users, when economically justified.
- **Energy Efficiency and Environmental**: Take advantage of freight rail's modal energy efficiency to reduce the negative environmental impacts of freight movement in the state.
- **Safety and Security**: Address the safety and security of the freight rail system and make enhancements, where appropriate.
- **Livability**: Encourage livable communities and family-wage jobs through the freight rail system and its improvements.

The *Washington State 2010-2030 Freight Rail Plan* is an update of the *Washington State Freight Rail Plan 1998 Update*. This update complies with Federal Railroad Administration (FRA) requirements that the state establishes, updates, and revises a rail plan in order to receive federal assistance. The freight rail plan also fulfills state requirements, under Revised Code of Washington (RCW) 47.76.220 and RCW 47.06.080, that the Washington State Department of Transportation (WSDOT) prepare and periodically revise a state rail plan that identifies, evaluates, and encourages essential rail services. This plan and its recommendations are

intended to be a living document that will be updated and revised as future conditions require. Currently a National Rail Policy is being developed by the FRA and is anticipated to be released in 2010. Washington's plan will be updated if a revision is required to maintain consistency with the National Rail Plan.

This plan will provide guidance for rail initiatives and investments in the state. Results from this plan will be included in the *Statewide Multimodal Transportation Plan*. WSDOT intends this next update to meet state and federal transportation planning requirements, thus maintaining the state's eligibility to receive federal surface transportation funding.

The freight rail plan also reflects strategies to:

- Increase the effectiveness of the rail program.
- Broaden understanding of rail issues for all stakeholders.
- Provide a framework to implement rail initiatives in the state.
- Support WSDOT in federal funding opportunities, such as Transportation Investment Generating Economic Recovery and American Recovery and Reinvestment Act of 2009 (ARRA).
- Implement the rail benefit/cost analysis required by the legislature.
- Fulfill new federal requirements for state rail plans.

2030 Vision for Freight Rail in Washington State

The Washington State freight rail system is:

- ***Reliable.***
- ***Cost effective.***
- ***Energy efficient.***
- ***Environmentally-friendly transportation mode for domestic and international cargo deliveries.***

As a critical part of Washington's multimodal transportation system, the rail system leverages intermodal connections:

- ***To provide a seamless system for cargo deliveries to customers.***
- ***To improve the mobility of people and goods.***
- ***To support Washington's economy by creating and sustaining family-wage jobs and livable communities.***

Freight rail has increasing importance that fosters economic growth and livable communities for the state and its citizens. The rail system is a critical part of the multimodal transportation system that supports national and international trade flows through the state and provides critical gateway opportunities for other cargo to move through the state. It is a vital system that supports state ports and the regional economies bringing

state goods to national and international markets. Freight rail in the state can be considered as a fundamental utility supporting the retail and wholesale distribution system.

Rail System in Washington State

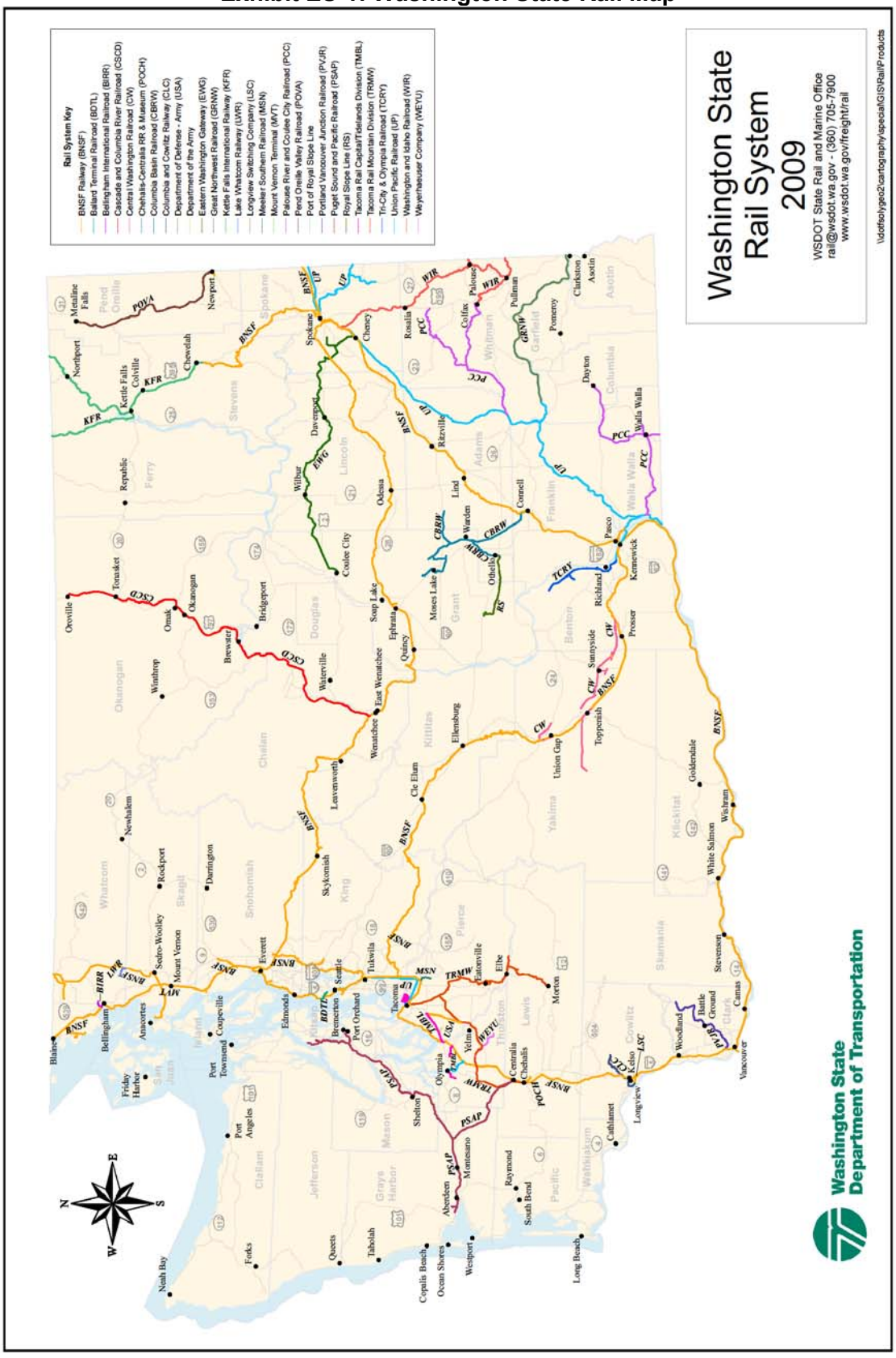
The state's rail network has evolved over the last century to serve a wide range of passenger and freight markets and has extended across many parts of the state. Thirty-two of the state's 39 counties are served by one of the state's freight railroads (Exhibit ES-1). The rail network in the state has three distinct types of rail services: intercity passenger, commuter, and freight.

The Class I railroad system primarily serves the inland transportation component of the supply chain for large volumes of import and export cargo moving through state ports. This Class I railroad system is supported locally by the short-line network consisting of many small railroads, many of which evolved from abandonments of the Class I railroads.

The state's mainline railroad system is comprised of two Class I railroads: the BNSF Railway (BNSF) and the Union Pacific Railroad (UP). Both operators have invested in improvements and upgrades to their rail systems, including new locomotives, new traffic control systems, and rolling stock substantial infrastructure improvements. The Class I railroads are supported by one Class II and 19 active Class III short-line railroads. This brings the total number of active freight railroads in the state to 22.

There are three major rail corridors in the state. First, the north-south corridor is the I-5 rail corridor running from Portland, Oregon (OR) to Vancouver, British Columbia (B.C.). There are two east-west corridors: the Columbia River Gorge—running from Vancouver, Washington (WA) to the east—and Stevens Pass running from Everett to Spokane. These three corridors carry the majority of the current freight rail volumes and are supported by other less dense mainline routes as well as the short lines that feed into the mainlines, such as Stampede Pass running from Auburn to Pasco.

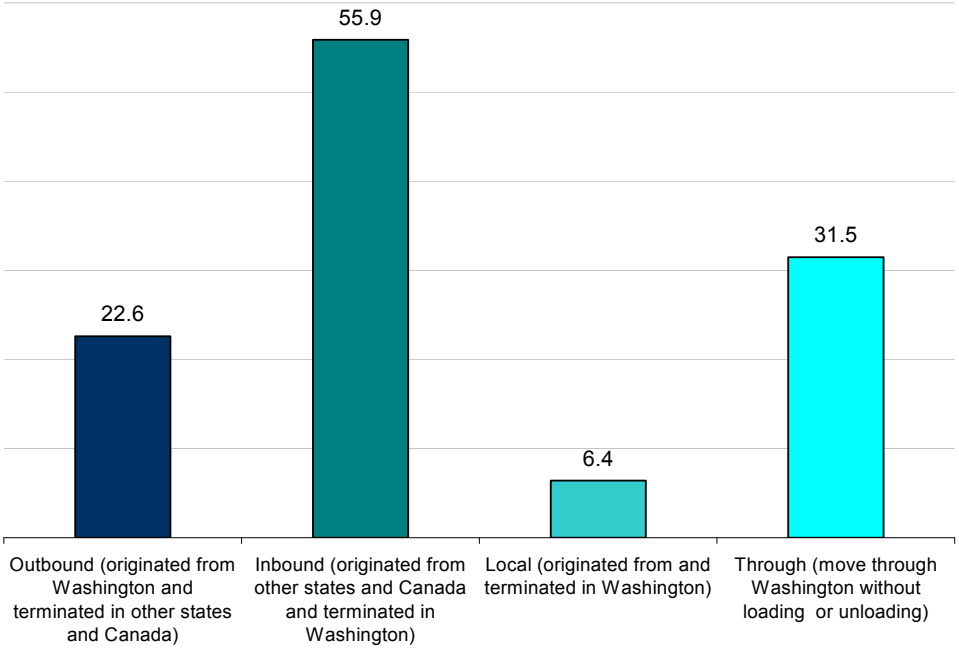
Exhibit ES-1: Washington State Rail Map



Economic Impact

Freight rail transportation is a fast growing service. In 2007 the state rail system carried 116 million tons of freight, compared with 64 million tons in 1991, for an annual growth rate of 3.8 percent. Among the 116 million tons of rail freight, 56 million tons arrived in the state from 44 other states and Canada, while almost 23 million tons were shipped from the state ports and industries to 46 other states and Canada. Over 6 million tons of local rail freight moved within state borders and Almost 32 million tons of rail freight moved through the state without loading and unloading (Exhibit ES-2).

Exhibit ES-2: Washington State Rail Freight Directional Flows □ 2007
(Million Tons)



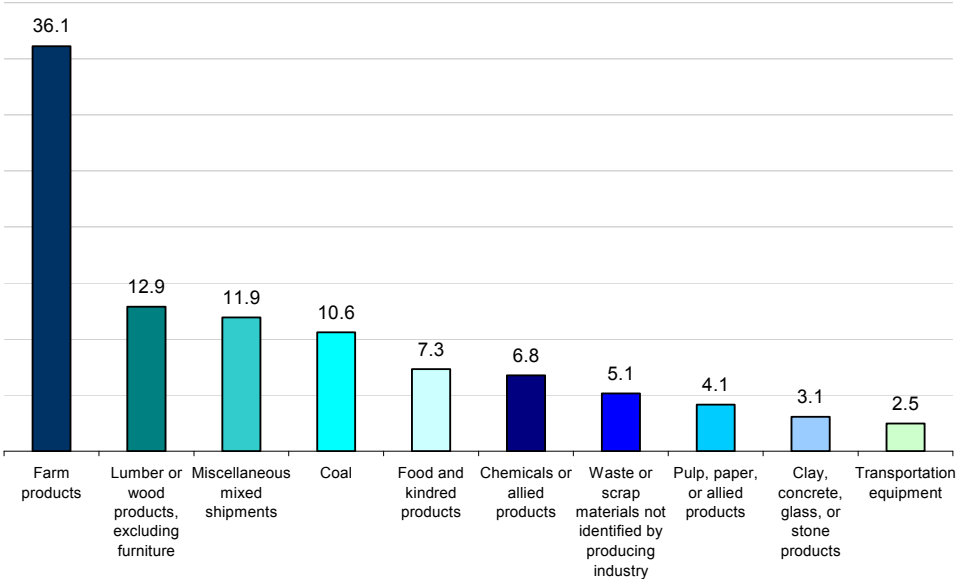
Source: WSDOT State Rail and Marine Office □ 2007 Surface Transportation Board (STB) Waybill Sample Data Analysis

The economic vitality of the state requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. The state is well known for its agricultural products, such as apples, wheat, fruit, and potatoes. Freight rail plays an important role to underpin the state's agriculture sector. Lumber and wood product producers, manufacturers, waste management, and mining also rely on rail transportation to move heavy, bulky products to markets in a cost-effective manner.

Farm products (36.1 million tons) were the top commodity by weight moved on the state's rail system, followed by lumber and wood

(12.9 million tons), miscellaneous mixed shipments (11.9 million tons), and coal (10.6 million tons) (Exhibit ES-3). In 2007, 86 percent of the freight moved on state rail lines was from the top ten commodities.

Exhibit ES-3: Top 10 Commodities Shipped by Rail
Washington State 2007 (Million Tons)



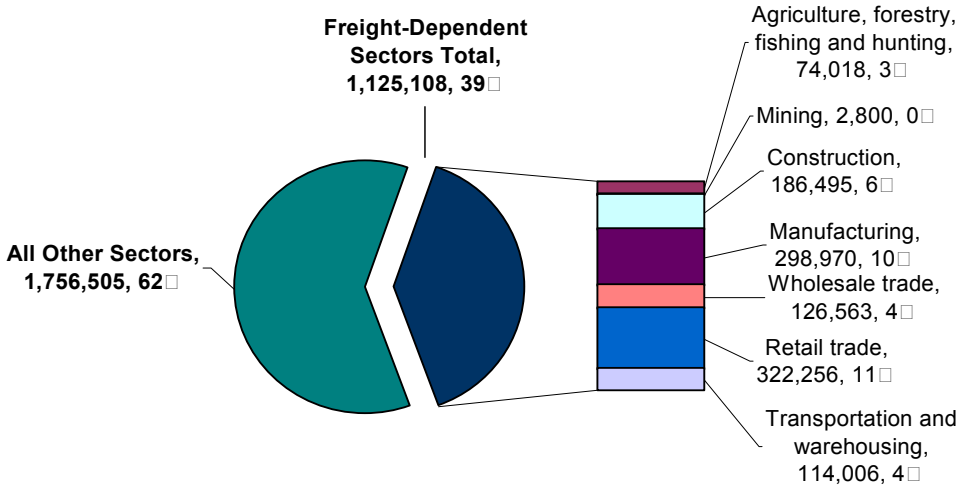
Source: WSDOT State Rail and Marine Office 2007 STB Waybill Sample Data Analysis

Rail freight transportation has significant economic impacts. In 2007 total rail freight revenue, including rail only and rail intermodal, amounted to $1.2 billion.[1] Freight rail employed 4,207 people in the state and contributed $533 million directly to the state's Gross Domestic Product (GDP).

A large part of the state's economy depends on freight for its competitiveness and growth. The state's freight rail system, as an integrated part, also supports freight-dependent sectors of the economy. Freight-dependent sectors, in general, include agriculture, mining, construction, manufacturing, wholesale, retail, transportation, and warehousing. In 2008 freight-dependent sectors accounted for 33 percent of the state's GDP, 71 percent of business income, and 39 percent of state's employment (Exhibit ES-4).

[1] Rail intermodal refers to double-stack container trains that move as a unit train and has one or more modes to move a shipment from origin to destination.

Exhibit ES-4: Freight-Dependent Sectors Employment
Washington State 2008 First Quarter
Freight-Dependent Sectors: 1.125 Million Jobs
All Sectors: 2.881 Million Jobs



Source: Washington State Employment Security Department 2008, compiled by WSDOT State Rail and Marine Office

Societal Impact

Transportation is one of the largest greenhouse gases (GHG) sources in the state. Transportation GHG sources includes light- and heavy-duty (on-road) vehicles, aircraft, rail engines, and marine engines. Carbon dioxide (CO_2) accounts for about 98 percent of transportation GHG emissions from fuel use. Most of the remaining GHG emissions from the transportation sector are due to nitrogen oxide (NOx) emissions from gasoline engines. Rail is a more environmentally-friendly transportation mode (Exhibit ES-5). Increasing the use of rail transportation can contribute to a reduction in GHG.

Exhibit ES-5: Greenhouse Gas Emissions by Mode
(grams/ton-mile)

	Road	Rail	Air
Carbon Dioxide (CO_2)	235.33	40.00	1,469.33
Nitrogen Oxide (NOx)	1.99	0.74	6.31
Particulate Matter (PM_{10})	0.47	0.05	0.80
Carbon Monoxide (CO)	1.21	0.42	6.26
Sulfur Dioxide (SO_2)	0.30	0.12	2.27

Source: Environmental Science Technology, 2007, 41, 7138-7144

Publicly- and privately-owned railroads are implementing cleaner fuels and working to achieve increased fuel efficiency by retrofitting existing

engines and purchasing newer cleaner engine technologies on new equipment, as well as continuing to make operational efficiency improvements.[2]

Increasing the use of rail for both the movement of freight and passengers can help the state make progress towards its GHG emissions reduction goals. On a national level, freight demand is projected to almost double in the next 35 years. Without improvements in freight rail capacity, this increase in demand would need to be accommodated by trucks using the roadway network.

In the case of moving freight from trucks to trains, a net decrease in GHG emission reductions is tied to a permanent change in mode split: freight volumes are forecast to grow, and if trucks shift one commodity to rail simply to haul another commodity on the road, there will not be a net decrease in GHG emissions.

Rail Infrastructure Needs and Investment Program

Currently, the Class I railroads are meeting the existing long-haul traffic demands, but are experiencing capacity limitations during peak volumes on some of their routes. It must be noted that the majority of the state's passenger rail services run on rail owned by these Class I railroads. Thus, infrastructure improvements and operational changes will be needed to accommodate projected growth in freight and passenger traffic, and to support a competitive rail freight environment.

An assessment of the freight needs was completed as part of this plan. The assessment is based on data provided directly by the state's freight railroads, ports, public agencies, and other key stakeholders. In total, this needs assessment identifies 109 short- and long-term capital improvement projects and other initiatives. The total cost for the requested projects, where cost estimates are available, is $2.0 billion. Other issues that need to be considered in the development of this plan are: proposed rail abandonments and at-risk lines, port access, intermodal connectors, and emerging issues that face freight rail in this state. The state needs to develop a comprehensive system to prioritize these projects, using a cost benefit approach, to obtain the maximum benefit for the public's investment into any private infrastructure that is clearly measurable.

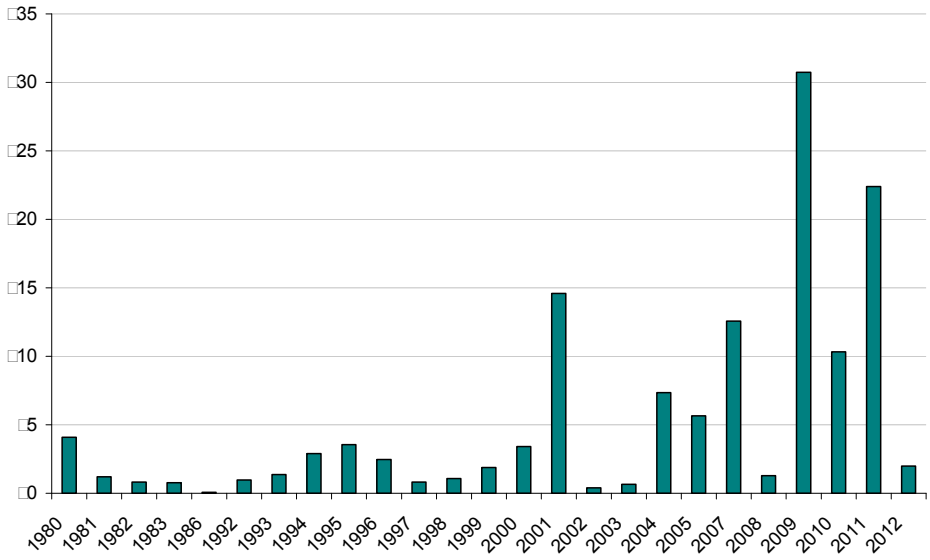
Preservation of At-Risk Railroads

The state has one of the best rail preservation and development programs in the country. The state has invested $99 million in its rail freight

[2] www.maritimeairforum.org/news/NW_Ports_Clean%C2%ADAirStrategy_Draft.pdf.

infrastructure since 1980. An additional $35 million in investment is anticipated from 2010 to 2012 (see Exhibit ES-6).

Exhibit ES-6: Washington Rail Investments (in Millions)



Source: WSDOT State Rail and Marine Office

These investments include the Freight Rail Assistance Program ($6 million 2007-2011), and Freight Rail Investment Bank Program (Rail Bank) loans. The Rail Bank has made $7.5 million in funding available from 2007-2011, with a maximum loan of $250,000. All of these investments have been in regional and small railroads, in recognition of the fact that these railroads are a vital component of the state's transportation system and economic well-being.

Port Access

Port access to rail is very important to the vitality of local, state, and national economies. As economic development agencies, ports are a fundamental part of the state's infrastructure. State ports face substantial competition from other ports and shipping routes. The majority of the cargo that comes through state ports is discretionary cargo (i.e., containers, autos, grain, dry bulks, and break-bulk cargoes) that can shift to other gateways, if shipping through these other ports becomes more efficient or cost effective than using state ports. To be competitive, ports must have good rail access[3] and connect effectively to the rest of the system. As an added benefit, rail is a community-friendly mode, as it is a safe, energy-efficient way to move goods along major corridors.

[3] Good rail access means that trains can get in and out of a rail facility without delay to the facility, the train, or other rail operations on a rail line.

The state has 75 ports, not all with water access, as shown in Exhibit ES-7. The state has 11 deep-draft ports, a tremendous asset for the state's economy.[4] This is an asset because these ports can berth most of the cargo ships on the ocean due to the ability to handle ships that draw up to 40 feet of draft. Seven of these ports are on the Puget Sound. The largest ports, the Ports of Seattle and Tacoma, together comprise the third largest container load center in the nation—behind the complexes at Los Angeles/Long Beach and New York/New Jersey. One deep-draft port, the Port of Grays Harbor, is located on the coast; and three are located on the Columbia River. Together, these ports comprise a seamless network that sends state goods to a global market, and imports goods from other countries, bound for state stores.

Vital to the continued success of state ports is capitalizing on our inherent competitive advantage—a shorter ocean trade route to the Asia/Pacific Rim through the state's gateways. However, if these critical gateways, which handle a majority of the state's freight rail tonnage, lead to a system that is slow and unreliable, they will be noncompetitive and the flow of trade may shift. This could result in added costs to shippers.

Thus, state ports are only a part of the freight rail picture. Each part of the system needs to contribute to the success of the whole. Investment of public dollars needs to follow a prioritized plan that will deliver the maximum system benefit.

The Columbia/Snake River Inland Waterway system stretches 365 miles inland from the Pacific Ocean. The three deep-draft ports along this system—Longview, Kalama, and Vancouver—are major shipping centers for the state. Upstream, the Ports of Klickitat, Pasco, Kennewick, and Benton are served by barge along the Columbia River. The Ports of Garfield, Whitman County, Walla Walla, and Clarkston are served by barge along the Snake River.

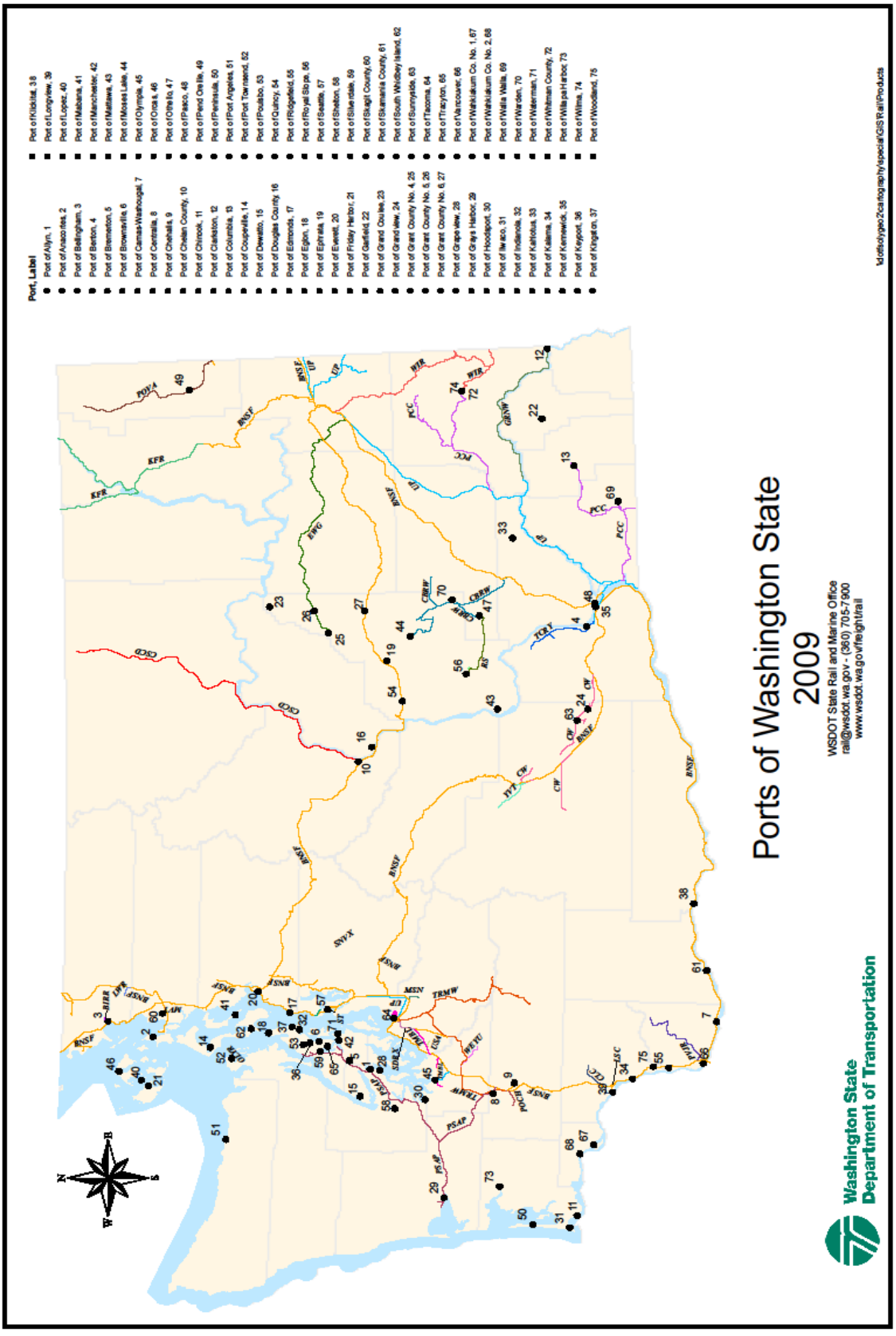
Although there are many ways to classify ports in the state, this plan has selected four classifications for ports that are rail served:

- **Intermodal (Container) Ports[5] –** Seattle and Tacoma.

[4] A deep draft Port is a port that can receive a ship with a laden draught of 40 feet or less. A very deep draft port is one that can handle a laden draught of 45 feet or less, which are most container ships and other large ships including military ships. http://www.globalsecurity.org/military/systems/ship/container-types.htm/.

[5] Intermodal ports are those ports that move containers from ship to rail, producing unit trains of containers to be transported to the inland destinations.

Exhibit ES-7: Ports of Washington State



- **Agricultural and Bulk Ports –** Clarkston, Garfield, Grays Harbor, Longview, Kalama, Seattle, Tacoma, Vancouver (WA), Walla Walla, and Whitman County.
- **Rail-Dependent Break-Bulk and Industrial Ports –** Anacortes, Everett, Garfield, Grays Harbor, Kalama, Longview, Olympia, Seattle, Tacoma, and Vancouver (WA).
- **Rail-Serviced Industrial Ports –** Benton, Bremerton, Chelan, Clarkston, Columbia, Ephrata, Garfield, Kennewick, Mattawa, Moses Lake, Othello, Pasco, Quincy, Ridgefield, Royal Slope, Shelton, Sunnyside, and Whitman County 3 & 4.

Each of these categories has different access needs and challenges, although efficient and timely rail service is mandatory to all these ports. Port access issues are more closely related to location than to type of port.

Nearly all of the state's deepwater ports are located adjacent to the Interstate 5 (I-5) corridor, or are on short-line railroads that branch off the I-5 corridor. As a result, rail connectivity issues for the ports and capacity issues on the I-5 rail corridor are necessarily tied. Along the corridor there are five main areas where mainline capacity needs and connectivity issues intersect, including: Vancouver (WA), Kalama to Longview, Centralia, Tacoma, and Seattle. Each of these is examined in more detail in Chapter 5 of the plan.

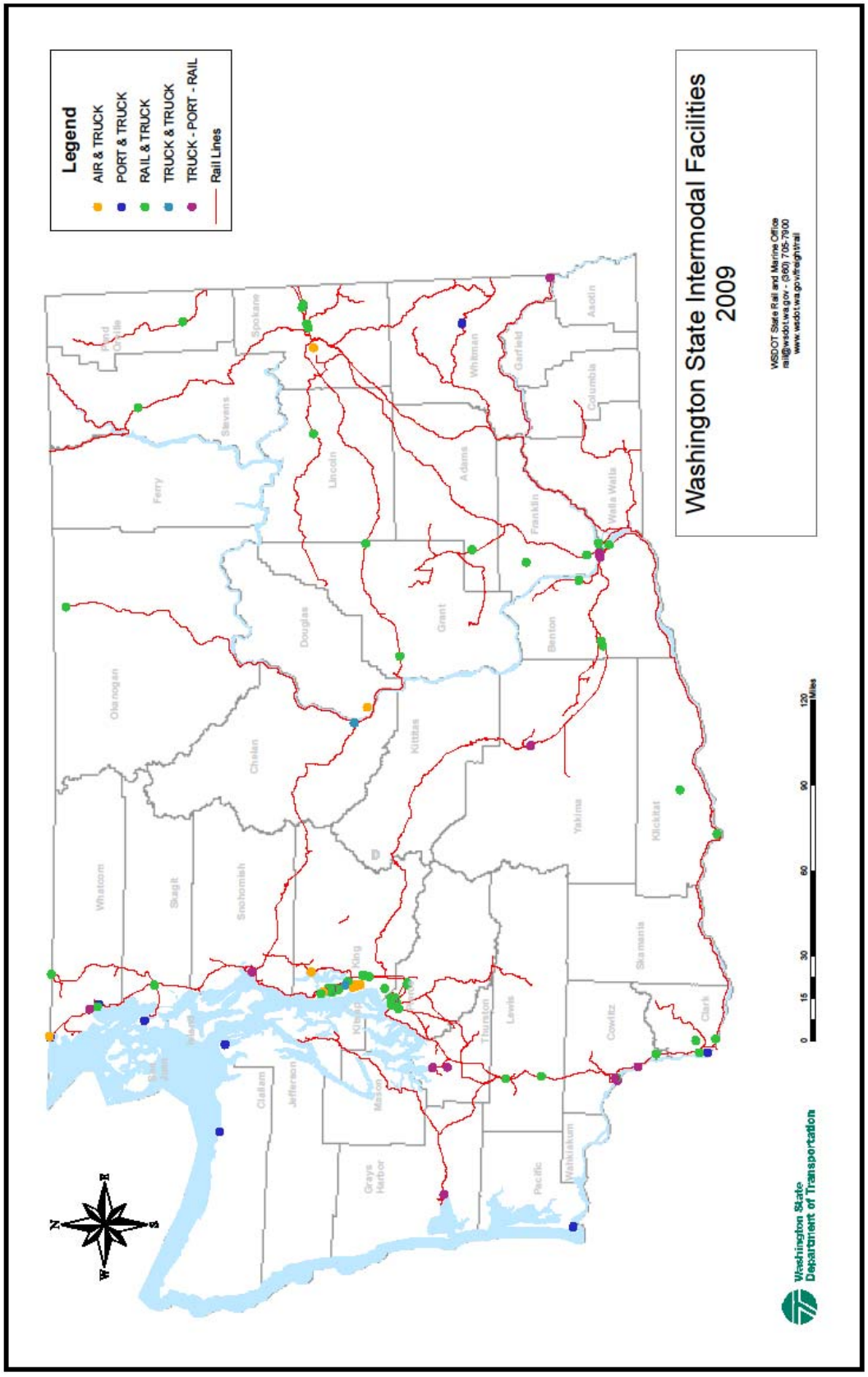
Intermodal Connectors

Intermodal connectors are a location where two modes meet and the cargo moves from one mode to another.[6] In most cases this is moving a piece of cargo from a truck to a train or vice versa. Two examples are inland ports and on-dock intermodal yards. Exhibit ES-8 shows major intermodal facilities located in the state by type of connector.

Rail access is a significant element of port competitiveness. By providing an inland port service, a seaport can (in theory) make intermodal rail service available to a broader range of customers. There must be efficient rail service to both the seaport and the inland port for the model to work. If priced competitively, the inland port service can offer cost savings to container shippers and thereby increase the port's competitiveness.

[6] The intermodal connectors shown are those identified by the USDOT BTS Intermodal Facility database.

Exhibit ES-8: Intermodal Freight Connectors in Washington State



In addition to rail served inland ports, the two most prominent alternatives that involve rail transportation are on-dock intermodal and near-dock intermodal. Examples of these intermodal yards can be seen at the Ports of Seattle and Tacoma. There are other types of intermodal connectors, such as rail-to-barge, truck-to-grain elevators, rail-to-bus, as well as airports. In most cases airports are not supported by rail, although for freight there is the truck-to-plane intermodal connector.

Freight System Issues and Needs

Capacity Bottlenecks

The benefits that the state can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many state businesses.

The pressure on the rail system will increase in the next decades, as a result of increased population and demand, economic globalization, and continued containerization. The total freight tonnage rail system is expected to increase by about two to three percent annually over the next 20 years. To accommodate this growth, many more rail lines within the state will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting state communities by increasing delays for automobile and truck drivers at rail-highway crossings. Increased noise, congestion, and safety problems exist at these crossings. Dealing with these problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

Competition

State ports are facing competition not only from the southern California ports, but also increased competition from western Canadian ports, including Prince Rupert. There is also the concern that once the Panama Canal is expanded for the larger container ships that the cargo may go 'all water' to the East Coast through the canal instead of by rail from the West Coast. At this point, there are many studies predicting potential outcomes of the larger canal, but there is not a consensus on the effect it will have on the state. This plan includes strategies to favorably position the state in the changing competitive marketplace.

Emerging Issues

North-South High Capacity Corridor

The fluidity of the I-5 rail corridor is mandatory for the economic health of the state. This corridor can be classified as extending from Portland, OR to Vancouver, B.C. A north-south corridor, supporting the east-west movements of the majority of the cargo moving through the state, is required to keep the rail network flowing. The BNSF I-5 corridor carries both freight and passenger rail traffic. As the projections of cargo and passenger volumes are met, it will be especially important that attention is kept on the health of this north-south corridor.

It is important to note that the mainline in the I-5 corridor, from Vancouver (WA) to Vancouver, B.C., is owned by BNSF. Amtrak has rights to operate passenger service on this mainline. UP has rights to run on this rail line from Vancouver (WA) to Tacoma. From Tacoma to Seattle, both Class I railroads have their own rail lines and operate separately on their respective rail.

Currently, BNSF has no public plans, other than those announced to support intercity passenger train volumes, to increase capacity over the route. From a freight perspective, BNSF believes sufficient capacity exists for the foreseeable future. Indeed, BNSF's planning staff sees nothing in this corridor as "freight driven" with the current volumes at this time. Increased volumes may require capacity improvements.

In the future, it will be very important to monitor the capacity versus demand of this corridor and prepare capacity improvements to meet the growth projections. This will require coordination between all stakeholders and partners to ensure that capacity is available for this corridor and its communities to meet their respective needs. This may require a true public-private partnership including regional agencies (such as metropolitan planning organizations), Sound Transit, Amtrak, rail freight customers, ports, local communities, as well as other stakeholders. Public funding could include safety improvements, such as grade separations.[7] Private railroad funding could include improvements, such as longer sidings or additional mainline tracks. BNSF has stated that the funding of these longer sidings and additional mainline tracks should not be the exclusive responsibility of the private railroads, when the need is driven by passenger rail service or the need to preserve freight rail service due to increasing passenger rail service.

[7] A grade separation is when an at-grade road that crosses a rail line is separated from the rail line by elevating the road as an overpass over the rail line or the rail line on a trestle.

East-West High-Capacity Freight Rail Corridor

For the state to stay competitive, a strong coalition of stakeholders must build an integrated plan to develop the necessary capacity to retain the state's rail freight market share. A high-capacity rail corridor should be maintained and improved upon from the Puget Sound to Chicago, Illinois. A national cohesive effort needs to be developed by both the public and private partners in order to achieve the economic growth that is required to keep the state competitive.

A compelling business case for proposed improvements to this corridor should be developed. This corridor will require infrastructure and operational improvements as well as improved cooperation between BNSF and the UP. An agreement on priorities needs to occur and a funding program developed. It is important to the state's economy to have healthy railroads competing for business in the state. This competitive positioning influences the Class I railroads' investment within the state. BNSF and UP capital investment decisions and strategies are based upon Return on Investment. Capacity must be available to attract more volume and new customers. To encourage the Class I railroads to invest in this state, it is critical that public investment dollars are available for projects with public benefit.

To hold the Class I railroad's attention to the state, the state's economy must be growing, the ports efficient, and the stakeholders must understand how important the rail system is both to the economy and ports. There must be consensus on the priority of projects and the funding mechanism to get the improvements built. Thus, there needs to be a prioritization of the freight rail projects that have a clear economic benefit to the state. This priority list needs the support of all stakeholders in order for the high priority projects to get done.

Dedicated High-Speed Passenger Rail Track

On August 24, 2009, WSDOT submitted their High-Speed Intercity Passenger Rail Program application to the FRA. This is the first step to the development of a dedicated high-speed passenger rail track along the I-5 corridor from Portland, OR to Vancouver, B.C. This will allow the separation of lower speed freight trains from the higher speed passenger trains and allow for increased service levels for both freight and passengers.

WSDOT applied for nearly $435 million in ARRA funding in this first round under Track 1 projects. The primary focus of Track 1 projects is to help speed economic recovery through construction of "ready-to-go" intercity passenger rail projects. WSDOT has a total of 20 capital rail projects that qualify for Track 1 consideration. When completed, these

projects will add an additional daily Amtrak *Cascades* round trip between Seattle and Portland, improve on-time reliability, reduce rail congestion, and provide enhanced service without affecting freight capacity.

Without the necessary improvements on the I-5 rail corridor, the available capacity on the segment will be exceeded by about 2018, at even the lowest freight recovery scenario. Consequently, it should be expected that BNSF will not allow growth in passenger operations without a clearly defined set of capacity improvements. These improvements would protect freight performance regardless of how the economy recovers over the next few years.

Impacts of Dam Breaching or Loss of the Columbia-Snake Inland Waterway System

The current Columbia-Snake Inland Waterway System is very efficient for moving cargo. This system provides shippers with an alternative to shipping by rail, supplies price competition to the railroads, and imposes sufficient capacity to absorb substantial fluctuations in grain shipments, especially during peak export months and years.

Due to the fear that numbers of Chinook salmon and steelhead in the Snake River would continue to decline, the possibility of breaching (removing) the four Snake River dams was examined in a report issued by the US Army Corp of Engineers in 2002.[8] The discussion on removing the dams continues to this day.

In addition to the effect that dam breaching would have on the system, transportation impacts would also be shifted to the road and rail systems in the region. The mainline rail system, short-line rail system, and state and county road systems could all be expected to bear an increased share of the freight now shipped by barge. This could cause some capacity constraints to be reached.

Statewide Information and Data Needs

Currently, there is not enough rail and freight data collected for statewide rail planning and rail operations. The U.S. Department of Transportation (USDOT) expects that the state rail plan from each state will provide detailed insight into the concerns facing state transportation systems and set forth state visions of how rail transportation can address those issues. One of the elements that USDOT views as necessary includes multimodal transportation, especially ways in which modes can be leveraged to serve transportation customers more effectively and efficiently.

[8] www.efw.bpa.gov/IntegratedFWP/DamBreachingFacts.pdf.

States are in a unique position to provide information on local rail bottlenecks and resultant road and rail traffic congestion. The lack of this information can negatively affect the larger transportation network. Resolution of such issues can improve transportation flows and positively affect the movement of goods and people far beyond state borders.

States can also provide information on projects that they are planning to develop, which may have repercussions beyond state borders, and hence should be considered in the National Rail Plan.[9]

States need greater information management capacity to assess statewide demand, analyze utilization data, and develop and maintain asset inventories and rail system physical and condition inventories.

The Partners

In this state there are numerous partners or players in the rail freight system: first and foremost is the owner of the asset—the railroads—as well as the customers served; second, the ports who are logistics and transportation partners in moving the cargo from ship-to-rail or barge-to-rail; and finally, the regulators and partial funders of the system—the state and federal governments are partners in this system. Other stakeholders included local communities, planning organizations, and tribes. The State Freight Rail Plan Advisory Committee represented these stakeholders in the development of this plan and some are encouraging that the committee stays intact.

Investment Prioritization and Project Evaluation

Freight rail has many benefits. With its cost effectiveness, fuel efficiency, safety records, and lower environmental impacts, freight rail is a viable option that can be included in policy aimed at solving economic, social, and environmental problems with integrated solutions.

Although predominantly privately owned, the freight rail system provides many public benefits that warrant taxpayer participation in improvements at both federal and state levels. The common public benefits associated with freight rail include stimulating the state's economy, supporting local communities and businesses with jobs and revenues, reducing congestion, improving public safety, offering a transportation choice for shippers, reducing environmental pollution, and saving energy.

For rail-related investment, private benefits have typically accrued to rail carriers, shippers, rail property owners, and other non-governmental

[9] See page 1-4 in Chapter 1 for more detail on the National Rail Plan.

groups. Public benefits are broadly assigned to government agencies that represent taxpayers.

Priorities and Criteria

WSDOT developed a benefit/cost methodology and uses it to evaluate state projects against six legislative priorities:

- Economic, safety, or environmental advantages of freight movement by rail compared to alternative modes.
- Self-sustaining economic development that creates family-wage jobs.
- Preservation of transportation corridors that would otherwise be lost.
- Increased access to efficient and cost-effective transport to market for the state's agricultural and industrial products.
- Better integration and cooperation within the regional, national, and international systems of freight distribution.
- Mitigation of impacts of increased rail traffic on communities.

Financing the Needs

The need for expansion to meet future demand can only be achieved through involvement of both the public and private sectors. The state, as well as private rail owners, has invested vigorously in the rail systems in the recent years. Although federal transportation funding in the United States has remained at 1 percent over the last 20 years, more federal investment in the state's freight rail system is needed.

There should be a national freight policy and a dedicated consistent funding stream for freight rail transportation. There has been movement at the federal level in this area, with efforts by the FRA, to develop the National Rail Plan, which should then provide input into a National Freight Policy.

State Role

This plan describes the state's role and investment policies for freight rail that should be used as a guideline for the state's future freight infrastructure investments. Funding the necessary investments in the freight rail system should be shared among those that receive benefits from the system in proportion to those benefits received.

A consistent investment program that maintains and improves the state freight rail system is critical. This will create an outline for the state's funding that meets the public benefit criteria. These should include improvements that divert truck traffic from overburdened highways, including many of the vertical clearance limitations. Priority should be

made on investments that leverage weight carrying abilities of rail to increase efficiencies, as well as increasing safety at rail-highway crossings.

Conclusion

This plan will address the goals and strategies of improving freight rail service within the state. The plan will be updated on a regular basis to respond to the changing economic climate. The completion of the National Rail Plan at the federal level may require a revision to this plan to meet any new requirements directed to the states. In addition, any future studies will be incorporated into appendices as new information becomes available.

The greatest obstacle to implementation of this plan is the lack of a dedicated reoccurring funding source at both the state and federal levels. With 90% of the $2.0 billion in rail needs identified in this plan unfunded, the state will have to pursue federal funding, as well as boost state spending, and establish public-private partnerships to close the gap between available resources and freight rail needs.

The second largest obstacle will be determining the priority of the projects and which projects should be implemented first to gain the maximum benefit to the system as a whole.

Washington State Department of Transportation

Chapter 1: Plan Purpose and Authority

Purpose of the State Freight Rail Plan

The *Washington State 2010-2030 Freight Rail Plan* is an update of the *Washington State Freight Rail Plan 1998 Update*. These plans fulfill the Federal Railroad Administration's (FRA) requirements that a state must establish, update, and revise a rail plan in order to receive federal funds. This plan also reflects strategies to:

- Increase the effectiveness of the rail program.
- Broaden understanding of rail issues for all stakeholders.
- Provide a framework to implement rail initiatives in Washington State (state).
- Support the Washington State Department of Transportation (WSDOT) in federal funding opportunities, such as the Transportation Investment Generating Economic Recovery/American Recovery and Reinvestment Act grants.
- Implement the rail benefit/cost analysis required by the legislature.
- Fulfill new federal requirements for state rail plans.

Washington State Department of Transportation

WSDOT is the steward of the state's interstate, highway, and ferry systems. WSDOT directly manages the planning, design, project delivery, and operations for over 18,000 lane miles of state highway and more than 3,600 bridges, as well as operates the largest ferry fleet in the United States. In addition to building, maintaining, and operating the state highway system and state ferry system, WSDOT works in partnership with others to maintain and improve local roads, railroads, airports, and multimodal facilities and programs that offer alternatives to driving alone. WSDOT also own 323 miles of rail and operates 297 miles of these rail lines.

WSDOT's State Rail and Marine Office

WSDOT's State Rail and Marine Office is responsible for managing and directing the state's freight and passenger rail capital and operating programs. It enacts the direction of the legislature as it impacts rail and marine initiatives and manages rail system improvements that support economic development, move people and goods, relieve road and airport congestion, and reduce greenhouse gas emissions. The State Rail and Marine Office works with railroads, ports, communities, and other

organizations to improve the state's rail system. This office is also responsible for rail project identification and assessment, strategic rail transportation planning, development of state rail and marine data, and state rail grant program administration.

State and Federal Legislative and Planning Requirements

WSDOT's rail planning efforts are implemented within the context of specific state and federal legislation and related planning requirements that are summarized below.

State Requirements

There are four requirements for a rail plan in state law. The two primary statutes are: the Revised Code of Washington (RCW) 47.76.220 that requires WSDOT to create a state rail plan and RCW 47.06.080 that requires WSDOT to create a freight rail plan. This plan satisfies both statutory requirements. Highlights of these and other pertinent statutes follow.

RCW 47.76.220 (state rail plan - contents) requires WSDOT to prepare and periodically update a state rail plan that identifies, evaluates, and encourages essential rail services. The plan must identify and evaluate mainline capacity issues, port and congestion issues, and address at-risk or abandoned lines. It must establish priorities to determine which rail lines should receive state support. Priorities should include anticipated benefits to the state and local economy, anticipated line impact to roads and highway improvements, financial viability of state-funded lines, and line impact on energy use and air pollution. It must identify, describe, and map the state rail system; identify and evaluate rail commodity flows and traffic types; identify rail banked or preserved lines or corridors; and identify and describe other issues affecting the state's rail traffic.

RCW 47.06.080 requires WSDOT to include a state freight rail plan as one of the state-interest components of the statewide multimodal transportation plan. This plan must fulfill the statewide freight rail planning requirements of the federal government, identify freight rail mainline issues, identify light-density freight rail lines threatened with abandonment, establish criteria for determining the importance of preserving the service or line, and recommend funding priorities. It must also identify existing intercity rail rights of way that should be preserved for future transportation use.

RCW 47.04.280 (Transportation System Policy Goals) states that all public investments in transportation, including transportation planning,

should support achievement of these five policy goals: preservation, safety, mobility, environment, and stewardship.

RCW 47.06.040 (statewide multimodal transportation plan) requires WSDOT to coordinate development of the *Washington State 2010-2030 Freight Rail Plan* with other transportation plans to ensure consistency with each other and with the state transportation policy plan.

Government-to-Government Tribal Consultation

WSDOT maintains government-to-government relations with 35 federally recognized tribal governments. The following policies and documents guide WSDOT:

- The **1989 Centennial Accord Between the Federally-Recognized Indian Tribes in Washington State and the State of Washington** was executed between the federally-recognized Indian tribes of Washington signatory to this Accord and the state of Washington through its Governor. The Accord provides a framework for a government-to-government relationship and implementation procedures to assure execution of that relationship.
- The **1999 Government-to-Government Implementation Guidelines** provide a consistent approach for state agencies and tribes to follow.
- The **2005 Governor's Executive Order 05-05, Archaeological and Cultural Resources** orders all state agencies to review capital construction projects and land acquisitions, which do not undergo Section 106 review under the National Historic Preservation Act of 1966, with the Department of Archaeology and Historical Preservation and affected tribes to determine potential impacts to cultural resources.
- The **2009 Washington State Secretary of Transportation Executive Order 1025.01, Tribal Consultation** reaffirms the commitment of WSDOT to provide consistent and equitable standards for working with the various tribes across the state. WSDOT recognizes that each federally recognized tribe is a distinctly sovereign nation. WSDOT's goal is to create durable intergovernmental relationships that promote coordinated transportation partnerships in service to all citizens. More information on specific consultation procedures is available in the *WSDOT Centennial Accord Plan*.

Federal Statutory Requirements

The Passenger Rail Investment and Improvement Act of 2008 (PRIIA) amends Title 49 of the United States Code to prevent railroad fatalities, injuries, and hazardous material releases, to authorize the Federal Railroad

Safety Administration, and for other purposes. It is known as Public Law 110-432 (PL 110-432) and was approved as House Resolution 2096.[1]

PL 110-432, Division B, Title 3, Section 303, Chapter 227 attempts to put rail on an equal footing with planning for other transportation modes by requiring state rail planning as the basis for federal and state rail investments within the state. State rail plans are comprehensive documents intended to lay out the state's vision, objectives, service goals, capital investment plans, and project funding priorities for all passenger and freight rail services. They are submitted to the U.S. Department of Transportation (USDOT) Secretary for review and approval and updated at least every five years for re-approval.

PL 110-432 requires designation of the state authority to prepare, maintain, coordinate, and administer the rail plan, and designation of the authority to approve the rail plan. The authority to prepare, maintain, coordinate, and administer the rail plan is the WSDOT State Rail and Marine Office. The authority to approve the rail plan is the WSDOT Secretary of Transportation.

See Appendix 1-A for the detailed state and federal requirements referenced in this plan.

Development of the State Freight Rail Plan

Federal Planning □ the National Rail Plan

Under PRIIA Section 307, the USDOT is to develop a national rail plan that is consistent with approved state rail plans and national rail needs to promote an integrated, cohesive, efficient, and optimized national rail system for the movement of goods and people. The national rail plan will expand upon the vision of a national rail system, including identifying specific corridor goals and success measures. The plan will likely provide an opportunity to revise the high-speed rail designations, including a new category of approved corridors, i.e., those corridors for which a detailed corridor plan and institutional framework are in place to permit development of a successful corridor that meets the national rail goals.[2]

FRA and their stakeholders are discussing the following:

- What should be in America's national rail plan?

[1] HR 2096, pp 100-104, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h2095enr.txt.pdf.
[2] www.fra.dot.gov/downloads/rrdev/hsrstrategicplan.pdf.

- What is the best process to bridge from a preliminary national rail plan to the long-range national rail plan?
- What should be the interface between state and national plans?

The FRA preliminary plan sets forth a proposed approach for developing the long-range national rail plan, including goals and objectives for greater inclusion of rail in the national transportation system. The preliminary plan does not offer specific recommendations, but instead describes itself as the "springboard" for future discussions.

Relationship with Other Plans

The *Washington State 2010-2030 Freight Rail Plan* is related to statewide, regional, and tribal transportation plans that include multimodal components and are designed to meet federal and state requirements.

Washington State Freight Rail Plan 1998 Update

The *Washington State Freight Rail Plan 1998 Update* is the previous update. It was prepared by the WSDOT freight rail program to meet state and federal requirements to identify, evaluate, and encourage essential rail services.

Passenger Rail Plans

The *Long-Range Plan for Amtrak Cascades* (2006) and the *Amtrak Cascades Mid-Range Plan* (2008) are passenger rail planning counterparts of the *Washington State 2010-2030 Freight Rail Plan.*[3] They were developed by the WSDOT State Rail and Marine Office to meet federal and state requirements for passenger rail development. The long-range plan is the state's blueprint for the development of intercity passenger service—it identifies the needed improvements to the state's intercity rail system for the next 20 years. The mid-range plan identifies and develops options that outline the steps needed to achieve incremental Amtrak *Cascades* services in meeting demands of the next eight years.

Statewide Transportation Plans

The *Washington State 2010-2030 Freight Rail Plan* recognizes that rail passenger and freight services are critical to the state's transportation system. Cost-effective investment of the state's resources must consider other modes, including highways, aviation, and water. The preferred mode of transportation and investment is dependent on the type of traffic as well as the origin and destination of the cargo.

[3] www.wsdot.wa.gov/Freight/publications/PassengerRailReports.htm.

The *Washington State 2010-2030 Freight Rail Plan* is coordinated with these other transportation planning efforts.

- The *2007-2026 Washington Transportation Plan* (WTP) is the statewide multimodal transportation plan that meets state and federal planning requirements to guide investments in the entire transportation system. It includes investment strategies for state-owned facilities as well as descriptions of the state's interest in aviation, marine ports and navigation, freight rail, intercity passenger rail, bicycle and pedestrian walkways, and public transportation. WSDOT will update this plan after the federal transportation planning requirements are passed, at which time this plan will be renamed the *Statewide Multimodal Transportation Plan*. The *Washington State 2010-2030 Freight Rail Plan* is consistent with the 2007-2026 WTP.
- The Washington State Transportation Commission (WSTC) is preparing a *Washington Transportation Plan 2011-2030 Update* that meets state requirements for a statewide transportation plan that is consistent with the state's growth management goals and transportation system policy goals, reflects the priorities of government, addresses regional needs, and recommends policies to the Governor and legislature. This plan is due December 2010, and is updated every four years.
- The *2009-2015 WSDOT Strategic Plan, Business Directions*, identifies WSDOT's strategic direction for the 2009-2011 biennium and beyond. WSDOT has diverse responsibilities and many lines of business, and not everything WSDOT does is represented here. Instead, the plan focuses on what is believed to be the highest priorities for state citizens, now and into the future.

- For other transportation "modal" plans developed by WSDOT, please go to www.wsdot.wa.gov/planning/ModalPlans.htm.

Metropolitan Transportation Plans

A Metropolitan Planning Organization (MPO) is an organization of elected officials in urbanized regions with 50,000 or more population. MPOs are required by federal regulations to create metropolitan transportation plans and a list of proposed transportation improvements called a Metropolitan Transportation Improvement Program.

Regional Transportation Plans

Regional Transportation Planning Organizations (RTPO) are formed through a voluntary association of local governments within a county or contiguous counties. RTPOs create a regional transportation plan and a list of proposed transportation improvements called a Regional Transportation Improvement Program. RTPO members include WSDOT,

cities, towns, counties, tribes, ports, transportation service providers, private employers, and others.

If an MPO is within the boundary of an RTPO, then the RTPO is the lead agency for the MPO.

Federal Lands Highway Program Transportation Plans

The Office of Federal Lands Highway (FLH) works with numerous agencies. Approximately 30 percent of the land in the U.S. is under jurisdiction of the federal government. The federal land management agencies (FLMAs) are: the Bureau of Indian Affairs, U.S. Forest Service, National Parks Service, Fish and Wildlife Service, Bureau of Land Management, Military Surface Deployment and Distribution Command, U.S. Army, U.S. Army Corps of Engineers, Department of Defense, Tennessee Valley Authority, and the Bureau of Reclamation. The FLH also works closely with many state and territorial partners.

The Federal Lands Highway Program (FLHP) is subdivided into five core areas, namely, the Forest Highway Program, Park Roads and Parkways Program, Public Lands Highway Discretionary Program, Indian Reservations Roads Program, and the Refuge Roads Program. The FLHP is administered through partnerships and interagency agreements between the Federal Highway Administrations' FLH, FLMAs, and tribal customers. The FLHP also supports other important FLMA partners by providing funding (about $6 million per year total) for integrated transportation planning, bridge inspections, and other technical assistance activities.

State Freight Rail Plan Methodology

The strategy adopted by WSDOT to develop the *Washington State 2010-2030 Freight Rail Plan* is fact-based and data-driven. WSDOT strengthened its data collection and analytical capacity and developed improved databases and forecast models to better describe and articulate the needs of the freight rail system. Economic impact assessment, benefit/cost analysis, and cross modal comparison link investments to their effects on the economy and society. With this plan, policymakers and other users can address socioeconomic policy issues and integrate transportation solutions when considering funding freight rail projects.

Key References

The following are key references used in developing this plan:

- The *2009 AASHTO State Rail Planning Guidebook*, developed by the American Association of State Highway and Transportation Officials

(AASHTO), is designed to help states produce PRIIA-compliant state rail plans customized to the unique circumstances of each state. This plan was developed using this guidebook.

- The *Statewide Rail Capacity and System Needs Study* (2006)[4] is a key reference prepared by the WSTC. This comprehensive study was developed to address the key question asked by the legislature, "Should the state continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" The conclusion: the state should continue to participate in the freight and passenger rail systems, although each investment must be extensively evaluated for its cost and benefits to the state. **Because its components are similar to the *Washington State 2010-2030 Freight Rail Plan's* state and federal requirements, the study is referenced throughout this plan.**
- The *2009 Marine Cargo Forecast Technical Report*[5] is another key reference prepared by the Washington Public Ports Association and WSDOT. Its purpose is to assess the expected flow of waterborne cargo through Washington's port system and evaluate the distribution of cargo throughout the state's transportation network, including waterways, rail lines, roads, and pipelines.
- In order to keep stakeholders and citizens aware and involved in the plan development process, WSDOT provided this Web page: www.wsdot.wa.gov/Freight/Rail/WashingtonStateFreightRailPlan.htm.
- The WSDOT Web site, www.wsdot.wa.gov, provides public access to transportation-related information. It is a key communication tool used to meet state and WSDOT goals to be a high performance organization that is credible and accountable to the Governor, legislature, taxpayers, and transportation delivery partners across the state.[6]

Key Stakeholders

This plan was developed by WSDOT State Rail and Marine Office staff. The staff augmented their knowledge with the help of public involvement and assistance, primarily from the State Freight Rail Plan Advisory Committee (Advisory Committee).

The Advisory Committee consisted of self-selected, volunteer stakeholders from around the state. In May 2009, members of railroads,

[4] *Statewide Rail Capacity and System Needs Study* (2006) by the WSTC, www.wstc.wa.gov/Rail/default.htm.
[5] *2009 Marine Cargo Forecast Executive Summary*, www.wsdot.wa.gov/NR/rdonlyres/270BB86A-FC7B-48F3-8546-8CB3A435A2B8/0/MCF2009ExecutiveSummary32309doc.pdf.
[6] WSDOT Accountability & Performance Information, www.wsdot.wa.gov/Accountability.

ports, shippers, industries, metropolitan planning organizations, regional transportation planning organizations, state and federal agencies, cities, counties, tribes, and other interest groups were invited to participate on the Advisory Committee. The role of this committee was to:

- Help develop the vision and goals of the state freight rail plan.
- Provide assistance to update information for the freight rail system, capacity, and needs.
- Help identify and assess port access and rail abandonment issues.
- Help assess and evaluate beneficial impacts of rail infrastructure improvements on society.
- Help WSDOT understand concerns of local communities and organizations.
- Share information.

Public Involvement Process

Public involvement and outreach was essential to the development of the *Washington State 2010-2030 Freight Rail Plan*. Public involvement and outreach included Advisory Committee meetings, a workshop, communication, Web interfaces (e-updates, Web pages, Web linkages), presentations, internal and external stakeholder meetings, press releases, and an open house.

See Appendix 1-B for more information about the public involvement, public participation, and documentation of these planning processes.

Environmental Review

Environmental documentation will be project-specific and comply with the State Environmental Policy Act (SEPA) and/or National Environmental Policy Act (NEPA), depending on the existing and anticipated source of project funding. The level of environmental documentation will be determined based on the potential environmental effects of the proposed projects.

Plan Organization

Chapter 1 introduces the *Washington State 2010-2030 Freight Rail Plan*, its state and federal statutory requirements, and its relationships with other plans. It discusses the purpose of the plan, describes the WSDOT State Rail and Marine Office, legislative, and planning requirements for the plan. The plan purpose and the methodology WSDOT adopted to develop the plan including public involvement is also described.

Chapter 2 discusses the overview of the rail system and macroeconomic environment. The vision statement, goals, and goal strategies are introduced in this chapter.

Chapter 3 defines the current freight rail systems in the state. It provides maps, a physical inventory of railroads and facilities, railroad profiles, descriptions of strategic intermodal sites, and addresses the need for a condition inventory of railroads and facilities.

Chapter 4 describes how the state's freight rail system supports the state's economy. It assesses commodity flows and industrial use of freight rail capacity. This includes the ancillary freight benefits that can be passed on to shippers and carriers as a result of passenger rail infrastructure development. It also describes the macroeconomic context of the state's freight rail system development. Components include economic vitality; mobility and congestion; environment, energy, and climate change; and safety and security.

Chapter 5 addresses the changing rail systems. It provides rail system maps and a database of recently abandoned rail lines. It identifies port access issues as well as intermodal connectors. It identifies and describes state, regional, local, and private rail projects.

Chapter 6 discusses the current state role, the players, and partnerships involved in state rail investments. It describes the current needs including data management and information capacities, statewide coordination, funding capacities, and strategic planning efforts.

Chapter 7 describes investment prioritization and project evaluation, including the decision-making process, a discussion on priority methods and criteria, and the benefit/cost methodology used to analyze freight rail projects.

Chapter 8 discusses the projects and current funding sources in the state, federal, local, and private arenas; the strategies of how funding should be acquired; and the vision of future funding options. Discussions include the public interest in private freight rail development and related federal and state legislation, financing, and funding strategies.

Chapter 9 concludes the plan with a discussion of next steps.

Washington State Department of Transportation

Chapter 2: State Rail Vision

Introduction

Railroads carry a significant share of Washington State's (state) freight and make contributions to the state economy. The state freight rail system is part of the larger freight transportation network, providing businesses, ports, and farms with competitive access to North American and international markets.

Currently in Washington State, 53 percent of goods by weight are moved by truck, 18 percent by rail, 17 percent by pipeline, 10 percent by water, and 2 percent by air and other modes.[1] The trucking system is the railroad's biggest customer. Transportation modes do not operate in isolation, but generally operate together to provide an integrated system of movement. Little in the way of goods or people gets to their destination without the use of several modes of transportation. Consequently, the modal interchanges—in the case of freight, ports, transloading facilities, and distribution centers—are critical nodes in the system. These modal interchanges can function smoothly or create bottlenecks in the system. Chapters 3 and 5 discuss bottlenecks in more detail.

In addition to contributing to the state's economic vitality, rail transportation and investment could significantly alter the current transportation modes and practices of the way cargo has been historically moved. Rail can be used to relieve congestion in some urban areas, as well as provide redundancy within the transportation system. Rail is an energy-efficient and cleaner transportation alternative to many other modes.

The state's freight rail system is largely operated by the private sector. Because it is essential to the state economy and society, the Washington State Department of Transportation (WSDOT) has a public role to play under state and federal statutory requirements that guide public freight rail investments and development. Funding and delivery of freight mobility projects at the state level is primarily focused on two agencies: WSDOT and the Freight Mobility Strategic Investment Board (FMSIB).

[1] WSDOT State Rail and Marine Office – Analysis based on Federal Highways Administration (FHWA) Freight Analysis Framework (FAF) data and Surface Transportation Board (STB) Waybill Data.

The *Washington State 2010-2030 Freight Rail Plan* articulates the existing and future role of freight rail within a state multimodal transportation system. The plan establishes a vision and goals for statewide freight rail systems development, examines current and needed freight rail assets, and provides a clear path to implement rail improvements.

The state's multimodal transportation system is comprised of a mix of modes that are owned and operated by public and private entities. The transportation network includes: rail lines, highways, ferries, local roads, public transit systems, bicycle and pedestrian facilities, ports, waterways, airports, pipelines, and intermodal terminals. This integrated system supports the movement of people and goods within the state, facilitating economic vitality to business and residents. The state's freight network serves three functions:

1. It supports regional economies by bringing state goods to national and international markets as well as domestic products to the state.
2. It is also a fundamental local utility supporting the retail and wholesale distribution system.[2]
3. It serves as a global gateway to support national and international trade flows through the state, providing a competitive advantage for such sectors as logistics and trade, manufacturing, agribusiness, and timber/wood products sectors.

Freight mobility is critical to the state's economy. In 2007[3] the state's freight systems supported over one million jobs in state freight-dependent industry sectors, which produced $434 billion in Gross Business Income. This is 71 percent of the state's Total Gross Business Income of $627 billion.[4]

The rail industry is one of the most capital intensive businesses in the nation. Most available capital is used by the railroads to maintain their infrastructure and equipment with very little left for capacity improvements. To improve the margins, the Class I railroads[5] have increased their efficiencies by using a "hook and haul" operating method. Hook and haul refers to the model of having other entities (ports or short lines) prepare the train for long distance runs of 500 miles or more. Hook and haul operations with short lines provide continuation of service and often improve service levels to the industrial customers the short lines serve. Efforts to improve Class I railroad efficiencies include the

[2] Washington Transportation Plan (WTP) Freight Report, 2006.
[3] 2007 data is the most current year available.
[4] Gross Business Income is a measure of total revenues reported to the state.
[5] The classes of railroads are classified by revenue produced per year. Refer to Appendix 9 for definitions of Class I, Class II, and Class III railroads.

consolidation of shipments. It is understood that resulting cost efficiencies and savings are to be passed on to shippers.

Changes that improve Class I railroad efficiencies may hurt agricultural growers and other small shippers. This is in addition to the challenges these smaller customers have in gaining access to empty rail cars in a timely basis.

As private sector system owners, the Class I railroads have a need to achieve their own objectives. The lack of congruency in the two sets of goals raises conflicts between Class I railroads and the state. This is a dilemma for the state as it looks to a cleaner, more efficient hauler of goods. The challenge for the state is to develop a working relationship with Class I railroads that promotes the use of rail, while requiring private investment for private benefit. This includes determining what and when public benefit is achieved and investing public monies when this benefit is earned. A new approach needs to be crafted as rail dynamics shift. All stakeholders should work together as partners with the Class I railroads to develop strategies that meet the goals of the state and the needs of the railroads.

Another area of concern is the short-line system, which has largely been developed by the spin-off/sale of smaller unprofitable branch lines. These feeders or spurs are vital to the state's agriculture and small business owners. Many of the short lines are constantly struggling to perform and survive. This is a place where the state has focused its support in the past. This public support helps the smaller shippers in the rural areas continue to access the national rail systems via the short-line network.

Macroeconomic Environment

The state faces both challenges and opportunities resulting from the fundamental changes in the economy and society within a macroeconomic policy environment. Freight rail development, similar to passenger rail development,[6] was once viewed by the state as simply a means to move people and goods. Now such development is increasingly viewed and used as an integrated macroeconomic solution to achieve multiple ends.

Driving forces in the state's macroeconomic environment are trends in economic vitality, living-wage employment, transportation system efficiency, environmental sustainability, and safety and security. Challenges include economic globalization, population growth, capacity

[6] *Amtrak Cascades Mid-Range Plan*, (2008), www.wsdot.wa.gov/freight/publications/amtrakcascades.htm.

increases on rail corridors, higher fossil fuel prices, and global climate changes.

The state, including WSDOT, is increasing the monitoring, analytical, and policy efforts to increase efficiency, relieve congestion, and develop robust and resilient transportation systems.

The Washington State Legislature, in 2007, passed SSB 5412, which states that all public investments in transportation should support achievement of five transportation policy goals listed in the Revised Code of Washington (RCW) 47.04.280. Public investments in transportation should support achievement of these policy goals. This plan was developed around these five goals.

1. **Preservation:** To maintain, preserve, and extend the life and utility of prior investments in transportation systems and services.
2. **Safety:** To provide for and improve the safety and security of transportation customers and the transportation system.
3. **Mobility:** To improve the predictable movement of goods and people throughout the state.
4. **Environment:** To enhance the state's quality of life through transportation investments that promote energy conservation, enhance healthy communities, and protect the environment.
5. **Stewardship:** To continuously improve the quality, effectiveness, and efficiency of the transportation system.

Changes in Transportation

Transportation has encountered many changes and pressures in the last decade. Some of these pressures are listed below.

Mobility and Congestion

The transportation system is increasingly stressed, manifesting itself in capacity and congestion problems at key regional gateways, intermodal transfer facilities,[7] and along critical transportation corridors. Population growth adds to the pressure on this already constrained infrastructure. It is increasingly difficult to balance freight mobility needs with environmental, social, and financial concerns. Rapidly rising infrastructure maintenance costs across all modes raises awareness that neither the public nor private sectors—acting independently—have the necessary resources to fully address rising transportation demands. Individually or collectively, these issues erode the efficiency and productivity of the region's transportation system. This leads to economic

[7] Intermodal transfer facilities are locations where freight is transferred between freight modes.

implications that reverberate locally, regionally, nationally, and internationally.[8]

Moving Washington[9] is WSDOT's program to realize a vision of congestion relief in the next decade. In the program are strategies to add capacity strategically, operate systems more efficiently, and provide more choices to help manage demand. The program's primary objective is to improve, which is one of the state legislature's five transportation priorities, along with preserving our transportation infrastructure, making the system safe for all, ensuring environmental sustainability, and practicing sound stewardship.

Moving Washington is also a 2-, 6-, and 10-year plan that focuses on the most troublesome corridors in Washington.

Over the next ten years we will:

- Improve travel times by 10 percent.
- Reduce collisions by 25 percent.
- Improve trip reliability by 10 percent.
- Provide choices for commuters in our major corridors.

Freight rail transportation is consistent with *Moving Washington*'s congestion relief strategies, if it can reduce long-haul truck traffic on the state highways.[10]

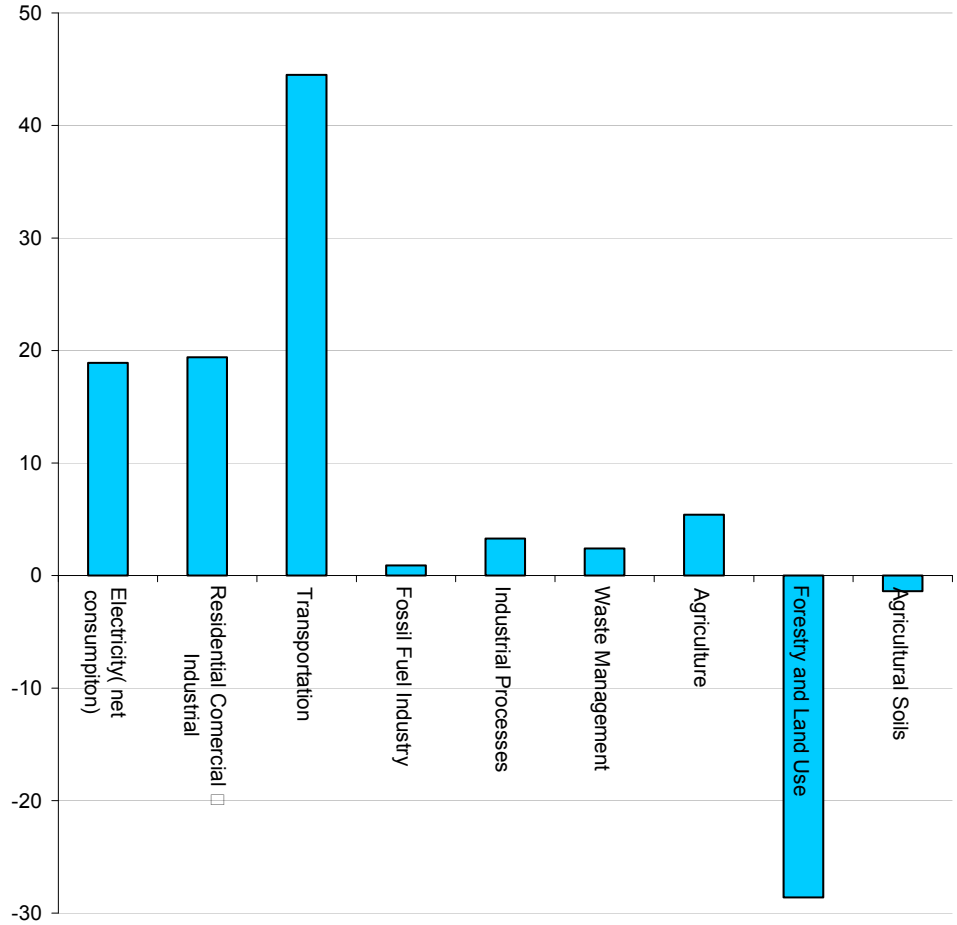
Environment, Energy, and Climate Change

In the state, transportation accounts for nearly half (47 percent) of the total greenhouse gas (GHG) emissions, including emissions from cars, trucks, trains, planes, and ships (Exhibit 2-1). The large amount of hydroelectric generation in the state leads to lower contribution of the electric sector to total emissions, compared with the national average.[11] WSDOT is developing effective, measurable, and balanced emission reduction strategies for all transportation modes, including rail, to protect public health and the environment.[12]

---

[8] *West Coast Corridor Coalition Trade and Transportation Study, Executive Summary*, www.camsys.com, April 2008.
[9] *Moving Washington* – A program to fight congestion, www.wsdot.wa.gov/movingwashington/.
[10] WSDOT, *Moving Washington with Rail Transportation*, folio, www.wsdot.wa.gov/movingwashington.
[11] Washington State GHG Inventory and Reference Case Projection, Center for Climate Strategies, Spring 2007. In 2005, Washington had a much larger fraction (47%) of the GHG emissions from transportation activities as compared to the US (28%).
[12] WSDOT Climate Change, www.wsdot.wa.gov/environment/climatechange/.

Exhibit 2-1: Washington 2005 GHG Emissions
(Millions Metric Tons CO_2)[13]



Source: Washington Department of Ecology

Transportation is one of the largest GHG source sectors in the state. The transportation sector includes light- and heavy-duty (on-road) vehicles, aircraft, railroad locomotive engines, and marine engines. Carbon dioxide (CO_2) accounts for about 98 percent of transportation GHG emissions from fuel use. Most of the remaining GHG emissions from the transportation sector are due to nitrogen oxide (NOx) emissions from gasoline engines. Rail emits fewer greenhouse gases than other transportation modes (Exhibit 2-2). Increasing the use of rail transportation may lead to a reduction in GHG from the transportation sector.

[13] Forestry and Land Use and Agricultural Soils are negative due to the fact that these two categories are effective in reducing GHG.

Exhibit 2-2: Greenhouse Gas Emissions by Mode
(grams/ton-mile)

	Road	Rail	Air
Carbon Dioxide (CO_2)	235.33	40.00	1,469.33
Nitrogen Oxide (NOx)	1.99	0.74	6.31
Particulate Matter (PM_{10})	0.47	0.05	0.80
Carbon Monoxide (CO)	1.21	0.42	6.26
Sulfur Dioxide (SO_2)	0.30	0.12	2.27

Source: Environmental Science Technology, 2007, 41, 7138-7144

Congress has proposed a bill that, if enacted, may create clean energy jobs, achieve energy independence, reduce global warming pollution, and transition to a clean energy economy.[14] For rail transportation, this means that more publicly- and privately-owned railroads will switch to cleaner fuels and increased fuel efficiency, retrofit existing engines, ensure that the best available engine technologies are purchased for new equipment, and continue to make operational efficiency improvements.[15]

Climate change is redefining transportation planning throughout the world with calls for additional data and measurement criteria and eventually recommending new policies.

In 2009 several bills were signed into state law related to transportation and climate change. E2SSB 5560 (Agency Climate Leadership) resulted in several state laws.

RCW 70.235.050 requires all state agencies to meet statewide GHG emission limits and report GHG emissions to the Department of Ecology.

RCW 43.21M.040 requires that agencies "shall consider" an integrated climate change response strategy when designing, planning, and funding infrastructure projects.

RCW 43.21M.010 directs the Departments of Ecology, Agriculture, Commerce, Fish and Wildlife, Natural Resources, and Transportation to develop an integrated climate change response strategy for state, local, and private businesses to prepare for, address, and adapt to the impacts of climate change.

[14] American Clean Energy and Security Act of 2009, www.opencongress.org/bill/111-h2454/show/.
[15] www.maritimeairforum.org/news/NW_Ports_Clean%C2%ADAirStrategy_Draft.pdf.

Governor Gregoire's Executive Order 09-05[16] directs the Department of Ecology to participate in the Western Climate Initiative and assist in developing a regional greenhouse gas emission reduction program. Under this executive order WSDOT is required to:

- Consult with state agencies, local governments, business, and environmental representatives to evaluate potential changes to the vehicle miles traveled benchmarks established in RCW 47.01.440.
- Report recommendations to the Governor by December 31, 2010.

Livable Communities

The use of rail for both freight and passenger transportation can increase a community's vitality and livability.

Livability is defined in many ways but the term typically describes a compact, mixed-use community or neighborhood that makes efficient use of existing public infrastructure, supports transportation choices, and provides affordable residential areas near shopping, work, and schools. Increased access to passenger rail supports the concept of livable communities. In addition, separating rail from vehicles and non-motorized transportation modes can increase a community's livability by increasing driver and pedestrian safety.

In the state's communities, as the rail system nears capacity due to economic growth, service quality can be strained. Rail rates are increasing for many businesses. Thus, the pressures on the rail system and its corridors are escalating.[17] Rail investments are generating jobs, as other family-wage jobs are lost to overseas operations and businesses reduce their workforce to survive.[18] Integrating rail and land use planning and policies that are consistent with the state's vision is a must, if livability in the form of sustainable communities is to be achieved. Building strong public-private partnerships that develop sound funding strategies will enable the enhancement of the existing rail infrastructures and corridors. These actions will allow for the maintenance and preservation of additional right of ways.

[16] 2009 Legislation and Governor's Climate Change Executive Order Summary www.wsdot.wa.gov/environment/climatechange/.
[17] Washington State Transportation Commission, December 2006, *Statewide Rail Capacity and System Needs Study: Final Report*, www.wstc.wa.gov/Rail/RailFinalReport.pdf.
[18] WSDOT, December 2008, folio, *Moving Washington with Rail Transportation*.

Vision of Rail Transportation in Washington State

Developing a long-term vision for rail transportation in the state takes many voices. These voices include many stakeholders, including Indian tribes; public entities—federal, state, and local agencies, ports and metropolitan/regional transportation planning organizations (MPOs/RTPOs)—; and private entities, such as rail industry representatives, shippers, various interest groups, and residents and businesses. The State Freight Rail Plan Advisory Committee (Advisory Committee) includes many of these stakeholders, who provided invaluable assistance and input into the planning process.

The vision statement development process began with knowledge gathered from the *Washington State Freight Rail Plan 1998 Update*, the *Statewide Rail Capacity and Systems Needs Study* (2006), and other resources. The WSDOT State Rail and Marine Office held a workshop with the Advisory Committee and other key stakeholders to create a vision statement and goals matrix. Workshop input was summarized and synthesized into draft documents that were further reviewed and refined. Key stakeholders also provided focused assistance in refining the vision and goals documents.

2030 Vision of Rail

The Washington State freight rail system is:

- ***Reliable.***
- ***Cost effective.***
- ***Energy efficient.***
- ***Environmentally-friendly transportation mode for domestic and international cargo deliveries.***

As a critical part of Washington's multimodal transportation system, the rail system leverages intermodal connections:

- ***To provide a seamless system for cargo deliveries to customers.***
- ***To improve the mobility of people and goods.***
- ***To support Washington's economy by creating and sustaining family-wage jobs and livable communities.***

The state is committed to work in partnership with all publicly- and privately-owned railroads in order to ensure a viable and positive future for freight rail in the state.

Goals, Objectives, Strategies, and Actions

WSDOT goals for freight rail service in the state are presented below with their respective objectives, strategies, and actions. These are aligned, as

appropriate, with the goals and strategies in existing state transportation plans and programs, such as the *2007-2026 Washington Transportation Plan*. Chapter 1 discusses the relationship of this plan with other plans.

These goals, objectives, strategies, and actions were developed in collaboration with many stakeholders, including the Advisory Committee and rail industry representatives, ports, government planners, and other interest groups. The responsibility for implementing these proposed strategies may lie with the public sector, the private sector, the private railroads, or jointly.

The Detailed Goal Matrix developed by the Advisory Committee at their workshops can be found in Appendix 2. The matrix reflects the relationships between the goals, objectives, strategies, and actions.

Economic Competitiveness and Viability

Goal: Support Washington's economic competitiveness and economic viability through strategic freight rail partnerships.

Objectives

- Identify the statewide industry needs for rail transportation.
- Increase integration of freight rail planning at all levels of government.
- Provide access to national markets for state products and cargo entering into the United States (U.S.) or being exported through state ports.
- Increase coordination with private sector partners.
- Identify barriers to the efficient use of freight rail in the state.
- Strategically prioritize the removal of these barriers.
- Improve public-private partnerships at the local, regional, corridor, national, and international levels, enabling a larger investment in freight rail infrastructure than any partner can make by themselves.
- Improve rail system/project assessment and evaluation processes that support state goals and assist the decision-making process.
- Understand the railroad system benefits and investments in transportation.

Strategies

- Increase understanding of the competitive positions of the state's shippers and ports using the state's freight rail system.
- Increase coordination of corridor-level freight rail planning within the state.
- Support multistate freight rail corridor strategic planning partnerships.
- Support and enhance economic partnerships between the state and the rest of the nation and its trading partners.

- Lead and coordinate with the state's ports, shippers, and industry on a continuing basis to identify infrastructure, regulatory, and administrative barriers to their efficient use of the freight rail system.
- Expand the state role to manage, coordinate, and facilitate strategic freight rail infrastructure improvements and investments that are in the public interest.
- Develop the criteria for corridor level freight rail transportation to integrate into the National Rail Plan.

Actions

- Carry out needs analysis to support emerging and existing industries to ensure the freight rail system supports the state's ports and rail-dependent industries.
- Work with the state's MPOs, RTPOs, and tribes to integrate freight rail into future regional transportation plans.
- Work with public and private sector partners in states along any appropriate national corridor to eliminate bottlenecks and improve capacity and velocity inside and outside of this state.
- Establish a process to work and communicate with the ports and industry representatives to coordinate activities at the regional, state, and national level on needed projects, programs, and policy decisions.
- On an ongoing basis and at designated intervals, update planning information with representatives from ports, shippers, railroads, and industry to identify constraints.
- Develop an action plan to address those issues where WSDOT has authority.
- Increase the state ability to develop and manage freight rail system information, research capacity, and data capacity that improves oversight and encourages funding for priority freight rail development.
- Increase public awareness of freight rail as a vital mode of transportation within the supply chain.
- Lead the planning effort to integrate investment decisions with the multiple partners.

Preservation

Goal: Appropriately preserve the ability of Washington's freight rail system to efficiently serve the needs of its customers and to ensure it is available to meet all likely future needs.

Objectives

- Preserve the functionality of the existing rail network.
- Provide access to mainline rail for small customers.
- Create sustainable funding sources for rail preservation and maintenance of low density lines.

- Support long-term economic vitality and diversity.
- Enhance the stewardship of the state-owned abandoned railroad corridor, returning it to active service as soon as feasible.
- Preserve the use of at-risk lines for future rail service.
- Preserve the use of at-risk lines for other public use of corridors (i.e. rails to trails).

Strategies

- Assist all classes of railroads' efforts to maintain and preserve the functionality of tracks, bridges, and rail yards.
- Assist short-line railroads in preserving efficient access to the Class I railroads, ensuring system viability and continuity.
- Ensure long-term preservation of existing industrial land, freight rail corridors, and rights of way for future use.

Actions

- Work with the Class I railroads and other partners to identify at-risk system components that can benefit from public support.
- Support the efforts of Class I railroads to compete for state and federal funding for major capacity preservation projects, when appropriate.
- Provide financial assistance to short-line railroads to maintain and preserve essential rail lines and prevent abandonment, when appropriate.
- Develop plans for at-risk rail corridor maintenance and preservation, including funding strategies.
- Integrate freight rail system development, land use planning and policies, public-private partnerships, and funding strategies consistent with the state vision and policy goals to protect and grow freight mobility.
- Work with ports and railroads to project the functionality and viability of existing connections between port terminals, intermodal rail yards, and mainline tracks.
- Work with short-line and mainline railroads to allow compatible interim use of rail corridor right of way (i.e. rail to trails) within statutory limits, until such time that the right of way is returned to active rail use.
- Acquire rail corridors scheduled for abandonment that have the potential to be reactivated in the future, when appropriate.

Capacity

Goal: Facilitate freight rail system capacity increases to improve mobility, connectivity, reduce congestion, and meet the growing needs of Washington's freight rail users, when economically justified.

Objectives

- Improve freight and passenger mobility.
- Improve connectivity to national and global economies.
- Understand future freight rail volume projections.
- Reduce railroad congestion, eliminating port access bottlenecks, and increasing reliability.
- Improve connectivity to other states and other countries, especially with the areas which Washington State has a competitive advantage.
- Make operational process improvements.
- Improve the overall safety of rail and roads.
- Increase public support for strategic public investment in the freight rail system.
- Increase state funding and implementation of priority projects.

Strategies

- Continue efforts to regularly evaluate freight rail capacity needs.
- Create additional capacity, improve connectivity, and improve operational efficiency by making or supporting targeted infrastructure investments.
- Pursue grade separation of roads and rails, where appropriate.
- Support the implementation of passenger rail projects where investments improve freight rail mobility.
- Use and update existing project assessment tools to include performance measures and benefit/cost analysis to prioritize projects.
- Promote public awareness of and support for freight rail investments that provide economic, mobility, safety, and environmental benefits.
- Support efforts to develop viable federal funding sources for freight rail projects with strategic public benefits.
- Support efforts to enhance state funding sources for freight rail projects with public benefits.

Actions

- Continue working with partners with an interest in freight rail capacity to determine future needs. Assess capacity and use the results to support prioritized investment in freight rail capacity improvements.
- Invest in infrastructure development projects that enable cost-effective, smooth, and efficient transport of freight through multimodal corridors and hubs (i.e. lines, ports, industrial areas).

- Identify and prioritize projects that improve mainline capacity, eliminate bottlenecks, and improve mainline access for ports and other freight rail traffic generators.
- Support the efforts of the state's freight rail providers to solicit state or federal funds for projects that provide needed new capacity, where strategically appropriate.
- Identify grade separation projects that should be included in national, tribal, state, regional, and local transportation plans.
- Work with passenger rail agencies and support funding of projects that support freight movement.
- Use and update the current freight rail project evaluation methodology to prioritize projects.
- Seek public input and develop public support for priority projects.
- Lead efforts to position the state's freight rail system for future federal funding with railroads, ports, shippers, and industry.
- Advocate for the East-West Rail Corridor to be designated by the Federal Government as a Corridor of National Significance.
- Coordinate with multistate stakeholders to obtain federal funding for priority projects along multistate corridors (Northern Tier).[19]
- Work with MPOs and RTPOs to facilitate inclusion of appropriate freight rail projects in metropolitan and regional transportation plans.
- Review programs such as the Freight Action Strategy corridor program and determine WSDOT's role in facilitating public-private partnerships in funding freight rail projects in the state.
- Develop a statewide freight rail advisory body to promote freight rail development.

Energy Efficiency and Environmental

Goal: Take advantage of freight rail's modal energy efficiency to reduce the negative environmental impacts from increased freight movement in Washington while maintaining economic viability.

Objectives

- Improve community health and the environment.
- Create a sustainable transportation system

Strategies

- Identify and implement freight rail projects that decrease targeted emissions, where economically viable.

[19] The Northern Tier refers to the rail corridor that runs through the eight neighboring states from the Pacific Northwest to Chicago. These neighboring states are Washington, Oregon, Idaho, Montana, North Dakota, Minnesota, Wisconsin, and Illinois.

- Encourage rail partners to invest in technologies to reduce their fuel consumption and related air emissions.

Actions

- Develop performance measurements and track achievements.
- Develop an analysis to determine the feasibility and factors that will enable minimizing GHG through modal change from truck to rail.
- Implement rail projects that reduce congested highway traffic, when economically feasible.
- Encourage increased use of locomotive anti-idling devices, electric support equipment, and reduction of wheel/track friction to decrease fuel consumption and air emissions.
- Encourage use of environmentally-friendly switching locomotives in port areas and other rail yards close to residential areas.
- Examine the use of locomotives powered by natural gas.
- Assess the effects of climate change where weather and climate events can impact rail infrastructure and operation.

Safety and Security

Goal: Address the safety and security of the freight rail system and make appropriate enhancements.

Objectives

- Reduce the number of rail-highway, rail-pedestrian, rail-rail, and trespassing incidents.
- Meet federal requirements.
- Improve pedestrian safety and reduce liability.
- Improve emergency recovery and prevention.
- Improve the security of the state rail system in its ability to deter or respond to attacks on rail facilities or domestic targets, while ensuring mobility for all users.
- Reduce the negative impacts from natural disasters.

Strategies

- Continue to identify new focus areas for enhancing rail transportation safety.
- Support the Class I railroads' efforts to meet the federal mandate to install positive train control systems on Class I railroads.
- Continue the Operation Lifesaver partnership to educate the public about rail safety.
- Enhance emergency management, operations, and strategies to be coordinated with Washington Emergency Management.
- Address improvements in rail system security and homeland security.

Actions

- Continue to support safety improvements of rail-highway crossings, signal systems, rail lines, and rail facilities.
- Expand education outreach to new and existing stakeholder groups.
- Continue coordination and support of positive train control systems development.
- Work with railroads and other partners to reduce pedestrian trespassing through educational efforts.
- Work with partners to address rail safety before, during, and after emergencies.
- Review best practices, consult with area experts, work with partners, and develop a list of temporary rail-highway grade crossing closures and alternative routes in the event of emergencies.
- Support railroads, Amtrak, local law enforcement agencies, and others to identify and implement rail security measures based on guidance from existing federal law (PL 110-432), by identifying partnerships and other funding sources to enhance rail system security.

Livable Communities

Goal: Encourage livable communities and family-wage jobs through freight rail system improvements.

Objectives

- Sustain communities through reduced congestion, preserved and expanded infrastructure, economic growth, and optimized safety, security.
- Reduce environmental impacts.

Strategies

- Continue to support local community development improvements that include freight rail options.

Actions

- Support strategic partnerships along the state's rail corridors that improve the quality of life for state residents.

Conclusion

The *Washington State 2010-2030 Freight Rail Plan* lays the foundation for an improved and sustainable freight rail system in the state. The plan does this by identifying a vision for the state's freight rail service and establishing goals, objectives, strategies, and actions to achieve that vision. This vision was accomplished by working with various stakeholders, including the rail industry, shippers, rail advocates, ports,

tribes, governments, elected officials, and many other concerned groups and individuals. This collaboration created a vision that reflects the needs of the community and ultimately to have a responsive, efficient, and sustainable rail transportation network.

Dedicated investment by all partners will be required to reach these goals and accomplish all of the rail improvements identified in this plan.

Washington State
Department of Transportation

Chapter 3: Rail System and Freight Rail Services in Washington State

Efficient transportation systems are critical to the economic vitality of the nation. Washington State (state), in particular, relies on multimodal and intermodal transportation for economic development and job creation. As the vital conduit for goods and people, transportation systems influence the long-term competitiveness, viability, and sustainability of economy and quality of life. At the same time, the state encompasses unique environmental richness and biological diversity, resulting in steadily increasing concerns about the impacts of development on vulnerable habitats and ecosystems. A rail system—with advantages from its potential for mass movement of people and goods, higher efficiency on energy use, and relatively lighter environmental emissions—could play an increasing role in development of a highly efficient and environmentally-friendly transportation system. Policies and decisions in transportation investment are embracing rail as a viable component and option to meet the challenges in transportation planning, design, construction, operation, maintenance, and regulation.

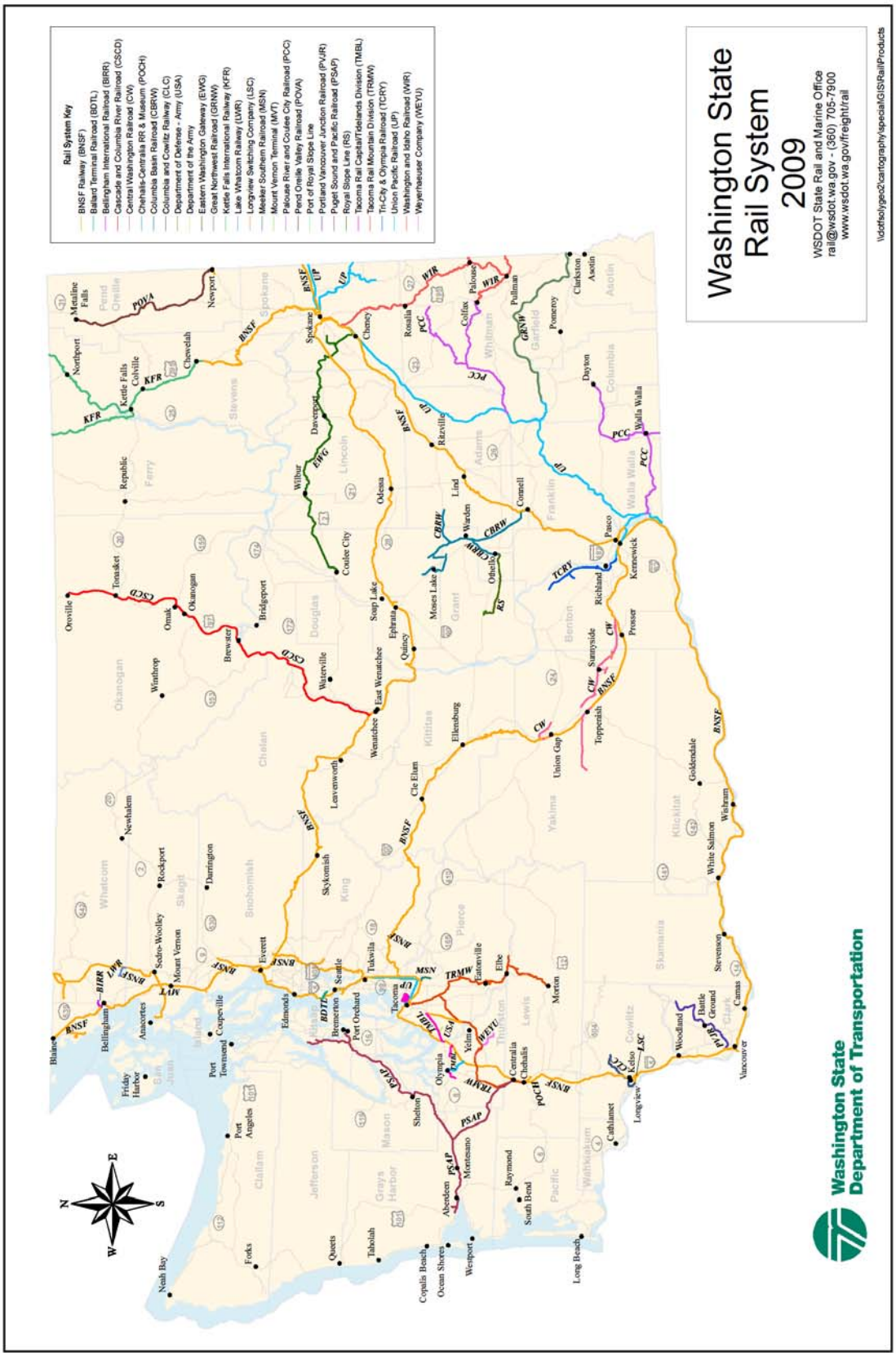
Overview of Washington State Rail System Services

From 1828 to present, the rail system in the United States (U.S.) has expanded and contracted to meet the needs of a growing nation, influenced by public and private interests. Mileage peaked in the 1920s at approximately 380,000 miles of track. Since then the rail network has been modernized and downsized to a core network that is less than half of its peak size. Appendix 3-B contains a brief history of national and state rail development.

The state's rail network has evolved over the last century to serve a wide range of passenger and freight markets and has extended across many parts of the state. Thirty-two of the state's 39 counties are served by one of the state's freight railroads. The rail network in the state has three distinct types of rail services: intercity passenger, commuter, and freight. There are two mainline freight railroads—the BNSF Railway Company (BNSF) and the Union Pacific Railroad (UP)—and 19 active short-line railroads operating in the state.

Exhibit 3-1 depicts the railroad network in the state.

Exhibit 3-1: Washington State Rail System



Rail transportation supports economic competitiveness and economic viability. In 2007 freight railroads operating in the state carried 116 million tons of freight over 3,647 operated route miles. It accounts for 19 percent of total freight in the state. Passenger rail services share rail lines with freight in the state. In 2008 intercity passenger rail, including the Amtrak *Cascades*, *Empire Builder*, and *Coast Starlight*, provided services to more than one million riders who leave, arrive, travel through, or travel within state. Since September 2000, Sound Transit's *Sounder* has provided commuter rail service in the Puget Sound area. In 2008 *Sounder's* ridership was 16.13 million.

Freight Service

The state freight rail system consists of mainlines, branch lines, industrial spurs and leads, and rail yards and terminals operated by a variety of public and private rail carriers (see Exhibit 3-1). The freight railroads operate over 3,647 miles of rail service in the state over 2,418 miles of rail lines.[1] Long-haul rail transportation is provided by two Class I railroads—BNSF and UP.[2] The BNSF owns and operates the most mileage in the state—1,604 in-state-operated miles, constituting 5 percent of the BNSF's total system mileage. The dominant position of BNSF in many of the state's rail markets has significant implications for the degree of leverage that the state, rail shippers, and communities have in influencing its business decisions.

Both of the Class I railroads are served by a number of smaller regional, short-line, and terminal railroads, which pick up and distribute rail cars to individual industrial and agricultural shippers and receivers. These railroads provide critical services, particularly in lower-density rail corridors and markets where the Class I railroads cannot operate cost-effectively. In most of cases, the short lines operate on branch lines that were previously owned and operated by the Class I railroads.

Freight Rail Volume and Flows

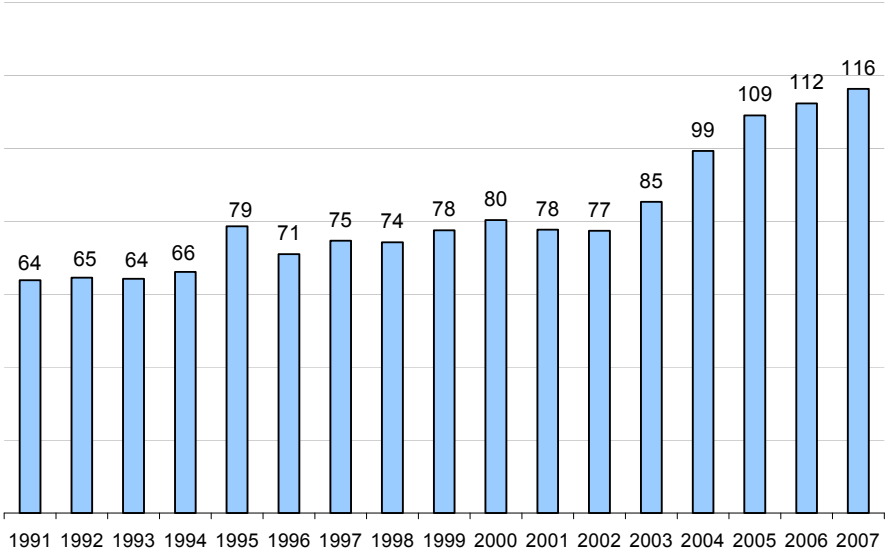
Freight rail transportation is a fast growing service. In 2007 the state rail system carried 116 million tons of freight, compared with 64 million tons

[1] Due to the fact that owner railroads lease operating rights over their lines to other railroads, operated miles are greater than owned miles. In a few areas, the U.S. Department of Transportation (USDOT) Surface Transportation Board (STB) has mandated provision of operating rights to ensure competition between railroads.

[2] The USDOT STB defines Class I railroads as having annual carrier operating revenues of $250 million or more. Class II railroads, often referred to as a regional railroad, have annual carrier operating revenues of less than $250 million but in excess of $20 million. Class III railroads, or short lines, have annual carrier operating revenues of $20 million or less. Switching or terminal railroads are railroads engaged primarily in switching and/or terminal services for other railroads.

in 1991, accounting for an average annual growth rate of 3.8 percent (Exhibit 3-2). However, the current economic recession has impacted freight transportation. Although current freight rail volumes are not available at the state level, other data indicates a sharp decline for 2008 and 2009. Therefore, the long-term growth rate is likely to be mild, in the range of 2 percent.

Exhibit 3-2: Washington State Rail Freight
1991 to 2007 (Million Tons)



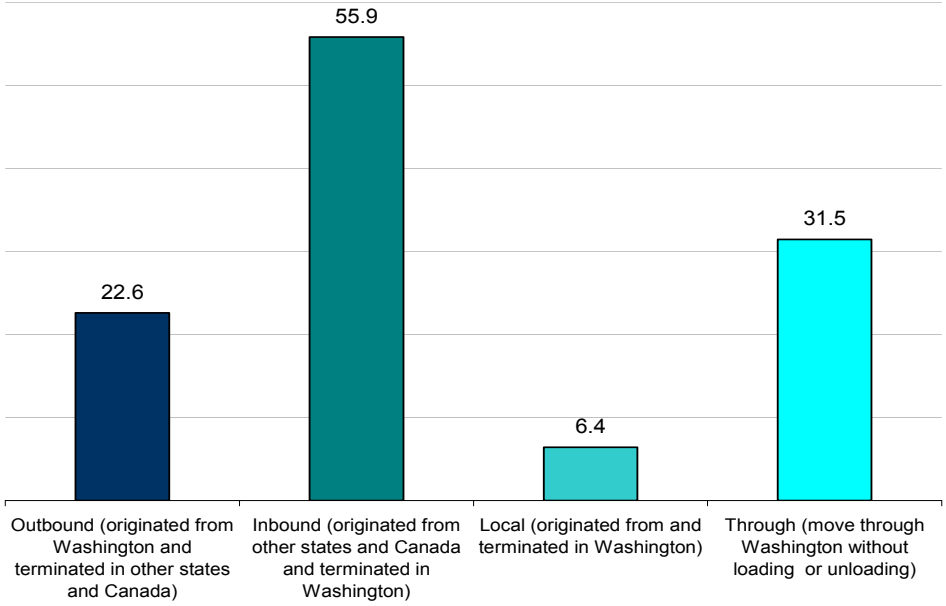
Source: Washington State Department of Transportation (WSDOT) State Rail and Marine Office and Association of American Railroads

Among the 116 million tons of rail freight, 56 million tons arrived in the state from 44 other states and Canada, while almost 23 million tons shipped from the state to 46 other states and Canada. Over 6 million tons of rail freight moved within the state's borders and almost 32 million tons of rail freight moved through the state without loading and unloading (Exhibit 3-3).

Of the 116 million tons of rail freight, 86 million tons, or 74 percent, is intermodal[3] traffic, while 30 million tons, or 26 percent, is rail only (single mode) traffic (Exhibit 3-4).

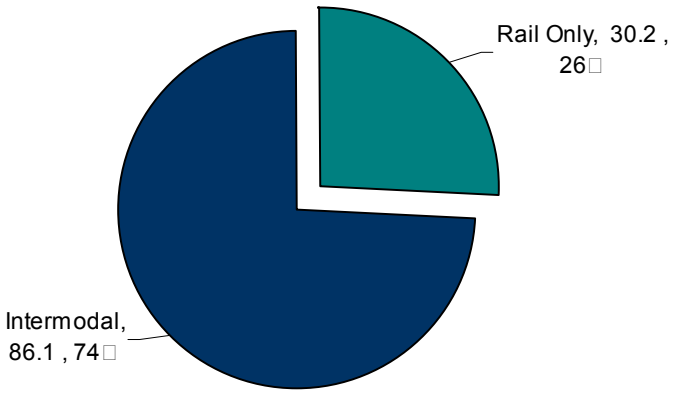
[3] Intermodal is using more than one transportation mode such as rail and truck. In this chapter the reference to intermodal is not limited to intermodal container traffic. It is all rail that also has another mode of transport used in the movement of the cargo.

Exhibit 3-3: Rail Freight Flows in Washington State □2007
(Million Tons)



Source: WSDOT State Rail and Marine Office □2007 STB Waybill Data Analysis

Exhibit 3-4: Freight Rail Intermodal Traffic □Washington State 2007
(Million Tons)



Source: WSDOT State Rail and Marine Office □2007 STB Waybill Data Analysis

Washington State Freight Rail System Profiles

This section profiles the 22 active freight railroads operating in the state, along with one inactive railroad. This section also examines the mainline corridors where they operate and then the lower density corridors. The mainline corridors connect the state with the rest of the North American rail network, while the lower density corridors offer collection/distribution services and access to key industries. Finally, the principal terminals and yards impacting state rail traffic are described.

Railroad Classification

The state is served by two Class I freight railroads, BNSF and UP. These two railroads provide the primary connections between the state's ports, farmers, and industries and the rest of North America. This is done over a series of ten major rail corridors within the state; seven cross the state east-to-west, while the other three parallel Interstate 5 (I-5) on the western side of the state. The BNSF operates seven of these corridors, while the UP operates the remaining three corridors. These corridors are profiled in the BNSF and UP sections, respectively.

There is one Class II (regional) railroad operating in the state. The Montana Rail Link offers limited service in the state and only reaches Spokane over trackage rights on BNSF track from Idaho.

The 19 active Class III (short-line and terminal/switching) railroads in the state provide important collector/distributor services for the larger railroads and local rail services for state shippers. Their range varies from lines that operate over 100 miles in the state to switching railroads that connect ports to line-haul railroads inside a yard. Exhibit 3-5 is a list of the state's railroads and their mileage and class.

Track Mileage Inventory

Exhibit 3-5 also summarizes railroad mileage, including miles operated (owned track and trackage rights) and miles of road[4] owned in the state. BNSF[5] owns the most mileage in the state, but the 1,505 in-state miles represents only five percent of BNSF's total system mileage. In total, freight railroads operate over 3,647 miles and own 2,418 miles of trackage in the state.

[4] "Miles of road" is a linear measure of distance that does not consider the number of tracks.

[5] BNSF Railway Co. Annual Report to the Utilities and Transportation Commission (UTC), 2008.

Exhibit 3-5: Washington Freight Railroads, Mileage, and Class[6]

Name	Reporting Mark	Mileage in Washington State		Class
		Operated[a]	Owned	
Ballard Terminal Railroad	BDTL	3	0	III
BNSF Railway	BNSF[b]	1,604	1,505	I
Cascade Columbia River Railroad	CSCD	135	135	III
Central Washington Railroad Company	CWA	83	0	III
Columbia Cowlitz Railway	CLC	8.5	8.5	III
Columbia Basin Railroad	CBRW[c]	124	0	III
Eastern Washington Gateway RR	EWG	108	0	III
Great Northwest Railroad	GRNW	58	58	III
Kettle Falls International Railway	KFR	142	58	III
Longview Switching Company	LSC	17	0	III
Meeker Southern Railroad	MSN	5	5	III
Montana Rail Link	MRL	16	0	II
Mount Vernon Terminal Railroad	MVT	2	2	III
Palouse River Coulee City Railroad	PCC	169	0	III
Pend Oreille Valley Railroad	POVA	61	61	III
Puget Sound Pacific Railroad	PSAP[d]	178	109	III
Royal Slope Railroad (Inactive)	RS	26	26	III
Tacoma Municipal Belt Line	TMBL	72	36	III
Tacoma Rail Mountain Division	TRMW	134	134	III
Tri-City Olympia Railroad	TCRY	56	0	III
Union Pacific Railroad	UP	558	280	I
Washington Idaho Railway Inc.	WIR	87		III
Western Rail Switching	WRS			III
Total		**3,647**	**2,418**	

[a] Miles operated includes all owned track plus trackage rights.
[b] Per BNSF s report to the STB, December 31, 2008.
[c] Includes Portland Vancouver Junction Railroad s 33 miles of trackage rights.
[d] Includes U.S. Navy s Shelton-Bangor line.

Source: *Railroad Service in Washington*, Association of American Railroads, 2007. This information was then updated using BNSF timetables, UP timetables and charts, Amtrak charts, and STB filings for short-line railroads.

[6] Excludes standard gauge track operated as a light rail system.

Freight Rail Service Corridors

The state currently has ten major rail corridors and 12 low-density corridors. These corridors are defined and operated by BNSF and UP. Exhibit 3-6 lists all the corridors. Appendix 3-B has a description of each rail service corridor. While these rail corridors are defined by private railroads, the state has an interest in defining rail corridors in terms of public benefits. The Freight Mobility Strategic Investment Board is authorized to define strategic rail corridors and update them periodically. Some short-line routes are critical to the economic viability of local communities and certain industries. The state needs to develop criteria to define rail corridors in terms of their impacts on the state's economic and societal needs, as discussed in Chapter 5.

Exhibit 3-6: Rail Service Corridors in Washington State

Railroads	Major Corridors	Low-Density Corridors
BNSF	Seattle-Spokane	Tukwila-Snohomish
	Seattle-Portland, Oregon (OR)	Woodinville-Redmond
	Portland, OR-Pasco	Burlington-Sumas
	Auburn-Pasco	Sumas-Lynden
	Pasco-Spokane	Burlington-Anacortes
	Spokane-Sandpoint, Idaho (ID)	Intalco-Cherry Point
	Everett-Vancouver, British Columbia (B.C.)	Marysville-Arlington
		Lakeview-Roy
		Spokane-Chewelah
UP	Hinkle, OR-Spokane	Spokane-Plummer, ID; Manito-Fairfield
	Spokane-Eastport, ID	Ayer Junction-Riparia
	Tacoma-Seattle	Wallula-Kennewick

Source: *Statewide Rail Capacity and System Needs Study* (2006)

Railroad Profiles

Appendix 3-B also contains more information about the freight rail carriers in the state including descriptions, maps, revenue, and history.

Class I Railroads

BNSF Railway

BNSF, one of the four largest U.S. railroads, owns and operates track over seven major corridors and nine low-density corridors in the state. BNSF

operates almost 44 percent of the state's total system route miles.[7] Primary commodities include coal, agricultural products, intermodal (containers/ trailers), forest products, chemicals, metals, and minerals. According to BNSF's annual report, 2008 revenue totaled $17.5 billion.[8] In the state BNSF reported total interstate operating revenue of $1,040,184 and total gross intrastate operating revenue of $97,876,862, according to their 2008 Annual Report to the UTC.

Union Pacific Railroad

The UP is the largest railroad in North America. Primary commodities moving through the state include chemicals, coal, food and food products, forest products, grain and grain products, intermodal, metals and minerals, and automobiles and parts. The UP reported 2008 revenue as $18 billion.

Class II and Class III Railroads

Ballard Terminal Railroad

The Ballard Terminal Railroad (BDTL[9]) is a Class III railroad in Seattle. The BDTL reported total interstate operating revenue of $6,148 and $70,012 for total gross intrastate operating revenue in their 2008 Annual Report to the UTC.

Cascade and Columbia River Railroad

The Cascade and Columbia River Railroad (CSCD) is a Class III railroad that interchanges with the BNSF in Wenatchee and runs north to Oroville. Primary commodities are limestone, pulp wood and lumber products. CSCD reported total gross intrastate operating revenue of $1,614,149 in their 2008 Annual Report to the UTC.

Central Washington Railroad

The Central Washington Railroad (CWA) is a Class III railroad in the Yakima Valley. The CWA carries cattle feed, propane, paper products, plastic pellets, cheese, juice concentrate, lumber, apples, and other agricultural goods.[10] The CWA reported total interstate operating revenue of $1,436,210 and total gross intrastate operating revenue of $374,225 in their 2008 Annual Report to the UTC.

---

[7] BNSF Railway 2008 Annual Report to the Utilities and Transportation Commission.
[8] www.bnsf.com/investors/investorreports/2Q_2009_Investors_Report.pdf
[9] BDTL is the reporting mark for Ballard Terminal Railroad. A reporting mark is a two-to-four-letter alphabetic code used to identify owners or lessees of rolling stock and other equipment used on the North American railroad network. The marks are stenciled on each piece of equipment, along with a one-to-six-digit number, which together uniquely identify every such rail car. This allows the cars to be tracked by the railroad they are traveling over, which shares the information with other railroads and customers.
[10] http://www.temple-industries.com/companies/central_washington_railroad.php/.

Columbia and Cowlitz Railway

The Columbia and Cowlitz Railway (CLC), a wholly-owned subsidiary of Weyerhaeuser Company, is a Class III railroad that moves freight from the Weyerhaeuser Company mill in Longview to the junction just outside the city limits of Kelso.[11] Primary commodities include forest products, steel, and chemicals. The CLC reported total gross intrastate operating revenue of $2,654,693 in their 2008 Annual Report to the UTC.

Columbia Basin Railroad

The Columbia Basin Railroad (CBRW) is a Class III railroad located near Moses Lake, serving Connell, Warden, Bruce, Schrag, and Othello. The CBRW hauls agricultural goods, inbound fertilizer, chemicals, and processed potatoes and vegetables. The CBRW reported total interstate operating revenue of $4,240,109 and total gross intrastate operating revenue of $787,720 in their 2008 Annual Report to the UTC.

The Portland Vancouver Junction Railroad (PVJR) is a newly formed, wholly-owned subsidiary of CBRW. It is owned by Clark County, serving the Vancouver area since 2004. The Chelatchie Prairie Railroad (BYCX), a tourist railroad, operates passenger excursions between Lucia and Yacolt on weekends and holidays.

Eastern Washington Gateway Railroad

The Eastern Washington Gateway Railroad (EWG) is a Class III railroad that operates a 108-mile branch line that extends from Cheney to Coulee City. Wheat and barley are the principle commodities shipped. It is one of three branch lines of the Palouse River & Coulee City Railroad System owned by the state. The EWG reported total interstate operating revenue of $1,803,601 in their 2008 Annual Report to the UTC.

Great Northwest Railroad

The Great Northwest Railroad (GRNW), a Class III railroad, moves freight between Lewiston, ID, Riparia, and Ayer, interchanging with both the BNSF and UP mainlines in Ayer. Primary commodities are forest products consisting of lumber, bark, paper and tissue, agricultural products, industrial and farm chemicals, scrap iron, and frozen vegetables. The GRNW reported total interstate operating revenue of $3,962,836 in their 2008 Annual Report to the UTC and reported total gross intrastate operating revenue of $113,584.

Kettle Falls International Railway

The Kettle Falls International Railway, LLC (KFR), a Class III railroad, moves freight from the BNSF interchange at Chewelah to Columbia Gardens, British Columbia (B.C.). A second line operates from Kettle Falls to Grand Forks, B.C. Primary commodities include lumber,

[11] http://en.wikipedia.org/wiki/Columbia_and_Cowlitz_Railway/.

plywood, wood products, minerals, metals, fertilizer, industrial chemicals, and abrasives.[12] KFR reported total interstate operating revenue of $4,319,638 and total gross intrastate operating revenue of $460,891 in their 2008 Annual Report to the UTC.

Longview Switching Company

The Longview Switching Company (LSC), a jointly-owned subsidiary of BNSF and UP, is a Class III railroad. The LSC switches trains approximately five miles from the railroad mainlines into the Port of Longview.[13] The LSC reported estimated annual revenue of $1,600,000 in 2008.

Meeker Southern Railroad

The Meeker Southern (MSN) is a 5-mile Class III railroad that connects Meeker Junction in Puyallup with an industrial park in McMillan. The MSN is a wholly-owned subsidiary of the Ballard Terminal Railroad. MSN reported no total gross intrastate operating revenue, but did report $181,796 in interstate operating revenue.

Montana Rail Link

Montana Rail Link (MRL) is a Class II regional railroad that connects with the BNSF at Spokane. MRL is an independently-owned unit of the Washington Companies, headquartered in Missoula, Montana.[14] MRL reported total intrastate revenue of $4,434,250 in 2008.

Mount Vernon Terminal Railway

The Mount Vernon Terminal Railway (MVT) is a Class III railroad providing service and interchanges with BNSF at Mount Vernon. The railroad consists of a 3-track wide yard used for storage and transloading. MVT reported total interstate operating revenue of $61,174 and no intrastate operating revenue.

Palouse River & Coulee City Railroad

The Palouse River and Coulee City Railroad Company (PCC), a subsidiary of Watco Companies operates this Class III railroad, which contains a total of 84 miles of mainline track. PCC reported total interstate operating revenue of $1,479,726 and $355,186 intrastate operating revenue.

Palouse River & Coulee City Railroad System

The Palouse River & Coulee City Railroad System is owned by the state. It is comprised of three Class III railroad lines: the PV Hooper (operated by PCC), CW (operated by EWG), and P&L (operated by WIR).

[12] http://www.omnitrax.com/rail_kfr.aspx/.
[13] http://en.wikipedia.org/wiki/Port_of_Longview/.
[14] http://www.montanarail.com/general_info.htm/.

Pend Oreille Valley Railroad

The Pend Oreille Valley Railroad (POVA) is a Class III railroad, moving freight between Metaline Falls, Newport, and Dover, Idaho on owned and leased trackage. POVA also hosts occasional tourist trains between Ione and Metaline Falls. POVA reported a total interstate operating revenue of $1,899,339 and total gross intrastate operating revenue of $506,001.

Puget Sound and Pacific Railroad

The Puget Sound and Pacific Railroad (PSAP) is a Class III railroad headquartered in Elma. Its main commodities include lumber, logs, and chemicals for the pulp and paper mills. PSAP reported interstate operating revenue of $8,115,618 and total gross intrastate operating revenue of $64,840.

The PSAP also operates on United States Government (Navy) trackage from Shelton to Bangor and on a spur to the U.S. Navy base at Bremerton.

Royal Slope Railroad

The Royal Slope Railroad (RS) is a Class III railroad owned by the state. It connects Royal City to the Columbia Basin Railroad at Othello. The line currently is inactive, but could play a role in future freight rail development.

Tacoma Rail

Tacoma Rail is comprised of two Class III railroads with three distinct and separate divisions—Tidelands Division, Mountain Division, and the Capital Division. The Tacoma Municipal Belt Line (TMBL), which includes the Tidelands and Capital Divisions, is owned by the city of Tacoma, Public Utilities. The Tacoma Rail Mountain Division (TRMW) is owned by the city of Tacoma and operated by Tacoma Rail. TMBL reported a total interstate operating revenue of $14,359,192 and total gross intrastate operating revenue of $785,908 in 2008. TRMW reported a total interstate operating revenue of $539,950 and total gross intrastate operating revenue of $118,641 in 2008.

Tri-City and Olympia Railroad

The Tri-City and Olympia Railroad (TCRY) is a Class III railroad that serves the Richland area, including the Port of Benton and the U.S. Department of Energy. In 2009 the Olympia line ceased operations. Major commodities include agricultural products, grain, feed stock, food and beverages, consumer products, wood products, paper, coal and minerals, building materials, machinery and equipment, vehicles, chemicals, fertilizer, waste and scrap, and nuclear waste as bulk goods, break bulk materials, and liquids.[15] The TCRY reported no total gross intrastate operating revenue in their 2008 Annual Report to the UTC.

[15] Tri-City and Olympia Railroad, www.tcry.com/.

Washington and Idaho Railway, Inc.

The Washington and Idaho Railway (WIR), a Class III railroad, operates the P&L Branch of the Palouse River and Coulee City Railroad System south of Spokane, connecting with BNSF in various locations. Primary commodities are fertilizer, beans and lentils, and forest products. The WIR reported total gross intrastate operating revenue of $824,945 in their 2008 Annual Report to the UTC.

Western Rail Switching

Western Rail Switching (WRS) is a switching and terminal railroad owned by Western Rail, Inc., a used locomotive seller located on the line. In 2004, Spokane County bought BNSF's Geiger Spur and designated WRS to operate it. In January 2009, realignment bypassed Fairchild Air Force Base, through which the spur had run. The west end of the spur now connects to the Eastern Washington Gateway Railroad (EWG) near Medical Lake. EWG now operates the Geiger Spur. WRS continues as an operating business.

Intermodal Facilities, Railroad Terminals, and Rail Yards

Freight terminals are facilities where freight cars are gathered up into trains or where trains are broken down so that cars can be distributed to shippers. Intermodal facilities are locations where freight containers or trailers are transferred between freight modes involved in the intermodal freight trip. Typically, this includes some combination of rail, truck, and water modes. Rail yards are facilities where individual rail cars are grouped together (blocked) by destination and then made up into trains containing many blocks of cars.

Intermodal Facility

The STB defines an intermodal facility as a site consisting of tracks, lifting equipment, paved and/or unpaved areas, and a control point for the transfer (receiving, loading, unloading, and dispatching) of trailers and containers between rail and highway and between rail and truck to/from marine modes of transportation.

There are three primary forms of containers for freight intermodal traffic between rail and highway modes:

- **RoadRailers®** – a specialized truck trailer where the trailer can be attached to rail wheels to haul along the railroad without the use of a separate rail flat car. At the intermodal facility, the trailer can be detached from the rail wheels and driven via truck to its final destination.

- **Trailer on flat car** – a standard truck trailer or container on a chassis loaded onto a flat rail car and hauled to a facility, where it is unloaded from the rail flat car and hauled by truck to its final destination.
- **Container on flat car** – a standardized container loaded onto a flat car or stack car, where it is moved by rail to an intermodal facility and unloaded from the rail car, placed on a rubber-tired highway chassis, and hauled by truck to its final destination.

Standardized containers facilitate the transition between modes of transportation. These standardized containers can be loaded onto and from an ocean-going vessel in a very efficient manner. These same containers can be attached to either a rail chassis or truck trailer chassis to be hauled by rail or truck to their final destination. Container sizes are 8 feet wide and typically 8 feet, 6 inches tall. "Hicube" containers are 9 feet, 6 inches tall. Lengths can vary from 20 feet to 56 feet. A limitation to the container lengths is the maximum allowable trailer lengths in the U.S.

There are 119 intermodal facilities in the state based on U.S. Bureau of Transportation Statistics data. There are 95 intermodal facilities that include freight rail mode. Exhibit 3-7 displays the sites of these intermodal facilities.

Appendix 3-C provides details of these intermodal facilities and commodities and shipments associated with these freight rail intermodal facilities.

Railroad Terminals and Yards

Terminals and yards serve many functions for the railroads. They originate and terminate traffic by building outbound trains and breaking down inbound trains. They are used to classify inbound cars for assignment to outbound trains for through traffic. Yards can offer refueling, crew change, storage, and maintenance functions. Given this key role in the rail network, a significant amount of rail capacity is impacted by the size and efficiency of the terminals and yards.

Exhibit 3-8 summarizes the major terminals and yards that have the most impact on state railroad movements. This table includes the owner, yard/terminal name, location, and function.

Exhibit 3-7: Rail Intermodal Facilities in Washington State

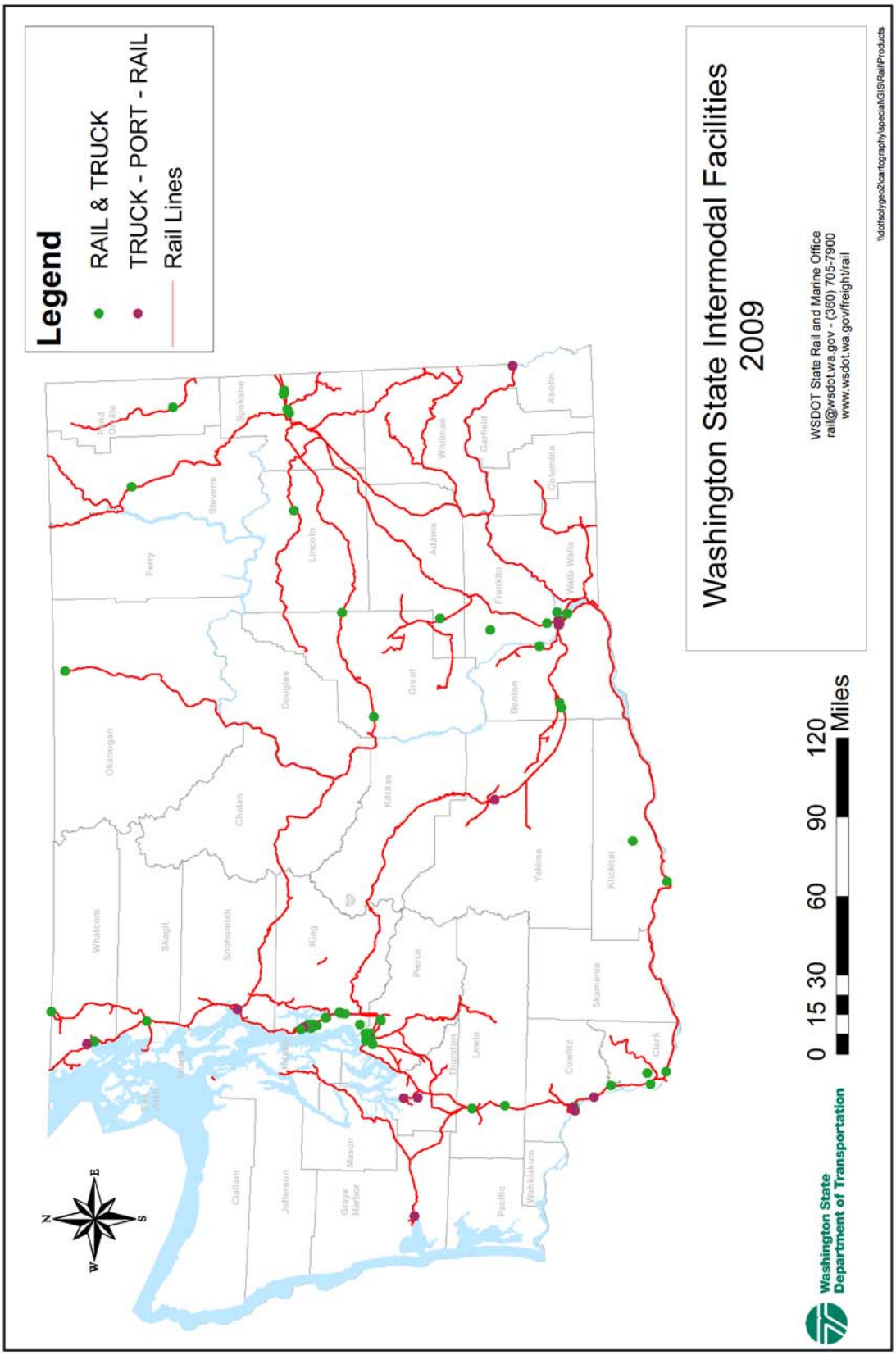


Exhibit 3-8: Railroad Terminals and Yards Impacting Washington State Rail Movements

Owner	Yard Terminal	Location	Function
BNSF	Bayside Delta Yards	Everett	Everett generates some traffic locally, but is principally a classification yard for through traffic. It is the southern endpoint for most through traffic on the Everett-Vancouver, B.C. route. Generally traffic from south and east of Everett arrives in Bayside Yard, where it is switched, and made up into trains for north of Everett. Traffic from north of Everett arrives in Delta Yard, where it is switched and made up into trains for south and east of Everett.
BNSF	Hauser Yard	Hauser, ID	Hauser Yard is not important as a terminal; however, it is important as a fuel station and crew change point. Westward trains stop for fuel, providing sufficient fuel for a trip to Seattle, Tacoma, Kalama, Longview, Vancouver, Washington (WA), Portland, Oregon (OR), or Pasco and return. Eastward trains stop for fuel, providing sufficient fuel to reach the next fueling station at Havre, Montana.
BNSF	Pasco Yard	Pasco	Pasco processes traffic to and from local industries and is the BNSF classification yard for carload traffic moving to and from Washington State. Virtually all traffic handled by Pasco Yard is originating from classified traffic or terminating for classification. Pasco also is a crew change point for through trains (generally grain and intermodal trains).
BNSF	East St. Johns	Portland, OR	East St. Johns processes traffic for local industries and is an interchange point for traffic moving between BNSF and UP. Traffic is a combination of through trains and transfers.
BNSF	Lake Yard	Portland, OR	BNSF Lake Yard is adjacent to the Portland Terminal Railroad Lake Yard. It is the BNSF intermodal terminal for the Portland area. Traffic is generally originating and terminating trains.
BNSF	Willbridge	Portland, OR	Willbridge processes traffic for local industries. Traffic is a combination of through trains and yard transfers.
BNSF	Balmer Yard	Seattle	Balmer Yard at Interbay is primarily a classification yard for the Portland-Seattle route. Traffic from the south is distributed to local industries or forwarded to Everett for further classification and forwarding. Traffic from the north is classified by destination station between Seattle and Portland and made up onto trains. Traffic processed by Balmer Yard is generally originating and terminating only. Interbay also is a crew change point for through trains that do not originate or terminate in Seattle terminal. The primary commodity at Balmer is grain hauled for Cargill.

Owner	Yard Terminal	Location	Function
BNSF	Seattle International Gateway Terminal	Seattle	The Seattle International Gateway (SIG) is the BNSF international intermodal terminal in Seattle. Containers are drayed to and from the Port of Seattle terminals. This traffic is originating and terminating only.
BNSF	South Seattle Domestic Intermodal Yard	Seattle	The South Seattle Domestic Intermodal Yard processes domestic cargo traffic in 53-foot (vs. 40- to 48-foot) containers.
BNSF	Stacy Street Yard	Seattle	Stacy Street Yard is in the same physical location as SIG. Stacy Street Yard is the terminal used by most local industry traffic originating and terminating in Seattle. Traffic to and from Seattle industries south of King Street Station and in West Seattle is processed at Stacy Street Yard. Traffic is generally originating and terminating only.
BNSF	Yardley	Spokane	Yardley processes cars to and from local industries and is a block swap location for intermodal trains. Train traffic is a mixture of originating, terminating, and through trains, including through trains that stop for block swapping as well as setout or pickup. Yardley is a crew change point for through trains.
BNSF	Tacoma Yard	Tacoma	Tacoma Yard processes traffic for Tacoma industries in the Tideflats area west of the Puyallup River. It also is the classification yard for traffic originating and terminating in the Tacoma Rail yard. Traffic arrives in Tacoma from through or terminating trains and the Tacoma Rail traffic is delivered after the train has been switched (sorted). Carload traffic from Tacoma Rail is switched by destination and forwarded on the appropriate train. Traffic is a mixture of originating, terminating, and through.
BNSF	Vancouver Yard	Vancouver, B.C.	Vancouver Yard processes traffic to and from local industries in Vancouver, B.C., and the Port of Vancouver. Traffic is a combination of originating, terminating and through trains that set out and pick up cars.
BNSF	Vancouver Yard	Vancouver, WA	The Vancouver Yard has locomotive maintenance and fueling facilities. It serves as a major switching yard for BNSF railway in the Portland Vancouver metro area. Vancouver also is a crew change point for through trains moving between the Portland-Seattle route and the Portland-Pasco route.
BNSF	Wenatchee Yard	Wenatchee	Wenatchee Yard processes cars to and from local industries and is the interchange point for traffic moving between BNSF and Cascade Columbia River Railroad. Traffic is originating and terminating trains. Wenatchee also is a crew change point for through trains.

Owner	Yard Terminal	Location	Function
Canadian National	Thornton Yard	Surrey, B.C.	This is the northern endpoint for virtually all through traffic on the Everett-Vancouver, B.C. route. Traffic is generally originating and terminating only.
Longview Switching Company	Longview Yard	Longview	Longview Switching Company (jointly owned by BNSF and UP) processes all traffic to and from the Port of Longview and local industries. All traffic is transfer movements between Longview Junction yard and Longview Yard.
Longview Switching Company	Longview Junction Yard	Longview	Longview Junction Yard is the interchange point among Longview Switching Company, BNSF, and UP. It also processes local industry traffic for Ridgefield, Woodland, and Kalama, and interchange traffic to and from Columbia Cowlitz Railway in Rocky Point. Traffic is a combination of originations and terminations, and traffic arriving or leaving on through trains.
Port of Kalama	Kalama Export Company Terminal	Kalama	The Kalama Export grain terminal (also known as Peavey) can accommodate five grain trains of about 108 cars each and can unload six trains in 24 hours. Traffic is generally originating and terminating only.
Port of Kalama	Cenex-United Harvest Terminal	Kalama	The Cenex-United Harvest grain terminal can accommodate two grain trains of about 108 cars each and can unload two trains in 24 hours. Traffic is generally originating or terminating only.
Port of Portland	Port of Portland	Portland, OR	Port of Portland has several marine terminals and industrial sites that generate traffic directly related to Washington State rail operation. These facilities are connected to BNSF at North Portland Junction and to UP at Barnes. Traffic is a combination of complete trains and traffic to and from through trains.
Port of Seattle	Terminal 5 Intermodal Yard	Seattle	Terminal 5 Intermodal Yard is a Port of Seattle on dock international terminal. BNSF provides the switching service. UP currently has the contract for all traffic originating and terminating at this terminal. Traffic is originates and terminates in this yard.
Port of Tacoma	Port of Tacoma Intermodal Yard	Tacoma	Port of Tacoma has four intermodal yards supporting marine terminals in the Tideflats area. Trains originate or terminate directly in these yards.
Portland Terminal Railroad	Lake Yard	Portland, OR	Lake Yard processes traffic for local industries and serves as an interchange point for BNSF and UP. Traffic is generally originating and terminating trains and yard transfers.
Tacoma Rail (TMBL)	Tideflats Yard	Tacoma	Tideflats Yard switches traffic originating and terminating in the Tacoma Tideflats area east of the Puyallup River, adjacent to the Port of Tacoma intermodal terminals. Traffic is transfer movements between the Tideflats customers and the BNSF and UP.

Owner	Yard Terminal	Location	Function
UP	Albina Terminal	Portland, OR	Albina processes traffic to and from Portland area industries on UP. It also is one of two UP intermodal terminals for the Portland area. Traffic is generally originating and terminating trains and yard transfers.
UP	Argo Yard	Seattle	Argo Yard also includes subyards Manar and Van Asselt. Argo is the UP intermodal terminal (domestic and international) in Seattle as well as a truck to rail transfer station for solid waste. Argo Yard is almost exclusively used for intermodal traffic and interchanges between BNSF and UP. Van Asselt and Manar yards are used for carload freight originating and terminating at industries on UP in Seattle and Tukwila. Traffic is generally originating and terminating only.
UP	Barnes	Portland, OR	Barnes processes traffic for local industries and the Port of Portland terminals and is an interchange point for traffic moving between BNSF and UP.
UP	Brooklyn Terminal	Portland, OR	Brooklyn is one of two UP intermodal terminals in Portland, Oregon. Traffic is generally through trains with setouts and or pickups.
UP	Hinkle Yard	Hinkle, OR	Hinkle Terminal is located just southeast of the Tri-Cities in Oregon. It has a major classification yard for carload freight. UP also has a major diesel locomotive maintenance, repair, and fueling facilities in Hinkle. It is also a crew change point for UP trains.
UP	Spokane Yard	Spokane	Spokane Yard processes cars to and from local industries. Train traffic is generally originating and terminating trains. Spokane is a crew change point for through trains.
UP	Tacoma Fife Yards	Tacoma	The UP Tacoma terminal is split between two yards. The Tacoma Yard processes carload traffic to and from the Tacoma Tideflats area west of the Puyallup River. The Fife Yard processes carload traffic for industries east of the Puyallup River and on Tacoma Rail. Traffic is a combination of originating terminating and traffic arriving or leaving on through trains.

Capacity of the Washington State Rail System

Exhibit 3-9 compares the average number of trains operated on each Class I railroad mainline to the practical capacity[16] of the line in 2008. Exhibit 3-10 shows the projected practical capacity for each line in 2028. The data for these maps were derived from the *Statewide Rail Capacity and System Needs Study*, the *2009 Marine Cargo Forecast Technical Report*, BNSF, and UP.

The two maps compare and contrast 20 years of demand growth with current capacity, identifying the gaps in capacity.

Stevens Pass

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major northern transcontinental route for double-stack intermodal container trains. It is heavily used, operated at about 70 percent of practical capacity in 2008.

Stampede Pass

The BNSF's Auburn-Pasco line, which passes through the Stampede Tunnel, operates today at a low level of practical capacity. The line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains. Grades over Stampede Pass also make it difficult to haul heavily-loaded unit grain trains along this line.

Columbia River Gorge

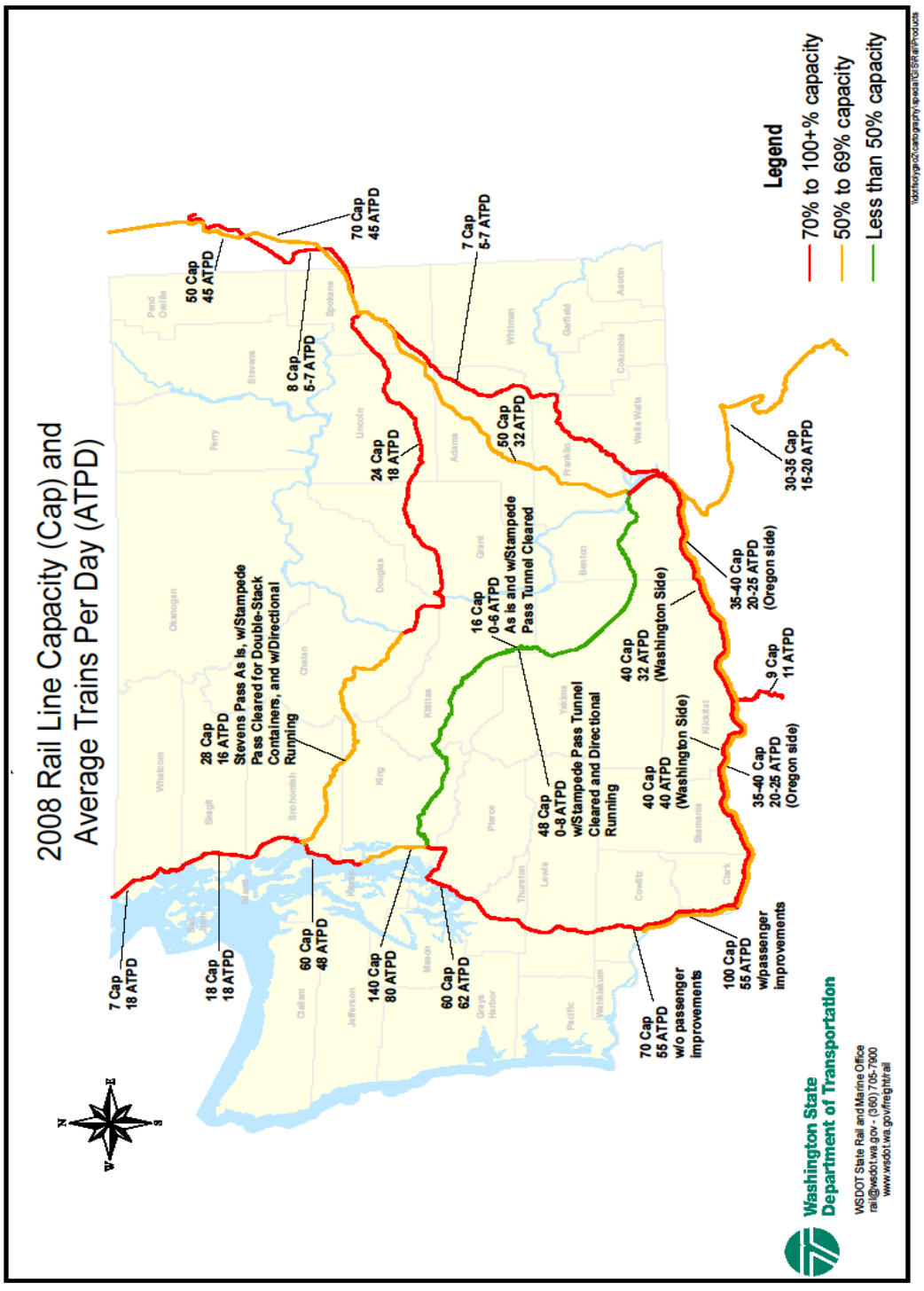
The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Columbia River Gorge, is used by double-stack intermodal container trains moving east and grain trains moving west to the Puget Sound and Columbia River ports, and carload trains moving both east and west to serve state industrial and agricultural shippers. The line is operating today at about 80 percent of practical capacity.

Interstate 5 (I-5) Corridor

The I-5 corridor rail line runs the length of the state from the Canadian border, through Bellingham, Everett, Seattle, and Tacoma to Vancouver (WA) and Portland. It is the backbone of the state rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights over significant portions of the line with

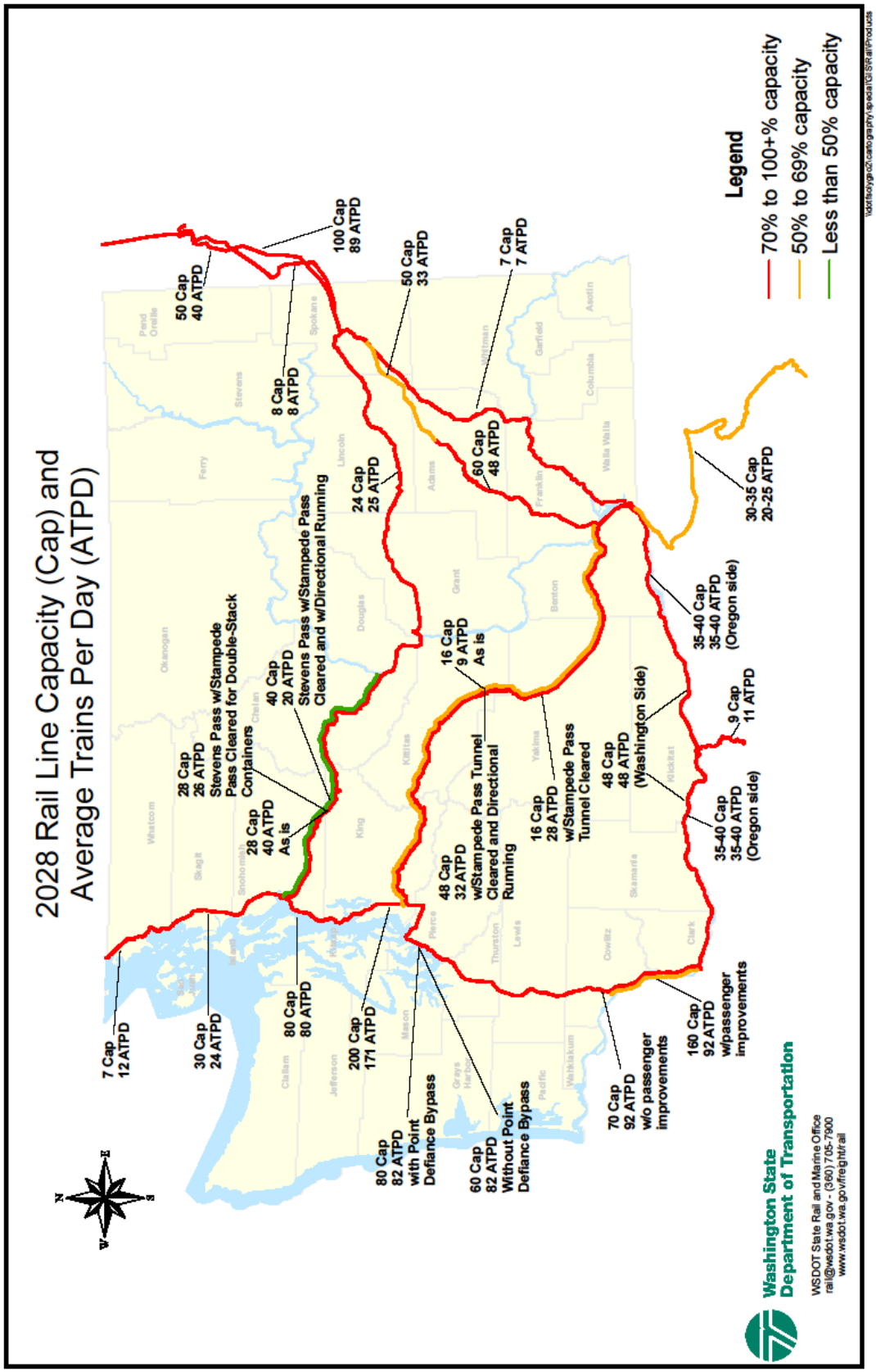
[16] Practical capacity is the highest activity level that a line can operate with an acceptable degree of efficiency, taking into consideration unavoidable losses of productivity.

Exhibit 3-9: 2008 Rail Line Capacity[17]



[17] Train volumes (average trains per day) reflect business activities that are fluctuated sharply and sensitive to economic climate. Although the long-term trend is upward, the short-term trend could drop significantly. The information in this map reflects the long-term forecast results. These numbers were derived based on the best knowledge of the researchers and information available at the time of the research. The recent recession impacts may not be captured by this map.

Exhibit 3-10: 2028 Rail Line Capacity



the UP, Amtrak's intercity rail services, and the *Sounder* commuter rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic chokepoints, causing delays that ripple across the entire state and Pacific Northwest rail system.

Rail Bottlenecks

Exhibit 3-11 locates the major rail bottlenecks by type across the state rail system.

Exhibit 3-11: Railroad Bottlenecks

Bottleneck	Type of Bottleneck
Portland – Vancouver (WA)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Vancouver (WA)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation
Ridgefield	Yard Infrastructure
Woodland – Castle Rock	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation
Vader – Chehalis	Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Geography, Geology, Topography, Regulation
Chehalis	Yard Infrastructure
Centralia	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation
Centennial	Passenger Operation
Nelson Bennett – Ruston	Main Line Infrastructure (Except Signal and Traffic Control)
Ruston – Reservation	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition
Reservation – Puyallup	Yard Infrastructure Signal and Traffic Control Systems
Auburn	Yard Infrastructure Infrastructure Condition
Tukwila – Argo	Main Line Infrastructure (Except Signal and Traffic Control)

Bottleneck	Type of Bottleneck
Argo – South Portal (Seattle)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Tacoma – Tukwila (UP)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
South Portal (Seattle) – MP 8 (Ballard)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
MP 8 (Ballard) – Edmonds	Main Line Infrastructure (Except Signal and Traffic Control)
Edmonds	Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition
Edmonds – Mukilteo	Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control)
Mukilteo	Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition
Everett Jct. – PA Jct.	Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition
PA Jct. – Delta Jct.	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Marysville	Infrastructure Condition Geography, Geology, Topography, Regulation
English – Bow	Main Line Infrastructure (Except Signal and Traffic Control)
Bow – Swift	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation

Bottleneck	Type of Bottleneck
Swift – Thornton Yard (Surrey, BC)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
Vancouver (WA) – Wishram	Main Line Infrastructure (Except Signal and Traffic Control)
Wishram – Pasco	Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Auburn – Ellensburg	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
Ellensburg – Pasco	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
Everett – Wenatchee	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
Wenatchee – Spokane	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition Geography, Geology, Topography, Regulation
Pasco – Spokane	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Spokane – Athol, ID (BNSF)	Main Line Infrastructure (Except Signal and Traffic Control)
Hinkle, OR – Spokane	Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition
Spokane – Eastport, ID	Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Infrastructure Condition
Vancouver (WA) (BNSF)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation
Kalama (BNSF)	Yard Infrastructure

Bottleneck	Type of Bottleneck
Tacoma (BNSF)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Tacoma (Tacoma Rail)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Fife (UP)	Yard Infrastructure Main Line Infrastructure (Except Signal and Traffic Control)
Argo (UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Port of Seattle (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
SIG/Stacy (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Geography, Geology, Topography, Regulation
Interbay (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Main Line Infrastructure (Except Signal and Traffic Control) Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Everett (BNSF)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation Infrastructure Condition Geography, Geology, Topography, Regulation
Wishram (BNSF)	Yard Infrastructure
Arco (Cherry Point; BNSF)	Yard Infrastructure
Longview Jct. (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems
Pasco (BNSF)	Yard Infrastructure
Centralia (BNSF & UP)	Yard Infrastructure Signal and Traffic Control Systems Passenger Operation
Spokane (BNSF)	Yard Infrastructure

Source: Washington State Transportation Commission (WSTC) *Statewide Rail System and Capacity Study*, 2006

Rail Capacity

Exhibit 3-12 lists the rail segments where mainline practical capacity will be exceeded within 20 years, even with the additional capacity gained by operating longer trains and implementing better scheduling.[18] The existing bottlenecks will persist and worsen, some more quickly than others.

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[19]

Examples of capacity constraints:

Stevens Pass. With the Everett-Spokane line nearing its maximum capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver (WA) and then east. This has added considerable volume to the Vancouver-Pasco line along the Columbia River Gorge, and made the scheduling of train moves through the Gorge and along the I-5 rail corridor more complex.

I-5 Corridor. The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UP freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver (WA) area, where the railroads' north-south and east-west routes intersect. Rail simulation studies (i.e. grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor) show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[20] Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[18] Demand is total demand not just traffic of the owner.

[19] See for example: American Association of State Highway and Transportation Officials, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

[20] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

Exhibit 3-12: Rail Lines in Washington State Exceeding Practical Capacity 2008 and 2028

(Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains)

Rail Segment	RR	2008 Capacity	2008 Demand	2008 Utilization as % of Capacity	2028 Capacity	2028 Demand	2028 Utilization as % of Capacity
Everett to Seattle	BNSF	60	48	80%	80	80	100%
Seattle to Tacoma	BNSF	140	80	57%	200	171	86%
Tacoma to Kalama/Longview w/Point Defiance Bypass	BNSF	60	62	103%	80	82	103%
Tacoma to Kalama/Longview w/o Point Defiance Bypass	BNSF	60	62	103%	60	82	137%
Kalama/Longview to Vancouver, WA w/Passenger Improvements	BNSF	100	55	55%	160	92	58%
Kalama/Longview to Vancouver, WA w/o Passenger Improvements	BNSF	70	55	79%	70	92	131%
Everett to Wenatchee, as is	BNSF	28	16	57%	28	40	143%
Everett to Wenatchee Stevens Pass as is, w/Stampede Pass cleared for double-stack countainers	BNSF	28	16	57%	28	26	93%
Everett to Wenatchee Stevens Pass as is, w/Stampede Pass cleared for double-stack countainers, and w/directional running	BNSF	28	16	57%	40	20	50%
Wenatchee to Spokane	BNSF	24	18	75%	24	25	104%
Auburn to Pasco, as is	BNSF	16	6	38%	16	9	56%
Auburn to Pasco w/o Stampede Pass Tunnel Cleared	BNSF	16	6	38%	16	28	175%
Auburn to Pasco w/Stampede Pass Tunnel Cleared and directional running	BNSF	48	8	17%	48	32	67%
Vancouver, WA to Pasco	BNSF	40	32	80%	48	48	100%
Vancouver, WA to Pasco	UP	40	40	100%	40	40	100%
Pasco to Spokane	BNSF	50	32	64%	60	48	80%
Pasco to Spokane	UP	7	7	100%	7	7	100%
Spokane to Sandpoint, ID	BNSF	70	45	64%	100	89	89%
Spokane to Sandpoint, ID	UP	8	7	88%	8	8	100%

Blue shows lines that are at or are projected to be at 100 percent or more of capacity by 2028.

Source: 2009 Marine Cargo Forecast

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places

enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UP have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers.

Furthermore, the national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and the state. Continuing high levels of growth and the competition between BNSF and UP for the lucrative southern California rail market have made southern California the key focal point of investment for both railroads.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not overtake slower-moving carload freight trains.[21]

Recent Major Policy Changes Impacting the Rail System in Washington State

Safety Regulation

The state has very little safety jurisdiction over rail operations, except for public highway-rail crossings. States can conduct inspections in various

[21] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

safety disciplines as part of a state-federal participation program, but any enforcement is done by the Federal Railroad Administration (FRA) in the areas of hazardous materials, track, signals, and operating practices.

Appendix 3-B discusses rail safety regulation, including rail employee safety, remote control operations, community notice, blocked crossings, train speeds, grade crossing protective zones, housekeeping, quiet zones, crossing consolidation/closure, and Operation Lifesaver—an international organization promoting rail safety and awareness.

Positive Train Control[22]

Positive Train Control (PTC) refers to technology that is capable of preventing train-to-train collisions, over-speed derailments, and casualties or injuries to roadway workers. PTC systems vary widely in complexity and sophistication based on their level of automation, functionality, system architecture (i.e., non-signaled, block signal, cab signal), and degree of control.

Prior to October 2008, PTC systems were being voluntarily installed by various carriers. However, the Rail Safety Improvement Act of 2008 (RSIA), signed by the President Bush on October 16, 2008 as Public Law 110-432, has mandated the widespread installation of PTC systems by December 2015.

Currently, all of the affected railroads are aggressively developing PTC implementation plans as required by the RSIA and adapting their PTC systems to maximize interoperability.[23] The FRA is supporting all rail carriers that have statutory reporting and installation requirements to install PTC, as well as rail carriers that are continuing to voluntarily implement PTC through a combination of regulatory reform, project safety oversight, technology development, and financial assistance.

On March 7, 2005, FRA published regulations regarding performance standards for processor-based signal and train control systems per Title 49 Code of Federal Regulations Part 236, Subpart H. A working group of the Railroad Safety Advisory Committee first developed these performance-based regulations versus traditionally prescriptive regulations. The new performance-based regulations require that a railroad demonstrate with a high degree of confidence, that the risks associated with a new product

[22] http://www.fra.dot.gov/us/content/1265.

[23] The BNSF, UP, Norfolk Southern Railway, and CSX Transportation are leading the interoperability effort for technologies based on the Electronic Train Management System for rail traffic outside of the Northeast Corridor. The National Passenger Rail Corporation (Amtrak) is undertaking similar action for rail traffic in the NEC using the Advanced Civil Speed Enforcement System.

being implemented are less than or equal to the risks associated with the product that is being replaced.

After extensive participation and contributions by railroads, rail labor, suppliers, and other agencies, including the National Transportation Safety Board, the performance-based regulations became effective on June 6, 2005. The Subpart H regulations support the voluntary introduction of innovative technology, including systems using computers and radio data links, to accomplish PTC functions. In addition to supporting advancement of PTC systems, these regulations also facilitate the ever-growing use of processor-based equipment and functioning in otherwise conventional signal and train control systems.

FRA is working to develop a new performance-based regulation to address the various statutory requirements of RSIA and to better support railroads that must install PTC systems. This new regulation is being crafted to ensure system safety while reducing the administrative overhead.

There are currently 11 different PTC pilot projects in varying stages of development and implementation, involving nine different railroads in at least 16 different states, and consisting of over 4,000 track miles. These pilot projects are not only allowing railroads to continue to advance the various technologies used to implement PTC systems, but are providing the railroads valuable experience on installation and test procedures required to meet the 2015 deployment completion date.

Washington State Department of Transportation

Chapter 4: Freight Rail Services – Effects on the Economy and Society

Functions of Freight in Washington's Economy

Washington State's (state) multimodal transportation system supports economic vitality and quality of life in the state and region. The smooth functioning of highways, railways, ports, pipelines, and airports allows businesses and consumers to trade and purchase the goods necessary to sustain business and daily life. With coordinated planning and strategic investments, the state and its partners can provide a transportation system that meets the challenges and opportunities ahead. Including statewide freight rail into statewide transportation planning and investment decisions is increasingly important.

The three components of the state's freight activities are:

Made in Washington – Regional Economies Rely on the Freight System

The state's manufacturers and farmers rely on the freight system to ship Washington-made products to local customers, big United States (U.S.) markets in California and on the east coast, and worldwide. The state's producers generate wealth and jobs in every region in the state.

Delivering Goods to You – The Retail and Wholesale Distribution System

The state's distribution system is a fundamental local utility; without it state residents would have no food to eat, clothes to wear, books to read, spare parts, fuel for their cars, or heat for their homes. In other words, the economy of the region would no longer function. The value and volume of goods moving in these freight systems is huge and growing.

Global Gateways – International and National Trade Flows Through Washington

This is a gateway state, connecting Asian trade flows to the U.S. economy, Alaska to the Lower 48, and Canada to the U.S. West Coast. About 70 percent of international goods entering the state's gateways continue on to the larger U.S. market. Thirty percent become part of the state's manufactured output or are distributed in the state's retail system (Exhibit 4-1).

Exhibit 4-1: Washington State Is a Global Gateway

Source: Washington State Department of Transportation (WSDOT) Geographic Services and Strategic Analysis and Program Development, 2004

These components underpin our national and state economies, support national defense, directly sustain hundreds of thousands of jobs, and distribute the necessities of life to every resident of the state every day.

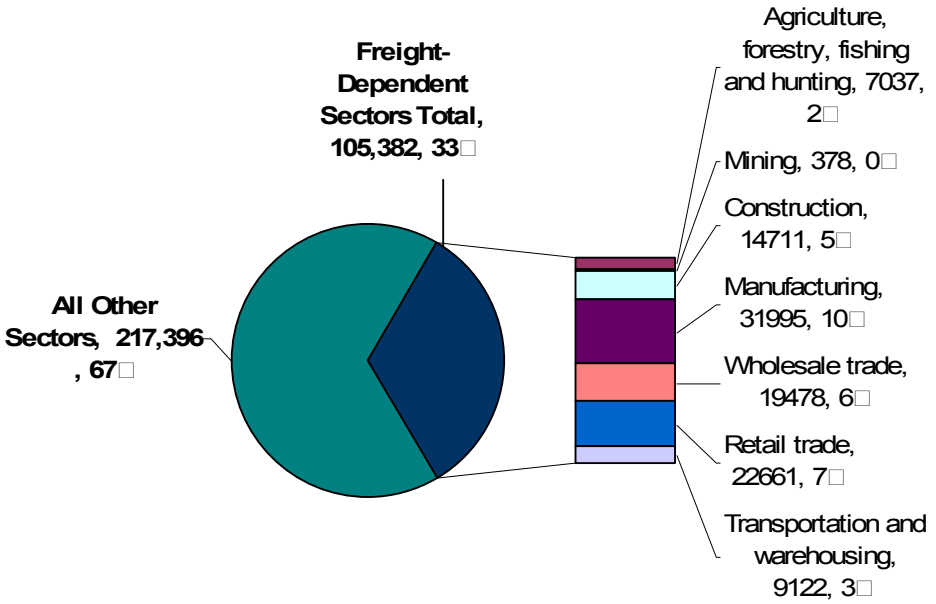
A large part of the state's economy depends on freight for its competitiveness and growth. The most highly freight-dependent sectors include agriculture, mining, construction, manufacturing, wholesale, retail, transportation, and warehousing. In 2008 freight-dependent sectors accounted for 33 percent of the state's Gross Domestic Product (GDP), 71 percent of business income, and 39 percent of state employment (Exhibits 4-2, 4-3, and 4-4).

Freight Rail in Washington's Economy

Rail provides critical transportation for manufacturers, agricultural producers, lumber and wood product producers, the food products industry, and the ports and international trade sector—all important sectors of the state economy. Freight rail, in terms of tonnage, accounted for 19 percent of total freight in the state in 2007.

Exhibit 4-2: Freight-Dependent Sectors GDP
Washington State 2008 (□Millions)

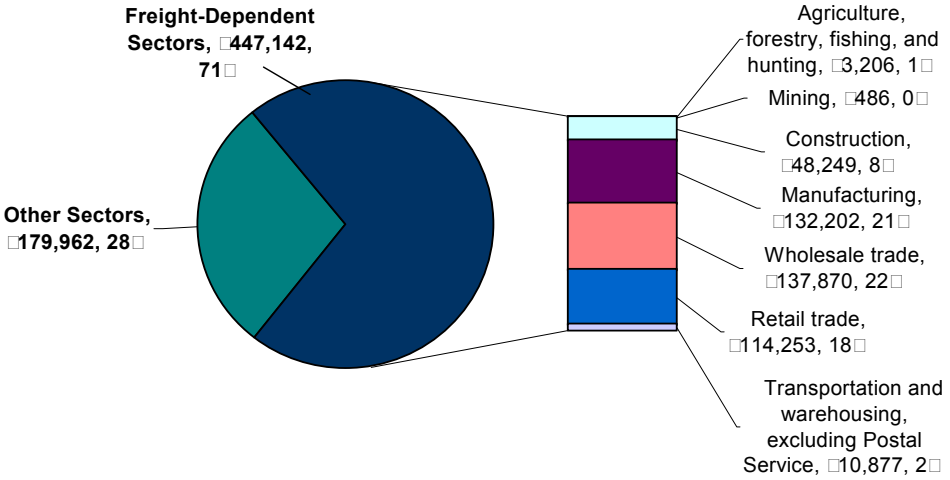
Freight-Dependent Sectors: □105,382
All Sectors: □217,396



Source: U.S. Department of Commerce (USDOC), Bureau of Economic Analysis, compiled by WSDOT State Rail and Marine Office

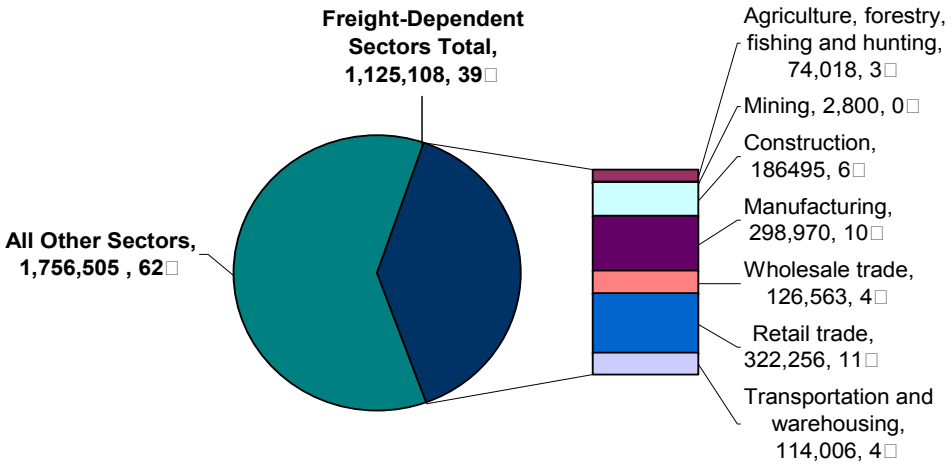
Exhibit 4-3: Business Incomes of Freight-Dependent Sectors
Washington State 2008 (□Millions)

Freight-Dependent Sectors: □447,142
All Sectors: □627,104



Source: Washington State Department of Revenue, compiled by WSDOT State Rail and Marine Office

Exhibit 4-4: Freight-Dependent Sectors Employment
Washington State 2008 First Quarter
Freight-Dependent Sectors: 1.125 Millions Jobs
All Sectors: 2.881 Millions Jobs

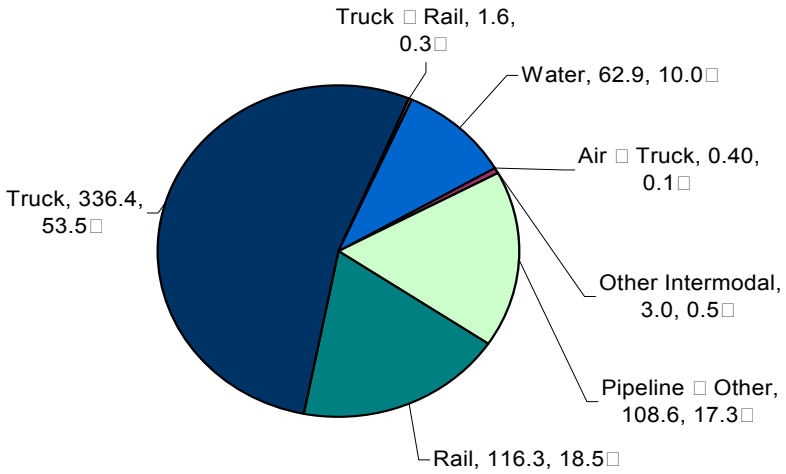


Source: Washington State Employment Security Department 2008, compiled by WSDOT State Rail and Marine Office

Freight Rail Flows

Freight rail provides shippers with cost-effective transportation, especially for heavy and bulky commodities, and can be a critical factor in retaining and attracting industries that are central to state and regional economies (Exhibit 4-5).

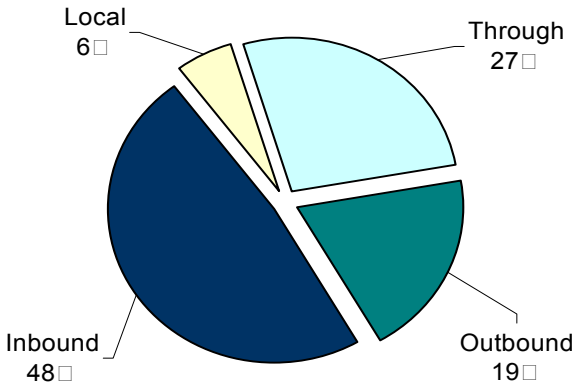
Exhibit 4-5: Freight by Mode – Washington State 2007
(Million Tons)



Source: WSDOT State Rail and Marine Office – Analysis based on Federal Highway Administration (FHWA) Freight Analysis Framework (FAF) Data and 2007 Surface Transportation Board (STB) Waybill Data

In 2007 the state's freight railroads moved more than 116 million tons of freight, an almost 40 percent increase from 83 million tons in 1996. Cargo moving on rail inbound was 48 percent—originating from other states or Canada and terminating in the state. The second largest flow type at 27 percent was cargo moving through the state without loading or unloading. Local cargo, which originated and terminated within the state, comprised six percent of the total rail cargo. Outbound cargo—originating in the state and terminating in another state or Canada—was 19 percent of total state rail freight (Exhibit 4-6).

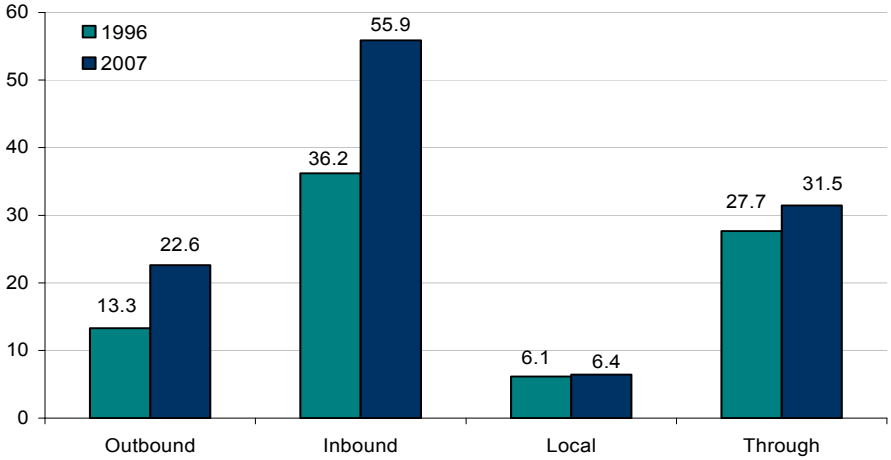
Exhibit 4-6: Rail Freight Flows – Washington State 2007[1]



Source: WSDOT State Rail and Marine Office – 2007 Surface Transportation Board Waybill Analysis

The largest increase in percentage terms is outbound with a 70 percent increase, followed by inbound with a 54 percent increase (Exhibit 4-7).

Exhibit 4-7: Growth of Rail Freight Flows
Washington State 2007 versus 1996 (Million Tons)

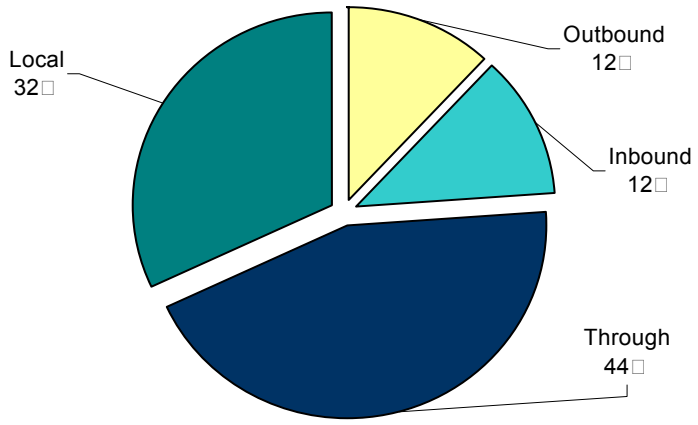


Source: WSDOT State Rail and Marine Office – 2007 Surface Transportation Board Waybill Analysis

[1] Federal Waybill data is available for 2007. 2008 data is not available until early 2010.

As can be seen by comparing Exhibit 4-6 and Exhibit 4-8, the state is much more dependent on inbound cargo than the average state, which has only 12 percent inbound cargo that is moved by rail. In other states approximately one third of the freight rail traffic is local. Local moves by rail in this state are only 6 percent of the total rail freight. The state is truly a Global Gateway for the U.S. Due to this being a coastal state, its through traffic of 31.5 million tons (27 percent) is considerably below the average of all states' through traffic of 44 percent.

Exhibit 4-8: Directional Rail Freight Flows
Average of Other States in U.S. 2007



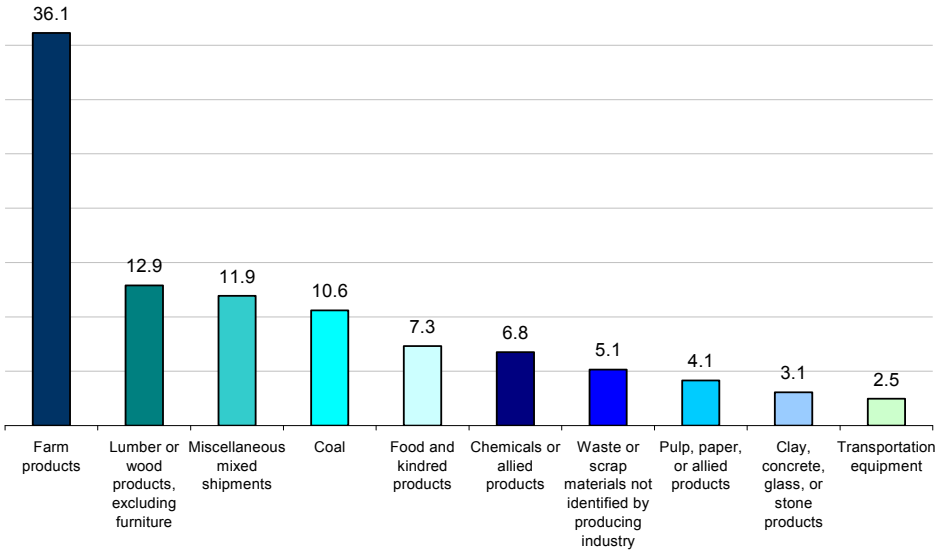
Source: WSDOT State Rail and Marine Office 2007 Surface Transportation Board Waybill Analysis

Major Commodities Shipped by Rail

The economic vitality of the state requires a robust rail system capable of providing its industries, ports, and farms with competitive access to North American and overseas international markets. The state is well known for its agricultural products such as apples, wheat, soft fruits, and many other agricultural products. Freight rail plays an important role in the state's agriculture sector. Lumber and wood product producers, manufacturers, waste management, and mining also rely on rail transportation to move heavy, bulky products to markets cost-effectively.

Farm products, primarily wheat and grain (36.1 million tons), were the largest commodity moved on our rail system in 2007, followed by lumber and wood (12.9 million tons), miscellaneous mixed shipments (11.9 million tons), and coal (10.6 million tons). In 2007, 100.4 tons (almost 86 percent) of freight moved on state rail was from the top ten commodities (Exhibit 4-9).

Exhibit 4-9: Top 10 Commodities Shipped by Rail
Washington State 2007 (Million Tons)



Source: WSDOT State Rail and Marine Office 2007 Surface Transportation Board Waybill Analysis

Trade Partners

The state's rail freight supports regional, national, and international trade and economies. In 2007 more than 55 million tons of goods arrived in the state from 42 other states and Canada by rail for export and in-state consumption. Meanwhile, 23 million tons of goods were exported from the state to 45 other states and Canada by rail. Exhibits 4-10 and 4-11 provide details of inbound and outbound flows that reflect the state's trades with its partners.

The state itself plays an important role in support of trade and economy. One example is the Produce Rail Car program operated by WSDOT with leveraged federal grant funds. This program maintains economic viability in farming areas of the eastern side of the state by supporting produce exports through a lower shipping cost. Exhibit 4-12 shows the estimated 2008 economic impacts of this program.

If rail service deteriorates, these businesses may shift their freight to trucks, but this could increase their transportation costs and may increase the road maintenance costs for state and local governments. In some cases, the loss of rail service could drive businesses to relocate or close. Rail service deterioration would also contribute to more congestion, higher green house gas emissions, higher energy use, and a negative impact on safety.

Exhibit 4-10: Inbound Rail Freight Flows

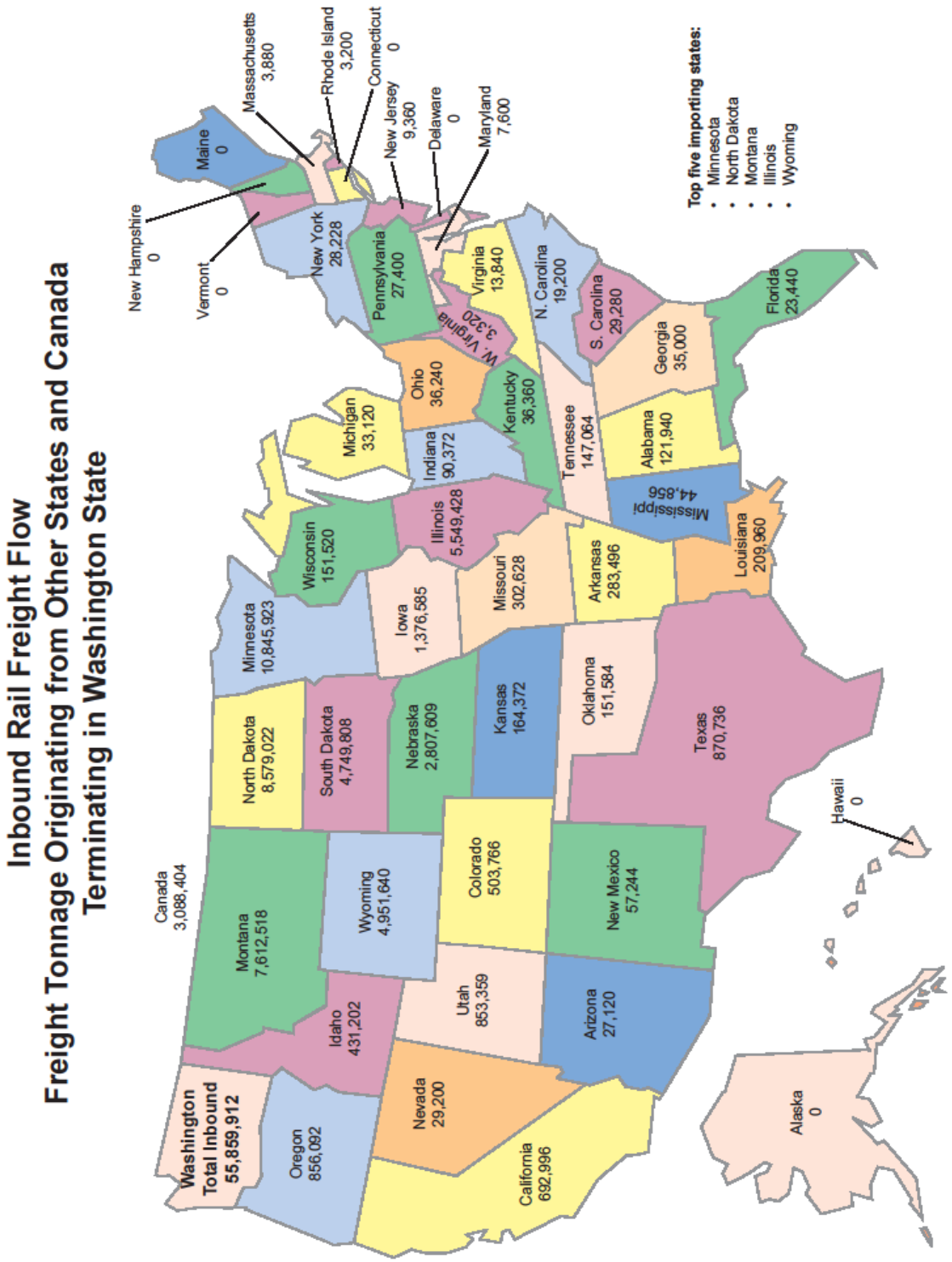


Exhibit 4-11: Outbound Rail Freight Flows

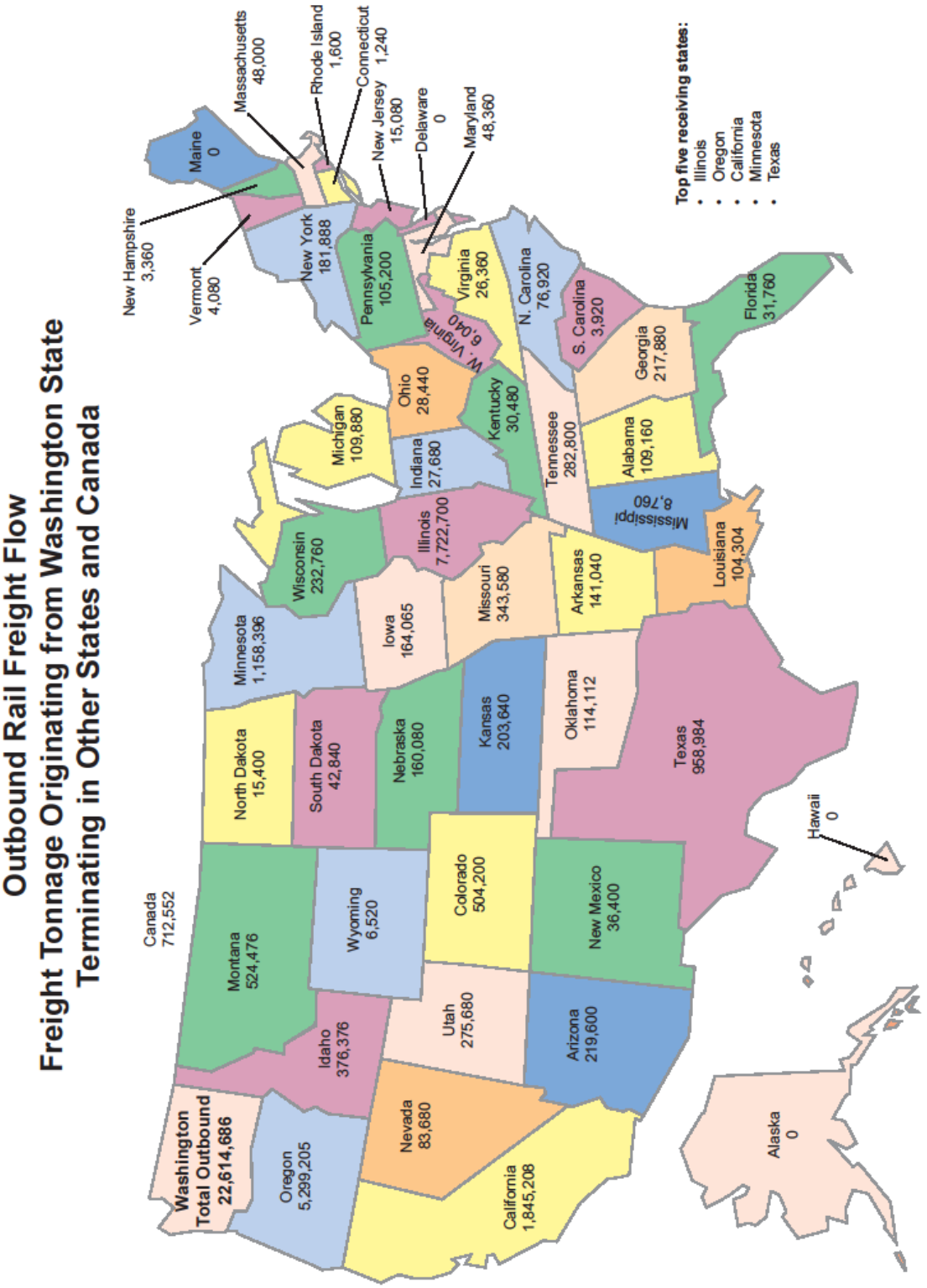


Exhibit 4-12: Economic Output and Employment Supported by Produce Rail Car Program – Year 2008

Impacts	Direct	Indirect	Induced	Total
Economic Output (Million)	30	17	18	66
Employment (Jobs)	409	133	151	693
Value Added (Million)	13	8	11	32

Source: WSDOT State Rail and Marine Office - IMPLAN Input-Output model for Washington State and its local areas.

Economic impacts are assessed using the IMPLAN Input-Output model for Washington State and its local areas. Using classic input-output analysis in combination with regional specific Social Accounting Matrices and Multiplier Models, IMPLAN provides a highly accurate and adaptable model for its users. The IMPLAN database contains county, state, zip code, and federal economic statistics which are specialized by region, not estimated from national averages, and can be used to measure the effect on a regional or local economy of a given change or event in the economy's activity.

Direct impact is measured as the jobs, outputs, and value added within farming industries and shippers supported by the produce rail car program. Indirect impact is measured as the jobs, outputs, and value added occurring within other industries that provide goods and services to the directly affected industries. Induced impact is the change in jobs, outputs, and value added resulting from household spending of income earned either directly or indirectly from the shippers industry s spending.

Difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the GDP.

The following section discusses rail-intensive industries in the state and their impacts on the state's economy and dependence on freight rail.

Rail Intensive Sectors and Industries in Washington State

Agriculture and Food Products Industry Bulk and Specialized Carload Shippers[2]

Agriculture and food product manufacturers are important economic sectors in the state, generating 2.9 percent of the gross state product[3] and accounting for 4.1 percent of 2008 employment.[4] The state agricultural and food manufacturing production was valued at over $13.6 billion in

[2] The section is adopted from the Washington State Transportation Commission's (WSTC) *Statewide Rail Capacity and System Needs Study* (2006).
[3] USDOC Bureau of Economic Analysis.
[4] Employment Security Department.

2008.[5] Agriculture is the primary source of employment in many of the state's rural counties.

Agricultural rail traffic outbound from the state is expected to grow at a compound annual growth rate of 3.3 percent over the next 20 years. The state also has an expanding food products industry with particular strengths in frozen foods (7.3 percent of U.S. output) and wine production.[6]

However, most of the agricultural tonnage moving on the state rail system is midwestern grain moving to the Lower Columbia River and Puget Sound ports for export. And because midwestern grain is moving long distances by unit train, it is generally more attractive for the railroads than local state agricultural shipments, which must move shorter distances for export and may require specialized handling.

The Class I railroads are asking state agricultural shippers to consolidate their shipments at new facilities, and this may be economical for those shippers who can accommodate the changes. However, these changes can also lead to un-served and underserved markets where shippers have difficulty finding efficient transportation. These changes could affect the short lines, which may see declines in their markets; operators of small grain elevators along the short lines who also stand to lose business; and the remaining shippers on the short lines who could see reductions in service and increased costs. The challenge faced by state agriculture is to maintain competitive rail service as it focuses on higher-value added crops and produce that may not generate the volumes that are attractive to the Class I railroads. This need to consolidate carloads for more efficient rail service is a prime situation where state funding could make sense. This has been done very successfully in Oregon.

Ports and International Trade Sector – Intermodal Container Shippers[7]

The state's ports and international trade industry depend on rail to export grain and other agricultural products, and to import intermodal containers of consumer goods. Although in 2007 rail only accounts for 19 percent of total freight in the state in terms of tonnage, it accounts for 42 percent of marine cargo.[8] If the rail system cannot deliver high-quality transportation services, especially for intermodal cargo that is not destined

[5] Department of Revenue.
[6] WSTC – *Statewide Rail Capacity and System Needs Study* (2006).
[7] The section is developed based on 2006 WSTC *Statewide Rail Capacity and System Needs Study* and WSDOT/Washington Public Ports Association (WPPA) *2009 Marine Cargo Forecast.*
[8] WSDOT/WPPA *2009 Marine Cargo Forecast*, STB Waybill data 2007, and United States Department of Transportation (USDOT) FAF 2008.

for this state, shippers may shift to other ports. This could affect port-supported economic sectors. In addition, export trade plays a major role in the state economy. Rail frequency and quality affects the frequency and array of service offered by shipping lines. Without good rail connections to support both import and export trade, state ports would become less attractive to ocean carriers, and ultimately, the state would become a less attractive location for export businesses.

About 40 percent of the state's rail traffic is related to port activity. The amount moving to state ports by rail is forecast to increase from the current 42 million tons to 66 million tons in 2030.[9] The state's ability to meet this opportunity will depend on the investments made to expand and improve rail operations and infrastructure.

International trade generates large flows of intermodal containers through the Ports of Seattle and Tacoma. Between 1999 and 2008, container traffic grew at an average annual rate of 2.9 percent from 2.76 million Twenty-Foot Equivalent Units[10] (TEUs) to 3.57 million TEUs at Puget Sound ports.[11] Much of the container traffic consists of merchandise and retail goods imported from Asia through the ports, and then transferred to rail for shipment to Midwestern and eastern U.S. markets. Businesses and consumers across the U.S. benefit from this international trade, but healthy deepwater ports also provide benefits to the state.

The state is among the top export states due to the strong market for Boeing aircraft. While many state exporters do not use the rail system to deliver goods to state ports, the existence of a healthy rail system is important, because it brings more traffic to the ports and more shipping services that can be used by state exporters. Strong long-haul rail services allow ocean carriers to access larger and more distant inland markets. Local export shipments help to balance import and export flows for the carrier. Thus, a strong rail system helps attract ocean carrier services to state ports and makes the state a more attractive location for national, regional, and local export businesses.

Manufacturers Industrial Carload Shippers[12]

Manufacturing and industrial product industries are among the largest rail-using state businesses, and they primarily use rail carload services. Shippers include producers of metals, machinery, transportation equipment (including aircraft), wood and paper, petroleum, and plastic

[9] WSDOT/WPPA *2009 Marine Cargo Forecast.*
[10] Twenty-Foot-Equivalent Unit. The 8-foot by 8-foot by 20-foot intermodal container is used as a basic measure in many statistics.
[11] Port of Seattle and Port of Tacoma.
[12] The section is adopted from *Statewide Rail Capacity and System Needs Study*.

products. In 2008 the largest tonnage volumes of outbound shipments from these industries were waste and scrap materials; pulp, paper, and allied products; transportation equipment; primary metal products; and chemicals and allied products.[13] Inbound manufactured or industrial products included coal; chemicals; clay, concrete, glass, and stone; pulp and paper; and primary metal products.[14]

The volume of shipments of manufacturing goods is expected to grow steadily. However, many of the shippers reported that they were paying higher prices, were getting lower quality service, and were often having business turned away by the railroads.[15] These shippers will substitute truck for rail when they can, but for shippers of bulky, semi-finished products, or primary materials, trucking may not be feasible or cost effective. Hence, there is a risk that the state will lose some of the businesses, such as coal and gravel that depend on carload shipments, to relocation or closure.

A key feature of rail is the ability to move heavy and high/wide manufacturing products that cannot be moved via truck.

Economic Impacts of Freight Rail

Freight rail has significant economic impacts. In 2007 total state rail freight revenue, including rail-only and rail intermodal, amounted to $2 billion. Freight rail employed 4,207 people in the state and contributed $533 million to the state's GDP directly. The state's freight rail system also supports other economic sectors. Exhibit 4-13 provides an overview of the economic impacts of freight rail in the state.

Major Drivers in Freight Rail Demand

There are four major drivers that determine freight demand:

- Population size and trends; demographic changes.
- Economic activity, both domestic and international.
- Trade activity, both domestic and international.
- Supply chain practices.

[13] Goods shipped from this state to other states and countries by rail.
[14] Goods shipped from other states and countries to this state by rail. Do not confuse this with state import.
[15] Shippers' survey conducted by researchers of *2006 Statewide Rail Capacity and System Needs Study*.

Exhibit 4-13: Economic Impacts of Freight Rail Transportation □ Washington State 2007

Impact Category	Direct□	Indirect□□	Total
Employment (Jobs)	4,207	6,057	10,264
Business Revenue (□Million) □□□	□1,154	□884	□2,038
Employee Compensation (□ Million)	□417	□259	□676
GDP (□Million) □□□□	□533	□383	□916
Tax Impact (□Million)	N□A	N□A	□271

□Directly related to freight rail transportation industry.

□□Jobs that support freight rail transportation but not hired by rail transportation industry.

□□□Business revenue of an industry is total sales of all business in the industry.

□□□□GDP is value-added or the difference between the value of its output and the value of its input. GDP of an industry is measured as sum of values added by all businesses in the industry. It is sales of goods minus purchase of intermediate goods to produce the goods sold.

Sources: Association of American Railroads, WSDOT State Rail and Marine Office - IMPLAN Input-Output model for Washington State and its local areas.

Population Growth and Trade Growth

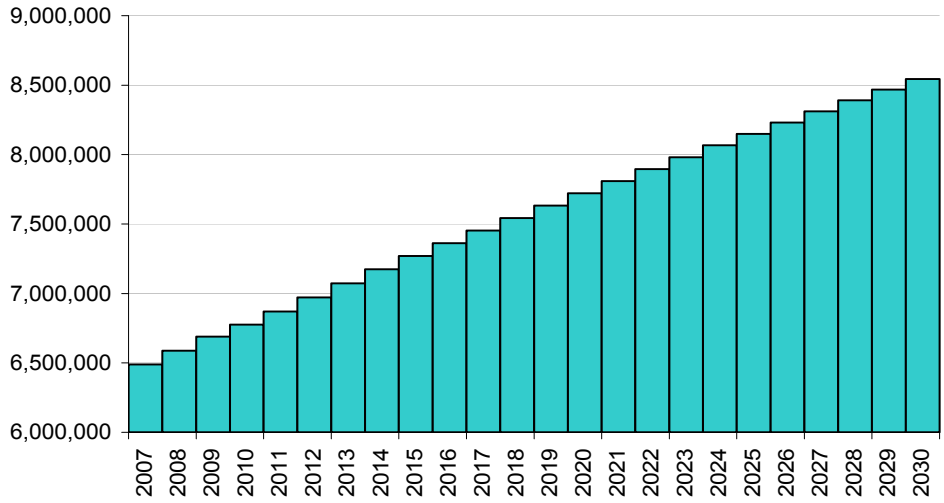
As Exhibit 4-14 shows, the population of the state is projected to grow at 1.2 percent a year. However, freight rail demand in the state is tied both to U.S. population growth and to state population growth, due to the fact that the state is one of the major global gateway states and plays an important role in the national economy and international trade. Therefore, freight rail demand grows faster in Washington State than the national average.

It is estimated that one in four jobs in the state is trade related.[16] Thus, for the import side of the equation, it is the growth in the total U.S. population and their consumption that drives the demand for freight rail in this state. On the export side of the equation, the demand is built on world population growth of developing countries in Asia and their need to feed their people. U.S. imports grew at an annual pace of 8.8 percent between

[16] www.washingtonports.org and www.portjobs.org/.

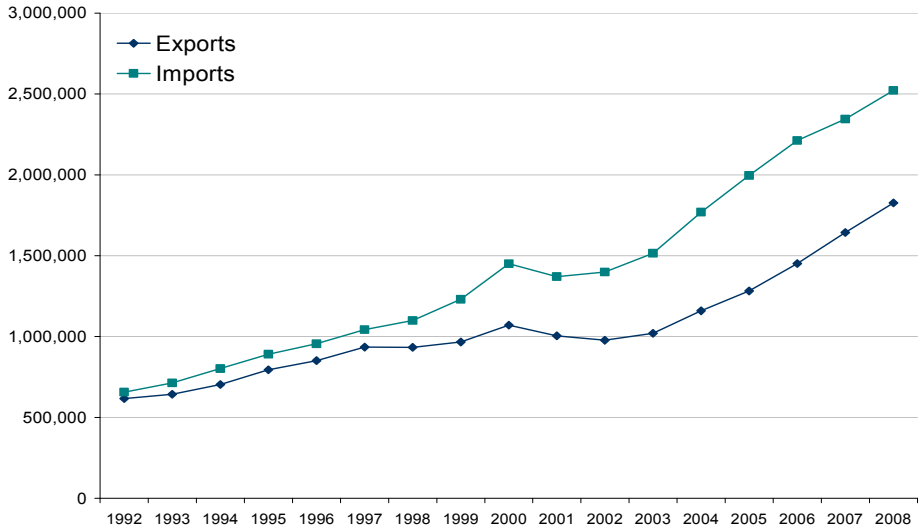
1992 and 2008, and U.S. exports grew at 7.0 percent during the same period (Exhibit 4-15).

Exhibit 4-14: Population Growth □ Washington State 2007-2030



Source: Washington State Office of Financial Management

Exhibit 4-15: U.S. Export and Import, 1992 to 2008
(□ Million)



Source: U.S. Census Bureau, Foreign Trade Division

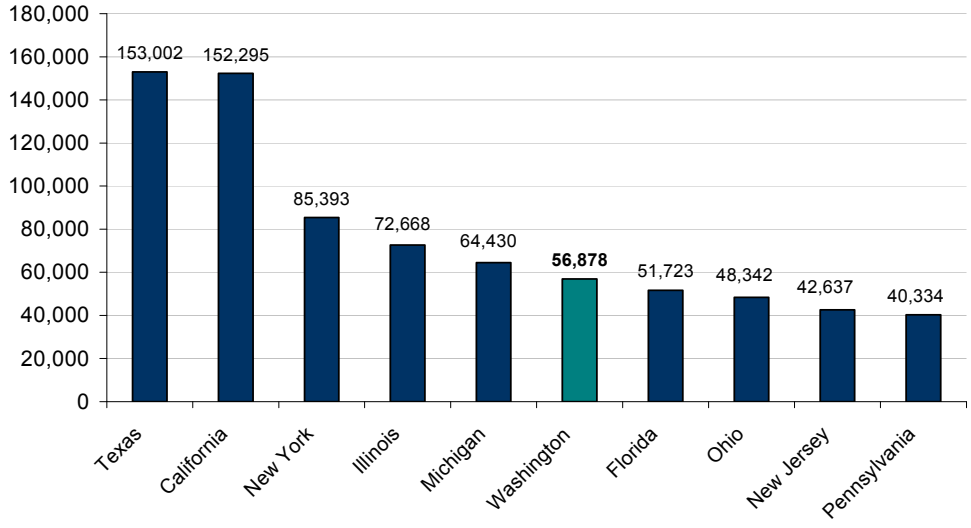
Most trade forecasters agree that the degree of foreign trade dependency on the world's major economies will continue to grow. That is the U.S. and its major trading partners will continue to become more "open" economies. This trend will continue because the developing world continues to offer increasingly advantageous locations for production. Economic efficiency is the driver for economic globalization. As a consequence, the ability to produce lower cost goods and services in

different locations leads to more trade and transportation. While the past growth rate is not expected to be sustainable, it is believed the trend of imports and exports is likely to continue to grow at a slow but steady pace.

The state, as a major global gateway state, shared a significant portion of such growth in 2008, ranking sixth in exports (Exhibit 4-16).

Imports drive the demand for rail service in the state as the fast growth of international container traffic through state gateways to U.S. markets continues. However, the trend has been slowing lately and future growth is likely to continue at a slower pace (Exhibit 4-17).

Exhibit 4-16: Top Ten Export States in the United States □ 2008
(□ Millions)

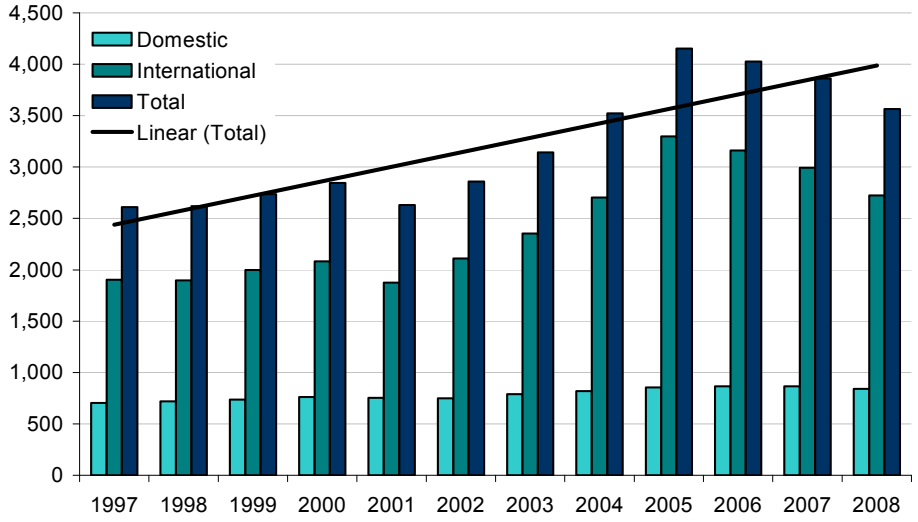


Source: U.S. Census

Economic Growth

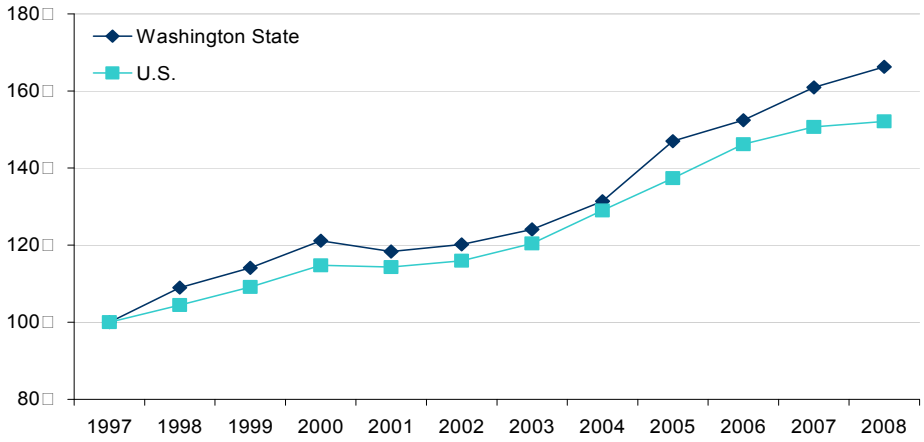
The economic growth of many sectors of the state economy is dependent on freight. Most of these freight-dependent sectors at some point depend on the rail system within the state to move their goods. The growth of freight dependent sectors in the state is faster than that of the U.S. (Exhibits 4-18 and 4-19).

Exhibit 4-17: Container Traffic Through Puget Sound Ports
1998–2008 (1000 TEUs)



Source: Port of Seattle and Port of Tacoma

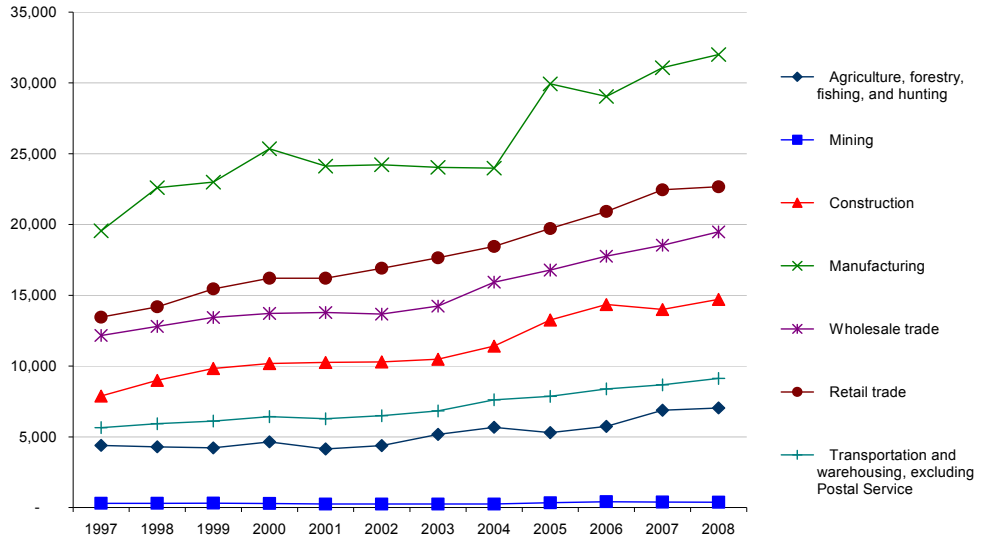
Exhibit 4-18: GDP Growth of Freight-Dependent Sectors – Washington State vs. United States, 1997 to 2008



Note: Freight-dependent sectors include agriculture, mining, construction, manufacturing, wholesale, retail and transportation, and warehousing.

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Exhibit 4-19: GDP Growth by Freight-Dependent Sectors □ Washington State 1997 to 2008 (□ Million)



Source: U.S. Bureau of Economic Analysis

Future Demand □ Washington State Rail Forecast

Sources

Future demand of rail freight services are assessed based on five main studies (Appendix 4):

- Washington State Transportation Commission (WSTC): *Statewide Rail Capacity and System Needs Study – Freight Transportation Demand Forecasts* (2006).
- USDOT Federal Highway Administration: *2007 Updates of Freight Analysis Framework Forecast.*
- WSDOT/WPPA: *2009 Washington State Marine Cargo Forecast.*
- U.S. STB: *2007 Rail Waybill Sample Data.*
- American Association of State Highway and Transportation Officials (AASHTO): *Freight Demand and Logistic Bottom Line Report* (Draft), 2006.

Methodology and Forecasts

The WSDOT State Rail and Marine Office adopted the forecast results from the above sources. For rail mode related forecasts, 2007 Waybill data are used as a base for projections, since data for 2008 was not available at the time of forecasting.

However, the 2008 and 2009 recession has had profound impacts on the U.S. and world economies and many effects are likely to take many years

to understand. Therefore, the results of the forecasts in this plan could be slightly optimistic from a long-term forecast perspective. The forecasts will be updated as necessary as the data for 2008 and 2009 become available.

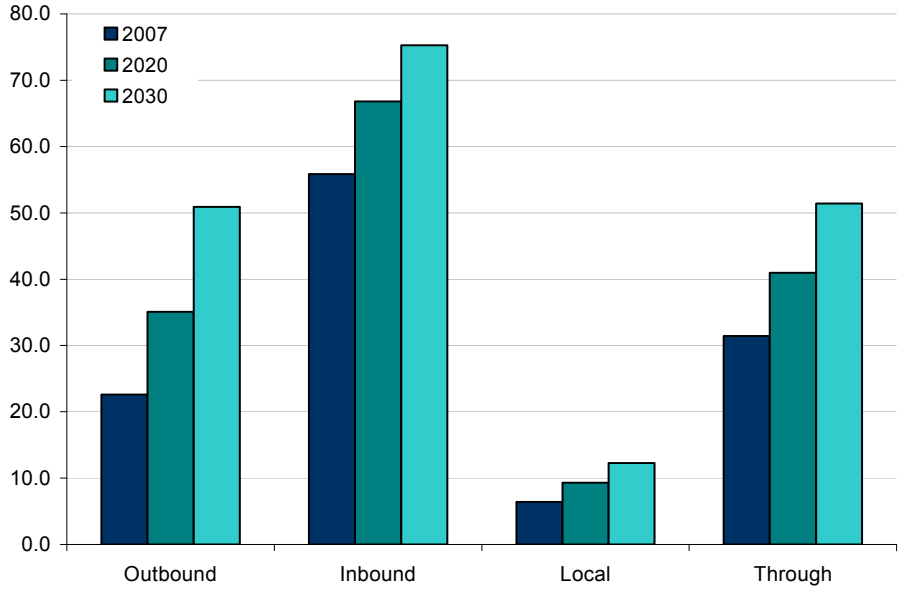
While the most recent recession data for freight is not available and therefore not incorporated into most of the analytical models, the sources used for the forecasts are long-term data. Historical data used in those models reflect the effects of previous recessions. In addition, while the economy went into recession in 2008, state port-related imports and exports started to decline in 2007. Rail traffic in 2007 was not as strong as the economy itself in that year. Therefore, the correction factor of this recession to the forecast results may not be dramatic, but could be significant when the data are incorporated into the long-term trends.

Summary of Rail Freight Forecast

The state's mainline freight rail demand can expect continued growth over the next 10 to 20 years. The railroads are expected to need to move more than 152.1 million domestic tons of freight in 2020, up from 116.3 million in 2007, a 2.1 percent compound annual growth rate. In 2030, it is projected that there will be close to 189.9 million tons needing to be moved, a 2.2 percent annual growth over the 10 years from 2020 to 2030, and a steady 2.2 percent growth rate over the 23 years between 2007 and 2030. Exhibit 4-20 shows the growth of rail tonnage in the forecast years. While local and inbound traffic continue to grow, they will slow to slightly lower levels of growth from 2020 to 2030 compared to 2007 to 2020 growth levels. Outbound and through traffic will both grow at higher rates in the more distant future as compared to the next 10 years.

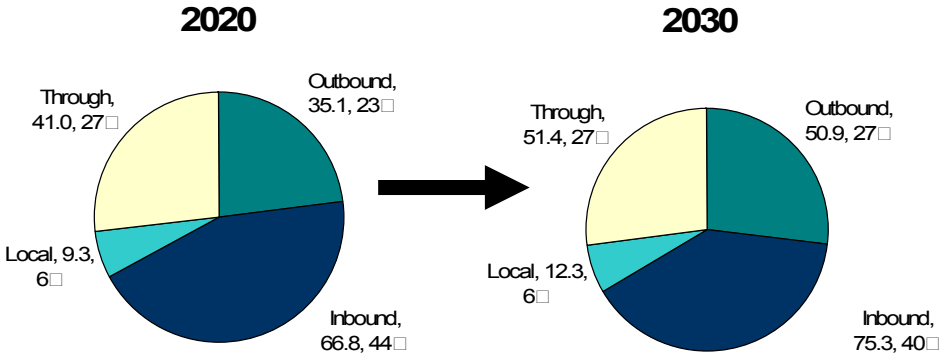
Exhibit 4-21 shows the projected distribution of the inbound, outbound, through, and local shares of the state's total freight rail tonnage for both forecast years of 2020 and 2030. Of all shares, outbound traffic is projected to continue to grow the most between 2020 and 2030, growing from 23 percent to 27 percent between 2007 and 2020, and expanding to 35 million tons. Local and through traffic is projected to continue to maintain approximately 6 percent and 27 percent of the tonnage, respectively, over the next 10 and 20 years. Inbound traffic is projected to encompass a smaller percent of the traffic, as it will claim 44 percent of the tonnage in 2020 and only 40 percent in 2030.

Exhibit 4-20: Washington State Rail Freight 2007, 2020, and 2030 (Million Tons)



Source: WSDOT State Rail and Marine Office

Exhibit 4-21: Rail Freight Distribution (Million Tons)



Source: WSDOT State Rail and Marine Office

The distribution of traffic tonnage by commodity through the forecast years is shown in Exhibit 4-22. Farm products shipped by rail are projected to continue to be a significant tonnage commodity group, growing to more than 64.7 million tons in 2030, up from 36.1 million tons in 2007. Miscellaneous mixed shipments, primarily in the form of imports, are projected to increase from 11.9 million tons in 2007 to 14.3 million in 2020 and 17.6 million in 2030.

Exhibit 4-22: Projected Rail Freight Growth of Top 10 Commodities
Washington 2007-2030 (Million Tons)

Commodity	Year					
	2007	2010	2015	2020	2025	2030
Farm products	36.1	38.8	42.8	48.1	55.2	64.7
Lumber or wood products, excluding furniture	12.9	12.8	12.0	11.2	10.2	9.2
Miscellaneous mixed shipments	11.9	12.6	13.4	14.3	16.0	17.6
Coal	10.6	11.0	12.7	14.8	17.1	19.9
Food and kindred products	7.3	7.2	7.9	9.3	11.0	13.2
Chemicals or allied products	6.8	7.8	8.2	8.7	9.1	9.5
Waste or scrap materials not identified by producing industry	5.1	5.1	5.8	6.6	7.6	8.9
Pulp, paper, or allied products	4.1	4.1	4.2	4.2	4.2	4.3
Clay, concrete, glass, or stone products	3.1	3.4	3.9	4.5	5.1	6.0
Transportation equipment	2.5	2.5	2.3	2.3	2.5	2.8
State Total	**116.3**	**122.2**	**131.9**	**145.7**	**161.9**	**183.0**

Source: WSDOT State Rail and Marine Office - Analysis and forecast based on FHWA Freight Analysis Framework Data and 2007 Surface Transportation Board Waybill data.

2009 Marine Cargo Forecast

In 2009 the WPPA and WSDOT jointly conducted a 5-year update of the *2004 Marine Cargo Forecast*. These two organizations have been providing joint cargo forecasts since 1985. The purpose is to assess the expected flow of waterborne cargo through the state port system and to evaluate the distribution of cargo through the rest of the state's transportation network. The current report is a 20-year forecast of trade (2008 to 2030) moving through the state by water, rail, roads, and current capacity of transportation infrastructure.

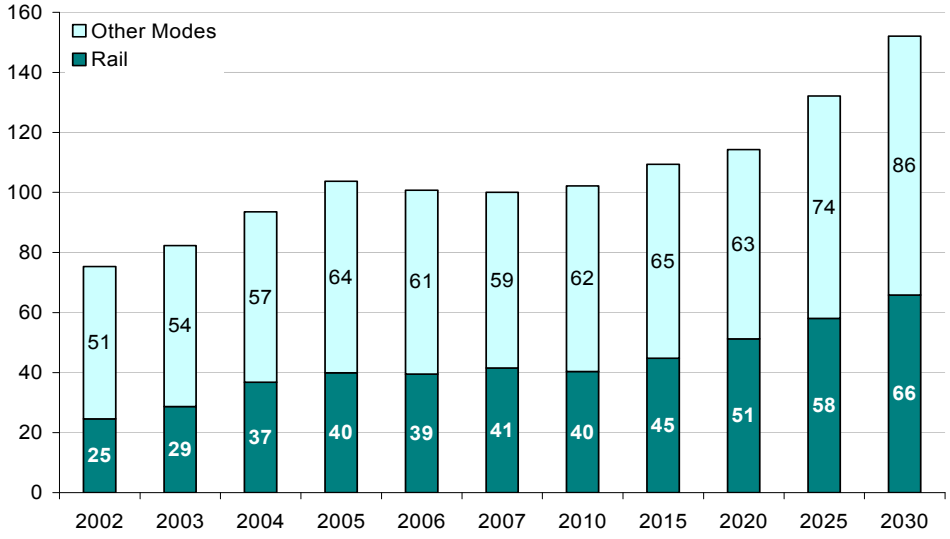
The Marine Cargo study found that rail freight is likely to play an increasingly important role in marine cargo movement. As Exhibit 4-23 and Exhibit 4-24 demonstrate, rail freight demand is expected to account for a larger share of marine cargo movement in the future, due to a higher growth rate than other modes over the forecast period.

Three factors drive increased marine cargo growth. First, U.S. consumption increases as population and living standards increase.

Second, economic globalization makes countries more specialized in production to achieve efficiency. As a result of this globalization, exports and imports increase. Last, containerization of the transportation industry generates more intermodal traffic that demands rail services.

However, the recent economic recession is likely to have impacts on long-term growth potential. Forecast results presented in this section, which did not include the data of this severe recession, are likely to be optimistic. This plan will be updated as the new data and forecast results become available.

Exhibit 4-23: Marine Cargo Trends – Rail vs. Other Modes 2002 to 2030 (Million Tons)

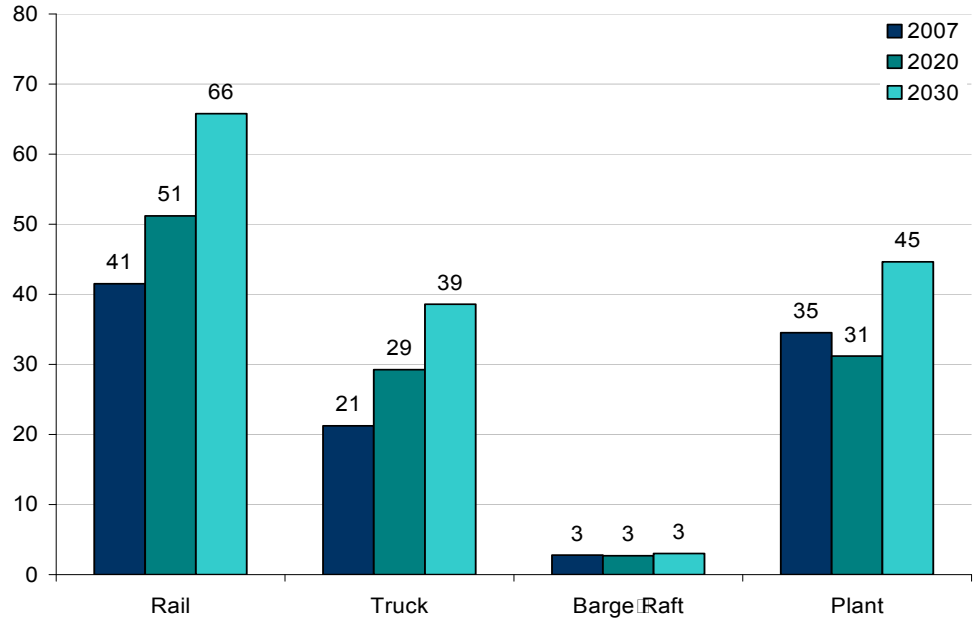


Source: 2009 WPPA–WSDOT Marine Cargo Forecast

Findings identified by the 2009 Marine Cargo Forecast are as follows:

- State public ports have experienced strong and steady growth during the past quarter of a century. State ports have experienced the following increases over the last 16 years:
  - Almost all cargo types have shown substantial gains, with the exception of timber.
  - Cargo volumes at deep water ports have tripled.
  - Containerized cargo has increased 500 percent.
- The study suggests that strong growth can be anticipated into the future. The state's waterborne commerce is expected to grow at slightly less than 2 percent per year through 2030. Growth is anticipated within all cargo categories, although it will vary by commodity type.

Exhibit 4-24: Marine Cargo Port Modal Distribution
Washington State 2007, 2020, and 2030 (Million Tons)



Source: 2009 WPPA WSDOT Marine Cargo Forecast

Highlights of the forecast include the following:

- **Containers are projected to continue to be the fastest growing cargo type.** State ports can expect continued competition, but the growth opportunities are projected to remain positive for the next 20 years. Container traffic grew from nearly 2.9 million TEUs in 2002 to nearly 3.9 million TEUs in 2007. Puget Sound containerized trade is projected to grow by an average of 4.1 percent per year in the forecast period, reaching 9.7 million TEUs in 2030, given the three drivers (population growth, globalization, and containerization) explained in the previous section.
- **Auto imports will experience rapid growth.** Auto imports are expected to more than double from 690,000 units in 2007 to approximately 1.5 million units in 2030. Competitive rail service will be essential to meeting this demand, as three quarters of auto imports currently move to inland locations by rail.
- **Log exports will level off.** After decades of decline, log exports are expected to level off and remain flat through the forecast period. The loss of log exports has affected many ports, which have responded with successful diversification programs. Many have found niche opportunities, such as importing wind energy equipment.

- **Break-bulk cargo volumes will grow slowly.**[17] Metal, forest products, and other break-bulk cargo will grow slowly due to containerization and structural changes in the industries that produce these cargoes. Much of the expansion will occur as ports diversify. As a result, break-bulk traffic through state ports is projected to grow from 2.3 million metric tons in 2007 to around 3.0 million metric tons in 2030.
- **Grain shipments will expand moderately.** After increasing substantially in recent years, grain shipments are likely to grow modestly in the face of significant domestic and international competition, maximum yields per acre, and maximum acres in production.
- **Dry bulk trends will continue.** Some stalwart cargoes (such as bauxite) have decreased while others (such as petroleum coke) have increased. These trends will continue.
- **Liquid bulk will shift from domestic to foreign.** Both crude oil and petroleum product imports will shift from domestic to foreign sources as Alaskan production tapers off.

Update on National Trends

The demand for freight rail services will grow because the rail freight is driven by three factors (population growth, globalization, and containerization). Assuming moderate rates of economic growth, the tonnage of freight moved in the U.S. is likely to increase three quarters in 30 years (2006 to 2035) (Exhibit 4-25). This rate of growth is about the same as the last 20 years and roughly tracks growth in the U.S. Gross Domestic Product. The following section first looks at the projected growth in the demand for freight traffic (both total and for rail) and then discusses the rail industry response to this demand growth.

The growth in freight tonnage is expected to continue at 2.5 percent to 3 percent per year at least through 2035. The demand for freight rail services is projected to increase by a total of 73 percent based on tons through 2035, assuming continued investment in the rail system to handle growth. Despite this, the rail share of national freight shipments is shrinking slightly. By 2035 rail's share of total freight tonnage is expected to decline from 9.7 percent to 9.5 percent, and rail's share of value could decline from 2.9 percent to 2.8 percent. Exhibit 4-26 shows freight modal distribution in 2006 and 2035.

[17] Break-bulk cargo is cargo that is too big or too heavy to fit into a container or traditionally cannot be vacuumed out of a ship.

Exhibit 4-25: U.S. Shipments by Mode □ 2006 and 2035 (Millions of Tons)

Mode	2006				2035			
	Total	Domestic	Exports[3]	Imports[3]	Total	Domestic	Exports[3]	Imports[3]
Total	20,974	18,985	620	1,369	(R) 37,212	33,668	(R) 1,112	(R) 2,432
Truck	12,659	12,389	169	101	22,814	22,231	262	320
Rail	2,040	1,905	41	95	3,525	3,292	57	176
Water	688	582	48	58	1,041	874	114	54
Air, air □ truck	15	5	4	6	(R) 61	10	(R) 13	(R) 38
Intermodal[1]	1,503	194	353	956	2,598	334	660	1,604
Pipeline □ unknown[2]	4,068	3,909	6	153	7,172	6,926	5	240

[1] Intermodal includes U.S. Postal Service and courier shipments and all intermodal combinations, except air and truck.

[2] Pipeline and unknown shipments are combined because data on region-to-region flows by pipeline are statistically uncertain.

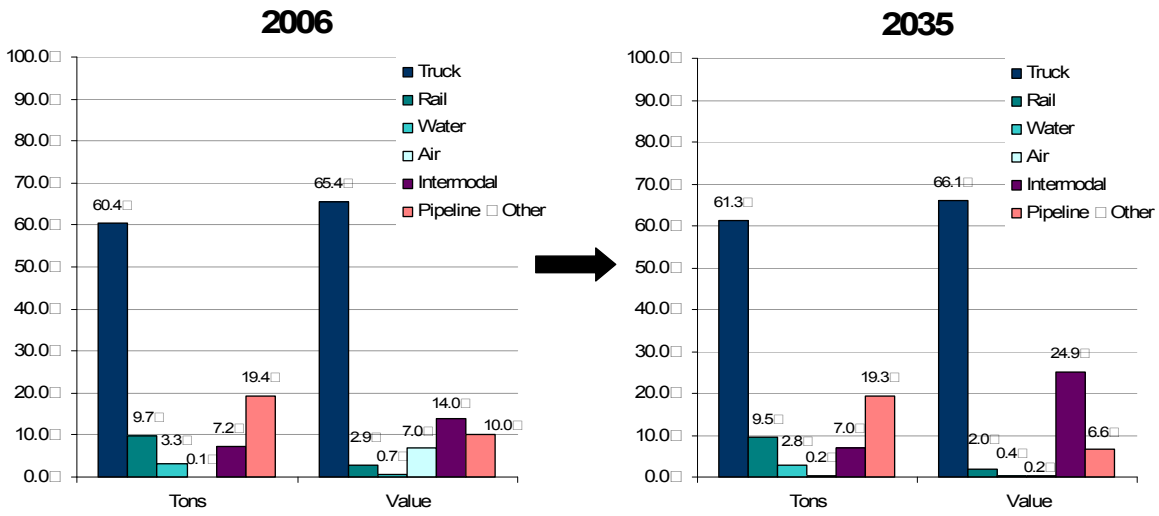
[3] Data do not include imports and exports that pass through the U.S. from a foreign origin to a foreign destination by any mode.

(R) Revised

Note: Numbers may not add to total due to rounding.

Source: USDOT, FHWA, Office of Freight Management and Operations, FAF, Version 2.2, 2007

Exhibit 4-26: U.S. Freight Tons and Value by Mode, 2006 and 2035



Source: USDOT FHWA, FAF, 2007

Rail market share is also shrinking in part because of structural changes in the economy. The U.S. is producing and shipping more value-added products and fewer heavy manufactured goods. Freight shipments are

lighter, less bulky, and higher in value, making them better suited to highway container transport or truck than rail. This trend is expected to continue, with the value per ton going up over the next decade, suggesting more growth in high-value commodities than low-value commodities and more demand for trucking services.

Rail market share also may be shrinking because of the slow pace of rail investment. The industry is purposefully operating near capacity because of its capital intensity, and it is using demand management as well as investment to respond to traffic volumes. This means that some customers are not well served by the market. Railroads, like all private industry, will continue to make capital decisions based on private financial returns, and public benefits will be just an incidental part of the decision unless public capital plays a role. Demand for rail transportation is driven by the commodity markets it serves, as well as by carrier performance. Almost three-quarters of the current national rail tonnage and revenue come from four market groups: coal, farm and food products, chemicals and petroleum, and the intermodal business (listing them in order of tonnage size). Some 40 percent of the physical volume is in coal alone, but the revenue picture is different and more balanced: intermodal and coal each comprise about 20 percent of the revenue (with intermodal somewhat the larger), while the farm and food group and the chemicals and petroleum group comprise about 15 percent each. Roughly 60 percent of all new rail tonnage is attributable to coal and intermodal, and although the top four markets remain the same, by 2035 intermodal should be second only to coal in terms of physical volume, and will be substantially the most important source of rail revenue. The intermodal business is projected to maintain a 3.8 percent compound annual growth rate over the next three decades, causing it to more than triple in size, primarily because of its role in carrying containerized imports for the globalizing economy. Traffic in transportation equipment will also grow at an above-average pace, expanding by 2.6 percent per year and more than doubling in volume by 2035. This business is chiefly automotive products.

Bulk services are dedicated unit trains hauling a single bulk commodity, such as coal or grain. Intermodal services, as defined by the rail industry, are trains hauling international and domestic containers and trailers. All other rail freight, such as chemicals, forest products, and automobiles, move as general merchandise. The long-term prospects of national growth for selected rail commodities through the year 2035 are:[18]

- **Coal** – Rail should remain its primary mode of transport, with a 62 percent cumulative growth in national rail tonnage by 2035.

[18] Forecasts developed by Global Insight and obtained from the AASHTO Freight Demand and Logistic Bottom Line Report (Draft), 2006

- **Farm and Food Products** – Modest growth of slightly less than 1 percent per year, with cumulative growth in 2035 projected to be 21 percent larger than today.
- **Chemical and Petroleum** – Slow growth of less than 1 percent per year and accumulating to a 27 percent increase by 2035.
- **Lumber and Forest Products** – Slow growth around or just above 1 percent per year, and a total increase in rail shipments of 40 percent to 49 percent by 2035.
- **Transportation Equipment** (Automobiles) – Solid growth of 123 percent in tonnage through 2035.
- **Intermodal** – Prospects for rail intermodal business are robust, with tonnage volumes rising 213 percent by 2035.

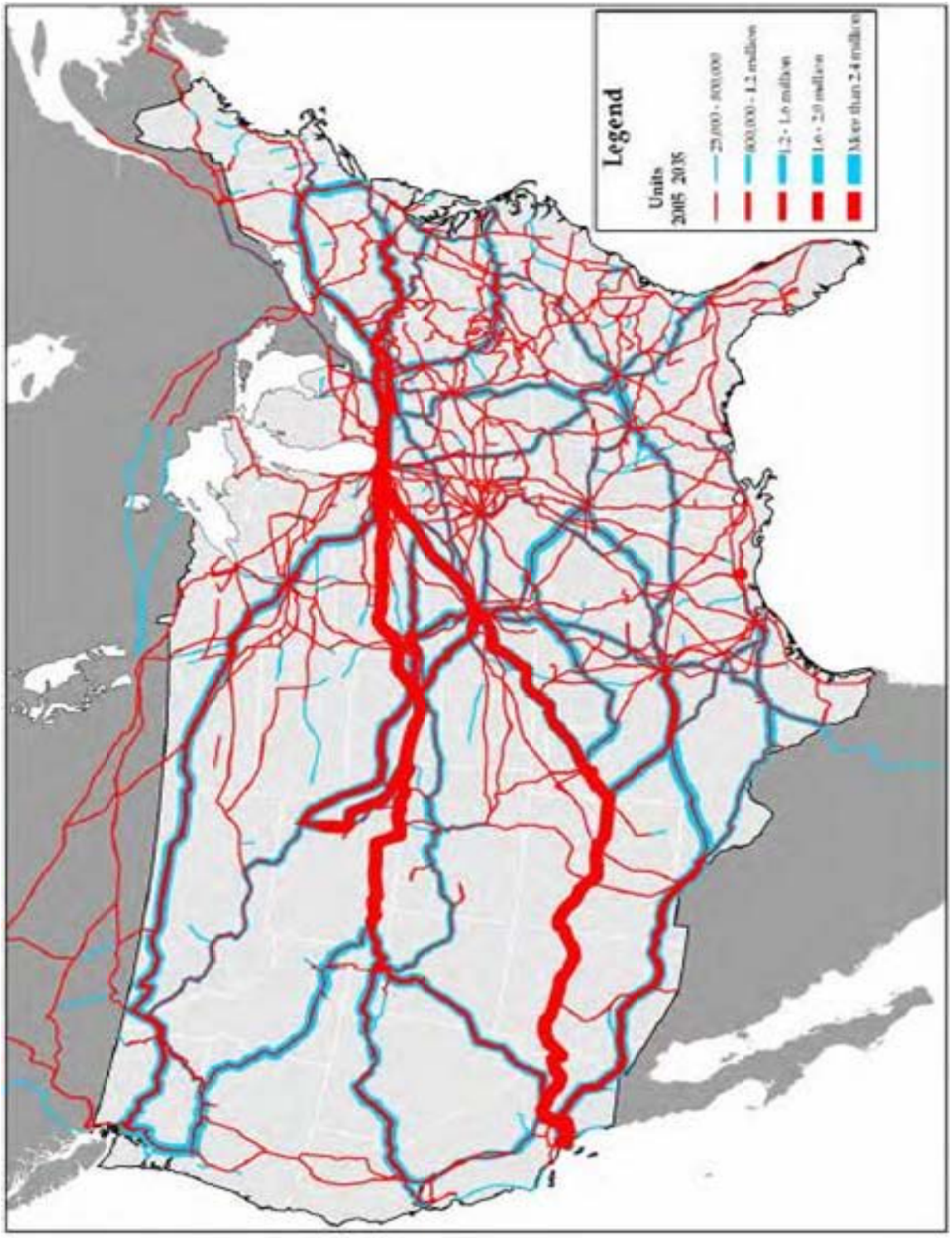
Exhibit 4-27 demonstrates the projected growth demand for rail in the U.S. between 2005 and 2035. More capacity will have to be developed in the rail network in this state. This topic will further be explored in Chapter 5.

Impacts of Freight Rail on Society

All transportation modes (motor vehicles, rail, air, barge, and so on) produce externalities—unintended consequences or indirect effects that are created by some activity. The costs associated with these externalities are not directly charged to any specific individual, but are borne by society as a whole. The negative health impacts associated with air pollution are a classic example of such an externality. Although travel by air, car, or rail creates air pollution impacts, riders, in general, are not charged for their contribution to decreasing air quality. How are these externalities assessed to society? This can be explained by a classic theory in benefit/cost analysis or project investment analysis—with or without analysis—as shown in Exhibit 4-28.

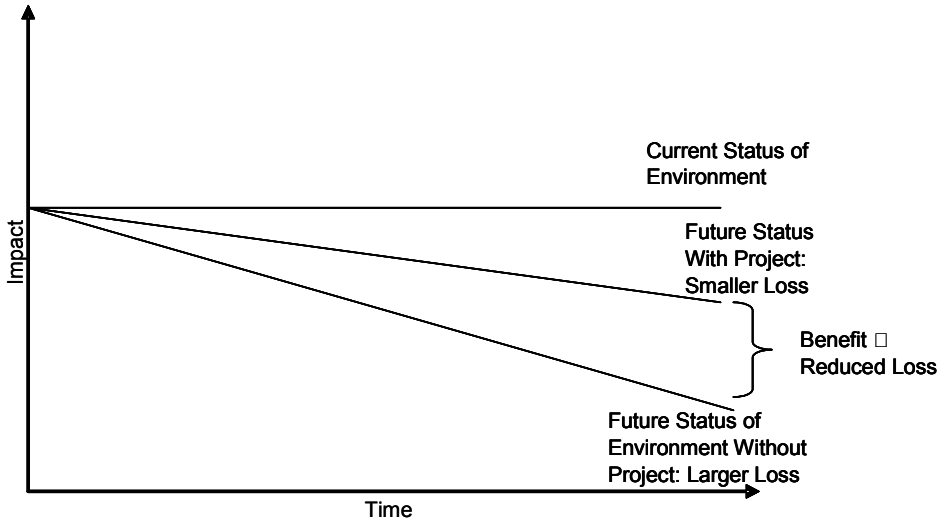
As the chart shows, pollution is likely to increase over time because of current practices. With a project that could lead to less pollution created, society gets benefits by having fewer negative impacts. The reduction in cost of loss would be the benefits of the project invested. This principle applies to freight rail investment. In general, rail has less negative impacts on society. Since rail generates fewer emissions per ton-mile, using rail as an option to ship heavy goods helps reduce pollution. This emission reduction would be the benefit of investment in freight rail.

Exhibit 4-27: Comparison of Total Rail Flow Railcars per Year □ 2005 and 2035



Source: AASHTO Freight Demand and Logistic Bottom Line Report (Draft), 2006

Exhibit 4-28: Principle of With Without Analysis



There are multiple benefits associated with freight rail. The magnitude of benefits received by the people of this state depends on how freight rail will be integrated into the policies. These policies should embrace integrated solutions for interconnected problems. In general freight rail has been identified by many studies to have four categories of societal impacts: transportation benefits; economic impacts; safety, energy, and environmental impacts; and land use impacts.

Transportation Benefits

Low Shipping Costs

Rail provides shippers of heavy materials or large volumes of materials with a transportation option that can be significantly cost effective. Depending on the density of the commodity, one railcar may move the same weight or volume as four or five trucks. For such shippers, rail is usually the low-cost option, and rail rates have been dropping. On average, it costs 29 percent less to move freight by rail today than in 1981, adjusted for inflation. The associated cost savings (in the billions of dollars annually) are vital to the viability of these businesses. The availability of rail service can be an important factor for states and municipalities interested in retaining and attracting these types of businesses. Availability of freight rail can improve the competitiveness of our economy by reducing overall shipping costs.

Intermodal Connectivity and International Trade

Freight-rail service provides a critical link in the nation's intermodal freight transportation system, serving the trucking and maritime shipping industries, and supporting the nation's international trade and global competitiveness. The rail and trucking industries are competitors, but they are also partners. Unless a rail move is "door-to-door," it begins or ends

with a truck move. This could involve the transfer of an intermodal container or the transfer of bulk and carload commodities via transload or transflow operations. Rail and trucking companies are partnering to provide integrated door-to-door intermodal services that optimize the relative strengths and efficiencies of each mode.

Congestion Relief

As the economy and population continue to grow, freeway traffic congestion problems, particularly in the I-5 corridor, will increase. Freight rail can help share some incremental demand, which otherwise would be picked up by trucks. However, the substitutability between highway freight and rail freight is limited. The potential of freight rail as part of the solution for congestion needs further examination.

Transportation Choice

Freight rail provides shippers another transportation option, especially for long-distance and intermodal shipping.

Economic Benefits

Supports Local Communities

Freight rail construction projects bring jobs and revenue to local communities and businesses.

Supports Economic Viability

Freight rail that serves an underserved market can help maintain economic viability of local economies.

Generates Tax Revenues for Public Programs

Rail supports growth of many businesses in various industries that pay business taxes to governments.

Safety, Energy, and Environmental Benefits

Public Safety

Rail transportation has a strong safety record with a lower national accident fatality rate. Freight rail provides an option for policymakers who would like to improve public safety.[19]

Energy Benefit

Freight rail is much more efficient than airplanes and motor vehicles in terms of energy use per ton hauled. Increasing rail capacity will reduce

[19] Government statistics show that freight rail is safer in terms of both fatality and injuries. See Texas Transportation Institute: A Modal comparison of domestic freight transportation effects on the general public. 2007.

the growth of other energy-inefficient modes and help tackle the energy dependence problems.

Pollution Reduction

Emission reduction is an important environmental issue facing transportation operators. The environment plays a fundamental role in determining quality of life and economic well-being for state citizens. The level of released toxic substances and greenhouse gas emissions for freight rail is low.[20] Increasing the use of rail for long-haul freight is an option that would help reduce environmental pollution.

Land Use and Community Impacts

Rail helps reduce land use impacts because it uses less right of way than highway for the same carrying capacity. It also requires less land for yards than the trucking industry based on per ton-mile freight. Rail also releases fewer harmful substances into the environment.

State land use planning authority primarily resides within local government. WSDOT, local governments, and regional governments have a shared responsibility to enhance the quality of life and economic vitality for all state residents while providing a safe and efficient transportation network. Because land use decisions and patterns of land development can significantly influence the safety and efficiency of the transportation system, local government land use decisions, both individually and collectively, are matters of critical importance to WSDOT and freight owners. The Growth Management Act, the Shorelines Management Act, and the State Environmental Policy Act provide WSDOT with opportunities to coordinate and communicate with local governments as they draft plans and regulations that may affect the state transportation system. These acts ensure the needs of both the communities and the freight owners are met.

[20] AASHTO: Railroads provide significant environmental benefits. The U.S. Environmental Protection Agency estimates that for every ton-mile, a typical truck emits roughly three times more nitrogen oxides and particulates than a locomotive. Related studies suggest that trucks emit six to 12 times more pollutants per ton-mile than do railroads, depending on the pollutant measured. According to the American Society of Mechanical Engineers, 2.5 million fewer tons of carbon dioxide would be emitted into the air annually if 10 percent of intercity freight now moving by highway were shifted to rail.

Washington State Department of Transportation

Chapter 5: The Changing Rail System – Issue Discussion and Needs Assessment

Overview of Issues and Needs Assessment

This section presents short- and long-term freight rail needs in Washington State (state). The assessment is based on data provided directly by the state's freight railroads, ports, public agencies, and other key stakeholders. In total, this needs assessment identifies 109 short- and long-term capital improvement projects and other initiatives. Several freight rail needs have been included in this total, even though they have not progressed to the point of having full solutions and cost estimates. The total cost for the projects, where cost estimates are available, is $2.0 billion.[1]

Key Issues

The key issues addressed in this section are rail system needs, abandonment, port access and competitive needs of the ports, intermodal connectors, and emerging issues and data needs. Each of these topics is described in detail in this chapter.

Purpose of the Needs Assessment

The primary purpose of the needs assessment is to develop a reasonably comprehensive list of necessary or desired freight rail improvements. This list will allow the Washington State Department of Transportation (WSDOT) to gauge the condition of the system and assess potential public involvement. Railroad needs, for the purposes of this rail plan, are restricted to capital needs and do not include operating expenses or subsidies. A need for this plan is defined as a need regardless of whether it is privately- or publicly-funded or remains unfunded. Thus, the needs included in this assessment should be considered "unconstrained" needs and not a funding commitment.

WSDOT will review and evaluate these needs when determining appropriate levels of public support for a project. Inclusion of a need in the *Washington State 2010-2030 Freight Rail Plan* does not constitute a commitment on the part of WSDOT or the state to provide funding. As comprehensive as this plan attempts to be, it must be noted that this document does not include all freight rail needs.

[1] Twenty-one projects did not report a cost for their project.

The freight railroads are private, for-profit businesses and in some cases did not submit all their capital needs for inclusion in this public document. This is especially true in cases where private capital is available to fully fund planned improvements. Traditionally, railroads are less likely to submit projects where the railroads believe that public involvement in specific projects is less likely or where disclosure of a need could adversely affect their strategic business ventures. Therefore, the needs that are listed in this section are only those projects that have been specifically submitted for inclusion in this list of projects.

Methodology

WSDOT compiled a list of needs for the state's freight rail system from prior studies, a survey, and a set of interviews and reviews with key stakeholders. Specifically, the freight railroads, the ports, and other stakeholders were engaged in this effort. The needs range from well developed plans that have been through a full planning and design process, to new concepts, to a wish list of projects. This is why not all projects have full information in the list contained in Appendix 8-A. The only restrictions on the needs submitted for inclusion in the list were:

- The needs focus on freight rail projects, since passenger rail needs continue to be identified in other studies. Although some passenger rail needs were included, especially when they also impact freight operations, this list should not be considered a comprehensive list of passenger rail needs.
- The needs focus on projects that improve the movement of rail freight. For example, improvement of a road-rail grade crossing to help mitigate highway congestion is not a freight rail need; it is generally classified as a safety issue.
- The needs focus on capital improvements, and do not include operating expenses for the freight railroads. The freight rail system is dynamic and driven by customer demands and trends.

Therefore, needs continually change. The needs in this plan are current through October 2009, and were assembled with the procedure outlined in Exhibit 5-1 below.

Exhibit 5-1: Procedure for Collecting Freight Rail Needs

Timeframe	Activity
June 2009	Held initial stakeholder meeting.
August 2009	Requested railroads, ports, and other stakeholders fill out survey of needs.
September 2009	Conducted initial in-person interviews with some of the railroads and ports.
October 2009	Reviewed the list of needs for duplicates and incomplete information. Followed up with reminder telephone calls and clarified any questions.
November 2009	Sent out to the railroads, ports, and stakeholders for final review, and conducted final round of follow-up questions as necessary.

Rail Abandonments: Recent, Proposed, and At-Risk Lines

Abandoned Rail Lines

Current Abandoned Lines

Exhibit 5-2 shows the abandoned rail lines 1998 and before, and the current abandoned rail lines (1999 to 2009) in the state.

As of the *Washington State Freight Rail Plan 1998 Update*, there had been a total of 1,975 miles of rail lines (132 segments) abandoned from 1953 to 1998. Since 1998 there has been an additional 70.23 miles abandoned. A list of abandonments from 1953 to 2009 can be found in Appendix 5-A.

This state has one of the best state rail preservation and development programs in the country. The state has invested $99 million in its rail freight infrastructure since 1980. An additional $35 million in investment is anticipated from 2010 to 2012 (see Exhibit 5-3).

These investments include the Freight Rail Assistance Program ($6 million 2007-2011) and Freight Rail Investment Bank Program (Rail Bank) loans. The Rail Bank has $7.5 million in funding available from 2007-2011, with a maximum loan of $250,000. All of these investments have been in regional and small railroads, in recognition of the fact that these railroads are a vital component of the state's transportation system and economic well-being.

Exhibit 5-2: Abandoned Rail Lines

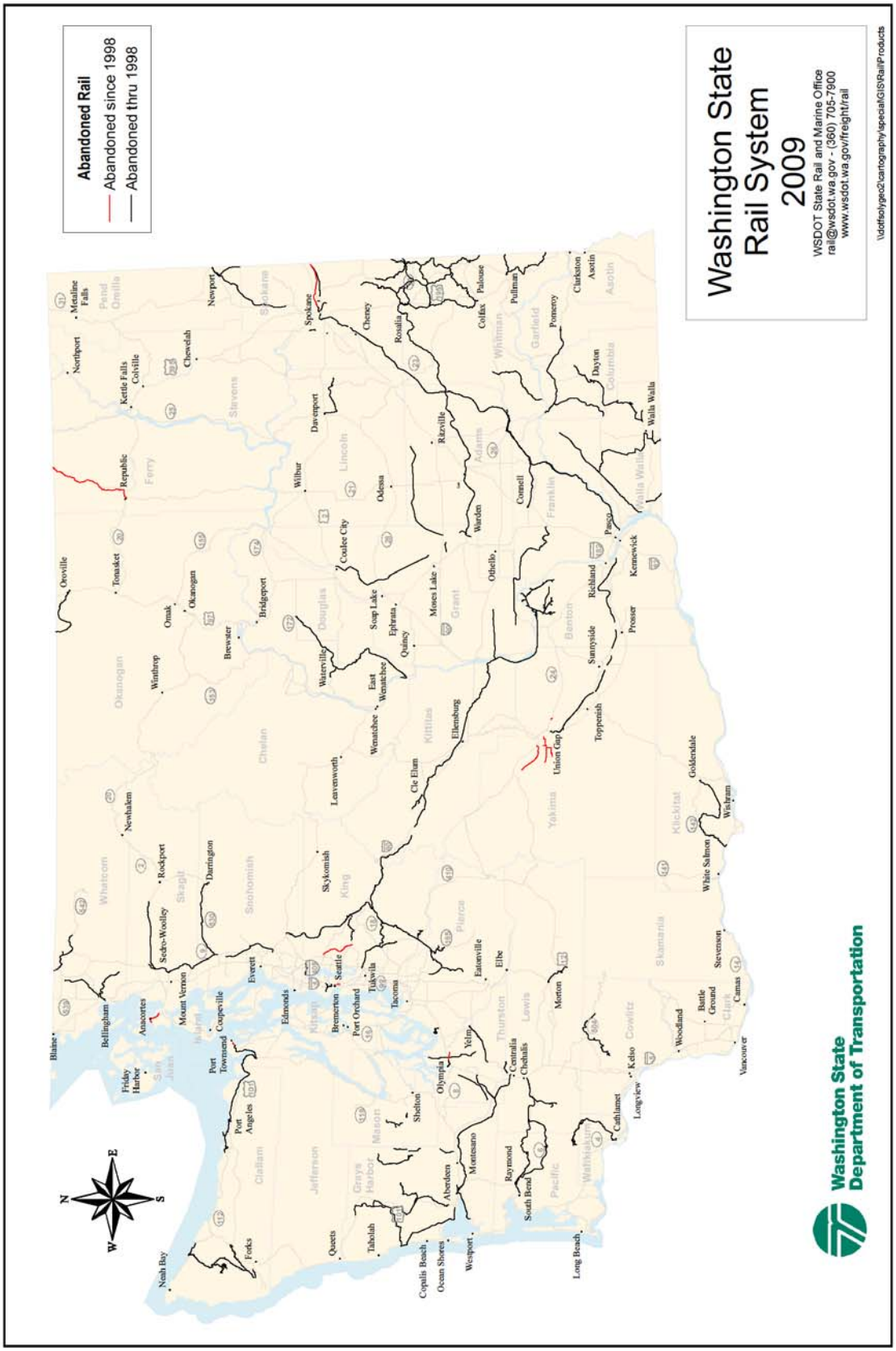
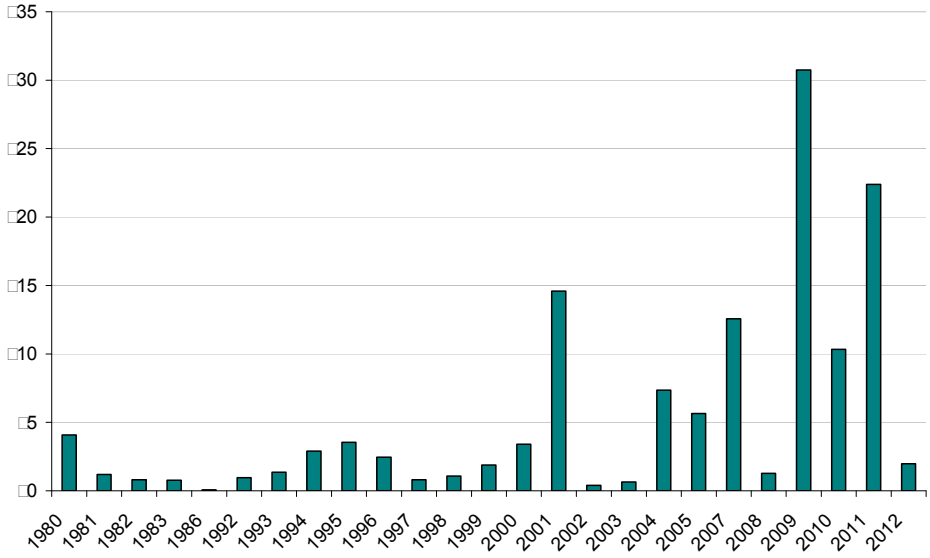


Exhibit 5-3: Washington Rail Investments (□ Millions)



Source: WSDOT State Rail and Marine Office

Rail abandonments have been widespread in the United States (U.S.) since the passage of the national railroad reform legislation, ending most federal regulation of railroads, over 20 years ago. Given a greater opportunity to control costs and generate revenues, Class I railroads sold, abandoned, or leased their less profitable lines. This proved to be an opportunity for others; a great many short-line railroads were formed to operate lines divested by Class I railroads. In other cases, rail lines were abandoned and the real estate was used for other purposes.

The state's rail abandonment program is assisted by the federal government through the Local Rail Freight Assistance program. The state has been one of several states that has worked to preserve rail infrastructure. This program has preserved and developed rail lines that would otherwise have been abandoned. This has been very important in meeting present and future transportation needs.

Many of the short lines around the nation and in the state were created from branch or light density lines of the larger Class I railroads. These lines were either abandoned or sold by the Class I railroads during their industry restructuring of the 1980s and 1990s. Most of the lines sold through the abandonment process by Class I railroads were in poor[2] physical condition at the time of abandonment. Many of these branch lines have sections of lighter rail than is necessary for today's new railcar load limits and weight-restricted bridges.

[2] Poor physical condition is track that is in disrepair from wear and tear or has deteriorated due to lack of maintenance.

As illustrated in Exhibit 3-5 in Chapter 3, there are 19 active short-line railroads operating in the state. The majority of these railroads operate on light density lines that were divested by the Class I (mainline) railroads. They are located throughout the state and play a critical role in moving a wide variety of products, including agricultural products, frozen foods, lumber, gravel, and petroleum products. Often locally-owned and operated, many short-line railroads in the state keep hundreds of small businesses and communities connected to the national mainline rail system.

Many of these branch lines were sold by the Class I railroads because they could not make a profit operating these light density lines. Nearly every short-line railroad began its existence with track that had received little investment under previous owners. Whether they are municipally or privately held, many short lines are in need of infrastructure funding for rehabilitation or improvement.

These existing lines present an opportunity to the state. In many cases, improvements for the state's short lines involve upgrades to existing infrastructure, rather than capacity expansion projects that involve more significant environmental issues. They should therefore be able to move more readily from planning to construction. A review of the most recent WSDOT short-line funding proposals indicates that most of these projects involve improvements to existing infrastructure. In many cases these improvements involve increasing track capacity maximums from 263,000 pounds per car to 286,000 pounds per car to meet Class I railroad requirements. Upgrading track to handle the heavier cars may make economic sense, if it results in an increase in the amount of traffic on a line. However, if cargo volumes remain the same, but the number of carloads decreases due to the heavier loading, the benefit is less clear. This is especially the case if the contract between the short-line operator and the Class I railroad is on a per-car basis, in which case the reduced number of cars would result in reduced revenue. Some short lines are more successful than others, and the viability of each depends on its own particular circumstances. Those short lines that have faced ongoing problems with cash flow and capital for infrastructure improvements are the ones most at risk. WSDOT has been able to assist many of the short lines with project funding, but these infrastructure investments may not be sufficient to make each short line economically viable. However, even if lines are marginal, there may be a compelling state interest in supporting these lines in order to reduce truck traffic or to maintain jobs, among other reasons that serve the public interest.

To determine future potential abandonments, the WSDOT State Rail and Marine Office surveyed the rail industry with the results below in Exhibit 5-4. The exhibit shows the results of the survey taken in summer

2009, which reported that there are four potential future abandonments and one anticipated re-opening.

Exhibit 5-4: Abandonment Survey List – Likely Abandonments

Submitted by	Railroad Owner	Railroad Operator	Location
Port of Grays Harbor	PSAP	PSAP	West of Hoquiam River
Port of Othello	State of WA – Columbia Basin RR	Closed	Reopen Milwaukee Line
Port of Seattle	BNSF	BNSF	Eastside Line: Woodinville–Renton and Woodinville–Redmond
Union Pacific	UP	None	Yakima Industrial Lead, MP 57.3 to MP 58.75
Union Pacific	UP	None	Yakima Industrial Lead, MP 62.75 to MP 63.55

Projection of Future Abandonments and Their Impacts, Capacity, and Needs Forecasts

When a rail line is abandoned, it is critical that the integrity of the right of way be maintained. If an abandoned line ends up parceled off piece by piece, it would be extremely difficult, if not impossible, to reconstruct the line for a future transportation use. Given the limited opportunity to expand the highway system, an abandoned railroad right of way represents an extremely valuable transportation resource.

As a result of the decrease in route miles, many of the state's communities no longer have access to rail service. To counter that trend and support economic development initiatives of the state, the WSDOT State Rail and Marine Office has implemented a rail line preservation initiative to retain the potential of rail service along these abandoned routes.

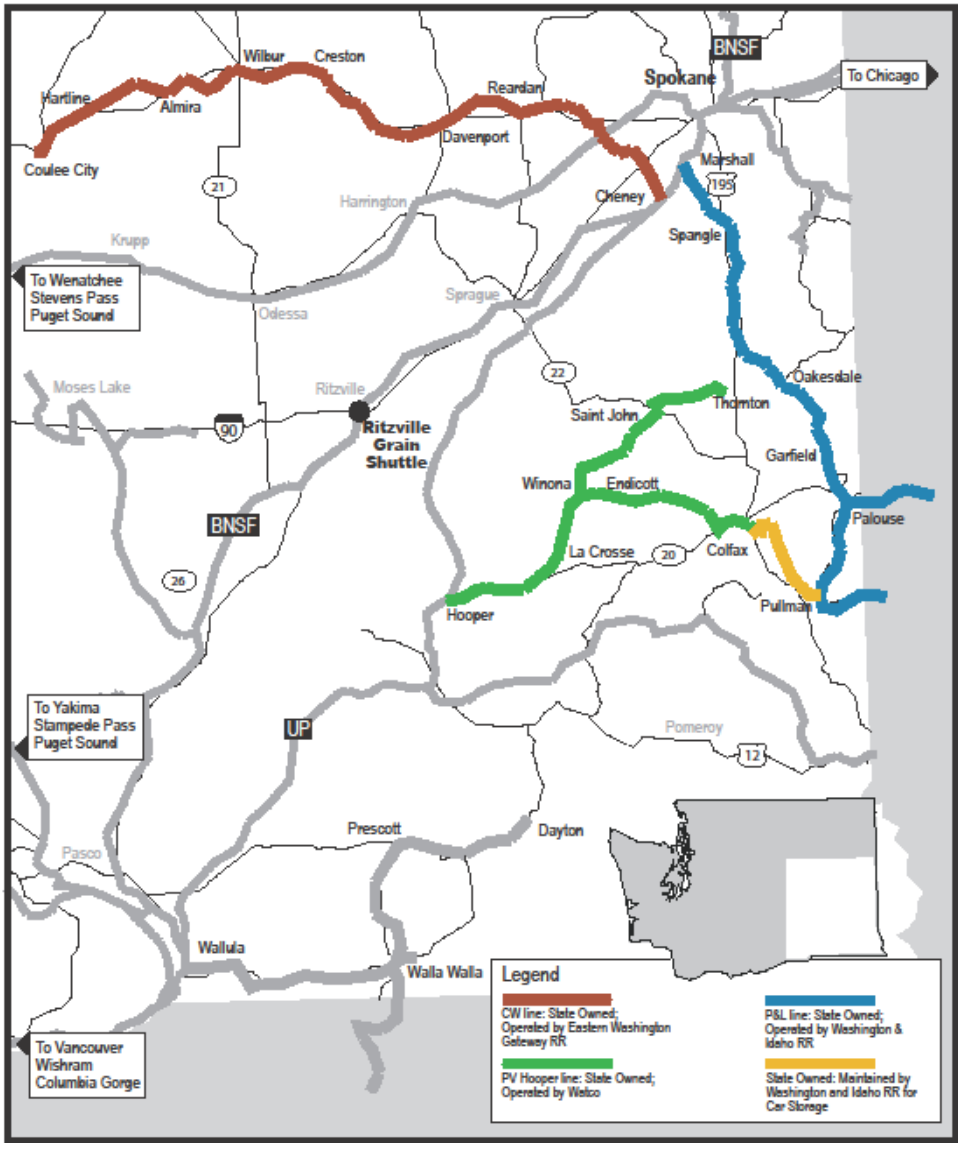
Examples of Successes

Purchase of the Palouse River and Coulee City Rail System

The state currently owns the former Palouse River and Coulee City Rail System, which consists of three branches (see Exhibit 5-5). WSDOT purchased the rights of way and rail on the P&L Branch and PV Hooper Branch of the rail system in November 2004. WSDOT purchased the CW Branch and the remaining rights in the other two branches in May 2007.

WSDOT contracted with private railroads to operate each of the branches. The Palouse River and Coulee City Railroad operates the PV Hooper Branch; the Eastern Washington Gateway Railroad operates the CW Branch; and the Washington and Idaho Railway operates the P&L Branch.

Exhibit 5-5: Palouse River and Coulee City Rail System



WSDOT oversees the facilities and regulatory portions of the operating leases. The Palouse River and Coulee City Rail Authority (an intergovernmental entity formed by Grant, Lincoln, Spokane, and Whitman Counties) oversees the business and economic development portions of the operating leases.

The Palouse River and Coulee City Rail System currently provides local rail service to grain shippers and other businesses in Whitman, Lincoln,

Grant, and Spokane Counties. The three lines require rehabilitation to remain commercially viable.

Public ownership of the Palouse River and Coulee City Rail System capital assets provides an opportunity for private operators to provide economically viable rail service to shippers along the lines. Rehabilitation is needed to correct the effects of decades of deferred maintenance. Many places along the lines must be operated at a speed lower than would be allowed if the lines had been properly maintained on an ongoing basis. Rehabilitation will prevent further deterioration, help raise operating speeds in some locations, and make the operation of the lines more efficient and commercially viable.

Rail Banking

Rail banking is used by the state when the state has an interest in retaining rail lines that have been abandoned, should they become economically viable at a future date. If it appears that a line could become economically viable within ten years, the line may be rail banked or purchased by the state to prevent its loss as a rail corridor. A rail banked line may be used as a trail on an interim basis. Maintenance or other changes on a rail banked line used as a trail must preserve the ability to use the line as a railroad in the future.

A good example of this is the Milwaukee Road Corridor (Milwaukee Road). In the 1980s, the state acquired the abandoned Milwaukee Road and, through legislation, gave much of the line to the Washington State Parks and the Department of Natural Resources. Both segments are managed by their respected departments as a recreation trail. Washington State Parks created a trail along the railbed with their part of the line. It is now known as part of the John Wayne Trail. In its heyday, the Milwaukee Road was a vital trade link between Seattle and the Midwest and was the world's longest electric rail line at the time. The railroad bed follows I-90 across Snoqualmie Pass. The 100-mile portion from Cedar Falls (near North Bend) to the Columbia River near Vantage has had the tracks removed and the area has been turned into a state park, known as Iron Horse State Park. On average, the trail is about a half mile from the highway and about 300 feet higher. The trail follows the former railbed of the Chicago, Milwaukee, St. Paul, and Pacific Railroad two-thirds of the way across the state. The gravel pathway offers hikers, bicyclists, equestrians, and cross-country skiers a chance to travel along the historic Milwaukee Road right of way on a gentle, easy-to-negotiate grade. In 2006 WSDOT was given the authority to enter into a franchise agreement for a rail line over the portions of the Milwaukee Road between Ellensburg and Lind by July 1, 2019.[3]

[3] RCW 79A.05.120.

Port Access

Port access to rail service is very important to the vitality of the ports in the state. As economic development agencies, ports are a fundamental part of the state's economy. State ports face substantial competition from other ports and shipping routes. The majority of the cargo that comes through state ports is discretionary cargo (i.e., containers, autos, grain, dry bulks, and break-bulk cargos) that can shift to other gateways, if shipping through these other ports becomes more efficient or cost effective than using state ports. To be competitive, ports must have good rail access. As an added benefit, rail is a community-friendly mode, as it is a safe, energy-efficient way to move goods along major corridors.

Washington State Ports

The state has 75 ports, not all with water access, as shown in Exhibit 5-6. The state has 11 deep-draft ports, a tremendous asset for the state's economy. Seven of these ports are on the Puget Sound. The largest ports, the Ports of Seattle and Tacoma, together comprise the third largest container load center in the nation—behind the load center complexes of Los Angeles/Long Beach and New York/New Jersey. One deep-draft port, the Port of Grays Harbor, is located on the coast; and three are located on the Columbia River. Together, these ports create a seamless network that sends goods to global markets, and imports goods from other countries, bound for in-state stores and other destinations across the U.S.

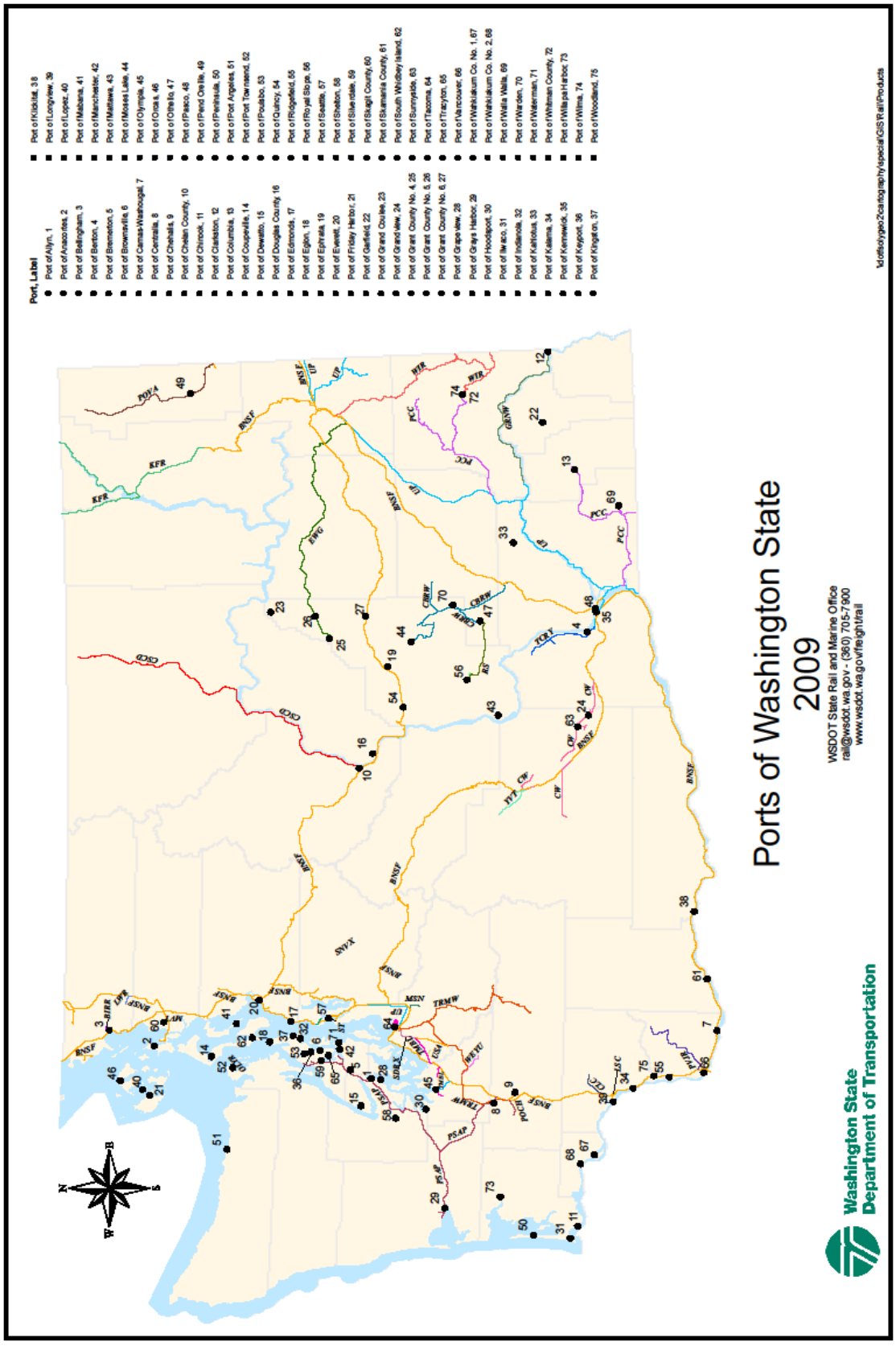
The Columbia/Snake River system stretches 365 miles inland from the Pacific Ocean. The three deep-draft ports along this system—Longview, Kalama, and Vancouver, Washington (WA)—are major shipping centers for the state. Upstream, the Ports of Klickitat, Pasco, Kennewick, and Benton are served by barge along the Columbia River. The Ports of Whitman County, Walla Walla, and Clarkston are served by barge along the Snake River.

Although there are many ways to classify ports in the state, this plan has selected four classifications:

- Intermodal Ports.
- Agricultural and Bulk Ports.
- Rail-Dependent Break-Bulk and Industrial Ports.
- Rail-Serviced Industrial Ports.

The following is a listing of ports by category. It should be noted that some of the larger ports will be listed multiple times depending on their diversity.

Exhibit 5-6: Washington State Ports



Intermodal (Container) Ports Seattle and Tacoma

These ports have on-dock and off-dock intermodal rail yards, where containers are loaded directly from ships to rail, removing the need for truck drayage. The cargo is transported from ship to rail either by truck or yard equipment (in the case of on-dock rail). Unit trains of containers are built by destination and usually depart within 24 hours of ship arrival. The majority of these containers are destined for the Midwest and Upper East Coast regions.

Agricultural and Bulk Ports, (primarily grain elevator facilities) Garfield, Grays Harbor, Longview, Kalama, Seattle, Tacoma, Vancouver (WA), Snake River Elevators: Almota, Clarkston, Lewiston, Walla Walla, Whitman, and Wilma

By tonnage, 36 percent of all state agricultural shipments move by rail. Agricultural rail traffic outbound from this state is expected to grow at a compound annual growth rate of 3.3 percent over the next 20 years. The state also has a growing food products industry with particular strengths in frozen foods (7.3 percent of U.S. output) and wine production.

Agriculture and food product manufacturers are an important economic sector in the state, generating 3 percent of the gross state product and accounting for 6 percent of the employment. Agriculture is the major source of employment in many of the state's rural counties.

However, most of the agricultural tonnage moving on the state rail system is Midwestern grain moving to the Lower Columbia River and Puget Sound ports for export. And because Midwestern grain is moving long distances by unit train, the Midwest grain is generally more profitable for the railroads than local state agricultural shipments, which often are moving shorter distances for export or require specialized handling. Products such as wheat, corn, and soybeans, from the Midwest and eastern Washington, also travel by barge and rail to these Lower Columbia seaports.

The Class I railroads are asking state agricultural shippers to consolidate their shipments at new facilities (such as the Ritzville loader), and this may prove economical for those shippers who can accommodate the changes. These changes may affect the short lines, which could see declines in their market share. There is a concern by the operators of small grain elevators along the short lines, who also stand to lose business. The remaining shippers on that line could also experience reductions in service and increased costs.

The challenge faced by the Department of Agriculture, the Agriculture Commission and the WSDOT State Rail and Marine office is to maintain

competitive rail service as it focuses on higher value-added crops and produce that may not generate the volumes that are attractive to Class I railroads.

Rail-Dependent Break-Bulk and Industrial Ports – Anacortes, Everett, Garfield, Grays Harbor, Kalama, Longview, Olympia, Seattle, Tacoma, and Vancouver (WA)

Break-bulk cargo is too big or too heavy to fit into a container or traditionally cannot be vacuumed out of a ship. There are, however, exceptions, such as "identity preserved" or "designer" bulk grain that is blown into containers for transportation in order to keep the origin of the crop separated from other production sources. Historically, the major commodity groups moved in break-bulk form to and from Pacific Northwest ports have included apples and other fruit, metals, and forest products. Apples were at one time one of the most important break-bulk cargos, but they have essentially become 100 percent containerized. Some cargos that move in break-bulk form can also move in containers (so-called "swing" cargos), and the differences in pricing between the two modes can lead to cargo shifting from one to the other, while others have moved completely to containers. Although a number of factors influence whether swing cargos are shipped in break-bulk or containerized form—such as westbound trans-Pacific container rates, frequency of sailings, and the size of overseas orders—price is probably the most significant factor. Shipping lines have added so much container ship capacity to satisfy demand for U.S. imports from Asia that there has been substantial excess westbound capacity. This resulted in a decrease in westbound container rates, which attracted break-bulk swing cargos. Another general trend impacting break-bulk cargos has been a continuing decline in exports of forest products. This decline has been offset by the increase in imports of metal products.

Here are examples of break-bulk cargos moved by the different ports:

- The Port of Port Angeles serves as a gateway for logs and lumber.
- The Port of Anacortes exports logs, chemicals, and petroleum coke from the Anacortes oil refinery.
- The Port of Bellingham handles break-bulk and liquid-bulk commodities.
- The Port of Everett handles fruit, logs, general break-bulk, and some containers.
- The Port of Olympia specializes in handling break-bulk, ro-ro (roll-on, roll-off), bulk, forest products, and containerized cargos.
- Port of Tacoma break-bulk includes wide and heavy cargos such as farm machinery, large factory/production parts for the Canadian Oil Sands, large motorized vehicles.

- Port of Vancouver, USA handles a large volume of wind energy components and has developed a successful "land bridge" rail strategy for moving these components to the U.S. Midwest and western Canadian destinations in addition to other break bulk commodities.

Rail-Serviced Industrial Ports Benton, Bremerton, Chelan, Clarkston, Columbia, Ephrata, Garfield, Kennewick, Mattawa, Moses Lake, Othello, Pasco, Quincy, Ridgefield, Royal Slope, Shelton, Sunnyside, and Whitman County 3 4

The above-named ports have rail-served industrial property. In many cases these ports do not have water access although, through their economic development capacities, these ports are able to provide land and facilities that are rail-served, enabling the local community to have rail access.

Port access issues are more closely related to location than to type of port. Some of the current access challenges and related projects are summarized below. It should be noted that several of the ports have significant rail projects currently underway or scheduled for the near future.

The Military and Rail

Another area of break-bulk cargo that is sometimes forgotten is the U.S. military cargo that moves through the state annually via multiple break-bulk ports. The growth of the state's bases is due in part to the freight infrastructure system's ability to support the U.S. military's readiness and operational movements.[4] Military facilities in the state are important contributors to the U.S. defense and national security system. This state is home to the largest Army base on the West Coast, two Air Force bases, six critical Navy facilities, and two military medical centers. The military's ability to efficiently move freight in and through the state is dependent on an effectively functioning intermodal freight movement system. Specific freight mobility issues for the military in the state are summarized below.

Puget Sound seaports have a strategic role in support of Fort Lewis as the only Power Projection Platform—for gathering, staging, and mobilizing forces and material—on the West Coast. If a major military conflict were to trigger mobilization activity, inbound cargo needed for that mobilization would travel by road and rail from across the U.S. to Fort Lewis, for shipment through the Port of Tacoma to points outside the country.

[4] Surface Deployment and Distribution Command – Transportation Engineering Agency: 2004. This information is provided to the state for planning purposes.

Under such a scenario, it is expected that the Port of Tacoma would need to handle daily volumes of up to 600 containers, 350 rail cars, and 1,100 wheeled vehicles. This volume could create truck bottlenecks at the Interstate 5 (I-5)/Port of Tacoma Road exit and rail chokepoints at Bullfrog Junction in the Port of Tacoma tideflats.

In 2004 the military also began using the Port of Olympia for shipments out of Fort Lewis. The efficient movement of cargo may be hindered because of needed rail capacity enhancements at the ports. There has been a five-fold increase in the number of rail cars that have passed through the Port of Olympia since 2002. At that time 168 cars came through the Port of Olympia. It increased to 876 in 2004. The return of Army shipments related to the Iraq War accounted for about 17 percent of rail volume. In response, the Port of Olympia spent $1.4 million to add a rail line on its docks closer to where ships berth.[5]

The Port of Seattle also has as a role in supporting overseas military logistics. The Port of Seattle has been designated as a sustainment port, one that will be used to ship consumable supplies to troops in the event of a major overseas conflict. Under this scenario, 300 to 600 containers of supplies could arrive on 100 to 350 rail cars on a typical day, with a peak of up to 1,100 containers per day. Military logistics officials have expressed concern about potential bottlenecks when accessing Terminals 5, 18, and 46 at the intersection of East Marginal Way and South Spokane Street, and the single railroad track access under the Spokane Street Bridge to the Port's terminals. The Port of Seattle is working to solve this problem through an East Marginal Way grade separation.

In addition to the ports named above, there are Ordnance Transport Requirements for Bangor, provided by the state rail system. Ordnance is delivered to the Port Hadlock Naval Ordnance Center via rail car to Bangor on the Hood Canal, and then trucked to Port Hadlock.

Autos and Rail

Fully assembled autos are imported primarily through the Ports of Tacoma and Vancouver (WA). These are discharged from the ports on rail and truck. In order for these ports to keep these auto accounts, reliable rail service is a must; there is also a competitive advantage compared to San Pedro Bay in Los Angeles, California as the Pacific crossing is one day less.

[5] As reported by Szymanski, Jim, *Rail cargo business chugs along at port*. The Olympian. Sunday, February 27, 2005. Retrieved as of February 2005 from: www.theolympian.com/home/news/20050227business/96117.shtml.

Key Needs of Ports

Nearly all of the state's deep-water ports are located adjacent to the I-5 corridor, or are on short-line railroads that branch off the I-5 corridor. As a result, rail connectivity issues for the ports and capacity issues on the I-5 corridor are necessarily tied. Along the corridor there are five main areas where mainline capacity needs and connectivity issues intersect, including:

- Vancouver (WA).
- Kalama to Longview.
- Centralia.
- Tacoma.
- Seattle.

Each of these is examined in more detail in Appendix 5-B.

WSDOT, as the state agency that administers state and federal transportation funds that are spent on rail projects in the state, works closely with port districts to improve freight rail access throughout the state. These rail projects help the state's business community gain better access to rail transportation. As referenced in other areas of this plan, examples of past WSDOT projects include purchases of grain hopper cars, rehabilitation of short lines, purchase of branch lines, and preservation of abandoned rail right of way.

Intermodal Connectors

These are locations where two modes meet and the cargo moves from one mode to another. In most cases this involves transferring a piece of cargo from a truck to a train or vice versa.

Within this label, intermodal connectors can be seen in many different types of facilities. The following describes some of these facility types.

Inland Ports

Rail access is a significant element of port competitiveness strategy. By providing an inland port service, a seaport (in theory) can make intermodal rail service available to a broader range of customers. If priced sufficiently low, the inland port service can offer cost savings to container shippers and thereby increase the port's competitiveness.

Inland ports have become an increasingly popular concept as the drive for transportation efficiency continues. Inland ports are perceived to reduce congestion, improve transit times and reliability, while at the same time

decreasing costs and promoting economic development. For a detailed discussion of inland ports, see Appendix 5-C.

Other Intermodal Connectors Within the State

In addition to rail-served inland ports, the two most prominent alternatives for rail transportation are on-dock intermodal and near-dock intermodal.

On-Dock Intermodal

Port of Seattle

Terminals 5 and 18 have on-dock intermodal facilities within the terminal footprint (see Exhibit 5-7). Both on-dock intermodal yards can load international containers from the ship without using a public street.

Port of Tacoma

The Port of Tacoma has four intermodal yards; three are on-dock and one near-dock. These four yards are served by Tacoma Municipal Belt Line, the short line that serves the Tacoma Tideflats area. All four of these intermodal yards were built by the Port over the years to meet customer needs (see Exhibit 5-8).

Near-Dock Intermodal

South Intermodal Yard in the Port of Tacoma is a near-dock intermodal facility located on Milwaukee Avenue near the entrance of the APM terminal. It is operated by a third-party operator, Pacific Rail Services, under the direction of the Port of Tacoma. It has direct street access and has the capability of loading or unloading directly to road-ready trucks.

Seattle is supported with two near-dock international intermodal facilities, the BNSF Railway's (BNSF) Seattle International Gateway and the UP's Argo Yard. Both facilities are located less than two miles from Terminals 5 and 18 and directly across from Terminals 46 and 30. Both yards have direct access to the mainlines for each railroad.

Mainline Domestic Intermodal Terminals

In addition to the on-dock international intermodals yards, both BNSF and UP have intermodal yards in the Puget Sound that cater to domestic intermodal cargo. This is cargo that is in larger domestic containers, which are usually a 53-foot box that mirrors the domestic trucks used by the large retailers, such as Safeway, Target, or Wal-Mart. Due to the length of the domestic container, this type of train requires dedicated rail cars that will hold these longer boxes.

Exhibit 5-7: Seattle Freight Network

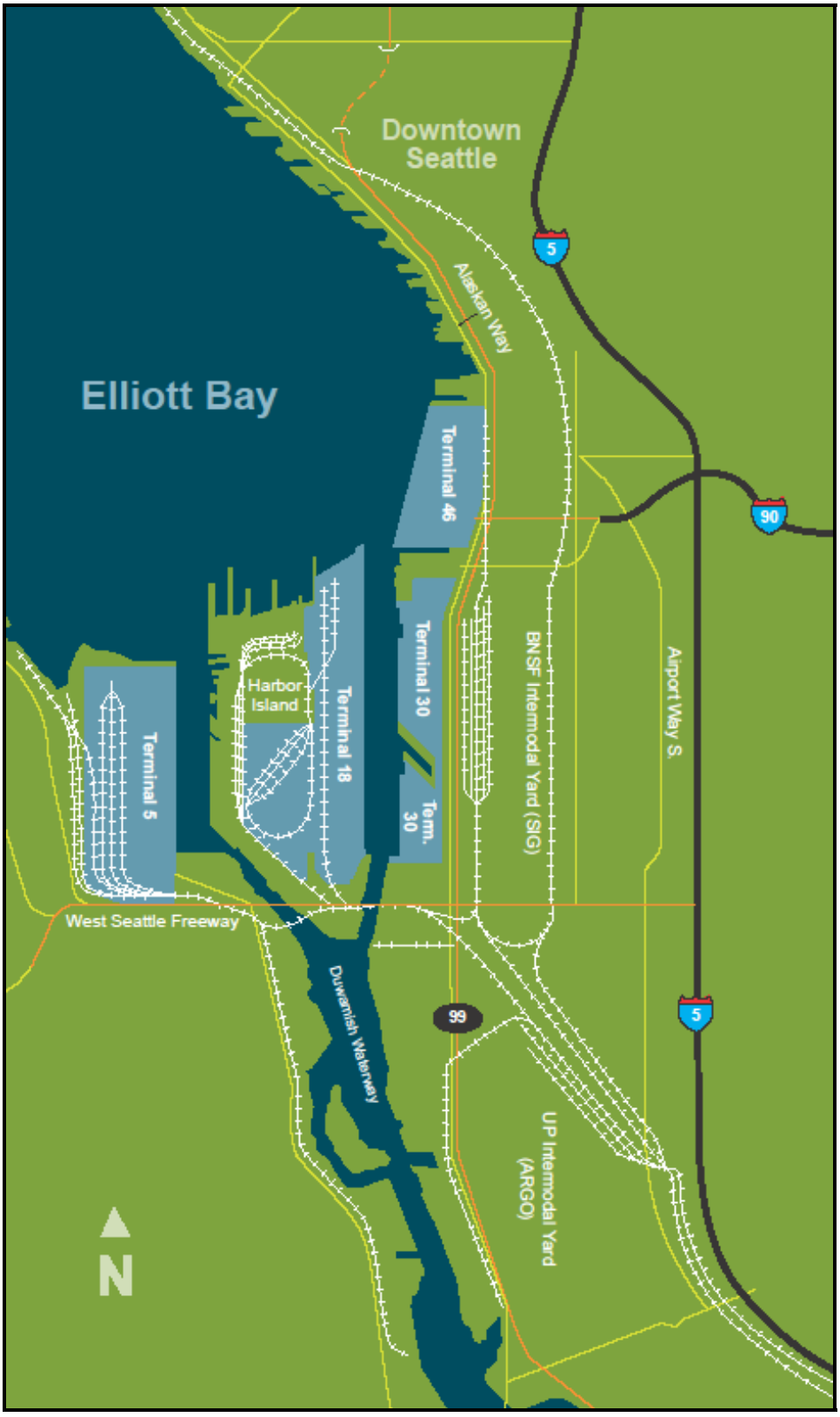


Exhibit 5-8: Tacoma Freight Network

BNSF has their South Seattle yard located near the south end of Boeing field.

UP loads domestic containers at both their Seattle Agro facility and their new Domestic Yard in Tacoma, co-located in the South Intermodal Yard.

Intermodal Connections

There are other types of intermodal connectors such as rail-to-barge, truck-to-grain elevators, rail-to-bus, as well as airports. In most cases airports are not supported by rail, although for freight there is the truck-to-

plane intermodal connector. Exhibit 5-9 shows all intermodal connections in Washington State. Exhibit 5-10 shows intermodal facilities in the Puget Sound area. Exhibit 5-11 shows intermodal facilities that include the rail mode. Appendix 3-C provides a detailed commodity description for these intermodal facilities.

Many smaller-size intermodal facilities are not included in BST's database. But, these intermodal facilities are important to the state's economy and should be identified. A study is needed to expand the database to include all intermodal connections.

Rail Freight System Issues and Needs

Mainline Freight Issues

Capacity Bottlenecks

The benefits that the state can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many state businesses. The examples of rail lines that are currently running at capacity or near capacity are discussed in Chapter 3.

The pressure on the rail system will increase in the next decades. To accommodate this growth, many more rail lines within the state will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting state communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise[6] and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

[6] The Final Horn Rule was promulgated by the Federal Railroad Administration and published in the Federal Register on April 27, 2005. The rule required trains to sound a horn or whistle when approaching a highway railroad grade crossing. The intent was to develop a mechanism for a public authority to authorize a whistle/horn ban at a crossing(s) with the authority jurisdiction under the context of an existing state law or modified state law.

Exhibit 5-9: All Intermodal Freight Connectors in Washington State

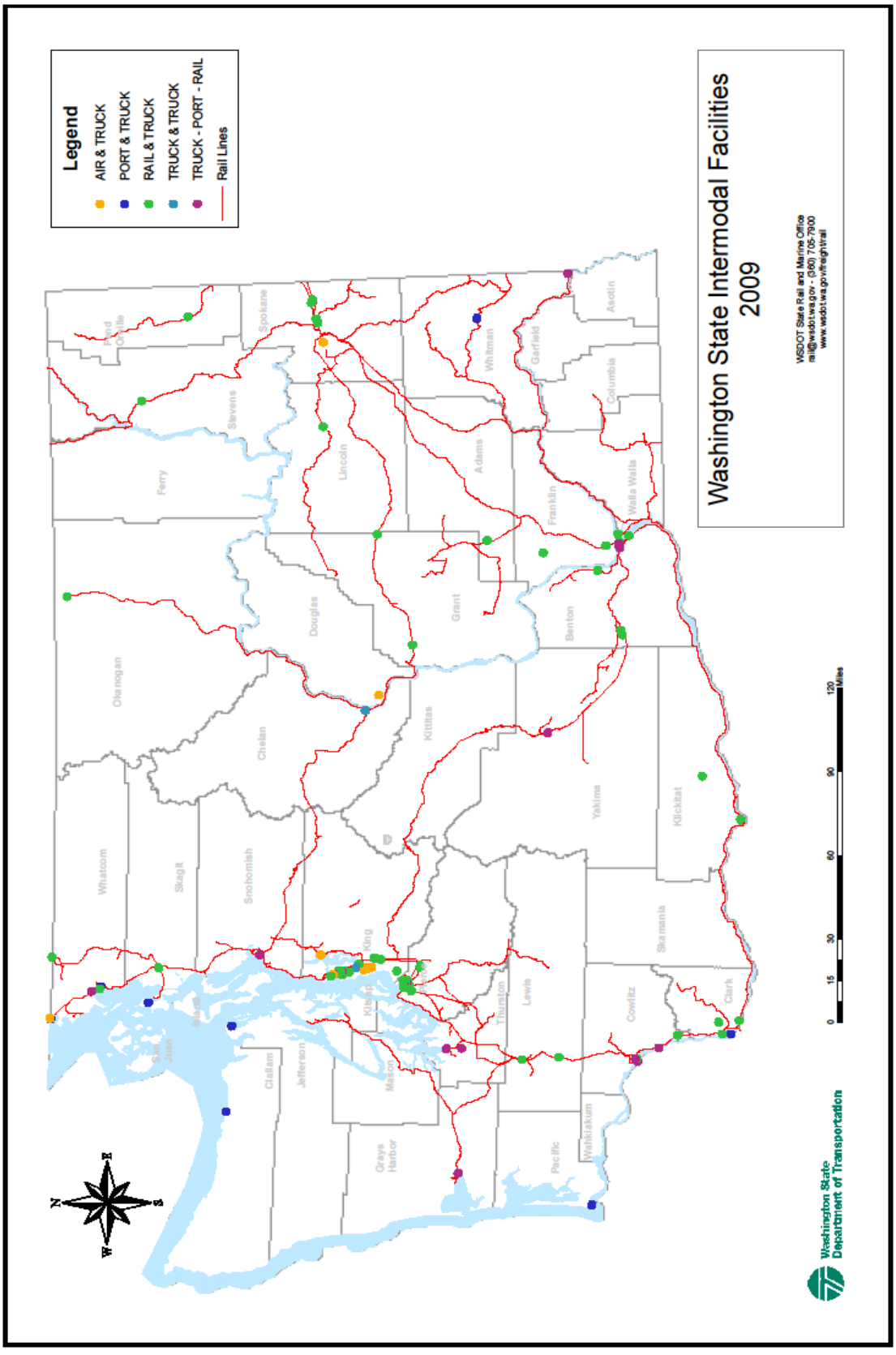


Exhibit 5-10: All Intermodal Freight Connectors in the Puget Sound Region

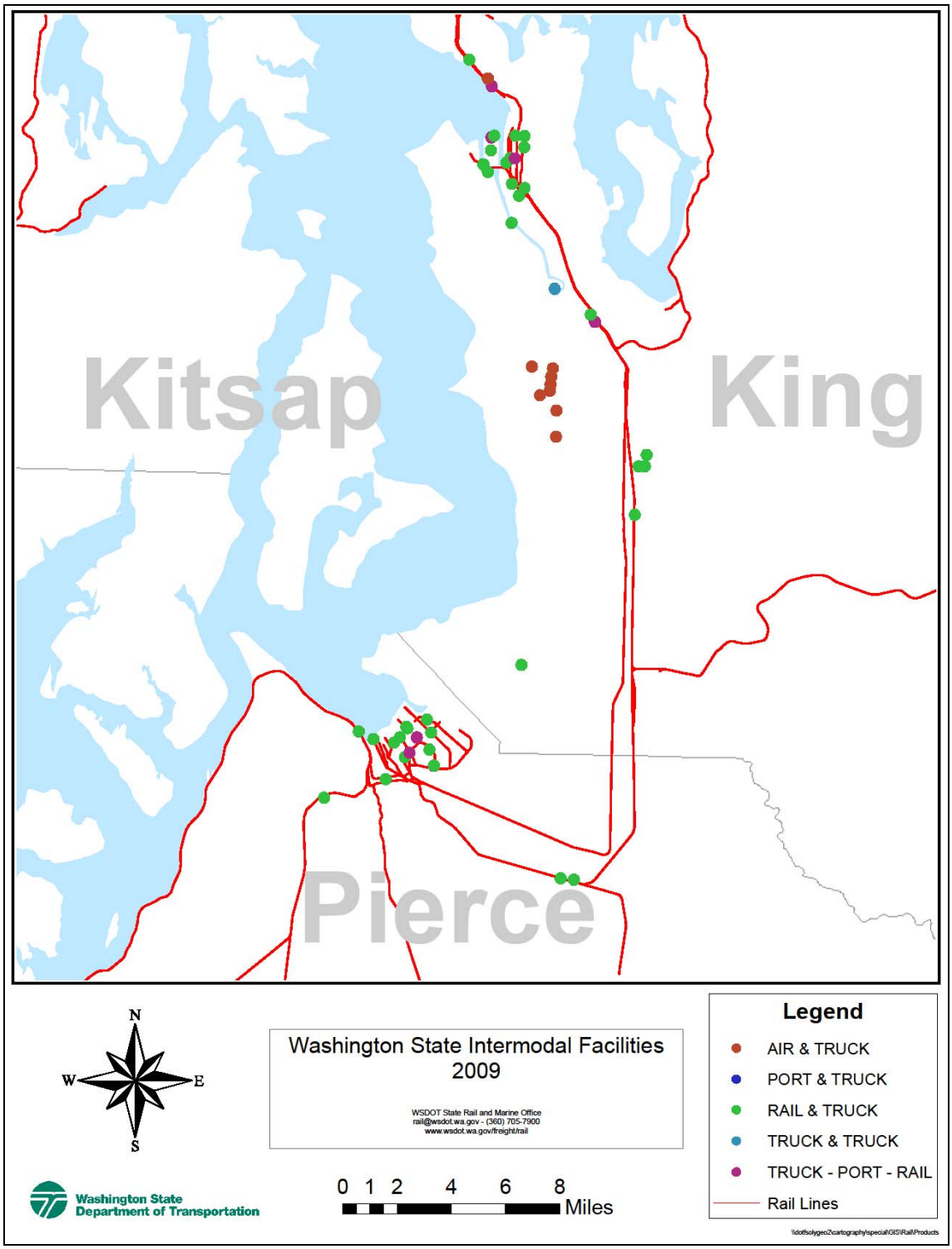
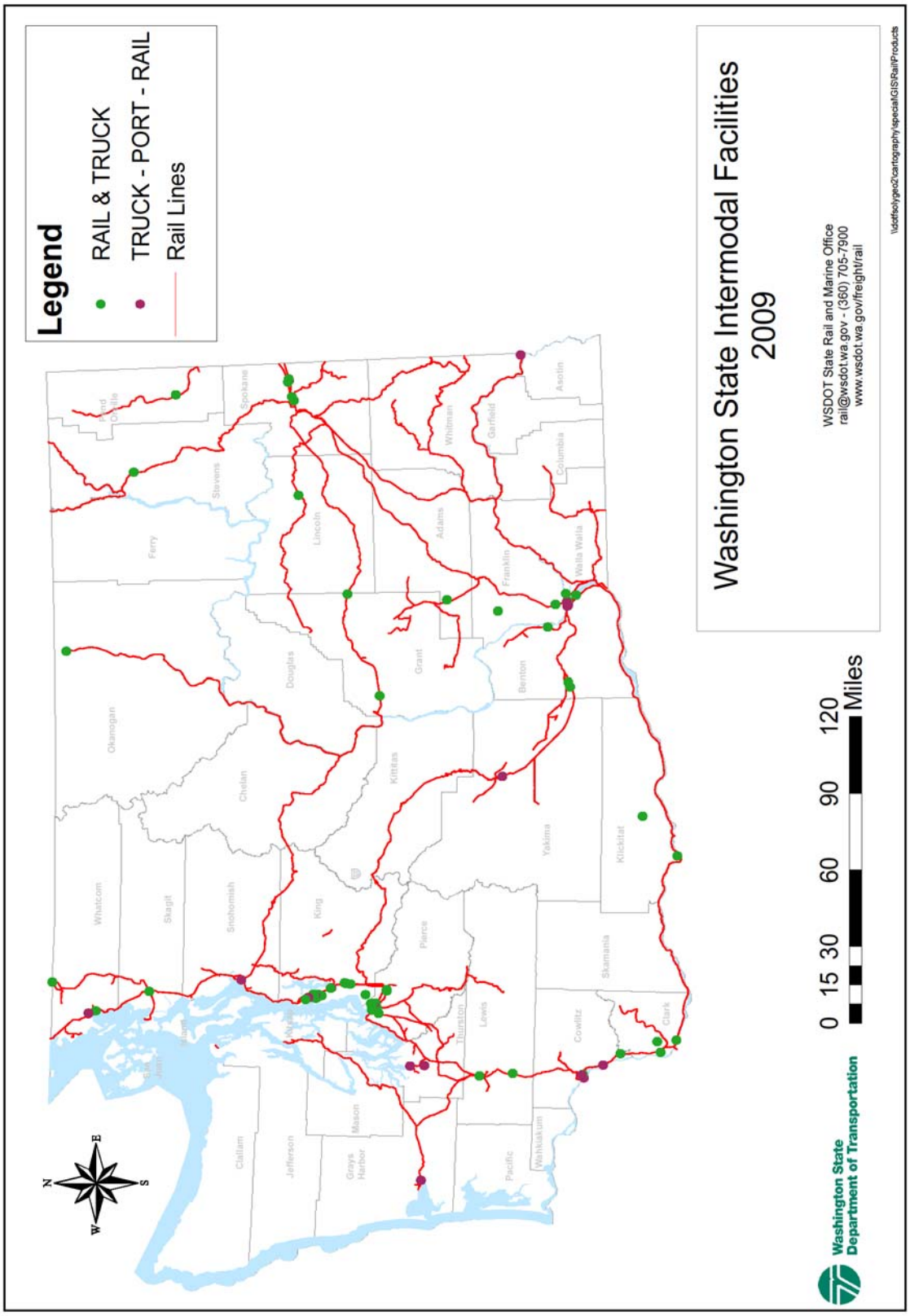


Exhibit 5-11: Rail Intermodal Freight Connectors in Washington State



Clearances

As referenced earlier in Chapter 3, the Stampede Pass route is limited to single-stack trains due to the clearance restrictions of that line, as it can not handle the height of double-stack trains. There are also height limitations caused by the Chuckanut tunnels on the I-5 rail corridor between Everett and Bellingham.

Freight and Passenger Mainline Issues

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the state's passenger rail program. The cost of resolving the rail chokepoints in the I-5 corridor to meet passenger service and ridership goals is increasing. WSDOT continues to look for funding solutions to these issues. Currently, WSDOT has $1.3 billion of grant applications into the federal government under the American Recovery and Reinvestment Act of 2009 (ARRA) programs. Current grant requests are described later in this chapter under High-Speed Passenger Rail in the Emerging Issues section.

Without capacity improvements, rail will not meet the demand of the state freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the state's industrial and agricultural shippers.

Freight and Commuter Issues

Sound Transit provides *Sounder* commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks.

The ongoing improvements at King Street Station in Seattle have contributed to more efficient combined freight and passenger operations between the Seattle Tunnel and Argo Interlocking. As with the Vancouver (WA) to Tacoma segment of the I-5 corridor, BNSF has no capacity expansion plans in its 5-year capital investment plan for this segment beyond that being driven by increases in intercity and commuter passenger growth plans.

Sound Transit and BNSF are currently in discussions to update the operating and volume agreement between Tacoma and King Street Station in Seattle. These discussions are focusing on an agreement similar to the one now in place between King Street Station and Everett. Under this scenario, Sound Transit would purchase additional train slots rather than paying for specific physical improvements. Assuming an agreement is reached, this arrangement would ultimately result in 15 round-trip

commuter trains per day between Seattle and Tacoma. In return, BNSF would be expected to construct the capacity improvements necessary to ensure that passenger and freight movements continue to operate efficiently. Ports are concerned that improvements are made in a timely manner, before the service starts, to avoid disrupting freight service when the additional commuter trips begin.

Short-Line Freight Issues

As regulatory changes allowed for Class I railroads to rationalize their networks by selling off unprofitable lines, more new enterprising, innovative, and customer-oriented rail companies emerged. Although some have failed, many more have lowered the cost structures of marginal, neglected rail lines and turned them into prosperous operations. Short lines now comprise 37 percent of the active rail network in the state in terms of operational miles.

However, the short-line railroads still have challenges. Some of these are capacity issues at interchange points with the Class I mainline and handling heavier weighted rail cars. In the case of the interchange the issue may only affect the short lines and may not impact Class I mainline capacity.

In general short lines have lower operating speeds and track conditions in comparison to Class I railroads. Further, it is clear that the need for capacity improvements are not limited to the Class I railroads. Prior to being sold to a short line, the "excess" sidings and yard tracks of a Class I-owned branch line were often removed to minimize maintenance costs and real property tax liabilities. Those actions made business sense under the regulatory and tax framework at the time. However, today, under the management of short-line operators, rail traffic has returned to these branch lines; the lack of runaround sidings, yard tracks, and interchange tracks can cause inefficient operations that increase the railroad's cost to serve shippers or can decrease safety.

Heavy-Axle Load Rail Cars

In the 1970s, many coal-originating railroads increased rail car weight limits for coal cars from 263,000 pounds to 286,000 pounds, as a result of heavier track structures being implemented at that time. In 1994 the Association of American Railroads (AAR) approved the same increase in weights for covered hopper cars. The latter change had a much bigger impact because covered hopper cars circulate throughout the North American rail system, hauling a variety of commodities on Class I railroads, as well as on short-line railroads.

A lengthy and costly effort was undertaken by the Class I railroads and some of the short lines to upgrade their lines to carry the heavier cars. However, track and bridge structures of many of the short lines are still incompatible with the interline standard of 286,000 pounds. Unfortunately, these are the railroads that are the least able to afford the high cost of upgrading their tracks to this standard.

Most recently, the Class I railroads across the nation are now carrying some 315,000-pound cars on main routes that have been certified for this new weighted car. Again, it is unlikely that short lines will be able to afford to upgrade their track to handle such cars in the near future. Even if they are able to upgrade the capacity of the track, it is unlikely that the bridges will be upgraded to this new standard. Thus, this incompatibility has forced bulk cargo either into less efficient cars or on to the highways.

System Preservation

Many of the short-line railroads are owned by private operators, making information on system conditions difficult to compile. Indications are that short-line rail tracks are facing large rehabilitation needs, and may be at least partly unfunded. Worsening track conditions could lead to further abandonment.

There is a no more fundamental transportation capital investment than system preservation to keep the physical infrastructure in good condition.[7] As transportation facilities age and are used, a regular schedule of rehabilitation, reconstruction, and replacement is needed to keep the system usable. Timing is important: if preservation investment is deferred, costs increase dramatically, leading to the saying "Pay me now, or pay me more—significantly more—later."

"Asset management" is a term that describes a proactive approach to investing in preservation at the right time to optimize rail condition. Asset management includes having comprehensive inventories of transportation facilities; a system for measuring and reporting system condition; predictive condition models that anticipate rehabilitation or replacement needs; and an investment program that ensures that the right investments are made at the right time.

In 2002 and 2003, the legislature reinforced this state's commitment to asset management. Legislation specifically required maintenance and preservation to be included in state plans for highways, ferries, and rail, and required cities, counties, and transit agencies to manage and report system condition. These requirements will help ensure that more

[7] Good condition is defined as not needing repair or maintenance.

consistent condition information will exist in the future about all transportation assets.

This chapter later discusses information needs in more detail; however the list below is an example of needed data and analysis related to abandonments and short-line railroad development.

1. **Abandonment** – What service area did these lines serve? Have they been banked or converted?
2. **Inventory** – What are the current short-line facilities and conditions?
3. **Assessment** – What is the short-line economic impact to the state? What is the short-line economic impact of the preservation or abandonment?

Underserved Markets (Grain Trains and Produce Cars)

Grain Trains

In the early 1990s, a national shortage of rail covered hopper cars made it difficult and expensive for state farmers to get grain to market. To help alleviate this shortage of grain cars, the Washington State Energy Office and WSDOT used federal funds to purchase 29 used grain cars in 1994 to carry wheat and barley from loading facilities in eastern Washington to export facilities in western Washington and Oregon. The Washington Grain Train currently has 89 grain cars in the fleet (71 are owned by the state, and 18 are owned by the Port of Walla Walla). The UP, BNSF, and state short-line railroads operate the cars and carry the grain to market. WSDOT is currently in the process of purchasing an additional 29 cars mandated by the state legislature.

Serving over 2,500 cooperative members and farmers in one of the most productive grain-growing regions in the world, the Washington Grain Train helps carry thousands of tons of grain to deep-water ports along the Columbia River and Puget Sound for transport to ships bound for Pacific Rim markets.

The Washington Grain Train produces a number of important public benefits, including:

- Helps move state products reliably and efficiently to domestic and international markets.
- Helps preserve the state's short-line railroads by generating revenues that may be used to upgrade rail lines and support the railroad's long-term infrastructure needs.
- Helps support a healthy rail network that may maintain and attract new businesses in rural areas of the state.

- Saves fuel over shipping by truck.
- Supports air quality improvement initiatives.
- Helps reduce wear and tear on local roadways by using rail.
- Supports the users by using equipment not subject to market based premiums.

The Washington Grain Train was started with federal "seed" money and operates without any taxpayer subsidy. WSDOT, the Port of Walla Walla, the Port of Moses Lake, and the Port of Whitman County all manage the Washington Grain Trains. WSDOT oversees the entire program, and the port districts collect monthly payments from the railroads for the use of the cars. The ports can use up to one percent of the payments they receive from the railroads for fleet management services.

The Washington Grain Train collects wheat and barley from grain elevators in eight cities in eastern Washington. These are: Warden, Schrag, La Crosse, Prescott, Endicott, Willada, St. John, and Thornton. The grain is transported to export facilities in Kalama, Tacoma, Seattle, Vancouver (WA), and Portland, Oregon.

Since its beginning, the Washington Grain Train program has carried over 9,000 carloads totaling more than 900,000 tons of grain from the state to national and international markets. Total carloads for the second quarter of 2009 increased 5.4 percent over the second quarter of 2008. There were 412 carloads shipped in the second quarter of 2009, compared with 391 in the second quarter of 2008. In 2008, a total 1,332 carloads were shipped compared to 1,822 carloads in 2007.

Produce Cars

In 2003 the state legislature enacted legislation (RCW 47.76.400) that authorized WSDOT to established a pool of refrigerated railcars to transport perishable agricultural goods. This legislation was in response to the state's agricultural community's inability to secure an adequate supply of refrigerated railcars during peak seasons from the railroads.

WSDOT started operation of the Washington State Produce Rail Car Program in 2006. Federal fund appropriations of $2 million and $200,000 from the state for startup operations and contract monitoring enable the railcar pool program to start.

On August 18, 2006, WSDOT signed a contract with Rail Logistics, LC to lease up to 50 refrigerated railcars and to manage the fleet. This contract was renewed in June 2009 for two additional years. The program is intended to provide the opportunity to open new markets for Washington State produce while maintaining economic viability for Washington's

agricultural community. The public benefit is that these rail cars minimize the added wear and tear on state roadways caused each year by thousands of heavy truckloads.

New Services

In October 2007, the partnership of UP, RailEx, and CSX Transportation initiated a new twice weekly unit train service carrying perishables (fresh fruit and vegetables) from Wallula, WA to Schenectady, New York. The cross-country trip takes 128 hours, a time that is very competitive with an over-the-road truck.

The 55-car train has next generation refrigerated boxcars that have the most efficient insulation, uses an environmentally-friendly and energy-efficient refrigeration unit, and has a global positioning system to monitor the "health" of the refrigeration unit and the temperature in the car.

Each train carries about the same amount of produce and perishable items that would have been moved by more than 200 over-the-road trucks. With the produce moving by rail instead of truck, 100,000 fewer gallons of diesel fuel are used each time the produce unit train operates.

Emerging Issues

Following is a discussion of four major emerging issue categories:

- Freight Rail Capacity and Competition.
- Positive Train Control Implementation.
- Impacts of Dam Breaching or Loss of Columbia-Snake Inland Waterway System.
- Statewide Information and Data Needs.

Freight Rail Capacity and Competition

Challenges that the state faces to achieve continued economic growth include:

- Increased rail competition for the Pacific Northwest (PNW) from other regions in the U.S. and Canada.
- East-west rail capacity issues.
- PNW ports serve discretionary traffic that can easily move to another gateway.
- Panama Canal expansion.
- Increasing competition from Pacific Southwest and Canadian Ports.
- Highway congestion.
- Restoration of Puget Sound.

On a per ton basis, trucking uses over 10 times more energy on average to transport freight than rail transportation. However, the average truck carries just less than six tons of freight, while the average rail car carries a load of 46 tons, reflecting the heavier, bulky commodities that railroads generally haul. Thus, when comparing energy intensity on a per-vehicle-mile or per-car-mile basis, the difference between the two modes is significantly reduced. It should be noted that rail is still less energy intensive.

The *National Rail Freight Infrastructure Capacity and Investment Study*, performed by AAR, assumes the Class I railroads will be able to generate approximately $96 billion of the $135 billion cumulative in the 28-year investment indentified through increased earnings from revenue growth, higher freight volumes, and productivity improvements. This would leave a national gap of approximately $39 billion or $1.4 billion per year to be funded from other sources in order to achieve performance improvements, while meeting the demand of the current rail market for freight shipments.

BNSF's capacity investment plan for the state over the next five years does not include any significant expenditure due to the current reduction of traffic volumes other than participation in siding extensions at Mount Vernon and Stanwood, and construction of a new customs inspection siding at Swift (Blaine) between Everett and the Canadian border.

In the meantime, competition from other ports on the west coast of North America continues to grow. Ports in southern California continue to attract a large portion of the West Coast international trade due to the huge local market they serve, and Oakland, while often considered less of a competitive threat, has continued to develop new properties as they have become available, and has seen growth in its international trade.

Of special importance for state ports, however, is competition from the Canadian ports of Vancouver, British Columbia (B.C.) and Prince Rupert; substantial investments are being made at both of these ports in order to improve their competitive positioning. Port Metro Vancouver (PMV), in particular, is developing ambitious plans for container facilities that could increase capacity by a factor of four over the next dozen years. The Port of Prince Rupert (PPR) also has ambitious plans to increase container throughput four-fold over the foreseeable future.

Both PMV and PPR have and are receiving significant support from the federal and provincial governments for their efforts to expand and improve freight mobility. That support will potentially involve government investment exceeding $1 billion (Canadian) for projects currently identified and under consideration. In addition, at least in

PMV's case, the ports have taken a proactive role in moving a variety of freight mobility projects forward.

The widening of the Panama Canal also provides shippers improved alternative routes to U.S. midwestern and eastern destinations. It is currently unknown the actual impacts that this expansion will have on state ports. There are numerous studies available on the subject without a consistent conclusion on the effects on the West Coast ports. There are many criteria that will be evaluated in a shipper's decision to use or not route their cargo through the expanded canal. Some of these include time to destination, fully loaded cost of the transport, customer service of the transportation vendors, etc. The newer, larger, more efficient ships will be able to use the expanded canal. Passage through the Panama Canal is currently limited to Panamax ships, which are no wider than 106 feet.[8] The challenge for the shipper is that although the larger ships can transit the canal, port facilities that are capable of berthing these larger ships are limited in number. Many West Coast ports are capable of handling these larger ships, but many of the gulf and East Coast ports have depth or height limitations at their ports that may prevent these larger ships from berthing. Various ports are in the process of making improvements in order to handle the larger ships.

The recent economic downturn has resulted in both Class I railroads serving the state (BNSF and UP) to reduce planned 2009 capital expenditures by $100 to $200 million in pure capacity expansion projects. This brings concerns that the Class I railroads could delay capacity enhancements in an attempt to control capacity, which could affect the competitiveness of the state as compared to other states. The capacity expansion projects that remain are those where previous commitments have been made including BNSF's intended improvements on the "Transcon" between southern California and Chicago (Abo Canyon double-track) and UP intended double-tracking on the "Sunset Route" between southern California and El Paso, Texas.

The positive side is that both BNSF and UP plan on continuing to invest in maintenance of existing track and purchase of locomotives—both are key components in maintaining capacity capability over existing track infrastructure. This capital investment, with a view to the long term, provides a good example of the path that the state should pursue in funding rail improvements, especially for those projects where the long-term interests of the state are clearly identifiable and the project timelines are long.

[8] A Panamax ship is no larger than a ship that can carry the equivalent of 3000 Twenty foot Equivalent Units (TEU). A TEU is a measure used in the marine industry to measure a container into equivalent units of 20 feet long, 8 feet wide, and 8 feet high.

For the state to stay competitive, a strong coalition must be developed among the stakeholders. This coalition must develop an integrated plan to develop the needed capacity to retain the state's rail freight market share. In this chapter the needs as well as risks have been identified. It will be detrimental to this state if a cohesive rail network is not maintained.

Some suggest that a High-Capacity Freight Corridor be developed. This High-Capacity Freight Corridor has been referenced by some stakeholders as the Northern Corridor and by others as the Hi-C. These two concepts have slight variations, but are built on the same assumption concept that a high-capacity rail corridor must be maintained and improved upon from the Puget Sound to Chicago, Illinois. This is not currently supported by either BNSF or UP. Perhaps the designation as a Corridor of National Significance will meet the goal. No matter which name or design is chosen, a national cohesive effort needs to be developed by both the public and private partners in order to achieve the economic growth that benefits the state's competitive position. The corridor will require infrastructure and operational improvements as well as cooperation between the BNSF and UP. An agreement on the priorities would need to occur and a funding program developed. Below is a selection of highly visible projects that need to be considered as the competitive strategy is developed.

Class I Railroad Competition

It is important to the state's economy to have healthy railroads competing for business in the state. This competitive environment will influence how aggressive is the rate structure offered and the level of investments the Class I railroads are willing to make within the state to increase their network capacity.

BNSF and UP capital investment decisions and strategies are based upon capacity needs and positioning their network to be more attractive to the customer. Class I railroads normally spend approximately half of their annual budgets for maintenance of their physical network (e.g., rail, ties, ballast, bridges, etc.). With capital expenditures for UP and BNSF amounting to $3 billion per year over the last few years, a significant portion of both railways' capital expenditures has been for maintenance of existing track. This expenditure is very important to the efficiency of the system since deferred or reduced maintenance can result in lower throughput on deteriorating track.

Similarly, BNSF and UP continue to make significant investments in locomotives. Trains that are under-powered often cannot maintain the maximum allowable speed, consuming more capacity than trains that have

sufficient power to maintain track speed. Both railroads continue to purchase locomotives that are much cleaner in emissions and more fuel efficient than older generations of locomotives. For instance, the required use of "green" locomotives in the Los Angeles Basin has caused the railroads to replace older locomotives with the newer more environmentally-friendly engines. In addition to locomotives, capital expenditures for new or improved signal systems on existing networks also enhance the capacity of a segment of track.

Both BNSF and UP allocate 10 percent to 12 percent of annual capital spending to expansion of their physical networks. This normally amounts to capacity expansion expenditures between $200 and $300 million spread across their respective 30,000 plus mile systems; though this expenditure accelerated somewhat in the period from 2005 to 2007. The emphasis of both railways was in constructing double track on the single-track segments for their respective mainline routes into and out of southern California. For example, BNSF's project to construct the 3rd main track over Cajon Pass was a project that took four years to complete at a total cost of approximately $90 million. The new mainline is 16 miles long and is projected to increase total train capacity by 50 trains per day to approximately 150 trains per day.

In addition to physical capacity expansion projects—such as constructing new main track, building new meet/pass sidings, and extending sidings—capacity expansion dollars are also used for expanding or constructing new yard and intermodal facilities. Consequently, competition for expansion capital is intense each year and the railroads normally focus those expenditures in locations they consider to be competitively sensitive or have the highest return on investment.

To focus BNSF and UP on the state's rail needs, the following things must happen:

- The state's economy must be growing.
- State ports must be efficient.
- Stakeholders must demonstrate their understanding of how important the rail system is to both the economy and ports.
- Rail operator's business needs must be acknowledged.

Another issue is the potential for Canadian National (CN) and Canadian Pacific (CP) to gain access to the state through either their current agreements with the BNSF and UP or through future agreements. This would again change the competitive landscape of the PNW. Depending on the agreement, this may be very positive or very detrimental to the state's ports and their competitiveness compared to other ports.

Finally, there must be consensus on what are the priority projects and the funding mechanism to get the improvements built.

East-West Issues

Northern Corridor/Northern Tier/High-Capacity Freight Rail Corridor

It is important for the economic growth of this state to have efficient, well-connected east-west rail corridors leading to other population centers in the U.S., especially the Midwest and upper northeast regions. As has been noted in Chapter 4, the state is dependent on freight movements in and out of the state to other mega regions where the goods are consumed or produced. The concept of the Northern Corridor is built upon the current routes of the Class I railroads along the Northern Tier from Washington to Illinois. This corridor links the two economic regions of the Pacific Northwest and the Great Lakes. Unfortunately, there are limited numbers of markets between Spokane and Minneapolis-St. Paul. Thus, the majority of the container trains leaving the state are direct trains with their first destination as St. Paul, before moving on to the Chicago area, where the train is either unloaded or switched to an eastern railroad for movement to the eastern or southern populated regions of the U.S. This route handles a magnitude of cargo types, such as intermodal containers, automobiles, agricultural products, and bulk commodities, such as minerals and coal. This corridor is of national significance and needs to be designated as such; and is essential to the competitiveness of the state's ports and other industries that drive economic growth within the state. It competes with six other transcontinental corridors extending from the Pacific to the East Coast.

The importance of the Northern Corridor should be recognized as one that connects Asian and North American markets together. This corridor competes with the central and southern U.S. rail corridors. In addition, the Canadian, Mexican, and Panamanian corridors provide effective alternatives for transportation of goods to all U.S. markets.

To achieve this, a coordinated approach between the corridor states and the private sector is needed to ensure that this corridor gets the same attention and funding as other parallel corridors. The obvious partners in the Northern Corridor include the states of Washington, Oregon, Idaho, Montana, North Dakota, South Dakota, Wyoming, Minnesota, Wisconsin, Indiana, and Illinois. This is the broad band of states that encompass the I-90 and I-95 highway corridors. The improvements in this corridor must

include the improvements required at the eastern end of this corridor, primarily Chicago and the CREATE[9] project.

While this corridor has experienced satisfactory maintenance and modernization, no large scale capacity improvements are currently scheduled, unlike competing corridors in the Southwest.

Regardless of the method chosen to improve capacity, there have been three barriers that are addressed in Chapter 8: identifying funding sources, developing participation across the states within the corridor from all stakeholders, and reaching agreement with the private owners of the rail infrastructure (i.e. the mainline railroads) on the priority of necessary improvements. Federal, tribal, state, local, and port governments all have a stake in the successful operations of railroads in the Northern Corridor.

Potential railroad benefits of the high-capacity freight corridor are:

- Increase east-west train capacity.
- Improve crew utilization/reduces labor costs.
- Improve fuel savings and locomotive use.
- Improve mainline train velocity across the state.
- Allow increase in train length for intermodal trains in the eastward direction from 7,000 feet to 8,000 feet without distributive power.

Potential public benefits are:

- Provide east-west rail capacity needed for port growth enabling a strong local economy.
- Mitigate for increased train traffic.
- Bypass major eastern Washington cities.
- Tie into the WSDOT-owned short lines in eastern Washington.
- Provide short-haul capacity to eastern Washington growers.
- Remove trucks from I-90.
- Spur economic development in eastern Washington.
- Improve air quality through reduced emissions.
- Improve national security.

WSDOT State Rail and Marine Office should lead the organization of the corridor coalition to make sure the development of the coalition and corridor meet the needs of the state and its stakeholders. The partnership should be formed and the cost and benefits analyzed. The following must be determined:

[9] CREATE stands for Chicago Region Environmental and Transportation Efficiency Program. This is a $1.5 billion project to improve freight rail connections in and around Chicago, Illinois.

- What is considered a public benefit to be funded by public funds?
- Which improvements are private and need private funding?

Once the coalition is organized these neighboring states can develop a joint plan to encourage and facilitate more service to the shippers along the Northern Tier.

Stampede Pass Clearance and Signal Systems

In the *Washington Public Ports Association (WPPA) Rail Capacity Study – 2004*, an analysis was performed on two scenarios that involved rerouting of traffic from Stevens Pass to Stampede Pass. The first anticipated the "clearing" of the Stampede Pass tunnels for double-stack rail cars in order to relieve capacity pressure on Stevens Pass.[10] The second analysis involved directional running of trains between Spokane and the Puget Sound, with westbound trains operating via Stevens Pass and eastbound trains operating via Stampede Pass.[11] 'Clearing" the Stampede Pass tunnel will significantly increase the capacity over Stevens Pass. But, BNSF has no capital investment allocated for clearing the tunnel in its current 5-year plan.

The issue of directional running is more problematic. This is an operational consideration for the private entities and cannot be enforced by the state. Directional running requires a one-way westbound route and a separate one-way eastbound route. Because of the grade issues on the two passes, it is thought that Stevens Pass would be the westbound route and Stampede Pass would be the eastbound direction. The re-routing of trains eastbound over Stampede Pass would add 82 miles to the trip. The longer distance and the lower speed per mile on the Stampede Pass route to Spokane require an additional crew shift to be added. The additional crew is due to labor rules restricting the number of hours a crew can work. This extra labor cost is in addition to other operational issues this route presents. Re-opening the Ellensburg to Lind cut-off would reduce the number of miles traveled since it would eliminate the need to go through Pasco. It could also alleviate some of these operational issues. However, the timing of these improvements is subject to various long-term issues that can't be forecast with any sense of confidence. The more significant questions, from a capacity demand perspective, are when will growth frequently stress the capacity on Stevens Pass and how will BNSF address the issue.

[10] Clearing refers to the crowning of a tunnel to allow taller rail cars to pass through or "clear" under the ceiling of the tunnel.

[11] Directional running is the concept that trains are routed only one direction on a corridor so that operational capacity is increased due to the fact that all trains move in the same direction not unlike a one-way street.

Both the *WPPA Rail Capacity Study – 2004* and the *Statewide Rail Capacity and Systems Needs Study* (2006) projected that as daily capacity demand on Stevens Pass reached daily sustainable capacity, overflow BNSF trains would be rerouted to or from the Puget Sound, either via Stampede Pass or the I-5 corridor to Vancouver (WA) and the Columbia River Gorge route.

Finally, additional capacity may be achieved if some bulk trains can be rerouted over Stampede Pass versus their current routing along the Columbia River Gorge. Currently testing is underway using mid-train helpers to enable heavy trains to climb steep grades. Should the distributed power (i.e. mid-train helper[12]) test prove to be productive, BNSF will have the ability to allocate additional trains to Stampede Pass that would otherwise operate via the Columbia River Gorge between Pasco and Vancouver (WA).

Bridging the Valley (Spokane to Athol)

A series of rail and road improvements jointly referred to as the "Bridging the Valley" project, have been planned between Spokane, WA and Athol, Idaho to separate vehicle traffic from train traffic. Where there are currently 75 railroad/roadway crossings, this project will construct approximately 19 grade-separated crossings within the BNSF corridor. The UP mainline will be relocated to an alignment within BNSF's mainline corridor to eliminate all mainline at-grade crossings on the UP line between Spokane and Athol, Idaho. However, the BNSF has indicated that capacity on this segment is sufficient. BNSF supports the grade separations envisioned, but does not support the relocation of UP onto the BNSF line. The railroad currently sees no value in participating in the project due to the fact that conjoining the two railroads on one line could damage the BNSF franchise significantly.

North-South Issues

North-South Corridor (I-5 Corridor Including Access to Canada)

As discussed in earlier chapters, the fluidity of the I-5 rail corridor is mandatory for the economic health of the state. This corridor can be classified as extending from Portland, Oregon to Vancouver, B.C. A north-south corridor supporting the east-west movement of cargo moving through the state is required to keep the rail network flowing. As the projections of cargo and passenger volumes are met, it will be especially important that attention is kept on the health of this north-south corridor.

[12] Distributed power or mid-train helpers are engines that are placed in the middle of the train. These additional engines help "power" a long or heavy train by distributing the load of the train between the front engines and those in the middle of the train.

Currently, BNSF has no public plans, other than those proposed to support intercity passenger train volumes, to increase capacity over the route. From a freight perspective, BNSF believes sufficient capacity exists for the foreseeable future. Indeed, BNSF sees nothing in this corridor as "freight driven." BNSF indicated it will construct additional capacity in the corridor only as driven by growth in passenger train volumes.

In the future, it will be very important to monitor the capacity and needs of this corridor and advocate capacity improvements to meet the growth projections. This will require coordination between all stakeholders and partners to assure the capacity is available for this corridor and its communities to meet their respective needs. This may require a true public-private partnership including regional agencies such as metropolitan planning organizations, Sound Transit, Amtrak, rail freight customers, ports, local communities, as well as other stakeholders. Public funding could include safety improvements, such as grade separations. Private railroad funding could include improvements, such as longer sidings or additional mainline tracks. One of the options to eliminate passenger freight conflicts and to enhance capacity for both is to create a dedicated high-speed passenger rail track.

In addition to the above improvements, BNSF recently constructed a 10,000-foot clear siding at Colebrook, B.C. Colebrook is located where the British Columbia Railway (BCRC)[13] Port Subdivision from Roberts Bank merges with BNSF's mainline to New Westminster and is approximately halfway between Swift and Brownsville. Prior to constructing the new Colebrook siding, BNSF had no meet/pass locations between the border and Brownsville.

Dedicated High-Speed Passenger Rail Track

This is an emerging issue in the United States as 11 high-speed rail corridors have been identified, with projects in various stages of development. One of the most ambitious, California's high-speed rail system, eventually will connect San Diego with San Francisco and Sacramento.

Here in Washington, the concept of dedicating tracks solely for high-speed passenger rail is under discussion. There are many differing opinions that are not fact based. Typically high-speed passenger rail is defined as trains that are capable of moving at a rate of speed between 150 to 180 mph. Currently our rail lines are limited to a maximum of 79 mph. As has been discussed in this plan, the I-5 rail corridor is currently shared with passenger rail (both commuter and intercity) through the state from

[13] BCRC is a class II regional railroad owned by the British Columbia provincial government until it was sold to CN in 2004.

Vancouver, WA to Vancouver, B.C. The potential speed differential burdens both freight and passenger operations.

Thus, the high-speed concept needs to be explored in more detail to determine the true pros and cons of a dedicated corridor. One of the advantages of the concept of freight rail is that freight could re-gain rail capacity on the I-5 corridor rail line if passenger rail has its own dedicated rail line in that corridor.

An example of separating freight from passenger within a corridor is the Pt. Defiance Bypass project. This project plans to separate passenger trains from freight trains by re-routing passenger trains to an inland route that runs parallel to the I-5 highway from Tacoma to DuPont. The line will be extended to reconnect with the BNSF mainline in Nisqually.

The improvements will allow passenger trains to use the bypass route without being delayed by freight trains. This will result in:

- Improved passenger rail reliability.
- Provide faster and more frequent Amtrak *Cascades* service. Speeds will be increased up to 79 mph.
- Allow increased freight rail service around Pt. Defiance and along southern Puget Sound by eliminating passenger trains from the BNSF mainline.

Eastside Line

BNSF is in the process of abandoning this corridor and the Port of Seattle has committed to acquiring it through the federal abandonment process and rail banking two of the lines. The future use of the corridor has been discussed among various groups in the region for many years.

The Eastside Rail Corridor consists of a 42-mile rail corridor stretching from the city of Renton to the city of Snohomish, with an 8-mile rail spur running between the cities of Woodinville and Redmond. The rail corridor passes through the cities of Newcastle, Renton, Bellevue, Kirkland, Woodinville, Maltby, Snohomish, and Redmond.

In fall 2003, BNSF indicated its intent to divest roughly 42 miles of railroad corridor in east King and south Snohomish Counties from its operational rail lines. BNSF asked if there was public interest in maintaining/preserving this extensive corridor for transportation purposes. The Puget Sound Regional Council (PSRC) took on the question of "public interest" and conducted a series of discussions with the eight jurisdictions along the corridor plus WSDOT, Sound Transit, and several of the regions' environmental/bicycling interests. The resulting

recommendation to preserve the corridor for future transportation uses was endorsed by PSRC's Executive Board, who unanimously agreed that this regional rail corridor should be preserved for future transportation uses and communicated this regional interest to BNSF in July 2004.

The final PSRC recommendations, completed in 2007, proposed transportation uses over different time periods such as short, medium, and long term. The findings include:

- This unique corridor should be preserved.
- It is not a strategic regional or state freight rail corridor.
- Freight rail access to Boeing's Renton plant needs to be preserved.
- Prior regional public transit studies in north-south Eastside Corridor need to be respected.
- "Medium-term" timeframe is needed to achieve long-term passenger rail objectives.
- The cost effectiveness of trail development should be optimized.

Port of Seattle is currently in the final acquisition stages to purchase this corridor. It is anticipated that this transaction will close by early 2010. The Eastside Corridor has two portions: the northern portion, between Snohomish and Woodinville, and the southern portion, which stretches from Woodinville to Renton and includes the Redmond spur. Under the terms of the acquisition agreement, BNSF agreed to select a third-party rail operator to maintain the operation. The operator will pay the Port of Seattle for the rights to use the land and will provide freight rail service for shippers in Snohomish County.

Positive Train Control Implementation

Both the BNSF and the UP face a new capital expenditure requirement as a result of the recent Federal Railroad Administration (FRA) and Congressional decision that mandates that Positive Train Control (PTC) be implemented on all mainline corridors that carry both freight and passenger trains. The legislation, passed in the wake of a head-on collision in California between a UP freight train and a Metrolink commuter train, requires the installation of PTC by the end of 2015. The legislation also requires that PTC be installed on all routes that handle certain hazardous materials.

As a practical matter, this means that the U.S. freight railways will be required to install PTC on virtually all mainline corridors. Nationwide, it has been estimated that implementation of PTC will cost billions. The capital requirements needed to meet the PTC mandate is likely to place further pressure on discretionary capital spending for capacity expansion

The major U.S. railroads, including BNSF, UP, CSX Corporation, Norfolk Southern, and Kansas City Southern, have been in various stages of testing PTC for a number of years. One of the significant issues the railroads have been dealing with is inter-operability, or the ability of the PTC systems of each railroad to communicate with another railroad's system when locomotives are operating on another railroad. As a result of the recent legislation, the railroads have initiated an effort to develop a system that will work across all of the railroads.

Impacts of Dam Breaching or Loss of the Columbia-Snake Inland Waterway System

Transportation System Impacts

The current Columbia-Snake Inland Waterway System is efficient for moving cargo. This system provides shippers with an alternative to shipping by rail, imposes price competition on the railroads, and supplies sufficient capacity to absorb substantial fluctuations in grain shipments, especially during peak export months and years. The major components of the existing barge transportation system include:

- Barge terminals and river elevators.
- Access roads to the barge terminals and river elevators.
- Navigation channel.
- Locks.
- Barge fleet.
- Export elevators.[14]

To complicate this issue is the fact that the waterway is owned and controlled by the Army Corp of Engineers.

Siltation has been problematic in the McNary Dam pool, which is the first Columbia River dam below the Snake River. If the Snake River dams were to be breached (removed), much of the grain (and other commodities) that is now barged on the Snake River could be expected to shift to loading or unloading facilities in the McNary Dam pool. Elimination of barge transportation on the lower Snake River will result in a less efficient system for moving freight.

In addition to the effect that dam breaching would have on the barge system, transportation impacts would also be shifted to the road and rail systems in the region. The mainline rail system, short-line rail system, and state and county road systems could all be expected to carry an increased share of the freight now shipped by barge. Depending on the

[14] Export elevators are elevators that can load export ships directly from the elevator.

closure all grain currently shipped by barge may be shifted to rail. This could cause capacity constraints to be reached.

The short-line rail system can also be expected to handle an increased volume of grain if the Snake River dams are breached. Unfortunately, the short-line railroads that currently operate in the grain-producing region of eastern Washington only generate enough revenue to cover operating costs, and are not generally able to finance capacity upgrades. Rail-served grain elevators may also require substantial capital improvements, if they are to handle the grain expected to shift from barge transportation. Many of these elevators have not been used for rail loading in years, and the condition of their equipment is unknown. Additionally, the rail sidings at many of these elevators are only long enough for three cars, while the current standard for sidings is a minimum of 25 or 26 cars.

The highway system will also face increased costs, due to shifting transportation patterns. Roads that were not designed and constructed to handle large volumes of truck traffic can be expected to face increased maintenance costs.

Other issues to be considered in this discussion are:

- The need for the eastern Washington producers to continue to move containerized commodities such as peas and lentils.
- The need to move products from the coast to eastern Washington that barges will not handle, such as fertilizers.
- The cost of long distance trucking as compared to either rail or barge.
- The transportation of products that do not have access to a waterway.
- Rail competitiveness as compared to barge and truck.

Rate Impacts

The fact that the region served by the Snake River barge system is also served by railroads means that neither mode of transportation is able to charge monopoly rates for service. Breaching the Snake River dams, however, would decrease competition and would likely lead to rate increases. According to the National Corn Growers Association, "it has been demonstrated numerous times that areas throughout the country that do not have access to barge transportation have higher rail rates." The Tennessee Valley Authority examined the effect of barge transportation on rail rates on the upper Mississippi River, and concluded that "the continued availability of water transport appears to have a significant impact on the pricing behavior of other surface transportation modes—at least when these modes are reasonably close to the river. In particular,

there is a large body of economic literature, which suggests that available barge transportation effectively constrains railroad pricing for the transportation of commodities that are moved by barge. These barge-constrained rail prices have come to be called 'water-compelled' rates."

Statewide Information and Data Needs

The United States Department of Transportation (USDOT) and FRA are aware that statewide information and data is needed by the states in order to develop statewide rail plans. In these plans, the states set policies for freight and passenger rail transportation within their boundaries, establish priorities and implementation strategies that enhance rail service in the public interest, and serve as the basis for federal and state rail investments within the state. Currently, there is not enough data collected by the states or for the states in order for the analysis to be done to meet all of these expectations.

It is recognized that not only does the data need to be available but this data needs to be centralized into a designated office within state Departments of Transportation. The USDOT expects that these state rail plans will provide detailed insight into the concerns facing state transportation systems and set forth state visions of how rail transportation can address those issues. An element that the USDOT views as necessary includes multimodal transportation, especially ways in which modes can be integrated to serve transportation customers more effectively and efficiently.

States are in a unique position to provide information on local rail bottlenecks and resulting traffic congestion. Such information can affect the movement of goods and people, not only in that location but throughout the rest of the corridor as well. This lack of information can negatively affect the larger transportation network. Resolving such issues can improve transportation flows and positively affect the movement of goods and people far beyond state borders.

The current lack of a centralized point of data collection and retention limits the depth of the analysis that can occur on the system as a whole. As discussed throughout this plan, it is critical that the rail within the state and the nation be viewed as a total system and not individual ownerships or projects. Rail is one mode in the U.S. transportation system and it must be viewed as a part of the whole transportation system that must adequately and efficiently move both goods and people.

An example of the lack of critical information needed for decision makers is adequate data on short-line railroads within the state.

Short-line railroads (approximately 2,000 operating miles) are essential to the state economy, yet the state has virtually no physical condition information about these railroads. Most short-line railroads have no detailed condition inventory, while others have not updated their detailed condition inventory for many years.

A detailed, physical condition inventory of the state short-line railroad lines and facilities is needed to guide state investments for rail projects, specifically in the areas of project level analysis, infrastructure delivery planning, and decision making about rail infrastructure improvements. The condition inventory is estimated to cost between $1 million to $2 million, depending on level of detail and inclusivity required in the inventory.

A Statewide Rail Information Center Is Needed

A Statewide Rail Information Center would enable transportation planning and policy development to incorporate rail information to better support economic development and societal needs to address unexpected and disruptive events. A great deal of rail information and data exists at national, state, and regional levels. However, such data and information were not systematically organized and normalized to meet the needs of transportation planning and regional socioeconomic development.

The fact that rail information and data was not developed in a consistent way over time becomes a barrier for integrating rail information in transportation decision making. Gaps exist between availability of rail data and information and the needs for such data and information. This center would be able to develop needed data systematically and consistently to meet WSDOT's needs.

Regional economic planning organizations, transportation planning organizations, local communities, private industries, and information producers have a strong need for a statewide information center. This information center would assist these stakeholders to meet the challenges of systematically and consistently collecting, developing, and distributing freight information and data.

Summary

To retain the state's ability to compete in the complex world of goods movement, the state and its partners must position the state to provide efficient rail transportation. In order to accomplish this goal, the partners must work together to collect data that can be used to identify the chokepoints in the system. Those chokepoints must then be evaluated to determine their costs and benefits to both public and private stakeholders. A priority list must be developed based upon this analysis so that

policymakers can make educated decisions on the improvements that need to be funded and when. Working together the state can build an efficient rail network to support it citizens, businesses, and customers.

Washington State Department of Transportation

Chapter 6: State Roles and Partners

Washington State's Current Roles

Transportation planning is an ongoing collaborative process to develop a multimodal transportation system that:

- Supports sound transportation investment decisions as evidenced in the overall program and its elements.
- Supports economic vitality.
- Increases safety and security.
- Increases accessibility and mobility options.
- Protects the environment and improves quality of life.
- Enhances system integration and connectivity.
- Promotes efficient system management and operation.
- Emphasizes system preservation.[1]

"Moving Washington" articulates Washington State's (state) vision for transportation. The vision focuses on improving freight rail capacity, promoting public safety, maintaining economic viability, and enhancing environmental sustainability. State roles support this vision through varied legislative statutes.

Four groups within the state government have legislatively mandated roles and responsibilities for oversight, management, and implementation of the state's interest in passenger and freight rail. They are the Washington State Department of Transportation (WSDOT), the Freight Mobility Strategic Investment Board (FMSIB), the Utilities and Transportation Commission (UTC), and the Washington Community Economic Revitalization Board (CERB).

Washington State Department of Transportation

WSDOT is charged with planning, funding, implementing, constructing, and maintaining the multimodal transportation system in this state. As such, it is the conduit for state and federal transportation dollars. Freight and passenger rail programs are housed within the State Rail and Marine Office. See Chapter 1 for authorizing statutes.

WSDOT is the steward of a large and robust transportation system, and is responsible for ensuring that people and goods move safely and efficiently. In addition to building, maintaining, and operating the state

[1] WSDOT Planning Office, www.wsdot.wa.gov/planning/.

highway system, WSDOT is responsible for the state ferry system, and works in partnership with others to maintain and improve local roads, railroads, airports, multimodal transportation facilities, and promote programs that encourage citizens to use alternatives to driving alone.

WSDOT works towards supporting the following statewide transportation policy goals established by the state legislature for all public investments in transportation:

- Safety.
- Preservation.
- Mobility.
- Environmental quality.
- System stewardship.

State Rail Transportation Authority

WSDOT is the agency that oversees multimodal planning, including rail, at a statewide level. The WSDOT State Rail and Marine Office provides project management, oversight capacity, and editorial control over the *Washington State 2010-2030 Freight Rail Plan.*

State Rail Approval Authority

The WSDOT Secretary of Transportation is the state-designated approving authority for the *Washington State 2010-2030 Freight Rail Plan*.

State Freight Rail Plan Advisory Committee

The State Freight Rail Plan Advisory Committee serves as the external rail advisory body for the *Washington State 2010-2030 Freight Rail Plan.*

Internal Advisory Group

The WSDOT Strategic Planning and Programs Office coordinates statewide multimodal transportation planning, priorities, and issues, including programming and financial planning.

WSDOT State Rail and Marine Office

The State Rail and Marine Office, which is part of the WSDOT Freight Systems Division, has a strategic leadership role for freight rail investment that is essential to manage the state's freight and passenger rail capital programs and operations.

Strategic Planning

The State Rail and Marine Office coordinates with public and private sector partners to develop strategic rail plans, policies, and legislative proposals that guide strategic investment in freight rail transportation. The office conducts legislative-directed policy and legislation analyses and strategic investment assessments. It develops and uses benefit/cost tools that reflect legislative priorities and stakeholder interests to prioritize freight projects and evaluate funding requests. It also develops strategic plans, such as the *Washington State 2010-2030 Freight Rail Plan*.

Program and Project Management

The State Rail and Marine Office manages freight rail programs and projects (i.e. capital construction projects, Freight Rail Investment Bank, Freight Rail Assistance Program, Grain Train program, Produce Railcar program, and state-owned rail lines discussed in Chapters 3, 5, and 8) that promote the goals of the freight rail system. Some increase public safety by reducing at-grade crossings with high accident potential (WSDOT/FMSIB projects), while others enhance capacity or leverage federal funding sources that enhance economic viability to meet the needs of the overall state economy.

Statewide Freight Rail System Utilization Data and Information

The State Rail and Marine Office helps stakeholders build an understanding of the issues and think about the potential of freight rail as part of a strategic multimodal transportation system. The office conducts research and analyses for freight policies and legislations. It develops and provides statewide freight rail system utilization data and information that is essential for regional and local freight planning and operations. Examples include freight rail system databases, physical and condition inventories, maps, needs assessment analysis, capacity studies, commodity flow and socioeconomic impact analyses, and freight modeling to forecast future capacity and needs.

Public Outreach

The State Rail and Marine Office provides outreach consistent with state and federal policies to increase public awareness and to broaden the understanding of railroad system costs, benefits, and investments necessary to form a cohesive and efficient multimodal transportation network.

In the past 18 years, the State Rail and Marine Office has used its powers and authorities under Chapter 47.79 RCW (high-speed ground transportation), Chapter 47.76 RCW (rail freight service), and Chapter 47.06 RCW (statewide transportation planning) in the following ways:

- To develop the Amtrak *Cascades* service as part of its high-speed intercity rail program.
- To acquire and preserve rail lines and rights of way abandoned by Class I railroads (and other railroads).
- To provide assistance to short-line railroads to maintain service for shippers and receivers who do not have access to mainline rail service.
- To lease specialized railcars (e.g. hopper cars for the Washington Grain Train program, refrigerated cars for the Produce Rail Car program) to ensure an adequate pool of equipment for state growers.
- To develop Amtrak *Cascades* long-range and mid-range plans, and coordinate with other statewide planning efforts.
- To develop a benefit/cost methodology to evaluate projects for potential investment.

The State Rail and Marine Office is currently managing more than 50 capital rail projects that are proposed, funded, or underway, and support freight and passenger rail mobility in the state. When completed, these rail projects will result in improved freight mobility, improved safety, reduced rail congestion, upgraded tracks, and improved frequency of Amtrak *Cascades* passenger rail service.

The State Rail and Marine Office follows a rail improvement strategy for state participation that is consistent with the Washington State Constitution. There are a number of provisions in the constitution that limit the state's involvement in the private rail system. The guidelines outlined in Article VIII of the constitution, "State, County, and Municipal Indebtedness," limit the extent to which the state, counties, or cities can give or loan credit to corporations. The provisions of RCW 47.76.250 (essential rail assistance account - purposes) address this limitation by clarifying how a state may participate in projects with private ownership. This RCW also allows private entities that meet minimum eligibility criteria to receive grant funds, if contractual consideration is provided in return. At a minimum, such contractual consideration shall consist of defined benefits to the public with a value equal to or greater than the grant amount, and where the grant recipient provides the state a contingent interest adequate to ensure that such public benefits are realized.

Freight Mobility Strategic Investment Board

FMSIB was created by the Washington State Legislature in 1998 and is established as a rule-making board by RCW 47.06A.030. Its purpose is to administer projects and strategies that lessen the impacts of freight movement on local communities and facilitate efficient and profitable freight movement in the state. The 10-member board has representatives from state ports, railroads, cities, counties, WSDOT, the Governor's Office, truckers, marine operators, and private citizens. Periodically,

FMSIB issues a call for projects in order to maintain a 6-year list of active projects. FMSIB's past rail funding has primarily supported grade separation and crossing improvement projects.

Utilities and Transportation Commission

The UTC protects consumers by ensuring that utility and transportation services are fairly priced, available, reliable, and safe. The UTC is responsible for railroad safety under Title 81 RCW (transportation). The rail group is part of the UTC Safety and Consumer Protection Division, but separate from the Transportation Safety Group, which covers persons and property traveling on state roads. A primary responsibility of the rail group is to work with the Federal Railroad Administration (FRA) to inspect rail shipments of hazardous materials. There are more than 300 inspection points throughout the state, including shippers' facilities, railroad yards, and terminals.

Washington Community Economic Revitalization Board

CERB is a statutorily authorized state board. CERB is the state's strategic economic development resource, focused on creating and retaining jobs in partnership with local governments, and financing public infrastructure that encourages new development and expansion in targeted areas. It receives administrative support from the state Department of Commerce. It issues grants and loans that will retain existing jobs and create new ones, boosting business growth across the state. CERB can provide funding for rail projects that promote industrial development and has done so in the past. An example of this type of project was its $1,000,000 low-interest loan to the Port of Longview to help construct a second rail line and rail spurs serving a planned new facility for processing newly imported cars.[2]

Summary

Each of these groups within state government has knowledgeable staff that carries out its mandates effectively. However, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to work with the state. In some cases, it weakens the state's negotiating position.

The existing statutes, in Appendix 1-A, define the state interest in freight and passenger rail, assign roles and responsibilities for the oversight of the state's interest in rail, and establish a number of specific passenger and freight investment programs. The statutes provide a broad foundation for continued state participation in the preservation and improvement of the

[2] *Statewide Rail Capacity and System Needs Study, Final Rail Study Report*, Section 4.3, pp. 36-37, 2006.

rail transportation system, where there are public benefits to the state, its businesses, and its communities.

Washington's Strategic Partners

The state has a leadership role to encourage and build strong partnerships within the public and private sectors that ensures future economic competitiveness and viability among the railroads, ports, shippers, governments, communities, and other key stakeholders. Such partnerships are built on common interests, common understandings, and existing relationships. Appendix 6 contains a list of WSDOT freight partnerships. Some of these partners and partnerships are discussed below.

Freight Railroads

Freight railroads are business ventures. Their motivation to work with the state originates from the possibility of improved financial return. They increasingly recognize their important role in meeting public goals, such as improved air quality. Freight rail projects and policies that simultaneously boost a railroads' bottom line and advance the public interest may merit greater attention and resources from the state during the planning processes as railroads are more likely to reciprocate. Chapter 3 describes the state's railroads in more detail.

Ports

Ports are the only public agencies whose primary mission is to promote economic development, and the related businesses and jobs.[3] According to the Washington Public Ports Association (WPPA), there are 75 port districts in the state that were originally authorized in 1911 to provide maritime shipping facilities and rail/water transfer facilities. Since then, many additional authorities have been granted, such as building and operating airports (1941); establishing industrial development districts (1955); developing trade centers (1967); and developing economic development programs and promoting tourism (1980s). Ports provide the public a direct way to own and manage important community assets such as waterfront land and airport facilities. Chapter 5 describes the state's ports in more detail.

Shippers

Shippers are the public and private sector customers of the statewide rail system. They move a wide variety of goods, including raw materials, finished goods, and waste, from origin to destination, using rail and other modes of transportation. Top shippers are the manufacturers/industrial

[3] WPPA, Commissioner Resource Guide, www.washingtonports.org/downloads/commissionerresourceguide.pdf/.

carload shippers, the ports and international trade sector/intermodal container shippers, and the agricultural and foods products industry/bulk and specialized carload shippers.[4] Chapters 3 and 4 describe shipping demand and rail freight services in more detail.

Other Partners

Federal Railroad Administration

The FRA was created by the Department of Transportation Act of 1966 (49 United States Code 103, Section 3(e)(1)). The purpose of the FRA is to promulgate and enforce rail safety regulations; administer railroad assistance programs; conduct research and development in support of improved railroad safety and national rail transportation policy; provide for the rehabilitation of Northeast Corridor rail passenger service; and consolidate government support of rail transportation activities. Today, the FRA is one of ten agencies within the United States Department of Transportation (USDOT) concerned with intermodal transportation. It operates through seven divisions under the offices of the Administrator and Deputy Administrator.[5]

The federal government, through the Passenger Rail Investment and Improvement Act of 2008 (PRIIA), requires coordination of the state rail plan with state transportation planning goals and programs. It also requires coordination of rail transportation roles within the state transportation system. Under the "Intergovernmental Coordination" section of PRIIA, the state should also review freight and passenger service activities and initiatives with regional planning agencies, regional transportation authorities, and municipalities.

Regional Planning Organizations

There are two types of transportation planning organizations in the state with coordination and development roles for projects and programs by region. A Metropolitan Planning Organization (MPO) is comprised of elected officials in an urbanized region with 50,000 or more in population. MPOs provide a forum for local decision making on transportation issues of a regional nature. Under the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the policy for the metropolitan planning process is to promote consistency between transportation improvements and state and local planned growth and economic development patterns.[6]

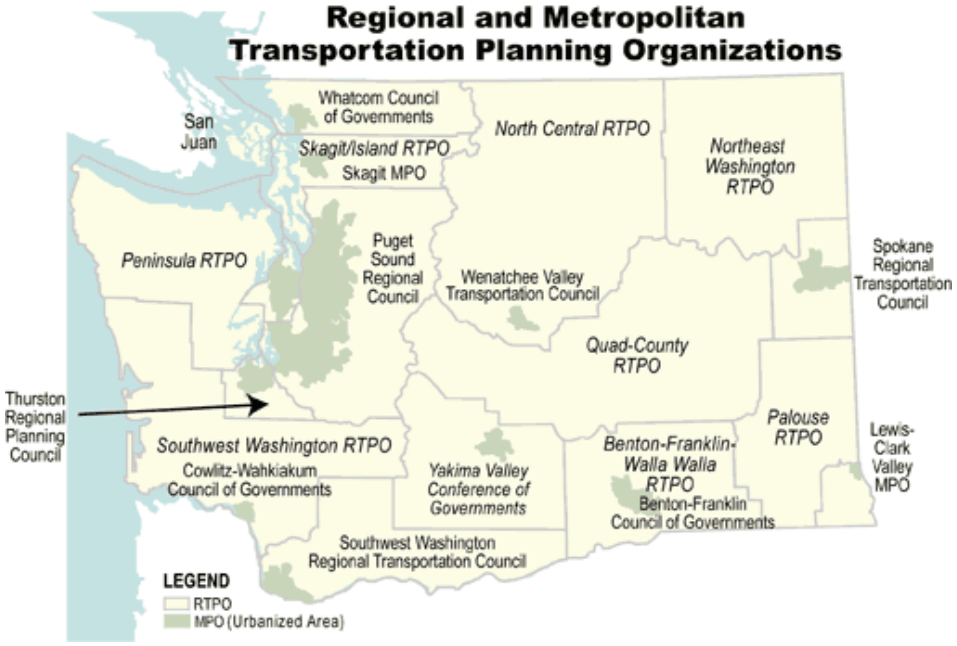
---

[4] *Statewide Rail Capacity and System Need Study*, Tech Memo 10.1, Analytical Plan, pages 4-5, 2006.
[5] FRA, www.fra.dot.gov/.
[6] MPO, www.wsdot.wa.gov/planning/metro/.

A Regional Transportation Planning Organization (RTPO) is formed through a voluntary association of local governments within a county or contiguous counties. RTPO members include cities, counties, WSDOT, tribes, ports, transportation service providers, private employers, and others. RTPOs were authorized by the state as part of the 1990 Growth Management Act to ensure local and regional coordination of transportation plans.[7]

MPOs and RTPOs are organized by function into executive, boards, policy boards, and technical assistance committees with supporting staff. Exhibit 6-1 is a map of the MPO and RTPO coverage across the state.

Exhibit 6-1: Regional and Metropolitan Transportation Planning Organizations



The MPO/RTPO Coordinating Committee includes a representative from each MPO and RTPO. It also includes a representative of the Tribal Transportation Planning Organization (TTPO). The TTPO is an advisory committee comprised of designated transportation planners from each tribe along with state and federal government representatives. The TTPO serves in a technical assistance and advisory capacity for tribal, state, and federal governments.

[7] RTPO, www.wsdot.wa.gov/planning/Regional/.

Tribal Governments

WSDOT maintains government-to-government relations with 35 federally recognized tribal governments. Twenty-nine tribes are located in the state; the additional six tribes have reservations outside the state, but have traditional homelands, treaty rights, or other interests within the state. Tribes may have public and private interests in freight rail development through the community and economic development arms of their governments.

Many tribes, including Chehalis Confederated Tribes, Colville Confederated Tribes, Kalispel Tribe, Nisqually Indian Tribe, Puyallup Tribe, Squaxin Island Tribe, Swinomish Tribe, Tulalip Tribes, and Yakama Nation, have reservation lands that are on or near railroad main lines or spurs. WSDOT will work with tribes to develop any potential rail-related projects and develop a detailed map that shows tribal reservation boundaries in relation to rail access.

WSDOT is committed to working with tribes to build durable intergovernmental relationships that promote coordinated transportation partnerships in service to all citizens. The *WSDOT Centennial Accord Plan* was created in accordance with the *1989 Centennial Accord* and the *1999 Centennial Accord Implementation Guidelines*. The *Centennial Accord* mandated that each state agency must have a procedure to implement effective government-to-government relations. The *WSDOT Centennial Accord Plan* includes the WSDOT Secretary's Executive Order on Tribal Consultation, a Dispute Resolution Policy, and detailed descriptions of the programs, services, and funding available to tribes from key WSDOT divisions and offices.[8]

Public-Private Partners

With funding limited for any infrastructure project, future investments may require involvement in public-private partnerships. Public-private partnerships are defined as a cost-sharing method of funding a project between public and private entities based on expected benefits. They may use a combination of funding sources and may include an integration of tax exempt bond financing (when available), state and federal loan guarantees, grants, or contributions from the railroads, as well as dedicated funding sources. Public ports use public-private partnerships, for example, in their lease arrangements for joint development of a terminal or facility. Ports transfer the future services rendered by a fixed

[8] WSDOT *Centennial Accord Plan*, March 2009, www.wsdot.wa.gov/tribal/Centennial_Accord.htm/.

asset (e.g., a container crane or other terminal facility) to a private organization, while retaining the title to that fixed asset.[9]

Strategic Rail Corridor Network

The Railroads for National Defense (RND) Program ensures the readiness capability of the national railroad network to support defense deployment and peacetime needs. The RND Program, in conjunction with the FRA, established the Strategic Rail Corridor Network (STRACNET) to ensure that FRA minimum rail needs are identified and coordinated with appropriate transportation authorities. STRACNET is a nationwide, interconnected, and continuous rail line network serving defense installations. STRACNET works with the FRA and USDOT's Surface Transportation Board, state departments of transportation, American Association of Railroads, American Railway Engineering and Maintenance of Way Association, Railway Industrial Clearance Association, and individual railroad companies to protect this railroad infrastructure.[10]

West Coast Corridor Coalition

The West Coast Corridor Coalition (WCCC) is a partnership of state departments of transportation, regional and local transportation agencies, ports, and related transportation organizations (both public and private) from Alaska to California. The WCCC has begun to identify regional, system-wide issues and develop a foundation allowing the coalition and its members to address issues and chokepoints that cross jurisdictional interests and financial boundaries.[11]

Strategic Planning

The State Rail and Marine Office recently participated in an FRA meeting as part of the development of a preliminary national rail plan. The issues discussed were summarized in the *2009 Preliminary National Rail Plan* (below).[12]

- Collaboration and stakeholder agreements.**
- Implementation timeline and evaluation criteria.***
- Need for public education/outreach.*
- Livability issues.
- Interconnectivity.*
- Sustainable federal funding.**

---

[9] *Statewide Rail Capacity and System Needs Study*, Tech Memo 6, p, 25, 2006.
[10] RND, www.tea.army.mil/DODProg/RND/default.htm/.
[11] *West Coast Corridor Coalition Trade and Transportation Study*, www.wsdot.wa.gov/NR/rdonlyres/5A019EA4-50EF-4286-96F9-05398B52608A/0/_DR1_WCCC_TradeandTransportationStudy_COMPLETEweb.pdf.
[12] *2009 Preliminary National Rail Plan*, page 32.

- Sustainable state funding.*
- National equipment standards.**
- Environmental processes.
- Positive Train Control.*

* Issue was briefly discussed at the Seattle meeting.
** Issue was raised multiple times/discussed in greater detail at the Seattle meeting.
*** Most prominent issue discussed at the Seattle meeting.

The *2009 Preliminary National Rail Plan* addresses the need to rebalance the transportation system by strategically aligning the state rail plans and the national rail plan. It requires states to provide key leadership in developing common understandings, aligning goals, and taking actions that further state and national policy goals.

PRIIA (PL 110-432, Division B, Section 303) contains a legislative mandate that directs the FRA to develop a long-range national rail plan consistent with state-approved plans. PRIIA requires states to establish or designate a state rail transportation authority. This authority is responsible for:

- Developing statewide rail plans and policies for freight and passenger rail transportation within their boundaries.
- Establishing priorities and implementing strategies that enhance rail service in the public interest.
- Serving as the basis for federal and state rail investments within the state.

The FRA expects state rail plans to provide detailed insight into the concerns facing state transportation systems and to set forth their vision of how rail transportation can address those issues.

In addition to PRIIA requirements, the *2009 Preliminary National Rail Plan* provides the states with a framework of elements that the FRA views as necessary for creating a viable national rail plan. The FRA encourages states to collaboratively raise additional issues and provide other relevant information. States need to consider all other modes of transportation, especially ways in which modes can be leveraged to serve transportation customers more effectively and efficiently.

The National Rail Plan will examine passenger and freight corridors running through and between states, and coordinate the states' plans into a blueprint for an efficient national system, thereby meeting both regional and national goals. The majority of the infrastructure is owned and

maintained by the freight railroads. Therefore, the FRA will continue to work with states to develop plans that contain proposals or initiatives for partnering with freight carriers and other stakeholders in the development of plans and objectives.

The National Rail Plan will likely encourage rail development and growth, much like the model of the interstate highway system. The plan will also recognize that the traffic flow of passengers and freight rely on the connectivity of regional corridors that pass through several states.

Future Roles

Washington State

The *Statewide Rail Capacity and System Needs Study* (2006) made the following recommendations about building and aligning existing state powers and authorities to further the state interest in the rail system (some recommendations have been implemented):

- Influence the investment decisions of the Class I railroads to resolve rail chokepoints of critical importance to key rail user groups in the state and, thereby, provide more capacity for state rail users. This will generally involve public-private partnerships in which the state is a minority partner, but the state's investment can influence the timing and priority of the Class I railroads' investment decisions.
- Increase advocacy for a federal program that addresses critical national rail capacity needs. Many of the key capacity chokepoints in the state rail system affect the national economy and shippers outside of the state. The state should look for federal action and funding to address these chokepoints.
- Work with rail users in industrial and agricultural markets to assist in the transition to rail service models that preserve high quality, reasonably priced, rail service options. The state can help ensure that these transitions occur in a timely fashion before the lack of action has negative economic consequences for the state.
- Work with third-party service providers and advocate for innovative operations practices and services that support the economic development goals of the state and its communities.
- Establish local governance models that allow shippers and affected communities to be involved directly in the resolution of short-line problems.
- Support cost-effective intercity passenger rail options that improve the overall balance and performance of the state's highway and air passenger systems.

- Create a more effective, centralized, rail management function within state government with authority to advocate and negotiate state interests with the railroads.[13]

The study recommended that the state continue to participate in the preservation and improvement of the freight and passenger rail transportation system where there are public benefits to state businesses and communities. The study also recommended that state decisions to participate in projects, programs, and other rail initiatives be based on a systematic assessment and comparison of benefits and costs across users and across modes.

State Rail and Marine Office

Based on recommendations of this study and previous studies, the State Rail and Marine Office should continue to preserve and improve the rail transportation system, guided by the following general principles.[14]

1. Emphasize operations and nonfinancial participation in projects before capital investment.
2. Preserve and target competition.
3. Encourage private investment that advances state economic development goals.
4. Leverage state participation by allocating cost responsibility among beneficiaries.
5. Require projects to have viable business plans.

The State Rail and Marine Office should be designated by legislation as the single entity to coordinate and direct the state's participation in the preservation and improvement of the rail transportation system. The office should have the authority to negotiate directly with the railroads.

As a single entity performing these duties, the State Rail and Marine Office should be able to:

1. Represent the interests of multiple stakeholders in negotiations with rail carriers more effectively than individual stakeholders by themselves.
2. Develop strategic packages of projects and actions across the state that would effectively promote state interest and be more attractive to the rail carriers than dealing with projects on a case-by-case basis.

[13] *Statewide Rail Capacity and System Needs Study*, Final Rail Study Report, Section 4.4 through Section 5.6, pp. 37-55, 2006.
[14] *Statewide Rail Capacity and System Needs Study*, Final Rail Study Report, Section 4.4 through Section 5.6, pp. 51-52, 2006.

3. Better serve the interests of multiple communities in resolving common rail issues.
4. Work more effectively with partners in other states and at the national level.

The State Rail and Marine Office should continue its leadership role to influence and shape state and national level development of rail policies and programs, including the coordinated development of multistate coalitions to address rail system needs across the Pacific Northwest.

The State Rail and Marine Office should continue its leadership role to work with the railroads to identify, prioritize, and implement the most cost-beneficial regional improvements.

The State Rail and Marine Office should also implement an asset management plan to govern investment and management decisions for state-owned rail assets. Guiding principles should include:

1. Decisions based on a business-case analysis of the goals and objectives for each class of assets.
2. Clear performance measures and a monitoring system to determine how assets are performing.
3. Benchmarks for each performance measure based on industry standards.
4. Development and use of an inventory management system, including information about condition and disposition of assets.

Continued Statewide Coordination and Partnerships

Public-public, public-private, and private-private partnerships of the future will increase in importance and include new financing mechanisms that involve multistate, multimodal coordination. The *Statewide Rail Capacity and System Needs Study* (2006) includes examples of innovative partnerships, such as rural rail transportation districts, multistate consortiums, statewide strategic partnership board, and rail operations forums. Rail operations forums, for example, are meetings of public and private sector rail stakeholders that are held on a monthly or quarterly basis. At the meetings, stakeholders discuss, plan, and implement operational actions that can improve the efficiency or velocity of the rail operations of the group.[15]

Investments in big projects with statewide public benefits will require public leadership and partnerships driven by public interest. With the American Recovery and Reinvestment Act of 2009 Track 3 and 4 grant

[15] *Statewide Rail Capacity and System Needs Study*, Tech Memo 10.3, pp. 1-8, (2006).

applications, for example, the lead agency of each project would need to develop a funding plan and partnership profile in order to demonstrate the 50 percent funding match and leverage funds for public funding support. To enable effective corridor-level system development with impacts beyond the confines of state boundaries, multistate multimodal coalitions and plans are needed. Such coalitions and partnerships, using a sound benefit/cost methodology based on goals and legislative priorities, will provide input into the state prioritization and investment processes to prioritize projects in the statewide public interest. The state will have an important leadership role to encourage partnerships that succeed in meeting future rail infrastructure priority needs.

Conclusion

The WSDOT State Rail and Marine Office has an increasing strategic planning role in statewide passenger rail and freight rail development. Clarification is needed to align the office's role and authority with the vision and goals developed earlier in this plan. To be in alignment with other state plans, the state passenger and freight rail plans should be combined into a "one-rail" plan and updated frequently in the future.

Washington State Department of Transportation

Chapter 7: Investment Prioritizing and Project Evaluation

Freight rail has many benefits. With its cost effectiveness, fuel efficiency, safety records, and lower environmental impacts, freight rail is a viable option to help solve economic, social, and environmental problems with integrated solutions.

The freight railroads in Washington State (state) are owned mainly by private entities and for-profit companies. Despite primarily private ownership, freight rail transportation provides public benefits that warrant taxpayer participation in improvements at both federal and state levels. The common public benefits associated with freight rail include stimulating the state's economy, supporting local communities and businesses with jobs and revenues, reducing congestion, improving public safety, offering a transportation choice for shippers, reducing environmental pollution, and saving energy.

Investment policies in freight rail are developed by both public and private policymakers. However, the benefits and costs from public perspectives are very different than those from private perspectives. Therefore public investment priorities, criteria, and decision-making processes are also different from those of private investment.

Decision makers of public investment include federal agencies, state agencies, tribal agencies, and regional and local public entities, such as counties, cities, and ports. Private investment decision makers include private entities and individuals, such as railroads.

Public and Private Benefits

For rail-related investment, private benefits have typically accrued to rail carriers, shippers, rail property owners, and other non-governmental groups. Public benefits are broadly assigned to government agencies that represent taxpayers.

The Passenger Rail Investment and Improvement Act of 2008 (PRIIA)[1] definitions of public and private benefit are described below:

[1] PRIIA (Public Law No. 110-432, Division B, enacted Oct. 16, 2008, Amtrak/High-Speed Rail).

Private Benefit

Private benefit is a benefit accrued to a person or private entity, other than Amtrak, that directly improves the economic and competitive condition of that person or entity through improved assets, cost reductions, service improvements, or any other means as defined by the Secretary.

Public Benefit

Public benefit is a benefit accrued to the public, in the form of enhanced mobility of people or goods, environmental protection or enhancement, congestion mitigation, enhanced trade and economic development, improved air quality or land use, more efficient energy use, enhanced public safety or security, reduction of public expenditures due to improved transportation efficiency or infrastructure preservation, and any other positive community effects as defined by the Secretary.[2]

Federal Requirements

The new law (PRIIA) requires the project list, in states' long-range service and investment programs, to document the anticipated public and private benefits and the public investment benefit-cost correlation for each project. PRIIA also specifies that states consider additional economic and societal impacts of investment projects (Exhibit 7-1).

Exhibit 7-1: Federal Requirements for Benefit Assessment and Documentation

Required Documentation for Each Project	**Anticipated private benefits**	• Economic competitiveness • Cost reductions • Improved assets • Service improvements
	Anticipated public benefits	• Congestion mitigation • Enhanced trade and economic development • Improved air quality • Improved land use • Enhanced public safety • Enhanced public security • Reduction in public expenditures • Community effects
	Correlation between public funding contributions and public benefits	***Statement and/or benefit/cost ratio***

Source: American Association of State Highway and Transportation Officials (AASHTO) *State Rail Planning Guidebook September 2009*

[2] *2009 AASHTO State Rail Planning Guidebook*

State Requirements

Under ESHB 1094, the Washington State Legislature required the Washington State Department of Transportation (WSDOT) to develop and implement the benefit/impact evaluation methodology recommended in the *Statewide Rail Capacity and System Needs Study*, which was published December 2006.

The study recommended that three categories of public benefits should be included in benefit/cost (B/C) analysis (Exhibit 7-2).

The study also recommended that the state measure benefits in terms of each user group. The measures that best describe the potential benefits and impacts to each group are presented in Exhibit 7-3.

Freight Rail Investment Analysis in Washington State

Priorities and Criteria

Projects should be evaluated using the same methodology that would provide consistent and objective comparisons to federal grants, state funds, local public entities, and private partners. The value of a standard methodology, or at least broadly accepted factors or parameters, is to establish mutually acceptable benefits vernacular for evaluating the projects side-by-side.

Priorities and criteria for evaluation reflect public investment policies and determine how the evaluation will be performed.

Benefit evaluation in this state will follow both federal and state priorities and criteria. PRIIA does not specifically require states to prioritize projects, but it does require a prioritization of options to increase intermodal connectivity. State legislation requires that WSDOT develop a B/C methodology and use it to evaluate state projects based on six clearly specified legislative priorities:

- Economic, safety, or environmental advantages of freight movement by rail compared to alternative modes.
- Self-sustaining economic development that creates family-wage jobs.
- Preservation of transportation corridors that would otherwise be lost.
- Increased access to efficient and cost-effective transport to market for the state's agricultural and industrial products.
- Better integration and cooperation within the regional, national, and international systems of freight distribution.
- Mitigation of impacts of increased rail traffic on communities.

Exhibit 7-2: Variables for the State Benefit Cost Analysis

Variable Description	Explanation
Transportation and Economic Benefits	
Avoided maintenance costs	If the project preserves rail service, the no-action alternative may put more trucks on the highway. This may produce a net positive or negative benefit, to be evaluated based on the type of road affected and the cost of maintaining the rail line.
Reduction in shipper costs (for shipments originating in state) freight only	Benefits are derived from lower logistical costs to the shippers, which ultimately can lead to lower consumer prices.
Reduction in automobile delays at grade crossings	Benefits result from improving grade crossings and decreasing automobile delays.
Economic Impacts	
New or retained jobs	Jobs that a particular project action may keep from moving out of the state (e.g., by construction of a rail spur serving a factory or warehouse, etc.), or new jobs that are created within the state. Also to be considered are changes in job quality and pay levels (e.g., adding, losing, or changing union jobs). This measure accounts for both retained and new jobs.
Tax increases from industrial development	A rail action project may foster industrial development that results ultimately in increased industrial property taxes to the state.
External Impacts	
Safety improvements	By diverting truck freight to rail, savings on highway safety improvements can occur.
Environmental benefits	Railroads are on average three or more times more fuel efficient than trucks. The state can benefit from savings due to environmental improvements.

Source: *Statewide Rail Capacity and System Needs Study* (2006)

Exhibit 7-3: Benefit and Cost Measures

Rail User	Benefit and Cost Measures
State	• Jobs created□retained (private sector, public sector, and impact on rail-related union jobs). • Tax benefits (through new or retained businesses). • Contribution to transportation system efficiency□balance (measured in terms of reduced travel delays, improved system reliability, or system redundancy as appropriate). • Environmental benefits (air pollution and water quality impacts). • Safety benefits (reduced property damage, injuries, and fatalities). • Availability of partner funding. • Cost to state. • B□C ratio (using recommended B□C analysis methodology)
Shippers	• Business cost impact (through impact on cost of service). • Access to service (does project increase rail□transportation service options). • Service reliability (on-time performance). • Transit time.
Passengers	• Rail capacity for passenger trains. • Travel costs. • Travel time. • Increased modal choice□access.
Railroads	• System velocity improvements. • Hours of train delay. • Yard dwell time. • Increased revenue traffic. • Equipment availability.
Ports	• Throughput. • Market share.
Communities (similar to state)	• Environmental benefits. • Safety benefits. • Reduced roadway delays and truck□auto delay at grade crossings. • Local jobs created or retained.

Source: *Statewide Rail Capacity and System Needs Study* (2006)

These priorities are in order of relative importance specified by the legislature. This requirement also directed WSDOT to evaluate rail project benefits compared to alternative modes.

Understanding Principles in Assessing Public Investment

Investment analysis in the public sector is very different from private sector analysis. There are several principles that must be understood in analyzing public investment and public benefits.

Discounting

Discounting addresses the problem of translating values from one time period to another. The larger the discount rate, the more weight that is placed on benefits and costs in the near-term, over benefits and costs in the future. Long-term benefits, such as environmental quality, are important public policymaking criteria. Consequently, public investment analysis usually uses a relatively lower discount rate than the private sector.

Leveraging

Public projects usually involve multiple sources of investment and partnership. While the analysis of such an investment assesses the efficiency, it also assesses the effectiveness of public investment only. In other words, a measure of the effectiveness of public investment is how much additional investment a public investment can bring into a specific project. This measure is called leveraging.

Distributional Benefits

Many public investment projects provide distributional benefits to the public by transferring public resources to where they are needed most. Such a transfer payment is not a traditionally defined benefit. It could be measured as a public benefit, if it helps reach the goal of public policy to benefit the targeted public group.

With Without Principle

Many public investment projects provide benefits to the public by mitigating negative impacts. While such investment does not create positive value, it reduces the negative value. The difference between the larger negative value and the smaller negative value is defined as a benefit based on the with/without principle. For example, a freight rail capital project could lead to removal of some trucks from a highway. This will reduce environmental emissions since rail, in general, has less emission per ton-mile. Without such an investment project, societal loss due to higher emissions would be much larger. The reduced societal loss would be the benefit of the investment project.

Period of Analysis

The length of a period used for analyzing benefits and costs is very important. Many public benefits last for a long period of time, while investment occurs in early stages of a project life. Therefore, a full lifecycle is preferred in public investment analysis.

Evaluation Strategies and Methods

PRIIA-Defined Benefits and Potential Project Evaluation Strategies

Exhibit 7-4 outlines each of the PRIIA-defined benefits and potential project evaluation strategies for these benefits.

Exhibit 7-4: PRIIA-Defined Benefits and Evaluation Strategies

Benefits	Source of Benefits or Impacts	Potential Measurement
Economic competitiveness	Improved assets and service reliability or frequency allows companies to do business more efficiently.	Lower business costs (e.g., savings resulting from faster travel time and other improvements) increase the competitiveness and business attraction to the state.
Improved assets	Infrastructure, rolling stock, or facilities improvements.	Lower costs for capital maintenance of assets.
Cost reductions	Time savings provides unit cost reductions (labor, inventory, etc.) accruing to carriers, shippers, and passengers.	Lower total business costs (from all categories) and lower personal travel costs (e.g., less auto maintenance and gasoline; fewer hours of highway delay).
Service improvements	Time savings, improved reliability, new access, increased frequency, added capacity.	Time savings due to increased speed, reliability, and frequency accruing to rail passengers, carriers, and shippers.
Enhanced mobility of people and goods	Improved mode choice options and services.	Reduced distance to passenger stations or freight terminals and improved intermodal linkages.
Environmental protection or enhancement	This consideration is closely related to air quality effects (below) but could measure other benefits to water quality, wildlife, noise, historic resources, or other factors outlined in National Environmental Policy Act (NEPA).	States should use existing study information from Environmental Impact Statements (EIS), Environmental Assessments (EA), or other resources and customize to the unique characteristics of the project.

Benefits	Source of Benefits or Impacts	Potential Measurement
Congestion mitigation	Highway-to-rail diversion of passengers and freight decreases highway congestion. Investment in rail capacity decreases rail congestion.	Some statewide or multi-state highway models can predict change in hours of delay. Other tools, including FHWA's HPMS or HERS can be used to estimate delay effects. Rail carriers can predict similar measures.
Enhanced trade and economic development	Similar to the economic competitiveness measure with benefits originating from improved travel time, capacity, or improved access or connectivity.	Estimated increase in tonnage or value of commodities due to rail improvement.
Improved air quality	Changes in mode share are the chief drivers of air quality benefits. On a per-passenger-mile and per-ton-mile basis, rail generally produces more savings than other modes.	Use the change in miles traveled by mode to estimate the net reduction in emissions from standard factors for pollutants produced on a per-mile basis for passengers or freight.
Improved land use	Better coordination of transportation and land use.	Percentage of residents and businesses with good access to rail facilities/stations. Cost savings by reducing average trip distance to rail by auto or commercial vehicle.
Enhanced public safety	Reduced highway vehicle miles traveled (VMT) for truck and auto, lowering crash exposure.	Savings resulting from lower medical care, vehicle repair, highway delay, and legal costs associated with crashes. Standard cost of crash rates per mile.
Enhanced public security	Protecting the public from crime or terrorist events results in public cost savings similar in scope to those associated with safety.	Reduced risk of security incident resulting from investment in surveillance, physical barriers, or other measures.
Reduction in public expenditures	Improved transportation efficiency or infrastructure preservation from decreased highway VMT.	Savings from lower maintenance and safety directly resulting from lower auto and truck VMT.
Community effects	Enhanced livability provided by expanded transportation options, including intermodal linkages, walk-ability, and local commerce.	New or improved linkages between modes, high-density development, and non-motorized transport (e.g., walking paths, bike trails).

Source: *AASHTO State Rail Planning Guidebook* September 2009

Methods Recommended in the *Statewide Rail Capacity and System Needs Study* (2006)

The Washington State Transportation Commission (WSTC) *Statewide Rail Capacity and System Needs Study* used several sources of information to determine the variables to measure public benefits in the state, including the following:

- Best practices review of rail B/C methodologies used by other states and organizations.
- Consultation with area experts—including shippers, community association representatives, ports, railroads, and others—who are members of the Washington State Rail Study Technical Resource Panel.
- Metrics derived from established state policy as captured in the Revised Code of Washington and in previous case studies of state participation in the rail system.

The study recommended that B/C ratio be applied to all projects, both passenger and freight. The B/C ratio would enable state decision makers to evaluate cost-benefit tradeoffs and not focus solely on benefits. The precise calculation methodology for the B/C ratio is left to WSDOT to finalize and may vary depending on the project type and the level of investment. The study also recommended that the three category benefits (in Exhibit 7-2) are quantified in the benefit/impact methodology to be developed by WSDOT.

However, the B/C ratio is only one of the measures used to evaluate benefits and impacts to the state. Some of the other measures are also included within the B/C calculation, but they are also broken out separately so that decision makers can weight these more heavily when making decisions than they would be in a true B/C ratio. The framework does not recommend a specific weighting procedure, but leaves this decision to the legislature or the WSTC.

The study also recommended user group benefit assessment. Measures that best represent public benefit are determined for each user group. The metrics to characterize and measure the public benefit of a rail action are presented in Exhibit 7-3. The metric selection reflects the stakeholder involvement process in WSTC's study. Benefits and impacts of individual projects or groups of projects are evaluated for each of four groups of affected parties: 1) the state; 2) users (shippers and passengers); 3) carriers (railroads and ports); and 4) communities (affected by rail service to or through the community). The idea of the framework is to determine whether the impacts of the project or package on each group is positive or negative, and if the impact is high, medium, or low, relative to the needs

of that group. The results of this evaluation tell whether other parties should be involved in the project and what type of partnership arrangement is most appropriate. The evaluation of a project as having high, medium, or low benefits/impacts is always based on a comparison with some other action—at least a no-action scenario, but preferably at least one other option that may or may not involve providing the transportation service by another mode (Exhibit 7-5).

Exhibit 7-5: Possible Methodology to Measure Public Benefit in Washington State

	Measures	No action	Alternative A	Alternative B
State	Jobs			
	Tax Fee Benefits			
	System Efficiency			
	Environmental Benefits			
	Safety Benefits			
	Partner Funding			
	Cost to State			
	Benefit Cost			
	Transit Time			
Summary State				
Shippers	Business Cost Impacts			
	Access to Service			
	Service Reliability			
Summary Shippers				
Passengers	Rail Capacity for Passenger Trains			
	Travel Costs			
	Travel Time			
	Increased Modal Choice Access			
Summary Passengers				

	Measures	No action	Alternative A	Alternative B
Railroads	System Velocity Improvements			
	Hours of Train Delay			
	Yard Dwell Time			
	Increased Revenue Traffic			
	Equipment Utilization			
Summary Railroads				
Ports	Throughput			
	Market Share			
Summary Ports				
Communities	Environmental Benefits			
	Safety Benefits			
	Reduced Roadway Delays			
	Local Jobs			
Summary Communities				
National	Percent Benefits in Washington State			
	Other States Benefiting			
Summary National				

Source: WSTC *Statewide Rail Capacity and System Needs Study* (2006)

Rail Benefit Impact Evaluation Methodology Description

The benefit/impact evaluation method was developed in 2007, based on legislative direction and priorities specified by the legislature.

Stakeholder Involvement

WSDOT formed an advisory group that includes a broad range of stakeholders to guide the development of Rail Benefit/Impacts Methodology. The Advisory Committee consisted of the Freight Mobility Strategic Investment Board, Department of Commerce, Department of Agriculture, WSTC, labor, mainline railroads, short-line private railroads, representatives from cities and counties, various ports, legislative and Governor's staff, and WSDOT staff.

Guiding Principles

The Advisory Committee developed six guiding principles for the development process:

- Provide a benefit/impact evaluation methodology and supporting tools as recommended in the *Statewide Rail Capacity and System Needs Study* (2006).
- Develop a benefit/impact evaluation methodology that includes the priorities set forth in ESHB 1094.
- Develop a benefit/impact evaluation methodology that includes measurable public benefits.
- The *Statewide Rail Capacity and System Needs Study* (2006) recommends using only a few good measures, including applying qualitative analysis techniques.
- This document is dynamic and proposed alternative evaluation methods should be reviewed for incorporation or used as supplements.
- Decision makers will take into account the public interest and good, going beyond analysis of single stakeholder interests.

Rail Benefit/Impact Evaluation Methodology

The Rail Benefit/Impact Evaluation Methodology is comprised of the following components:

- Rail Benefit/Impact Evaluation Methodology (Guidance Document)
- Proposal Application
- Rail Benefit/Impact Evaluation Workbook
  - Legislative Priority Matrix
  - Project Management Analysis
  - User Benefit Levels Matrix
  - Benefit/Cost Analysis Calculator
  - Benefit/Cost Analysis Summary Sheet
  - Benefit/Impact Evaluation Summary Sheet

The components of the methodology are intended to assist the decision maker in the evaluation and recommendation process. The level of rigor applied to the use of any tool should recognize the type, size, and complexity of project and expectations of results.

Application Process

The application for a rail grant or loan is the document that gathers the initial information that will be evaluated for possible selection. The application needs to collect enough information to effectively start the evaluation and selection process. It also needs to contain information for follow-up calls to users and applicants.

Since calls for projects may be driven by a variety of factors and limitations, there needs to be clear communication on the application document to ensure the right information is gathered. A standard application may not fit all calls for projects; therefore the application may need to be modified to gather the appropriate information.

At other times, a project may simply be assigned without an application process through legislation. Such a project still requires that a benefit/impact evaluation be conducted and the results and recommendations shared with the appropriate parties to validate the project or show the level of impacts and alternatives.

Benefit Cost Calculator

The B/C Analysis is a major component of the Rail Benefit/Impact Evaluation Methodology that will be used when evaluating rail projects. The calculation (B/C ratio) produced will also be supplemented with an assessment of other benefit categories. That supplemental information will be generated by the requested project information in the application form. The major categories for B/C Analysis will be:

- Transportation and economic benefits.
- Economic impacts.
- External impacts.

The Benefit/Cost Analysis Calculator was created to assist in a fast evaluation of benefits as specified in the previous section. The Benefit/Cost Analysis Calculator is a spreadsheet with areas of benefit, equations for calculations, and benefit parameters to calculate the B/C ratio for a given project or action on a project.

The defined equations and input areas in the calculator are based on documented standards, research, and common practice. These equations will be periodically reviewed and updated with changes in industry practices, price indexes, and new accepted standards. The input values must be verified based on actual data and verifiable field information in consideration of expected project results, freight logistics, user logistics, local economic influences, current costs, impacts to industries, and historical data. The Benefit/Cost Analysis Calculator uses default values that are included in the equations contained in the Benefit/Cost Instruction sheet. They are used to calculate a dollar value for benefits. These default values are based on generally accepted practices and some may need to be adjusted for project specific goals and objectives. For more detailed information on the application of values to specific project objectives and

goals, a review of *NCHRP Report 586* should be done.[3] WSDOT economists will update these default values every biennium.

Legislative Priority Matrix

This qualitative evaluation tool was also developed to help policymakers understand the results and effects of proposed investment. One of these qualitative matrices is Legislative Priority Matrix. The Legislative Priority Matrix worksheet is intended to help the evaluator determine how a project aligns with the legislative priorities. The priorities were provided in a relative order of importance. Each priority area is weighted based on that order.

The benefit measures that have been identified for each priority are to be used as a baseline of measures. In the future, there may need to be other or different measures considered for a project. As the new measures and their parameters are identified and proven, they should be included for use on future projects. This matrix is used to aid benefit/impact evaluation in terms of state priorities and to provide additional information based on expert and value judgments to determine a project's public value.

Project Management Assessment Matrix

The Project Management Assessment Matrix is intended to help determine the current status of the project and how likely it can successfully be delivered within the constraints of scope, schedule, and budget. The scores are compiled to determine a project management score. The comment box should note how a score was determined.

User Benefit Levels Matrix

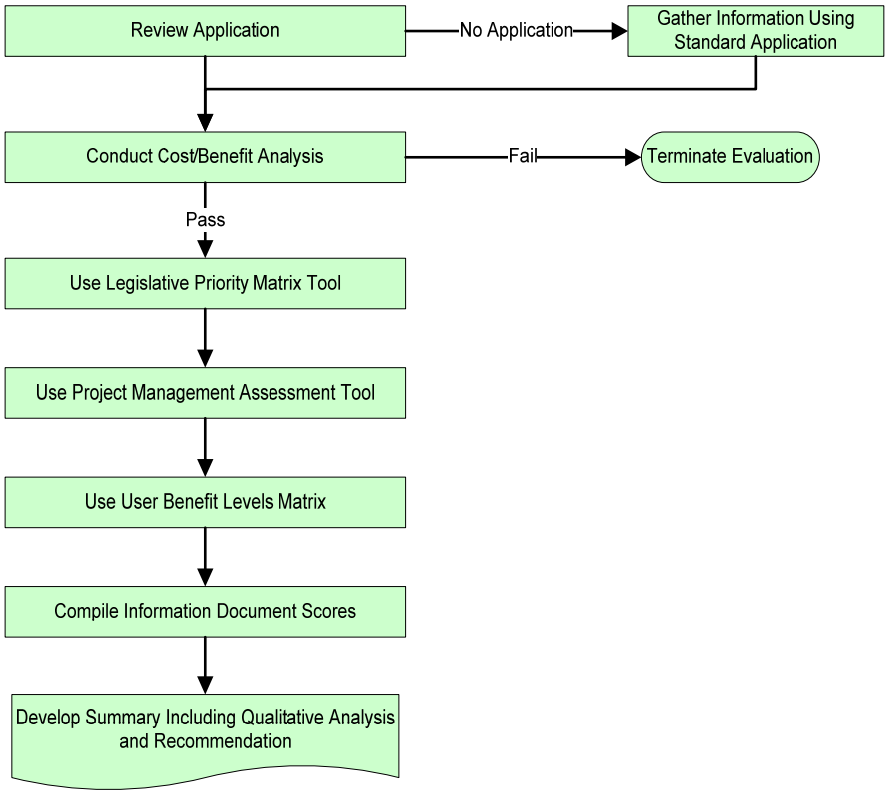
The User Benefit Levels Matrix is intended to help determine who benefits from the project and at what level. Each measure of the matrix is to be completed by assigning a percentage that represents the amount of benefit for each user. The percentage of benefits is then added for each user and divided by the number of measures used, to provide an overall project benefit for each user.

Project Evaluations

A project evaluation may begin with a proposal application or by a request from the legislature. Both will require evaluation steps to be completed as indicated in Exhibit 7-6 and as described below:

[3] TRB NCHRP Report 586: Rail Freight Solutions to Roadway Congestion - Final Report and Guidebook.

Exhibit 7-6: Benefit Impact Evaluation Process



1. Review the application or obtain information to conduct the evaluation. If there is no application, use the current general project application, eliminating superfluous questions. This is a tool to identify what information is needed from the project stakeholders.
2. Next, the WSDOT State Rail and Marine Economist will compile data for a B/C analysis and use the Benefit/Cost Analysis Calculator. Any additional data or information necessary to analyze the true benefits and costs will be included. This may require a qualitative analysis and summary.
3. If the Benefit/Cost Analysis Calculator indicates a ratio greater than one, then the Legislative Priority Matrix should be used. The evaluator should use the tool as indicated in its guidance for each priority measure. Once complete, justification for selections and a score will become part of the project documentation.
4. The evaluator will use the Project Management Assessment Matrix. If the evaluator has questions on any of the project management assessment areas, they should contact one of the State Rail and Marine Office Project Managers. This will ensure consistent interpretation with adopted standard operating procedures.
5. The final tool to be used is the User Benefit Levels Matrix. This tool helps determine which users are receiving a benefit and at what level.

6. Once a project has been through the above steps, the evaluator needs to compile all of the information to generate a score and to develop a recommendation. Depending on the project, a qualitative summary may need to be included to convey benefits that are not easily quantifiable.
7. If there are multiple recommendations, a summary should be written to incorporate all recommendations for easy review.

Decision Documentation

While the workbook spreadsheets provide documentation and justification for the decisions made, there may be additional documentation requirements. Documentation on value judgments that are qualitative rather that quantitative will need to have supporting information about the decision. When required, the decision documentation package should include:

1. Summary of spreadsheet determinations including alternatives.
2. Additional social or economical values considered.
3. Justification for value judgment determinations.
   a. Benefits and impacts reviewed.
   b. How the reviewed benefits and impacts apply.
   c. Determination considerations.
   d. Justification documentation.

Appendix 7 provides more details about the benefit/impact methodology.

Limitations and Future Improvements

Limitations

The Rail Benefit/Impact Evaluation Methodology has limitations:

- While this tool is a way to consistently evaluate proposed projects in a fast-paced legislative decision process, it is more suitable for smaller size projects that need decision support information in a short timeframe. Large investment projects need customized B/C analysis and socioeconomic impact assessment specifically designed for the project, based on both federal and state requirements and other specific considerations.
- While default benefit values built into the model can provide consistent and fast analyses to present valuable information, these values, in general, reflect an average of those benefits. Some projects deviate greatly from the average situation and might find that the benefit evaluation from the tool is not accurate. Again, large

investment projects need a customized B/C analysis and socioeconomic impact assessment to justify the size of the investment.

- The evaluation of societal impacts is standard in this tool. This might not reflect true societal impacts of some rail projects. Large investment projects need a more detailed assessment of societal impacts of the rail project.

Future Needs and Improvements

The methodology was developed primarily based on state requirements and federal requirements before PRIIA. The new federal requirements to evaluate and document project benefits have not yet been incorporated into the methodology. WSDOT is prepared to update the methodology when federal guidelines become available.

The Rail Benefit/Impact Evaluation Methodology and tools have been developed with the ability to expand future versions. One such expansion will be the inclusion of the information from the Statewide Rail Data and Analytic Program. This new information will be part of all project evaluations once it is available. Incorporation of this data into project evaluations will generate recommendations consistent with statewide freight strategic goals.

In addition, as changes in the economy and state goals occur, the methodology will need to be updated to ensure the correct benefits and measures are being used. The methodology addresses the need to use lessons learned for improvement as well as being dynamic enough to stay current. A technical work group will be put in place to periodically review baseline evaluation results and the latest evaluation results to ensure that the correct measures and benefits for the current freight conditions are being used.

Washington State Department of Transportation

Chapter 8: Financing Washington's Freight Rail System

This chapter reviews the needs of Washington State's (state) freight rail system as identified by the stakeholders and Washington State Department of Transportation (WSDOT) staff. The project list is discussed followed by a synopsis of funding sources. The chapter concludes with the vision of future funding for state freight rail investments.

Needs for Investment

This section presents short- and long-term freight rail needs in the state. The needs assessment is based on unconstrained capital projects submitted directly by the state's railroads, ports, public agencies, and other key stakeholders. The needs assessment identifies 109short- and long-term statewide capital improvement projects and initiatives. The total investment needed for the projects, where cost estimates are available, is $2.0 billion.

Driven by customer demands and changing trends, freight rail needs constantly change. The primary purpose of the needs assessment is to develop a comprehensive project list of unconstrained, current priority freight rail improvements as identified by the stakeholders. This list will allow WSDOT to gauge the condition of the system and assess potential public involvement. The freight railroad system needs include both private and public sector capital improvement projects.

Inclusion of a need/project in the *Washington State 2010-2030 Freight Rail Plan* does not constitute a commitment on the part of WSDOT or the state to provide funding.

Exhibit 8-1 describes the needs identification process to develop the project list.

Exhibit 8-1: Needs Identification Process

Timeframe	Activity
March through June 2009	Develop the Projects Survey (online and PDF file formats) based on American Association of State Highway and Transportation Officials (AASHTO) guidelines, model rail plans, and key stakeholder interviews.
	Introduce the needs assessment and survey tool at the June 11 Advisory Committee kick-off meeting.
July through December 2009	E-mail the Projects Survey to Advisory Committee, railroads, ports, shippers, Metropolitan Planning Organizations (MPO) Regional Transportation Planning Organizations (RTPO) Coordinating Committee, and associated organizations.
	Use e-mail, Web site, and e-newsletter to promote the survey and encourage responses.
	Open the survey to maximize responses. The survey was originally opened from July 31 to August 19, extended to August 21, then left open.
	Review survey responses and clarify any questions. Present a project list summary for discussion and suggestions at the September 30 and October 6 Advisory Committee meetings.
	Augment the project list and needs assessment based on suggestions, prior studies, sources, and knowledge of WSDOT project team.
	Evaluate and analyze the project list for inclusion in the plan.
	Review the project list with stakeholders as part of the overall plan review process.

Source: WSDOT State Rail and Marine Office

The plan does not include all of the statewide freight rail needs for several reasons. First, the freight railroads are private, for-profit businesses. In some cases, they did not submit all their capital needs for inclusion in this public document. This is especially true in cases where private capital is available to fully fund planned improvements, where railroads believe that public involvement in specific projects is less likely, and where disclosure of a need could adversely affect strategic business ventures. Second, the

outreach effort to develop the needs assessment/project list was limited due to resources available. Increased outreach to stakeholders could encourage respondents (i.e. more interviews, more rounds of review) to identify more projects. Therefore, the needs/projects list in this plan represents those projects that have been submitted and do not involve speculation or rumors.

The project list includes project information about the organization and railroad, project type, public benefits, private benefits, and project estimates and funding details. Projects range from well-developed projects to new concepts. Chapter 5 includes a discussion of large-scale emerging projects that are not included in the project list.

Projects Survey

The project list contains the detailed needs submitted by freight stakeholders participating in developing the *Washington State 2010-2030 Freight Rail Plan*. Appendix 8-A contains the project list that was generated by the Projects Survey with the following data collection fields:

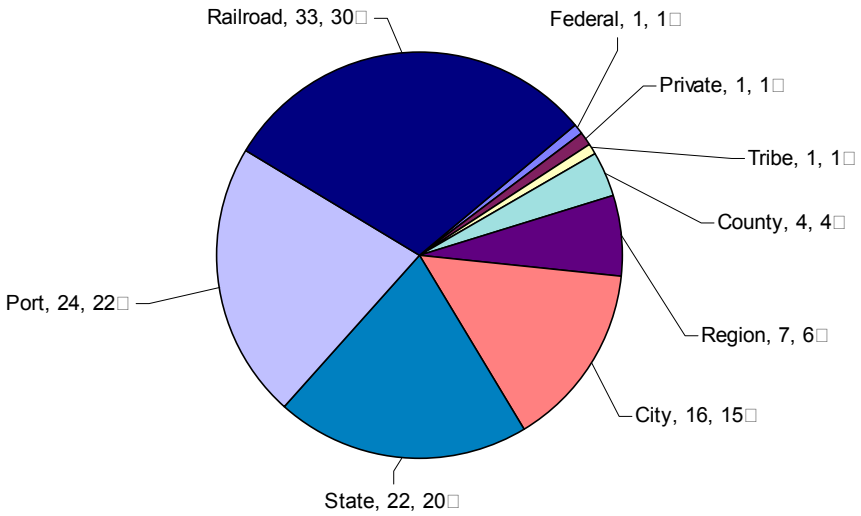
- **Respondent Information.** Organization, name, title (optional), e-mail address, and phone number.
- **Project Information.** Railroad owner (list of railroads was provided), railroad operator (list of railroads was provided), and any others involved in the project (optional).
- **Project Details.** Project name, location, description (optional).
- **Project Benefits.** Project type (list of project types was provided), public benefits (list of public benefits was provided, optional), and private benefits (list of private benefits was provided, optional).
- **Project Estimates and Funding Details.** Estimated total project cost, cost breakdown (preliminary engineering, right-of-way, construction, unknown), committed funds (federal, state, local, tribal, private, other), additional funds needed (federal, state, local, tribal, private, other), start dates (preliminary engineering, right-of-way, construction), and estimated project completion date.

The project list has been edited for length and clarity, but otherwise represents the extent of information provided by the stakeholder participants in the needs identification process. Thus, some cells are blank and, for some needs, there is a lack of cost estimates and other information that may become available in the future. The amount of detail provided varies by stakeholder. For example, a railroad may have included milepost information as part of the location description while another stakeholder may have referenced only the county.

Project Summaries

A general project assessment is provided below. Exhibit 8-2 shows the project respondents. Note that top respondents are ports, railroads, and the state.

Exhibit 8-2: Survey Respondents



Source: WSDOT State Rail and Marine Office

Estimated Completion Dates

Exhibit 8-3 shows a summary of projects and their project completion dates. Note that most of the reported project completion dates are 2010 and 2011.

Exhibit 8-3: Estimated Completion Dates

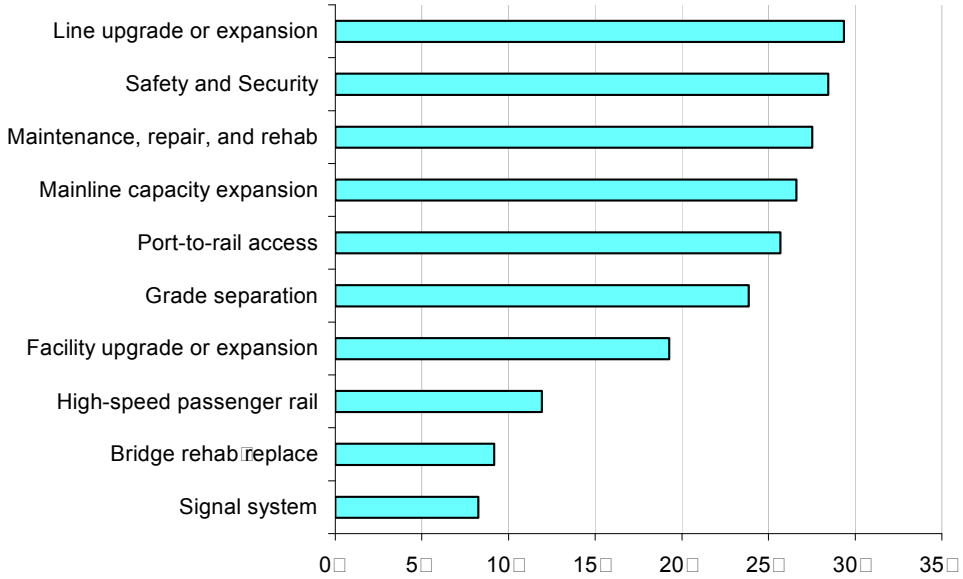
Year of Expected Completion	Number of Projects
2010	12
2011	21
2012	5
2013	4
2014	6
2015	2
2016	2
2018	1
2020	2
Not Specified	54

Source: WSDOT State Rail and Marine Office

Project Types

Exhibit 8-4 shows a summary of projects that reported project types (multiple choices are possible). Note that the top project types are line upgrade or expansion; safety and security; maintenance, repair and rehab; mainline capacity expansion, port-to-rail access, and grade separation projects.

Exhibit 8-4: Project Types

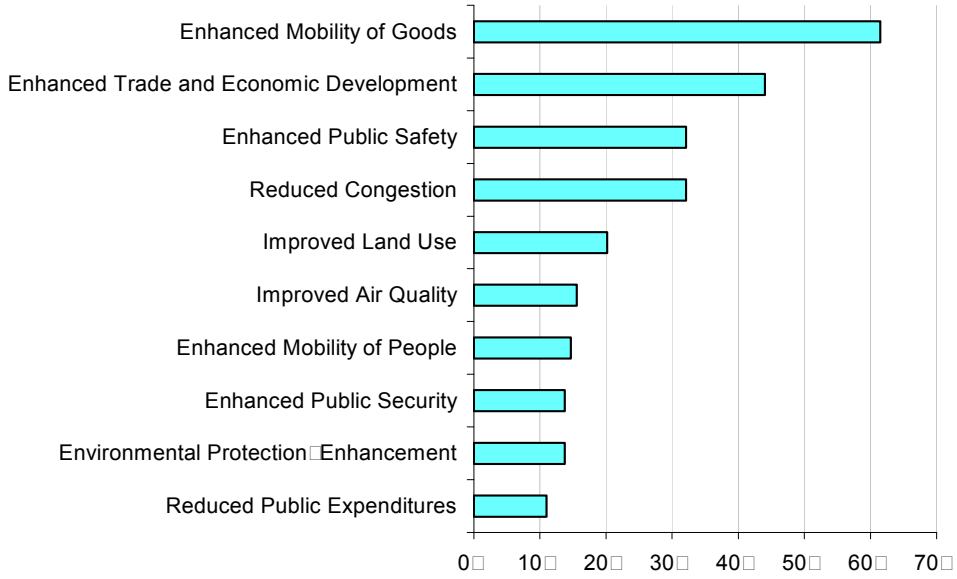


Source: WSDOT State Rail and Marine Office

Public Benefits

Exhibit 8-5 shows a summary of projects that reported public benefits (multiple choices are possible). The most common public benefit is enhanced mobility of goods, followed by enhanced trade and economic development, enhanced public safety, and reduced congestion.

Exhibit 8-5: Public Benefits

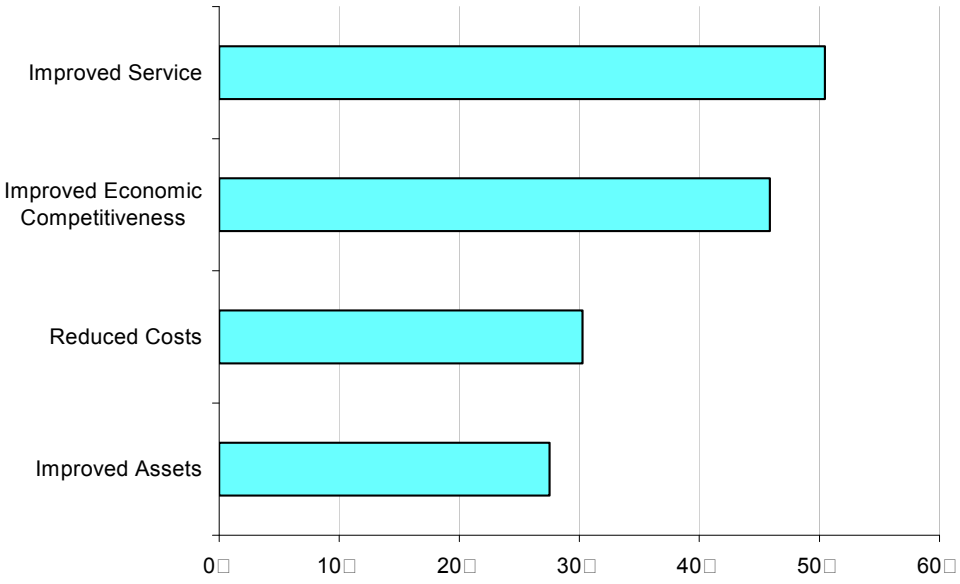


Source: WSDOT State Rail and Marine Office

Private Benefits

Exhibit 8-6 shows a summary of projects that reported private benefits (multiple choices are possible). The top benefit is improved service, followed by improved economic competitiveness, reduced costs, and improved assets.

Exhibit 8-6: Private Benefits



Source: WSDOT State Rail and Marine Office

Mainline Summary

Class I railroad owner or operator projects that reported project type (multiples are possible) are primarily mainline capacity upgrade and safety and security projects. The top public benefits are moving goods, trade and economic development, and safety and security. The top private benefits are economic competitiveness and improved service.

Short-Line Summary

Class II or Class III railroad owner or operator projects (not in the summary above) that reported project type (multiples are possible) are primarily maintenance and rehab, line upgrade, and facility upgrade projects. The top public benefit is moving goods. The top private benefits are economic competitiveness, reduced costs, and improved service.

Port-to-Rail Projects Summary

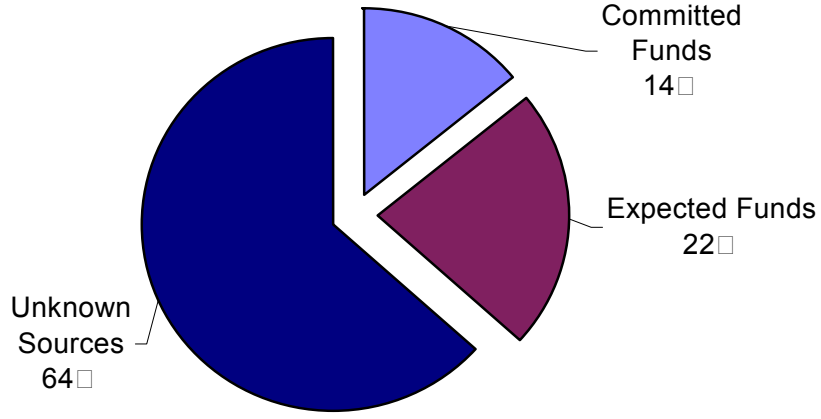
Of the reported projects, 26 percent listed port-to-rail access as one of the project types.

Funding Needs Summaries

Funding Needs by Commitment

Of the projects that report funding needs, only 14 percent are reported as committed funds, 22 percent are reported as funds expected from various sources, and 64 percent are reported as needs that have no identified sources (Exhibit 8-7).

Exhibit 8-7: Funding Needs by Commitment

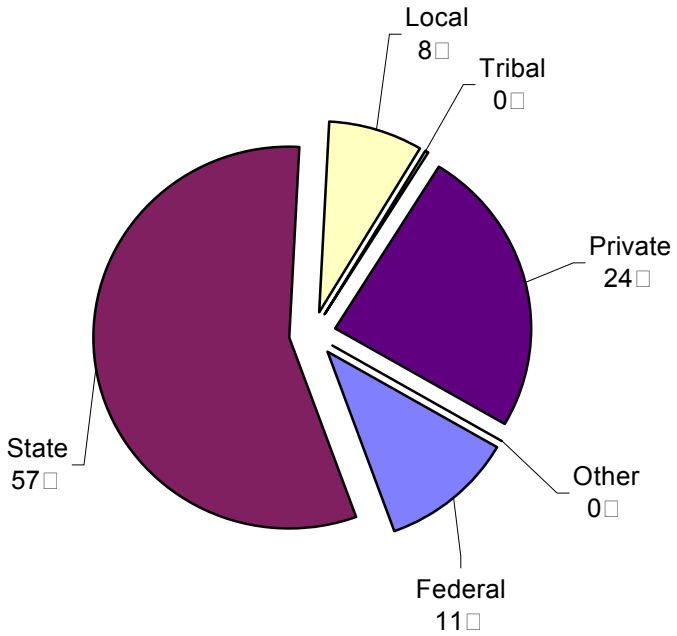


Source: WSDOT State Rail and Marine Office

Committed Funds by Source

Breaking down the committed funds portion further shows that of those projects that reported committed funds, 57 percent reported as state funds, 24 percent reported as private funds, 11 percent was reported as federal funds, 8 percent reported as local funds, and 2 percent reported tribal funding needs (Exhibit 8-8).

Exhibit 8-8: Committed Funds by Source



Source: WSDOT State Rail and Marine Office

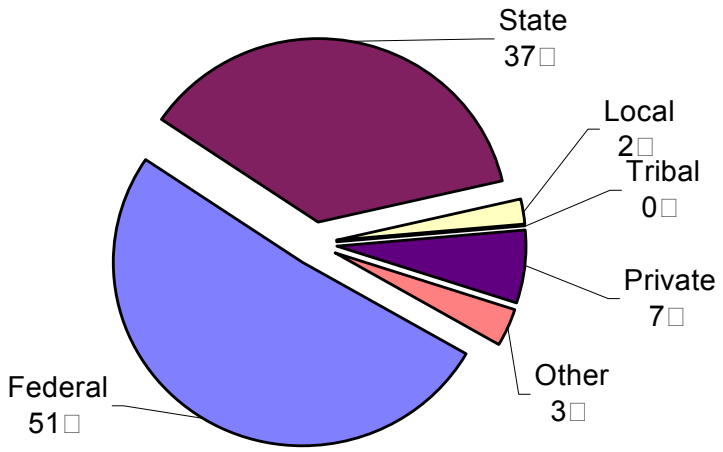
Expected Funds by Source

Of the projects that reported expected funds, 51 percent are expected from federal sources, 37 percent are expected from state, 7 percent are expected from private sources, 2 percent are expected from local funds, and 3 percent are expected from other sources (Exhibit 8-9).

The expectation of a 51 percent share from federal sources is very optimistic. This is 11 percentage points higher than the average federal aid of 40 percent for highway capital expenditure projects over the last 50-year history of that program.[1]

[1] TRB Special Report 297, Funding Options for Freight Transportation Projects, November 2009 pg 25.

Exhibit 8-9: Expected Funds by Source

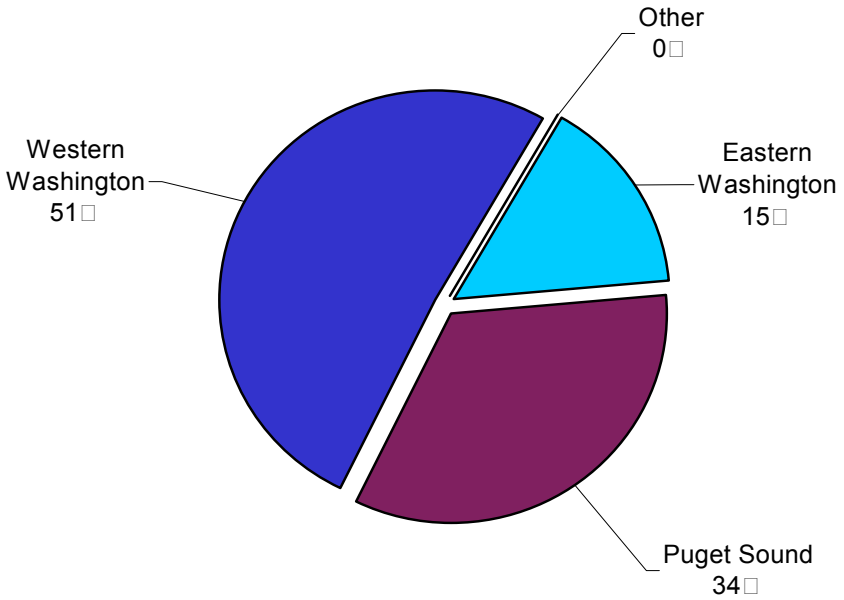


Source: WSDOT State Rail and Marine Office

Funding Needs by Area

In Exhibit 8-10, about half of the projects are located in western Washington, one-third is located in Puget Sound area, and most of the remaining projects are located in eastern Washington.

Exhibit 8-10: Funding Needs by Area



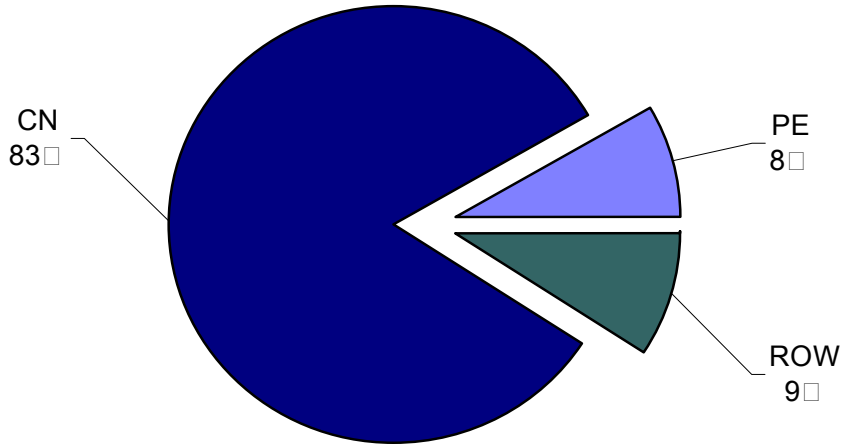
Source: WSDOT State Rail and Marine Office

Funding Needs by Phase

Of the projects reporting funding needs by project phase, 83 percent of the funding needs are associated with the construction (CN) phase of development. Right-of-way (ROW) and preliminary engineering (PE)

phases have funding needs of 9 percent and 8 percent, respectively, as shown in Exhibit 8-11.

Exhibit 8-11: Funding Needs by Phase



Source: WSDOT State Rail and Marine Office

The summaries above are very rough indicators, in part, due to the limited amount of data processing completed at this stage of freight rail statewide needs assessment. However, they do provide some value and insight into statewide need. The State Rail and Marine Office will continue to work with stakeholders to further clarify statewide need, improving the quality and quantity of the project information and analysis.

Funding for Freight Rail

All state and federal governments must address the needs for rail within the United States (U.S.). At the federal level, there has not been a dedicated nor consistent source of funds for rail development. This has resulted in rail receiving only 1 percent of the governmental expenditures as compared to the other transportation modes as shown in Exhibit 8-12 below. From 1995 to 2006, overall actual government funding for all modes has increased by 40 percent, with air transport doubling. Governmental support of rail expenditures remained at 1 percent of the total expenditure. Highway funding, as the largest sector at $99 billion, lost expenditure shares over a 10-year period, dropping from 63 percent of the total down to 50 percent.

Exhibit 8-12: Governmental Transportation Expenditure by Mode
(□Millions)

Mode	1995	□ of Total	2006	□ of Total
Highway	□90,075	63□	□99,784	50□
Transit	25,460	18□	44,097	22□
Rail	1,049	1□	1,548	1□
Air	19,250	13□	41,195	21□
Water	6,623	5□	10,888	5□
Pipeline	24	0□	91	0□
General Support	775	1□	1,795	1□
Total	**□143,256**	**100□**	**□199,398**	**100□**

Note: Percentages may not add correctly due to rounding.

Source: U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics, 2009

Numerous studies have identified the need for increased rail investment nationwide. Many of these studies called for the federal government to become a stronger rail investment partner.

On the passenger rail side, the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) authorized slightly more than $13 billion over a 5-year period to Amtrak and states to encourage the development of new and improved intercity rail passenger services. The American Recovery and Reinvestment Act of 2009 (ARRA) provides the ability for states to apply for funds to design and build high-speed rail corridors for passenger movement.

In addition to the high-speed rail grants, there are $27 billion of highway infrastructure funds available to states for "shelf" ready highway projects. States will receive the funds and will have 120 days to allocate those funds—each state has a large degree of freedom on what projects to fund. The $27 billion constitutes the majority of the funds destined for highway infrastructure spending under the stimulus act.

A third source of grant funds under ARRA is Transportation Investment Generating Economic Recovery (TIGER) grants. Eligible projects for this grant program include highway or bridge work normally funded under programs like the Surface Transportation Program; public transportation projects, such as those funded by the New Starts or Small Starts program;

passenger and freight rail infrastructure projects; and port infrastructure projects.

Eligible TIGER grantees include state, local, tribal, and territorial government entities, such as transit agencies, port authorities, and multijurisdictional coalitions. Award amounts will range from a minimum of $20 million to a maximum of $300 million, though the USDOT may waive the minimum threshold in the case of small projects.

These are examples of a substantially increased role of the federal government in funding the nation's passenger rail network. At the state level, the state funding has been accomplished through small funding sources that need to be reauthorized every couple of years.

Within the state the majority of the rail lines are privately owned and the majority of the passenger rail movements share these rail lines with freight. The efforts of the federal government has helped leverage other limited resources to improve our rail systems. But the needs for these rail system improvements always exceed the funding available for these improvements.

The state has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity passenger rail service. Since 1994 it has also provided emergency funding to failing short-line railroads and purchased specialized freight cars to ensure that agricultural shippers in the state have access to service and equipment.

The Washington State Transportation Commission prepared and submitted the *Statewide Rail Capacity and System Needs Study* in 2006. The key question asked by the legislature of this study was: "Should the state continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" The conclusion was that the state should continue to participate in freight and passenger rail systems.

The study concludes that the economic vitality of the state requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. However, it also concludes that the mainline rail system is nearing capacity. Service quality is strained and rail rates are going up for many state businesses. The pressure on the rail system will increase as the state economy grows over the long term. It is recognized that although the long-term trend increases over time, there are major fluctuations year to year in the growth pattern. The total freight tonnage moved over the state rail system is expected to increase by 2 to 3 percent per year for the next

20 years. The state's role is necessarily shaped by the fact that nearly all freight railroads are privately-owned, for-profit companies.

The major freight railroads are investing to add capacity and improve service in the state, but their business practices and investment priorities are understandably driven primarily by the railroads' national-level needs and competition. The needs of state businesses and communities are just one part of the railroads' considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets the state's economic needs, as well as the railroads' business needs.

A carefully planned program of state investments, and other actions that are consistent with the policies recommended by that study, will allow the state to realize a higher level of public benefits—in economic growth, jobs, tax revenues, and reduced community impacts—from the rail system than would be obtained without state participation. However, the state should invest only when it has been demonstrated that projects will deliver public benefits to the citizens and businesses of this state, and when it has been demonstrated that there is a low likelihood of obtaining those benefits without public involvement.

Advances towards a national rail policy and funding framework were more modest in the federal Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)[2] than many had hoped for. However, there is a growing recognition that multistate coalitions and the federal government will play a role in the future of the nation's rail system because the scale of the rail system transcends state boundaries. Recently, there has been emphasis in national transportation policy discussions of the need for a national rail policy to ensure that there is adequate investment to eliminate critical rail chokepoints and add needed capacity. The emphasis has increased as states have considered the difficulties of accommodating more truck traffic on highways and as shippers and motor carriers face increased fuel costs and labor shortages.

WSDOT is very active with the Federal Railroad Administration (FRA) in the development of the mandated National Rail Plan. This participation at the national level will enable the state to influence the plan development so that the state's needs are supported as well as the corridors and markets that are connected to the state's economy.

[2] SAFETEA-LU was the federal surface transportation authorization act that provides federal funding to state transportation agencies. SAFETEA-LU was enacted in 2005 and expired in 2009.

Current Funding Sources

State

The state provides several funding sources for priority freight rail investment projects that provide statewide public benefits. They are described by agency below.

Each of these agencies has knowledgeable and effective staff, and each carries out its mandates effectively; however, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to deal with the state, and in some cases, weakens the state's negotiating position.

Washington State Department of Transportation

WSDOT has the following funding programs:

Freight Rail Investment Bank Program

This grant program is managed by the State Rail and Marine Office. The Governor and legislature provided $5 million for the Freight Rail Investment Bank (Rail Bank) grant program for the 2009-2011 biennium. It is anticipated the Washington State Legislature will continue allocating $5 million for Rail Bank projects in the following biennia. The goal of the Rail Bank is to assist with the funding of smaller capital rail projects. Funds will be available for up to $250,000 and must be matched by at least 20 percent of funds from other sources.

The Governor and legislature expect these projects to be prioritized using the following priorities, in order of relative importance:

1. Economic, safety, or environmental advantages of freight movement by rail compared to alternative modes.
2. Self-sustaining economic development that creates family-wage jobs.
3. Preservation of transportation corridors that would otherwise be lost.
4. Increased access to efficient and cost-effective transport to market for the state's agricultural and industrial products.
5. Better integration and cooperation within the regional, national, and international systems of freight distribution.
6. Mitigation of impacts of increased rail traffic on communities.

Prior to 2009 the Rail Bank program was open to public sector participants only, participants such as publicly-owned railroads, port districts, rail districts, and local governments. However, in 2009 the legislature opened the loan program to eligible private sector organizations with projects that will further the state interest.

Eligible projects must have one or more of the following state benefits:

- Advance the state economic development goals.
- Leverage state participation by allocating cost responsibilities among beneficiaries.
- Demonstrate that there is a low likelihood of obtaining public benefits without public involvement.

Project examples include:

- Strategic multimodal consolidation centers. Project proponents to provide:
  - Service agreement from the BNSF Railway and/or the Union Pacific Railroad.
  - Volume commitment from shippers.
  - Business analysis of value offered.
- Rail rolling stock purchases (powered or unpowered).
- Intermodal transfer or transload facilities or terminals, including attached fixtures and equipment used exclusively for this facility.
- Terminals, yards, roadway buildings, fuel stations, or railroad wharves or docks, including attached fixtures and equipment used exclusively in the facility.
- Railroad signal, communication, or other operating systems, including components of such systems that must be installed on locomotives or other rolling stock.
- Siding track.
- Railroad grading or tunnel bore.
- Track including ties, rails, ballast, or other track material.
- Bridges, trestles, culverts, or other elevated or submerged structures.

Freight Rail Assistance Program

This is a grant program where the Washington State Legislature authorized WSDOT to provide grants to:

- Support branch lines and light density rail lines.
- Provide or improve rail access to ports.
- Maintain adequate mainline capacity.
- Preserve or restore rail corridors and infrastructure.

As required by Revised Code of Washington Chapter 47.76, projects must be shown to maintain or improve the freight rail system in the state and benefit the state's interests. Project proposals may be submitted if they include one or more of the following benefits to the state:

- Improve freight mobility.

- Increase economic development opportunities.
- Increase domestic and international trade.
- Preserve or add jobs.
- Reduce roadway maintenance and repair costs.
- Reduce traffic congestion.
- Improve port access.
- Enhance environmental protection.
- Enhance safety.
- Support economic viability of branch lines or light density lines.
- Maintain adequate mainline capacity.
- Preserve or restore rail corridors and infrastructure.

Project examples include:

- Rehabilitate tracks or restore tracks that were removed.
- Upgrade tracks to handle heavier rail cars and/or improve system velocity.
- Provide a rail connection to existing industries not currently served by rail.
- Develop rail infrastructure that can be proven essential to attract new businesses.
- Repair damaged rail infrastructure.
- Increase rail system capacity and/or velocity in general.
- Preserve a rail corridor.
- Improve connections to a port or transload facility.
- Construct transload or other facilities.
- Purchase or rehabilitate railroad equipment.

The Washington State Legislature has allocated $2.75 million for freight rail assistance projects in 2009-2011. The legislature will determine how those funds will be spent based upon the applications submitted through WSDOT. Appendix 8-B shows a list of historical and planned projects managed by WSDOT.

Two other boards that were created by the Washington State Legislature as mentioned in Chapter 6 are the Freight Mobility Strategic Investment Board (FMSIB) and Washington Community Economic Revitalization Board. Both agencies have grant programs for qualified projects.

Grain Train Revolving Fund

This revolving fund is a financially self-sustaining transportation program that supports Washington's farmers, short-line railroads, and rural economic development. The Washington State Grain Train Program operates without taxpayer subsidy. Operations of the Grain Train began in 1994 and it has grown to a 89-grain car fleet (71 are owned by the state,

and 18 are owned by the Port of Walla Walla). Currently, WSDOT is in the process of acquiring an additional 29 cars.

The grain train's day-to-day business operations support a unique revolving fund that pays for fleet expansion. It is an excellent example of a self-sustaining state financing model. The expansion financing is set up as follows:

- The grain shippers pay the railroads a haulage fee for the grain movement to the deepwater ports. The Class I railroads and the short lines share these haulage fees.
- The Class I railroads then pay the short line a "rental" fee for the use of the publically-owned grain hopper cars. These rental fees are deposited directly into the accounts managed by each of the three port districts; a portion of these funds are used for grain car maintenance, a portion is set aside for eventual car replacement (estimated 20-year life), and the rest is set aside and used as a "revolving' fund that is periodically tapped for fleet expansion.
- Once the revolving fund has grown large enough to purchase used grain hopper cars (a standard 26-car set plus three extras), a process is put into place to locate and purchase the said cars.

Federal

The funding sources described in this section are continuations of existing programs or were newly created by the SAFETEA-LU legislation. There had been high hopes that Congress would take a bolder stance on funding flexibility as part of the reauthorization process and allow funding of rail projects from highway provisions as was done for transit; however, this did not happen. There were successes, including the new provisions for Transportation Infrastructure Finance and Innovation Act (TIFIA) loans that allowed funding of freight projects. However, there continues to be a lack of diversity of funding sources for freight projects. This continues to be an obstacle to a major national funding program for rail. Highway agencies, much of the trucking industry, and portions of the construction industry are opposed to changing federal law to allow the Highway Trust Fund to be used for investments in non-highway projects, fearing that this will aggravate the current and expected shortfalls in investments in highways.

Another disappointing aspect of the 2005 federal surface transportation reauthorization process was the degree to which promising new programs were subject to project earmarks and how little discretion the USDOT was given in implementing these programs. This was particularly true of the National Corridor Infrastructure Improvement Program, the Projects of National and Regional Significance, and the Freight Intermodal

Distribution Pilot Grant Program. Almost all funds in those programs were earmarked by Congress to specific projects.

Nonetheless, the Federal Highway Administration (FHWA) is preparing regulations for these programs with the intent of influencing the character of the projects that were earmarked by Congress. While this might seem to be of little importance, it may still be beneficial for the state to comment on the regulations and to meet with the FHWA staff to influence the regulations for these programs and their future directions. This could set the stage for a more favorable outcome in the next reauthorization (as well as ensure that any project earmarks received by the state can be implemented consistent with the state's rail policies).

Congestion Mitigation and Air Quality Program

The Congestion Mitigation and Air Quality (CMAQ) Program was created in 1991 by the Intermodal Surface Transportation Efficiency Act. CMAQ was created to provide innovative funding for transportation projects that improve air quality and help achieve compliance with national air quality standards set forth by the Clean Air Act. CMAQ funds are often used for freight and passenger projects, including priority control systems for transit vehicles, intermodal facilities, rail track rehabilitation, and new rail sidings. CMAQ funds also can be used for construction activities that benefit private companies; if it can be shown that the project will improve air quality by removing trucks off the road. SAFETEA-LU provided $8.6 billion for the CMAQ program for the FY2006 through FY2009 period. The funds were fully allocated to the individual states. The state received approximately $153.241 million for FY2004 to FY2009.

Because CMAQ funds are allocated to states based on the population of local areas in the state that are in noncompliance, or seeking to maintain compliance with national standards for ozone and carbon monoxide, there is little that the state can do to increase its share. However, it can estimate its next CMAQ allotment and make plans for packaging funds with other sources to create the largest benefit to the rail system. Projects that will result in either maintaining or adding to the amount of traffic diverted from autos and trucks to rail would be particularly well suited for these funds.

Capital Grant Program for Rail Line Relocation and Improvement Projects

The Capital Grant Program for Rail Line Relocation and Improvement Projects was created under Section 9002 of SAFETEA-LU to fund local rail line relocation and improvement projects. States were eligible to receive grant funds from this program for the following types of rail projects:

- Rail line improvement projects serving the purpose of mitigating the impacts of rail traffic on safety, motor vehicle traffic flow, community quality of life, and/or economic development.
- Rail line relocation projects involving a lateral or vertical relocation of any portion of the rail line.

Section 9002 of SAFETEA-LU[3] authorized, but did not appropriate, $350 million per year for the FY2006 through FY2009 period. According to the grant allocation requirements slated under this program, at least 50 percent of the grant funds awarded under this program in a fiscal year must have been provided as grant awards, not to exceed $20 million each. The state or non-federal entity receiving the grant was required to pay at least 10 percent of the total cost of the project being funded by this grant program.

Projects of National and Regional Significance Program

The Projects of National and Regional Significance (PNRS) Program was created by Section 1301 of SAFETEA-LU to provide grant funds for high-cost projects of national or regional significance. Projects eligible for funding under this program included any surface transportation project authorized under 23 United States Code (USC) for assistance, including freight rail projects. In addition, projects must have had a total eligible project cost greater than or equal to the minimum of $500 million; or 75 percent of the total federal highway funds apportioned to the state where the project was located (in the most recent fiscal year). Federal shares for this program were generally 80 percent of total project cost.

Eligible project activities included development phase activities, right-of-way acquisition, construction, reconstruction, rehabilitation, environmental mitigation, construction contingencies, equipment acquisition, and operational improvements. Funds were allocated to projects based on a competitive evaluation process based on the ability of projects to satisfy criteria that included, but were not limited to, generating national economic benefits, reducing congestion, and improving transportation safety.

SAFETEA-LU authorized $1.602 billion for this program from FY2006 to FY2009. In the future, the state should consider positioning several of the larger rail infrastructure projects for PNRS funding, if available under the next transportation funding authorization. The state also should consider supporting projects under this program that are located in other states, but have significant benefits to this state.

[3] SAFETEA-LU authorization ended September 2009; no reauthorization has been passed at this time.

Freight Intermodal Distribution Pilot Grant Program

The Freight Intermodal Distribution Pilot Grant Program was created under Section 1306 of SAFETEA-LU to provide grant funds to states to facilitate and support the development of intermodal freight transportation initiatives at the state and local levels. This Pilot Grant program was for congestion reduction and safety enhancements, and to provide capital funds to address freight distribution and infrastructure needs at intermodal freight facilities and inland ports. This was a pilot program and Congress earmarked all the grant funds from this program, totaling $30 million, to five states (Alaska, California, Georgia, North Carolina, and Oregon) for six projects, with each project receiving $1 million for the five years from FY2005 through FY2009.

United States Department of Commerce Economic Development Administration Funds

The United States Department of Commerce's Economic Development Administration (EDA) provides grants for economic development projects in economically distressed industrial sites. A critical objective of the program is to promote job creation and/or retention in the region. Eligible projects must be located within an EDA-designated redevelopment area or economic development center. Freight-related projects that are eligible for funding from this program include industrial access roads, port development and expansion, and railroad spurs and sidings.

Evidence of the economic distress that the project is intended to alleviate is required of the grantees. The program provides grant assistance up to 50 percent of a project cost; however, it can provide up to 80 percent of cost for projects located in severely depressed areas. During the fiscal year 2008, the EDA awarded 146 grants for $281 million. EDA funds have been used as a funding source by at least one rail project in the state in the past.[4] This funding source should be considered for state rail improvement projects, such as industrial rail spurs and sidings in industrial areas, that can be shown to support employment growth and contribute to economic development.

U.S. Department of Agriculture Community Facilities Program

The U.S. Department of Agriculture Community Facilities Program provides three types of funding for the construction, enlargement, extension, or improvement of community facilities in rural areas and towns with a population of 20,000 or less. The three programs are:

[4] D St. Project in Tacoma, WA.

1. Direct Community Facility Loans.
2. Community Facility Loan Guarantees.
3. Community Facility Grant Program.

Grant assistance is available for up to 75 percent of project cost. Rail-related community facilities eligible for funding from this program include rail spurs serving industrial parks, and other railroad infrastructure in the region, such as yards, sidings, and mainline tracks.

The Community Facility Program amounted to $297 million in direct loans, $208 million in loan guarantees, and $17 million in grants for FY2007. The average loan, loan guarantee, and grant amounts are estimated to be $442,000, $860,000, and $32,000, respectively. This funding source could be used by the state for rail improvement projects in rural agricultural and industrial regions.

Produce Rail Car Program

This project, modeled on the successful Washington Grain Train project, provides refrigerated rail cars to help address the critical shortage of railcars for Washington farmers and agricultural shippers. These farmers and shippers need to move perishable commodities like fruit and vegetables to ports and other markets.

In 2001, the Washington State Potato Commission and Washington Potato & Onion Association proposed the program because rail-car shortages were becoming an annual problem for perishable product shippers.

Washington legislators passed a produce rail car law in 2003. Senator Murray secured $2 million in funding from the 2004 and 2005 omnibus appropriation bills to make this project fully operational.

Federal Rail Assistance Program

This is a state administered federal matching program for projects associated with light density rail lines that is currently not funded. The program was originally established in 1973 to provide financial assistance to states for the continuation of rail freight service on abandoned light density lines in the Northeast. The Railroad Revitalization and Regulatory Reform Act of 1976 expanded the program to all states and to lines threatened with abandonment. Funding for this program has not been re-authorized since 1989. However, some states used Local Rail Freight Assistance Program funds to create revolving loan programs, which permitted new loans to be made as existing loans were repaid.

Federal Loans and Tax Credits

The funding programs described in this section include both loans and credit enhancement programs. In the case of loans, a project sponsor borrows funds directly from a state Department of Transportation (DOT) or the federal government under the condition that the funds will be repaid. Credit enhancement involves the state DOT or the federal government making the funds available on a contingent, or standby, basis. An example of this is a TIFIA loan guarantee. This type of credit enhancement helped to reduce the risk to investors and, thus, allowed the project sponsor to borrow at lower interest rates.

Several loan and credit programs that can be used to finance freight rail projects at the state level were created or changed substantially in SAFETEA-LU. These include:

- The Railroad Rehabilitation and Investment Financing Program (RRIF), which saw a tenfold increase in funding, from $3.5 billion to $35 billion between 2000 and 2006.
- TIFIA, which widened the definition of eligible projects to include freight rail projects. Eligible projects included projects that improved/facilitated public or private freight rail facilities that provided benefits to highway users, intermodal freight transfer facilities, and port terminals and port access.
- Private Activity Bonds (PABs) were established as a new source of funding in SAFETEA-LU. This reauthorization of the surface transportation bill amended the Internal Revenue Service (IRS) code to allow use of PABs for highway and freight transfer facilities. PABs, otherwise known as tax-exempt facility bonds, were qualified bonds, which meant that interest on the bonds was excluded (not subject to income reporting) for federal income tax purposes in the gross income of recipients. With this qualified status and the resulting tax benefit to investors, exempt facility bonds was offered at lower interest rates, reducing the cost of financing projects for the bond issuer.

These three actions helped to widen the pool of funding available to freight rail projects. They are explained in greater detail below.

Railroad Rehabilitation and Investment Financing Program

Section 9003 of SAFETEA-LU amended the RRIF program, which was created originally under Section 7203 of the 1998 Transportation Equity Act for the 21st Century (TEA-21). The RRIF program, administered by the FRA, provided financial assistance in the form of direct loans and loan guarantees to eligible recipients for the following types of rail projects:

- Acquisition, improvement, or rehabilitation of freight (intermodal or carload) and passenger rail equipment and facilities, including tracks, yards, bridges, etc.
- Refinancing of outstanding debt incurred in the acquisition, improvement, or rehabilitation of freight and passenger rail equipment and facilities.
- Development of new freight and passenger rail facilities.

The RRIF program did not provide financial assistance for rail operating expenses. Recipients eligible for direct loans and/or loan guarantees from the program included public and private entities, railroads, joint ventures (including at least one railroad), limited-option freight shippers (e.g., shippers who owned a plant or facility served by no more than a single railroad), and interstate compacts consented to by Congress under Section 410(a) of the Amtrak Reform and Accountability Act of 1997. Thirteen loans, totaling $517 million, have been issued since 2002. The smallest and largest loans approved were $2.1 million for the Mount Hood Railroad and $233 million for the Dakota, Minnesota, and Eastern Railroad.

Direct loans from the program were used to finance 100 percent of the total project cost, while loan guarantees were made for up to 80 percent of the cost of a loan, for terms up to 35 years. The program required applicants to cover the subsidy costs through payment of a "credit risk premium" equal to a fraction of the loan amount calculated based on the financial viability of the applicant and the value of the collateral provided to secure the debt.

Transportation Infrastructure Finance and Innovation Act

TIFIA was created in 1998 by TEA-21. The strategic goal of this program was to leverage limited federal resources and stimulate private capital investment by providing credit assistance (up to one-third of the project cost) for major transportation investments of national or regional significance. The program had a project cost threshold for eligibility, which is the lower of $50 million or 33 percent of a state's annual federal-aid apportionment for highway projects.

SAFETEA-LU expanded TIFIA eligibility to certain private rail projects. Eligibility for freight facilities included the following:

- Public or private freight rail facilities providing benefits to highway users.
- Intermodal freight transfer facilities.
- Access to freight facilities and service improvements, including capital investments for Intelligent Transportation Systems.

- Port terminals, but only when related to surface transportation infrastructure modifications to facilitate intermodal interchange, transfer, and access into and out of the port.

The TIFIA credit program offered three distinct types of financial assistance: secured (direct) federal loans to project sponsors; loan guarantees by the federal government to institutional investors; and standby lines of credit in the form of contingent federal loans.

Federal credit assistance from this program could not exceed 33 percent of the total project cost. SAFETEA-LU authorized $122 million per year to pay the subsidy costs of supporting federal credit under TIFIA. There was no limit on amount of credit assistance that was provided to borrowers in a given fiscal year. Repayment of TIFIA loans came from tolls, user fees, or other dedicated revenue sources. As of July 2006, TIFIA assistance amounted to $3.2 billion, leveraging $13.2 billion of investment in 14 transportation projects.

TIFIA has been a promising funding source that should be reviewed for applicability by the state during authorization of the successor bill to SAFETEA-LU.

State Infrastructure Bank

The State Infrastructure Bank (SIB) program was started as a pilot program that was authorized under Section 350 of the National Highway System Designation Act of 1995 (NHS). SIBs are revolving infrastructure investment funds, which are established and administered by states and are eligible for capitalization with federal-aid highway apportionments and state funds. The purpose of SIBs is to provide innovative and flexible financial assistance to states for rail, highway, and transit projects in the form of loans and credit enhancements. The state should consider establishing an SIB. Financial assistance is available to public and private entities through SIBs. The assistance includes below market rate subordinate loans, interest rate buy-downs on third-party loans, loan guarantees, and line of credit. Law makers should be encouraged to include this program in reauthorization packages. The following federal transportation funds may be used to capitalize SIBs:

- **Highway Account.** Up to 10 percent of the federal-aid highway apportionments to the state for the NHS program, Surface Transportation Program, Highway Bridge Program, and the Equity Bonus.
- **Transit Account.** Up to 10 percent of the federal funds for transit capital projects under Urbanized Area Formula Grants, Capital Investment Grants, and Formula Grants for other than Urbanized Areas.

- **Rail Account.** Federal funds for rail capital projects under Subtitle V (Rail Programs) of Title 49 USC.

A state that sets up and uses an SIB is obliged to match the federal SIB capitalization funds on an 80 to 20 federal/non-federal basis. The exception is funds from the highway account, where a sliding-scale matching provision applies.

Railroad Track Maintenance Credit

The Railroad Track Maintenance Credit authorized under Section 45G of the IRS Code provides tax credits to qualified taxpayers for expenditures on railroad track maintenance on railroad tracks owned or leased by a Class II or a Class III railroad.

The amount of tax credit provided equals 50 percent of the qualified railroad track maintenance and rehabilitation expenditures. Qualified railroad track expenditures include all expenditures towards maintenance and rehabilitation of railroad track, including roadbed, bridges, and related track structures.

Eligible taxpayers qualifying for this credit include any Class II or Class III railroad, and any person transporting property on a Class II or a Class III railroad facility, or furnishing railroad-related property or services to a Class II or a Class III railroad on miles of track assigned to such person by the Class II or Class III railroad. The maximum credit allowed under this program is $3,500 per mile of railroad track owned or leased by an eligible taxpayer, or railroad track assigned to the eligible taxpayer by a Class II or a Class III railroad that owns or leases the railroad track. This credit program, which was released in 2004, was for a 3-year period from December 31, 2004 to December 31, 2007.

However, for eligible taxpayers not having enough taxable income to make full use of the credit, the credits can be carried forward for a 20-year period.

Ports

Ports have multiple external financing options. One of these is the ability to issue private activity bonds.

Private Activity Bonds (Tax Exempt Bonds)

Title XI Section 11143 of SAFETEA-LU amended Section 142(a) of the IRS Code to allow the issuance of tax-exempt private activity bonds for highway and freight transfer facilities. States and local governments were

allowed to issue tax-exempt bonds to finance highway and freight transfer facility projects sponsored by the private sector.

SAFETEA-LU included a cap of $15 billion on private activity bonds. Passage of the private activity bond legislation reflected the federal government's desire to increase private sector investment in U.S. transportation infrastructure. Providing private developers and operators with access to tax-exempt interest rates lowered the cost of capital significantly, enhancing investment prospects. Increasing the involvement of private investors in highway and freight projects also generated new sources of money, ideas, and efficiency.

A tax-exempt bond is an obligation issued by a state or local government, where the interest received by the investor is not taxable for federal income tax purposes. Because of the exception of federal income tax on the interest earned, these bonds have a lower cost of financing compared to taxable bonds. Section 11143 of SAFETEA-LU created a new type of exempt facility eligible to be financed with tax-exempt bonds—the qualified highway or surface freight transfer facility. The new type of exempt facility bonds could be used to finance certain projects for surface transportation, projects for certain international bridges or tunnels, or facilities to transfer freight from truck to rail or rail to truck, provided the project or facility received federal assistance. In general, the law limited the total amount of such bonds to $15 billion and directed the Secretary of Transportation to allocate this amount among qualified facilities.

Section 142(m) 1) defines "qualified highway or surface freight transfer facilities" as:

(A) Any surface transportation project that receives federal assistance under Title 23 USC (as in effect on August 10, 2005, the date of the enactment of Section 142(m));
(B) Any project for an international bridge or tunnel for which an international entity authorized under federal or state law is responsible and which receives federal assistance under Title 23 USC (as so in effect); or
(C) Any facility for the transfer of freight from truck to rail or rail to truck (including any temporary storage facilities directly related to such transfers) that receives federal assistance under Title 23 or Title 49 as so in effect.

Private

Other Funding Sources

The other source of funding for freight rail projects that must not be overlooked is investments by the railroads. In 2006 U.S. Class I freight railroads spent more than $8.3 billion laying new track, buying new equipment, and improving infrastructure. This was a 21 percent increase from 2005 and represented record levels of investment.[5] Much of this money went toward maintenance of existing facilities, but there was significant double-tracking and siding construction to expand freight rail capacity along several high-density routes.

The emergence of both the public and private sectors to enter into new partnerships, such as the Alameda Corridor in southern California and the Chicago Region Environmental and Transportation Efficiency (CREATE) project in Chicago, are the most likely scenario of the future funding for large-scale rail projects. Multistate coalitions, such as those pioneered by the I-95 Corridor Coalition with its Southeastern Rail Operations Study (SEROps), hold promise as models for how states and private freight railroads can work together in the future. AASHTO's new *Freight Bottom Line Report* is attempting to define directions for national rail freight policy, recognizing the need to define a national rail network and better understand the chokepoints in this network. Recent funding increases proposed for Amtrak and the strong role that a number of states have taken in intercity passenger rail also suggest directions for future public funding of the passenger rail system.

The state continues to take an aggressive position in promoting an appropriate role for the public sector in shaping the future of the private rail system. By clearly defining when and how the public sector should play a constructive role in partnership with the private sector to advance rail system goals, this state is a leader in the national rail policy discussion. By examining emerging directions in this national discussion, the state also can position itself effectively to take advantage of emerging funding opportunities and offer itself as a model for the rest of the nation. As growth in trade and passenger travel put increasing pressure on the state's rail system, the necessity of protecting, maintaining, and growing the system will be viewed as a crucial aspect of the state's economic well being.

[5] Association of American Railroads, "Major Freight Railroads to Invest $8.3 Billion in Infrastructure in 2006," March 16, 2006, retrieved from www.aar.org/Index.asp?NCID=3582.

Public-Private Partnerships

Public-Private Partnerships (PPP) are contractual agreements formed between a public agency and a private-sector entity that allow for greater private-sector participation in the delivery of transportation projects. Expanding the private-sector role allows the public agencies to tap private-sector technical, management, and financial resources in new ways to achieve certain public agency objectives, such as greater cost and schedule certainty, supplementation of in-house staff, innovative technology applications, specialized expertise, or access to private capital.

To address future capacity issues from the growth in freight, the freight railroads have indicated an interest in participating in PPPs that provide tangible benefits for both the public and private sectors. As referenced above, the Alameda corridor is an example of a PPP—it is a $2 billion, 20-mile rail expressway connecting the Ports of Los Angeles and Long Beach with rail yards near downtown Los Angeles. Some other successful freight rail related PPPs are:[6]

- **CREATE** – a $1.5 billion project to improve rail freight connections involving the state of Illinois, city of Chicago, and major freight and passenger railroads serving the region.
- **Heartland Corridor** – a $200 million multistate partnership with Norfolk Southern to increase the flow of goods between the East Coast and Chicago.
- **Reno Trench** – a multimillion-dollar project that separates trains running through downtown Reno, Nevada from motor vehicle traffic.

Strategies

State Rail and Marine Office actions should be guided by the general principles in the *Statewide Rail Capacity and System Needs Study* (2006). These principles should be followed when sufficient public benefits are identified to justify public participation in the preservation and improvement of the rail transportation system:

- **Emphasize operations and nonfinancial participation in projects before capital investment.** The state should give priority to preserving and improving rail transportation through leadership, planning, permitting, maintenance, and operations that leverage existing rail infrastructure and services rather than through capital investment.

[6] Association of American Railroads, "Public-Private Partnerships for Freight Rail Infrastructure Projects", February 2008.

- **Preserve and encourage competition.** Investment in one railroad's infrastructure can change the competitive balance among railroads to the detriment of the overall system. Before making an investment that directly benefits only one rail company, the state should conduct a comprehensive analysis of competitive impacts on other rail carriers and users.
- **Target actions to encourage private investment that advances the state's economic development goals.** State actions should influence railroad investment decisions so that rail improvements generate greater benefits to the state than could be achieved if the state did not invest.
- **Leverage state participation by allocating cost responsibility among beneficiaries.** The state should not invest in the private rail system unless the railroads and other beneficiaries participate in proportion to their benefits and risks.
- **Require projects to have viable business plans.** Funding from the state should be contingent upon demonstration that the project proponent has rail service and customer agreements in place in order to make the project financially viable.

Additional strategies that WSDOT should consider are:

- **Establish a State Infrastructure Bank.** Refer to page 8-24 for more information on the State Infrastructure Bank program.
- **Continue as a leader in the development of the National Rail Plan.** This leadership role is an important asset for the state as the development of the plan can be influenced to make sure that the final plan supports the needs of the state, the corridors that carry the state's cargo, as well as the markets that are the foundation for the state's economy.
- **Maximize the use of federal funding available through federal transportation funding programs**. This is especially true for intercity passenger rail and for multistate initiatives. Federal funding support for freight rail investments has traditionally been offered through a mixture of grants, loans, and credit enhancement programs.
- **Be active in the development of the authorization of the next surface transportation bill** advocating for programs that benefit Washington State' rail programs. Position WSDOT for any pilot projects that become available in the authorization, such as the state of Oregon involvement in the Freight Intermodal Distribution Pilot Grant Program under SAFETEA-LU.
- **Continue to engage the railroads in public-private partnerships**, with a goal of sustaining a freight and passenger rail system that provides benefits to both.

- **Remain active in regional and national rail issues, to ensure that state investments achieve maximum value, and to ensure that efficient access to and from the state is maintained.** States have been very effective at supporting and funding improvements on short-line railroads and funding spot improvements on Class I lines solely within their jurisdictions, but states have been less effective at funding corridor-scale rail improvements that cross state boundaries. The Class I railroads long ago reorganized themselves to invest and operate at the regional and national scale. The states and the federal government have not built comparable institutional mechanisms to plan, negotiate, and finance large multistate rail projects. WSDOT should pursue multistate projects that sufficiently benefit the state.
- **Strengthen coordination with state economic development agencies to ensure that rail investments are supporting and spurring the desired economic growth.** Evaluation of rail investments need to consider the type of business, so focus is placed on industries important to the state's current economy, or are targeted as important to sustain the state's future economy. These include, but are not limited to, agriculture, international trade, energy, and construction.
- **Continue to support maintenance and modernization of the rail system to enhance local freight and passenger rail service, when public benefits to the state, residents, and shippers can be demonstrated.** It also includes supporting new technologies, especially when those technologies support WSDOT long-term transportation goals.
- **Support investment in freight and passenger rail projects that enrich quality of life and support responsible environmental stewardship.** This includes projects that reduce transportation delays, improve transportation safety, improve air quality, reduce noise, and reduce other negative transportation impacts to communities.
- **Develop a strategy for passenger rail services in the state outside the intercity (Amtrak *Cascades*) and Sound Transit areas.** This would address the growing requests and needs and establish a methodology for integrating this into future rail plans.

Vision for Future Funding

For the state rail system to serve the many roles described in this plan, the system must be maintained and expanded when and where necessary. As the past has shown, leaving this funding responsibility to the private railroads alone may not result in a rail system that meets the needs of the state and the nation. These needs include the ability to compete in the global economy by improving the intermodal connectivity and assuring both public and private benefits to all stakeholders. The responsibility for funding the necessary investments for the rail system to serve both state

and interstate commerce should be shared, where appropriate, among the private railroads that own much of the rail infrastructure and the various levels of government.

There needs to be a stable, predictable funding partnership consisting of the railroads (including Amtrak), the federal government, and state government to invest in rail transportation. This is in parallel to funding mechanisms for other modes of transportation, such as highways, transit, and aviation. The state's investment policy supports sharing of project funding among the partners in relation to the benefits received. The share of funding for specific projects will differ based upon the specific type of investment and benefit attributes. The funding package must be developed on the demonstrated benefits received by all parties.

Federal

The enactment of PRIIA and ARRA are examples of the expansion of the federal role in this partnership. These two authorizations are examples of good models that should be expanded into the freight rail funding arena. These models would provide infusion of federal funding for freight rail investments that benefit interstate commerce, the environment, and the public. Funding infrastructure projects—such as the removal of network bottlenecks that impede interstate commerce, last mile access to ports of entry, and constructing rail-truck or rail-barge intermodal transfer facilities—have these interstate commerce and public benefits.

Funding from government should be dedicated and predictable so that rail investments can be adequately included in transportation plans and programs. New federal funding programs should be multi-year and not depend on annual appropriations from Congress. A dedicated, predictable funding source for future rail investments is needed at both the federal and state level. Continuing and supplementing state funding with a dedicated funding source for rail will provide an advantage to the state in the ability to leverage future federal aid as well as leverage longer-term commitments from the private railroads.

State

The current dependency on bi-annual appropriations from state government makes funding for longer-term rail investments difficult to predict. In addition, similar to capital program development for other modes, rail projects start as proposals and require planning and engineering during the early project development process in order to result in a specific project with detailed cost and schedule. A dedicated funding source needs to be indentified and implemented.

This plan contains the results of the survey of the rail industry's 20-year needs for freight-related infrastructure improvements and presents the WSDOT State Rail and Marine Office's rail investment strategy for freight rail infrastructure improvements. The strategy presented in Chapter 4 is intended as a guide for WSDOT in selecting future freight projects.

Freight rail investments identified in the rail needs survey total more than $2.0 billion over the next 20 years. The project sponsors as a whole have only identified committed funds for 10 percent of the total need. Thus, 90 percent of the $2 billion, or $1.8 billion, is needed to complete the funding packages of the identified projects. Many of the projects do not even have a targeted funding plan.

In addition,the listing is an underestimate of the total need, due to the fact that it does not include projects that are private in nature or are joint investments that benefit both freight and passenger service. It should be noted that the list does not include the cost of Mega projects, such as the crowning of Stampede Pass tunnel, or the investments required to develop the multistate national corridor from the Puget Sound to Chicago.

Traditionally, the state, through WSDOT's State Rail and Marine Office and FMSIB, has assisted the freight railroads in improving their infrastructure where there is a clear public benefit. Projects that improve the railroads' ability to divert truck traffic from overburdened highways, construct intermodal facilities, reduce vehicle emissions, and increase safety rail-highway crossings all have public benefits. Many rail investments have significant economic development benefits such as port access improvements. While many projects have public benefits, the rail freight infrastructure investments will continue to be a primary benefit to the railroads and their stakeholders and should be funded as such.

This rail plan recommends that the state continue to support freight rail infrastructure improvements that have demonstrated public benefit. Future federal funding programs to increase investment in freight service should also be implemented.

Summary

There are existing funding programs at the federal and state levels that provide some opportunity of funding freight rail projects. However, these programs are relatively small or narrowly focused, while there is a rapidly growing need to increase investment in rail transportation. The enactment of PRIIA is an excellent example of a multi-year authority for Amtrak and creates new federal funding programs for intercity passenger rail. PRIIA authorizes a rail passenger funding program for states to use to improve

and expand passenger rail service, similar to federally funded programs for other transportation modes. A comparable program for freight rail should be enacted at the federal level.

Additional investment from both public and private sources will be needed in the future to address existing freight rail infrastructure needs and allow for growth in freight rail systems to serve the economy.

Chapter 9: Challenges and Opportunities

The proceeding chapters of this plan have indentified and discussed a number of freight rail issues in Washington State (state). The majority of the issues concern rail capacity of the rail system and funding for the needed infrastructure improvements. The challenges are summarized below followed by an action plan formulated around the six goals that have been developed by the State Rail and Marine Office in conjunction with the State Freight Rail Advisory Committee (Advisory Committee).

Transportation Challenges

This chapter is developed as guidance for future Washington State Department of Transportation (WSDOT) actions. The following trends were taken into consideration:

Population Growth

The state's growth puts pressure on all aspects of the state's infrastructure, especially the transportation system. A growing population not only needs to move people, it also increases the economic activities required to support this growth and generates freight requirements to support this expanded population base. Thus, this population growth challenges our transportation capacity, with the demands to move people and goods.

Safety and Security

The state puts a high priority on the safety and security of its transportation system. However, as the demand for mobility grows, so does the incident of accidents. To this end, it is beneficial to move as much freight and people as economically feasible as possible on rail. As more goods and people are moved on our rail system, it will be even more important to retain the high level of safety and security the system currently achieves.

Preservation and Maintenance

As documented in earlier chapters there is a significant level of investment needed in the state rail system for both expansion and maintenance of the current system. It is mandatory that the system is kept up to modern standards, especially the supporting short lines. In addition, as rail corridors are abandoned or freight services suspended, it is important that the state plan for long-term preservation of these rail corridors and rights of way for future use.

Rail's Role in the State's Economy

A large part of the state's economy depends on freight for its competitiveness and growth. Freight-dependent sectors, in general, include agriculture, mining, construction, manufacturing, wholesale, retail, transportation, and warehousing. In 2008 freight-dependent sectors accounted for 33 percent of the state's Gross Domestic Product, 71 percent of business income, and 39 percent of the state's employment. These sectors will demand faster and more reliable transportation options in the future for both their employees and their freight. Significant increases in freight are forecast both for the state and nationally. Although trucks will continue to handle the majority of the freight, highway congestion, climate concerns, and energy costs will influence more freight to be moved by rail within the state.

Capacity Constraints in the Transportation System

The urban and interregional highway corridors are currently heavily congested during peak periods and are forecast to be increasingly congested over the next 20 years. Significant additional capacity is required at our ports to meet the future forecasts for international cargo flows. Freight rail capacity will have to grow to meet this demand, if the state wants to retain their competitive edge as a gateway to the Midwest and Upper East Coast of the United States.

Rising Cost of Transportation

Although the current economic downturn has resulted in a very competitive cost environment in which to provide transportation infrastructure, it is forecast that these costs will rise in the future. As energy costs rise and state revenues decline, transportation budgets are strained during the same time that capacity improvements are needed.

Energy Efficiency and Climate Change Concerns

The Governor's 2008 Climate Action Team – Transportation Implementation Working Group (Climate Team) identified that emissions from transportation related activities account for nearly half of the total greenhouse gas (GHG) emissions in the state. The Climate Team stated that achieving significant reductions related to GHG emissions is critical for the state and will require meeting the short- and long-term vehicle miles traveled benchmark. The challenge is compounded by the paradox that transportation funding is dependent on the gas tax, while the goal of the Climate Team is to reduce the amount of miles traveled. The ultimate goal is to build, operate, and maintain a transportation infrastructure that is efficient and effective at moving people and goods. To achieve this vision, the state must reexamine how investments in transportation infrastructure and services are made. The state needs to make funding decisions and

pursue revenue generating strategies that stimulate behaviors that support climate change solutions and discourage behaviors that contribute to the problem. One of the solutions recommended by the Governor's Climate Action Team is rail transportation, as it is one of the most energy-efficient ways to move people and goods along major corridors.

Balancing Transportation and Community Livability

The balance between transportation and community livability continues to be a challenge in this state. As demand for mobility of people and freight continues to increase and choices for locating new development in or near urban areas becomes more constrained, investing in rail creates an opportunity. Rail transportation can be the solution to meeting mobility needs while promoting and retaining livable communities.

Transportation Funding

The Governor has announced that there is a transportation funding crisis in this state. As mentioned above the state budget is under pressure from reduced revenues, not only from gas taxes but all general fund revenues. This is a challenge both for the state as it attempts to meet citizen and business needs, but also as it pursues funding from other sources that require matches from the state.

Transportation Opportunities: Implementation of the Plan

Economic Competitiveness and Viability

Goal: Support Washington's economic competitiveness and economic viability through strategic freight rail partnerships.

Next Steps:

- WSDOT's State Rail and Marine Office should prepare a "needs" analysis on the project list to determine which infrastructure improvements can be financially supported.
- The State Rail and Marine Office needs to lead the planning effort to integrate individual plans into a system plan by:
  - Working with the state's Metropolitan Planning Organizations (MPOs), Regional Transportation Planning Organizations (RTPOs), and tribes to integrate freight rail into future regional transportation plans.
  - Working with the Department of Commerce and Department of Agriculture to develop a coordinated economic development approach, including infrastructure funding options for economic viability programs, such as grain trains and produce rail cars.

  - Working with the federal government to get the Northern Tier route designated as a National Rail Corridor.
  - Developing a plan to eliminate bottlenecks and improve capacity and velocity inside and outside of the state. The office needs to work with public and private sector partners in states along the I-5 rail corridor as well as newly designated East/West national corridor.
  - Using the Advisory Committee to enhance communication with the railroads, ports, shippers, industry representatives, and local communities and coordinate activities at the regional, state, and national level on needed projects, programs, and policy decisions.
- The State Rail and Marine Office should create a Rail Data Center to improve the state capacity to develop and manage freight rail system information, research capacity, and data capacity that support federal and state decision making and policy development in freight rail, enhance state and local freight rail planning and statewide coordination, and evaluate funding priorities of freight rail development.
- State agencies need to increase awareness of freight rail, when appropriate, as a vital mode of transportation within the supply chain through a public education process coordinated with other freight partners.

Preservation

Goal: Preserve the ability of Washington s freight rail system to efficiently serve the needs of its customers.

Next Steps:

- WSDOT's State Rail and Marine Office should confirm the at-risk system components that can benefit from public support.
- The State Rail and Marine Office should support the efforts of Class I railroads to compete for state and federal funding for major capacity preservation projects, when appropriate.
- The state should provide financial assistance to short-line railroads to maintain and preserve essential rail lines and prevent abandonment, when appropriate.
- The state should lead the coordination of plans involving rail corridor maintenance and preservation, including the identification of funding strategies for implementation of these plans.
- State agencies should integrate freight rail system development, land use planning and policies, public-private partnerships, and funding strategies consistent with the state vision and policy goals to protect and grow freight mobility.

- The State Rail and Marine Office should work with ports and railroads to project the functionality and viability of existing port access connections between port terminals, intermodal rail yards, and mainline tracks.
- The State Rail and Marine Office should create criteria to be used to evaluate at-risk rail corridors for public investment.
- The State Rail and Marine Office should consider acquiring rail corridors scheduled for abandonment that have met public investment criteria and have the potential to be reactivated in the future.
- The State Rail and Marine Office should work with short-line and mainline railroads to enable compatible interim use of a rail corridor right of way (i.e. rail/trails) within statutory limits, until such time that the right of way is returned to active rail use.

Capacity

Goal: Facilitate freight rail system capacity increases to improve mobility, reduce congestion, and meet the growing needs of Washington's freight rail users, when economically justified.

Next Steps:

- The state should designate a single entity to coordinate and direct the state's participation in the preservation and improvement of the rail transportation system. This entity should have the authority to negotiate directly with the railroads.
- WSDOT's State Rail and Marine Office should develop a comprehensive strategy to increase the state's east/west and north/south rail capacity in partnership with Class I railroads, ports, communities, and the federal government.
- The State Rail and Marine Office should continue to pursue passenger rail funding for the north/south Interstate 5 (I-5) corridor at the federal level that either maintains or creates freight rail capacity, such as the American Recovery and Reinvestment Act of 2009 application for a dedicated high-speed rail corridor.
- The State Rail and Marine Office should develop a comprehensive strategy for the coordination and support of positive train control systems development within the state.
- WSDOT should develop data and information, through a Statewide Rail Information Center, for freight rail demand, rail capacity constraints, and capacity use information needed for statewide planning and operation to enhance freight capacity.
- The State Rail and Marine Office should continue pursuance of funding for a rail facility inventory to include assessments for location of rail facilities and condition of physical assets.

- The State Rail and Marine Office should provide technical assistance to public and private entities such as the Freight Mobility Strategic Investment Board, Puget Sound Regional Council, and local communities for evaluation and prioritization of freight rail projects.

Energy Efficiency and Environmental

Goal: Take advantage of freight rail's modal energy efficiency to reduce the negative environmental impact of freight movement in Washington.

Next Steps:

- WSDOT should implement rail projects that reduce truck traffic, when economically feasible.
- The state should encourage use of environmentally-friendly equipment to decrease fuel consumption and air emissions such as:
  - "Green" switching locomotives in port areas and other rail yards close to residential areas, including the use of locomotive anti-idling devices.
  - Technologies that reduce wheel/track friction.
- The state should assess the effects of climate change on the rail system and identify where weather and climate events can impact rail infrastructure and operation. The state should coordinate these findings with the capacity needs and prioritization of improvements.
- The Department of Ecology and the State Rail and Marine Office should provide assistance in evaluating benefits of reducing environmental emissions and energy savings of rail-mode based options in intermodal and multimodal transportation planning.

Safety and Security

Goal: Address the safety and security of the freight rail system and make enhancements, where appropriate.

Next Steps:

- The state should expand education outreach to new and existing stakeholder groups, such as working with railroads and other partners to reduce pedestrian trespassing through joint public awareness efforts.
- The state should continue to support safety improvements of rail-highway crossings, signal systems, rail lines, and rail facilities, through regulations and partnership.
- WSDOT should review best practices, consult with area experts, work with partners, and develop a list of temporary rail-highway grade crossing closures and alternative routes in the event of natural and man-made disasters.

- WSDOT's State Rail and Marine Office should work with partners to plan for rail safety measures and routing before, during, and after emergencies.
- The State Rail and Marine Office should support railroads, Amtrak, local law enforcement agencies, and others to identify and implement rail security measures based on guidance from existing federal law (PL 110-432), identifying partnerships and other funding sources to enhance rail system security.

Livable Communities

Goal: Encourage livable communities and family-wage jobs through freight rail system improvements.

Next Steps:

- The state should support strategic partnerships along the state's rail corridors that improve the quality of life for the state's citizens.
- The state should encourage rail partners to implement projects on the project list that would improve the livability of a community by reducing emissions and noise.
- The state should encourage rail partners to implement projects that provide wages and jobs for local economies and communities.
- The state should encourage rail partners to involve local communities in program planning and project implementation processes.
- The state should encourage private investment that advances state economic development goals.

Conclusion

The *Washington State 2010-2030 Freight Rail Plan* lays the foundation for an improved and sustainable freight rail system in the state by identifying a vision for the state's freight rail service and establishing goals, objectives, strategies, and actions to achieve that vision. This has been accomplished by working with various stakeholders, including the rail industry, rail advocates, ports, governments, elected officials, and many other concerned groups and individuals. This collaboration is essential to creating a vision that reflects the needs of the community and ultimately to having a responsive, efficient, and sustainable rail transportation network.

Dedicated investment by government and the private railroads will be required to reach these goals and accomplish all of the rail improvements identified in this plan.

Washington State

2010-2030
Freight Rail Plan
Appendices

December 2009

Washington State
Department of Transportation

For more information, contact:

- Call the WSDOT State Rail and Marine Office at (360) 705-7900;
- Write to the WSDOT State Rail and Marine Office at P.O. Box 47407, Olympia, WA 98504-7407;
- Fax your comments to (360) 705-6821; or
- E-mail your comments to rail@wsdot.wa.gov

Americans with Disabilities Act Information: Materials can be provided in alternative formats: large print, Braille, cassette tape, or on computer disk for people with disabilities by calling the Office of Equal Opportunity (OEO) at (360) 705-7097. Persons who are deaf or hard of hearing may contact OEO through the Washington Relay Service at 7-1-1.

Title VI Statement to Public: It is the Washington State Department of Transportation's (WSDOT) policy to assure that no person shall, on the grounds of race, color, national origin and sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated, may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For Title VI complaint forms and advice, please contact OEO's Title VI Coordinator at (360) 705-7098.

Washington State
2010-2030
Freight Rail Plan
Appendices

Prepared by

Washington State
Department of Transportation
State Rail and Marine Office

December 2009

Washington State
Department of Transportation

Washington State Department of Transportation

Appendices Table of Contents

Appendix 1-A: State and Federal Requirements

State Requirements ..... Appendix 1-A1
Federal Requirements ..... Appendix 1-A2

Appendix 1-B: Public Participation and Stakeholder Involvement

State Freight Rail Plan Advisory Committee ..... Appendix 1-B1
Electronic Communication Standards ..... Appendix 1-B3
Outreach Activities ..... Appendix 1-B3
FRA Reporting ..... Appendix 1-B7
Government-to-Government Tribal Consultation ..... Appendix 1-B7

Appendix 2: Detailed Goal Matrix

Goal 1 ..... Appendix 2-3
Goal 2 ..... Appendix 2-4
Goal 3 ..... Appendix 2-5
Goal 4 ..... Appendix 2-6
Goal 5 ..... Appendix 2-7
Goal 6 ..... Appendix 2-8

Appendix 3-A: Passenger Rail Service and Ridership in Washington State □ A Brief

Amtrak Intercity Passenger Rail ..... Appendix 3-A1
Commuter Rail ..... Appendix 3-A3

Appendix 3-B: Railroad History, Profiles, Service Corridors, and Safety Regulatory History

National Freight Rail History ..... Appendix 3-B1
Washington State Rail History ..... Appendix 3-B2
Class I Railroad Profiles ..... Appendix 3-B6
Class II and Class III Railroad Profiles ..... Appendix 3-B10
Rail Service Corridors ..... Appendix 3-B28
Safety Regulatory History ..... Appendix 3-B39

Appendix 3-C: Intermodal Facility Commodity Descriptions

Appendix 4: Freight Forecast

Sources ..... Appendix 4-1
Methodology and Forecasts ..... Appendix 4-1

Appendix 5-A: Washington Historical Rail Abandonments

Appendix 5-B: Port Access Projects

Port Access Points ..... Appendix 5-B1
Other Access Issues ..... Appendix 5-B3

Appendix 5-C: Inland Port Concepts

Inland Ports ..... Appendix 5-C1
Rail Intermodal Transportation Moves ..... Appendix 5-C1
Status ..... Appendix 5-C2
Studies ..... Appendix 5-C2
Success of Inland Ports ..... Appendix 5-C3

Appendix 6: WSDOT Freight Partnerships

Appendix 7: Bibliography

Appendix 8-A: Project List

Appendix 8-B: Freight Rail Investments □ Historical and Planned □ Managed by WSDOT

Appendix 9: Glossary

List of Appendix Exhibits

Exhibit 1B-1: Advisory Committee Member Organizations ..... Appendix 1-B2
Exhibit 1B-2: June 11, 2009 Advisory Committee Meeting Attendees ..... Appendix 1-B4
Exhibit 1B-3: September 30, 2009 Advisory Committee Western Washington Meeting Attendees ..... Appendix 1-B5
Exhibit 1B-4: October 6, 2009 Advisory Committee Eastern Washington Meeting Attendees ..... Appendix 1-B6
Exhibit 1B-5: October 22, 2009 Open House Attendees ..... Appendix 1-B7
Exhibit 1B-6: August 5, 2009 Advisory Committee Workshop Attendees ..... Appendix 1-B8
Exhibit 3A-1: Ridership of Intercity Passenger Rail Service – Washington State 2008 ..... Appendix 3-A2
Exhibit 3A-2: Amtrak *Cascades* Annual ridership – 1994 to 2008 ..... Appendix 3-A3
Exhibit 3B-1: Rail Service Corridors in Washington State ..... Appendix 3-B29
Exhibit 4A-1: Projected Rail Freight Traffic Growth Rates .. Appendix 4-3
Exhibit 4A-2: Washington State Rail Freight 2007, 2020, and 2030 ..... Appendix 4-4
Exhibit 4A-3: Rail Freight Distribution ..... Appendix 4-4
Exhibit 4A-4: Projected Rail Freight Growth of Top 10 Commodities – Washington 2007-2030 ..... Appendix 4-5
Exhibit 4A-5: U.S. Shipments by Mode – 2006 and 2035 .... Appendix 4-7
Exhibit 4A-6: Freight Tons, Value, and Ton-Miles by Mode, 2006 and 2035 ..... Appendix 4-7
Exhibit 4A-7: Marine Cargo Trends – Rail vs. Other Modes 2002 to 2030 ..... Appendix 4-8
Exhibit 4A-8: Marine Cargo Port Modal Distribution Washington State 2007, 2020, and 2030 ..... Appendix 4-9
Exhibit 4A-9: Comparison of Total Rail Flow Railcars per Year – 2005 and 2035 ..... Appendix 4-12
Exhibit 8A-1: Project List by Area, Location, and Organization ..... Appendix 8-A3
Exhibit 8A-2: Project List by Location, Area, and Organization ..... Appendix 8-A7
Exhibit 8A-3: Project List by Organization, Location, and Area ..... Appendix 8-A11
Exhibit 8A-4: Project List by Project Types ..... Appendix 8-A16
Exhibit 8A-5: Project List by Public Benefits ..... Appendix 8-A21
Exhibit 8A-6: Project List by Private Benefits ..... Appendix 8-A26
Exhibit 8A-7: Project List by Cost Estimates ..... Appendix 8-A30
Exhibit 8A-8: Project List by Committed Funds ..... Appendix 8-A34

Washington State
Department of Transportation

Appendix 1-A: State and Federal Requirements

State Requirements

RCW 47.76.220
State rail plan □ Contents.

(1) The department of transportation shall prepare and periodically update a state rail plan, the objective of which is to identify, evaluate, and encourage essential rail services. The plan shall:

(a) Identify and evaluate mainline capacity issues;

(b) Identify and evaluate port-to-rail access and congestion issues;

(c) Identify and evaluate those rail freight lines that may be abandoned or have recently been abandoned;

(d) Quantify the costs and benefits of maintaining rail service on those lines that are likely to be abandoned;

(e) Establish priorities for determining which rail lines should receive state support. The priorities should include the anticipated benefits to the state and local economy, the anticipated cost of road and highway improvements necessitated by the abandonment or capacity constraints of the rail line, the likelihood the rail line receiving funding can meet operating costs from freight charges, surcharges on rail traffic, and other funds authorized to be raised by a county or port district, and the impact of abandonment or capacity constraints on changes in energy utilization and air pollution;

(f) Identify and describe the state's rail system;

(g) Prepare a state freight rail system map;

(h) Identify and evaluate rail commodity flows and traffic types;

(i) Identify lines and corridors that have been rail banked or preserved; and

(j) Identify and evaluate other issues affecting the state's rail traffic.

(2) The state rail plan may be prepared in conjunction with the rail plan prepared by the department pursuant to the federal Railroad Revitalization and Regulatory Reform Act.

Federal Requirements

Passenger Rail Investment and Improvement Act of 2008
PL 110-432

H. R. 2095
One Hundred Tenth Congress of the United States of America
AT THE SECOND SESSION
Begun and held at the City of Washington on Thursday, the third day of January, two thousand and eight
An Act
To amend title 49, United States Code, to prevent railroad fatalities, injuries, and hazardous materials releases, to authorize the Federal Railroad Safety Administration, and for other purposes.
Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

DIVISION B AMTRAK
SEC. 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This division may be cited as the "Passenger Rail Investment and Improvement Act of 2008".

(b) TABLE OF CONTENTS.—The table of contents for this division is as follows:

Sec. 1. Short title; table of contents.
Sec. 2. Amendment of title 49, United States Code.
Sec. 3. Definition.

TITLE I AUTHORIZATIONS

Sec. 101. Authorization for Amtrak capital and operating expenses.
Sec. 102. Repayment of long-term debt and capital leases.
Sec. 103. Authorization for the Federal Railroad Administration.

TITLE II AMTRAK REFORM AND OPERATIONAL IMPROVEMENTS

Sec. 201. National railroad passenger transportation system defined.
Sec. 202. Amtrak board of directors.
Sec. 203. Establishment of improved financial accounting system.
Sec. 204. Development of 5-year financial plan.
Sec. 205. Restructuring long-term debt and capital leases.
Sec. 206. Establishment of grant process.
Sec. 207. Metrics and standards.
Sec. 208. Methodologies for Amtrak route and service planning decisions.
Sec. 209. State-supported routes.
Sec. 210. Long-distance routes.

Sec. 211. Northeast Corridor state-of-good-repair plan.
Sec. 212. Northeast Corridor infrastructure and operations improvements.
Sec. 213. Passenger train performance.
Sec. 214. Alternate passenger rail service pilot program.
Sec. 215. Employee transition assistance.
Sec. 216. Special passenger trains.
Sec. 217. Access to Amtrak equipment and services.
Sec. 218. General Amtrak provisions.
Sec. 219. Study of compliance requirements at existing intercity rail stations.
Sec. 220. Oversight of Amtrak's compliance with accessibility requirements.
Sec. 221. Amtrak management accountability.
Sec. 222. On-board service improvements.
Sec. 223. Incentive pay.
Sec. 224. Passenger rail service studies.
Sec. 225. Report on service delays on certain passenger rail routes.
Sec. 226. Plan for restoration of service.
Sec. 227. Maintenance and repair facility utilization study.
Sec. 228. Sense of the Congress regarding the need to maintain Amtrak as a national passenger rail system.

TITLE III INTERCITY PASSENGER RAIL POLICY

Sec. 301. Capital assistance for intercity passenger rail service.
Sec. 302. Congestion grants.
Sec. 303. State rail plans.
Sec. 304. Tunnel project.
Sec. 305. Next generation corridor train equipment pool.
Sec. 306. Rail cooperative research program.
Sec. 307. Federal rail policy.

TITLE IV MISCELLANEOUS PROVISIONS

Sec. 401. Commuter rail mediation.
Sec. 402. Routing efficiency discussions with Amtrak.
Sec. 403. Sense of Congress regarding commuter rail expansion.
Sec. 404. Locomotive biofuel study.
Sec. 405. Study of the use of biobased technologies.
Sec. 406. Cross-border passenger rail service.
Sec. 407. Historic preservation of railroads.

TITLE V HIGH-SPEED RAIL

Sec. 501. High-speed rail corridor program.
Sec. 502. Additional high-speed rail projects.

TITLE VI CAPITAL AND PREVENTIVE MAINTENANCE PROJECTS FOR WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

Sec. 601. Authorization for capital and preventive maintenance projects for Washington Metropolitan Area Transit Authority.

.
.
.

SEC. 303. STATE RAIL PLANS.

(a) IN GENERAL.—Part B of subtitle V is amended by adding at the end the following:
"CHAPTER 227—STATE RAIL PLANS
"Sec.
"22701. Definitions.
"22702. Authority.
"22703. Purposes.
"22704. Transparency; coordination; review.
"22705. Content.
"22706. Review.
"§ 22701. Definitions
"In this subchapter:
"(1) PRIVATE BENEFIT.—
"(A) IN GENERAL.—The term 'private benefit'—
"(i) means a benefit accrued to a person or private entity, other than Amtrak, that directly improves the economic and competitive condition of that person or entity through improved assets, cost reductions, service improvements, or any other means as defined by the Secretary; and
"(ii) shall be determined on a project-by-project basis, based upon an agreement between the parties.
"(B) CONSULTATION.—The Secretary may seek the advice of the States and rail carriers in further defining this term.
"(2) PUBLIC BENEFIT.—
"(A) IN GENERAL.—The term 'public benefit'—
"(i) means a benefit accrued to the public, including Amtrak, in the form of enhanced mobility of people or goods, environmental protection or enhancement, congestion mitigation, enhanced trade and economic development, improved air quality or land use, more efficient energy use, enhanced public safety or security, reduction of public expenditures due to improved transportation efficiency or infrastructure preservation, and any other positive community effects as defined by the Secretary; and
"(ii) shall be determined on a project-by-project basis, based upon an agreement between the parties.

"(B) CONSULTATION.—The Secretary may seek the advice of the States and rail carriers in further defining this term.
"(3) STATE.—The term 'State' means any of the 50 States and the District of Columbia.
"(4) STATE RAIL TRANSPORTATION AUTHORITY.—The term 'State rail transportation authority' means the State agency or official responsible under the direction of the Governor of the State or a State law for preparation, maintenance, coordination, and administration of the State rail plan.
"§ 22702. Authority
"(a) IN GENERAL.—Each State may prepare and maintain a State rail plan in accordance with the provisions of this chapter.
"(b) REQUIREMENTS.—The Secretary shall establish the minimum requirements for the preparation and periodic revision of a State rail plan, including that a State shall:
"(1) establish or designate a State rail transportation authority to prepare, maintain, coordinate, and administer the plan;
"(2) establish or designate a State rail plan approval authority to approve the plan;
"(3) submit the State's approved plan to the Secretary of Transportation for review; and
"(4) revise and resubmit a State-approved plan no less frequently than once every 5 years for reapproval by the Secretary.
"§ 22703. Purposes
"(a) PURPOSES.—The purposes of a State rail plan are as follows:
"(1) To set forth State policy involving freight and passenger rail transportation, including commuter rail operations, in the State.
"(2) To establish the period covered by the State rail plan.
"(3) To present priorities and strategies to enhance rail service in the State that benefits the public.
"(4) To serve as the basis for Federal and State rail investments within the State.
"(b) COORDINATION.—A State rail plan shall be coordinated with other State transportation planning goals and programs, including the plan required under section 135 of title 23, and set forth rail transportation's role within the State transportation system.
"§ 22704. Transparency; coordination; review
"(a) PREPARATION.—A State shall provide adequate and reasonable notice and opportunity for comment and other input to the public, rail carriers, commuter and transit authorities operating in, or affected by rail operations within the State, units of local government, and other interested parties in the preparation and review of its State rail plan.
"(b) INTERGOVERNMENTAL COORDINATION.—A State shall review the freight and passenger rail service activities and initiatives by regional planning agencies, regional transportation authorities, and municipalities within the State, or in the region in which the State is

located, while preparing the plan, and shall include any recommendations made by such agencies, authorities, and municipalities as deemed appropriate by the State.

"§ 22705. Content

"(a) IN GENERAL.—Each State rail plan shall, at a minimum, contain the following:

"(1) An inventory of the existing overall rail transportation system and rail services and facilities within the State and an analysis of the role of rail transportation within the State's surface transportation system.

"(2) A review of all rail lines within the State, including proposed high-speed rail corridors and significant rail line segments not currently in service.

"(3) A statement of the State's passenger rail service objectives, including minimum service levels, for rail transportation routes in the State.

"(4) A general analysis of rail's transportation, economic, and environmental impacts in the State, including congestion mitigation, trade and economic development, air quality, land use, energy-use, and community impacts.

"(5) A long-range rail investment program for current and future freight and passenger infrastructure in the State that meets the requirements of subsection (b).

"(6) A statement of public financing issues for rail projects and service in the State, including a list of current and prospective public capital and operating funding resources, public subsidies, State taxation, and other financial policies relating to rail infrastructure development.

"(7) An identification of rail infrastructure issues within the State that reflects consultation with all relevant stakeholders.

"(8) A review of major passenger and freight intermodal rail connections and facilities within the State, including seaports, and prioritized options to maximize service integration and efficiency between rail and other modes of transportation within the State.

"(9) A review of publicly funded projects within the State to improve rail transportation safety and security, including all major projects funded under section 130 of title 23.

"(10) A performance evaluation of passenger rail services operating in the State, including possible improvements in those services, and a description of strategies to achieve those improvements.

"(11) A compilation of studies and reports on high-speed rail corridor development within the State not included in a previous plan under this subchapter, and a plan for funding any recommended development of such corridors in the State.

"(12) A statement that the State is in compliance with the requirements of section 22102.

"(b) LONG-RANGE SERVICE AND INVESTMENT PROGRAM.—

"(1) PROGRAM CONTENT.—A long-range rail investment program included in a State rail plan under subsection (a)(5) shall, at a minimum, include the following matters:
"(A) A list of any rail capital projects expected to be undertaken or supported in whole or in part by the State.
"(B) A detailed funding plan for those projects.
"(2) PROJECT LIST CONTENT.—The list of rail capital projects shall contain:
"(A) a description of the anticipated public and private benefits of each such project; and
"(B) a statement of the correlation between—
"(i) public funding contributions for the projects; and
"(ii) the public benefits.
"(3) CONSIDERATIONS FOR PROJECT LIST.—In preparing the list of freight and intercity passenger rail capital projects, a State rail transportation authority should take into consideration the following matters:
"(A) Contributions made by non-Federal and non-State sources through user fees, matching funds, or other private capital involvement.
"(B) Rail capacity and congestion effects.
"(C) Effects on highway, aviation, and maritime capacity, congestion, or safety.
"(D) Regional balance.
"(E) Environmental impact.
"(F) Economic and employment impacts.
"(G) Projected ridership and other service measures for passenger rail projects.
"§ 22706. Review
"The Secretary shall prescribe procedures for States to submit State rail plans for review under this title, including standardized format and data requirements. State rail plans completed before the date of enactment of the Passenger Rail Investment and Improvement Act of 2008 that substantially meet the requirements of this chapter, as determined by the Secretary, shall be deemed by the Secretary to have met the requirements of this chapter."
(b) CONFORMING AMENDMENT.—The chapter analysis for subtitle V is amended by inserting the following after the item relating to chapter 223:
Chapter 227, § 22701 Definitions.

Washington State Department of Transportation

Appendix 1-B: Public Participation and Stakeholder Involvement

The Washington State Department of Transportation (WSDOT) benefits from broader interaction with the public and rail stakeholders. The public participation and stakeholder involvement component of this plan meets state and federal requirements. It educates citizens and rail stakeholders about the role of rail in a balanced transportation system. And it collects and synthesizes comments from the public and rail stakeholder groups to assist in developing the vision, projects, prioritization, financing, and implementation of the state rail plan.

In the development of the plan, an advisory committee was formed, involving as many stakeholders as possible. Three advisory committee meetings were held, along with one workshop and one public open house. Progress reports and opportunities for public comments and discussion were provided. After the advisory committee meetings, the draft plan was available for two weeks of public review and comment.

State Freight Rail Plan Advisory Committee

WSDOT is required by federal and state statutes to provide "adequate and reasonable notice and opportunity for comment and other input to the public, rail carriers, commuter and transit authorities operating in, or affective by rail operations within the state, units of local government, and other interested parties in the preparation and review of the state rail plan." Ideally much of the opportunity for comment and review takes place through the State Freight Rail Plan Advisory Committee (Advisory Committee), which is the rail advisory body for this planning project.

The Advisory Committee is a group of key stakeholder representatives focused on plan development. The Advisory Committee roles are:

1. To help develop a vision for the freight rail plan.
2. To provide assistance to update information for the freight rail system, capacity, and needs.
3. To help identify and assess port access and rail abandonment issues.
4. To help WSDOT understand concerns of local communities and organizations.
5. To facilitate information sharing.

Stakeholders invited to participate in the Advisory Committee included Class I railroads, short-line railroads, other carriers, public transportation

providers, rail operators, rail logistics, rail and other transportation mode advocates, rail research, ports, cities, towns, counties, tribes, federal and state agencies, WSDOT offices, regional planning organizations (e.g. MPO/RTPOs), shippers, and labor. A list of Advisory Committee member organizations that accepted the invitation for participation in this plan is provided in Exhibit 1B-1.

Exhibit 1B-1: Advisory Committee Member Organizations

AgVentures NW, LLC	Port of Tacoma
All Aboard Washington	Port of Vancouver
Ballard Terminal RR. (BDTL)	Portland Vancouver Junction RR (PVJR)
Benton-Franklin Council of Gov.	Puget Sound □ Pacific RR (PSAP)
BNSF Railway (BNSF)	Puget Sound Regional Council (PSRC)
Brotherhood of Locomotive Engineers and Trainmen	Rail Management, Inc. (RMI)
CWCOG□SWRTPO	Spokane Regional Trans. Council
City of Richland	SW WA Regional Trans. Council
Clark County	Tacoma Rail
Columbia Basin Railroad (CBRW)	Thurston Regional Plan Council (TRPC)
Cowlitz Indian Tribe	Tulalip Tribes
Eastern Washington Gateway Railroad (EWG)	Union Pacific Railroad UP
Eastside Transportation Assoc.	Utilities □ Transportation Comm. (UTC)
Freight Mobility Strategic Investment Board (FMSIB)	Washington Dept. of AHP (DAHP)
ILWU Puget Sound Dist. Council	Washington Dept. of Commerce
Kalispel Tribe	Washington Legislature
Lummi Nation and TTPO	Washington Public Ports Assoc. (WPPA)
McGregor Company	Washington St. Dept. of Ag. (WSDA)
Meeker Southern Railroad	WA St. Transportation Comm. (WSTC)
Nisqually Tribe	Whatcom Council of Governments
NW Grain Growers	Woodland Trail Greenway Assoc
NW Tribal Technical Assist. Pgm.	WSDOT □ Budget Office
Pacific Northwest Farmers Coop	WSDOT □ Environmental Svcs.
Parsons Brinckerhoff	WSDOT □ Freight Systems Div.
Port of Everett	WSDOT □ Government Relations
Port of Grays Harbor	WSDOT □ Hwys. □ Local Pgms. (H□LP)
Port of Kalama	WSDOT □ Northwest Region
Port of Moses Lake	WSDOT □ Public Transportation (PTD)
Port of Olympia	WSDOT □ South Central Region
Port of Ridgefield	WSDOT □ State Rail and Marine Office
Port of Royal Slope	WSDOT □ Strat. Planning □ Pgms
Port of Seattle	WSDOT □ Urban Planning Office (UPO)
	YVCOG

Three Advisory Committee meetings were held:

- June 11 at WSDOT Headquarters in Olympia.
- September 30 at WSDOT Headquarters in Olympia.
- October 6 in Moses Lake.

In addition, a workshop was held with Advisory Committee participants and other stakeholders on August 5 at WSDOT Headquarters in Olympia.

The Advisory Committee participants for the meetings are shown in Exhibits 1B-2, 1B-3, and 1B-4.

Electronic Communication Standards

WSDOT uses a standard set of electronic communication tools for communication and outreach that includes a project Web page (www.wsdot.wa.gov/Freight/Rail/WashingtonStateFreightRailPlan.htm), e-mail, and a monthly e-newsletter. The State Freight Rail Plan Web page includes information and links to the meeting information, the surveys, and contacts. E-mail is the primary communication tool between WSDOT and stakeholders; e-mail is sent as early as possible to provide ample response time. Mail is used occasionally. The WSDOT State Rail and Marine Office monthly e-newsletter provides planning project updates to registered subscribers.

Outreach Activities

Outreach activities offer additional opportunities to engage a larger group of stakeholders as well as the general public and receive their feedback.

Key Stakeholder Interviews and Presentations

WSDOT State Rail and Marine Office staff and management conducted a limited amount of interviews to collect specific information about the state freight rail plan. Phone and in-person interviews included key external stakeholders (Port of Tacoma, Tacoma Rail, Port of Seattle, Benton-Franklin-Walla Walla Regional Transportation Planning Organization) and internal stakeholders (WSDOT Freight Systems Division, WSDOT Strategic Planning and Programs Office). WSDOT management also gave presentations to internal and external organizations (WSDOT Executive Team, American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Rail Transportation, Western Freight Roundtable) about the planning project. Documentation about these interviews and presentations is provided later in this appendix.

Exhibit 1B-2: June 11, 2009 Advisory Committee Meeting Attendees

Attendee	Organization
Lloyd H. Flem	All Aboard Washington
James Forgette	BDTL
Terry Finn	BNSF
Rosemary Siipola	CWCOG□SWRTPO
John Howell	EWG
Steve Gibson	EWG
Karen Schmidt	FMSIB
Gary Nelson	Port of Grays Harbor
Mindi Linquist	Port of Kalama
Brent Grening	Port of Ridgefield
Dan Burke	Port of Seattle
Brian Mannelly	Port of Tacoma
Mike Reilly	Port of Tacoma
Wayne Harner	Port of Tacoma
Todd Coleman	Port of Vancouver
Kevin Spradlin	PSAP
Sean Ardussi	PSRC
Eric Temple	PVJR
Steve Murray	RMI
Lynda David	RTC
Dale King	Tacoma Rail
Richard Myers	WPPA
Brad Avy	WSDA
Eric Hurlburt	WSDA
Elizabeth Phinney	WSDOT
Jeff Schultz	WSDOT
Julie Rodwell	WSDOT
Kevin Jeffers	WSDOT
Megan Beeby	WSDOT
Mike Rowswell	WSDOT
Aaron Butters	WSDOT □H□LP
Jerry Ayres	WSDOT □PTD
Thomas Noyes	WSDOT □UPO
WSDOT State Rail and Marine Office Staff	
Andrew Wood	Lynn Scroggins
Brent Thompson	Scott Witt
Brian Calkins	Teresa Graham
George Xu	

Exhibit 1B-3: September 30, 2009 Advisory Committee Western Washington Meeting Attendees

Attendee	Organization
Terry Finn	BNSF
Mike Elliott	Brotherhood of Locomotive Engineers Trainmen
Fred Abraham	Clark County
Russ Holter	DAHP
Will Knedlik	Eastside Transportation Assoc.
Mark K. Ricci	Endeavors Consulting
Jeff Davis	ILWU
Jim Longley	Nisqually Tribe
Mike Zachary	Parsons Brinkerhoff
Gary Nelson	Port of Grays Harbor
Mark Wilson	Port of Kalama
Jim Knight	Port of Olympia
Clare Gallagher	Port of Seattle
Dan Burke	Port of Seattle
Sean Eagan	Port of Tacoma
Wayne Harner	Port of Tacoma
Alan Hardy	Tacoma Rail
Jailyn Brown	TRPC
Brock Nelson	UP
Eric Johnson	WPPA
Eric Hurlburt	WSDA
Jerry Ayres	WSDOT PTD
Thomas Noyes	WSDOT Urban Planning
WSDOT State Rail and Marine Office Staff	
George Xu	Scott Witt
Lynn Scroggins	Teresa Graham

Exhibit 1B-4: October 6, 2009 Advisory Committee Eastern Washington Meeting Attendees

Attendee	Organization
Len Pavelka	Benton-Franklin COG
Scott Williams	CBRW
Tim Kelly	CBRW
John Howell	EWG
Dave Gordon	Northwest Grain Growers
Norm Ruhoff	PNW Farmers Coop
Craig Baldwin	Port of Moses Lake
Alan Schrom	Port of Royal Slope
Steve Murray	RMI
Glenn Miles	SRTC
John Gruber	WSDOT South Central
WSDOT State Rail and Marine Office Staff	
George Xu	Teresa Graham
Lynn Scroggins	

Surveys

WSDOT designed and conducted two surveys in Web-based and PDF formats to collect information about statewide needs for freight rail capital improvements (Projects Survey) and to identify railroad lines at-risk of abandonment (Abandonment Survey). Notices and links were sent to the Advisory Committee and key stakeholders using WSDOT electronic communication standards that included e-mail, Web page links, and e-newsletter. The surveys were also promoted at Advisory Committee and other key stakeholder meetings. Chapter 5 contains Abandonment Survey result summaries. Chapter 8 contains project list summaries that were based, in part, on the Projects Survey.

Public Open House

WSDOT held a public open house on October 22, 2009, to meet federal and state requirements and to provide information about the freight rail plan to stakeholders and the general public. The event included displays from past Advisory Committee meetings, handouts, sample documents, and comment sheets. In addition to electronic communication, the open house was advertised in Seattle, Vancouver, Olympia, Spokane, and Tri-Cities newspapers. WSDOT State Rail and Marine Office staff and management were on-hand to answer questions and discuss the planning project. The list of attendees is shown in Exhibit 1B-5.

Exhibit 1B-5: October 22, 2009 Open House Attendees

Attendees	
Adele McCormick	Jailyn Brown
Cathrine Martin	Jerry Ayres
Cecelia Jenkins	Jim Amador
Cliff Hall	Jim Zabel
Curtis Shuck	Kari Qvigstad
Cyndi Booze	Kathy Murray
David Smelser	Mike Beehler
Don Miller	Mindi Linquist
Edward Berntsen	Paula Connelley
Ernest W. Combs	Russell Holter
Forest Sutmiller	Scott Mills
Frank Kirkbride	Teri Hotsko
George L. Barner, Jr.	Thomas Hume
Greg Roche	Tom Palmateer
J. T. Wilcox	Virginia Stone

Workshop

WSDOT held a workshop on August 5, 2009, at WSDOT Headquarters in Olympia to help develop the vision statement and goals matrix for the state freight rail plan. The Advisory Committee and other key stakeholders were invited to participate in the workshop. The workshop attendees are shown in Exhibit 1B-6.

FRA Reporting

WSDOT submitted three progress reports and will submit the final plan to the United States Department of Transportation (USDOT) Federal Railroad Administration (FRA) for review. The progress reports documented activity to date and sought guidance and feedback.

Government-to-Government Tribal Consultation

The WSDOT Secretary's Executive Order requires WSDOT employees to consult with tribes on all decisions that may affect tribal rights and interests. Per tribal protocol, WSDOT mailed two sets of letters to statewide tribal leaders and their planning managers informing them about the State Freight Rail Plan, inviting their participation, and announcing meetings. WSDOT also offered to meet with tribes individually to discuss their comments or concerns with the plan. Chapter 6 contains information about tribal governments.

Exhibit 1B-6: August 5, 2009 Advisory Committee Workshop Attendees

Attendee	Organization
Lloyd H. Flem	All Aboard Washington
Terry Finn	BNSF
Rosemary Siipola	CWCOG□SWRTPO
Russ Holter	DAHP
Win Knedlik	Eastside Transportation Assoc.
John Howell	EWG
Steve Gibson	EWG
Karen Schmidt	FMSIB
Jeanine Viscount	Parsons Brinkerhoff
Carl Wollebek	Port of Everett
Mark Wilson	Port of Kalama
Mindi Linquist	Port of Kalama
Craig Baldwin	Port of Moses Lake
Jim Amador	Port of Olympia
Christine Wolf	Port of Seattle
Clare Gallagher	Port of Seattle
Brian Mannelly	Port of Tacoma
Sean Egan	Port of Tacoma
Curtis Shuck	Port of Vancouver
Eric Temple □ kids	PVJR
Lynda David	RTC
Glenn Miles	SRTC
Dale King	Tacoma Rail
Jailyn Brown	TRPC
Brock Nelson	UP
Eric Johnson	WPPA
Brad Avy	WSDA
Jerry Ayres	WSDOT □ PTD
John Gruber	WSDOT □ South Central
WSDOT State Rail and Marine Office Staff	
George Xu	Scott Witt
Lynn Scroggins	Teresa Graham

Washington State
Department of Transportation

Appendix 2: Detailed Goal Matrix

The detailed goals matrix includes the goals, objectives, strategies, and actions necessary to achieve the vision of the *Washington State 2010-2030 Freight Rail Plan*. It was developed in the stakeholder and public involvement process described in Chapter 2.

Please Note: The detailed goals matrix in this appendix is an *interim document*. The final set of goals, objectives, strategies, and actions are described in Chapter 2.

Goal 1: Support Washington's economic competitiveness and economic viability through strategic freight rail partnerships.		
Objectives	**Strategies**	**Actions**
To better understand the statewide industry needs for rail transportation.	Increase understanding of the competitive positions of the state's shippers and ports using Washington's freight rail system vs. other modes of transportation.	Carry out needs analysis to support emerging and existing industries to ensure the freight rail system supports Washington's ports and rail-dependent industries, where financially supported.
To better integrate freight rail planning at all levels of government.	Increase coordination of corridor-level freight rail planning within Washington State.	Work with Washington's MPOs, RTPOs, and Tribes to integrate freight rail into future regional transportation plans.
To provide access to national markets for Washington products and cargo entering the US through Washington ports.	Support multistate freight rail corridor strategic planning partnerships.	Work with public and private sector partners in states along any appropriate national corridor to eliminate bottlenecks and improve capacity and velocity inside and outside of Washington State.
To better coordinate with private sector partners.	Support and enhance economic partnerships between Washington State and the rest of the nation and its trading partners.	Establish a process or committee to work and communicate with the ports and industry representatives to coordinate activities at the regional, state, and national level on needed projects, programs, and policy decisions.
To better address barriers to efficient use of freight rail in Washington.	Lead and coordinate with Washington's ports, shippers and industry on a continuing basis to identify infrastructure, regulatory, and administrative barriers to their efficient use of the freight rail system.	On an ongoing basis and at designated intervals, update information with representatives from ports, shippers, railroads, and industry to identify constraints. Develop an action plan to address those issues over which WSDOT has authority.
To have a strategic prioritization of barriers to efficient use of freight rail in Washington State, with stonger public-private partnerships and freight rail infrastructure at the local, regional, corridor, national, and international levels.	Expand the state role to manage, coordinate, and facilitate strategic freight rail infrastructure improvements and investments that are in the public interest.	Increase the state capacity to develop and manage freight rail system information, research capacity, and data capacity that improves oversight and encourages funding for priority freight rail development.
To improve system and project assessment and evaluation processes to support state goals and assist the decision-making process.		
To have a broader understanding of railroad system benefits and investments.		Increase public awareness of freight rail as a vital mode of transportation within the supply chain.
To have an integrated plan that is recognized within the National Rail Plan.	Develop the criteria for corridor level freight rail transportation to integrate into the National Rail Plan.	Lead the planning effort to integrate with partners.

Draft – Interim Document

Goal 2: Preserve the ability of Washington's freight rail system to efficiently serve the needs of its customers.		
Objectives	**Strategies**	**Actions**
To preserve the functionality of the existing system.	Assist the Class 1 railroads efforts to maintain and preserve the functionality of mainline tracks, bridges, and rail yards.	Work with the Class 1 railroads and other partners to identify those system components at risk that can benefit from public support.
		Support the efforts of Class 1 railroads to compete for state and federal funding for major capacity preservation projects, when appropriate.
To continue to provide access to the mainline rail system.	Assist short-line railroads in preserving efficient access to the mainline, ensuring system viability and continuity.	Provide financial assistance to short-line railroads, maintaining and preserving essential rail lines to prevent abandonment, when appropriate.
To create sustainable funding sources for rail preservation and maintenance		Lead the development of rail corridor maintenance and preservation plans that include funding strategies
To support long-term economic vitality and diversity.	Work with stakeholders and partners to ensure long-term preservation of existing industrial land, freight rail corridors, and rights of way for future use.	Integrate freight rail system development, land use planning and policies, public-private partnerships, and funding strategies consistent with the state vision and policy goals to protect and grow freight mobility.
To retain industrial lands and the jobs needed to support them.		Work with ports and railroads to protect the functionality and viability of existing connections between port terminals, intermodal rail yards, and mainline tracks.
To better manage state-owned railroad corridors, returning them to active service as soon as feasible.		Work with short-line and mainline railroads to allow compatible interim use of rail corridor right of way (i.e. rail trails) within statutory limits, until such time that the right of way is returned to active rail use.
To preserve opportunities of abandoned lines for future rail service.		Acquire rail corridors scheduled for abandonment that have the potential to be reactivated in the future.
To preserve opportunities of abandoned lines for other public use of corridors (i.e. rail trails).		

Draft – Interim Document

Goal 3: Facilitate freight rail system capacity increases to improve mobility, reduce congestion, and meet the growing needs of Washington's freight rail users, when economically justified.		
Objectives	**Strategies**	**Actions**
To better understand future freight rail demands.	Continue efforts to regularly evaluate freight rail capacity needs.	Continue working with partners with an interest in freight rail capacity to determine future needs. Assess capacity and use the results to support prioritized investment in freight rail capacity improvements.
To continue reducing congestion, eliminating port access bottlenecks, and increasing reliability and mobility.	Create additional capacity, improve connectivity, and improve operational efficiency by making, or supporting targeted infrastructure investments.	Invest in infrastructure development projects that enable cost effective, smooth, and efficient transport of freight through multimodal corridors and hubs (i.e. lines, ports, industrial areas).
		Identify and prioritize projects that improve mainline capacity, eliminate bottlenecks and improve mainline access for ports and other freight rail traffic generators.
To continue making process improvements.		Support the efforts of Washington's freight rail providers to solicit state or federal funds for projects that provide needed new capacity, where strategically appropriate.
To reduce idling of cars and trucks and improve overall safety on rail and roads, where appropriate.	Pursue grade separation of roads and rails, where appropriate.	Identify grade separation projects that should be included in national, tribal, state, regional, and local transportation plans.
To improve freight and passenger rail mobility.	Support the implementation of passenger rail projects where investments also improve freight rail mobility.	Work with passenger rail agencies and support funding of projects that support freight movement.
To increase public support for public investment in the freight rail system.	Utilize and update existing project assessment tools to include performance measures and benefit-cost analysis to prioritize projects.	Utilize and update the current freight rail project evaluation methodology to prioritize projects.
	Promote public awareness of and support for freight rail investments that provide economic, mobility, safety, and environmental benefits.	The process should include an effort to seek public input and develop public support for priority projects.
To increase federal freight rail funding and increase ability to develop multi-year projects.	Support efforts to develop viable federal funding sources for freight rail projects with public benefits.	Lead efforts to position Washington's freight rail system for future federal funding with railroads, ports, shippers, and industry.
		Coordinate with multistate stakeholders to obtain federal funding for priority projects along multistate corridors (Northern Tier).
		Work with MPOs to facilitate inclusion of appropriate freight rail projects in regional transportation plans.
		Review programs like the FAST corridor program and determine WSDOT's role in facilitating public-private partnerships in funding freight rail projects in Washington.
To increase state funding and implementation of priority freight rail projects.	Support efforts to enhance state funding sources for freight rail projects with public benefits.	Develop a statewide freight rail advisory body to promote freight rail development

Draft – Interim Document

Goal 4: Take advantage of freight rail's modal energy efficiency to reduce the negative environmental impact of freight movement in Washington.		
Objectives	**Strategies**	**Actions**
To improve community environment and health.	Identify and implement freight rail projects which will reduce truck trips and decrease targeted emissions, where economically viable.	Implement rail projects that reduce truck traffic when ecnomically feasible.
	Encourage rail partners to invest in technologies to reduce their fuel consumption and related air emissions.	Encourage increased use of locomotive anti-idling devices, electric support equipment and reduction of wheel/track friction to decrease fuel consumption and air emissions.
		Encourage use of environmentally friendly switching locomotives in port areas and other rail yards close to residential areas.

Draft – Interim Document

Goal 5: Address the safety and security of the freight rail system and make enhancements, where appropriate.		
Objectives	**Strategies**	**Actions**
To reduce numbers of rail-highway incidents.	Continue to identify new areas of focus to enhance rail transportation safety.	Continue to support safety improvements of rail-highway crossings, signal systems, rail lines, and rail facilities.
To reduce the numbers of rail-highway, rail-pedestrian, rail-rail, and trespassing incidents.		Expand outreach and education to new and existing stakeholder groups.
To meet federal requirements.	Partner with the Class 1s efforts to meet the federal mandate and a support railroad requirement to install positive train control systems on mainlines	Continue coordination and support of positive train control systems development.
To improve pedestrian safety and reduce liability.	Continue the Operation Lifesaver partnership to educate the public about rail safety.	Work with railroads and other partners to educate the public and reduce pedestrian trespassing.
To improve emergency recovery and prevention.	Continue emergency management development.	Work with partners to address rail safety before, during, and after emergencies.
		Review best practices, consult with area experts, and develop a list of temporary rail-highway grade crossing closures and alternative routes in the event of natural and man-made disasters.
To improve the security of the state rail system in its ability to deter or respond to attacks on rail facilities or domestic targets, while ensuring mobility for all users.	Address rail system security and homeland security.	Support railroads, Amtrak, and local law enforcement agencies to identify and implement rail security measures based on guidance from existing federal law (PL 110-432). Identify partnerships and other funding sources to enhance rail system security.
To reduce the negative impacts from storm-related emergencies.		Assess the effects of climate change where weather and climate events can impact rail infrastructure and operation.

Draft – Interim Document

Goal 6: Encourage livable communities and family-wage jobs through freight rail system improvements.		
Objectives	**Strategies**	**Actions**
To sustain communities through reduced congestion, preserved and expanded infrastructure, economic growth, and optimized safety, secruity, and environmental impacts.	Continue to support local community development improvements that consider feight rail development options.	Support strategic partnerships along Washington's rail corridors that improve the quality of life of Washington's citizens.

Draft – Interim Document

Washington State Department of Transportation

Appendix 3-A: Passenger Rail Service and Ridership in Washington State □A Brief

Passenger rail, once used as a means to address only mobility problems, is increasingly viewed and used, at both national and regional levels, as an integrated part of robust and resilient multimodal transportation systems. Such transportation systems will help policymakers achieve multiple policy ends, including economic viability, societal mobility, environmental sustainability, and public safety.

Amtrak Intercity Passenger Rail

Amtrak, partnered with the states of Washington and Oregon and the Province of British Columbia, provides intercity rail passenger service in the Pacific Northwest. Passenger rail services operate exclusively over rail lines owned by freight railroads. Sound Transit serves the Puget Sound urban area with commuter rail services. Along the I-5 corridor, passenger intercity passenger rail services share track with freight on the BNSF Railway (BNSF) mainline. The Union Pacific Railroad (UP) also has operating rights on this mainline from Vancouver, Washington (WA) to Tacoma. Between Tacoma and Everett, Sound Transit commuter rail operates on the BNSF tracks. Freight, intercity passenger, and commuter operations share common infrastructure to meet their customers' needs. Exhibit 3A-1 shows the ridership of the three intercity passenger rail services in 2008.

Amtrak *Cascades*

Since 1994 the Washington State Department of Transportation (WSDOT) has partnered with Amtrak, the state of Oregon, the Province of British Columbia, the railroads, and others to provide fast, reliable, and more frequent intercity passenger rail service along the 466-mile Pacific Northwest Rail Corridor (PNWRC). As one of 11 federally designated corridors, the PNWRC extends from Eugene, Oregon (OR) to Vancouver, British Columbia (B.C.). The service, known as Amtrak *Cascades*, provides travelers with a viable transportation alternative for their intercity trips.

Exhibit 3A-1: Ridership of Intercity Passenger Rail Service
Washington State 2008

Rail Service	Description	Ridership
Amtrak *Cascades*	Arrive in Washington State from Oregon or Vancouver, B.C.	245,531
	Departure from Washington State to Oregon or Vancouver, B.C.	239,547
	Travel Within Boundaries of Washington State	189,916
	Travel Through Washington State Without Stopping in State	0
	Total Riders	**674,994**
Coast Starlight	Arrive in Washington State from Oregon or Vancouver, B.C.	51,565
	Departure from Washington State to Oregon or Vancouver, B.C.	62,707
	Travel Within Boundaries of Washington State	9,007
	Travel Through Washington State Without Stopping in State	0
	Total Riders	**123,279**
Empire Builder	Arrive in Washington State from Oregon or Vancouver, B.C.	68,791
	Departure from Washington State to Oregon or Vancouver, B.C.	70,177
	Travel Within Boundaries of Washington State	37,562
	Travel Through Washington State Without Stopping in State	46,464
	Total Riders	**222,994**
Total Intercity Passenger Rail Riders		**1,021,267**

Note: A state intercity passenger rail rider is defined as a passenger rail rider who arrives, departs, travels within and travels through the state using intercity passenger rail services, including Amtrak *Cascades, Coast Starlight*, and *Empire Builder*.

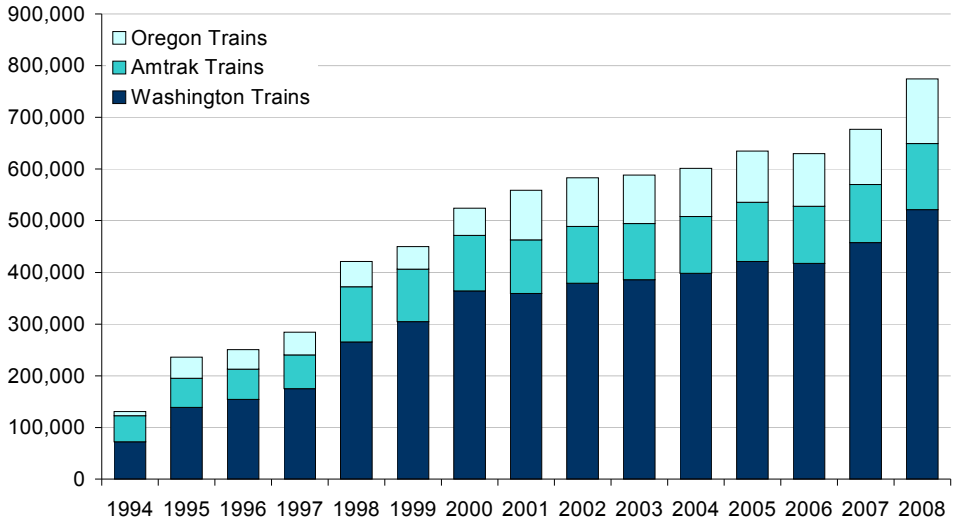
Source: WSDOT State Rail and Marine Office

Amtrak *Cascades* intercity passenger rail service in the state is operated over the BNSF mainline. Amtrak *Cascades* intercity passenger rail service in Oregon is operated over the UP mainline. The alignment roughly parallels Interstate 5 (I-5) and runs through western Washington and western Oregon. The Washington portion includes nine counties: Clark, Cowlitz, Lewis, Thurston, Pierce, King, Snohomish, Skagit, and Whatcom. In addition, a number of cities and towns are also traversed by the rail line, including Vancouver (WA), Kelso/Longview, Centralia, Olympia/Lacey, Tacoma, Tukwila, Seattle, Edmonds, Stanwood, Everett, Mt. Vernon, and Bellingham. In Oregon, the alignment travels through Portland, Oregon City, Salem, Albany, and Eugene. The corridor is diversely populated and contains a mixture of farmlands, small communities, natural habitats, and large metropolitan areas. Corridor development is a cooperative effort between the states of Oregon and Washington, BNSF, UP, Amtrak, Sound Transit, the Province of British Columbia, ports, local communities, passengers, and the general public.

Ridership for Amtrak *Cascades* on the PNWRC has been increasing. The following paragraphs highlight the changes in ridership between 1994 and 2008.

Amtrak *Cascades* ridership has risen steadily on the PNWRC from Eugene, OR to Vancouver, B.C., from less than 200,000 annual passengers in 1994 to 774,536 passengers in 2008. A complete history of the Amtrak *Cascades* annual ridership is shown in Exhibit 3A-2.

Exhibit 3A-2: Amtrak *Cascades* Annual Ridership □ 1994 to 2008



Source: WSDOT State Rail and Marine Office

Since 1994 when Washington State began financially supporting Amtrak service, consumers have responded to the increased frequency of daily train service. In every case when or where the supply of passenger train capacity increased higher ridership has quickly followed. Ridership increases are most significant between Seattle and Portland, with four daily Amtrak *Cascades* regional round trips.

Commuter Rail

Sound Transit provides *Sounder* commuter rail service in the Puget Sound area. *Sounder* commuter rail is a regional rail service operated by BNSF on behalf of Sound Transit. Service operates Monday through Friday during peak hours from Seattle, north to Everett and south to Tacoma. As of 2008, schedules serve the traditional peak commutes, with most trains running inbound to Seattle in the morning and outbound in the afternoon. Two daily round trips run the "reverse commute" to and from Tacoma. Additional *Sounder* trains operate on some Saturdays and Sundays for travel to and from Seahawks games at Qwest Field and Mariners games at Safeco Field. Both stadiums are a short walk from King Street Station.

Ridership has steadily increased year after year with the addition of new service. In 2008 *Sounder's* ridership was 16.13 million, up 17 percent over 2007. One of the key benefits to *Sounder* travel has been the on-time performance of the trains. Performance has reached the level of 99.85 percent in 2008.

Washington State Department of Transportation

Appendix 3-B: Railroad History, Profiles, Service Corridors, and Safety Regulatory History

This appendix contains a brief national and state freight rail history, Washington State (state) freight railroad profiles and service corridors, and a summary of safety regulations and history.

National Freight Rail History[1]

Construction of the nation's rail network started in 1828. The system expanded rapidly in the late 1800s and early 1900s. System mileage peaked in the 1920s at approximately 380,000 miles of track. Since then the rail network has been downsized and modernized to a core network whose route system is descended directly from its 19th century design.

The Class I railroad system today has 160,734 miles of track, less than half the number of miles it had in the 1920s.[2] The reduced size of the nation's freight rail network is the result of three factors: competition with the trucking industry, deregulation, and railroad efficiency.

Private businesses face stiff rate competition from trucks and shareholder pressure to generate profits. As a result, the nation's major railroads have divested in lines and services with insufficient traffic density to adequately cover their operating and maintenance costs. To improve productivity and profitability, they have invested in double-stack cars, larger hopper and tank cars, and higher boxcars and auto-rack cars, which in turn require investment in high-clearance tunnels, higher-weight-capacity track, and stronger bridges. The high cost of these improvements has limited railroads to upgrading only the highest volume and most profitable lines. Other lines have been downgraded or abandoned.

Abandonment has also occurred as a result of mergers and consolidations among railroads, which have led to duplicative or redundant lines. The merger trend began in the mid-19th century as railroads struggled to build networks and access profitable routes and markets.

Railroad abandonments began in the 1920s and continued steadily up to 1980, when many of the railroads were spiraling into bankruptcy. The Staggers Act of 1980 deregulated the railroad industry, helping railroads continue the process of merging, restructuring, and reorganizing. Since

[1] AASHTO, Transportation – Invest in America: Freight Bottom Line Report (2001), pp. 32-33.
[2] Association of American Railroads, www.aar.org/.

railroad deregulation in 1980, the pace of abandonments has slowed as more lines have been sold to create short-line and regional railroads. The result of these changes is a modern, efficient "core" network geared towards profitably serving today's freight-rail markets. But this efficiency has come at a cost. Railroad service has been withdrawn from many areas, forcing businesses to relocate or shift to truck service.

Washington State Rail History

In 1851 the first "railroad" in Washington Territory appeared along the north bank of the Columbia River near present-day Stevenson and used mule power to pull flatcars along six-inch square wooden rails topped with strap iron. This line covered a distance of roughly two miles and was later expanded to six miles.

Two years later Congress authorized the United States (U.S.) Army to conduct five transcontinental railway surveys to find a feasible route to the Pacific Ocean. Isaac I. Stevens led the northern survey, which headed west from St. Paul, Minnesota, looking for a suitable crossing of the Cascade Mountains. Isaac Stevens later became the first Governor of Washington State.

Abraham Lincoln and the Northern Pacific Railroad

In 1864 Congress and President Abraham Lincoln used the findings of the Army's northernmost survey to charter the Northern Pacific Railroad. The route loosely followed that of Lewis and Clark's 1804-1806 Corps of Discovery expedition to the Pacific Northwest. The Northern Pacific was charged with "constructing a railroad and telegraph line from Lake Superior to Puget Sound," in order to "secure the safe and speedy transportation of the mail, troops, munitions of war, and public stores." The Northern Pacific Railroad used the sale of huge federal land grants to finance its construction.

In 1870 the Northern Pacific began construction on its first set of tracks in Washington Territory, near present-day Kalama on the Columbia River. A fierce competition to determine where the tracks would connect to the Puget Sound ensued, and the communities of Olympia, Steilacoom, Seattle, and Whatcom, on Bellingham Bay, were all considered by the railroad. In July 1873, the railroad's Board of Directors selected Tacoma as its western terminus.

In 1874 regular train service began between Kalama and Tacoma. Despite major financial setbacks, the vision for a northern transcontinental railroad was kept alive and small portage railroads[3] along the southern shore of the

[3] Car ferries were used to cross the river from one track to another.

Columbia River were linked together to create a continuous set of tracks. In September 1883, Portland, Spokane Falls, and the cities of the upper Midwest were linked by rail for the first time when the final spike on the Northern Pacific mainline was driven near Gold Creek in Montana.

In 1873 residents of Seattle—upset with the Northern Pacific Railroad's selection of Tacoma as its western terminus—announced their intention to build a railroad to Walla Walla. Though Seattle's effort only made it to the western foothills of the Cascade Mountains, the declaration caused the owners of the Northern Pacific to take another look at a direct rail line between the eastern segment of Washington Territory and Puget Sound. When Congress indicated that the railroad would have to construct a direct route from the mouth of the Snake River to Tacoma—or risk losing large segments of its original land grant—the Northern Pacific began construction west from present-day Pasco through the Yakima Valley. At the same time, track work began near Tacoma in an easterly direction. The two rail lines were to meet at Stampede Pass.

Stampede Tunnel and Statehood

In May 1888, the 1.8-mile-long Stampede Pass tunnel was completed. The completion of the Northern Pacific's rail line between Pasco and Tacoma supported Washington's application for statehood.

In November 1889, Washington became the nation's 42nd state. Railroads now connected growing communities like Tacoma, Seattle, Ellensburg, North Yakima, Pasco, and Spokane with the rest of the nation. The new rail crossing of the Cascade Mountains also reduced the total freight costs for many American businesses trading in the Far East, which led to more port activity, business development, and population growth in Puget Sound.

The Great Northern Railway Comes to Washington

In the early 1890s, Nelson Bennett used some of the money he had earned overseeing the construction of the Stampede Tunnel to form the Fairhaven and Southern Railway on Bellingham Bay. The new rail line stretched north into British Columbia and south into the Skagit Valley. It was hoped that this rail line would lure the westward reaching Great Northern Railway to the Bellingham area.

At the same time, the Seattle, Lakeshore, and Eastern Railway began to build north from Seattle toward the Canadian border. The owners intentionally constructed the line several miles inland from Puget Sound (the part of the route is now the Burke Gilman Trail in Seattle) to prevent other speculators from building new port facilities along Puget Sound that would compete with Seattle. The line extended across the Skagit River to

Sedro-Woolley and on to Sumas City on the Canadian border. In August 1891, the line connected with the Canadian Pacific Railway, Canada's first transcontinental railroad.

The Great Northern Railway reached Spokane in 1892, continued west through Wenatchee, and completed a series of switchbacks across the Cascades Mountains near Stevens Pass. The railroad purchased the Fairhaven and Southern Railway, built tracks to Everett, and reached Seattle in 1893. In 1900, the Great Northern Railway completed their first Cascades Tunnel at Stevens Pass, which cut the travel time between Seattle and the rest of the nation by several hours.

At the turn of the twentieth century, the people of the state had rail access to commercial centers across North America. Passengers and freight came to the new state on the Canadian Pacific, the Northern Pacific, the Great Northern, and the Union Pacific railroads. The state's population continued to grow as immigrants from around the world came to work the land, the forests, the waters, and in thousands of small businesses across the state.

More Railroads and New Stations

In 1908 the Spokane, Portland, and Seattle Railway (SP&S) completed a new rail line along the north bank of the Columbia River, connecting Vancouver, Pasco, and Spokane. Later that same year, the railroad finished construction of a rail bridge across the Columbia River just west of the business district of Vancouver. The new steel bridge created a continuous rail link between Portland, Tacoma, Seattle, and British Columbia for the first time.

In 1909 the last of the major transcontinental railroads reached Seattle and Tacoma. The Chicago, Milwaukee, St. Paul, and Pacific (Milwaukee Road) completed track work and began operating trains across Snoqualmie Pass. The first Milwaukee Road train arrived in Seattle on June 14, 1909, and terminated at the temporary station at Washington Street and Railroad Avenue.[4] The arrival of the Milwaukee Road further intensified the railroads' competition for freight and passengers. The Milwaukee Road operated transcontinental passenger trains to both Seattle and Tacoma and operated transcontinental freight service into Tacoma, where their main freight yard was located.

The Milwaukee Road's line across Snoqualmie Pass and all lines in the state were embargoed[5] in 1979, and the last Milwaukee Road freight train

[4] Milwaukee Road Historical Association *The Milwaukee Railroader* – Volume 39, Number 3/Third Quarter 2009 – White River Productions.
[5] An embargo is a complete ban on economic exchange.

left Tacoma on March 15, 1980. The rail line across Snoqualmie Pass was sold to the Burlington Northern Railroad, but was ultimately abandoned and the trackage was removed by the end of 1987. This line is now part of the John Wayne Trail owned by Washington State Parks. Several portions of the old Milwaukee trackage in Moses Lake and in eastern/northeastern Washington have been picked up and operated by short-line or regional railroads. However, most of the old Milwaukee Road rail line across the state has been abandoned.

The Decline of Passenger Rail Service in Washington

In the early 1920s, automobile and truck transportation began to become very popular. The Washington Department of Highways and local highway districts often followed travel corridors developed by the railroads as they paved new roads between major cities. The completion of the first Pacific Highway between Seattle and Portland in 1924 lured away more passengers and freight traffic from the rails. For many people, this shift was inspired by the fact that automobile and truck transportation provided a greater degree of flexibility and freedom than was available with rail transportation. Travelers and shippers were no longer dependent upon the schedules and rates offered by the railroads.

The completion of the original Pacific Highway in western Washington caused the Great Northern, the Northern Pacific, and the Union Pacific railroads to pool their passenger services between Seattle and Portland and reduce the number of trains from 22 to 12 trains per day.

The federal government, which had required the railroads to continue to provide passenger service to communities across the nation, finally agreed to relieve the railroads from this obligation. In exchange, the railroads gave most of their old passenger equipment to the newly formed National Railroad Passenger Corporation, more commonly known as Amtrak (for *Am*erican *tra*vel by trac*k)*. Operating agreements between the private railroads and Amtrak were finalized, and national service began on May 1, 1971.

For more information about passenger rail history, see the *Amtrak Cascades Mid-Range Plan*, Appendix 3A.[6]

The following railroad profiles contain freight railroad history, descriptions, and maps for each railroad in Washington State.

[6] 2008 *Amtrak Cascades Mid-Range Plan* Appendix 3A, www.wsdot.wa.gov/Freight/publications/PassengerRailReports.htm.

Class I Railroad Profiles

BNSF Railway

On March 3, 1970, the Great Northern; Northern Pacific; the Spokane, Portland, and Seattle; and the Chicago, Burlington, & Quincy Railroads merged and become the Burlington Northern Railroad.

In 1980 the Staggers Rail Act deregulated rail transportation in the U.S. causing the largest railroads to sell off branch lines to smaller railroad companies. In 1983 the Burlington Northern Railroad discontinued rail service across the Stampede Pass. In 1995 the Burlington Northern Railroad merged with the Santa Fe Railroad and became the Burlington Northern and Santa Fe Railway, which later became the BNSF Railway Company (BNSF). And in 1996 the BNSF repaired and reopened the Stampede Pass line.

The BNSF is one of the four largest railroads operating in the U.S. (the largest U.S. railroad by 2009 revenue). BNSF, as it stands today, is the product of some 390 different railroad lines that merged or were acquired over more than 150 years.

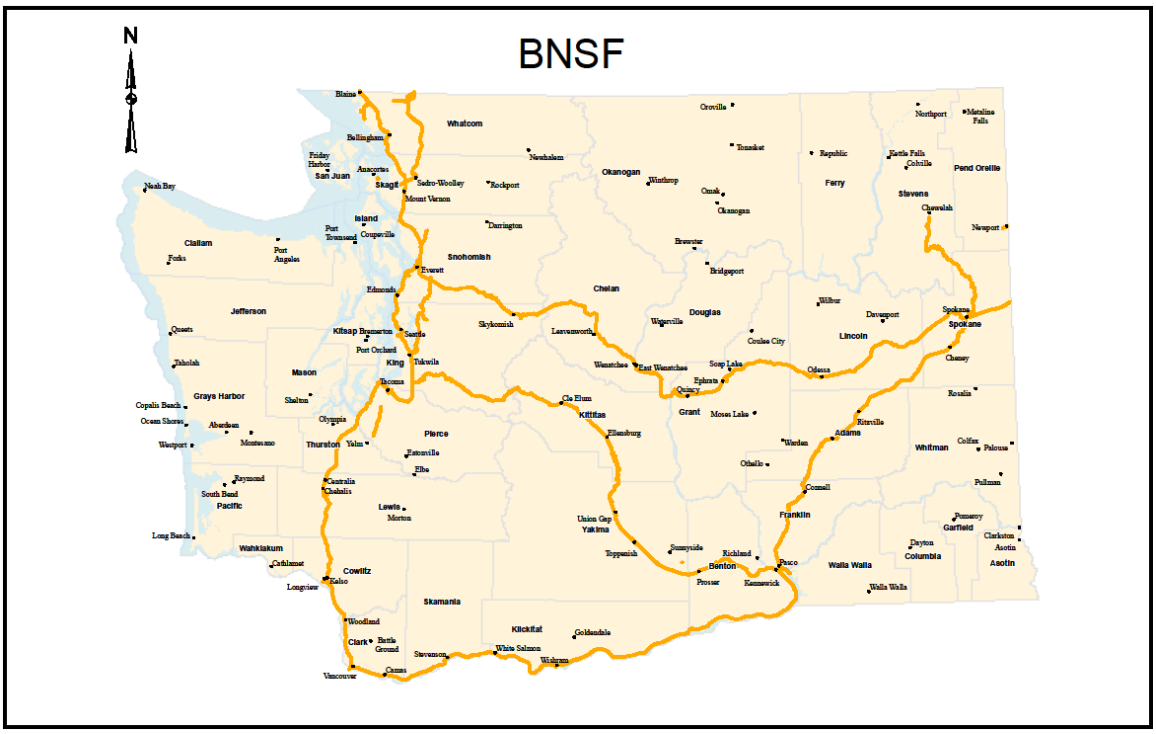
Service is provided over seven major corridors, and nine low-density corridors. The major corridors provide the primary conduits to the North American rail network, while the low-density corridors offer collection/distribution services. The major corridors are:

- Seattle-Spokane
- Seattle-Portland, OR
- Portland, OR-Pasco
- Auburn-Pasco
- Pasco-Spokane
- Spokane-Sandpoint, ID
- Everett-Vancouver, B.C.

BNSF operates over 1,640 miles in Washington State, which represents almost ten percent of their total system route miles operated.

An average of 220,000 rail cars operates on the BNSF network daily. Primary commodities include coal, agricultural products, intermodal (containers/trailers), forest products, chemicals, metals, and minerals. BNSF is one of the largest haulers of agricultural products. Chemicals hauled by the BNSF include propane, lube oil, petroleum, and asphalt.

According to the BNSF 2008 Annual Report to the UTC, revenue totaled $17.5 billion.[7] BNSF reported total interstate operating revenue of $1,040,184 and total gross intrastate operating revenue of $97,876,862.



Union Pacific Railroad

The Union Pacific Railroad (UP) was originally founded through the passage of the Pacific Railroad Act of 1862. This act designated the first transcontinental railroad line across the United States and chartered the UP and Central Pacific Railroads to build this line. The nation's first transcontinental railroad line was completed on May 10, 1869, when the UP and Central Pacific Railroads met at Promontory Summit, Utah.

The first UP line arrived in the Washington Territory in 1881 in the form of the Oregon Railway and Navigation Company (O-WR&N) with a line from Bonneville, Oregon (OR) to Walla Walla, Washington Territory. This line was extended further into Washington Territory with connections to Dayton in 1882, Riparia/Moscow in 1885, and Colfax and Spokane by 1890.[8] Line extensions were also built from Walla Walla to Pasco and ultimately Yakima/Selah and Sunnyside. The O-WR&N was sold in foreclosure to the Oregon-Washington Railway and Navigation Company, which became a fully-owned subsidiary of the UP in 1936.

[7] www.bnsf.com/investors/investorreports/2Q_2009_Investors_Report.pdf
[8] *Encyclopedia of Western Railroad History* – Volume III Oregon – Washington, Donald B. Robertson, The Caxton Printers Ltd. 1995

The UP considered building a parallel north-south mainline from Portland to Tacoma/Seattle in the early 1900s. However the UP ended up negotiating trackage rights over the Northern Pacific Railway mainline between Portland, OR and Tacoma, Washington (WA) through its O-WR&N subsidiary. The Union Pacific's O-WR&N subsidiary constructed a joint line with the Chicago, Milwaukee, St. Paul, and Pacific Railroad between Tacoma Junction and Black River Junction, near Seattle, providing access to the Seattle area. Further access to downtown Seattle was provided via trackage rights on the Northern Pacific and the Pacific Coast Railway. The UP/O-WR&N and the Milwaukee Road passenger trains called at Union Station in Seattle, which opened in 1911.

The Spokane International Railroad Company built a railroad line from Spokane up to the Canadian border at Eastport, ID and commenced operations on November 1, 1906. The Spokane International Railroad entered bankruptcy in 1933 and was re-organized as the Spokane International Railroad (SI). The UP acquired full control of the SI in 1958, and presently operates the Spokane to Eastport, ID line as part of the UP system. The UP operates a number of run-through international trains with the Canadian Pacific Railway via the connection at Eastport, ID.

The UP and the Southern Pacific Railroads (SP) merged on September 11, 1996. The SP only operated as far north as Portland, OR and never came into Washington State. The merger allowed the UP to offer some longer distance one-railroad routings, such as Seattle to Los Angeles and Seattle to San Francisco Bay area. The UP/SP merger also re-configured some of their adjacent terminal operations in Portland. This merger then resulted in the largest Class I railroad in the U.S., as measured by total route miles.

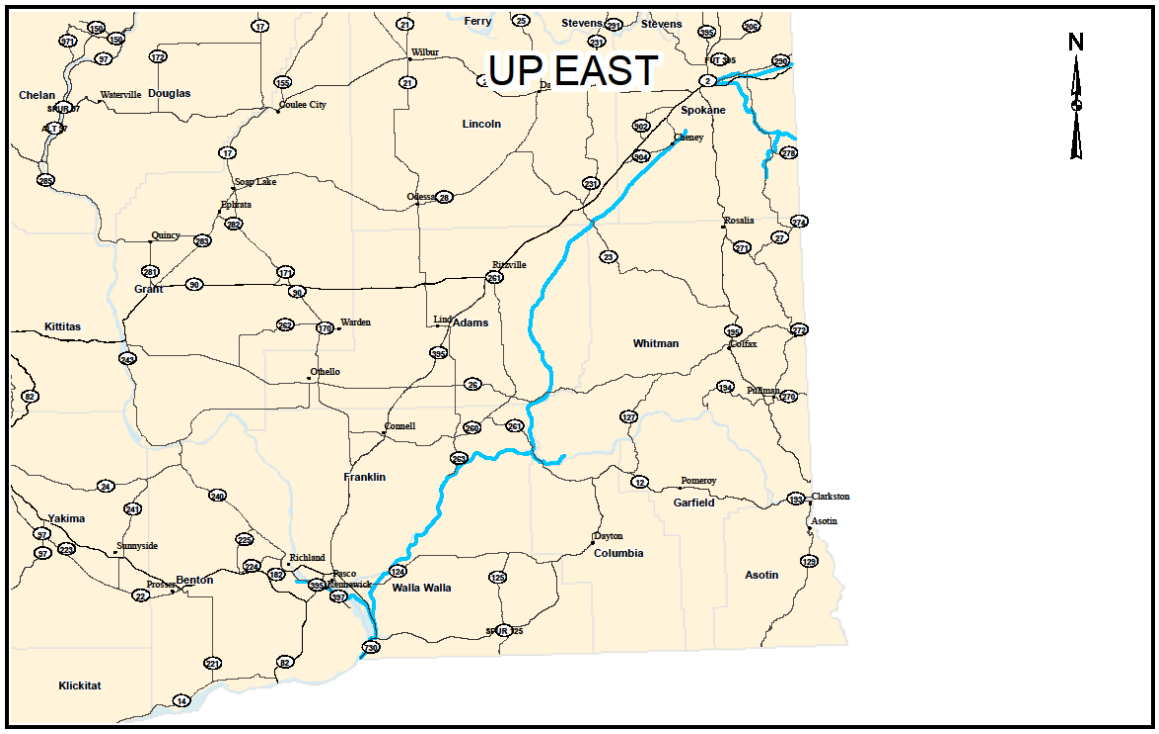
The railroad is still the largest railroad in North America by trackage, serving 23 states, operating over 32,000 miles in the western U.S., linking every major West Coast and Gulf Coast port, and providing east-west service through four major gateways (Chicago, St. Louis, Memphis, and New Orleans) with the eastern railroads. UP also operates key north-south corridors with several connections at the Mexican and Canadian borders.[9]

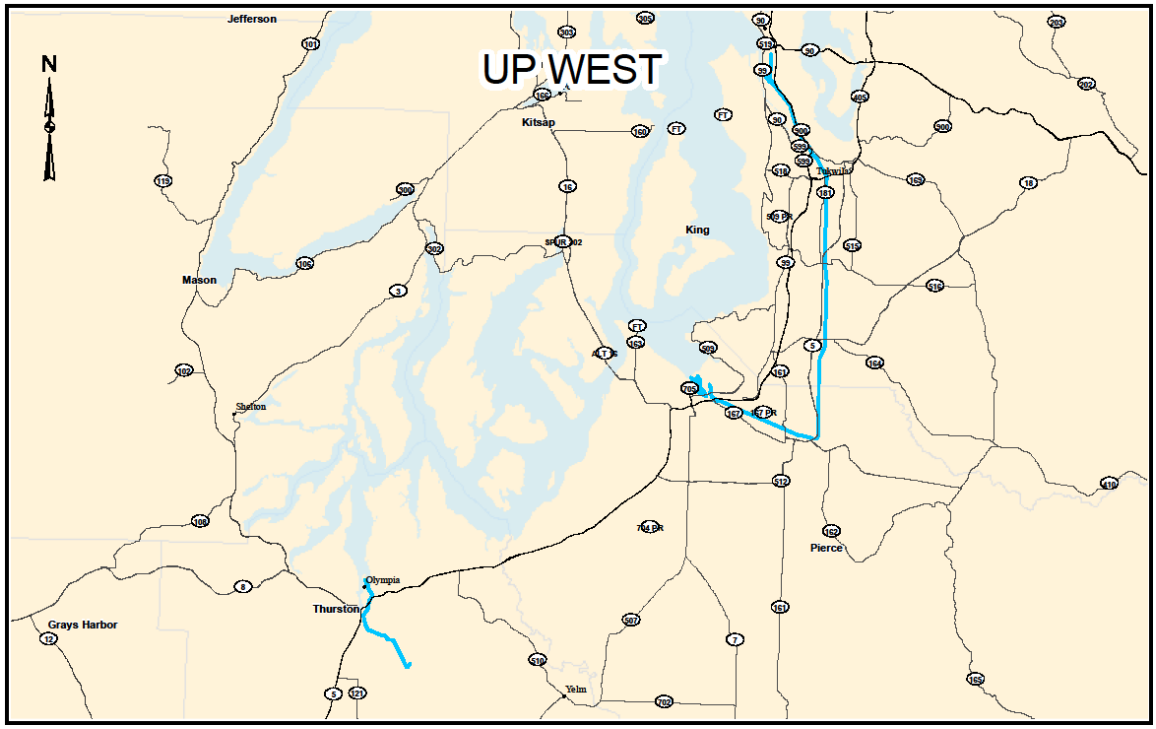
The UP operates on 678 route miles in the state with operating rights on BNSF tracks between Portland and Tacoma, and between Tukwila and the Port of Seattle. It operates on its own right-of-way between Tacoma and Tukwila. In eastern Washington, UP operates on its own tracks between Hinkle, OR and Spokane, and also to the "funnel" between Spokane and Sandpoint, ID.

[9] Introductory material adapted from www.up.com/.

The UP transports many commodities including chemicals, coal, food and food products, forest products, grain and grain products, intermodal, metals and minerals, and automobiles and parts. The UP is also one of the largest intermodal carriers (containers and trailers).

Revenue in 2008 totaled $18 billion per UP's 2008 Report to the UTC.





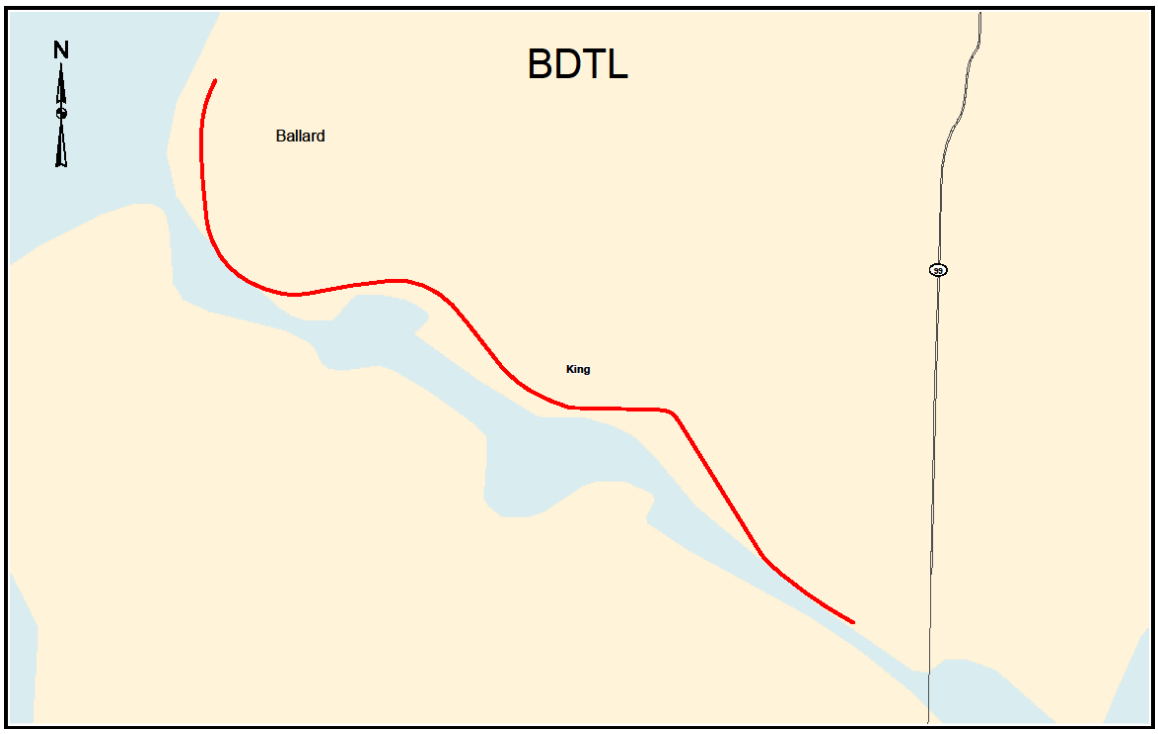
Class II and Class III Railroad Profiles

Ballard Terminal Railroad

The Ballard Terminal Railroad (BDTL[10]), a Class III railroad in Seattle, was formed in 1997 to operate trains on three miles of track on the north side of Salmon Bay. The BDTL runs from NW 40th Street and 6th Avenue NW, just south of its Bright Street Yard and on the edge of Fremont Avenue, northwest toward Ballard proper. There, it passes the Hiram M. Chittenden Locks and runs along Seaview Avenue NW to its Shilshole Yard, where it joins the BNSF mainline just north of NW 68th Street. Most of the railroad was originally part of the Great Northern Railway's mainline, which moved to the west when the Lake Washington Ship Canal was built.[11]

The BDTL reported total interstate operating revenue of $6,148 and $70,012 for total gross intrastate operating revenue in their 2008 Annual Report to the Utilities and Transportation Commission (UTC).

[10] BDTL is the reporting mark for Ballard Terminal Railroad. A reporting mark is a two-to-four-letter alphabetic code used to identify owners or lessees of rolling stock and other equipment used on the North American railroad network. The marks are stenciled on each piece of equipment, along with a one-to-six-digit number, which together uniquely identify every such rail car. This allows the cars to be tracked by the railroad they are traveling over, which shares the information with other railroads and customers.
[11] http://en.wikipedia.org/wiki/Ballard_Terminal_Railroad/.

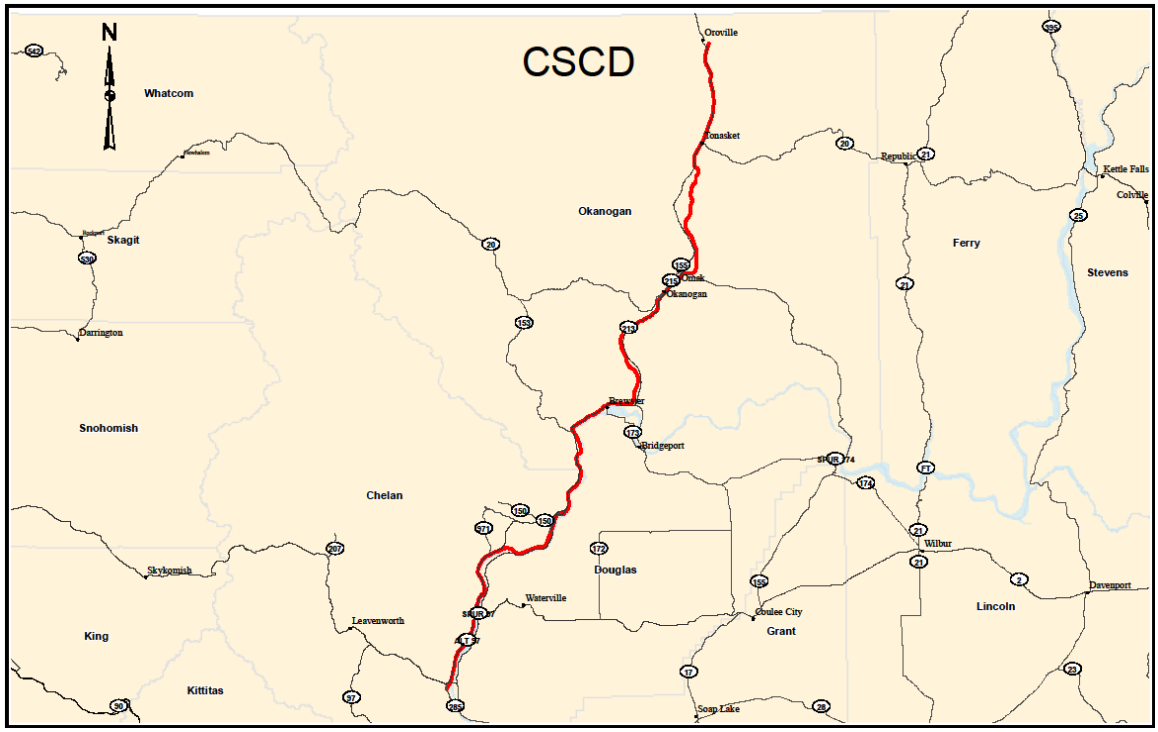


Cascade and Columbia River Railroad

The Cascade and Columbia River Railroad (CSCD) is a Class III railroad that interchanges with BNSF in Wenatchee and runs north to Oroville. This line was originally built in 1914 by the Great Northern Railroad to link the mainline at Wenatchee to the Washington & Great Northern/ Vancouver, Victoria & Eastern line at Oroville. The major commodities carried on the CSCD are limestone, pulpwood, and lumber products. The CSCD offers transload locations on its line to assist customers in getting their lumber to specific customers that may not be rail served or need additional services provided by these facilities. The CSCD operates 148 miles of track and moves over 5,200 cars per year to or from this area in the state. The CSCD has trackage rights over six miles of BNSF's Oroville Spur to Wenatchee for the purpose of performing interchange at Wenatchee Yard.[12]

CSCD reported total gross intrastate operating revenue of $1,614,149 in their 2008 Annual Report to the UTC.

[12] http://www.railamerica.com/RailServices/CSCD.aspx/.



Central Washington Railroad

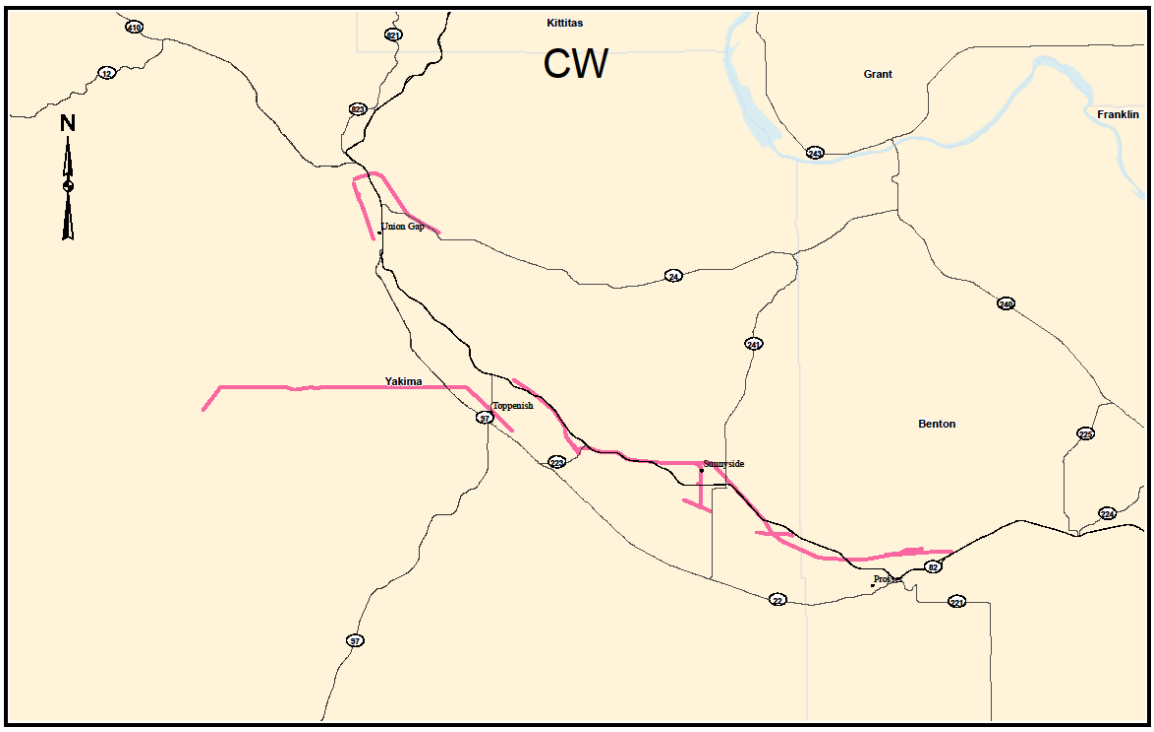
The Central Washington Railroad (CWA), a wholly-owned subsidiary of the Columbia Basin Railroad (CBRW), serves with a series of former BNSF and UP branch lines in central Washington. The CWA, a Class III railroad, consists of approximately 60 miles of track located in the Yakima Valley. The CWA serves the communities of Yakima, Union Gap, Moxee, Granger, Sunnyside, Grandview, and Prosser. These include:

- Former North Yakima & Valley Railway (NY&V, acquired by the Northern Pacific in 1914) from Yakima to Moxee City, 8.6 miles acquired from BNSF in 2005.
- Former NY&V from Yakima to Fruitvale, three miles acquired from BNSF in 2005.
- Former NP from Gibbon to Granger, 30 miles acquired from BNSF in 2005.
- Numerous short stretches of former NCRR trackage between Grandview and Zillah, 15.6 total miles of trackage rights assigned by BNSF over UP-owned lines in 2005.

Commodities hauled on this line include feed, propane, paper products, plastic pellets, cheese, juice concentrate, lumber, apples, and other agricultural goods.[13]

[13] http://www.temple-industries.com/companies/central_washington_railroad.php/.

The CWA reported total interstate operating revenue of $1,436,210 and total gross intrastate operating revenue of $374,225 in their 2008 Annual Report to the UTC.

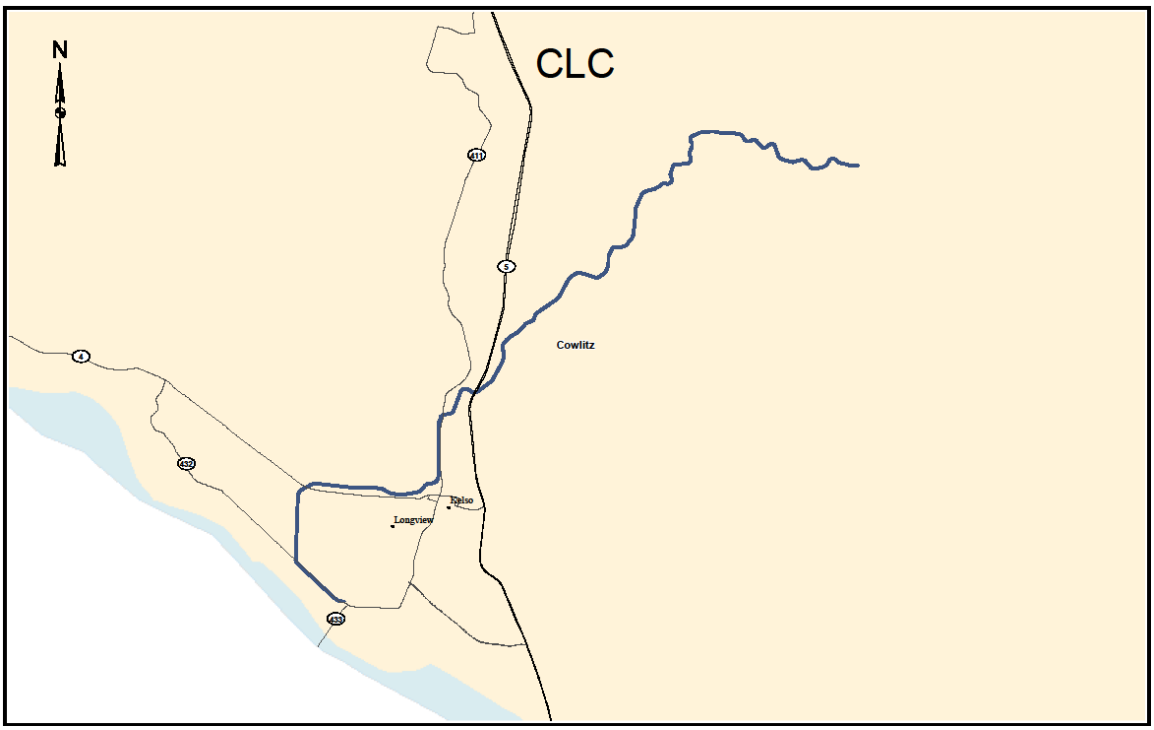


Columbia and Cowlitz Railway

The Columbia and Cowlitz Railway (CLC), a Class III railroad, is a wholly-owned subsidiary of Weyerhaeuser Company, and is headquartered in Longview, WA. The railroad serves an 8.5-mile public route from the Weyerhaeuser Company mill in Longview to the junction just outside the city limits of Kelso.[14] It also connects to a private route to serve Weyerhaeuser properties. The line was completed in 1928 and hauls forest products, steel, and chemicals.

The CLC reported total gross intrastate operating revenue of $2,654,693 in their 2008 Annual Report to the UTC.

[14] http://en.wikipedia.org/wiki/Columbia_and_Cowlitz_Railway/.

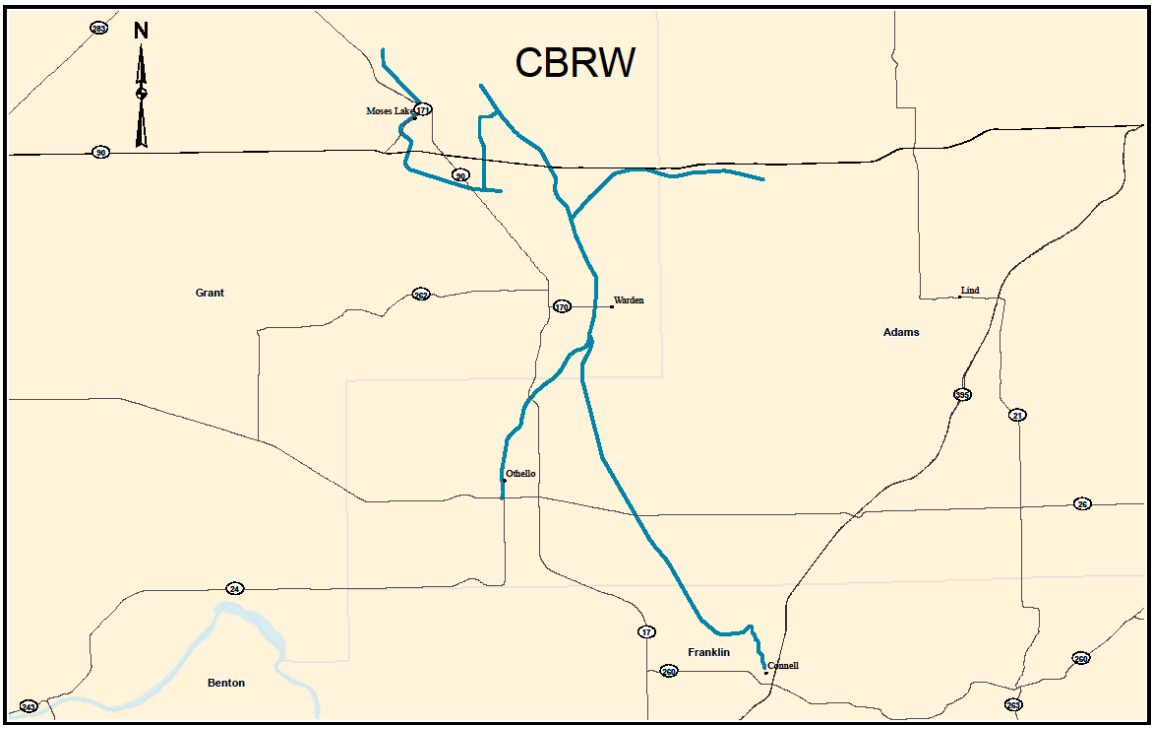


Columbia Basin Railroad

The Columbia Basin Railroad (CBRW) is a Class III railroad located in the Columbia Basin region of the state. Interchanging with the BNSF in Connell, the line runs north crossing I-90 before reaching Moses Lake. Along the route, the CBRW also serves Warden, Bruce, Schrag, and Othello. In total, the line consists of 86 track miles: 73 miles are owned by the CBRW and the other 13 track miles are on a long-term lease from the BNSF. Presently, the main commodities hauled on this line are agricultural goods, in-bound fertilizer, chemicals, and processed potatoes and vegetables.

The CBRW reported total interstate operating revenue of $4,240,109 and total gross intrastate operating revenue of $787,720 in their 2008 Annual Report to the UTC.

The Portland Vancouver Junction Railroad (PVJR) is a newly formed subsidiary of CBRW. It is owned by Clark County, serving the Vancouver (WA) area since 2004. The Chelatchie Prairie Railroad (BYCX), a tourist railroad, operates passenger excursions between Lucia and Yacolt on weekends and holidays.

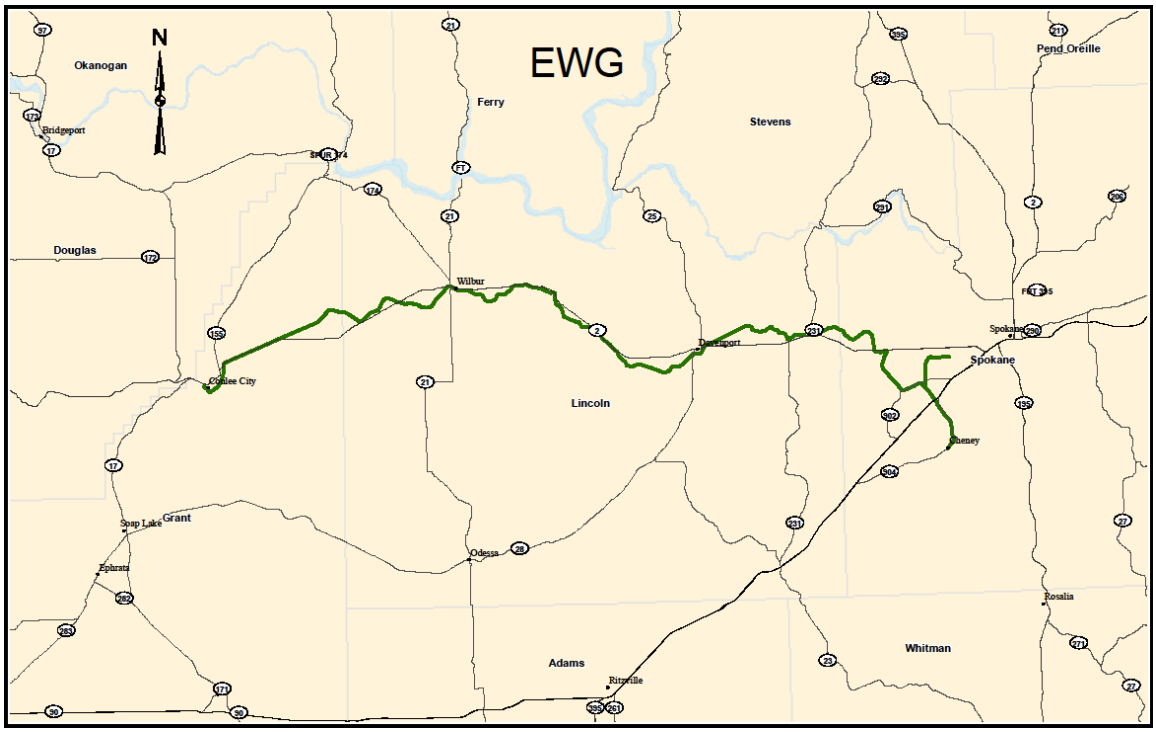


Eastern Washington Gateway Railroad

The Eastern Washington Gateway Railroad (EWG) operates a 108-mile Class III railroad that extends from Cheney to Coulee City. It is one of three state-owned branch lines of the Palouse River & Coulee City Railroad System. The primary customer is a grain cooperative, which ships barley and wheat from facilities located on the western portion of the branch. Other grain shippers transport grain by rail to a lesser extent. Most of the grain cars travel all of the way to the coast for shipment overseas. Other cars are taken in a 60-car shuttle operation to a loading operation in Ritzville, where the grain is placed in a 110-car shuttle train to the coast.

In January 2009, a new connecting track to the existing Geiger Spur in Airway Heights was opened. Formerly operated by Western Rail Switching (WRS) and owned by Spokane County, Geiger Spur customers include three metal fabricators and a locomotive parts reseller. Studies suggest that new industrial development in the greater Spokane area, including intermodal transload, will likely occur in the area served by the Geiger Spur.

The EWG reported total interstate operating revenue of $1,803,601 in their 2008 Annual Report to the UTC. WRS, in their last year of operation of the Geiger Spur, reported total interstate operating revenue of $58,500 in their 2008 report to the UTC.



Great Northwest Railroad

The Great Northwest Railroad (GRNW), a Class III railroad, is located in the Idaho Panhandle near the state line and consists of approximately 77 mainline miles. From Lewiston, ID, the railroad heads west to Riparia, WA. The GRNW interchanges with both the BNSF and UP at Ayer, WA, approximately 85 miles west of Lewiston.

The Camas Prairie Railroad Company was formed in 1909, jointly owned and operated by the former Northern Pacific Railway, now BNSF, and the former Oregon-Washington Railroad and Navigation Company, now UP. The GRNW is a wholly-owned subsidiary of Watco Companies, which purchased the line in 2004, renaming it the GRNW. [15]

Primary commodities are forest products consisting of lumber, bark, paper and tissue, agricultural products, industrial and farm chemicals, scrap iron, and frozen vegetables.

The GRNW reported total interstate operating revenue of $3,962,836 in their 2008 Annual Report to the UTC and reported total gross intrastate operating revenue of $113,584.

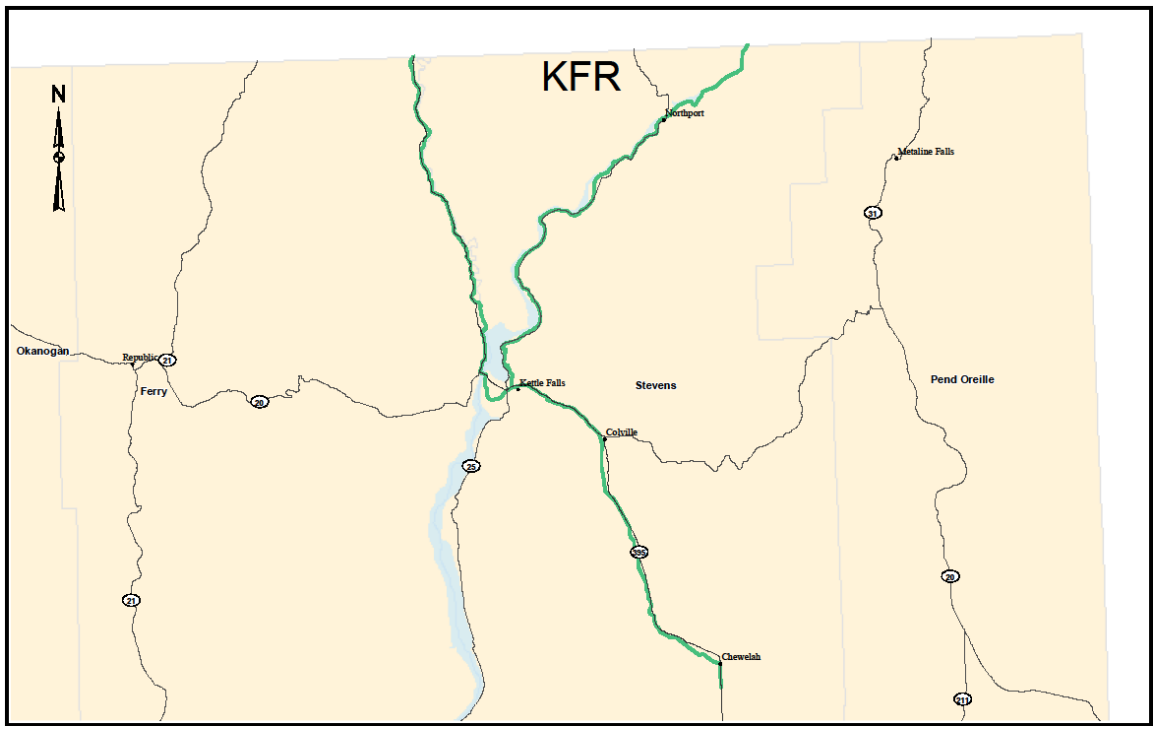
[15] http://www.watcocompanies.com/railroads/gnr/grnw.htm

Kettle Falls International Railway

The Kettle Falls International Railway, LLC (KFR) owns and operates over 160 miles of former BNSF trackage in northeastern Washington State and southeastern British Columbia (B.C.). KFR operates from the BNSF interchange at Chewelah, WA to Columbia Gardens, B.C. A second line operates from Kettle Falls to Grand Forks, B.C. KFR has a diverse traffic base, including lumber, plywood, wood products, minerals, metals, fertilizer, industrial chemicals, and abrasives.[16]

KFR reported total interstate operating revenue of $4,319,638 and total gross intrastate operating revenue of $460,891 in their 2008 Annual Report to the UTC.

[16] http://www.omnitrax.com/rail_kfr.aspx



Longview Switching Company

The Longview Switching Company (LSC), a Class III railroad, is a jointly owned subsidiary of BNSF and UP that performs terminal switching duties at the Port of Longview. LSC was once known as the Longview, Portland & Great Northern Railway (LP&N). The LP&N was owned by International Paper. Like Weyerhaeuser, International Paper owned its own railroads. The original LP&N went from Longview north to Ryderwood, but was later cut back to operate between Longview and a connection to the Northern Pacific (now BNSF) at Longview Junction. As International Paper built more mills in other parts of the northwest, they built more railroads as well, and all these railroads were part of the LP&N. When International Paper's Longview Mill closed, the railroad, which still served other customers, was sold to become Longview Switching. Longview Switching is a private company categorized under Railroad Switching and located in Longview. It was incorporated in 1971.[17]

The BNSF and UP mainlines run parallel to I-5, approximately five miles from the Port. The Longview Switching Company switches trains from the railroad mainlines into the Port. From there, Port locomotives move trains and rail cars to the marine terminals and industrial locations. The LSC operates on 17 miles of track owned by BNSF and UP.[18]

[17] http://people.msoe.edu/~westr/wtcx.htm
[18] http://www.manta.com/company/mtvr3mg

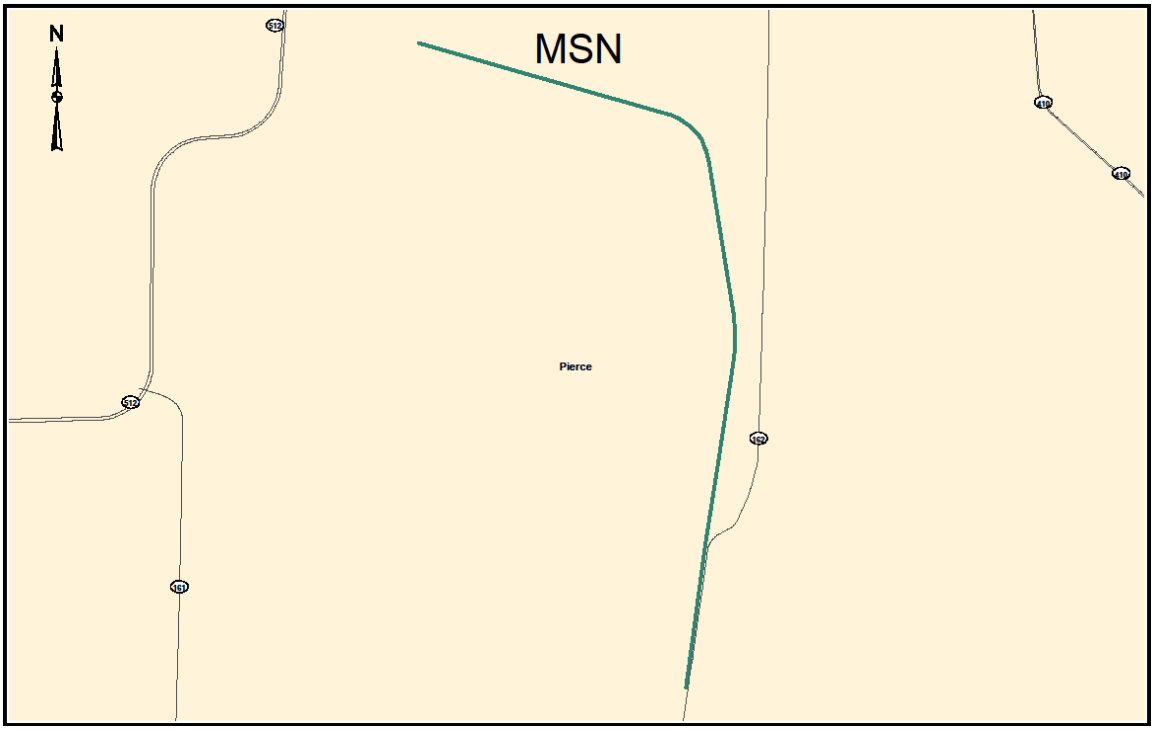
LSC reported estimated annual revenue of $1,600,000 in 2008.

Meeker Southern Railroad

The Meeker Southern (MSN) is a Class III railroad that connects Meeker Junction (Puyallup, WA), with an industrial park in McMillan, WA. The MSN is a wholly-owned subsidiary of the BDTL. The line is approximately 5 miles long, which is owned by MSN.

The commodities hauled on this line are fiberboard, building materials, and steel products.

MSN reported no total gross intrastate operating revenue, but did report $181,796 in interstate operating revenue.



Montana Rail Link

Montana Rail Link (MRL) is a Class II regional railroad with more than 900 miles of track serving 100 stations in Montana, Idaho, and Washington. MRL connects with the BNSF at Spokane, and at Laurel and Helena, Montana.

MRL hauls a variety of commodities including agriculture, chemicals, fertilizers, hazardous materials, lumber, coal, scrap iron, and paper.

MRL operates on 16 miles of track owned by BNSF from the Idaho border into Spokane.

MRL reported total intrastate revenue of $4,434,250 in 2008.

Mount Vernon Terminal Railway

The Mount Vernon Terminal Railway (MVT), a Class III railroad serving Mount Vernon, was formed in 1933 by acquisition of track from the Pacific Northwest Traction Company. The railroad expanded in 1939, when it acquired trackage abandoned by the Puget Sound & Cascade Railway. The railroad provides as-needed service and interchanges with BNSF at Mount Vernon. The railroad consists of a 3-track wide yard. It is used for storage and transloading, no on-line customers.

MVT reported total interstate operating revenue of $61,174 and no intrastate operating revenue.

Palouse River Coulee City Railroad System

The Palouse River & Coulee City Railroad System is owned by the state. It consists of three Class III railroads operating on 279 miles of mainline track and 18 miles of former mainline track that is now used for rail car storage. The system is divided into the following branches:

CW Branch

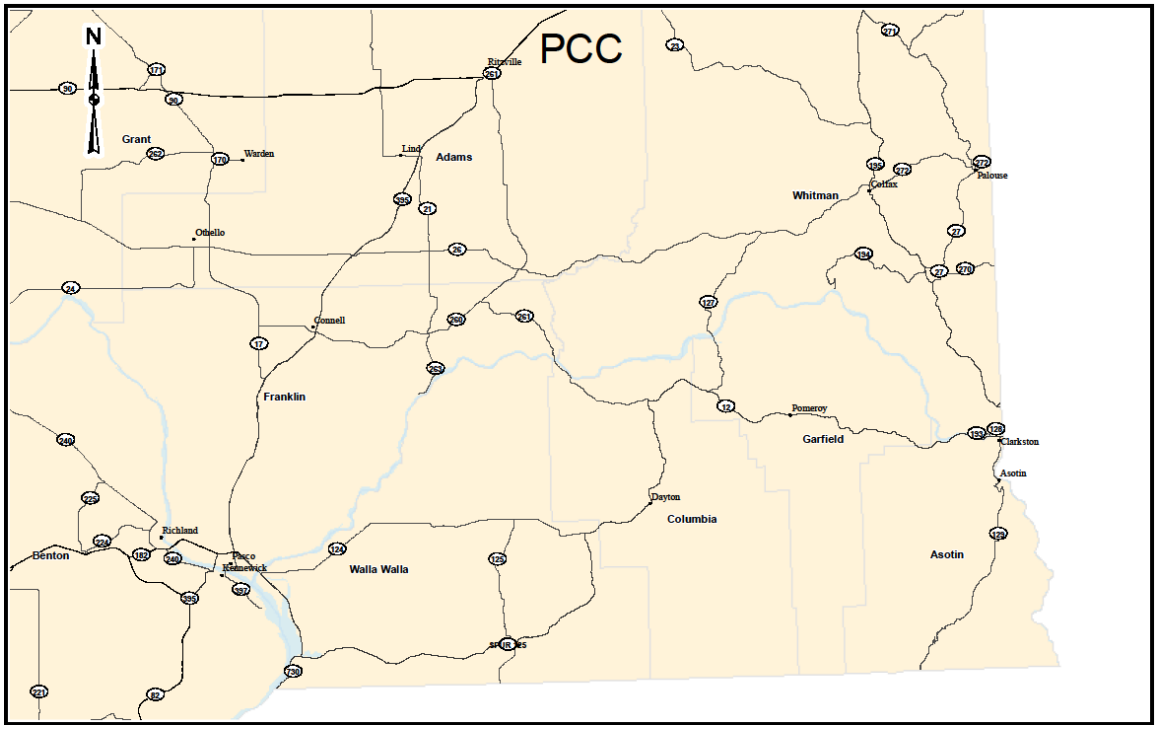
The Eastern Washington Gateway Railroad (EWG) operates this 108-mile-long branch that extends from Cheney to Coulee City. The primary customer is a grain cooperative, which ships wheat from facilities located on the western portion of the branch. Other grain shippers transport grain by rail to a lesser extent. Some of the grain cars travel all the way to the coast for shipment overseas. Other cars are taken in a 52-car shuttle operation to a mega-loader operation in Ritzville where the grain is placed in a 110-car shuttle train to the coast.

PV Hooper Branch

The PCC Railroad Company (PCC), a subsidiary of Watco Companies operates this branch, which contains a total of 84 miles of mainline track. Fertilizer products are brought into a facility located in Mockonema. However, grain is the primary commodity. Grain is taken to a transload facility in Wallula where it is loaded onto barges for transport to the coast. The Hooper sub-branch extends from Colfax to Hooper. The PV Hooper sub-branch extends from Thornton to Winona where it connects to the Hooper sub-branch.

P □ L Branch

The Washington and Idaho Railway, Inc. (WIR) operates this branch, which contains a total of 87 miles of mainline operating track. Grain is also the primary commodity shipped on the branch. Fertilizer and lumber are also shipped. The branch extends from Marshall through Pullman to Moscow, ID. A small spur extends from Palouse to the Idaho border directly to the east where it continues to Princeton, ID under private ownership. The operator also stores cars on an 18-mile section that extends from Pullman to a river crossing near Colfax where a bridge burned that severed the section from the PV Hooper Branch.

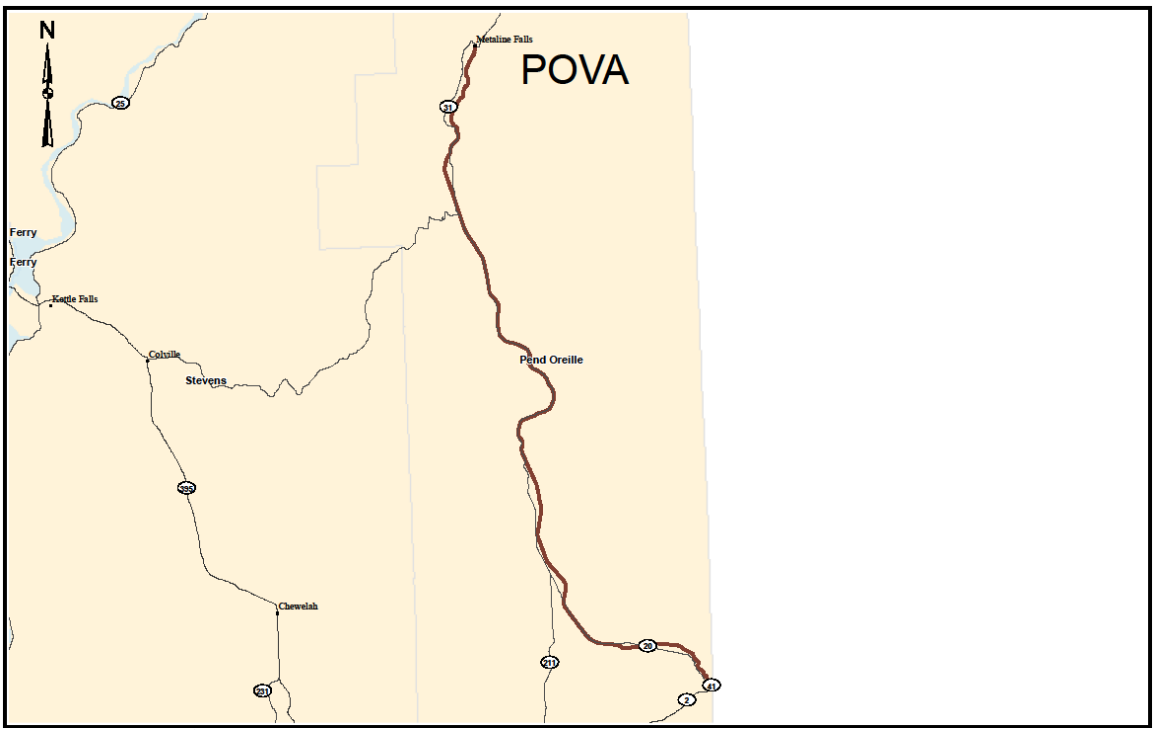


Pend Oreille Valley Railroad

The Port of Pend Oreille owns and operates the Pend Oreille Valley Railroad (POVA), a Class III railroad. Located in northeastern Washington, POVA-owned tracks run from Metaline Falls to Newport. POVA leases trackage from BNSF from Newport to Dover, ID.[19] Most of the POVA customers are located near the south end of the line, and the north end hosts occasional tourist trains between Ione and Metaline Falls.

POVA reported a total interstate operating revenue of $1,899,339 and total gross intrastate operating revenue of $506,001.

[19] http://www.povarr.com/



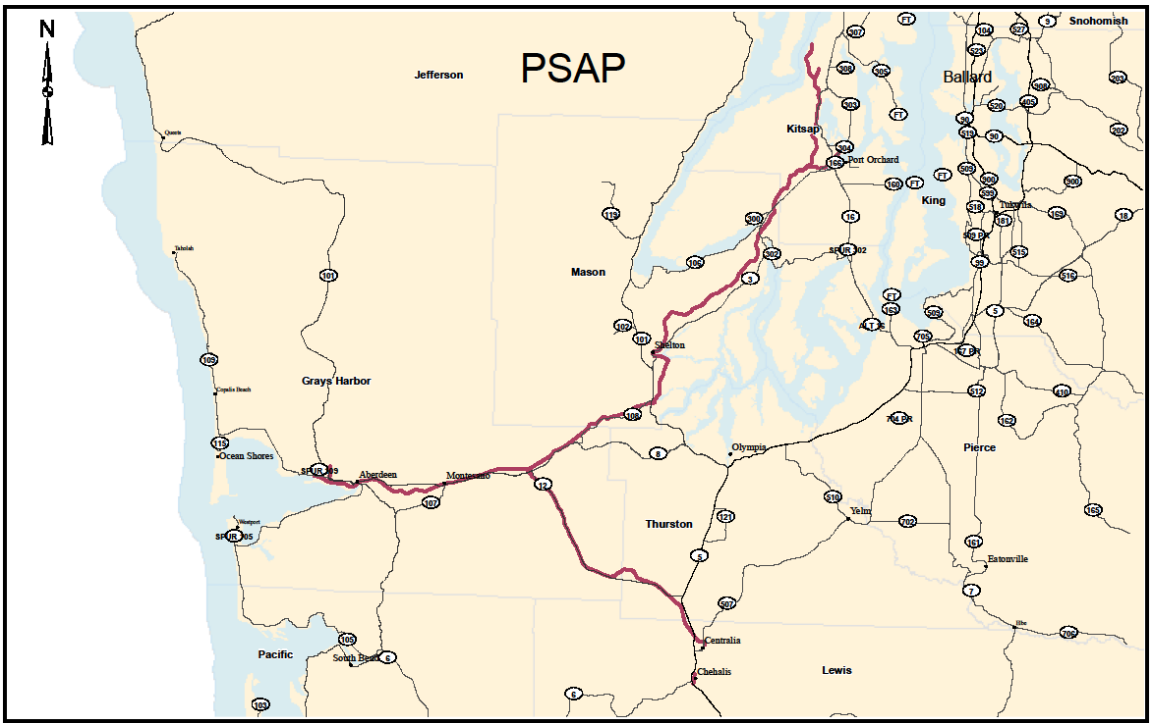
Puget Sound and Pacific Railroad

The Puget Sound and Pacific Railroad (PSAP), a Class III railroad, is headquartered in Elma, WA. PSAP interchanges with the BNSF and UP Class I railroads. PSAP runs through forest lands and serves major lumber customers. PSAP owns 109 miles of track and operates on 178 miles of track in Washington.

The line consists of the following segments: 1) Centralia to Elma to Aberdeen-Hoquiam, which connects with the Port of Grays Harbor; 2) Elma to Shelton, which connects with the U.S. Navy line that PSAP operates from Shelton to Bremerton and Bangor; and 3) Centralia to Chehalis to Curtis. The Port of Chehalis owns the section between Chehalis to Curtis. PSAP provides switching and haulage for UP at Aberdeen, Hoquiam, Grays Harbor, Shelton, and McCleary via Centralia.

The major commodities include lumber, logs, chemicals for the pulp and paper mills forest products, scrap metal, grains, aluminum, chemicals, and military cargo.

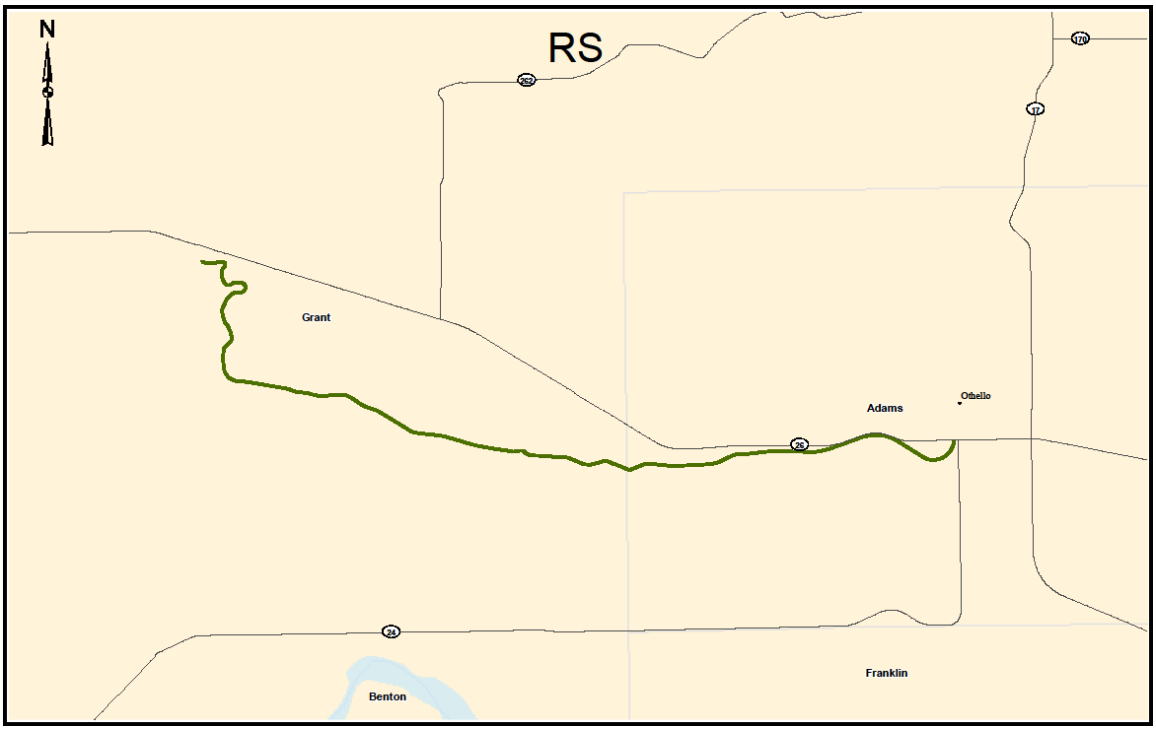
PSAP reported interstate operating revenue of $8,115,618 and total gross intrastate operating revenue of $64,840.



Royal Slope Line

The 26-mile WSDOT-owned Royal Slope Line (RS) is a remnant of the former Chicago, Milwaukee, St. Paul, and Pacific Railroad (Milwaukee Road). The eastern 20.5 miles were constructed as part of the "Pacific Extension," which was built between 1906 and 1909. The northwestern 5.5-mile spur was built by the Milwaukee Road in 1967. The line connects Royal City to the CBRW at Othello. The line currently is dormant, but could play important roles in two projects under consideration by the state:

- **Construction of a freight bypass between Ellensburg and Lind.** This project would rebuild the abandoned Milwaukee Road mainline to increase capacity on BNSF's Auburn-Pasco route and avoid the slow, circuitous routing through the Yakima River Valley. Some mitigation efforts would be necessary due to the line's passage through the Yakima Firing Range and steep grades on the original route.
- **Redevelopment of the Hanford Site as a large industrial complex.** If the federal government decides to redevelop the site as a large industrial complex, an alternative to reconstructing the original Milwaukee Road line between Beverly and Lind may be a bypass. The bypass would travel through the Hanford Site to Pasco, opening up the site to direct Class I rail service and addressing the capacity and environmental issues that affect the existing BNSF Ellensburg-Yakima-Pasco mainline.



Tacoma Rail

Tacoma Rail is a municipally held Class III and terminal switching railroad which is comprised of three distinct and separate divisions—Tidelands Division, Mountain Division, and the Capital Division.

Tacoma Municipal Belt Line

The Tacoma Municipal Belt Line (TMBL) is an operating division of the Tacoma Public Utilities. The Tidelands and Capital Divisions are under the governance of the Tacoma Public Utility Board.

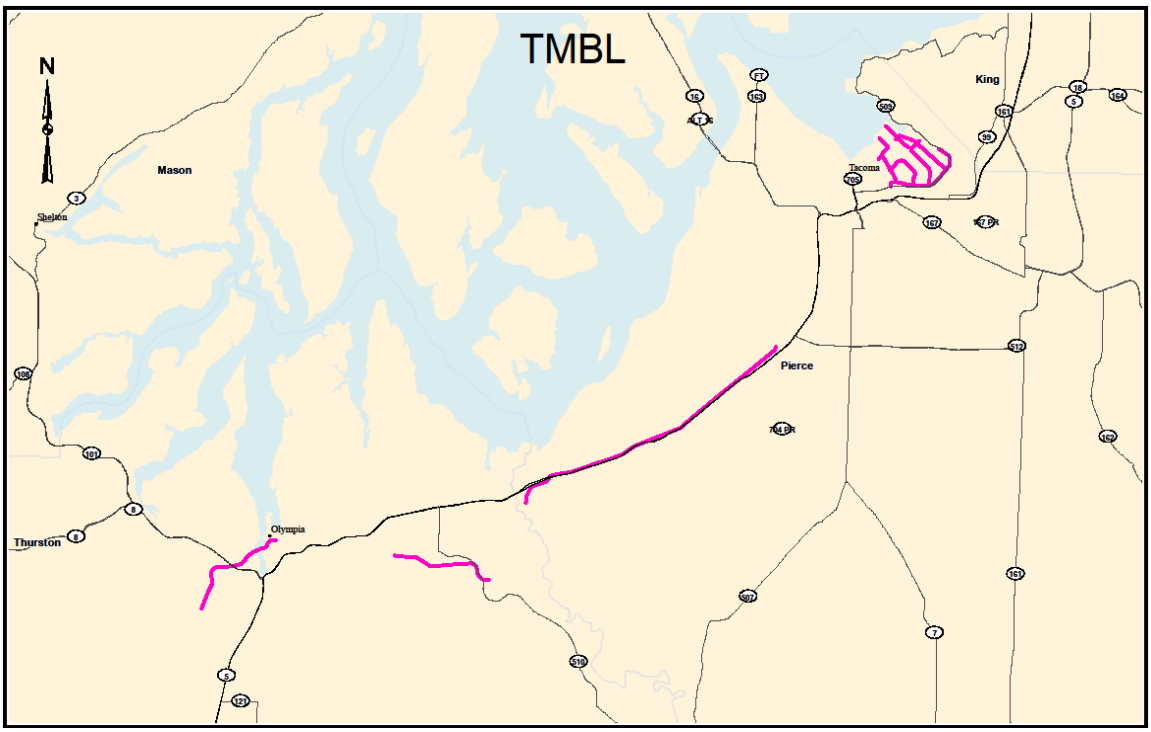
Tacoma Rail does the switching for TMBL's Tidelands Division, which includes the Port of Tacoma.

In 2004 TMBL formed its Capital Division by leasing three miles of BNSF's Lacey Spur (St. Clair-Quadlok) and 10 miles of the remaining original Northern Pacific mainline (Olympia-Belmore), in conjunction with obtaining a freight service easement over seven miles of BNSF's Lakeview Subdivision (South Tacoma-Lakeview) and 11 miles of BNSF's Lakeview Spur (Lakeview-Nisqually).

BNSF retains trackage rights over these lines to access the portion of the Lakeview Subdivision south of Lakeview that it still serves.

In addition to containerized cargo, TMBL's freight includes chemicals, automobiles, scrap metal, feed, grain, frozen food, lime, petroleum products, and lumber products.

TMBL had total interstate operating revenue of $14,359,192 and total gross intrastate operating revenue of $785,908 in 2008.



Tacoma Rail Mountain Division

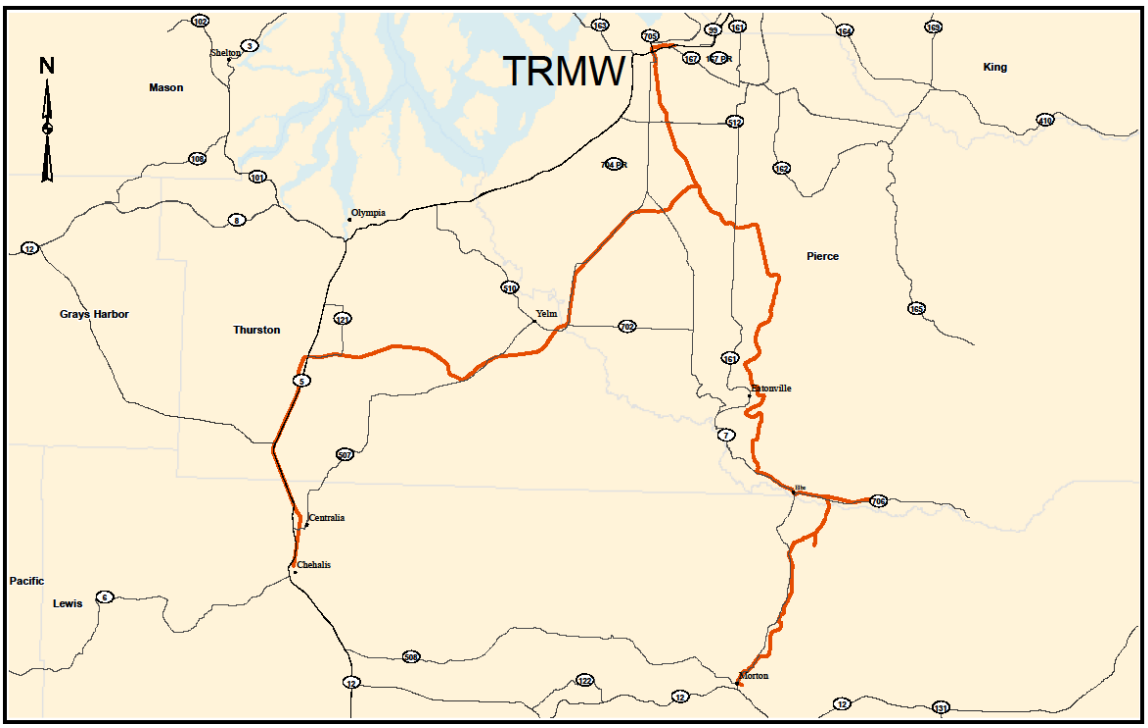
The Tacoma Rail Mountain Division (TRMW) is owned by the city of Tacoma, Public Works and operated by Tacoma Rail under the governance of the Tacoma City Council.

Tacoma Rail started operating the Mountain Division in November 1998 to provide freight rail service along the 132 miles of track connecting Tacoma with Frederickson in South Pierce County, Morton, and Chehalis.

It's called Mountain Division because the rail grade from Freighthouse Square up the gulch and south through the McKinley District is considered mountain grade. The 3.3 percent grade means the rail gains three and a third feet in altitude for every 100 feet in distance.

Current customers include Boeing, Hardie Building Products, MacMillan-Piper, Medallion Foods, and Harris Rebar. The Mountain Division also provides storage services for BNSF and UP. Commodities handled include forest products, chemicals, and airplane components.

TRMW reported a total interstate operating revenue of $539,950 and total gross intrastate operating revenue of $118,641 in 2008.



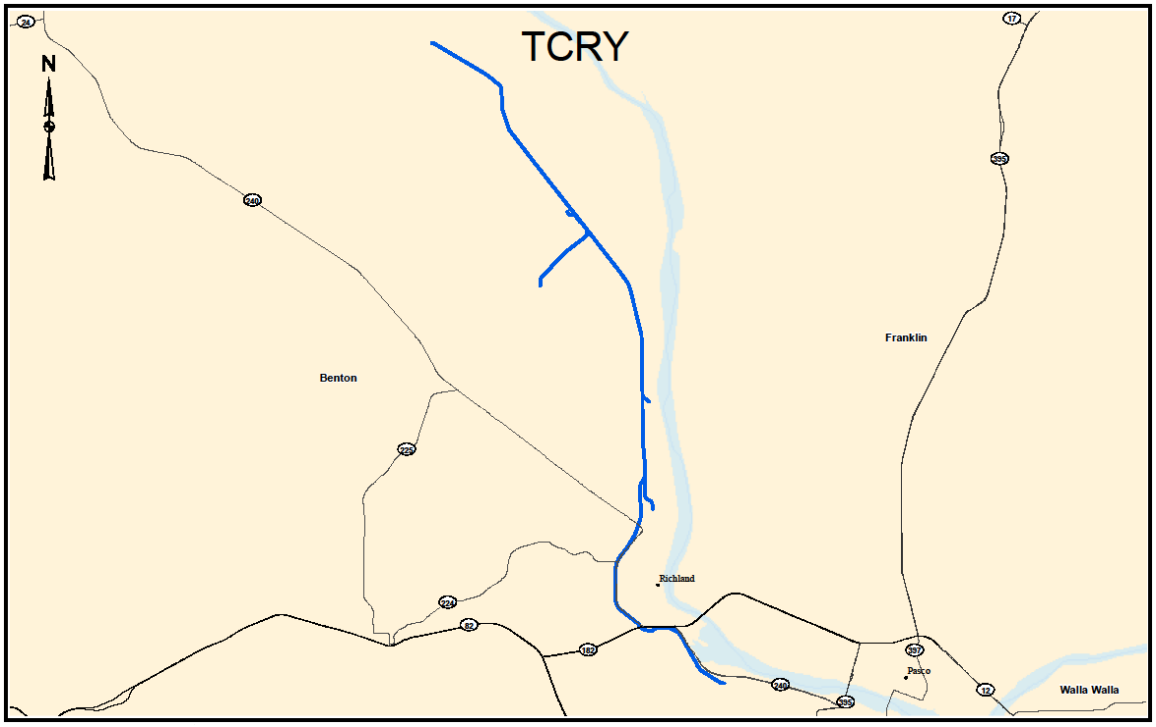
Tri-City and Olympia Railroad

The Tri-City and Olympia Railroad (TCRY) is a Class III railroad company that operates near Richland serving the Port of Benton and the U.S. Department of Energy, interchanging with BNSF and UP railroads in Richland. In 2009 TCRY ceased its Olympia operation. The TCRY provides repair shop services, on-site freight car switching, and rail-related services.

The TCRY transports many commodities including food, produce, military equipment, nuclear waste, feed, consumer products, beverages, agricultural commodities, grain, wood products, paper, coal and minerals, building materials, machinery and equipment, vehicles, chemicals, fertilizer as bulk goods, break bulk materials, feed stock, waste and scrap, liquids.[20]

The TCRY reported no total gross intrastate operating revenue in their 2008 Annual Report to the UTC.

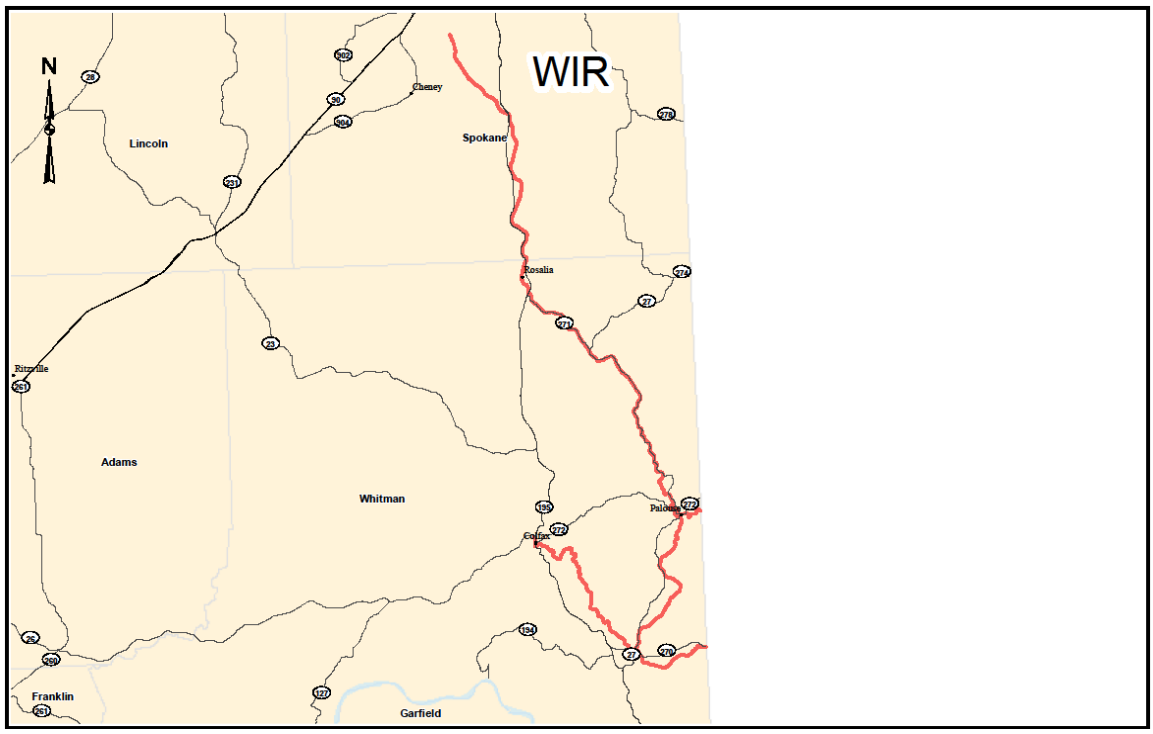
[20] http://www.tcry.com



Washington and Idaho Railway, Inc.

The Washington and Idaho Railway (WIR) is a Class III railroad that operates in the area south of Spokane, WA, connecting BNSF at Marshall to Palouse, WA, Harvard, ID, and Moscow, ID. It began operations in 2006 on ex-Northern Pacific Railway and Washington, Idaho and Montana Railway trackage.

The WIR reported total gross intrastate operating revenue of $824,945 in their 2008 Annual Report to the UTC.



Western Rail Switching

Western Rail Switching (WRS) is a switching and terminal railroad owned by Western Rail, Inc., a used locomotive seller located on the line. In 2004, Spokane County bought BNSF's Geiger Spur and designated WRS to operate it. In January 2009, realignment bypassed Fairchild Air Force Base, through which the spur had run. The west end of the spur now connects to the Eastern Washington Gateway Railroad (EWG) near Medical Lake. EWG now operates the Geiger Spur. WRS continues as an operating business.

Rail Service Corridors

The state currently has ten major rail corridors and 12 low-density corridors. These corridors are defined and operated by BNSF and UP. Exhibit 3B-1 lists all these corridors. While these rail corridors are defined by private railroads, the state has an interest to define rail corridors in terms of public benefits. The Freight Mobility and Strategic Investment Board (FMSIB) is authorized to define strategic rail corridors and update them periodically. Some short-line routes are critical to the economic viability of local communities and certain industries. The state needs to develop criteria to define rail corridors in terms of their impacts on the state's economic societal needs. A brief description of each rail service corridor is shown after the exhibit.

Exhibit 3B-1: Rail Service Corridors in Washington State

Railroads	Major Corridors	Low-Density Corridors
BNSF	Seattle-Spokane	Tukwila-Snohomish
	Seattle-Portland, Oregon (OR)	Woodinville-Redmond
	Portland, OR-Pasco	Burlington-Sumas
	Auburn-Pasco	Sumas-Lynden
	Pasco-Spokane	Burlington-Anacortes
	Spokane-Sandpoint, Idaho (ID)	Intalco-Cherry Point
	Everett-Vancouver, British Columbia (B.C.)	Marysville-Arlington
		Lakeview-Roy
		Spokane-Chewelah
UP	Hinkle, OR-Spokane	Spokane-Plummer, ID; Manito-Fairfield
	Spokane-Eastport, ID	Ayer Junction-Riparia
	Tacoma-Seattle	Wallula-Kennewick

BNSF Rail Service Corridors

BNSF operates over 1,604 miles in the state, which represents almost ten percent of their total system route miles operated. Service is provided over seven major corridors, and nine low-density corridors (Exhibit 3B-1). The major corridors provide the primary conduits to the North American rail network, while the low-density corridors offer collection/distribution services.

Seattle-Spokane Mainline

This 331-mile corridor consists of BNSF's Scenic Subdivision (Seattle-Everett-Wenatchee) and Columbia River Subdivision (Wenatchee-Spokane). The line traverses the longest railroad tunnel in the United States, the 7.8-mile Cascade Tunnel under the summit of Stevens Pass. Between Seattle and Everett, there are an average of 50 trains per day, with 25 per day operating between Everett and Spokane. Four Amtrak *Cascades* trains operate daily between Seattle and Everett, along with eight *Sounder* commuter trains each weekday. Amtrak's *Empire Builder* connecting Seattle and Chicago, operates once each way per day along the length of the corridor.

The line over Stevens Pass was completed in 1893 by the James Hill's Great Northern Railway (GN), creating a single-carrier link between Seattle and St. Paul, Minnesota. The GN later acquired control of the Chicago, Burlington, and Quincy Railroad (CBQ) to provide a direct

connection between the Northwest and Chicago, the railroad hub of the nation. Today, the line serves the same role for BNSF, conveying their highest-priority traffic to and from the west coast ports.

With only a few local exceptions, the corridor is controlled entirely by Centralized Traffic Control (CTC).[21] The portion of the line between Seattle and Everett is mostly two main tracks, and the majority of the Everett-Spokane segment is single-tracked. Maximum passenger train speed is 79 mph, maximum track speeds for freight trains are 60 mph between Wenatchee and Spokane and 50 mph between Seattle and Wenatchee, and railcars weighing up to 143 tons are permitted. The traffic base is primarily bridge movement of intermodal, agricultural and forest products, chemicals, automobiles, and other merchandise between the Northwest and the Midwest.

Seattle-Portland Mainline

BNSF's 177-mile Seattle Subdivision, connecting Seattle with Portland, OR, is the most heavily trafficked rail line in Washington State, conveying BNSF and UP trains (the latter via trackage rights) to and from the major Pacific Coast ports. The corridor hosts an average of 58 freight trains each day, with eight Amtrak *Cascades* trains operating daily, and 18 *Sounder* commuter trains connecting Seattle and Tacoma on weekdays. Amtrak's *Coast Starlight*, connecting Seattle and Los Angeles, operates once each way per day along the length of the corridor.

The portions of the corridor from Vancouver to Tenino and Tacoma to Seattle were completed by the Northern Pacific Railway by 1877, with the Oregon-Washington Railroad and Navigation Company obtaining trackage rights over the line. These segments were connected with the construction of the Port Townsend Southern Railroad along the shore of Puget Sound, with service beginning in 1914. It is this route via Point Defiance that carries the contemporary joint BNSF and UP mainline, with the Tenino-Yelm-Lakeview segment no longer hosting through traffic.

The entire corridor is two main tracks controlled by CTC, with the exception of short stretches in the Tacoma and Seattle terminals. Maximum train speeds are 79 mph for passenger and 60 mph for freight, with 143-ton-capacity cars permitted. Freight traffic includes intermodal, forest and agricultural products, refuse, chemicals, and finished automobiles.

[21] Railroad signaling systems are discussed in Chapter 5.

Portland-Pasco Mainline

The 233-mile BNSF Fallbridge Subdivision connects Portland, OR with Pasco—the junction with mainlines to Seattle and Spokane and location of an important classification yard. The line closely follows the Columbia River for its entire length, connecting with the Oregon Trunk Subdivision (BNSF's sole connection between the Northwest and California) at Wishram. An average of 31 freight trains traverse the line daily, with the Portland section of Amtrak's *Empire Builder* running once each way per day.

Seeking a water-level line to the Pacific coast to complement his Cascade crossings at Stampede and Stevens Passes, James Hill constructed the Spokane, Portland and Seattle Railway along the north bank of the Columbia River, completing the line between Pasco and Portland in 1908. The line is essentially level, with a maximum eastward grade of 0.20 percent, and today continues to be a vital link in BNSF's national network.

The Fallbridge Subdivision is almost entirely single-track mainline, with short stretches of two main tracks around Portland and Wishram. Traffic control over the entire line is via CTC. Passenger trains are permitted to operate at 79 mph and freight trains at 60 mph; the maximum allowable railcar weight is 143 tons. Annual freight traffic consists of intermodal, forest and agricultural products, refuse, coal, chemicals and finished automobiles.

Auburn-Pasco Mainline

BNSF's 227-mile mainline across central Washington consists of the Stampede Subdivision between Auburn and Ellensburg, and the Yakima Valley Subdivision connecting Ellensburg and Pasco. The Stampede Subdivision crosses the Cascade Mountains at Stampede Pass, entering the height-restricted Stampede Tunnel at the summit. The Yakima Valley Subdivision traverses the twisting Yakima River Canyon, which limits train velocity and line capacity. An average of six trains a day use this freight-only corridor.

Required by the federal government to connect Puget Sound to its eastern lines, or face the consequence of losing land grants, the Northern Pacific completed its link between Tacoma and Pasco in 1888. Decades later, after a merger which combined the Northern Pacific; Great Northern,; Spokane, Portland, and Seattle Railway; and Chicago, Burlington, and Quincy Railroad to form the Burlington Northern, and in response to the declining rail traffic of the early 1980s and the high cost of maintaining three mainlines across the state, Burlington Northern moth-balled the line over Stampede Pass in 1982; the majority of the corridor was sold to the

Washington Central Railroad. The line lay essentially dormant until the mid-1990s, when a period of unexpected growth stretched to the limit the capacity of BNSF's Stevens Pass and Columbia River routes, culminating in the decision to reacquire and reopen the line to allow the diversion of low-priority traffic from the vital intermodal corridors.

The corridor is almost entirely single track, except for a short stretch of two main tracks at Easton. Traffic control is via Track Warrant Control (TWC), with CTC islands in place at passing sidings. Maximum permitted train speed is 49 mph, and railcar weights up to 143 tons are allowed. Freight traffic includes forest, agricultural, and chemical products.

Pasco-Spokane Mainline

The 149-mile BNSF Lakeside Subdivision is a vital line connecting Pasco and Spokane, and its eastern 12 miles also hosts UP trains operating between Hinkle, OR, and Spokane. The line traverses rolling farmland as it skirts north of the Palouse Region. Approximately 33 BNSF freight trains operate on the line daily, along with a daily average of 11 UP trains on the shared line near Spokane. In addition, the Portland section of Amtrak's *Empire Builder* runs once each way per day.

The Lakeside Subdivision was Northern Pacific's original mainline from the east, completed between Spokane and Wallula in 1882. After the Burlington Northern merger of 1970, the line was operated in tandem with the parallel Spokane, Portland, and Seattle Railway route between Pasco and Spokane, before the latter was abandoned in the early 1990s in favor of the Northern Pacific route. The line currently is a vital link in BNSF's east-west network.

The corridor is primarily single-track, with short stretches of two main tracks in the vicinity of Spokane, Beatrice, and Pasco. Except for a short segment of Automatic Block Signaling (ABS) at Pasco, the entire line is controlled by CTC. Passenger trains are permitted to operate at 79 mph and freight trains at 60 mph; the maximum allowable railcar weight is 143 tons. Annual freight traffic consists of intermodal, forest and agricultural products, coal, chemicals and finished automobiles.

Spokane-Sandpoint, Idaho Mainline

BNSF's Kootenai River Subdivision between Spokane and Sandpoint, ID, commonly known as the "Funnel," is the second-busiest rail corridor in the state. The 69-mile line hosts an average of 46 freight trains each day, along with daily operation of Amtrak's *Empire Builder* service connecting Seattle and Portland to Chicago. Sandpoint also is the western end of the

Montana Rail Link (MRL) system; the MRL has operating rights over BNSF into Spokane.

The Funnel was part of the original Northern Pacific mainline, completed to Spokane in 1881. After the 1970 Burlington Northern merger, the Northern Pacific route was selected over the parallel ex-Great Northern route as the primary mainline from the east into Spokane, a function that it retains today for BNSF. Portions of the original Great Northern route continue under operation as segments of the Pend Oreille Valley Railroad and BNSF's Kettle Falls Subdivision, but abandonments have rendered that line no longer viable as a through route.

As the corridor experienced substantial growth in recent years, BNSF began to increase capacity by adding a second main track. As of April 2005, only 20 miles remained under single-track operation. Except for a short stretch in Spokane, the entire line is controlled by CTC. Annual freight traffic consists of intermodal, forest and agricultural products, coal, chemicals, and finished automobiles.

Everett-Vancouver, British Columbia Mainline

The 152-mile corridor spanning the Bellingham and New Westminster Subdivisions is the only remaining mainline link between the Washington State rail network and Canada (low-volume connections are served by BNSF at Sumas and KFR at Columbia Gardens, B.C.). An average of 23 freight trains operates on the line daily, with approximately 12 running through to Vancouver, B.C. Four daily Amtrak *Cascades* trains run between Everett and Vancouver, B.C.

This stretch of U.S. and Canadian railroad was completed by the Great Northern in 1891. From Blanchard to Bellingham, the line closely follows the shores of Samish and Bellingham Bays, a condition that limits both train speed and the ability to increase capacity without incurring great expenses. Additional delays are encountered while passing through Customs at the Blaine/White Rock border crossing. BNSF also operates a 2-mile stretch of former Milwaukee Road trackage in Bellingham that is owned by the Bellingham International Railroad (BIRR); the BIRR was formed for the purpose of preventing an industry from losing service on a line that BNSF intended to abandon.

The corridor is single-track CTC from Everett to New Westminster, with the exception of a few short stretches of Automatic Block Signaling/ Occupancy Control System (ABS/OCS). From New Westminster to Vancouver, the line is double-track CTC. Maximum train speeds are:

- Everett to Delta Junction: Talgo[22] 50 mph, passenger 35 mph, freight 15 mph.
- Delta Junction to Blaine: Talgo 79 mph, passenger 79 mph, freight 60 mph.
- Blaine to Vancouver, B.C.: Talgo 60 mph, passenger 60 mph, freight 40 mph.

Freight traffic includes intermodal, forest and agricultural products, refuse, chemicals, and finished automobiles.

Tukwila-Snohomish Branch Line

BNSF's 51-mile Woodinville Subdivision traverses the east side of the Seattle metropolitan area, connecting Tukwila, Renton, Bellevue, Woodinville, and Snohomish. BNSF operates one round-trip local on weekdays that serves industrial customers along the line, including delivery of 737 fuselages to Boeing's assembly plant in Renton.

The Woodinville Subdivision is a remnant of the former Northern Pacific (NP) mainline from Seattle to Sumas. The line to Sumas and a connection with the Canadian Pacific Railroad was completed by the Seattle, Lake Shore, & Eastern Railroad (SLS&E) in 1891; the SLS&E was subsequently absorbed into the NP in 1901. In the wake of the 1970 Burlington Northern merger, the Sumas line from Snohomish Junction to Sedro-Woolley was abandoned. In 2006 a study was conducted on the segment from Tukwila to Snohomish to consider potential future uses, including a parallel bicycle/pedestrian trail, mass transit, and as an emergency bypass route for freight traffic normally operating via Interbay, Edmonds, and Everett.

Traffic on the Woodinville Subdivision operates via TWC. Maximum permitted train speeds are 30 mph for passenger and 25 mph for freight. Railcar weights up to 143 tons can be operated from Snohomish Junction to Woodinville, while the remainder of the line is restricted to 134 tons. Tukwila-Woodinville freight corridor traffic consists of aircraft fuselages, forest products, and chemicals.

[22] Talgo, Inc. manufactures high-speed articulated trains. These operate as a set, with adjacent cars sharing axles and wheels and functioning as a single unit. This technology increases stability and improves safety and the smoothness of the ride. Talgo trains were initially allowed into the United States on a temporary basis and were leased for use in the Pacific Northwest from 1994 through 1998. Today, five trains built by Talgo operate in the Pacific Northwest and British Columbia as the Amtrak *Cascades* service.

Woodinville-Redmond Branch Line

Splitting from the Woodinville Subdivision at Woodinville, BNSF's Issaquah Spur runs seven miles to Redmond. There is rarely a demand for service, and trains operate on an as-needed basis.

The line was constructed by the SLS&E to compete with NP's line to Tacoma, but construction towards Snoqualmie Pass stalled in 1890 at North Bend, and the focus of the SLS&E was adjusted to continue its efforts to build to Sumas. The east end of the line, between Snoqualmie and North Bend, has been maintained as a tourist railroad (the Snoqualmie Valley Railroad) since 1957 by The Northwest Railway Museum. The remaining trackage between Snoqualmie and Redmond has been abandoned.

BNSF operates the line via TWC, with permitted track speeds of 25 mph for passenger and 10 mph for freight. The line is restricted to 134-ton railcars.

Burlington-Sumas Branch Line

BNSF's Sumas Subdivision connects Burlington and Sumas via Sedro-Woolley. It is served by a daily round-trip to and from Everett, and a local that switches on-line industries. The 4.7 miles between Burlington and Sedro-Woolley are the easternmost surviving segment of a former Great Northern branch that connected Anacortes and Rockport; the remaining 40 miles of the subdivision are formed from the north end of the NP's ex-SLS&E line from Seattle to Sumas. BNSF interchanges with Canadian Pacific Railway and the Southern Railway of British Columbia at Sumas.

Train operation on the line is via TWC, with a maximum permitted train speed of 40 mph. The line is restricted to 134-ton railcars from Burlington to Lawrence, but 143-ton cars are permitted from Lawrence to Sumas. Freight traffic includes forest and agricultural products, and chemicals.

Sumas-Lynden Branch Line

Breaking off the Sumas Subdivision at Sumas, BNSF operates a short stretch of former Bellingham Bay & British Columbia Railway trackage southwest to Lynden. The Lynden Spur, constructed in 1889, is served as-needed by the road switcher based at Sumas. Track speed on the TWC-controlled line is 10 mph, with cars limited to 131.5 tons.

Burlington-Anacortes Branch Line

The Anacortes Spur of BNSF's Bellingham Subdivision extends 12.4 miles west from Burlington to serve a Texaco refinery at Fidalgo, and hosts daily rail service. This line segment is the westernmost surviving

segment of a former Great Northern branch that connected Anacortes and Rockport.

The line is operated as an industrial track with a speed limit of 10 mph, and railcars up to 134 tons are permitted. Traffic includes petrochemicals.

Intalco-Cherry Point Branch Line

BNSF's Cherry Point Subdivision splits off the Bellingham Subdivision at Intalco, near the town of Custer, and runs southwest to serve a collection of industries at Cherry Point. BNSF operates two daily round trips on the line.

The Cherry Point Subdivision is operated by TWC, with a speed limit of 25 mph and a maximum railcar weight of 143 tons. The line was built in 1965 to serve the Intalco aluminum smelter, and later a series of petroleum-related industries were constructed on the line. Traffic includes metals and petrochemicals.

Marysville-Arlington Branch Line

Breaking off the Bellingham Subdivision at Kruse Junction, BNSF's Arlington Spur connects Arlington to the national rail network, and is classified by BNSF as an industrial spur. The line is served twice weekly by a road switcher based in Everett. Track speed on the line is 10 mph, and 143-ton railcars are permitted.

Lakeview-Roy Branch Line

Although BNSF sold freight rights on the north end of its Lakeview Subdivision and the entire length of the connecting Lakeview Spur to Tacoma Rail in 2004, it retained the remainder of the Lakeview Subdivision from Lakeview to Roy. The customers on the line are the U.S. Army's Fort Lewis, which occasionally ships or receives military equipment, and Wilcox Farms, which receives feed at Roy twice a week. Track speed on the line is 10 mph, and 143-ton railcars are permitted; however, as of spring 2006, the only connection to the rest of the BNSF network, via the Lakeview Spur and Nisqually, is restricted to 134-ton railcars.

Spokane-Chewelah Branch Line

BNSF's Kettle Falls Subdivision was constructed in 1889 by the Spokane Falls and Northern Railway, and came under control of James Hill's Great Northern in 1898. In late 2004, BNSF sold the Kettle Falls and San Poil Subdivisions north of Kettle Falls to OmniTRAX's Kettle Falls International Railway (KFR), and leased the Kettle Falls-Chewelah segment to the KFR; the two railroads interchange daily at the latter

location. BNSF's remaining Kettle Falls Subdivision trackage, between Spokane and Chewelah, is rated at 40 mph with 143-ton railcar weights, and is controlled by TWC.

UP Service Corridors

Union Pacific (UP) operates over 678 miles in the state, which represents less than three percent of their total system route miles. Service is provided over two major corridors, and three low-density corridors. The major corridors provide the primary conduits to the nationwide rail network, while the low-density corridors offer collection/distribution services. These corridors are summarized in Exhibit 3B-1.

Hinkle, OR-Spokane Mainline

UP's 171-mile Ayer Subdivision connects Hinkle Yard in Hermiston, OR to the Spokane terminal. At Fish Lake, the north end of the line, UP uses trackage rights on BNSF's Lakeside Subdivision to access Spokane. The Ayer Subdivision hosts an average of 11 freight trains per day, and does not have passenger service.

The "Washy" line is comprised of four segments:

1. Hinkle, OR to milepost (MP) 201 was completed in 1951 by the Oregon-Washington Railroad and Navigation Company.
2. MP 201 to Wallula (MP 215) was constructed by the U.S. government and completed in 1952.
3. Wallula to MP 264 (near Ayer) was completed by the Snake River Valley Railroad Company in 1899, with much of the line being rebuilt by the U.S. government in the 1960s as a result of their Snake River Dam projects.
4. MP 264 to Fish Lake (MP 355) was completed in 1914 by a joint venture between the Oregon-Washington Railroad and Navigation Company and the North Coast Railroad.

BNSF has trackage rights over the line from Pasco to Ayer Junction, and then down the Riparia Subdivision to its namesake city, for the purposes of interchange with the Great Northwest Railroad.

The Ayer Subdivision is operated by CTC from Hinkle, OR to Page and for four miles between Ayer Junction and Joso; the remainder of the line is controlled by TWC/ABS. Maximum permitted train speed is 40 mph, except for a 30-mile stretch of 50 mph trackage between Page and Ayer Junction. Maximum railcar weights are 158 tons between Hinkle, OR and Wallula Junction, and 143 tons between Wallula Junction and Spokane. Freight traffic is primary forest and agricultural products, potash, and chemicals.

Spokane-Eastport, Idaho Mainline

The Spokane Subdivision of UP roughly parallels BNSF's Kootenai River Subdivision for 74 miles from Spokane to Sandpoint, ID then heads north to Eastport, ID. Since this line is not an essential component of UP's transcontinental mainline, quite unlike the parallel BNSF route, UP operates an average of only seven trains per day east of Spokane.

Completed in 1906 by the Spokane International Railroad and acquired by UP in 1958, the route retains a reminder of its origins through the commonly used "SI" nickname. Train operation on the single-track line is via TWC, with infrequent sidings. To address slow-speed issues, UP performed upgrades, added a siding just east of Spokane, and added CTC islands at existing passing sidings.

Freight traffic is primary overhead tonnage connecting with Canadian Pacific Railway at Eastport, ID, and includes forest and agricultural products, potash, and chemicals.

Tacoma-Seattle

UP travels over BNSF track between Portland, OR and Tacoma. From Tacoma, the UP switches to its own rail line to reach Seattle. This corridor was once owned by the Milwaukee Road and purchased by UP.

Spokane-Plummer, Idaho Manito-Fairfield Branch Lines

UP operates two branch lines southeast of Spokane. The 45-mile Wallace Subdivision runs from Spokane to Plummer, ID, crossing the state line five miles east of Manito. Interchanges with the St. Maries Railroad (STMA) are performed at Plummer. The 13-mile Fairfield Industrial Lead departs the Wallace Subdivision at Manito and heads south to its namesake town.

The Spokane-Manito and Manito-Fairfield segments were constructed in 1888 to 1889 by the Washington & Idaho Railroad, while the Manito-Plummer segment was constructed between 1909 and 1914 by the Idaho & Western Railway (which was merged into the Chicago, Milwaukee, & Puget Sound Railway in 1912). These two branch lines serve the agricultural region of eastern Washington and western Idaho.

Ayer Junction-Riparia Branch Line

UP's 11-mile Riparia Subdivision connects the Ayer Subdivision to the Great Northwest Railroad (GRNW) at Riparia. BNSF has trackage rights over this line for the purpose of interchange with the GRNW, and the GRNW has trackage rights to MP 267.1 on the Ayer Subdivision to perform interchanges at Ayer (see the GRNW section for more

background information). The line was constructed in 1899 by the Snake River Valley Railroad, and was relocated in 1968 by the U.S. government.

Wallula-Kennewick Branch Line

The 19-mile UP Kalan Industrial Lead extends from the junction with the Ayer Subdivision at Wallula to the connection with the Tri-City & Olympia Railroad at Richland Junction. The line, which once extended west to Yakima, was completed in 1911 by the Oregon-Washington Railroad and Navigation Company and the North Coast Railroad.

Safety Regulatory History[23]

The state has very little safety jurisdiction over rail operations, except for public highway-rail crossings. In 1980 Congress passed sweeping legislation, which essentially pre-empted states from most areas of safety regulation (as well as rates and service regulation). States can conduct inspections in various safety disciplines as part of a state-federal participation program, but any enforcement is done by the FRA. Washington currently employs four FRA-certified state inspectors. They are certified in hazardous materials, track, signals, and operating practices.

Any changes in regulation, through legislation or rulemaking at the state level, is therefore fairly limited and generally handled through the Washington Utilities and Transportation Commission (UTC).

Rail Employee Safety

For the most part, safety regulation of railroad employees is done at the federal level. The state does have some limited jurisdiction, which is split between the UTC and the Washington State Department of Labor and Industries (L&I) by a Memorandum of Understanding (MOU). In 2000 the UTC completed a rulemaking on safety in rail yards. The primary emphasis was on walking surfaces or "walkways," where there was strong evidence of injuries to employees from uneven, unstable, or muddy walkways in the rail yards and around switches. The UTC also addressed other tripping/falling hazards such as excess debris laying around, overgrown vegetation, and other obstructions that got in the way of employees doing their jobs safely.[24]

Remote Control Operations

In the late 1990s, railroad companies developed technology for operating locomotives from remote locations with no engineers or other employees

[23] Utilities and Transportation Commission, Paul Curl, email dated 9/24/2009.
[24] The Washington Administrative Code (WAC) 480-60-035 addresses railroad company employee walkways.

on board. For the most part, remote control operations are conducted in rail yards to move equipment around, but the UTC had concerns about operations over public highway-rail grade crossings. The UTC completed a rulemaking in 2001 to address these issues.[25]

Community Notice

In the late 1990s, the UTC heard from a number of cities and towns that railroad companies were shutting down grade crossings, or otherwise disrupting traffic flow for routine construction and maintenance work, without any advance notice. The UTC addressed this issue with a rulemaking in 2001.[26]

Blocked Crossings

Another issue that came up in the late 1990s was blocked crossings. The UTC received a high number of citizen and local government complaints about trains blocking grade crossings for long periods of time. The UTC addressed this issue with a rulemaking in 2001.[27]

Train Speeds

Throughout the 1990s and early 2000s, the UTC reviewed petitions from railroads that wanted to increase speeds in certain areas to expand capacity and improve service. The UTC had, over the years, issued orders limiting train speeds in 162 communities around the state. Some of the orders dated back to the 1940s. The process for speed limit changes was extremely burdensome for the railroads, and local governments and their constituents had unrealistic expectations on what the UTC could do. Essentially, state law was obsolete and had not kept up with modern rail operations, safety improvements, changed circumstances, and federal law. In 2006 the UTC assisted the railroads in successful legislation that addressed the issue. The new law[28] established a procedure for changing speed limits in cities and towns that was substantially streamlined, but retained notice and opportunity to be heard for local governments and the public. The new law also effectively canceled the 162 speed limit orders in effect at that time.

Grade Crossing Protective Fund

The UTC had administered a grant program for upgrading and improving safety at public grade crossings since the 1960s. The program had been

[25] WAC 480-62-320 addresses railroad company remote controlled operations.
[26] WAC 480-62-305 addresses railroad company accident reports.
[27] WAC 480-62-220 addresses public grade crossings blockages (i.e. crossings shall not be blocked for more than ten consecutive minutes, if reasonably possible).
[28] RCW 81.48.040, transportation law specifying a procedure to fix or change speed limits.

successful, but was essentially declining by the late 1990s due to changes in federal funding, eligibility for funding, and limited purpose. In 2003 the UTC successfully proposed legislation that changed the eligibility to any public or private entity and expanded the purpose to include any rail safety related project. The program has been revitalized and since 2003, the UTC has awarded grants for hundreds of projects that would not have otherwise been done. Examples include trespass prevention, private crossing improvements, education, and sign replacement.[29]

Statutes Housekeeping

In 2007 the UTC successfully proposed legislation to clean up the statutes related to railroads. Many of the state laws were obsolete, pre-empted, or otherwise useless and confusing. Some of these laws had been on the books since the early 1900s. While this legislation appears mundane, it has proven useful in reflecting current reality and making it clear to the railroads, public, and local governments what the UTC can and cannot do.

Quiet Zones

As communities have grown, especially along the railroad tracks, many people have complained about the noise of train horns at rail crossings. Many rail lines run right along Puget Sound and the Columbia River where new homes have been built. As rail traffic increased, the noise became a significant issue in some communities where the horn sounds 24 hours a day. No reasonable alternative existed, even though the noise was bothersome, because the train horns at crossings were an important safety feature. In 2006 the FRA adopted a rule which allowed communities to establish "quiet zones," where railroads would be prohibited from blowing the horn except in an emergency.[30] In order to establish a quiet zone, the community is required to ensure continued safety at the affected crossings. While the rule is federal, the UTC has a role in the process of making sure the crossings meet federal guidelines, as well as suggesting changes and improvements to the crossings.

Crossing Consolidation Closure

Since about 1994, the FRA, Federal Highway Administration (FHWA), railroads, and state regulatory agencies have encouraged closure or consolidation of both private and public grade crossings. The theory is that the safest grade crossing is no grade crossing and the UTC has

[29] RCW 81.53.281 and WAC 480-62, addressing railroad crossings and operations.
[30] The Final Horn Rule was promulgated by the FRA and published in the Federal Register on April 27, 2005. The rule required trains to sound a horn or whistle when approaching a highway railroad grade crossing. The intent was to develop a mechanism for a public authority to authorize a whistle/horn ban at a crossing(s) with the authority jurisdiction under the context of an existing state law or modified state law.

participated in projects over the last 15 years to close or consolidate crossings in Washington. Nationally some 40,000 grade crossings have been closed over the last 15 years. During that time, the UTC has been supportive of the effort and BNSF has been the most aggressive of any railroad in the country in eliminating grade crossings, including in Washington. In the last few years, the UTC has taken a more proactive approach to crossing closures and the UTC now has specific goals for crossing closures in their 2009-2011 strategic plan.

Operation Lifesaver

Operation Lifesaver, Inc. (OLI) is a national non-profit organization dedicated to providing education and outreach on rail safety issues. The UTC has strongly supported OLI efforts over the years and currently a UTC employee serves as the Washington State Operation Lifesaver coordinator.

Washington State Department of Transportation

Appendix 3-C: Intermodal Facility Commodity Descriptions

The following information was gathered from the USDOT Bureau of Transportation Statistics, its National Transportation Atlas Database 2009 and Intermodal Terminal Facilities data sets.

Name	Type	Mode Type	Commodity Description
Alaska Airlines	Air	Air □ Truck	• Meat, Fish, and Preparations
Americold Logistics, Inc., Burlington, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Meat, Fish, and Preparations • Other Crops • Other Prepared Food Stuffs
Americold Logistics, Inc., Pasco, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Meat, Fish, and Preparations • Other Crops • Other Prepared Food Stuffs
Apex Cold Storage, Kent, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Forest Products • Gravel and Crushed Stone • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Prepared Food Stuffs • Wood Products
Atlas Columbia Warehouse, Inc., Tacoma, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Metal, and Articles of Metal • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Waste and Scrap • Wood Products
Bellingham Cold Storage, Bellingham, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Prepared Food Stuffs
Blaine Harbor	Port	Port □ Truck	• Meat, Fish, and Preparations
BNSF, Tacoma Blair, WA	Rail	Truck - Port - Rail	• Meat, Fish, and Preparations • Other Crops

Name	Type	Mode Type	Commodity Description
Bulk Service Transport James J. William's, Spokane, WA	Rail	Rail Truck	• Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Fertilizers • Metallic Ores • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Waste and Scrap
Cascade Warehouse Co., Inc., Chehalis, WA	Rail	Rail Truck	• Articles of Stone, Ceramic, Or Glass • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Non-Metallic Mineral Products N.E.C. • Plastics and Rubber • Wood Products
Columbia Colstor, Inc., Kennewick, WA	Rail	Rail Truck	• Alcoholic Beverages • Other Prepared Food Stuffs
Columbia Colstor, Inc., Quincy, WA	Rail	Rail Truck	• Furniture and Furnishings • Meat, Fish, and Preparations • Other Prepared Food Stuffs
Columbia Colstor, Inc., Woodland, WA	Rail	Rail Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Prepared Food Stuffs
Continental Grain Temco, Tacoma, WA	Rail	Rail Truck	• Cereal Grains • Other Crops
CSX Intermodal, Tacoma, WA	Rail	Truck - Port - Rail	• Meat, Fish, and Preparations • Other Crops
Daybreak Dispatch and Rail Transfer	Rail	Rail Truck	• Articles of Stone, Ceramic, Or Glass • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Other Metal, and Articles of Metal • Wood Products
Desticon Transportation Services, Inc., Sumas, WA	Rail	Rail Truck	• Forest Products
Devries Moving, Packing, Storage, Spokane, WA	Rail	Rail Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Furniture and Furnishings • Mechanical Machinery • Non-Metallic Mineral Products N.E.C. • Other Metal, and Articles of Metal • Pulp, Newsprint, Paper, and Paperboard
Gary Hamilton Trucking, Inc., Puyallup, WA	Rail	Rail Truck	• Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Other Metal, and Articles of Metal • Wood Products
GATX Terminals Corporation, Seattle, WA	Rail	Rail Truck	• Coal • Refined Petroleum Products N.E.C.

Name	Type	Mode Type	Commodity Description
Inland Empire Distribution Systems, Spokane, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Electrical Machinery and Equipment • Fertilizers • Furniture and Furnishings • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Non-Metallic Mineral Products N.E.C. • Other Crops • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Precision Instruments and Apparatus • Refined Petroleum Products N.E.C. • Wood Products
Kenyon Zero Storage, Inc., Prosser, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Animal Feed, Pet Food, and Products of Animal Orig • Meat, Fish, and Preparations • Other Crops • Other Prepared Food Stuffs
Kinder Morgan Bulk Terminals, Inc., Vancouver, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig Articles of Stone, Ceramic, Or Glass • Coal Fertilizers • Gravel and Crushed Stone • Monumental Or Building Stone • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Other Metal, and Articles of Metal • Refined Petroleum Products N.E.C.
Konoike Pacific Tacoma Terminals, Inc., Tacoma, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Furniture and Furnishings • Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Mechanical Machinery • Milled Grain Products and Preparations and Bakery • Miscellaneous Manufactured Products • Non-Metallic Mineral Products N.E.C. • Other Crops • Other Prepared Food Stuffs • Plastics and Rubber • Precision Instruments and Apparatus • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Lile Logistics Service, Kent, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Engines, Parts, and Accessories For Motor Vehicles • Furniture and Furnishings • Mechanical Machinery • Pulp, Newsprint, Paper, and Paperboard • Textiles, Leather, and Articles • Wood Products

Name	Type	Mode Type	Commodity Description
MacMillan, Piper, Seattle, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Mechanical Machinery • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard • Wood Products
MacMillan, Piper, Seattle, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Fertilizers • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Wood Products
MacMillan, Piper, Tacoma, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Mid-Columbia Warehouse, Inc., Pasco, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Converted Paper and Converted Paper Products • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Waste and Scrap • Wood Products
Morgan Trucking, Inc., Tacoma, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Plastics and Rubber • Wood Products

Name	Type	Mode Type	Commodity Description
Oroville Bin and Pallet, Oroville, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Electrical Machinery and Equipment • Furniture and Furnishings • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Non-Metallic Mineral Products N.E.C. • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Wood Products
Pacific Coast Container Northwest, Harbor Island, WA	Rail	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Motor Vehicles • Other Crops • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Pacific Coast Container Northwest, Tacoma, WA	Rail	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Motor Vehicles • Other Crops • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard
Pacific Coast Container Northwest Seattle, WA	Rail	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Motor Vehicles • Other Crops • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard
Pacific Terminals Limited, Seattle, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Iron and Steel In Primary Forms and Basic Shapes Mechanical Machinery • Metallic Ores • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Refined Petroleum Products N.E.C.
Pellissier Trucking, Inc., Dallasport, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Electrical Machinery and Equipment • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Other Metal, and Articles of Metal • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Wood Products

Name	Type	Mode Type	Commodity Description
Pend Oreille Valley Railroad, Usk, WA	Rail	Rail □ Truck	• Meat, Fish, and Preparations • Other Crops
Port of Anacortes	Port	Port □ Truck	• Crude Petroleum • Forest Products • Meat, Fish, and Preparations • Metallic Ores • Other Crops • Refined Petroleum Products N.E.C.
Port of Bellingham	Port	Port □ Truck	• Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Forest Products • Meat, Fish, and Preparations • Metallic Ores • Non-Metallic Mineral Products N.E.C. • Other Crops • Wood Products
Port of Clarkston	Port	Truck - Port - Rail	• Forest Products
Port of Everett	Port	Truck - Port - Rail	• Basic Chemicals • Engines, Parts, and Accessories For Motor Vehicles • Forest Products • Gravel and Crushed Stone • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Miscellaneous Manufactured Products • Motor Vehicles • Natural Sands Except Metal-Bearing • Other Crops • Transportation Equipment N.E.C. • Wood Products
Port of Grays Harbor	Port	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Cereal Grains • Chemical Preparations N.E.C. • Converted Paper and Converted Paper Products • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Motor Vehicles • Other Crops • Other Metal, and Articles of Metal • Refined Petroleum Products N.E.C. • Wood Products
Port of Kalama	Port	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Cereal Grains • Chemical Preparations N.E.C. • Forest Products • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Motor Vehicles • Other Crops • Pulp, Newsprint, Paper, and Paperboard • Wood Products

Name	Type	Mode Type	Commodity Description
Port of Longview	Port	Truck - Port - Rail	• Basic Chemicals • Motor Vehicles • Non-Metallic Mineral Products N.E.C. • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Port of Olympia	Port	Truck - Port - Rail	• Forest Products • Fuel Oils Including Aviation Turbine • Gasoline • Metallic Ores • Other Crops • Refined Petroleum Products N.E.C. • Wood Products
Port of Pasco	Port	Truck - Port - Rail	• Meat, Fish, and Preparations • Refined Petroleum Products N.E.C.
Port of Port Angeles	Port	Port □ Truck	• Pulp, Newsprint, Paper, and Paperboard • Wood Products
Port of Port Townsend	Port	Port □ Truck	• Meat, Fish, and Preparations
Port of Seattle	Port	Truck - Port - Rail	• Articles of Stone, Ceramic, Or Glass • Cereal Grains • Gravel and Crushed Stone • Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Milled Grain Products and Preparations and Bakery • Monumental Or Building Stone • Motor Vehicles • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Other Crops • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard • Refined Petroleum Products N.E.C. • Waste and Scrap • Wood Products
Port of Tacoma	Port	Truck - Port - Rail	• Animal Feed, Pet Food, and Products of Animal Orig • Basic Chemicals • Cereal Grains • Coal • Crude Petroleum • Engines, Parts, and Accessories For Motor Vehicles • Forest Products • Gravel and Crushed Stone • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Miscellaneous Manufactured Products • Motor Vehicles • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Refined Petroleum Products N.E.C. • Textiles, Leather, and Articles • Waste and Scrap • Wood Products

Name	Type	Mode Type	Commodity Description
Port of Tacoma Alumina Handling Facility Terminal	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Cereal Grains • Forest Products • Metallic Ores • Motor Vehicles • Wood Products
Port of Vancouver, USA	Port	Port □ Truck	• Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Cereal Grains • Fertilizers • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Mechanical Machinery • Metallic Ores • Motor Vehicles • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Other Crops • Other Metal, and Articles of Metal • Pulp, Newsprint, Paper, and Paperboard • Waste and Scrap • Wood Products
Port of Wilma	Port	Port □ Truck	• Cereal Grains • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Puget Sound International, Tacoma, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Electrical Machinery and Equipment • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Textiles, Leather, and Articles • Wood Products
Puget Sound Packaging, Seattle, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Articles of Stone, Ceramic, Or Glass • Gravel and Crushed Stone • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Motor Vehicles • Non-Metallic Mineral Products N.E.C. • Other Crops • Other Prepared Food Stuffs • Waste and Scrap
Rainier Cold Storage, Seattle, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Prepared Food Stuffs

Name	Type	Mode Type	Commodity Description
Seafreeze Cold Storage, Seattle, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Prepared Food Stuffs
Seattle Tacoma International Airport	Air	Air □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Other Crops • Other Prepared Food Stuffs
Skog Loading, Inc., Winlock, WA	Rail	Rail □ Truck	• Forest Products • Wood Products
Tidewater Terminal Co., Pasco, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Basic Chemicals • Chemical Preparations N.E.C. • Coal • Fertilizers • Mechanical Machinery • Refined Petroleum Products N.E.C. • Waste and Scrap
Tidewater Terminal Co., Pasco, WA	Rail	Rail □ Truck	• Basic Chemicals • Chemical Preparations N.E.C. • Fertilizers • Fuel Oils Including Aviation Turbine • Refined Petroleum Products N.E.C.
Tri Pak, Tacoma, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Gravel and Crushed Stone • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Natural Sands Except Metal-Bearing • Non-Metallic Mineral Products N.E.C. • Other Metal, and Articles of Metal • Plastics and Rubber • Pulp, Newsprint, Paper, and Paperboard • Waste and Scrap • Wood Products
Tri-City Railroad Company, Richland, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Articles of Stone, Ceramic, Or Glass • Cereal Grains • Electrical Machinery and Equipment • Forest Products • Furniture and Furnishings • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Miscellaneous Manufactured Products • Other Crops • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Plastics and Rubber • Precision Instruments and Apparatus
Trimax, Ltd (Weyerhaeuser), Tacoma, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Forest Products • Gravel and Crushed Stone • Non-Metallic Mineral Products N.E.C. • Plastics and Rubber • Wood Products

Name	Type	Mode Type	Commodity Description
Trimax, Ltd (Weyerhaeuser), Tacoma, WA	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Forest Products • Gravel and Crushed Stone • Non-Metallic Mineral Products N.E.C. • Plastics and Rubber • Wood Products
United Motor Freight, Inc., Seattle, WA	Rail	Rail □ Truck	• Electrical Machinery and Equipment • Forest Products • Iron and Steel In Primary Forms and Basic Shapes • Mechanical Machinery • Other Metal, and Articles of Metal
United Warehouse, Kent, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Articles of Stone, Ceramic, Or Glass • Cereal Grains • Chemical Preparations N.E.C. • Mechanical Machinery • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard
United Warehouse, Seattle, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Mechanical Machinery • Other Metal, and Articles of Metal • Other Prepared Food Stuffs • Pulp, Newsprint, Paper, and Paperboard
Up, Seattle, WA	Rail	Rail □ Truck	• Meat, Fish, and Preparations • Other Crops
Vanport Warehousing, Inc.	Rail	Rail □ Truck	• Articles of Stone, Ceramic, Or Glass • Chemical Preparations N.E.C. • Forest Products • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Metal, and Articles of Metal • Pulp, Newsprint, Paper, and Paperboard • Wood Products
Washington Cold Storage, Inc., Kent, WA	Rail	Rail □ Truck	• Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Prepared Food Stuffs
Washington Cold Storage, Inc., Puyallup, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Animal Feed, Pet Food, and Products of Animal Orig • Furniture and Furnishings • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Prepared Food Stuffs
Weatherproof Reload and Storage, Spokane, WA	Rail	Rail □ Truck	• Iron and Steel In Primary Forms and Basic Shapes • Meat, Fish, and Preparations • Mechanical Machinery • Other Crops • Other Metal, and Articles of Metal • Waste and Scrap

Name	Type	Mode Type	Commodity Description
Western Warehousing Services, Tacoma, WA	Rail	Rail □ Truck	• Alcoholic Beverages • Articles of Stone, Ceramic, Or Glass • Furniture and Furnishings • Miscellaneous Manufactured Products • Other Prepared Food Stuffs • Plastics and Rubber • Wood Products
Weyerhaeuser Company Wood Chip Facility, Tacoma, WA	Rail	Rail □ Truck	• Forest Products • Wood Products

Washington State Department of Transportation

Appendix 4: Freight Forecast

Sources

Future demand of rail freight services are assessed based on five main studies, including three major data sources recommended by the *2009 American Association of State Highway and Transportation Officials (AASHTO) Rail Planning Guidelines*: *2007 Surface Transportation Board Waybill Sample Data,* United States Department of Transportation (USDOT) Freight Analysis Framework (FAF), and Global Insight. In addition, the Washington State Transportation Commission (WSTC) *Statewide Rail Capacity and System Needs Study* and Washington State Department of Transportation (WSDOT) and Washington State Public Port Association (WPPA) *2009 Marine Cargo Forecast* provide information and data that are specific for Washington State.

- WSTC: *Statewide Rail Capacity and System Needs Study – Freight Transportation Demand Forecasts*, 2006.
- USDOT Federal Highway Administration: 2006 Updates of *Freight Analysis Framework Forecast.*
- WPPA/WSDOT: *2009 Washington State Marine Cargo Forecast.*
- United States (U.S.) Surface Transportation Board (STB): *2007 Rail Waybill Sample Data.*
- AASHTO: *Freight Demand and Logistic Bottom Line Report* (Draft), 2006.

Methodology and Forecasts

In general, the WSDOT State Rail and Marine Office adopted the forecast results from the above sources. For rail mode related forecasts, 2007 Waybill Data was used as a base for projection since data for 2008 was not available as we conducted the forecasts.

The 2008-2009 recession had profound impacts on U.S. and world economies and many effects are likely to take many years to understand. Therefore, the forecast results in this plan could be slightly optimistic from the perspective of a long-term forecast. The forecasts will be updated as the data for 2008 and 2009 become available.

While the most recent recession data for freight is not available and, therefore, not incorporated into most of these analytical models, the sources of forecast used in this plan are long-term data. Historical data used in those forecasts reflect the effects of previous recessions. In addition, while the economy went into recession in 2008, state port-related

imports and exports started to decline in 2007. Rail traffic in 2007 was not as strong as the economy itself in that year. Therefore, the correction factor of this recession to the forecast results would not be dramatic, but could be significant when the data are incorporated into to the long-term trends.

Statewide Rail Capacity and System Needs Study – Freight Transportation Demand Forecasts (2006)

This study was conducted by Cambridge Systematics. The researchers examined recent economic and trade forecasts for the state, the Pacific Northwest, and the United States focusing on four primary sectors—agriculture and foods products, merchandise trade and retail, manufacturing, and lumber and wood products. In addition, two other sectors of unique interest—military and municipal solid waste—were also examined. Particular attention was paid to the Pacific Rim trade that will account for much of the volume of import containers and exports (grains, fertilizers, food products, wood products, etc.) that is expected to move by rail in the state.

Among the forecasts reviewed was the *2009 Marine Cargo Forecast* for the WPPA, which used economic and trade forecasts developed by consulting team member, Global Insight, as well as individual trade forecasts developed for the Port of Tacoma and the Port of Seattle. Also reviewed were the Lower Columbia River cargo forecasts produced for the Port of Vancouver, Washington, and the Port of Portland, Oregon; and the Oregon State Commodity Flow forecasts produced for the Oregon Department of Transportation.

Global Insight used its own forecasts and local sources to develop and adapt economic forecasts for industries that are domestic and local rail shippers. From these and other relevant forecasts, Global Insight synthesized economic growth conditions and trend projections, making adjustments and extensions where appropriate, to bracket the most likely growth rates and freight forecasts for the state. The resulting forecasts are annual long-term forecasts capturing the path of growth for 20 years, as well as the forecast endpoint level of projected economic activity and trade.

Forecast data for the years 2015 and 2025 was created by routing the rail traffic and other modes across the respective modal networks. The carload and IMX forecast synthesizes economic growth conditions and trend projections, making adjustments and extensions, where appropriate, to bracket the most likely growth rates and freight forecasts for the state. The resulting forecast projects the long-term growth through 2025.

Washington State's freight railroads can expect continued growth over the next 10 and 20 years. Rail freight is projected to grow at 2.2 percent compound annual growth rate to 2015 and at a 2.3 percent annual growth from 2015 to 2025. This is a steady 2.2 percent growth rate over the next 20 years. Exhibit 4A-1 shows the growth of rail tonnage in the forecast years. While local and inbound traffic continue to grow, they will slow to slightly lower levels of growth after 2015. Outbound and through traffic will both grow at higher rates in the more distant future as compared to the next 10 years.

Exhibit 4A-1: Projected Rail Freight Traffic Growth Rates

Growth Rates of Rail Traffic by Tonnage			
Class	**2004-2015**	**2015-2025**	**2004-2025**
Through	1.90□	2.30□	2.10□
Local	3.30□	2.30□	2.80□
Inbound	1.50□	1.20□	1.40□
Outbound	3.20□	3.80□	3.50□
Total	**2.20**□	**2.30**□	**2.20**□

Source: Cambridge Systematics, 2006

WSDOT State Rail and Marine Office adapted the rail traffic growth rate to project future growth. The rail freight data from the 2007 STB Waybill Sample is used as a base. While the economy went into recession in 2008, port related imports and exports started to decline in 2007. Rail traffic in 2007 was not as strong as the economy in that year. The state's freight railroads activity can expect continued growth over the next 10 and 20 years. The railroads are expected to move more than 152.1 million domestic tons of freight in 2020, up from 116.3 million in 2007, a 2.1 percent compound annual growth rate. In 2030, it is projected that there will be close to 189.9 million tons moved, a 2.2 percent annual growth over the 10 years from 2020 to 2030, and a steady 2.2 percent growth rate over the 23 years between 2007 and 2030.

Exhibit 4A-2 shows the growth of rail tonnage in the forecast years. While local and inbound traffic continue to grow, they will slow to slightly lower levels of growth from 2020 to 2030 compared to 2007 to 2020 growth levels. Outbound and through traffic will both grow at higher rates in the more distant future as compared to the next 10 years.

Exhibit 4A-2: Washington State Rail Freight 2007, 2020, and 2030 (Million Tons)

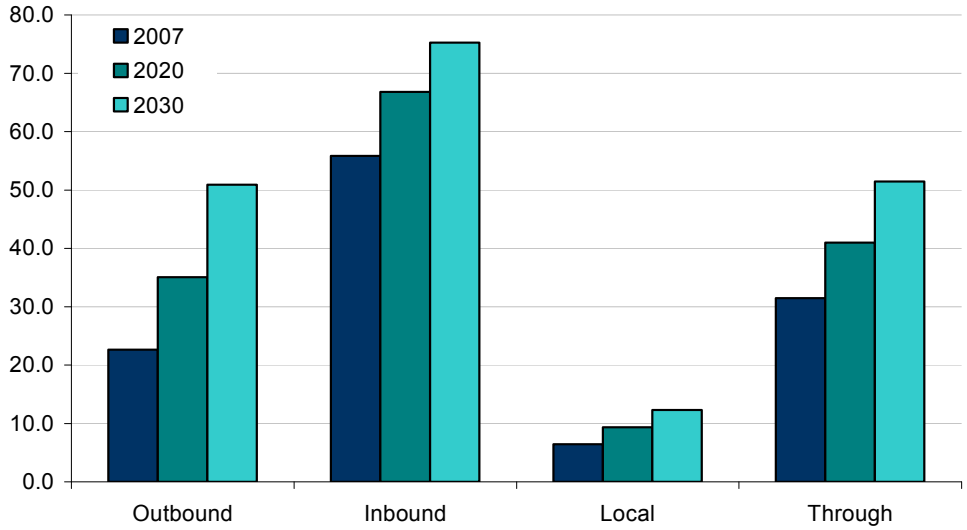
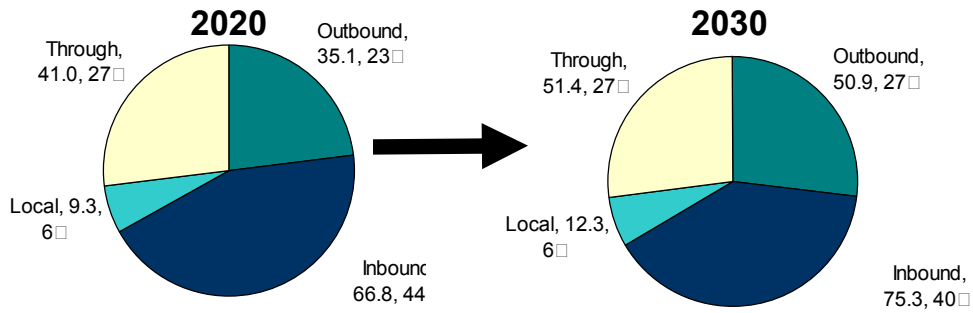


Exhibit 4A-3 shows the projected distribution of the inbound, outbound, through, and local shares of the state's total freight rail tonnage for both forecast years of 2020 and 2030. Of all shares, outbound traffic is projected to continue to grow the most between 2020 and 2030, growing from 23 percent to 27 percent between 2007 and 2020, and expanding to 35 million tons. Local and through traffic is projected to continue to maintain approximately 6 percent and 27 percent of the tonnage, respectively, over the next 10 and 20 years. Inbound traffic is projected to encompass a smaller percent of the traffic as it will claim 44 percent of the tonnage in 2020 and only 40 percent in 2030.

Exhibit 4A-3: Rail Freight Distribution (Million Tons)



Source: WSDOT State Rail and Marine Office

The projected distribution of traffic tonnage by commodity through the forecast years is shown in Exhibit 4A-4. Farm products are projected to continue to be a significant tonnage commodity group, growing to more than 64.7 million tons in 2030, up from 36.1 million tons in 2007. Not surprisingly, miscellaneous mixed shipments, primarily in the form of

imports, are projected to increase from 11.9 million tons in 2007 to 14.3 million in 2020 and 17.6 million in 2030.

Exhibit 4A-4: Projected Rail Freight Growth of Top 10 Commodities □ Washington 2007-2030 (Million Tons)

Commodity	Year					
	2007	2010	2015	2020	2025	2030
Farm products	36.1	38.8	42.8	48.1	55.2	64.7
Lumber or wood products, excluding furniture	12.9	12.8	12.0	11.2	10.2	9.2
Miscellaneous mixed shipments	11.9	12.6	13.4	14.3	16.0	17.6
Coal	10.6	11.0	12.7	14.8	17.1	19.9
Food and kindred products	7.3	7.2	7.9	9.3	11.0	13.2
Chemicals or allied products	6.8	7.8	8.2	8.7	9.1	9.5
Waste or scrap materials not identified by producing industry	5.1	5.1	5.8	6.6	7.6	8.9
Pulp, paper, or allied products	4.1	4.1	4.2	4.2	4.2	4.3
Clay, concrete, glass, or stone products	3.1	3.4	3.9	4.5	5.1	6.0
Transportation equipment	2.5	2.5	2.3	2.3	2.5	2.8
State Total	**116.3**	**122.2**	**131.9**	**145.7**	**161.9**	**183.0**

Source: WSDOT State Rail and Marine Office □ Analysis and forecast based on FHWA Freight Analysis Framework data and 2007 Surface Transportation Board Waybill data.

USDOT Federal Highway Administration: *2006 Updates of Freight Analysis Framework Forecast – Commodity Origin-Destination Database: 2002-2035*

FAF estimates commodity flows and related freight transportation activity among states, sub-state regions, and major international gateways. It also forecasts future flows among regions and relates those flows to the transportation network. FAF includes an origin-destination database of commodity flows among regions, and a network database in which flows are converted to truck payloads and related to specific routes.

The FAF commodity origin-destination database includes tons and value of commodity movements among regions by mode of transportation and type of commodity. Data sources documented in various papers are available at www.ops.fhwa.dot.gov/freight/freight_analysis/faf. FAF statistics do not match those in mode-specific publications, primarily due to different definitions that were used to avoid double counting. Methods in developing the 2002 base year data are transparent; and it has been

expanded to cover all modes and significant sources of shipments. Future projected data covers years from 2010 to 2035 with a 5-year interval. The approach/general procedure and assumptions used by the modeling packages have been documented and are available for download at www.ops.fhwa.dot.gov/freight/freight_analysis/faf. Detailed methods about modeling are available at www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/report3/index.htm.

The forecasts built in the FAF database were developed based on long-term growth perspectives and did not reflect the new challenges presented by the current recession. Again, the growth rates could be optimistic and the forecasts of this plan will be updated as the new data becomes available. The WSDOT State Rail and Marine Office adapted the rail traffic growth rate to project future growth of the top ten state commodities shipped by rail. The rail freight data from 2007 STB Waybill Sample is used as the base. National growth forecasts are directly adopted from FAF database.

The national demand for freight rail services are driven by three factors: population growth, globalization, and technology (primarily, containerization). Assuming moderate rates of economic growth—between 2.5 to 3 percent a year—the tonnage of freight moved in the United States is likely to increase 75 percent in 20 years (2006 to 2035) (Exhibit 4A-5). This rate of growth is about the same as the last 20 years and roughly tracks growth in the U.S. Gross Domestic Product. The problem is that no provisions have been made to accommodate this growth, and the nation is in the early stages of a freight transportation capacity crisis. This section first looks at the projected growth in the demand for freight traffic (both total and for rail) and then discusses the rail industry response to this demand growth.

The growth in freight tonnage is expected to continue at 2.5 percent to 3 percent per year at least through 2035. The demand for freight rail services is projected to increase by a total of 73 percent based on tons and through 2035, assuming continued investment in the rail system to handle growth. Despite this, the rail share of national freight shipments is shrinking slightly. By 2035 rail's share of total freight tonnage could decline from 13.3 percent to 12.9 percent and rail's share of value could decline from 4.2 percent to 2.9 percent.[1] Exhibit 4A-6 shows freight modal distribution in 2035.

[1] All forecasts in this section were developed by Global Insight and were obtained from the AASHTO *Freight Bottom Line Report*, 2006.

Exhibit 4A-5: U.S. Shipments by Mode □ 2006 and 2035 (Millions of Tons)

Mode	2006				2035			
	Total	Domestic	Exports[3]	Imports[3]	Total	Domestic	Exports[3]	Imports[3]
Total	20,974	18,985	620	1,369	(R) 37,212	33,668	(R) 1,112	(R) 2,432
Truck	12,659	12,389	169	101	22,814	22,231	262	320
Rail	2,040	1,905	41	95	3,525	3,292	57	176
Water	688	582	48	58	1,041	874	114	54
Air, air □ truck	15	5	4	6	(R) 61	10	(R) 13	(R) 38
Intermodal[1]	1,503	194	353	956	2,598	334	660	1,604
Pipeline □ unknown[2]	4,068	3,909	6	153	7,172	6,926	5	240

Key: R □ revised

[1] Intermodal includes U.S. Postal Service and courier shipments and all intermodal combinations, except air and truck.

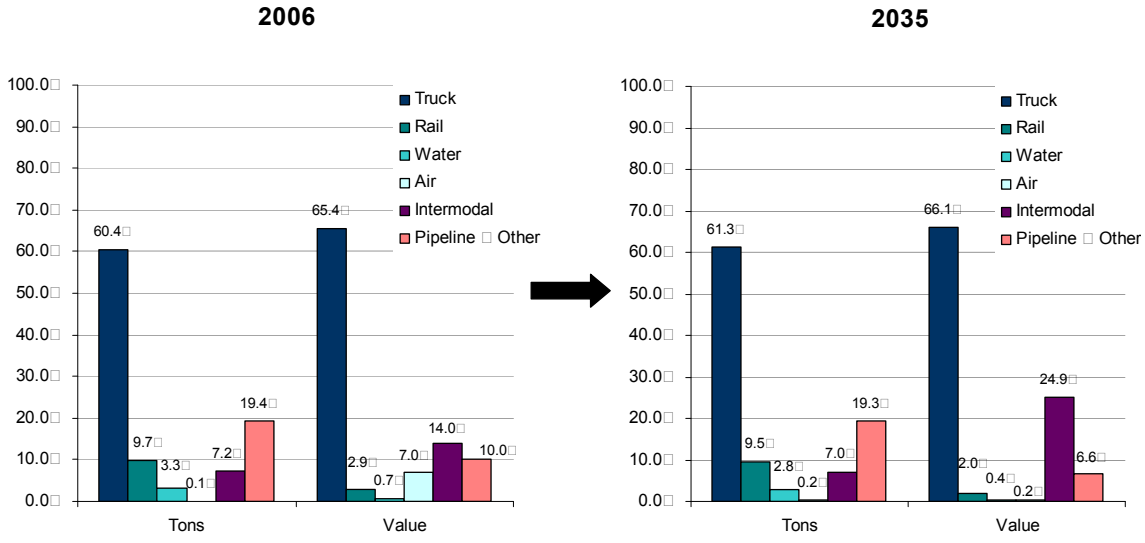
[2] Pipeline and unknown shipments are combined because data on region-to-region flows by pipeline are statistically uncertain.

[3] Data do not include imports and exports that pass through the U.S. from a foreign origin to a foreign destination by any mode.

Note: Numbers may not add to total due to rounding.

Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, Version 2.2, 2007.

Exhibit 4A-6: Freight Tons, Value, and Ton-Miles by Mode, 2006 and 2035



Source: USDOT FHWA Freight Analysis Framework, 2007

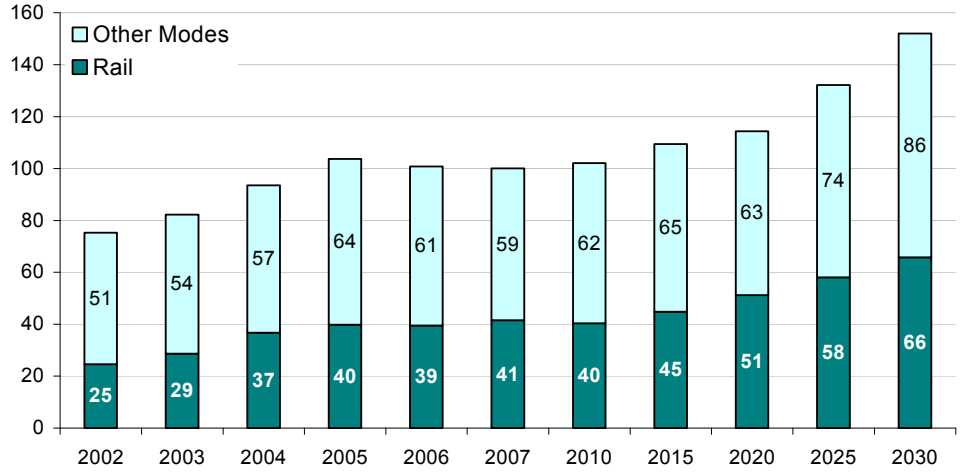
WSDOT WPPA: *2009 Washington State Marine Cargo Forecast*

In 2009 the WPPA and WSDOT jointly conducted a 5-year update of the 2004 Marine Cargo Forecast. These two organizations have been providing joint cargo forecasts since 1985. This report fulfills statutory requirements. The purpose is to assess the expected flow of waterborne cargo through the state's port system and to evaluate the distribution of cargo through the rest of the state's transportation network. The current report is a 20-year forecast of trade (2008 to 2030) moving through the state by water, rail, roads, and pipelines. It forecasts future demands not limited by the rail infrastructure capacity.

The approach used for this forecast is based on historic data trends and growth factor analysis of anticipated future changes. With the assistance of the technical advisory group, the BST consultants developed growth factors to project the growths. Many macro factors available at the forecast time were analyzed.

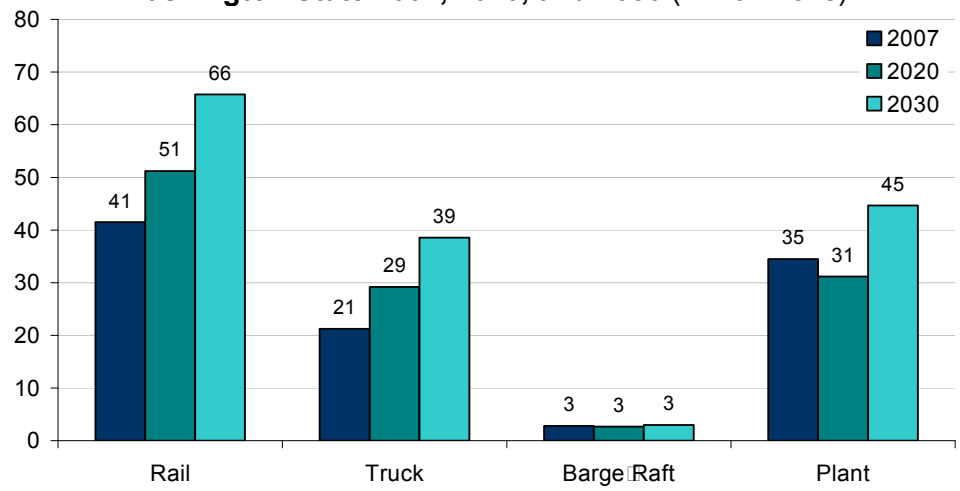
The Marine Cargo report found that rail freight is likely to play an increasingly important role in marine cargo movement. As Exhibit 4A-7 and Exhibit 4A-8 demonstrate, in the future rail freight may account for a larger share of marine cargo movement due to a higher growth rate than other modes over the forecast period.

Exhibit 4A-7: Marine Cargo Trends Rail vs. Other Modes 2002 to 2030 (Million Tons)



Source: WPPA WSDOT Marine Cargo Forecast 2009

Exhibit 4A-8: Marine Cargo Port Modal Distribution
Washington State 2007, 2020, and 2030 (Million Tons)



Source: WPPA WSDOT Marine Cargo Forecast 2009

There are three factors that drive fast marine cargo growth. First, U.S. consumption increases as population and living standards increase. Second, economic globalization makes countries more specialized in production to achieve efficiency. As a result of this globalization, exports and imports increase dramatically. Last, containerization of transportation industry drives more intermodal traffic that demands rail services.

However, the recent economic recession slowed down this growth and is likely to have impacts on long-term growth potential. Economists are debating the long-term effect of this recession and many of them expect a slower growth for the next 20 years. Therefore, forecast results presented in this section are likely to be optimistic, given that recent recession data have not been integrated into the forecast processes. This plan will be updated as the new data and forecast results become available.

AASHTO: *Freight Demand and Logistic Bottom Line Report* (Draft), 2006

This study was done by Cambridge Systematics and freight demand forecasts were conducted by Global Insight. The forecasts for each mode are driven by the growth in the commodities that they handle. Growth in freight demand, combined with forecast growth in passenger movement, will contribute to increased congestion and reduced performance of the nation's transportation system. However, the impacts on each mode will be different.

Rail market share also is shrinking because of its pace of investment. The industry is purposefully operating near capacity because of its capital intensity, and it is using demand management as well as investment to

respond to traffic volumes. This means low to higher profitability as business is being turned away to make room for more profitable business. Railroads, like all private industry, will continue to make capital decisions based on private financial returns, and public benefits will be just an incidental part of the decision, unless public capital plays a role. Demand for rail transportation is driven by the commodity markets it serves, as well as by carrier performance. Almost three-quarters of the current rail tonnage and revenue come from four market groups: coal, farm and food products, chemicals and petroleum, and the intermodal business (listing them in order of tonnage size). Some 40 percent of the physical volume is in coal alone, but the revenue picture is different and more balanced: intermodal and coal each are about 20 percent of the traffic (with intermodal somewhat the larger), while the farm and food group and the chemicals and petroleum group are about 15 percent each. Roughly 60 percent of all new rail tonnage is attributable to coal and intermodal, and although the top four markets remain the same, by 2035 intermodal should be second only to coal in terms of physical volume, and will be substantially the most important source of rail revenue. The intermodal business is projected to maintain a 3.8 percent compound annual growth rate over the next three decades, causing it to more than triple in size, primarily because of its role in carrying containerized imports for the globalizing economy. Traffic in transportation equipment also grows at an above-average pace, expanding by 2.6 percent per year and more than doubling in volume by 2035. This business is chiefly automotive products, for which rail offers a very successful service that should be able to keep abreast of an evolving market in the years ahead. Rail services fall into three distinct categories: bulk, general merchandise, and intermodal.

Bulk services are dedicated unit trains hauling a single bulk commodity, such as coal or grain. Intermodal services, as defined by the rail industry, are trains hauling international and domestic containers and trailers. All other rail freight, such as chemicals, forest products, and automobiles move as general merchandise. The long-term prospects for selected rail commodities through the year 2035 are:[2]

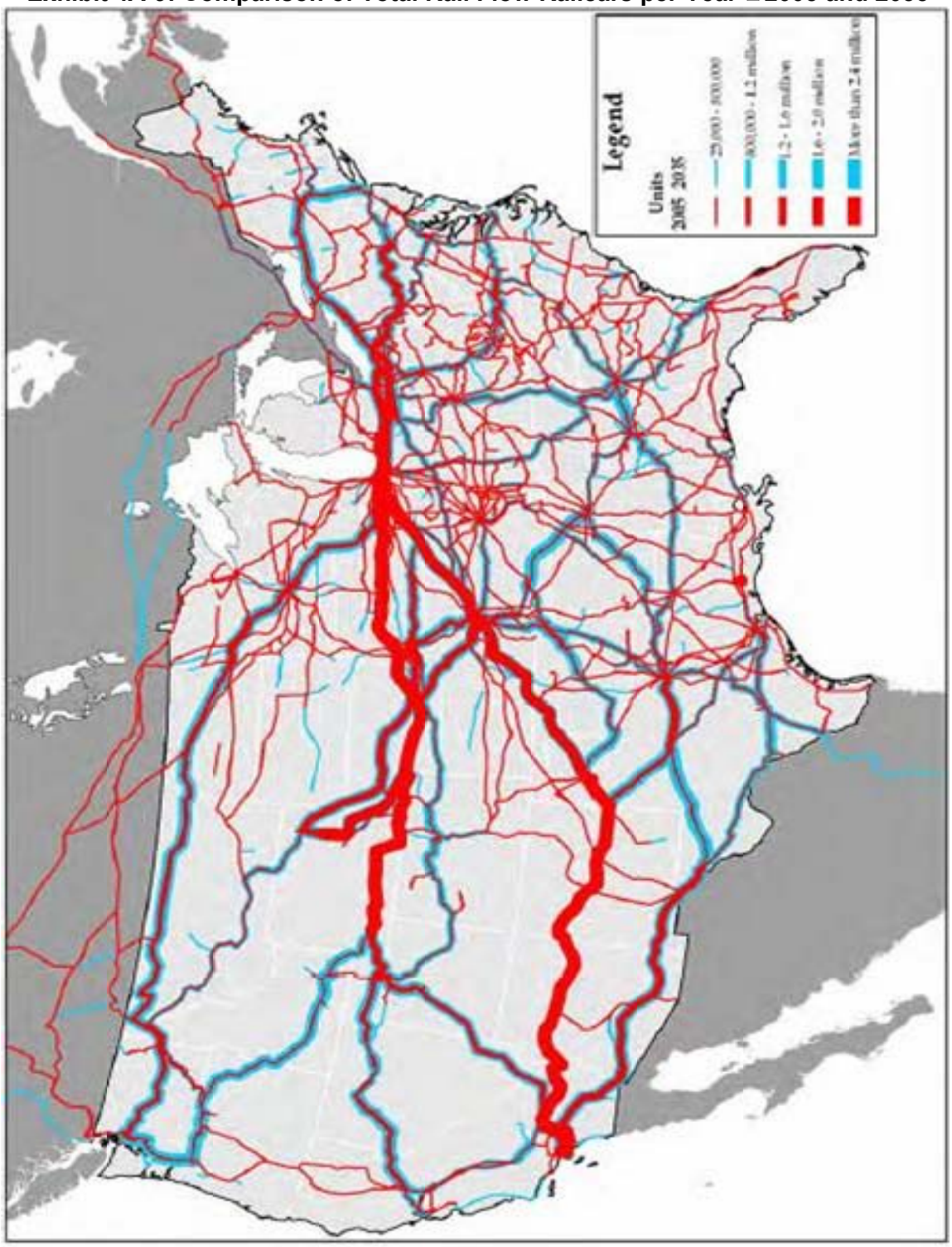
- **Coal** – Rail should remain its primary mode of transport, with a 62 percent cumulative growth in rail tonnage by 2035.
- **Farm and Food Products** – Modest growth of slightly less than 1 percent per year, with cumulative growth in 2035 projected to be 51 percent larger than today.
- **Chemical and Petroleum** – Slow growth of less than 1 percent per year and accumulating to a 27 percent increase by 2035.

[2] Forecasts developed by Global Insight and obtained from the *AASHTO Freight Bottom Line Report*, 2006.

- **Lumber and Forest Products** – Slow growth around or just above 1 percent per year, and a total increase in rail shipments of 40 percent to 49 percent by 2035.
- **Transportation Equipment** – Solid growth of 123 percent in tonnage through 2035.
- **Intermodal** – Prospects for rail intermodal business are very robust, with tonnage volumes rising 213 percent by 2035.

Exhibit 4A-9 demonstrates the projected growth demand using FAF data for rail in the U.S. between 2005 and 2035. Looking at the state, it can be observed that units moved on mainline railroads increase multifold to the 10 to 20 million unit designation. More capacity will have to be developed in our rail network in the state to meet this forecasted demand. This topic is further explored in Chapter 4.

Exhibit 4A-9: Comparison of Total Rail Flow Railcars per Year □ 2005 and 2035



Washington State Department of Transportation

Appendix 5-A: Washington Historical Rail Abandonments

Washington Historical Rail Abandonments		
Year	Miles	Segments
1953	9.35	1
1964	0.06	1
1966	1.80	1
1969	32.58	3
1970	9.72	2
1971	30.79	3
1972	61.65	10
1974	79.22	3
1976	15.54	2
1977	21.51	4
1978	76.93	5
1979	81.28	3
1980	458.26	15
1981	44.89	4
1982	38.10	5
1983	107.77	9
1984	179.54	17
1985	147.74	12
1986	104.41	9
1987	72.66	3
1988	12.37	2
1989	130.00	1
1990	37.38	1
1991	75.28	3
1992	94.43	2
1993	132.13	6
1994	3.57	1
1995	-104.65	1
1996	11.20	1
1997	1.18	1
1998	12.45	1
2003	0.41	2
2004	18.14	4
2005	0.80	1
2006	32.11	4
2007	1.06	2
2008	12.55	1
2009	5.15	3

Washington State Department of Transportation

Appendix 5-B: Port Access Projects

Port Access Points

The reduction of bottlenecks at port access points is very important to keep the rail systems flowing. As a result, rail connectivity issues for the ports and capacity issues on the Interstate 5 (I-5) corridor are necessarily tied. Along the corridor there are five main areas where mainline capacity needs and connectivity issues intersect:

1. Vancouver, Washington (WA).
2. Kalama to Longview.
3. Centralia.
4. Tacoma.
5. Seattle.

Vancouver (WA)

Vancouver (WA) is a major point of congestion in Washington State's (state) rail system for several reasons:

- The I-5 corridor ties to the Columbia River Gorge rail corridor (Vancouver to Pasco) in Vancouver.
- Port of Vancouver rail traffic moves through the area, and the BNSF Railway (BNSF) operates a yard in Vancouver.
- East/west traffic crosses north/south traffic at-grade, while local traffic moving at slow speeds consumes mainline capacity, slowing the more than 100 trains that pass through the Vancouver Rail Yard every day.

Two projects are planned or under construction to alleviate these conflicts. The first of these projects is the Vancouver Bypass. The Vancouver Bypass will provide a new mainline track around the Vancouver Yard that allows through trains to avoid moving through the yard. It also provides a grade separation between West 39th Street and the yard, improving vehicle and pedestrian safety. Construction of the siding tracks along the west side of the rail yard began in January 2009, and construction of the 39th Street Bridge began in May 2009, anticipated to be completed by mid-2011. Full funding for the remaining rail elements of the plan is not yet in place.

The Port of Vancouver Freight Access Project would separate port traffic from mainline traffic by grade-separating the primary route into the port. This would reduce the number of trains crossing the mainlines at grade. With port-related traffic exiting the Columbia River Gorge route farther

east, the project would also improve flow through the Vancouver Terminal area. Finally, a new configuration of yard tracks and leads within the port will increase the ability of the facility to handle additional and longer trains.

Kalama and Longview

In the 10-mile stretch between Kalama and Longview, local traffic consumes mainline capacity in two ways. First, grain trains exiting or entering the mainlines at Kalama must move relatively slow on or off the main, which delays through traffic moving along the mainline. Second, local operations working from the Longview Junction rail yard must make some moves on the mainline, and these also move relatively slow. The plan to alleviate the problems in this area involves construction of a third mainline between Kalama and Longview. Construction is planned to begin in the 2013-2015 biennium and to be completed by mid-2017.

Centralia

At Centralia the short-line railroad serving the Port of Grays Harbor, Puget Sound and Pacific Railroad (PSAP), branches off of the BNSF I-5 corridor mainline. The Tacoma Rail Mountain Division (TRMW) line parallels the I-5 corridor mainline through Centralia, crossing the PSAP line at Blakeslee Junction. The TRMW and PSAP/Centralia project will reconfigure Blakeslee Junction to provide TRMW access on the PSAP between Blakeslee Junction and the BNSF mainline, and will reconfigure and upgrade the PSAP line between Blakeslee Junction and the mainline. Once complete, the TRMW line through downtown Centralia will be removed. Further phases of the project will add rail capacity in Centralia, a second connection between PSAP and TRMW in Grand Mound, and additional storage track. Funding has not yet been secured for the full project. Only partial funding for the Blakeslee Junction to mainline is currently in place.

Tacoma

In Tacoma, train movements for BNSF and the Union Pacific Railroad (UP) between the mainlines, yards, and port terminals are somewhat inefficient. Two proposals to mitigate this have been considered in the past. The first is construction of a new rail bridge linking Bullfrog Junction on the Tideflats to the mainlines at Reservation Interlocking. The second is implementation by BNSF and UP of co-production[1] between Tacoma and Tukwila. Under the co-production proposal, UP port traffic to and from the south would use the BNSF line to connect through Bullfrog Junction, while BNSF port traffic to and from the south

[1] Co-production is where two railroads share the same track.

would use the UP connection at Reservation Interlocking, and would also use the UP mainline between Tukwila and Reservation Interlocking. To this point, the railroads have not agreed to such an arrangement, although dialog has taken place off and on over the last few years.

Seattle

In Seattle, neither the BNSF nor the UP has a direct route between the mainlines and on-dock intermodal facilities. BNSF international container traffic first moves through the Seattle International Gateway/Stacy Yard, which increases transit time. The UP line to the on-dock facilities is essentially a switching lead that extends through the Argo Yard, which significantly impacts operations at Argo. In addition, intermodal trains cross East Marginal Way at-grade, creating long roadway vehicle delays.

One project designed to ease part of this problem is the East Marginal Way Grade Separation. This project will construct an overpass that routes vehicle traffic up and over railroad tracks, eliminating delays on East Marginal Way caused by trains crossing at grade. Another concept for improving rail access to Port of Seattle facilities is the Duwamish Rail Corridor, which would essentially create a double-track connection between the UP Argo Interlocking and the Harbor Island line using one UP yard track and a BNSF track. However, this project has not moved beyond initial discussions.

Other Access Issues

There are two additional areas (Everett and Bellingham) along the I-5 rail corridor that may need improvements in the future and one 5-phase project in Pasco that is currently underway.

Everett

In Everett, rail access is not currently an issue. The single-track Everett Tunnel, which is located through Everett on the mainline south of the convergence of the Stevens Pass mainline and the mainline to Blaine, is handling an increasing number of passenger trains. The increase of passenger traffic impacts freight capacity through the tunnel. A solution to this conflict is the proposed Bayside Bypass that would extend a line from Delta Junction down the Bayside industrial track and connect back into the Seattle mainline at Everett Junction. In the future the BNSF may construct the Bayside Bypass route, but this project is unlikely to cause access problems to port properties.

Bellingham

In Bellingham, the city and Port of Bellingham are developing plans to convert the former Georgia Pacific industrial site into a mixed use waterfront development. As part of this project, a sharp curve in the BNSF mainline track near the site will be removed and the tracks moved further to the east. The relocated tracks will allow passenger and freight trains to travel at a slightly higher speed through this area.

Port of Pasco Projects

In Pasco, the Port of Pasco is making a series of improvements to the network of railroad tracks that serve the Big Pasco Industrial Center. These improvements include upgrading older track to handle heavier and longer trains, adding container terminal tracks along the Columbia River, improving road/rail crossings, and a second connection to the BNSF mainline. Three of five phases have been completed, with Phase 4 slated for construction to start in late 2009.

Appendix 5-C: Inland Port Concepts

Rail access is a significant element of port competitiveness strategy. By providing an inland port service, a seaport (in theory) can make intermodal rail service available to a broader range of customers. If priced sufficiently low, the inland port service can offer cost savings to container shippers and thereby increase the port's competitiveness.

Inland Ports

Inland ports have become an increasingly popular concept as the drive for transportation efficiency continues. Inland ports are perceived to reduce congestion, improve transit times and reliability, while at the same time decreasing costs and promoting economic development.

Inland ports have several dimensions. In the narrowest sense, an inland port is an inland container transfer facility that performs many of the cargo processing functions that are performed at seaports, including customs clearance. Intermodal containers are moved from the seaport to the inland port, often in bond, thus freeing valuable land at the port for maritime activity. In effect, the inland port serves as an extension of the seaport, although at a remote location, typically close to either a key market or principal components of the highway system. If rail is used to transport the cargo to the inland port, trucks are removed from the highways and roadway congestion near the water port can be reduced. This possibility has also led to the concept of moving cargo to a remote point outside of the immediate seaport area by a rail shuttle service and then returning it to truck on less congested highways.

A broad array of multimodal facilities that support international trade can also be defined as inland ports. An often-cited example of such a development is the Alliance Texas Logistics Park, a 15,000-acre development 15 miles north of Fort Worth that includes air, rail, and highway connections, a foreign trade zone, an enterprise zone, inventory tax exemption, and business parks, distribution areas, and other facilities.

Rail Intermodal Transportation Moves

Rail intermodal transportation moves involve high-fixed costs but low-variable costs. By contrast truck transport involves high-variable costs but lower-fixed costs. Generally rail intermodal moves are considered to have a low line-haul cost per mile. The challenge in Washington State (state) is that the railroads want a haul of at least 500 miles based upon their cost structure and available rail capacity. Since the fixed costs need to be

defrayed over a large number of miles, railroads do not typically market intermodal services for short distances.

Another complication is that depending on the port, these containers may have to be drayed to and from the intermodal facilities, and these short truck movements add significant costs. Furthermore, intermodal facilities are expensive to build and to operate. The cost of building a small starter-size facility is estimated to be around $25 million and one that would handle a significant volume is estimated at $70 to $80 million. In addition, if these terminals are operated as a shuttle service, rail intermodal equipment may have to be acquired, since it may be captive to the service.

Status

Due to the cost versus delivery time equation, the inland port concept has not come to fruition in many states, especially in Washington State. There have been attempts at the concept in both Quincy and Maytown. The Quincy facility is challenged by the current cost structure of rail versus truck. The potential Maytown development got caught up in a political struggle among stakeholders.

In the future, such developments could provide the base volume to generate the level of public benefits necessary to help justify the cost of a shuttle-type rail service to and from a port. The feasibility will depend on a number of variables, including access, what facilities are actually available at a port to transfer containers to rail and inland terminals, and capital and operating cost provisions.

Studies

Multiple studies in other states have concluded that the cost premium of the truck/rail transportation was particularly high for the shorter intermodal rail moves to inland port locations close to deepwater coastal ports.

A multi-year study[1] to determine if and how inland port concepts could be applied to reduce drayage miles and generate other public benefits was conducted in southern California. This study reached similar conclusions, namely the cost would be substantial, and an operating subsidy would be required. The results of the study's cost analysis suggested it would amount to at least $200 per container at current cost levels (2008).[2]

[1] The Tioga Group, Railroad Industries, Inc, and Iteris, *Inland Port Feasibility Study, Project No. 06-023, Tasks 3-5Draft Report*, prepared for the Southern California Council of Governments, June 5, 2008.
[2] Ibid, p.4

Inland port terminals may not be justified from direct transportation savings, but could perhaps be with the inclusion of public benefits. Benefits estimated in the study equated to a range of 5 to 70 percent of the estimated transportation cost difference depending on inland terminal location and estimated cost differential range.

Based on the analyses performed in other states, an inland terminal provides the greatest proportional share of public benefits when it is located near a large concentration of port customers. It is estimated that a starter intermodal facility requires an initial volume of 20,000 to 30,000 containers per year to be viable.

Success of Inland Ports

Under current economic conditions, trucking continues to be less costly and a quicker alternative within the state as compared to rail. It is believed that in the future this cost structure will change as fuel and environmental costs of trucking drastically increase. At that point, inland ports may develop in the state as they have in other parts of the country.

There are a number of factors that are key to the success of an inland port that need to be analyzed, as the inland ports concept is considered as a component of the transportation network in the future. Among these are:

Location

An inland port should intercept major container flows and provide easy access to rail and interstate highway networks that connect it with key markets.

Functions

The inland port should perform a range of functions including intermodal transfers, storage/warehousing, staging, inspections, parking, service, etc.

Institutional Arrangements

Arrangements must be made with rail carriers and port operators to establish the rail service, as well as the container consolidation and rail car loading at the port.

Scheduled and Reliable Service

Using the inland port cannot cause an excessive delay, either due to train scheduling, transfers, or the nature of the train service.

Costs

The capital and operating costs of an inland port must not exceed the expected benefits of the service. This does not necessarily mean that the service would operate without subsidies, only that the subsidies should not exceed the public benefit of the facility.

Washington State Department of Transportation

Appendix 6: WSDOT Freight Partnerships

The Washington State Department of Transportation (WSDOT) works in partnership with a variety of freight sectors.[1] Below is a list of WSDOT's freight partners:

- AASHTO Freight Transportation Network
- Amtrak
- Commercial Vehicle Information Systems and Networks
- Federal Highway Administration
- Federal Motor Carrier Safety Administration
- Federal Railroad Administration
- Freight Action Strategy Corridor
- Freight Mobility Strategic Investment Board
- International Mobility & Trade Corridor
- Puget Sound Maritime Air Forum
- TransNow (regional university transportation center administered by USDOT)
- Transportation Improvement Board
- USACE Waterborne Commerce Statistics Center
- USDOT Bureau of Transportation Statistics
- USDOT Hazardous Materials
- University of Washington Global Trade, Transportation, and Logistics Studies
- University of Washington Intelligent Transportation System
- Washington Public Ports Association
- Washington State Department of Ecology (Air Quality)
- Washington State Patrol, Commercial Vehicle Division
- Washington State Transportation Research Center
- Washington State University Strategic Freight Transportation Analysis
- Washington Trucking Associations
- Washington Utilities and Transportation Commission
- West Coast Collaborative (public-private partnership to reduce diesel emissions)
- West Coast Corridor Coalition

[1] www.wsdot.wa.gov/freight/partnerships/.

Appendix 7: Bibliography

A Modal Comparison of Domestic Freight Transportation Effects on the General Public. (2007). Prepared by Texas Transportation Institute and Center for Ports and Waterways.

AASHTO (2006) *AASHTO Freight Transportation Bottom Line Report, Freight Demand and Logistics, Review Draft, Not for Distribution*. Prepared by Cambridge Systematics, Inc. with Boston Logistics Group and Global Insight, Inc.

AASHTO (2006), *Freight-Rail Bottom Line Report.* http://freight.transportation.org/doc/FreightRailReport.pdf.

AASHTO (2007) *State Rail Plan Guidebook, Project Update*. Presented by D. Hunt on October 15, 2007, to ASSHTO Standing Committee on Rail Transportation by Cambridge Systematics, Inc. in Biloxi, MS.

AASHTO (2007). *Transportation Bottom Line Report and Transportation Commission Recommendations*.

AASHTO, (2009). *2009 AASHTO State Rail Planning Guidebook.* http://www.transportation.org/.

AASHTO (2009). *Transportation—Are We There Yet? The Bottom Line Report.* www.transportation.org/.

AASHTO, Standing Committee on Planning (2009) *Scoping Study for a Freight Data Exchange Network.* Prepared AECOM Consult, Inc. Arlington, VA. Prepared in part of NCHRP Project 8-36, Task 79, National Cooperative Highway Research Program.

Association of American Railroads (2007). National *Rail Freight Infrastructure Capacity and Investment Study*. Prepared for Association of American Railroads by Cambridge Systematics, Inc., Cambridge, MA.

Association of American Railroads (n.d.) *Freight Rail Works for the Environment*. http://www.FreightRailWorks.org/.

Bingham, P. (2009) *Expectations for the Economy and Trade, Annual Convention*. Presented October 27, 2009, IHS Global Insight: Galveston, TX.

Bingham, P. (2009) *Trade and Economic Trends, Marine Terminal Management Training Program.* Presented on September 21, 2009, IHS Global Insight: Long Beach, CA.

BNSF Railway Co. (2008). Annual Report to the Utilities and Transportation Commission (UTC).

BNSF Railway Co., Investors' Report, Second Quarter 2009. www.bnsf.com/investors/investorreports/2Q_2009_Investors_Report.pdf.

Bonneville Power Administration (n.d.). Dam Breaching and the Lower Snake River Dams. http://www.efw.bpa.gov/IntegratedFWP/DamBreachingFacts.pdf.

Bottom Line Technical Report: Highway and Public Transportation, National and State Investment Needs (2009)Cambridge Systematics, Inc. with Alan E. Pisarski. Prepared as part of NCHRP Project 20-24(54)G, National Cooperative Highway Research Program, Transportation Research Board.

Caldwell, H., Quinn, K.H., Meunier, J., Suhrbier, J., and Grenzeback. L. (n.d.). *Potential Impacts of Climate Change on Freight Transport.*

California Department of Transportation (2008). California State Rail Plan, 2007-08 to 2017-18.

Cambridge Systematics (2004) *Oregon Commodity Flow Database, Final Report.* Prepared for Oregon Department of Transportation.

Casavant, K.L. and Jessup, E. (2006) *Palouse River and Coulee City Railroad: Market Assessment.* Prepared for Washington State Department of Transportation, Office of Freight Strategy and Policy.

Center for Climate Strategies (2007) *Washington State Greenhouse Inventory and Reference Case Projections, 1990-2020.* Report prepared for Washington State Department of Ecology.

Central Washington Railroad (n.d.) www.temple-industries.com/companies/central_washington_railroad.php.

Columbia and Cowlitz Railway. (2009, August 7). In *Wikipedia, The Free Encyclopedia*. Retrieved 21:33, December 3, 2009, from http://en.wikipedia.org/w/index.php?title=Columbia_and_Cowlitz_Railway&oldid=306581801.

ECONorthwest (2007) *Highway Cost Allocation Study, 2007-2009 Biennium.* Prepared for Oregon Department of Administrative Services, Office of Economic Analysis.

Ensco, Inc. Applied Technology and Engineering Division (2009) *Track Inspection System and Services,Technical Description.*. Prepared for Washington State Department of Transportation.

Facanha, C., & Horvath, A. (2007). Evaluation of Life-Cycle Air Emission Factors of Freight Transportation, *Environmental Science Technology, 41*, 7138-7144.

Federal Rail Administration (2009) *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors.* Prepared for Federal Railroad Administration, Office of Policy and Communications.by ICF International. Washington, DC.

Federal Highway Administration (2009) *National Rail Plan: Engaging Stakeholders Today to Build a Solid Foundation for Tomorrow.* Presented by Karen Rae, Deputy Administrator, FRA, to Standing Committee on Railroad Transportation, September 22, 2009.

Federal Railroad Administration (2009) *Overview, Highlights and Summary of the Passenger Rail Investment and Improvement Act of 2008 (PRIIA)* (Public Law No. 110-432, Division B, enacted Oct. 16, 2008, Amtrak/High-Speed Rail.

Federal Railroad Administration (2009) *Positive Train Control Overview* www.fra.dot.gov/us/content/1265.

Federal Railroad Administration (2009), *Preliminary National Rail Plan.* http://www.fra.dot.gov/Downloads/RailPlanPrelim10-15.pdf.

Federal Railroad Administration (2009*). Vision for High-Speed Rail in America.* www.fra.dot.gov/downloads/rrdev/hsrstrategicplan.pdf.

Federal Highway Administration, Office of Freight Management and Operations, *Freight Shipments To, From, and Within Washington*. http://ops.fhwa.dot.gov/freight/freight_analysis/faf/state_info/faf2/pdfs/wa.pdf.

Florida Department of Transportation (2007). *2006 Florida Freight & Passenger Rail Plan, Final Report.* Prepared by Cambridge Systematics, Inc.: Bethesda, MD.

Freight Rail and the Oregon Economy, A Background Paper, Final Report (2004) Prepared for Port of Portland by Cambridge Systematics, Inc. Cambridge, MA.

Furst, T. (2005) *Freight Provisions in SAFETEA-LU.* PowerPoint Presentation by HOFM Director in September 2005.

Furst, T. (2006) Talking Freight, National Freight Policy Framework, February 21, 2006 Transcript. Federal Highway Administration, Freight Planning.

Grays Harbor Council of Governments and Washington State Department of Transportation (2007). *US 101 Regional Circulation Project, Final Report.*

H.R. 2095, Federal Rail Safety Improvements. 110th Cong., 122 STAT. 4848 (2008) (enacted). http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ432.110.pdf.

Hancock, K.L. and Sreekanth, A. (2000) *Conversion of Weight of Freight to Number of Rail Cars.* Transportation Research Record 1768 Paper No. 01-2056.

Herbert Engineering Corp. (2009) Carbon Footprint Study for the Asia to North America Intermodal Trade. Prepared for Port of Seattle.

Inhibitors to Rail Carload and Intermodal Market Share Growth, Industry Study (2009). Norbridge: Deerfield, IL. http://www.norbridgeinc.com.

Inland Port Feasibility Study, RFP 06-023 (n.d.) Paper Presented to the Southern California Association of Government by The Tioga Group, Inc., Railroad Industries, Inc. and Meyer, Mohaddes Associates.

Kansas Department of Transportation, Division of Planning and Development (200Available from: http://www.ksdot.org/burRail/Rail/default.asp.

Kruse, J. (2009) Communicating the Importance of Seaports, *Bringin' It Home.* Presented to AAPA Annual Convention, October 27, 2009. Galveston, TX.

Malekafzali, S. , Editor (n.d. *Healthy, Equitable Transportation Policy, Recommendations and Research.* PolicyLink, Prevention Institute, and Convergence Partnership.

Maryland Department of Transportation (2009) *Maryland Statewide Freight Plan.* Prepared by Cambridge Systematics, Inc. with Howard/ Stein Hudson Associates, Inc.

McCullough, G.J. (n.d.).*US Railroad Efficiency: A Brief Economic Overview.* Department of Applied Economics, University of Minnesota.

Military Traffic Management Command, Transportation Engineering Agency (2003) *Strategic Rail Corridor Network (STRACNET) and Defense Connector Lines.* Newport News, VA.

Minnesota Department of Transportation, Office of Freight and Commercial Vehicle Operations (2005). *Minnesota Statewide Freight Plan.* Plan Development Consultants: Cambridge Systematic, Inc. and SRF Consulting Group, Inc.

MIT Center for Transportation and Logistics (n.d.) Development of a Statewide Freight System Resiliency Plan, Final Research Report. MIT: Cambridge, MA.

Montana Department of Transportation (2009). *2009 Montana State Rail Plan, Draft Report.* Prepared by Cambridge Systematics, Inc.

Montana Rail Link (n.d.) www.montanarail.com/general_info.htm.

Northwest Ports Clean Air Strategy Draft (2007) Port of Seattle, Port of Tacoma, Vancouver Port Authority. www.maritimeairforum.org/news/NW_Ports_Clean%C2%ADAirStrategy_Draft.pdf.

OmniTrax (n.d). www.omnitrax.com/rail_kfr.aspx.

Ortiz, D. S., Weatherford, B., Willis, H.H., Collins, M., Mandava, N., and Ordowich, C. (2007) Conference Proceedings of "Increasing the Capacity of Freight Transportation, U.S. and Canadian Perspectives" Rand: Santa Monica, CA.

Port Jobs (2006) *Employment in Logistics and International Trade.* http://www.portjobs.org/LIT.pdf.

Port of Longview. (2009, January 13). In *Wikipedia, The Free Encyclopedia*. Retrieved 19:26, December 9, 2009, from http://en.wikipedia.org/w/index.php?title=Port_of_Longview&oldid=263829430.

Portland/Vancouver I-5 Transportation and Trade Partnership (2002) *Final Strategic Plan: June 2002.* http://www.i-5partnership.com/updates/assets/strategic_plan.pdf.

Portland/Vancouver I-5 Transportation and Trade Partnership (2002). *Freight, Intercity Passenger and Commuter Rail*. PowerPoint presentation at the Portland-Vancouver I-5 Transportation and Trade Partnership meeting on May 21, 2002.

Portland/Vancouver I-5 Transportation and Trade Partnership (2003). *I-5 Rail Capacity Study.* Submitted by HDR.

Puget Sound Regional Council (2007). *BNSF Corridor Preservation Study*. Prepared by HDR: Bellevue: WA.

Regional Transportation Commission (2006). *Regional Transportation Commission, Final Report*. http://www.globaltelematics.com/pitf/psrtc-report.pdf.

Roberson, D. B. (1995) *Encyclopedia of Western Railroad History*, Caldwell, ID: Caxton Printers.

Schwantes, C. A. (1993). *Railroad Signatures across the Pacific Northwest*, by Carlos A., Seattle, WA: University of Washington Press.

Scott, R.D. III and Casavant, K.L. (1999). *The Eastern Washington Intermodal Transportation Study*. EWITS Research Summary Report Number 26.

Shipyard construction records, maritime industry statistics and other maritime stuff. http://www.shipbuildinghistory.com/world/statistics/shipsizes.htm.

Sigman, S (2008) *World Macroeconomic Outlook, Impact for the Washington Economy*. Presentation Prepared for Washington Public Ports Association by Global Trade and Transportation Advisory Services, IHS Global Insight.

Small, K.A., Noland, R., Chu, X., and Lewis, D. (1999). *Report 431, Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation.* Transportation Research Board, National Research Council. National Academy Press: Washington, D.C.

Sound Transit (2007). *Sound Transit 2, Benefit-Cost Analysis Methodology with Analysis Results*. Prepared by PB Consult in Association with Parsons Brinckerhoff.

South Carolina (2009). *South Carolina State Rail Plan 2008 Update*. Prepared by WilburSmith Associates.

South Carolina Public Railways (2008) *South Carolina Transportation Cost Competitive Analysis.* August 15, 2008 Columbia, SC.

State of New York, Department of Transportation (2009) *2009 New York State Rail Plan.*

State of North Carolina, Department of Transportation, Rail Division (2006) *North Carolina Waybill Analysis, Executive Summary.*

State of Pennsylvania (2003). *State Rail Plan (2003)* Prepared by R.L. Banks & Associates, Inc.

State of Washington. (1989). *Centennial accord between the federally recognized tribes in Washington state and the state of Washington*. Olympia, WA.

State of Washington. (1999). *Government-to-Government Implementation Guidelines for "New Millennium Agreement."* Available from http://www.goia.wa.gov/Government-to-Government/Data/guidelines.htm.

State of Washington. (2005). *2005 Governor's Executive Order 05-05, Archaeological and Cultural Resources.* http://www.dahp.wa.gov/pages/EnvironmentalReview/documents/EO05_05.pdf.

State of Washington. (2009) *Summary of Executive Order 09-05, Washington's Leadership on Climate.* http://www.ecy.wa.gov/climatechange/docs/2009EO_summary.pdf.

Surface Transportation Board. (2009) *Waybill Sample Data, 2007* [Data file]. http://www.stb.dot.gov/.

Szymanski, Jim, 2005, February 27. *Rail cargo business chugs along at port. The Olympian.*

Tennessee Department of Transportation (2003). *Rail Plan –Scope and Purpose*. http://www.tdot.state.tn.us/publictrans/RailPlan/.

Tolliver, D., Jessup, E.L. and Casavant, K.L. (2003) *New Techniques for Estimating Impacts of Rail Line Abandonment on Highways in Washington. SFTA Research Report #7.* http://www.sfta.wsu.edu/research/reports/pdf/Rpt_7_Pavement_Analysis_Paper.pdf.

Transportation Impact Fee Study, City of Midway Florida (2007). Florida Planning and Development Lab, Department of Urban and Regional Planning, Florida State University.

Transportation Research Board (2007) *Preserving Freight and Passenger Rail Corridors and Service, A Synthesis of Highway Practice, NCHRP Synthesis 374.*

Transportation Research Board (2007) *Rail Freight Solutions to Roadway Congestion—Final Report and Guidebook, NCHRP Report 586.*

Transportation Research Board of the National Academies (2009) *Public and Private Sector Interdependence in Freight Transportation Markets, NCFRP Report 1.*

Transportation Research Board Special Report 297, Funding Options for Freight Transportation Projects, November 2009, pg 25.

Tri-City and Olympian Railroad Company (n.d.). www.tcry.com.

U.S. Accountability Office (2006), *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C.

U.S. Bureau of Transportation Statistics, Research & Innovative Technology Administration (2009). Pocket Guide to Transportation 2009.

U.S. Congress (2009) *American Clean Energy and Security Act of 2009,* www.opencongress.org/bill/111-h2454/show.

U.S. Department of Transportation (2008) *Map of Congressional High Priority Corridors on the National Highway System,* http://www.fhwa.dot.gov/planning/nhs//hipricorridors/hipri-big.pdf.

U.S. Department of Transportation, Bureau of Transportation Statistics, (2009) http://www.bts.gov/.

U.S. Department of Transportation, Federal Highway Administration (2009) *Freight Intermodal Distribution Pilot Grant Program, Report to Congress, Project Information and Program Recommendations.*

U.S. Environmental Protection Agency (2008). Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder EPA420-R08-001a. http://www.epa.gov/OMS/marine.htm.

U.S. Railroad Retirement Board, Bureau of the Actuary (2009) *Total Employment by State and Last Railroad Employer, Calendar Year 2007.* www.rrb.gov.

U.S. Transportation Command, Railroads for National Defense (n.d.) Retrieved from www.tea.army.mil/DODProg/RND/default.htm.

University of Texas at Austin (n.d.) *Freight Planning Factors Impacting Texas Commodity Flows, Project No. 0-06297*.

Virginia Department of Rail and Public Transportation (2008) *Statewide Rail Plan, Commonwealth of Virginia.*

Washington Public Ports Association (2004) *Rail Capacity Study.*

Washington Public Ports Association (2009). *Commissioner Resource Guide*. www.washingtonports.org/downloads/commissionerresourceguide.pdf.

Washington Public Ports Association and Washington State Department of Transportation (2009). *2009 Marine Cargo Forecast Executive Summar.y* http://www.wsdot.wa.gov/Freight/MarinePubs.htm.

Washington Public Ports Association and Washington State Department of Transportation (2009). *2009 Marine Cargo Forecast Technical Report.* http://www.wsdot.wa.gov/Freight/MarinePubs.htm.

Washington State Department of Ecology (2009) Frequently Asked Questions, Executive Office. Publication Number: 08-01-024.

Washington State Department of Transportation (1997). *Review of the WSDOT Rail Freight Program*.

Washington State Department of Transportation (1998). *Washington State Freight Rail Plan 1998 Update.*

Washington State Department of Transportation, (2006). *2007-2026 Washington Transportation Plan,* http://www.wsdot.wa.gov/NR/rdonlyres/B1E8FB10-D415-4228-817D-9C4BE4569128/0/WTPLinks2.pdf.

Washington State Department of Transportation (2006) *Long-Range Plan for Amtrak Cascades.*

Washington State Department of Transportation (2006). *Northern Columbia Basin Railroad Project Feasibility Study.*

Washington State Department of Transportation, (2008). *Business Directions: WSDOT's 2009-2015 Strategic Plan.* http://www.wsdot.wa.gov/Accountability/PerformanceReporting/StrategicPlan.htm.

Washington State Department of Transportation (2008) Freight Rail Assistance, Call for projects – 2008-Application Packet.

Washington State Department of Transportation (2008). Reducing Greenhouse Gas Emissions and Increasing Transportation Choices for the Future. 2008 Climate Action Team.

Washington State Department of Transportation (2009). *Amtrak Cascades Mid-Range Plan*. http://www.wsdot.wa.gov/freight/publications/PassengerRailReports.htm.

Washington State Department of Transportation (2009). *Centennial Accord Plan.* www.wsdot.wa.gov/tribal/Centennial_Accord.htm.

Washington State Department of Transportation (2009). *Modal Plans*. www.wsdot.wa.gov/planning/ModalPlans.htm.

Washington State Department of Transportation (2009) Pacific Northwest Rail Corridor. Washington State Segment—Columbia River to the Canadian Border, Program Environmental Assessment. Prepared for USDOT FRA.

Washington State Department of Transportation (2009). *Secretary's Executive Order Number 1025.01, Tribal Consultation.* http://www.wsdot.wa.gov/NR/rdonlyres/E4BAB595-12A5-45BE-B783-B63CC611D8FA/0/ExecOrder1025_01.pdf.

Washington State Department of Transportation (2009). *Washington State Freight Rail Plan - 2009 Update.*

www.wsdot.wa.gov/Freight/Rail/WashingtonStateFreightRailPlan.htm.

Washington State Department of Transportation (n.d.) *Climate Change* www.wsdot.wa.gov/environment/climatechange.

Washington State Department of Transportation (n.d.) *Freight Partnerships*, http://www.wsdot.wa.gov/Freight/partnerships.htm.

Washington State Department of Transportation (n.d.) *Passenger Rail Reports and Studies.* www.wsdot.wa.gov/Freight/publications/PassengerRailReports.htm.

Washington State Department of Transportation (n.d.), *Planning* http://www.wsdot.wa.gov/planning/.

Washington State Department of Transportation (n.d.) *The Gray Notebook A Quarterly Performance Report.* http://www.wsdot.wa.gov/accountability/graynotebook/default.htm.

Washington State Department of Transportation (n.d.) *Washington State Multimodal Transportation Plan.*

Washington State Department of Transportation (n.d.) *WSDOT Accountability & Performance Information.* www.wsdot.wa.gov/Accountability/.

Washington State Department of Transportation and FMSIB (2008) Freight Mobility: Joint Report on Washington State Freight Highway and Rail Projects. http://www.wsdot.wa.gov/NR/rdonlyres/DC73F2DC-AC6C-4D79-8FF3-32A9C08654ED/0/1FreightMobilityJointReport.pdf.

Washington State Department of Transportation, Freight Systems Division (2008) *Washington Transportation Plan Update Freight Movement Administrative Manual.*

Washington State Department of Transportation, FSD (2008) Statewide Freight Information Center: A Funding Proposal.

Washington State Department of Transportation, Metropolitan Transportation Planning. www.wsdot.wa.gov/planning/metro.

Washington State Department of Transportation, Planning Office. http://www.wsdot.wa.gov/planning/metro.

Washington State Department of Transportation, Regional Transportation Planning. www.wsdot.wa.gov/planning/regional/.

Washington State Department of Transportation, State Rail and Marine Office (2009) *Washington State Freight Rail Plan, 2010-2030*. PowerPoint presentation on June 11, 2009, at Olympia, WA.

Washington State Department of Transportation. Moving Washington – A program to fight congestion. (n.d.) Retrieved December 3, 2009, from www.wsdot.wa.gov/movingwashington.

Washington State Department of Transportation. Moving Washington with Rail Transportation, folio. http://www.wsdot.wa.gov/NR/rdonlyres/D6CD9C7C-54A8-4864-91FB-6715636076D1/0/Moving_Washington_Folio.pdf.

Washington State Transportation Commission. (2006) *Statewide Rail Capacity and System Needs Study*. www.wstc.wa.gov/Rail/RailFinalReport.pdf.

Washington State Transportation Commission (2009) *Washington Transportation Plan 2011-2030 Update* http://wstc.wa.gov/AgendasMinutes/agendas/2009/Oct20/20091020_BP3%20-%20WashTranspPlan.pdf.

Waterborne Freight Transportation Bottom Line, Draft Report (2008). Prepared for AASHTO by Cambridge Systematics, Inc. with Global Insight, Inc. Cambridge, MA.

Weatherford, B.A., Willis H. H. and Ortiz, D.S. (2008). *The State of U.S. Railroads, A Review of Capacity and Performance Data.* Rand Supply Chain Policy Center: Santa Monica, CA.

West Coast Corridor Coalition (2008). West Coast Corridor Coalition Trade and Transportation Study. www.wsdot.wa.gov/nr/rdonlyres/5A019EA4-50EF-4286-96F9-05398B52608A/0/_DR1_WCCC_TradeandTransportationStudy_COMPLETEweb.pdf

West Coast Corridor Coalition Trade and Transportation Study, Executive Summary (2008), Cambridge Systematics. www.camsys.com.

Washington State Department of Transportation

Appendix 8-A: Project List

This project list meets the current federal requirement to identify the statewide rail system need; it is not a funding list. The federal government is currently developing program requirements for future project lists, which will likely be linked to funding. The Washington State Department of Transportation (WSDOT) will respond with a development process after the next federal development occurs. WSDOT will also address emerging federal funding opportunities after information becomes available.

The project list is shown in different exhibits to better show different aspects:

- Exhibit 8A-1: Project List by Area, Location, and Organization
- Exhibit 8A-2: Project List by Location, Area, and Organization
- Exhibit 8A-3: Project List by Organization, Location, and Area
- Exhibit 8A-4: Project List by Project Types
- Exhibit 8A-5: Project List by Public Benefits
- Exhibit 8A-6: Project List by Private Benefits
- Exhibit 8A-7: Project List by Cost Estimates
- Exhibit 8A-8: Project List by Committed Funds

The areas listed in the exhibits are:

- EW – Eastern Washington
- NC – Non-Capital
- PS – Puget Sound
- SW – Statewide
- WW – Western Washington

Exhibit 8A-1: Project List by Area, Location, and Organization

Area	Location	Organization	Project Name	Estimated Project Cost	Estimated Completion
EW	Airway Heights	Spokane County	Geiger Spur Rehabilitation	□880,000	5□1□2013
EW	Bingen	SW Washington RTPO	Bingen Point Rail Crossing	□15,000,000	
EW	Cheney	Eastern Washington Gateway Railroad	Cheney Siding	□580,000	2□1□2012
EW	Cheney	Union Pacific Railroad	Extend Cheney Siding	□0	
EW	Cheney	Union Pacific Railroad	Install Centralized Train Control	□0	
EW	Cheney	Union Pacific Railroad	Power Operate Manual Sidings	□0	
EW	Creston	Eastern Washington Gateway Railroad	Webb Siding Extension	□297,000	
EW	Creston	WSDOT	Lincoln Co. PDA□Creston - New Rail Spur	□346,000	
EW	Davenport	Eastern Washington Gateway Railroad	CW Branch Rail Renewal	□64,860,000	10□1□2018
EW	Ellensburg	BNSF Railway	Ellensburg-Lind Corridor Reactivation	□0	
EW	Ephrata	WSDOT	Port of Ephrata□Ephrata Spur Rehab Phase II	□363,000	1□1□2010
EW	Kennewick	BNSF Railway	Vista Siding Extension	□0	
EW	Moses Lake	Columbia Basin Railroad	Bridge upgrades for 286K	□0	1□1□2016
EW	Moses Lake	WSDOT	Port of Moses Lake□Northern Columbia Basin - Railroad Engineering and Environmental	□29,650,000	6□30□2013
EW	Newport	Port of Pend Oreille dba Pend Oreille Valley Railroad	Tacoma Creek Bridge	□125,000	7□31□2010
EW	Othello	Port of Royal Slope	Royal Rail Line Rehabilitation Project	□1,750,000	
EW	Pasco	BNSF Railway	Pasco Bridge Span Replacement	□0	
EW	Pasco	Port of Pasco	BPIC Intermodal Hub Rail Development, Phase 4 and 5	□3,100,000	
EW	Quincy	Port of Quincy	Port of Quincy Rail Loop	□0	
EW	Reardon	WSDOT	CW Line□Lincoln County - Grade Crossing Rehab	□371,000	10□31□2010
EW	Richland	Richland	SR240 □ SR224 Interchange □ Grade Crossing	□9,300,000	
EW	Spokane	Spokane	SR27-Pines Rd BNSF Grade Separation	□11,720,000	
EW	Spokane	Spokane County	Park Rd BNSF Grade Separation	□32,382,000	

Area	Location	Organization	Project Name	Estimated Project Cost	Estimated Completion
EW	Spokane	City of Spokane	Havana St. - BNSF Crossing	$26,700,000	10/1/2011
EW	Spokane	WSDOT	Palouse River and Coulee City Railroad - Rail Authority-Sponsored Rehab	$8,600,000	6/1/2011
EW	Spokane	WSDOT	Geiger - New Transloader	$4,400,000	1/1/2014
EW	Spokane, Whitman, Lincoln and Grant Counties	WSDOT	PCC Rail System Rehab	$100,000,000	
EW	Stampede Pass	BNSF Railway	Ellensburg-Lind Corridor Reactivation	$0	
EW	Stampede Pass	BNSF Railway	Stampede Pass Project	$0	
EW	Stevenson	City of Stevenson	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	$505,000	7/1/2011
EW	Sunnyside	Port of Sunnyside	Port of Sunnyside	$0	10/1/2014
EW	Walla Walla	City of Walla Walla	13th Avenue Improvements	$2,100,000	
EW	Walla Walla	PCC Railroad	Riparia tie and surface project	$880,000	8/1/2011
EW	Wallula	WSDOT	Port of Columbia Wallula to Dayton - Track Rehab	$11,000,000	10/31/2015
EW	Wenatchee	Wenatchee Valley Transportation Council	Wenatchee Hawley Street Grade Separation	$22,000,000	11/1/2011
EW	Wishram	BNSF Railway	East Leg of Wishram Wye	$0	
EW	Yakima	City of Yakima	Yakima Grade Separated Rail Crossing	$42,774,000	10/1/2011
NC	Statewide	WSDOT	Statewide - Washington Produce Rail Car Pool	$1,974,000	12/31/2014
NC	Statewide	WSDOT	Statewide - Rail Bank	$0	
NC	Statewide	WSDOT	Statewide - Freight Rail Assistance Program	$0	
PS	Auburn	Auburn	M St SE Grade Separation Project	$26,230,000	
PS	Everett	City of Everett	East Everett Ave Crossing	$16,520,000	
PS	Everett	Port of Everett	Port of Everett Existing Rail Upgrades	$170,000	12/1/2013
PS	Everett	Port of Everett	South Terminal Freight Rail Improvements	$770,000	6/1/2012
PS	Everett	Port of Everett	Lehigh Cement Rail Extension	$0	
PS	Fife	Fife	Fife 70th Ave Grade Separation	$17,500,000	
PS	Fife	Union Pacific Railroad	Fife Yard Improvements	$0	
PS	Fife	Union Pacific Railroad	Fife Yard Improvements	$0	

Area	Location	Organization	Project Name	Estimated Project Cost	Estimated Completion
PS	Kent	City of Kent	Kent S 212th St Grade Separations	83,170,000	10 1 2015
PS	Kent	City of Kent	Kent S 228th St Corridor Project - Phases II III Grade Separations	45,600,000	7 1 2012
PS	Kent	City of Kent	Kent Willis St Grade Separations	81,700,000	6 1 2016
PS	Kent	Union Pacific Railroad	Kent Siding Extension	0	
PS	Puyallup	City of Puyallup	Puyallup Shaw Road Extension	24,600,000	8 31 2010
PS	Puyallup	Pierce County	Puyallup N Canyon Rd Ext-BNSF Overcrossing	25,000,000	
PS	Renton	City of Renton	Renton Strander Blvd-SW 27th St Connection	12,320,000	
PS	Seattle	Ballard Terminal Railroad	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	2,000,000	
PS	Seattle	Ballard Terminal Railroad	Re-rail 4.5 miles of mainline track on the MSN	4,500,000	1 1 2010
PS	Seattle	BNSF Railway	BNSF Seattle PNW Shop Projects	0	
PS	Seattle	BNSF Railway	Ballard Bridge Moveable Span Replacement	0	
PS	Seattle	BNSF Railway	South Seattle Domestic Intermodal Facility Improvements	0	
PS	Seattle	BNSF Railway	Bullfrog Junction Improvements	0	
PS	Seattle	City of Seattle	South Lander Street Grade Separation	152,000,000	On hold
PS	Seattle	Port of Seattle	Duwamish Corridor	12,000,000	
PS	Seattle	Port of Seattle	East Marginal Way Grade Separation	49,000,000	6 1 2011
PS	Seattle	WSDOT	SR519 Intermodal Access Project (Phase 2)	0	
PS	Tacoma	Port of Tacoma	Lincoln Avenue Grade Separation	53,200,000	4 1 2011
PS	Tacoma	Tacoma Rail	Bridge Rehabilitation	0	
PS	Tacoma	WSDOT	Tacoma Rail Tacoma - Rail Servicing Facility Upgrade Expansion	1,570,000	6 30 2011
PS	Tacoma	WSDOT	Tacoma Rail Tacoma - New Refinery Spur	825,000	4 1 2011
SW	Statewide	BNSF Railway	BNSF Positive Train Control Improvements	0	
SW	Statewide	BNSF Railway	BNSF Siding Extensions and Double Track Improvements	0	
WW	Aberdeen	Grays Harbor COG	Rail Car Storage East of Aberdeen	4,300,000	
WW	Aberdeen	Grays Harbor COG	Relocate Rail Line South of Port Industrial Road and or Create Loop Rail	15,000,000	
WW	Aberdeen	Port of Grays Harbor	Port Grays Harbor Terminal 2 Grain Storage Facility	69,000,000	6 30 2011
WW	Aberdeen	Port of Grays Harbor	Port of Grays Harbor Terminal 4 Rail Upgrade	8,000,000	
WW	Battle Ground	WSDOT	Clark County-Owned Railroad Vancouver - Track Rehab	403,000	4 1 2011

Area	Location	Organization	Project Name	Estimated Project Cost	Estimated Completion
WW	Battle Ground	WSDOT	Clark County Chelatchie Prairie Railroad Battle Ground to Vancouver - Track Rehab	1,000,000	4 1 2011
WW	Battleground	Clark County	Chelatchie Prairie railroad rehabilitation - Phase 1	23,000,000	9 1 2011
WW	Bellingham	Port of Bellingham	Bellingham Shipping Terminal Rail Spur Replacement	2,000,000	
WW	Bellingham	WSDOT	Bellingham - Waterfront Restoration	44,602,000	7 2 2010
WW	Bremerton	US Navy	Repair Railroad Bridges	2,500,000	10 1 2013
WW	Burlington	City of Burlington	BNSF Skagit River Bridge Replacment for Flood Risk Reduction	59,800,000	9 1 2014
WW	Centralia	BNSF Railway	Centrailia Steam Plant Switch Upgrade	0	
WW	Centralia	WSDOT	Tacoma Rail and Puget Sound and Pacific Railroad Centralia - Reconfigure Rail	17,500,000	6 30 2021
WW	Centralia	WSDOT	Tacoma Rail and Puget Sound and Pacific Railroad Centralia - Reconfigure Rail Phase 1B	9,500,000	6 30 2021
WW	Chehalis	Port of Chehalis	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	2,650,000	1 1 2012
WW	Chehalis	Port of Chehalis	Rail spur reload for styrofoam recycler	1,075,000	9 1 2010
WW	Deming	Nooksack Indian Tribe	Expansion on First Street	250,000	
WW	Frederickson	WSDOT	Tacoma Rail Frederickson to Morton - Track Rehab	1,485,000	12 31 2011
WW	Kelso Longview	Cowlitz-Wahkiakum COG	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	117,000,000	
WW	Kelso Longview	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	0	3 1 2011
WW	Kelso Longview	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	0	12 15 2010
WW	Kelso Longview	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	47,000,000	4 1 2010
WW	Kelso Longview	Port of Kalama	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	28,000,000	9 1 2010
WW	Longview	BNSF Railway	Interstate Yard	0	
WW	Longview	BNSF Railway	Longview Junction Bypass	0	
WW	Longview	Cowlitz-Wahkiakum COG	SR 432 433 Grade Separation Rail Improvements	180,000,000	11 1 2011
WW	Longview	Port of Longview	Port of Longview Rail Loop Construction	900,000	7 1 2011
WW	Longview	Swanson Bark Wood Products	Swanson Bark Rail Spur	2,385,000	1 31 2010
WW	Mt Vernon	BNSF Railway	Mt Vernon Bridge Replacement	0	
WW	Olympia	Port of Olympia	Port of Olympia and East Olympia Freight Rail Enhancement Project	40,000,000	12 31 2014

Area	Location	Organization	Project Name	Estimated Project Cost	Estimated Completion
WW	Ridgefield	Port of Ridgefield	Ridgefield Rail Overpass	$12,500,000	6/30/2014
WW	Roy/Yelm	WSDOT	Tacoma Rail/Roy - New Connection to BNSF and Yelm-Owned Spur	$1,928,000	6/30/2011
WW	Roy/Yelm	WSDOT	Tacoma Rail/Tacoma to Morton and Yelm - Track Rehab	$755,000	4/1/2011
WW	Sumner	Union Pacific Railroad	Extend Sumner Siding	$0	
WW	Vancouver	Port of Vancouver	West Vancouver Freight Access Schedule 2-4	$137,500,000	5/1/2010
WW	Vancouver-Clark County	Portland Vancouver Junction Railroad	Clark County Railroad Rehab	$29,000,000	12/1/2011
WW	Washougal	Port of Camas-Washougal	Rail Enhancement Project	$1,000,000	
WW	Woodland	Cowlitz-Wahkiakum COG	Scott Avenue Railroad Overcrossing/Grade Separation	$62,000,000	2/1/2012

Exhibit 8A-2: Project List by Location, Area, and Organization

Location	Area	Organization	Project Name	Estimated Project Cost	Estimated Completion
Aberdeen	WW	Grays Harbor COG	Rail Car Storage East of Aberdeen	$4,300,000	
Aberdeen	WW	Grays Harbor COG	Relocate Rail Line South of Port Industrial Road and/or Create Loop Rail	$15,000,000	
Aberdeen	WW	Port of Grays Harbor	Port Grays Harbor Terminal 2 Grain Storage Facility	$69,000,000	6/30/2011
Aberdeen	WW	Port of Grays Harbor	Port of Grays Harbor Terminal 4 Rail Upgrade	$8,000,000	
Airway Heights	EW	Spokane County	Geiger Spur Rehabilitation	$880,000	5/1/2013
Auburn	PS	Auburn	M St SE Grade Separation Project	$26,230,000	
Battle Ground	WW	WSDOT	Clark County-Owned Railroad/Vancouver - Track Rehab	$403,000	4/1/2011
Battle Ground	WW	WSDOT	Clark County/Chelatchie Prairie Railroad/Battle Ground to Vancouver - Track Rehab	$1,000,000	4/1/2011
Battleground	WW	Clark County	Chelatchie Prairie railroad rehabilitation - Phase 1	$23,000,000	9/1/2011
Bellingham	WW	Port of Bellingham	Bellingham Shipping Terminal Rail Spur Replacement	$2,000,000	
Bellingham	WW	WSDOT	Bellingham - Waterfront Restoration	$44,602,000	7/2/2010
Bingen	EW	SW Washington RTPO	Bingen Point Rail Crossing	$15,000,000	
Bremerton	WW	US Navy	Repair Railroad Bridges	$2,500,000	10/1/2013
Burlington	WW	City of Burlington	BNSF Skagit River Bridge Replacment for Flood Risk Reduction	$59,800,000	9/1/2014
Centralia	WW	BNSF Railway	Centrailia Steam Plant Switch Upgrade	$0	
Centralia	WW	WSDOT	Tacoma Rail and Puget Sound and Pacific Railroad/Centralia - Reconfigure Rail	$17,500,000	6/30/2021
Centralia	WW	WSDOT	Tacoma Rail and Puget Sound and Pacific Railroad/Centralia - Reconfigure Rail Phase 1B	$9,500,000	6/30/2021
Chehalis	WW	Port of Chehalis	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	$2,650,000	1/1/2012
Chehalis	WW	Port of Chehalis	Rail spur / reload for styrofoam recycler	$1,075,000	9/1/2010
Cheney	EW	Eastern Washington Gateway Railroad	Cheney Siding	$580,000	2/1/2012
Cheney	EW	Union Pacific Railroad	Extend Cheney Siding	$0	
Cheney	EW	Union Pacific Railroad	Install Centralized Train Control	$0	
Cheney	EW	Union Pacific Railroad	Power Operate Manual Sidings	$0	

Location	Area	Organization	Project Name	Estimated Project Cost	Estimated Completion
Creston	EW	Eastern Washington Gateway Railroad	Webb Siding Extension	297,000	
Creston	EW	WSDOT	Lincoln Co. PDA Creston - New Rail Spur	346,000	
Davenport	EW	Eastern Washington Gateway Railroad	CW Branch Rail Renewal	64,860,000	10 1 2018
Deming	WW	Nooksack Indian Tribe	Expansion on First Street	250,000	
Ellensburg	EW	BNSF Railway	Ellensburg-Lind Corridor Reactivation	0	
Ephrata	EW	WSDOT	Port of Ephrata Ephrata Spur Rehab Phase II	363,000	1 1 2010
Everett	PS	City of Everett	East Everett Ave Crossing	16,520,000	
Everett	PS	Port of Everett	Port of Everett Existing Rail Upgrades	170,000	12 1 2013
Everett	PS	Port of Everett	South Terminal Freight Rail Improvements	770,000	6 1 2012
Everett	PS	Port of Everett	Lehigh Cement Rail Extension	0	
Fife	PS	Fife	Fife 70th Ave Grade Separation	17,500,000	
Fife	PS	Union Pacific Railroad	Fife Yard Improvements	0	
Fife	PS	Union Pacific Railroad	Fife Yard Improvements	0	
Frederickson	WW	WSDOT	Tacoma Rail Frederickson to Morton - Track Rehab	1,485,000	12 31 2011
Kelso Longview	WW	Cowlitz-Wahkiakum COG	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	117,000,000	
Kelso Longview	WW	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	0	3 1 2011
Kelso Longview	WW	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	0	12 15 2010
Kelso Longview	WW	Port of Kalama	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	47,000,000	4 1 2010
Kelso Longview	WW	Port of Kalama	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	28,000,000	9 1 2010
Kennewick	EW	BNSF Railway	Vista Siding Extension	0	
Kent	PS	City of Kent	Kent S 212th St Grade Separations	83,170,000	10 1 2015
Kent	PS	City of Kent	Kent S 228th St Corridor Project - Phases II III Grade Separations	45,600,000	7 1 2012
Kent	PS	City of Kent	Kent Willis St Grade Separations	81,700,000	6 1 2016
Kent	PS	Union Pacific Railroad	Kent Siding Extension	0	

Location	Area	Organization	Project Name	Estimated Project Cost	Estimated Completion
Longview	WW	BNSF Railway	Interstate Yard	0	
Longview	WW	BNSF Railway	Longview Junction Bypass	0	
Longview	WW	Cowlitz-Wahkiakum COG	SR 432/433 Grade Separation & Rail Improvements	180,000,000	11/1/2011
Longview	WW	Port of Longview	Port of Longview Rail Loop Construction	900,000	7/1/2011
Longview	WW	Swanson Bark & Wood Products	Swanson Bark Rail Spur	2,385,000	1/31/2010
Moses Lake	EW	Columbia Basin Railroad	Bridge upgrades for 286K	0	1/1/2016
Moses Lake	EW	WSDOT	Port of Moses Lake/Northern Columbia Basin - Railroad Engineering and Environmental	29,650,000	6/30/2013
Mt Vernon	WW	BNSF Railway	Mt Vernon Bridge Replacement	0	
Newport	EW	Port of Pend Oreille dba Pend Oreille Valley Railroad	Tacoma Creek Bridge	125,000	7/31/2010
Olympia	WW	Port of Olympia	Port of Olympia and East Olympia Freight Rail Enhancement Project	40,000,000	12/31/2014
Othello	EW	Port of Royal Slope	Royal Rail Line Rehabilitation Project	1,750,000	
Pasco	EW	BNSF Railway	Pasco Bridge Span Replacement	0	
Pasco	EW	Port of Pasco	BPIC Intermodal Hub Rail Development, Phase 4 and 5	3,100,000	
Puyallup	PS	City of Puyallup	Puyallup Shaw Road Extension	24,600,000	8/31/2010
Puyallup	SW	Pierce County	Puyallup N Canyon Rd Ext-BNSF Overcrossing	25,000,000	
Quincy	SW	Port of Quincy	Port of Quincy Rail Loop	0	
Reardon	EW	WSDOT	CW Line/Lincoln County - Grade Crossing Rehab	371,000	10/31/2010
Renton	PS	City of Renton	Renton Strander Blvd-SW 27th St Connection	12,320,000	
Richland	EW	Richland	SR240 & SR224 Interchange & Grade Crossing	9,300,000	
Ridgefield	WW	Port of Ridgefield	Ridgefield Rail Overpass	12,500,000	6/30/2014
Roy/Yelm	WW	WSDOT	Tacoma Rail/Roy - New Connection to BNSF and Yelm-Owned Spur	1,928,000	6/30/2011
Roy/Yelm	WW	WSDOT	Tacoma Rail/Tacoma to Morton and Yelm - Track Rehab	755,000	4/1/2011
Seattle	PS	Ballard Terminal Railroad	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	2,000,000	
Seattle	PS	Ballard Terminal Railroad	Re-rail 4.5 miles of mainline track on the MSN	4,500,000	1/1/2010
Seattle	PS	BNSF Railway	BNSF Seattle PNW Shop Projects	0	
Seattle	PS	BNSF Railway	Ballard Bridge Moveable Span Replacement	0	

Location	Area	Organization	Project Name	Estimated Project Cost	Estimated Completion
Seattle	PS	BNSF Railway	South Seattle Domestic Intermodal Facility Improvements	0	
Seattle	PS	BNSF Railway	Bullfrog Junction Improvements	0	
Seattle	PS	City of Seattle	South Lander Street Grade Separation	152,000,000	On hold
Seattle	PS	Port of Seattle	Duwamish Corridor	12,000,000	
Seattle	PS	Port of Seattle	East Marginal Way Grade Separation	49,000,000	6 1 2011
Seattle	PS	WSDOT	SR519 Intermodal Access Project (Phase 2)	0	
Spokane	EW	City of Spokane	Havana St. - BNSF Crossing	26,700,000	10 1 2011
Spokane	EW	Spokane	SR27-Pines Rd BNSF Grade Separation	11,720,000	
Spokane	EW	Spokane County	Park Rd BNSF Grade Separation	32,382,000	
Spokane	EW	WSDOT	Palouse River and Coulee City Railroad - Rail Authority-Sponsored Rehab	8,600,000	6 1 2011
Spokane	EW	WSDOT	Geiger - New Transloader	4,400,000	1 1 2014
Spokane, Whitman, Lincoln and Grant Counties	EW	WSDOT	PCC Rail System Rehab	100,000,000	
Stampede Pass	EW	BNSF Railway	Ellensburg-Lind Corridor Reactivation	0	
Stampede Pass	EW	BNSF Railway	Stampede Pass Project	0	
Statewide	NC	WSDOT	Statewide - Washington Produce Rail Car Pool	1,974,000	12 31 2014
Statewide	NC	WSDOT	Statewide - Freight Rail Investment Bank	0	
Statewide	NC	WSDOT	Statewide - Emergent Freight Rail Assistance Project	0	
Statewide	SW	BNSF Railway	BNSF Positive Train Control Improvements	0	
Statewide	SW	BNSF Railway	BNSF Siding Extensions and Double Track Improvements	0	
Stevenson	EW	City of Stevenson	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	505,000	7 1 2011
Sumner	WW	Union Pacific Railroad	Extend Sumner Siding	0	
Sunnyside	EW	Port of Sunnyside	Port of Sunnyside	0	10 1 2014
Tacoma	PS	Port of Tacoma	Lincoln Avenue Grade Separation	53,200,000	4 1 2011
Tacoma	PS	Tacoma Rail	Bridge Rehabilitation	0	
Tacoma	PS	WSDOT	Tacoma Rail Tacoma - Rail Servicing Facility Upgrade Expansion	1,570,000	6 30 2011

Location	Area	Organization	Project Name	Estimated Project Cost	Estimated Completion
Tacoma	PS	WSDOT	Tacoma Rail Tacoma - New Refinery Spur	825,000	4 1 2011
Vancouver	WW	Port of Vancouver	West Vancouver Freight Access Schedule 2-4	137,500,000	5 1 2010
Vancouver-Clark County	WW	Portland Vancouver Junction Railroad	Clark County Railroad Rehab	29,000,000	12 1 2011
Walla Walla	EW	City of Walla Walla	13th Avenue Improvements	2,100,000	
Walla Walla	EW	PCC Railroad	Riparia tie and surface project	880,000	8 1 2011
Wallula	EW	WSDOT	Port of Columbia Wallula to Dayton - Track Rehab	11,000,000	10 31 2015
Washougal	WW	Port of Camas-Washougal	Rail Enhancement Project	1,000,000	
Wenatchee	EW	Wenatchee Valley Transportation Council	Wenatchee Hawley Street Grade Separation	22,000,000	11 1 2011
Wishram	EW	BNSF Railway	East Leg of Wishram Wye	0	
Woodland	WW	Cowlitz-Wahkiakum COG	Scott Avenue Railroad Overcrossing Grade Separation	62,000,000	2 1 2012
Yakima	EW	City of Yakima	Yakima Grade Separated Rail Crossing	42,774,000	10 1 2011

Exhibit 8A-3: Project List by Organization, Location, and Area

Organization	Location	Area	Project Name	Estimated Project Cost	Estimated Completion
Auburn	Auburn	PS	M St SE Grade Separation Project	26,230,000	
Ballard Terminal Railroad	Seattle	PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	2,000,000	
Ballard Terminal Railroad	Seattle	PS	Re-rail 4.5 miles of mainline track on the MSN	4,500,000	1 1 2010
BNSF Railway	Centralia	WW	Centrailia Steam Plant Switch Upgrade	0	
BNSF Railway	Ellensburg	EW	Ellensburg-Lind Corridor Reactivation	0	
BNSF Railway	Kennewick	EW	Vista Siding Extension	0	
BNSF Railway	Longview	WW	Interstate Yard	0	
BNSF Railway	Longview	WW	Longview Junction Bypass	0	
BNSF Railway	Mt Vernon	WW	Mt Vernon Bridge Replacement	0	
BNSF Railway	Pasco	EW	Pasco Bridge Span Replacement	0	
BNSF Railway	Seattle	PS	BNSF Seattle PNW Shop Projects	0	
BNSF Railway	Seattle	PS	Ballard Bridge Moveable Span Replacement	0	
BNSF Railway	Seattle	PS	South Seattle Domestic Intermodal Facility Improvements	0	
BNSF Railway	Seattle	PS	Bullfrog Junction Improvements	0	
BNSF Railway	Stampede Pass	EW	Ellensburg-Lind Corridor Reactivation	0	
BNSF Railway	Stampede Pass	EW	Stampede Pass Project	0	
BNSF Railway	Statewide	SW	BNSF Positive Train Control Improvements	0	
BNSF Railway	Statewide	SW	BNSF Siding Extensions and Double Track Improvements	0	
BNSF Railway	Wishram	EW	East Leg of Wishram Wye	0	
City of Burlington	Burlington	WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction	59,800,000	9 1 2014
City of Everett	Everett	PS	East Everett Ave Crossing	16,520,000	
City of Kent	Kent	PS	Kent S 212th St Grade Separations	83,170,000	10 1 2015
City of Kent	Kent	PS	Kent S 228th St Corridor Project - Phases II III Grade Separations	45,600,000	7 1 2012
City of Kent	Kent	PS	Kent Willis St Grade Separations	81,700,000	6 1 2016
City of Puyallup	Puyallup	PS	Puyallup Shaw Road Extension	24,600,000	8 31 2010
City of Renton	Renton	PS	Renton Strander Blvd-SW 27th St Connection	12,320,000	
City of Seattle	Seattle	PS	South Lander Street Grade Separation	152,000,000	
City of Spokane	Spokane	EW	Havana St. - BNSF Crossing	26,700,000	10 1 2011

Organization	Location	Area	Project Name	Estimated Project Cost	Estimated Completion
City of Stevenson	Stevenson	EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	505,000	7 1 2011
City of Walla Walla	Walla Walla	EW	13th Avenue Improvements	2,100,000	
City of Yakima	Yakima	EW	Yakima Grade Separated Rail Crossing	42,774,000	10 1 2011
Clark County	Battleground	WW	Chelatchie Prairie railroad rehabilitation - Phase 1	23,000,000	9 1 2011
Columbia Basin Railroad	Moses Lake	EW	Bridge upgrades for 286K	0	1 1 2016
Cowlitz-Wahkiakum COG	Kelso Longview	WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	117,000,000	
Cowlitz-Wahkiakum COG	Longview	WW	SR 432 433 Grade Separation Rail Improvements	180,000,000	11 1 2011
Cowlitz-Wahkiakum COG	Woodland	WW	Scott Avenue Railroad Overcrossing Grade Separation	62,000,000	2 1 2012
Eastern Washington Gateway Railroad	Cheney	EW	Cheney Siding	580,000	2 1 2012
Eastern Washington Gateway Railroad	Creston	EW	Webb Siding Extension	297,000	
Eastern Washington Gateway Railroad	Davenport	EW	CW Branch Rail Renewal	64,860,000	10 1 2018
Fife	Fife	PS	Fife 70th Ave Grade Separation	17,500,000	
Grays Harbor COG	Aberdeen	WW	Rail Car Storage East of Aberdeen	4,300,000	
Grays Harbor COG	Aberdeen	WW	Relocate Rail Line South of Port Industrial Road and or Create Loop Rail	15,000,000	
Nooksack Indian Tribe	Deming	WW	Expansion on First Street	250,000	
PCC Railroad	Walla Walla	EW	Riparia tie and surface project	880,000	8 1 2011
Pierce County	Puyallup	PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing	25,000,000	
Port of Bellingham	Bellingham	WW	Bellingham Shipping Terminal Rail Spur Replacement	2,000,000	
Port of Camas-Washougal	Washougal	WW	Rail Enhancement Project	1,000,000	
Port of Chehalis	Chehalis	WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	2,650,000	1 1 2012
Port of Chehalis	Chehalis	WW	Rail spur reload for styrofoam recycler	1,075,000	9 1 2010
Port of Everett	Everett	PS	Port of Everett Existing Rail Upgrades	170,000	12 1 2013
Port of Everett	Everett	PS	South Terminal Freight Rail Improvements	770,000	6 1 2012
Port of Everett	Everett	PS	Lehigh Cement Rail Extension	0	

Organization	Location	Area	Project Name	Estimated Project Cost	Estimated Completion
Port of Grays Harbor	Aberdeen	WW	Port Grays Harbor Terminal 2 Grain Storage Facility	□69,000,000	6□30□2011
Port of Grays Harbor	Aberdeen	WW	Port of Grays Harbor Terminal 4 Rail Upgrade	□8,000,000	
Port of Kalama	Kelso□Longview	WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	□0	3□1□2011
Port of Kalama	Kelso□Longview	WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	□0	12□15□2010
Port of Kalama	Kelso□Longview	WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	□47,000,000	4□1□2010
Port of Kalama	Kelso□Longview	WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	□28,000,000	9□1□2010
Port of Longview	Longview	WW	Port of Longview Rail Loop Construction	□900,000	7□1□2011
Port of Olympia	Olympia	WW	Port of Olympia and East Olympia Freight Rail Enhancement Project	□40,000,000	12□31□2014
Port of Pasco	Pasco	EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5	□3,100,000	
Port of Pend Oreille dba Pend Oreille Valley Railroad	Newport	EW	Tacoma Creek Bridge	□125,000	7□31□2010
Port of Quincy	Quincy	EW	Port of Quincy Rail Loop	□0	
Port of Ridgefield	Ridgefield	WW	Ridgefield Rail Overpass	□12,500,000	6□30□2014
Port of Royal Slope	Othello	EW	Royal Rail Line Rehabilitation Project	□1,750,000	
Port of Seattle	Seattle	PS	Duwamish Corridor	□12,000,000	
Port of Seattle	Seattle	PS	East Marginal Way Grade Separation	□49,000,000	6□1□2011
Port of Sunnyside	Sunnyside	EW	Port of Sunnyside	□0	10□1□2014
Port of Tacoma	Tacoma	PS	Lincoln Avenue Grade Separation	□53,200,000	4□1□2011
Port of Vancouver	Vancouver	WW	West Vancouver Freight Access Schedule 2-4	□137,500,000	5□1□2010
Portland Vancouver Junction Railroad	Vancouver-Clark County	WW	Clark County Railroad Rehab	□29,000,000	12□1□2011
Richland	Richland	EW	SR240 □ SR224 Interchange □ Grade Crossing	□9,300,000	
Spokane	Spokane	EW	SR27-Pines Rd BNSF Grade Separation	□11,720,000	
Spokane County	Airway Heights	EW	Geiger Spur Rehabilitation	□880,000	5□1□2013
Spokane County	Spokane	EW	Park Rd BNSF Grade Separation	□32,382,000	
SW Washington RTPO	Bingen	EW	Bingen Point Rail Crossing	□15,000,000	
Swanson Bark □ Wood Products	Longview	WW	Swanson Bark Rail Spur	□2,385,000	1□31□2010
Tacoma Rail	Tacoma	PS	Bridge Rehabilitation	□0	

Organization	Location	Area	Project Name	Estimated Project Cost	Estimated Completion
Union Pacific Railroad	Cheney	EW	Extend Cheney Siding	0	
Union Pacific Railroad	Cheney	EW	Install Centralized Train Control	0	
Union Pacific Railroad	Cheney	EW	Power Operate Manual Sidings	0	
Union Pacific Railroad	Fife	PS	Fife Yard Improvements	0	
Union Pacific Railroad	Fife	PS	Fife Yard Improvements	0	
Union Pacific Railroad	Kent	PS	Kent Siding Extension	0	
Union Pacific Railroad	Sumner	WW	Extend Sumner Siding	0	
US Navy	Bremerton	WW	Repair Railroad Bridges	2,500,000	10 1 2013
Wenatchee Valley Transportation Council	Wenatchee	EW	Wenatchee Hawley Street Grade Separation	22,000,000	11 1 2011
WSDOT	Battle Ground	WW	Clark County-Owned Railroad Vancouver - Track Rehab	403,000	4 1 2011
WSDOT	Battle Ground	WW	Clark County Chelatchie Prairie Railroad Battle Ground to Vancouver - Track Rehab	1,000,000	4 1 2011
WSDOT	Bellingham	WW	Bellingham - Waterfront Restoration	44,602,000	7 2 2010
WSDOT	Centralia	WW	Tacoma Rail and Puget Sound and Pacific Railroad Centralia - Reconfigure Rail	17,500,000	6 302021
WSDOT	Centralia	WW	Tacoma Rail and Puget Sound and Pacific Railroad Centralia - Reconfigure Rail Phase 1B	9,500,000	6 302021
WSDOT	Creston	EW	Lincoln Co. PDA Creston - New Rail Spur	346,000	
WSDOT	Ephrata	EW	Port of Ephrata Ephrata Spur Rehab Phase II	363,000	1 1 2010
WSDOT	Frederickson	WW	Tacoma Rail Frederickson to Morton - Track Rehab	1,485,000	12 31 2011
WSDOT	Moses Lake	EW	Port of Moses Lake Northern Columbia Basin - Railroad Engineering and Environmental	29,650,000	6 30 2013
WSDOT	Reardon	EW	CW Line Lincoln County - Grade Crossing Rehab	371,000	10 31 2010
WSDOT	Roy Yelm	WW	Tacoma Rail Roy - New Connection to BNSF and Yelm-Owned Spur	1,928,000	6 30 2011
WSDOT	Roy Yelm	WW	Tacoma Rail Tacoma to Morton and Yelm - Track Rehab	755,000	4 1 2011
WSDOT	Seattle	PS	SR519 Intermodal Access Project (Phase 2)	0	
WSDOT	Spokane	EW	Palouse River and Coulee City Railroad - Rail Authority-Sponsored Rehab	8,600,000	6 1 2011
WSDOT	Spokane	EW	Geiger - New Transloader	4,400,000	1 1 2014

Organization	Location	Area	Project Name	Estimated Project Cost	Estimated Completion
WSDOT	Spokane, Whitman, Lincoln and Grant Counties	EW	PCC Rail System Rehab	□100,000,000	
WSDOT	Statewide	NC	Statewide - Washington Produce Rail Car Pool	□1,974,000	12□31□2014
WSDOT	Statewide	NC	Statewide - Rail Bank	□0	
WSDOT	Statewide	NC	Statewide - Freight Rail Assistance Program	□0	
WSDOT	Tacoma	PS	Tacoma Rail□Tacoma - Rail Servicing Facility Upgrade □ Expansion	□1,570,000	6□30□2011
WSDOT	Tacoma	PS	Tacoma Rail□Tacoma - New Refinery Spur	□825,000	4□1□2011
WSDOT	Wallula	EW	Port of Columbia□Wallula to Dayton - Track Rehab	□11,000,000	10□31□2015

Exhibit 8A-4: Project List by Project Type

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
EW	13th Avenue Improvements				X					X	
EW	Bingen Point Rail Crossing								X	X	
EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5			X			X	X			
EW	Bridge upgrades for 286K							X			X
EW	Cheney Siding		X				X	X	X		
EW	CW Branch Rail Renewal		X	X	X		X	X			
EW	CW Line Lincoln County - Grade Crossing Rehab				X				X		
EW	East Leg of Wishram Wye										
EW	Ellensburg-Lind Corridor Reactivation		X		X		X			X	X
EW	Ellensburg-Lind Corridor Reactivation										
EW	Extend Cheney Siding		X								
EW	Geiger - New Transloader							X			
EW	Geiger Spur Rehabilitation		X	X	X						
EW	Havana St. - BNSF Crossing									X	
EW	Install Centralized Train Control	X				X					
EW	Lincoln Co. PDA Creston - New Rail Spur										
EW	Palouse River and Coulee City RR - Rail Authority-Sponsored Rehab				X				X		
EW	Park Rd BNSF Grade Separation									X	
EW	Pasco Bridge Span Replacement										X
EW	PCC Rail System Rehab		X		X		X				X
EW	Port of Columbia Wallula to Dayton - Track Rehab				X						
EW	Port of Ephrata Ephrata Spur Rehab Phase II				X		X		X		

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
EW	Port of Moses Lake Northern Columbia Basin - RR Engineering and Environmental			X	X		X		X		
EW	Port of Quincy Rail Loop										
EW	Port of Sunnyside										
EW	Power Operate Manual Sidings		X			X					
EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901					X			X		
EW	Riparia tie and surface project				X						
EW	Royal Rail Line Rehabilitation Project			X	X		X				
EW	SR240 SR224 Interchange Grade Crossing									X	
EW	SR27-Pines Rd BNSF Grade Separation									X	
EW	Stampede Pass Project										
EW	Tacoma Creek Bridge		X		X				X		X
EW	Vista Siding Extension		X				X				
EW	Webb Siding Extension		X				X	X			
EW	Wenatchee Hawley Street Grade Separation								X		
EW	Yakima Grade Separated Rail Crossing						X			X	
NC	Statewide - Freight Rail Assistance Program										
NC	Statewide - Rail Bank										
NC	Statewide - Washington Produce Rail Car Pool										
PS	Ballard Bridge Moveable Span Replacement										
PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL				X		X				

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
PS	BNSF Seattle PNW Shop Projects										
PS	Bridge Rehabilitation			X	X				X		X
PS	Bullfrog Junction Improvements										
PS	Duwamish Corridor		X	X							
PS	East Everett Ave Crossing									X	
PS	East Marginal Way Grade Separation			X					X	X	
PS	Fife 70th Ave Grade Separation									X	
PS	Fife Yard Improvements		X	X							
PS	Fife Yard Improvements		X	X							
PS	Kent S 212th St Grade Separations									X	
PS	Kent S 228th St Corridor Project - Phases II □ III Grade Separations									X	
PS	Kent Siding Extension		X							X	
PS	Kent Willis St Grade Separations									X	
PS	Lehigh Cement Rail Extension			X							
PS	Lincoln Avenue Grade Separation						X		X	X	
PS	M St SE Grade Separation Project									X	
PS	Port of Everett Existing Rail Upgrades			X	X						
PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing									X	
PS	Puyallup Shaw Road Extension					X			X	X	
PS	Renton Strander Blvd-SW 27th St Connection						X	X			
PS	Re-rail 4.5 miles of mainline track on the MSN				X		X				
PS	South Lander Street Grade Separation			X			X			X	
PS	South Seattle Domestic Intermodal Facility Improvements										
PS	South Terminal Freight Rail Improvements			X			X	X			

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
PS	SR519 Intermodal Access Project (Phase 2)									X	
PS	Tacoma Rail□Tacoma - New Refinery Spur			X				X			
PS	Tacoma Rail□Tacoma - Rail Servicing Facility Upgrade □ Expansion				X		X	X			
SW	BNSF Positive Train Control Improvements	X	X			X					
SW	BNSF Siding Extensions and Double Track Improvements	X	X				X				
WW	Bellingham - Waterfront Restoration	X					X				X
WW	Bellingham Shipping Terminal Rail Spur Replacement			X	X						
WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction							X	X		X
WW	Centrailia Steam Plant Switch Upgrade	X	X		X			X	X		
WW	Chelatchie Prairie railroad rehabilitation - Phase 1				X				X		
WW	Clark County Railroad Rehab	X	X		X	X	X	X	X		
WW	Clark County□Chelatchie Prairie RR□Battle Ground to Vancouver - Track Rehab				X						
WW	Clark County-Owned RR□Vancouver - Track Rehab				X						
WW	Expansion on First Street								X		
WW	Extend Sumner Siding		X								
WW	Interstate Yard		X	X			X				
WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	X	X						X	X	
WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	X	X						X		

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	X	X						X		
WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	X	X	X					X	X	
WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	X	X						X		
WW	Longview Junction Bypass										
WW	Mt Vernon Bridge Replacement										
WW	Port Grays Harbor Terminal 2 Grain Storage Facility			X				X			
WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component			X			X	X			
WW	Port of Grays Harbor Terminal 4 Rail Upgrade			X	X		X	X			
WW	Port of Longview Rail Loop Construction		X	X				X			
WW	Port of Olympia and East Olympia Freight Rail Enhancement Project			X	X	X	X	X	X		
WW	Rail Car Storage East of Aberdeen						X		X		
WW	Rail Enhancement Project				X			X	X		
WW	Rail spur □ reload for styrofoam recycler			X			X	X			
WW	Relocate Rail Line South of Port Industrial Road and□or Create Loop Rail			X			X		X		
WW	Repair Railroad Bridges				X				X		X
WW	Ridgefield Rail Overpass	X							X	X	
WW	Scott Avenue Railroad Overcrossing□Grade Separation	X	X	X				X	X	X	

Area	Project Name	High-Speed Pass Rail	Mainline Capacity Expan	Port-to-Rail Access	Maint, Repair, and Rehab	Signal System	Line Upgrade or Expan	Facility Upgrade or Expan	Safety and Security	Grade Sep	Bridge Rehab or Replace
WW	SR 432/433 Grade Separation & Rail Improvements	X	X	X		X	X		X	X	
WW	Swanson Bark Rail Spur				X			X	X		
WW	Tacoma Rail and Puget Sound and Pacific RR/Centralia - Reconfigure Rail		X	X		X	X		X		
WW	Tacoma Rail and Puget Sound and Pacific RR/Centralia - Reconfigure Rail Phase 1B						X				
WW	Tacoma Rail/Frederickson to Morton - Track Rehab				X		X				X
WW	Tacoma Rail/Roy - New Connection to BNSF and Yelm-Owned Spur						X				
WW	Tacoma Rail/Tacoma to Morton and Yelm - Track Rehab				X						
WW	West Vancouver Freight Access Schedule 2-4		X	X			X				

Exhibit 8A-5: Project List by Public Benefits

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
EW	13th Avenue Improvements			X			X	X			X
EW	Bingen Point Rail Crossing		X	X		X	X		X	X	X
EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5			X			X				X
EW	Bridge upgrades for 286K						X				X
EW	Cheney Siding						X		X		X
EW	CW Branch Rail Renewal	X	X		X	X	X				X
EW	CW Line Lincoln County - Grade Crossing Rehab				X		X		X		
EW	East Leg of Wishram Wye										
EW	Ellensburg-Lind Corridor Reactivation						X				X
EW	Ellensburg-Lind Corridor Reactivation										
EW	Extend Cheney Siding						X				
EW	Geiger - New Transloader						X				X
EW	Geiger Spur Rehabilitation		X								X
EW	Havana St. - BNSF Crossing			X			X				X
EW	Install Centralized Train Control						X				
EW	Lincoln Co. PDA Creston - New Rail Spur						X				X
EW	Palouse River and Coulee City RR - Rail Authority-Sponsored Rehab				X		X		X		
EW	Pasco Bridge Span Replacement						X				
EW	PCC Rail System Rehab				X		X		X		X
EW	Port of Columbia Wallula to Dayton - Track Rehab						X				X
EW	Port of Ephrata Ephrata Spur Rehab Phase II						X		X		

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
EW	Port of Moses Lake Northern Columbia Basin - RR Engineering and Environmental	X	X	X		X	X		X	X	X
EW	Port of Quincy Rail Loop										
EW	Port of Sunnyside										
EW	Power Operate Manual Sidings						X				
EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901					X			X		X
EW	Riparia tie and surface project										
EW	Royal Rail Line Rehabilitation Project	X		X			X		X		X
EW	Stampede Pass Project										
EW	Tacoma Creek Bridge						X		X		
EW	Vista Siding Extension										X
EW	Webb Siding Extension						X				X
EW	Wenatchee Hawley Street Grade Separation		X	X		X	X	X	X	X	X
EW	Yakima Grade Separated Rail Crossing			X			X	X	X		X
EW	Park Rd BNSF Grade Separation										
EW	SR240 SR224 Interchange Grade Crossing										
EW	SR27-Pines Rd BNSF Grade Separation										
NC	Statewide - Freight Rail Assistance Program										
NC	Statewide - Rail Bank										
NC	Statewide - Washington Produce Rail Car Pool						X				

Area	Project Name	Improve Air Quality	Enviro Protect□ Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
PS	Ballard Bridge Moveable Span Replacement										
PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL										
PS	BNSF Seattle PNW Shop Projects										
PS	Bridge Rehabilitation										
PS	Bullfrog Junction Improvements										
PS	Duwamish Corridor			X			X				
PS	East Everett Ave Crossing										
PS	East Marginal Way Grade Separation	X		X			X				X
PS	Fife 70th Ave Grade Separation										
PS	Fife Yard Improvements						X				
PS	Fife Yard Improvements						X				
PS	Kent S 212th St Grade Separations			X							
PS	Kent S 228th St Corridor Project - Phases II □ III Grade Separations			X			X		X		X
PS	Kent Siding Extension						X				
PS	Kent Willis St Grade Separations			X							
PS	Lehigh Cement Rail Extension										
PS	Lincoln Avenue Grade Separation			X			X		X		X
PS	M St SE Grade Separation Project										
PS	Port of Everett Existing Rail Upgrades						X				
PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing										
PS	Puyallup Shaw Road Extension			X			X	X	X		X

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
PS	Renton Strander Blvd-SW 27th St Connection										
PS	Re-rail 4.5 miles of mainline track on the MSN										
PS	South Lander Street Grade Separation			X			X		X		X
PS	South Seattle Domestic Intermodal Facility Improvements										
PS	South Terminal Freight Rail Improvements	X					X				X
PS	SR519 Intermodal Access Project (Phase 2)										
PS	Tacoma Rail Tacoma - New Refinery Spur			X			X				
PS	Tacoma Rail Tacoma - Rail Servicing Facility Upgrade Expansion										
SW	BNSF Positive Train Control Improvements						X	X	X	X	
SW	BNSF Siding Extensions and Double Track Improvements			X		X	X	X	X	X	X
WW	Bellingham - Waterfront Restoration					X					
WW	Bellingham Shipping Terminal Rail Spur Replacement					X	X				X
WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction		X		X				X		X
WW	Centrailia Steam Plant Switch Upgrade	X		X							
WW	Chelatchie Prairie railroad rehabilitation - Phase 1	X	X	X	X	X	X		X		X

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
WW	Clark County Railroad Rehab	X	X	X	X	X	X	X	X	X	X
WW	Clark County Chelatchie Prairie RR Battle Ground to Vancouver - Track Rehab				X		X				
WW	Clark County-Owned RR Vancouver - Track Rehab				X		X				
WW	Expansion on First Street								X		
WW	Extend Sumner Siding						X				
WW	Interstate Yard						X				
WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation						X	X	X		X
WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing						X	X	X		X
WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks						X	X	X		X
WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation			X	X	X	X	X	X	X	X
WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road						X	X	X		X
WW	Longview Junction Bypass										
WW	Mt Vernon Bridge Replacement										
WW	Port Grays Harbor Terminal 2 Grain Storage Facility	X		X		X	X				X
WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	X	X	X		X	X				X

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
WW	Port of Grays Harbor Terminal 4 Rail Upgrade	X		X	X	X	X				X
WW	Port of Longview Rail Loop Construction	X		X		X	X				X
WW	Port of Olympia and East Olympia Freight Rail Enhancement Project	X	X	X		X	X		X		X
WW	Rail Car Storage East of Aberdeen			X					X		
WW	Rail Enhancement Project						X		X		X
WW	Rail spur reload for styrofoam recycler	X	X	X	X	X	X				X
WW	Relocate Rail Line South of Port Industrial Road and or Create Loop Rail		X	X					X		
WW	Repair Railroad Bridges								X	X	
WW	Ridgefield Rail Overpass	X	X	X		X	X	X	X	X	X
WW	Scott Avenue Railroad Overcrossing Grade Separation					X	X		X	X	X
WW	SR 432 433 Grade Separation Rail Improvements	X	X	X	X	X	X		X	X	X
WW	Swanson Bark Rail Spur	X	X	X		X	X		X	X	X
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail			X			X	X		X	
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail Phase 1B									X	
WW	Tacoma Rail Frederickson to Morton - Track Rehab										

Area	Project Name	Improve Air Quality	Enviro Protect Enhance	Reduce Congest	Reduce Public Expense	Improve Land Use	Enhance Mobility of Goods	Enhance Mobility of People	Enhance Public Safety	Enhance Public Security	Enhance Trade and Econ Develop
WW	Tacoma Rail Roy - New Connection to BNSF and Yelm-Owned Spur						X				
WW	Tacoma Rail Tacoma to Morton and Yelm - Track Rehab						X	X			
WW	West Vancouver Freight Access Schedule 2-4			X			X				X

Exhibit 8A-6: Project List by Private Benefits

Area	Project Name	Improved Economic Competitiveness	Improved Assets	Improved Service	Reduced Costs
EW	13th Avenue Improvements		X		X
EW	Bingen Point Rail Crossing	X		X	
EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5	X	X	X	
EW	Bridge upgrades for 286K	X	X	X	X
EW	Cheney Siding	X	X	X	X
EW	CW Branch Rail Renewal	X		X	X
EW	CW Line Lincoln County - Grade Crossing Rehab	X		X	X
EW	East Leg of Wishram Wye				
EW	Ellensburg-Lind Corridor Reactivation				
EW	Ellensburg-Lind Corridor Reactivation				
EW	Extend Cheney Siding	X		X	
EW	Geiger - New Transloader	X			X
EW	Geiger Spur Rehabilitation	X	X		X
EW	Havana St. - BNSF Crossing				
EW	Install Centralized Train Control	X		X	
EW	Lincoln Co. PDA Creston - New Rail Spur	X		X	X
EW	Palouse River and Coulee City RR - Rail Authority-Sponsored Rehab	X		X	X
EW	Park Rd BNSF Grade Separation				
EW	Pasco Bridge Span Replacement	X	X	X	X
EW	PCC Rail System Rehab	X		X	X
EW	Port of Columbia Wallula to Dayton - Track Rehab	X			X
EW	Port of Ephrata Ephrata Spur Rehab Phase II	X		X	X
EW	Port of Moses Lake Northern Columbia Basin - RR Engineering and Environmental				
EW	Port of Quincy Rail Loop				
EW	Port of Sunnyside				
EW	Power Operate Manual Sidings	X		X	
EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	X			
EW	Riparia tie and surface project				
EW	Royal Rail Line Rehabilitation Project	X	X	X	X
EW	SR240 SR224 Interchange Grade Crossing				

Area	Project Name	Improved Economic Competitiveness	Improved Assets	Improved Service	Reduced Costs
EW	SR27-Pines Rd BNSF Grade Separation				
EW	Stampede Pass Project				
EW	Tacoma Creek Bridge	X		X	
EW	Vista Siding Extension	X		X	
EW	Webb Siding Extension	X		X	X
EW	Wenatchee Hawley Street Grade Separation	X	X	X	
EW	Yakima Grade Separated Rail Crossing	X		X	
NC	Statewide - Freight Rail Assistance Program				
NC	Statewide - Rail Bank				
NC	Statewide - Washington Produce Rail Car Pool				
PS	Ballard Bridge Moveable Span Replacement				
PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	X	X	X	X
PS	BNSF Seattle PNW Shop Projects				
PS	Bridge Rehabilitation				
PS	Bullfrog Junction Improvements				
PS	Duwamish Corridor	X		X	
PS	East Everett Ave Crossing				
PS	East Marginal Way Grade Separation			X	
PS	Fife 70th Ave Grade Separation				
PS	Fife Yard Improvements	X		X	
PS	Fife Yard Improvements	X		X	
PS	Kent S 212th St Grade Separations				
PS	Kent S 228th St Corridor Project - Phases II □ III Grade Separations				
PS	Kent Siding Extension	X		X	
PS	Kent Willis St Grade Separations				
PS	Lehigh Cement Rail Extension				
PS	Lincoln Avenue Grade Separation				
PS	M St SE Grade Separation Project				
PS	Port of Everett Existing Rail Upgrades		X		
PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing				
PS	Puyallup Shaw Road Extension				

Area	Project Name	Improved Economic Competitiveness	Improved Assets	Improved Service	Reduced Costs
PS	Renton Strander Blvd-SW 27th St Connection				
PS	Re-rail 4.5 miles of mainline track on the MSN	X	X	X	X
PS	South Lander Street Grade Separation			X	
PS	South Seattle Domestic Intermodal Facility Improvements				
PS	South Terminal Freight Rail Improvements	X	X	X	
PS	SR519 Intermodal Access Project (Phase 2)				
PS	Tacoma Rail□Tacoma - New Refinery Spur	X		X	X
PS	Tacoma Rail□Tacoma - Rail Servicing Facility Upgrade □ Expansion		X	X	
SW	BNSF Positive Train Control Improvements				
SW	BNSF Siding Extensions and Double Track Improvements	X	X	X	X
WW	Bellingham - Waterfront Restoration				
WW	Bellingham Shipping Terminal Rail Spur Replacement	X		X	X
WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction		X	X	X
WW	Centrailia Steam Plant Switch Upgrade	X	X	X	X
WW	Chelatchie Prairie railroad rehabilitation - Phase 1	X	X	X	X
WW	Clark County Railroad Rehab	X	X	X	X
WW	Clark County□Chelatchie Prairie RR□Battle Ground to Vancouver - Track Rehab			X	
WW	Clark County-Owned RR□Vancouver - Track Rehab			X	
WW	Expansion on First Street				
WW	Extend Sumner Siding	X		X	
WW	Interstate Yard				
WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation				
WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing				
WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks				
WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	X	X	X	X
WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road				
WW	Longview Junction Bypass				
WW	Mt Vernon Bridge Replacement				
WW	Port Grays Harbor Terminal 2 Grain Storage Facility	X	X	X	X
WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	X	X	X	X

Area	Project Name	Improved Economic Competitiveness	Improved Assets	Improved Service	Reduced Costs
WW	Port of Grays Harbor Terminal 4 Rail Upgrade	X		X	X
WW	Port of Longview Rail Loop Construction	X	X	X	X
WW	Port of Olympia and East Olympia Freight Rail Enhancement Project	X	X	X	X
WW	Rail Car Storage East of Aberdeen				
WW	Rail Enhancement Project	X	X	X	
WW	Rail spur □ reload for styrofoam recycler	X	X	X	X
WW	Relocate Rail Line South of Port Industrial Road and□or Create Loop Rail			X	
WW	Repair Railroad Bridges		X		
WW	Ridgefield Rail Overpass				
WW	Scott Avenue Railroad Overcrossing□Grade Separation	X	X	X	
WW	SR 432□433 Grade Separation □ Rail Improvements	X	X	X	X
WW	Swanson Bark Rail Spur	X	X	X	X
WW	Tacoma Rail and Puget Sound and Pacific RR□Centralia - Reconfigure Rail				
WW	Tacoma Rail and Puget Sound and Pacific RR□Centralia - Reconfigure Rail Phase 1B				
WW	Tacoma Rail□Frederickson to Morton - Track Rehab				
WW	Tacoma Rail□Roy - New Connection to BNSF and Yelm-Owned Spur			X	
WW	Tacoma Rail□Tacoma to Morton and Yelm - Track Rehab	X		X	
WW	West Vancouver Freight Access Schedule 2-4			X	

Exhibit 8A-7: Project List by Cost Estimates

Area	Project Name	Estimated Total Project Cost	Preliminary Engineering	Right-of-Way	Construction	Unknown
EW	13th Avenue Improvements	$2,100,000	$1,500,000	$500,000	$13,000,000	$0
EW	Bingen Point Rail Crossing	$15,000,000	$0	$0	$0	$0
EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5	$3,100,000	$0	$0	$0	$4,300,000
EW	Bridge upgrades for 286K	$0	$1,800,000	$0	$58,000,000	$0
EW	Cheney Siding	$580,000	$1,000,000	$300,000	$27,700,000	$0
EW	CW Branch Rail Renewal	$64,860,000	$3,000,000	$0	$6,186,000	$0
EW	CW Line Lincoln County - Grade Crossing Rehab	$371,000	$0	$0	$371,000	$0
EW	East Leg of Wishram Wye	$0	$0	$0	$0	$0
EW	Ellensburg-Lind Corridor Reactivation	$0	$0	$0	$0	$0
EW	Ellensburg-Lind Corridor Reactivation	$0	$0	$0	$0	$0
EW	Extend Cheney Siding	$0	$0	$0	$0	$0
EW	Geiger - New Transloader	$4,400,000	$400,000	$0	$4,000,000	$0
EW	Geiger Spur Rehabilitation	$880,000	$2,500,000	$500,000	$9,500,000	$0
EW	Havana St. - BNSF Crossing	$26,700,000	$1,300,000	$8,400,000	$17,000,000	$0
EW	Install Centralized Train Control	$0	$0	$0	$0	$0
EW	Lincoln Co. PDA Creston - New Rail Spur	$346,000	$0	$0	$346,000	$0
EW	Palouse River and Coulee City RR - Rail Authority-Sponsored Rehab	$8,600,000	$0	$0	$0	$0
EW	Pasco Bridge Span Replacement	$0	$0	$0	$0	$0
EW	PCC Rail System Rehab	$100,000,000	$1,500,000	$0	$98,500,000	$0
EW	Port of Columbia Wallula to Dayton - Track Rehab	$11,000,000	$1,000,000	$0	$10,000,000	$0
EW	Port of Ephrata Ephrata Spur Rehab Phase II	$363,000	$0	$0	$363,000	$0
EW	Port of Moses Lake Northern Columbia Basin - RR Engineering and Environmental	$29,650,000	$1,509,000	$0	$28,141,000	$0
EW	Port of Quincy Rail Loop	$0	$0	$0	$0	$0
EW	Port of Sunnyside	$0	$0	$0	$2,100,000	$0
EW	Power Operate Manual Sidings	$0	$0	$0	$0	$0
EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	$505,000	$1,000,000	$0	$14,000,000	$0
EW	Riparia tie and surface project	$880,000	$35,000	$0	$845,000	$0
EW	Royal Rail Line Rehabilitation Project	$1,750,000	$10,000	$0	$468,000	$0

Area	Project Name	Estimated Total Project Cost	Preliminary Engineering	Right-of-Way	Construction	Unknown
EW	Stampede Pass Project	0	0	0	0	0
EW	Tacoma Creek Bridge	125,000	0	0	1,000,000	0
EW	Vista Siding Extension	0	0	0	0	0
EW	Webb Siding Extension	297,000	0	0	0	0
EW	Wenatchee Hawley Street Grade Separation	22,000,000	0	0	0	0
EW	Yakima Grade Separated Rail Crossing	42,774,000	5,264,000	4,400,000	33,110,000	0
EW	Park Rd BNSF Grade Separation	32,382,000	0	0	0	0
EW	SR240 □ SR224 Interchange □ Grade Crossing	9,300,000	0	0	0	0
EW	SR27-Pines Rd BNSF Grade Separation	11,720,000	0	0	0	0
NC	Statewide - Freight Rail Assistance Program	0	0	0	0	0
NC	Statewide - Rail Bank	0	0	0	0	0
NC	Statewide - Washington Produce Rail Car Pool	1,974,000	0	0	0	0
PS	Ballard Bridge Moveable Span Replacement	0	0	0	0	0
PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	2,000,000	0	0	0	0
PS	BNSF Seattle PNW Shop Projects	0	0	0	0	0
PS	Bridge Rehabilitation	0	0	0	0	0
PS	Bullfrog Junction Improvements	0	0	0	0	0
PS	Duwamish Corridor	12,000,000	0	0	0	6,200,000
PS	East Everett Ave Crossing	16,520,000	0	0	0	0
PS	East Marginal Way Grade Separation	49,000,000	7,500,000	12,000,000	29,400,000	0
PS	Fife 70th Ave Grade Separation	17,500,000	0	0	0	0
PS	Fife Yard Improvements	0	0	0	0	0
PS	Fife Yard Improvements	0	0	0	0	0
PS	Kent S 212th St Grade Separations	83,170,000	8,550,000	0	58,620,000	16,000,000
PS	Kent S 228th St Corridor Project - Phases II □ III Grade Separations	45,600,000	3,900,000	10,400,000	26,400,000	4,900,000
PS	Kent Siding Extension	0	0	0	0	0
PS	Kent Willis St Grade Separations	81,700,000	7,700,000	1,000,000	53,000,000	20,000,000
PS	Lehigh Cement Rail Extension	0	0	0	0	0
PS	Lincoln Avenue Grade Separation	53,200,000	5,800,000	5,100,000	42,300,000	0
PS	M St SE Grade Separation Project	26,230,000	0	0	0	0

Area	Project Name	Estimated Total Project Cost	Preliminary Engineering	Right-of-Way	Construction	Unknown
PS	Port of Everett Existing Rail Upgrades	$170,000	$0	$0	$0	$0
PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing	$25,000,000	$0	$0	$0	$0
PS	Puyallup Shaw Road Extension	$24,600,000	$3,200,000	$3,200,000	$18,200,000	$0
PS	Renton Strander Blvd-SW 27th St Connection	$12,320,000	$790,000	$0	$11,530,000	$0
PS	Re-rail 4.5 miles of mainline track on the MSN	$4,500,000	$90,000	$0	$800,000	$10,000
PS	South Lander Street Grade Separation	$152,000,000	$8,300,000	$32,800,000	$110,900,000	$0
PS	South Seattle Domestic Intermodal Facility Improvements	$0	$0	$0	$0	$0
PS	South Terminal Freight Rail Improvements	$770,000	$2,000,000	$3,500,000	$25,000,000	$0
PS	SR519 Intermodal Access Project (Phase 2)	$0	$0	$0	$0	$0
PS	Tacoma Rail Tacoma - New Refinery Spur	$825,000	$0	$0	$825,000	$0
PS	Tacoma Rail Tacoma - Rail Servicing Facility Upgrade Expansion	$1,570,000	$0	$0	$367,000	$0
SW	BNSF Positive Train Control Improvements	$0	$0	$0	$0	$0
SW	BNSF Siding Extensions and Double Track Improvements	$0	$0	$0	$0	$0
WW	Bellingham - Waterfront Restoration	$44,602,000	$4,507,000	$4,975,000	$35,121,000	$0
WW	Bellingham Shipping Terminal Rail Spur Replacement	$2,000,000	$0	$0	$0	$0
WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction	$59,800,000	$400,000	$0	$1,600,000	$0
WW	Centrailia Steam Plant Switch Upgrade	$0	$0	$0	$0	$0
WW	Chelatchie Prairie railroad rehabilitation - Phase 1	$23,000,000	$0	$0	$80,000	$0
WW	Clark County Railroad Rehab	$29,000,000	$0	$0	$4,500,000	$0
WW	Clark County Chelatchie Prairie RR Battle Ground to Vancouver - Track Rehab	$1,000,000	$0	$0	$1,000,000	$0
WW	Clark County-Owned RR Vancouver - Track Rehab	$404,000	$5,000	$0	$399,000	$0
WW	Expansion on First Street	$250,000	$0	$0	$0	$0
WW	Extend Sumner Siding	$0	$0	$0	$0	$0
WW	Interstate Yard	$0	$0	$0	$0	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	$0	$15,000	$0	$155,000	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	$0	$150,000	$150,000	$4,200,000	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	$47,000,000	$500,000	$0	$7,500,000	$0
WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	$117,000,000	$0	$0	$0	$0

Area	Project Name	Estimated Total Project Cost	Preliminary Engineering	Right-of-Way	Construction	Unknown
WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	$28,000,000	$35,000	$65,000	$800,000	$0
WW	Longview Junction Bypass	$0	$0	$0	$0	$0
WW	Mt Vernon Bridge Replacement	$0	$0	$0	$0	$0
WW	Port Grays Harbor Terminal 2 Grain Storage Facility	$69,000,000	$5,000,000	$0	$64,000,000	$0
WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	$2,650,000	$150,000	$0	$2,000,000	$0
WW	Port of Grays Harbor Terminal 4 Rail Upgrade	$8,000,000	$0	$0	$0	$0
WW	Port of Longview Rail Loop Construction	$900,000	$35,000	$65,000	$800,000	$0
WW	Port of Olympia and East Olympia Freight Rail Enhancement Project	$40,000,000	$0	$0	$0	$0
WW	Rail Car Storage East of Aberdeen	$4,300,000	$0	$0	$0	$0
WW	Rail Enhancement Project	$1,000,000	$2,700,000	$0	$0	$0
WW	Rail spur reload for styrofoam recycler	$1,075,000	$50,000	$25,000	$1,000,000	$0
WW	Relocate Rail Line South of Port Industrial Road and or Create Loop Rail	$15,000,000	$0	$0	$0	$0
WW	Repair Railroad Bridges	$2,500,000	$0	$0	$2,500,000	$0
WW	Ridgefield Rail Overpass	$12,500,000	$0	$0	$12,500,000	$0
WW	Scott Avenue Railroad Overcrossing Grade Separation	$62,000,000	$275,000	$0	$22,675,000	$0
WW	SR 432 433 Grade Separation Rail Improvements	$180,000,000	$25,000	$0	$555,000	$0
WW	Swanson Bark Rail Spur	$2,385,000	$150,000	$85,000	$2,150,000	$0
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail	$17,500,000	$700,000	$6,700,000	$13,000,000	$0
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail Phase 1B	$9,500,000	$0	$400,000	$9,000,000	$0
WW	Tacoma Rail Frederickson to Morton - Track Rehab	$1,485,000	$0	$0	$1,485,000	$0
WW	Tacoma Rail Roy - New Connection to BNSF and Yelm-Owned Spur	$1,928,000	$250,000	$200,000	$1,478,000	$0
WW	Tacoma Rail Tacoma to Morton and Yelm - Track Rehab	$755,000	$0	$0	$755,000	$0
WW	West Vancouver Freight Access Schedule 2-4	$137,500,000	$7,250,000	$20,250,000	$110,000,000	$0

Exhibit 8A-8: Project List by Committed Funds

Area	Project Name	Federal	State	Local	Tribal	Private	Other
EW	13th Avenue Improvements	$0	$0	$0	$0	$0	$0
EW	Bingen Point Rail Crossing	$0	$0	$0	$0	$0	$0
EW	BPIC Intermodal Hub Rail Development, Phase 4 and 5	$0	$0	$0	$0	$0	$0
EW	Bridge upgrades for 286K	$0	$0	$600,000	$0	$0	$0
EW	Cheney Siding	$0	$1,366,000	$129,000	$0	$0	$0
EW	CW Branch Rail Renewal	$0	$0	$0	$0	$0	$0
EW	CW Line Lincoln County - Grade Crossing Rehab	$0	$371,000	$0	$0	$0	$0
EW	East Leg of Wishram Wye	$0	$0	$0	$0	$0	$0
EW	Ellensburg-Lind Corridor Reactivation	$0	$0	$0	$0	$0	$0
EW	Ellensburg-Lind Corridor Reactivation	$0	$0	$0	$0	$0	$0
EW	Extend Cheney Siding	$0	$0	$0	$0	$0	$0
EW	Geiger - New Transloader	$0	$790,000	$0	$0	$0	$0
EW	Geiger Spur Rehabilitation	$0	$0	$3,500,000	$625,000	$0	$0
EW	Havana St. - BNSF Crossing	$0	$0	$0	$0	$0	$0
EW	Install Centralized Train Control	$0	$0	$0	$0	$0	$0
EW	Lincoln Co. PDA Creston - New Rail Spur	$0	$346,000	$0	$0	$0	$0
EW	Palouse River and Coulee City RR - Rail Authority-Sponsored Rehab	$0	$8,600,000	$0	$0	$0	$0
EW	Pasco Bridge Span Replacement	$0	$0	$0	$0	$0	$0
EW	PCC Rail System Rehab	$0	$0	$0	$0	$0	$0
EW	Port of Columbia Wallula to Dayton - Track Rehab	$0	$252,000	$0	$0	$0	$0
EW	Port of Ephrata Ephrata Spur Rehab Phase II	$0	$363,000	$0	$0	$0	$0
EW	Port of Moses Lake Northern Columbia Basin - RR Engineering and Environmental	$0	$4,000,000	$0	$0	$0	$0
EW	Port of Quincy Rail Loop	$0	$3,684,000	$0	$0	$0	$0
EW	Port of Sunnyside	$0	$0	$0	$0	$0	$0
EW	Power Operate Manual Sidings	$0	$0	$0	$0	$0	$0
EW	Quiet zone application at the Russell Avenue Crossing, Crossing No. 0901	$0	$0	$3,000,000	$0	$0	$0
EW	Riparia tie and surface project	$0	$0	$0	$0	$0	$0
EW	Royal Rail Line Rehabilitation Project	$0	$363,000	$116,000	$0	$0	$0
EW	Stampede Pass Project	$0	$0	$0	$0	$0	$0
EW	Tacoma Creek Bridge	$0	$0	$50,000	$0	$0	$0

Area	Project Name	Federal	State	Local	Tribal	Private	Other
EW	Vista Siding Extension	□0	□0	□0	□0	□0	□0
EW	Webb Siding Extension	□0	□0	□0	□0	□0	□0
EW	Wenatchee Hawley Street Grade Separation	□0	□0	□0	□0	□0	□0
EW	Yakima Grade Separated Rail Crossing	□0	□0	□0	□0	□0	□0
EW	Park Rd BNSF Grade Separation	□0	□7,000,000	□0	□0	□0	□0
EW	SR240 □ SR224 Interchange □ Grade Crossing	□0	□0	□0	□0	□0	□0
EW	SR27-Pines Rd BNSF Grade Separation	□0	□0	□0	□0	□0	□0
NC	Statewide - Freight Rail Assistance Program	□0	□0	□0	□0	□0	□0
NC	Statewide - Rail Bank	□0	□0	□0	□0	□0	□0
NC	Statewide - Washington Produce Rail Car Pool	□1,974,000	□0	□0	□0	□0	□0
PS	Ballard Bridge Moveable Span Replacement	□0	□0	□0	□0	□0	□0
PS	Ballard Terminal RehabRe-rail 2 miles of mainline track on the BDTL	□0	□0	□0	□0	□0	□0
PS	BNSF Seattle PNW Shop Projects	□0	□0	□0	□0	□0	□0
PS	Bridge Rehabilitation	□0	□0	□0	□0	□0	□0
PS	Bullfrog Junction Improvements	□0	□0	□0	□0	□0	□0
PS	Duwamish Corridor	□0	□0	□0	□0	□0	□0
PS	East Everett Ave Crossing	□0	□0	□0	□0	□0	□0
PS	East Marginal Way Grade Separation	□0	□0	□0	□0	□0	□0
PS	Fife 70th Ave Grade Separation	□0	□0	□0	□0	□0	□0
PS	Fife Yard Improvements	□0	□0	□0	□0	□0	□0
PS	Fife Yard Improvements	□0	□0	□0	□0	□0	□0
PS	Kent S 212th St Grade Separations	□0	□0	□0	□0	□0	□0
PS	Kent S 228th St Corridor Project - Phases II □ III Grade Separations	□0	□0	□0	□0	□0	□0
PS	Kent Siding Extension	□0	□0	□0	□0	□0	□0
PS	Kent Willis St Grade Separations	□0	□0	□0	□0	□0	□0
PS	Lehigh Cement Rail Extension	□0	□1,200,000	□0	□0	□0	□0
PS	Lincoln Avenue Grade Separation	□0	□0	□0	□0	□0	□0
PS	M St SE Grade Separation Project	□0	□0	□0	□0	□0	□0
PS	Port of Everett Existing Rail Upgrades	□0	□4,000,000	□0	□0	□0	□0
PS	Puyallup N Canyon Rd Ext-BNSF Overcrossing	□0	□0	□0	□0	□0	□0
PS	Puyallup Shaw Road Extension	□10,500,000	□6,000,000	□7,500,000	□0	□750,000	□0
PS	Renton Strander Blvd-SW 27th St Connection	□0	□0	□0	□0	□0	□0
PS	Re-rail 4.5 miles of mainline track on the MSN	□0	□400,000	□0	□0	□500,000	□0

Area	Project Name	Federal	State	Local	Tribal	Private	Other
PS	South Lander Street Grade Separation	$0	$0	$0	$0	$0	$0
PS	South Seattle Domestic Intermodal Facility Improvements	$0	$0	$0	$0	$0	$0
PS	South Terminal Freight Rail Improvements	$0	$4,000,000	$200,000	$0	$0	$0
PS	SR519 Intermodal Access Project (Phase 2)	$0	$0	$0	$0	$0	$0
PS	Tacoma Rail Tacoma - New Refinery Spur	$0	$420,000	$0	$0	$405,000	$0
PS	Tacoma Rail Tacoma - Rail Servicing Facility Upgrade Expansion	$0	$337,000	$160,000	$0	$0	$250,000
SW	BNSF Positive Train Control Improvements	$0	$0	$0	$0	$0	$0
SW	BNSF Siding Extensions and Double Track Improvements	$0	$0	$0	$0	$0	$0
WW	Bellingham - Waterfront Restoration	$0	$5,000,000	$0	$0	$0	$0
WW	Bellingham Shipping Terminal Rail Spur Replacement	$0	$0	$0	$0	$0	$0
WW	BNSF Skagit River Bridge Replacment for Flood Risk Reduction	$0	$0	$0	$0	$0	$0
WW	Centrailia Steam Plant Switch Upgrade	$0	$0	$0	$0	$0	$0
WW	Chelatchie Prairie railroad rehabilitation - Phase 1	$0	$0	$0	$0	$0	$0
WW	Clark County Railroad Rehab	$0	$0	$0	$0	$200,000	$0
WW	Clark County Chelatchie Prairie RR Battle Ground to Vancouver - Track Rehab	$0	$1,000,000	$0	$0	$0	$0
WW	Clark County-Owned RR Vancouver - Track Rehab	$0	$367,000	$37,000	$0	$0	$0
WW	Expansion on First Street	$0	$0	$0	$0	$0	$0
WW	Extend Sumner Siding	$0	$0	$0	$0	$0	$0
WW	Interstate Yard	$0	$0	$0	$0	$0	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Grade Separation	$0	$0	$0	$0	$0	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Ped Crossing	$0	$0	$0	$0	$0	$0
WW	Kelso to Martin's Bluff - 3rd Main Line and Storage Tracks	$0	$0	$3,000,000	$0	$5,000,000	$0
WW	Kelso to Martin's Bluff - 3rd Main Line, Kelso to Longview Junction, Yew Street pedestrian access, Hazel Street grade separation	$0	$0	$0	$0	$0	$0
WW	Kelso to Martin's Bluff - new siding terminating just north of Toteff Road	$0	$0	$0	$0	$0	$100,000
WW	Longview Junction Bypass	$0	$0	$0	$0	$0	$0
WW	Mt Vernon Bridge Replacement	$0	$0	$0	$0	$0	$0
WW	Port Grays Harbor Terminal 2 Grain Storage Facility	$0	$0	$3,000,000	$0	$60,000,000	$0
WW	Port of Chehalis Regional Rail Reload and Freight Processing Facility - Rail component	$0	$0	$0	$0	$0	$0
WW	Port of Grays Harbor Terminal 4 Rail Upgrade	$0	$0	$0	$0	$0	$0
WW	Port of Longview Rail Loop Construction	$0	$0	$100,000	$0	$0	$0

Area	Project Name	Federal	State	Local	Tribal	Private	Other
WW	Port of Olympia and East Olympia Freight Rail Enhancement Project	0	0	0	0	0	0
WW	Rail Car Storage East of Aberdeen	0	0	0	0	0	0
WW	Rail Enhancement Project	0	0	0	0	0	0
WW	Rail spur reload for styrofoam recycler	0	0	0	0	0	0
WW	Relocate Rail Line South of Port Industrial Road and or Create Loop Rail	0	0	0	0	0	0
WW	Repair Railroad Bridges	0	0	0	0	0	0
WW	Ridgefield Rail Overpass	12,500,000	0	0	0	0	0
WW	Scott Avenue Railroad Overcrossing Grade Separation	0	1,366,000	129,000	0	0	0
WW	SR 432 433 Grade Separation Rail Improvements	0	0	0	0	0	0
WW	Swanson Bark Rail Spur	0	0	0	0	1,385,000	0
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail	0	7,400,000	0	0	0	0
WW	Tacoma Rail and Puget Sound and Pacific RR Centralia - Reconfigure Rail Phase 1B	3,915,000	1,500,000	0	0	0	0
WW	Tacoma Rail Frederickson to Morton - Track Rehab	1,485,000	0	0	0	0	0
WW	Tacoma Rail Roy - New Connection to BNSF and Yelm-Owned Spur	0	525,000	0	0	0	0
WW	Tacoma Rail Tacoma to Morton and Yelm - Track Rehab	755,000	0	0	0	0	0
WW	West Vancouver Freight Access Schedule 2-4	0	0	0	0	0	0

Washington State Department of Transportation

Appendix 8-B: Freight Rail Investments – Historical and Planned – Managed by WSDOT

Year	Location	Project Type	Funding	Description
1980	Newport to Metaline Falls	Rail line rehabilitation	$4,086,000	Supported several businesses after Milwaukee Road abandoned the line. State funds added in 1989.
1981	Othello to Royal City	Rail line acquisition and rehabilitation	$1,196,000	Maintained rail access after Milwaukee Road abandonment.
1982	Hampton to Lynden	Rail line rehabilitation	$815,714	Maintained rail access from Sumas line to Lynden.
1983	Port Townsend	Transfer bridge rehabilitation	$773,000	Repair of bridge near Port Townsend; railroad scrapped in 1984.
1986	Ronald to Cle Elum	Rail line relocation	$70,000	Line relocation.
1992	Centralia	Line acquisition and rehabilitation	$281,794	Rail spur to industrial park.
1992	Rye to Battle Ground	Rail line rehabilitation	$674,900	Supports service on the Lewis and Clark Railway.
1993	Othello to Royal City	Rail line acquisition and rehabilitation	$400,000	Further improvements to abandoned Milwaukee Road segment. A 2009 WSDOT assessment determined repair requirements to reopen this line.
1993	Toppenish to White Swan	Rail line acquisition	$348,100	Maintains service to the Yakama Indian Reservation.
1993	Whitman County	Operating and MOW equipment acquisition	$410,000	Equipment leased by Port to the Blue Mountain Railroad. Two locomotives leased by Port to the Blue Mountain Railroad.
1993	Yelm to Tenino	Rail line acquisition	$200,000	Rail Banked; 14.6-mile line for corridor preservation.
1994	Mt. Vernon	Rail line rehabilitation	$177,000	Repairs to 1.8-mile rail line.
1994	Port of Walla Walla	Grain car acquisition - first Grain Train	$719,500	29 cars; Uses Stripper Well overcharge funds. Serves co-ops in Prescott, Thornton, St. John, and Endicott. State funds used for car painting.
1994	Terrace Heights to Moxee	Rail line rehabilitation	$779,700	Maintains service to large manufacturer in Moxee. Line reverted to BNSF ownership in 1997.

Year	Location	Project Type	Funding	Description
1994	Walla Walla to Dayton	Rail line rehabilitation	□1,227,649	Maintains access to food processor and wheat elevator in Prescott.
1995	Blue Slide Tunnel	Tunnel repairs	□297,500	Phase 1 of 2. Prevents tunnel collapse, loss of rail service to shippers on the line, and damage to SR 20.
1995	Tacoma to Centralia	Rail line acquisition	□3,250,000	Acquisition of former Milwaukee Road. Line runs between Tacoma and Centralia and Frederickson and Graham.
1996	LaCrosse to Winona	Track rehabilitation	□330,640	Maintains essential service to major agricultural areas.
1996	Rye to Vancouver Junction	Line rehabilitation	□824,500	Flood damaged portion of BNSF line donated to county upon receipt of state assistance.
1996	Whitman, Walla Walla, and Columbia Counties	Flood damage repairs	□1,300,000	Emergency bridge and washout repairs. One-time grant directly from the WA Legislature.
1997	Cheney to Coulee City	Rail line rehabilitation	□810,170	Keeps grain hauling lines open.
1998	Seattle	Line rehabilitation	□450,000	Supports several businesses located long the rail line.
1998	Tacoma to Graham	Rail line rehabilitation	□626,846	Supports several businesses located long the rail line.
1999	Columbia County	Rail line rehabilitation	□254,846	Maintains service to communities and the Port. Kept county□s biggest employer from closing.
1999	Hoquiam	Construct spur track □ loading facility	□433,102	This project helps make the terminal more attractive to businesses considering relocating to Grays Harbor.
1999	Naches	Rail line rehabilitation	□516,369	Repairs approximately 11 miles of rail line.
1999	Olympia	Additional track capacity	□269,052	Maintains, with potential to increase, business for the Port, Tumwater, and Lacey.
1999	Yelm	Rail line acquisition	□411,500	Preserves rail service. Local funds include non-LRFA federal development grant.
2000	Blue Slide Tunnel	Tunnel repairs	□505,000	Phase 2 of 2. Prevents tunnel collapse, loss of rail service to shippers on the line, and damage to SR 20.

Year	Location	Project Type	Funding	Description
2000	Hoquiam	Marine terminal spur track	485,500	This project helps make the terminal more attractive to businesses considering relocating to Grays Harbor.
2000	Hoquiam	Repair work to the Hoquiam River Bridge	606,250	Repairs 90-year-old mechanical swing bridge. Bridge now capable of accommodating 286,000 lb. freight cars.
2000	Port of Moses Lake	2nd Grain Train - Acquire 36 used grain hoppers	458,887	Purchased by revenues generated by first Grain Train. Generates additional business for endangered Palouse grain rail lines; protects grain hauling rate competition in eastern Washington. Expands total fleet of grain cars to 65 (47 WSDOT, 18 Port of Walla Walla).
2000	Toppenish	Equipment purchase (locomotive)	65,000	Supports purchase of one used locomotive to replace under-powered and unreliable unit.
2000	Toppenish to White Swan	Track rehabilitation	60,000	Maintains service to several businesses.
2000	Wenatchee	Washington Fruit Express (WFE) refrigerated express railcar design	51,000	Design of new express refrigerated railcar. The Washington Fruit Express will carry WA produce behind Amtrak's *Empire Builder*. Helps local farmers and Amtrak.
2000	Whitman, Lincoln, Spokane Grant Counties	Track rehabilitation	1,170,000	Supports service to Grant, Lincoln, Spokane, Whitman Counties.
2001	Aberdeen	Loop track construction	10,000,000	Allows AgPro to construct a trans-shipment facility at the marine terminal for bulk meal and grains.
2001	Frederickson to Morton	Rail line reopening	2,500,000	Reopens washed out freight line for the first time since 1979. Restores rail service to five communities. Local contribution includes non-LRFA federal funds.
2001	Oroville	286K track upgrades	485,500	Replaces 2.5 miles of 68 lb. rail with 110 lb. rail for 286K railcar operation.

Year	Location	Project Type	Funding	Description
2001	Richland	Emergency bridge repairs	□500,000	Emergency grant to cover insurance deductible. Port of Benton had no rail service until fire-damaged bridge was repaired.
2001	White Swan	TS□W rail line extension	□1,100,000	Extends Toppenish, Simcoe □ Western rail line to Yakama Nation Forest Products Sawmill.
2002	Puyallup	Construct siding, basic rehab of 4 miles of rail line, acquire used locomotive	□400,000	Supports several rail side businesses, who depend on rail for low shipping costs on heavy materials.
2003	Chehalis	Mainline spur construction	□350,000	Final element needed to open new plastic pipe plant.
2003	Port of Whitman County	3rd Grain Train - acquire 29 used grain hoppers	□290,000	Generate additional business for endangered Palouse grain rail lines; protect grain hauling rate competition in eastern Washington. Purchased with revenues from first and second Grain Trains.
2004	Airway Heights	Track repairs and upgrades		Helps maintain rail service at the Airway Heights Industrial Park.
2004	Eastern Washington	Rail line acquisition	□7,350,000	Public acquisition of the Palouse River and Coulee City RR (PCC); places RR under stable ownership and will be combined with a long-term rehabilitation plan.
2004	Frederickson to Eatonville (emergency repairs) and Tacoma to Morton	Track repairs and upgrades		Repairs damaged section of track and upgrades other sections to accommodate more traffic between Morton and Tacoma.
2004	Quincy	Spur and loop track construction		New intermodal facility at Quincy may help divert some I-90 and Puget Sound port truck traffic to rail.
2005	Lewis County	Lewis County rail spur	□800,000	Constructs approx. 4,000-ft. industrial rail spur from BNSF mainline to a new glass manufacturing plant outside Winlock.

Year	Location	Project Type	Funding	Description
2005	Pierce Lewis Counties	Tacoma Rail Mountain Division Morton line repairs-Phase 2	3,122,000	Phase 2 of Tacoma Rail Mountain Division s Morton line reconstruction to restore rail service after 1996 floods.
2005	Port of Quincy	Port of Quincy intermodal facility	1,717,000	New transload facility.
2007	Clark County	Lewis Clark RR rehab - Vancouver to Battle Ground	300,000	Clark County will upgrade ties and ballast at critical points between Vancouver and Battle Ground.
2007	Olympia	Port of Olympia on dock rail spur	375,000	Construct an on-dock track the length of the west moorage at Port of Olympia.
2007	Pasco	Port of Pasco - intermodal facility improvements	5,400,000	Improvement of the east end connection for locomotives to access the port facility and track upgrades.
2007	Pend Oreille County	Port of Pend Oreille - 286K upgrades	655,000	Two miles of rail replacement and general track rehab.
2007	Skagit County	Eastern Skagit Rail Study	50,000	Examine the possibility of re-establishing rail service on former rail alignment that is not a trail.
2007	Snohomish County	Snohomish Riverfront redevelopment (rail)	1,800,000	Relocates 1.5 miles of BNSF rail line and installs a new junction to support the redevelopment of the Snohomish River waterfront in Everett.
2007	Walla Walla	Port of Walla Walla Railex project	3,985,000	Constructs a loop track around Port of Walla Walla property including five turnouts, potable water system, fire flow system, property acquisition, and relocation of irrigation water line.
2008	Cosmopolis	Port of Grays Harbor - rail access improvements	741,000	Rail access improvements to increase capacity and allow rail traffic to move easily in the congested area.
2008	Grays Harbor	Port of Grays Harbor Hoquiam - rail access improvements	543,000	Improvements at the Port s industrial site as well as a spur connecting the site with the Puget Sound and Pacific Railroad.

Year	Location	Project Type	Funding	Description
2009	Airway Heights to Medical Lake	Geiger Spur Airway Heights - new rail connection	6,800,000	Connects Airway Heights industrial track to Palouse River Coulee City Railroad at Medical Lake to avoid shutdown due to Fairchild AFB security issues.
2009	Benton County	Port of Benton Freight Rail Investment Bank (FRIB) spur	250,000	Spur track for transload facility.
2009	Chehalis	Port of Chehalis - track rehabilitation	398,000	Matches FEMA funds for the rehabilitation of a rail line to Curtis, and provides rehabilitation funding for flood damage to the rail line to Curtis that is not FEMA-eligible.
2009	Eastern Washington	Palouse River and Coulee City RR - acquisition	15,337,000	Purchase 296-mile PCC.
2009	Ephrata	Port of Ephrata Ephrata - spur rehabilitation	127,000	Upgrades and rehabilitates the Port s rail spur.
2009	Everett	Port of Everett - FRIB spur	250,000	Rail spur for secondary access to BNSF mainline.
2009	Longview	Port of Longview Longview - rail loop	281,000	Constructs a rail loop that increases operational flexibility and eases congestion on the BNSF mainline.
2009	Morton	Morton Business Development Park	1,181,000	Constructs improvements in Morton in support of operations of Tacoma Rail.
2009	Tacoma	City of Tacoma - FRIB locomotive facility	250,000	Locomotive servicing facility.
2009	Tacoma	City of Tacoma - FRIB locomotive idling	26,386	Locomotive idling improvement.
2009	Tacoma	Tacoma Rail Tacoma - yard switching upgrades	500,000	Automate the Tacoma Rail main yard switching operation at the Port of Tacoma, for increasing the yard capacity and through port to efficiently manage projected Port growth.
2009	Tacoma to Morton	Tacoma Rail Tacoma to Morton - track rehab	2,460,000	Track upgrades to facilitate the future operations of Tacoma s planned excursion train.

Year	Location	Project Type	Funding	Description
2009	Tacoma to Morton	Tacoma Rail Tacoma to Morton - track rehab	1,230,000	Track upgrades to facilitate the future operations of Tacoma s planned excursion train.
2009	Toppenish to White Swan	White Swan Toppenish - Yakama Sawmill traffic upgrade	637,000	Upgrades existing Toppenish Simcoe Western line for increased traffic from Yakama Tribe sawmill.
2009	Vancouver	Lewis and Clark RR Vancouver - rail improvements	1,019,000	Rehabilitates a portion of the rail line; also environmental and permitting work needed to improve the interchange facilities between the Lewis and Clark Railroad and the BNSF Railway.
2010	Bellingham	Bellingham - waterfront restoration	448,000	Environmental work for relocating a -mile section of the track to allow the site to be redeveloped for recreational, residential, and commercial uses.
2010	Eastern Washington	Palouse River and Coulee City RR rehabilitation	3,600,000	Rehabs PCC track bridges in Grant, Lincoln, Spokane, Whitman Counties.
2010	Ephrata	Port of Ephrata - FRIB	116,000	Rehabilitation of rail spur.
2010	Moses Lake	Port of Moses Lake Northern Columbia Basin - RR environmental	2,000,000	Develop the required environmental documents to build a more direct line to the airport.
2010	Olympia	Intermodal infrastructure enhancement project, Port	2,663,000	Improves the intermodal infrastructure at the Port of Olympia s ocean terminal. Three separate earmarks were provided.
2010	Quincy	Port of Quincy short-haul intermodal pilot project	984,000	Purchase a rail container lift used to load unload containers on to rail flat stack cars, a forklift to position containers, essential computer and related communications equipment for business management, and upgrade the water and electrical service at the facility.
2010	Walla Walla to Dayton	Port of Columbia Wallula to Dayton - track rehab	522,000	Rehabilitate the 69-mile line from Wallula to Dayton and various spur tracks.

Year	Location	Project Type	Funding	Description
2011	Creston	Lincoln County PDA Creston - new rail spur	337,978	Builds a stub-end spur into the publicly-owned industrial park directly west of Creston, WA.
2011	Creston	New Creston livestock feed mill spur track	30,000	Lincoln County PDA will construct 850` long railroad siding to connect to a new livestock feed plant.
2011	Eastern Washington	Palouse River and Coulee City RR Rail Authority - lines rehab	8,600,000	Rail authority-sponsored rehab of state-owned rail lines in Grant, Lincoln, Spokane, Whitman Counties.
2011	Ephrata	Port of Ephrata Ephrata - additional spur rehab	362,746	Replace additional 3,000 ties needed for a new shipper locating to the Port.
2011	Quincy	Port of Quincy - FRIB	3,684,000	Construction of a rail loop.
2011	Frederickson to Morton	Tacoma Rail Frederickson to Morton - track rehab	1,485,000	Replaces lightweight rail with new rail to handle heavier 286,000-pound freight cars.
2011	Frederickson to Morton	Tacoma Rail Tacoma to Morton and Yelm - track rehab	755,000	Replaces rail and ties, which handles heavier 286,000-pound freight cars.
2011	Lincoln County	CW Line Lincoln County - grade crossing rehab	370,650	Rehabilitates and upgrades 11 deteriorated road rail grade crossings on the CW Line, part of the state-owned former PCC, between Reardon and Wilbur.
2011	Everett	Port of Everett - FRIB	1,200,000	New rail track to connect a cement loading facility to the mainline.
2011	Moses Lake	Port of Moses Lake Northern Columbia Basin track rehab and extension	2,000,000	Extend and rehabilitate track that serves the industrial park to the east and north of the Grant County International Airport.
2011	Pasco	Port of Pasco - intermodal facility improvements	882,000	Expands the facilities rail infrastructure, improving east end connection for locomotives access through the port facility.

Year	Location	Project Type	Funding	Description
2011	Roy	Tacoma Rail□Roy - new connection to BNSF and Yelm	□525,000	Construct approximately 4,300 ft. of new track, including a crossing of SR 507, to connect the Tacoma Rail line between Frederickson and Centralia with the BNSF branch line west of Roy.
2011	Tacoma	Tacoma Rail□Tacoma - improved locomotive facility	□366,813	This project reconfigures the tracks for better accessibility as well as increasing the servicing capabilities with the new facilities.
2011	Tacoma	Tacoma Rail□Tacoma - new refinery spur tracks	□420,000	Constructs a third rail spur, installs a new turnout and associated rail infrastructure to improve capacity and logistical capabilities.
2011	Vancouver	Chelatchie Prairie RR□Vancouver - track rehabilitation	□366,813	This project will continue rehabilitation of the track between Rye Junction and Battle Ground, resulting in a Class I status, increasing freight mobility and attracting shippers to the line. The project replaces ties, ballast, services rail joints, and replaces light weight rail.
2011	Vancouver	Clark County□Chelatchie Prairie RR - track rehab	□1,000,000	Rehabilitation of the 33-mile segment of track between Vancouver and Battle Ground along the Chelatchie Prairie Railroad owned by Clark County.
2012	Eastern and Western Washington	Statewide - Washington Produce Rail Car Pool	□1,974,000	There is a shortage of refrigerated railcars available to Washington growers during peak seasons. This project will create a fleet of refrigerated railcars. This will result in lower costs to growers and reduce the wear and tear on state roadways caused by heavy truckloads.

Note: This table is summarized in Chapter 5, Exhibit 5-3.

Source: WSDOT State Rail and Marine Office

Washington State Department of Transportation

Appendix 9: Glossary

AAR

Association of American Railroads

AASHTO

American Association of State Highway and Transportation Officials

ACSES

Advanced Civil Speed Enforcement System

Amtrak

*Am*erican *tra*vel by trac*k* – National Railroad Passenger Corporation

ARRA

American Recovery and Reinvestment Act of 2009

B.C.

British Columbia

B□C

Benefit/cost

BCRC

British Columbia Railway

BDTL

Ballard Terminal Railroad

BNSF

BNSF Railway Company

Break-bulk

Break-bulk cargo is cargo that is too big or too heavy to fit into a container or traditionally cannot be vacuumed out of a ship.

BTS

Bureau of Transportation Statistics

BYCX

Battle Ground Chelatchie Prairie Railroad

CBRW

Columbia Basin Railroad

CERB

Community Economic Revitalization Board

CFR

Code of Federal Regulations

CIA

Central Intelligence Agency

Class I Railroad

A railroad having annual carrier operating revenues of $250 million or more.

Class II Railroad

A railroad having annual carrier operating revenues of less than $250 million, but in excess of $20 million.

Class III Railroad

A railroad having annual carrier operating revenues of $20 million or less.

Classification

A sorting and grouping of rail cars according to destination point

CLC

Columbia and Cowlitz Railway

Clearing

Clearing refers to the crowning of a tunnel to allow taller rail cars to pass through or "clear" under the ceiling of the tunnel.

Climate Team

Governor's 2008 Climate Action Team – Transportation Implementation Working Group

CMAQ

Congestion Mitigation and Air Quality

CO

Carbon Monoxide

CO_2

Carbon Dioxide

CREATE Program

Chicago Region Environmental and Transportation Efficiency Program

CSCD

Cascade and Columbia River Railroad

CSX

CSX Corporation

CSXT

CSX Transportation

CTC

Centralized Traffic Control

CWA

Central Washington Railroad

DAHP

Department of Archaeology and Historical Preservation

Deep Draft Port

A deep draft port is a port that can receive a ship with a laden draught of 40 feed or less. A very deep draft port is one that can handle a laden draught of 45 feed or less, which are most container ships and other large ships including military ships.

Directional Running

Directional running is the concept that trains are routed only one direction on a corridor. Similar to a one-way street, operational capacity increases when all trains move in the same direction.

DOT

Department of Transportation

DPU

Distributed power units or mid-train helpers are engines that are placed in the middle of the train. These additional engines help "power" a long or heavy train by distributing the load of the train between the front engines and those in the middle of the train.

EA

Environmental Assessment

EDA

Economic Development Administration

EIS

Environmental Impact Statement

EPA

Environmental Protection Agency

ETMS

Electronic Train Management System

EWG

Eastern Washington Gateway Railroad

Export Elevators

Export elevators are elevators that can load export ships directly from the elevator.

FAF

Freight Analysis Framework

FAST Corridor

Freight Action Strategy Corridor

FGTS

Freight Goods and Transportation System

FHWA

Federal Highway Administration

FLH

Office of Federal Lands Highway

FLHP

Federal Lands Highway Program

FLMA

Federal land management agencies

FMSIB

Freight Mobility Strategic Investment Board

FRA

Federal Railroad Administration
Fish and Wildlife Service

FRIB

Federal Rail Investment Bank

GDP

Gross Domestic Product

GHG

Greenhouse Gases

Good Condition

Not needing repair or maintenance.

Good Rail Access

Trains can get in and out of a rail facility without delay to the facility, trains or other rail operations on a rail line.

Grade Separation

A grade separation is when an at-grade road that crosses a rail line is separated from the rail line by elevating the road as an overpass over the rail line or elevating the rail line on a trestle.

GRNW

Great Northwest Railroad

Gross Business Income

Gross Business Income is a measure of total revenue reported to the state.

HCT

High Capacity Transit

HIM

Hyundai Intermodal Terminal

HR

House Resolution

HSIPR

High-Speed Intercity Passenger Rail

I-5, I-90

Interstate 5, Interstate 90

ID

Idaho

Intermodal Facility

A site consisting of tracks, lifting equipment, paved and/or unpaved areas, and a control point for the transfer (receiving, loading, unloading, and dispatching) of trailers and containers between rail and highway and between rail and truck to/from marine modes of transportation.

Intermodal Ports

Intermodal ports are those ports that move containers from ship to rail, producing unit trains of containers to be transported to the inland destinations.

Intermodal Trains

Intermodal trains are significant consumers of rail capacity because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains at premium prices. They generate substantial revenue for the railroads.

Intermodal Transfer Facility

Intermodal transfer facilities are locations where freight is transferred between freight modes.

IRS

Internal Revenue Service

ISTEA

Intermodal Surface Transportation Efficiency Act

ITS

Intelligent Transportation System

KCS

Kansas City Southern

KFR

Kettle Falls International Railway

L□I

Labor and Industries

LRFA

Local Rail Freight Assistance Program

LRT

Light Rail Transit

LSC

Longview Switching Company

Mainline Switching

Mainline switching is the process of picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity.

Miles of Road

Miles of road is a linear measure of distance that does not consider the number of tracks. Track miles is greater than miles of road. For example, if a rail segment has two mainlines, then the number of track miles is double the number of miles of road.

MOU

Memorandum of Understanding

MP

Milepost

MPO

Metropolitan Planning Organization

MRL

Montana Rail Link

MSN

Meeker Southern Railroad

MVT

Mount Vernon Terminal Railroad

NEC

Northeast Corridor

NEPA

National Environmental Policy Act

NHS

National Highway System Designation Act of 1995

NIM

North Intermodal Yard

NOx

Nitrogen Oxide

Northern Tier

The Northern Tier refers to the rail corridor that runs through the eight neighboring states from the Pacific Northwest to Chicago. These states are Washington, Oregon, Idaho, Montana, North Dakota, Minnesota Wisconsin, and Illinois.

NS

Norfolk Southern Railway

NTSB

National Transportation Safety Board

ODOT

Oregon Department of Transportation

OLI

Operation Lifesaver, Inc.

Operated Miles

Operated miles include the miles leased by the owner railroad to another railroad that operates on the owned line. Operated miles are greater than owned miles.

OR

Oregon

O-WR□N

Oregon-Washington Railway and Navigation

PABs

Private Activity Boards

Panamax ships

Panamax ships are ships that are physically able to pass through the current width of the Panama Canal. These ships can not be any wider than 106 feet.

PCC

Palouse River and Coulee City Railroad

PIM

Pierce County Terminal Intermodal

PL 110-432

Public Law 110-432, approved as HR 2096

PLHD

Public Lands Highway Discretionary Program

PM_{10}

Particulate Matter

PMV

Port Metro Vancouver

PNRS

Projects of National and Regional Significance

PNW

Pacific Northwest

PNWRC

Pacific Northwest Rail Corridor

Poor Physical Condition

Track that is in disrepair from wear and tear or has deteriorated due to lack of maintenance.

POVA

Pend Oreille Valley Railroad

PPR

Port of Prince Rupert

Practical Capacity

Practical capacity is the highest activity level at which the line can operate with an acceptable degree of efficiency, taking into consideration unavoidable losses of productivity.

PRIIA

Passenger Rail Investment and Improvement Act of 2008

PRP

Program, Park Roads and Parkways Program

PSAP

Puget Sound and Pacific Railroad

PSE

Puget Sound Energy

PSRC

Puget Sound Regional Council

PTC

Positive Train Control

PTRR

Portland Terminal Railroad

PVJR

Portland Vancouver Junction Railroad

Rail Bank

Freight Rail Investment Bank Program

Railroad Switch

A mechanical installation enabling railway trains to be guided from one track to another at a railway junction.

RCW

Revised Code of Washington

Reporting Mark

A reporting mark is a two- to four-letter alphabetic code used to identify owners or lessees of rolling stock (e.g. rail car) and other equipment used on the North American railroad network. The marks are stenciled on each piece of equipment, along with a one- to-six-digit number, which together uniquely identifies every piece of equipment. For example, this allows rail cars to be tracked by the railroad they are traveling over, which shares the information with other railroads and customers.

RND

Railroads for National Defense

Ro-ro

Roll-on, roll-off

RoadRailers

A specialized truck trailer where the trailer can be attached to rail wheels to haul along the railroad without the use of a separate rail flat car.

RR

Railroad

RRIF

Railroad Rehabilitation and Investment Financing

RS

Royal Slope Railroad (also known as the Royal Slope Line)

RSAC

Railroad Safety Advisory Committee

RSIA

Rail Safety Improvement Act of 2008

RTPO

Regional Transportation Planning Organization

SAFETEA-LU

Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users

SDDC

Military Surface Deployment and Distribution Command

SEPA

State Environmental Policy Act

SEROps

Southeastern Rail Operations Study

Short-Line Railroad

These are railroads that are regional or local (Class II and Class III) that provide service in support the Class I railroads. Many times the short-line railroads transport the cargo a short distance from the Mainline hub to its final rail destination on a specific spur or to a intermodal facility.

SI

Spokane International Railroad

SIB

State Infrastructure Bank

SIG

Seattle International Gateway

SIM

South Intermodal Yard

SO_2

Sulfur Dioxide

SP

Southern Pacific Railroad

SP□S

Spokane, Portland, and Seattle Railway

state

Washington State

STB

Surface Transportation Board

STRACNET

Strategic Rail Corridor Network (Department of Defense)

STP

Surface Transportation Program

Switching Railroad

A railroad engaged primarily in switching services for other railroads.

TCRY

Tri-City and Olympia Railroad

TEA-21

1998 Transportation Equity Act for the 21st Century

Terminal Railroad

A railroad engaged primarily in terminal services for other railroads.

TERR

Tacoma Eastern Railroad

TEU

Twenty-Foot Equivalent Unit measuring 20 feet long by eight feet high by eight feet wide.

TIFIA

Transportation Infrastructure Finance and Innovation Act

TIGER

Transportation Investment Generating Economic Recovery

TMBL

Tacoma Municipal Belt Line

TPA

Transportation Partnership Account

Train Volumes

Train volumes (average trains per day) reflect business activities that are fluctuated sharply and sensitive to economic climate. Although the long-term trend is upward, the short-term trend could drop significantly.

Transloading

The process of transferring a shipment from one mode of transportation to another.

Transloading facility

A facility where the transferring of a shipment from one mode of transportation to another takes place.

TRMW

Tacoma Rail Mountain Division

TTCI

Transportation Technology Center, Inc.

TTPO

Tribal Transportation Planning Organization

TWC

Track Warrant Control

UP

Union Pacific Railroad

U.S.

United States

USACOE

U.S. Army Corps of Engineers

USC

United States Code

USDOC

U.S. Department of Commerce

USDOT

U.S. Department of Transportation

USFS

U.S. Forest Service

UTC

Utilities and Transportation Commission

VMT

Vehicle MilesTraveled

WA

Washington

WAC

Washington Administrative Code

WCCC

West Coast Corridor Coalition

WIR

Washington and Idaho Railway, Inc.

WPPA

Washington Public Ports Association

WRS

Western Rail Switching

WSDOT

Washington State Department of Transportation

WSTC

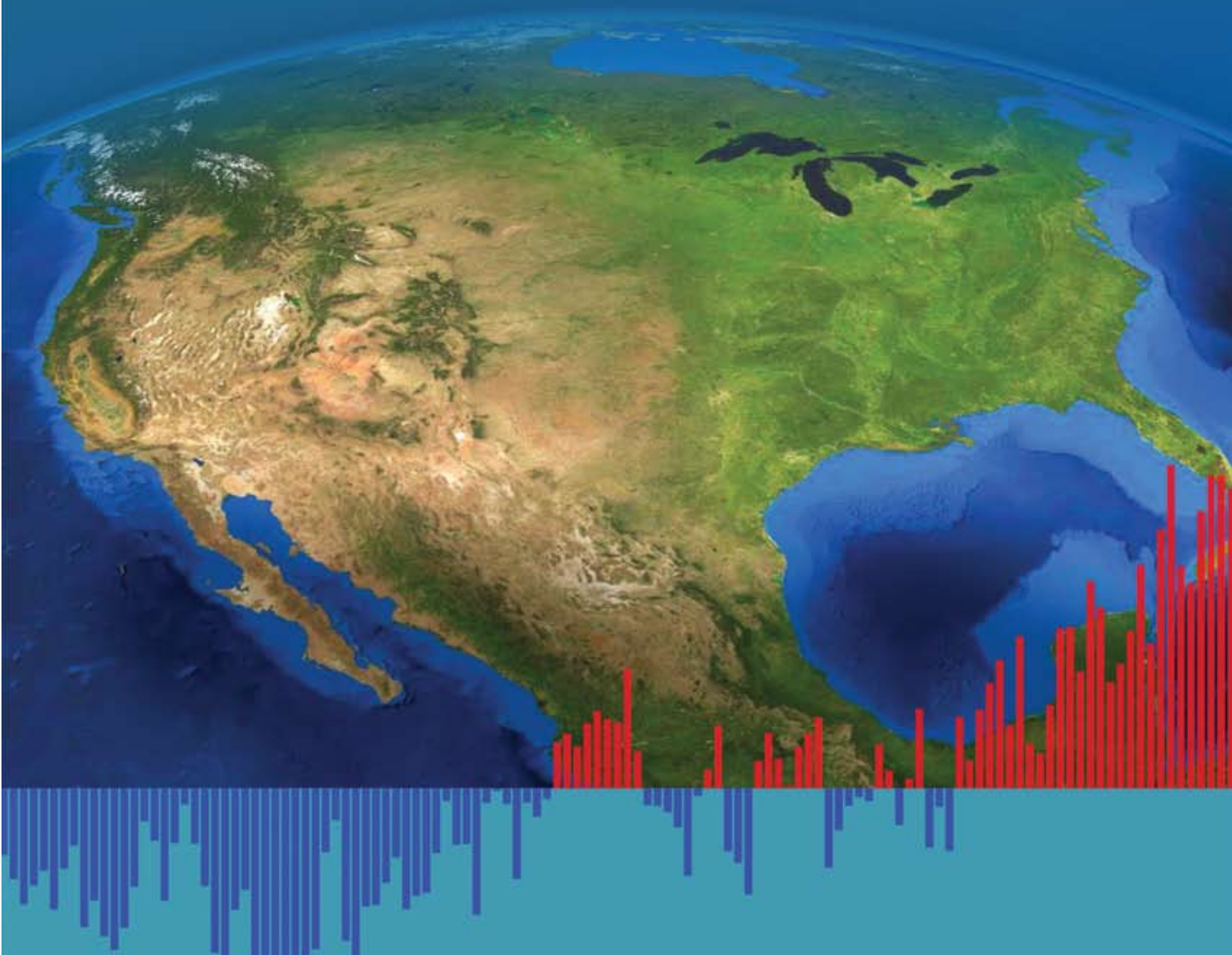
Washington State Transportation Commission

WTP

Washington Transportation Plan

Global Climate Change Impacts in the United States

U.S. GLOBAL CHANGE RESEARCH PROGRAM



Global Climate Change Impacts in the United States

A State of Knowledge Report from the
U.S. Global Change Research Program

The full report can be found online at www.globalchange.gov/usimpacts

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press
32 Avenue of the Americas, New York, NY 10013-2473, USA

www.cambridge.org
Information on this title: www.cambridge.org/9780521144070

This report was produced by an advisory committee chartered under the Federal Advisory Committee Act, for the Subcommittee on Global Change Research, and at the request of the U.S. Government. Therefore, the report is in the public domain. Some materials used in the report are copyrighted and permission was granted to the U.S. government for their publication in this report. For subsequent uses that include such copyrighted materials, permission for reproduction must be sought from the copyright holder. In all cases, credit must be given for copyrighted materials.

First published 2009

Printed in the United States of America

A catalog record for this publication is available from the British Library.

ISBN 978-0-521-14407-0 paperback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party Internet Web sites referred to in this publication and does not guarantee that any content on such Web sites is, or will remain, accurate or appropriate. Information regarding prices, travel timetables, and other factual information given in this work are correct at the time of first printing, but Cambridge University Press does not guarantee the accuracy of such information thereafter.

Recommended Citation:

Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

The bars at the bottom of the front cover show the global annual average temperature from 1900-2008, see page 17.

Federal Advisory Committee Authors

Co-Chairs and Editors-in-Chief

Thomas R. Karl,
NOAA National Climatic Data Center

Jerry M. Melillo,
Marine Biological Laboratory

Thomas C. Peterson,
NOAA National Climatic Data Center

Author Team

David M. Anderson,
NOAA World Data Center for Paleoclimatology

Donald F. Boesch,
University of Maryland Center for Environmental Science

Virginia R. Burkett,
U.S. Geological Survey

Lynne M. Carter,
Adaptation Network, Louisiana State University

Stewart J. Cohen,
Environment Canada and University of British Columbia

Nancy B. Grimm,
Arizona State University

Jerry L. Hatfield,
U.S. Department of Agriculture

Katharine Hayhoe,
Texas Tech University

Anthony C. Janetos,
Pacific Northwest National Laboratory

Jack A. Kaye,
National Aeronautics and Space Administration

Jay H. Lawrimore,
NOAA National Climatic Data Center

James J. McCarthy,
Harvard University

A. David McGuire,
U.S. Geological Survey/University of Alaska Fairbanks

Edward L. Miles,
University of Washington

Evan Mills,
Lawrence Berkeley National Laboratory

Jonathan T. Overpeck,
University of Arizona

Jonathan A. Patz,
University of Wisconsin at Madison

Roger S. Pulwarty,
NOAA Climate Program Office and Earth System Research Laboratory

Benjamin D. Santer,
Lawrence Livermore National Laboratory

Michael J. Savonis,
U.S. Department of Transportation

H. Gerry Schwartz, Jr.,
Consultant/Transportation

Eileen L. Shea,
NOAA National Climatic Data Center/ Integrated Data and Environmental Applications Center

John M.R. Stone,
Carleton University

Bradley H. Udall,
University of Colorado/NOAA Earth System Research Laboratory

John E. Walsh,
University of Alaska Fairbanks

Michael F. Wehner,
Lawrence Berkeley National Laboratory

Thomas J. Wilbanks,
Oak Ridge National Laboratory

Donald J. Wuebbles,
University of Illinois

Senior Science Writer and Lead Graphic Designer

Senior Science Writer

Susan J. Hassol,
Climate Communication, LLC

Lead Graphic Designer

Sara W. Veasey,
NOAA National Climatic Data Center

Key Support Personnel

Jessica Blunden, Editorial Assistant, STG, Inc.

Marta Darby, Copy Editor, STG, Inc.

David Dokken, CCSP Technical Advisor, USGCRP

Byron Gleason, Data Analysis/Visualization, NOAA National Climatic Data Center

Glenn M. Hyatt, Graphics Support, NOAA National Climatic Data Center

Clare Keating, Editorial Support, Texas Tech University

Staci Lewis, Technical Advisor, NOAA

Jolene McGill, Logistical Support, NOAA National Climatic Data Center

Deborah J. Misch, Graphics Support, STG, Inc.

William Murray, Technical Support, STG, Inc.

Susan Osborne, Copy Editor, STG, Inc.

Tim Owen, Logistical Support, NOAA National Climatic Data Center

Ray Payne, Printing Support NOAA Nationa Climatic Data Center

Deborah Riddle, Graphics Support, NOAA National Climatic Data Center

Susanne Skok, Copy Editor, STG, Inc.

Mara Sprain, Editorial Support, STG, Inc.

Michael Squires, Cartographic Support, NOAA National Climatic Data Center

Jeff VanDorn, Technical and Graphics Support, ATMOS Research

David Wuertz, Data Analysis/Visualization, NOAA National Climatic Data Center

Christian Zamarra, Graphics Support, STG, Inc.

Federal Executive Team

Acting Director, U.S. Global Change Research Program: ..... Jack A. Kaye

Director, U.S. Global Change Research Program Office: ..... Peter A. Schultz

Lead Agency Principal Representative to CCSP (through January 2009),
National Oceanic and Atmospheric Administration: ..... Mary M. Glackin

Lead Agency Principal Representative to CCSP,
Product Lead, National Oceanic and Atmospheric Administration: ..... Thomas R. Karl

Lead Agency Principal Representative to CCSP,
Group Chair Synthesis and Assessment Products, Environmental Protection Agency: ..... Michael W. Slimak

Synthesis and Assessment Product Coordinator,
U.S. Global Change Research Program Office: ..... Fabien J.G. Laurier

Communications Advisor/Coordinator/Editor,
U.S. Global Change Research Program Office: ..... Anne M. Waple

Special Advisor, National Oceanic and Atmospheric Administration: ..... Chad A. McNutt

Federal Advisory Committee Designated Federal Official,
National Oceanic and Atmospheric Administration: ..... Christopher D. Miller

Reviewers

Blue Ribbon Reviewers

Robert W. Corell,
Global Change Program, H. John Heinz III Center for Science, Economics and the Environment

Robert A. Duce,
Department of Atmospheric Sciences, Texas A&M University

Kristie L. Ebi,
Independent consultant, ESS, LLC
Alexandria, VA

Christopher B. Field,
Carnegie Institution

William H. Hooke,
Atmospheric Policy Program, American Meteorological Society

Michael C. MacCracken,
Climate Institute

Linda O. Mearns,
Environmental and Societal Impacts Group, National Center for Atmospheric Research

Gerald A. Meehl,
Climate and Global Dynamics Division, National Center for Atmospheric Research

John Reilly,
Sloan School of Management, Massachusetts Institute of Technology

Susan Solomon,
NOAA, Earth System Research Laboratory

Steven C. Wofsy,
Harvard University

Communication Reviewers

Robert Henson,
University Corporation for Atmospheric Research

Jack W. Williams,
American Meteorological Society

This report on Global Climate Change Impacts in the United States was prepared in accordance with Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) and the information quality act guidelines issued by the Department of Commerce and NOAA pursuant to Section 515 <http://www.noaanews.noaa.gov/stories/iq.htm>.

June 2009

Members of Congress:

On behalf of the National Science and Technology Council, the U.S. Global Change Research Program is pleased to transmit to the President and the Congress this state of knowledge report: "*Global Climate Change Impacts in the United States*." This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future.

As our nation strives to develop effective policies to respond to climate change, it is critical to have the latest and best scientific information to inform decision making. More than a year in the making, this report provides that information. It is the first report in almost a decade to provide an extensive evaluation of climate change impacts on the United States at the regional level.

An expert team of scientists operating under the authority of the Federal Advisory Committee Act, assisted by communication specialists, wrote the document. The report was reviewed and revised based on comments from experts and the public in accordance with the Information Quality Act guidelines issued by the Department of Commerce and the National Oceanic and Atmospheric Administration.

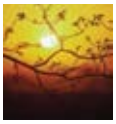
We highly commend the authors and support personnel of both this report and the underlying Synthesis and Assessment Products for the outstanding quality of their work in providing sound and thorough science-based information for policy formulation and climate change research priority setting. We intend to use the essential information contained in this report as we make policies and decisions about the future, and we recommend others do the same.

Sincerely,

Dr. John Holdren
Director,
Office of Science and Technology Policy

Dr. Jane Lubchenco
Administrator,
National Oceanic and Atmospheric Administration

CONTENTS



About this Report 7

Executive Summary 9

Global Climate Change 13

National Climate Change 27

Climate Change Impacts by Sector

Water Resources 41

Energy Supply and Use 53

Transportation 61

Agriculture 71

Ecosystems 79

Human Health 89

Society 99

CONTENTS

Regional Climate Change Impacts

Northeast 107

Southeast 111

Midwest 117

Great Plains 123

Southwest 129

Northwest 135

Alaska 139

Islands 145

Coasts 149

An Agenda for Climate Impacts Science 153

Concluding Thoughts 157

Author Team Biographies 159

Primary Sources of Information 161

Acronyms and Abbreviations 164

References 165

Photo and Figure Credits 188

About this Report

What is this report?

This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is largely based on results of the U.S. Global Change Research Program (USGCRP),[a] and integrates those results with related research from around the world. This report discusses climate-related impacts for various societal and environmental sectors and regions across the nation. It is an authoritative scientific report written in plain language, with the goal of better informing public and private decision making at all levels.

Who called for it, who wrote it, and who approved it?

The USGCRP called for this report. An expert team of scientists operating under the authority of the Federal Advisory Committee Act, assisted by communication specialists, wrote the document. The report was extensively reviewed and revised based on comments from experts and the public. The report was approved by its lead USGCRP Agency, the National Oceanic and Atmospheric Administration, the other USGCRP agencies, and the Committee on the Environment and Natural Resources on behalf of the National Science and Technology Council.[b] This report meets all Federal requirements associated with the Information Quality Act, including those pertaining to public comment and transparency.

What are its sources?

The report draws from a large body of scientific information. The foundation of this report is a set of 21 Synthesis and Assessment Products (SAPs), which were designed to address key policy-relevant issues in climate science (see page 161); several of these were also summarized in the *Scientific Assessment of the Effects of Climate Change on the United States* published in 2008. In addition, other peer-reviewed scientific assessments were used, including those of the Intergovernmental Panel on Climate Change, the U.S. National Assessment of the Consequences of Climate Variability and Change, the Arctic Climate Impact Assessment, the National Research Council's Transportation Research Board report on the Potential Impacts of Climate Change on U.S. Transportation, and a variety of regional climate impact assessments. These assessments were augmented with government statistics as necessary (such as population census and energy usage) as well as publicly available observations and peer-reviewed research published through the end of 2008. This new work was carefully selected by the author team with advice from expert reviewers to update key aspects of climate change science relevant to this report. The icons on the bottom of this page represent some of the major sources drawn upon for this synthesis report.

On the first page of each major section, the sources primarily drawn upon for that section are shown using these icons. Endnotes, indicated by superscript numbers and compiled at the end of the book, are used for specific references throughout the report.

See page 161 for descriptions of these sources.

a. The U.S. Global Change Research Program (USGCRP), which was established in 1990 by the Global Change Research Act, encompasses the Climate Change Science Program (CCSP).

b. A description of the National Science and Technology Council (NSTC) can be found at www.ostp.gov/cs/nstc.

Does this report deal with options for responding to climate change?

While the primary focus of this report is on the impacts of climate change in the United States, it also deals with some of the actions society is already taking or can take to respond to the climate challenge. Responses to climate change fall into two broad categories. The first involves "mitigation" measures to reduce climate change by, for example, reducing emissions of heat-trapping gases and particles, or increasing removal of heat-trapping gases from the atmosphere. The second involves "adaptation" measures to improve our ability to cope with or avoid harmful impacts and take advantage of beneficial ones, now and in the future. Both of these are necessary elements of an effective response strategy. These two types of responses are linked in that more effective mitigation measures reduce the amount of climate change, and therefore the need for adaptation.

This report underscores the importance of mitigation by comparing impacts resulting from higher versus lower emissions scenarios. The report shows that choices made about emissions in the next few decades will have far-reaching consequences for climate change impacts. Over the long term, lower emissions will lessen both the magnitude of climate change impacts and the rate at which they appear.

While the report underscores the importance of mitigation as an essential part of the nation's climate change strategy, it does not evaluate mitigation technologies or undertake an analysis of the effectiveness of various approaches. These issues are the subject of ongoing studies by the U.S. Government's Climate Change Technology Program and several federal agencies including the Department of Energy, Environmental Protection Agency, National Oceanic and Atmospheric Administration, Department of Transportation, and Department of Agriculture. The range of mitigation responses being studied includes more efficient production and use of energy, increased use of non-carbon-emitting energy sources, and carbon capture and storage.

Adaptation options also have the potential to moderate harmful impacts of current and future climate variability and change. While this report does address adaptation, it does not do so comprehensively. Rather, in the context of impacts, this report identifies examples of actions currently being pursued in various sectors and regions to address climate change, as well as other environmental problems that could be exacerbated by climate change such as urban air pollution and heat waves. In most cases, there is currently insufficient peer-reviewed information to evaluate the practicality, effectiveness, costs, or benefits of these measures, highlighting a need for research in this area. Thus, the discussion of various public and private adaptation examples should not be viewed as an endorsement of any particular option, but rather as illustrative examples of approaches being tried.

How is the likelihood of various outcomes expressed given that the future is not certain?

When it is considered necessary to express a range of possible outcomes and identify the likelihood of particular impacts, this report takes a plain-language approach to expressing the expert judgment of the author team based on the best available evidence. For example, an outcome termed "likely" has at least a two-thirds chance of occurring; an outcome termed "very likely," at least a 90 percent chance.[1] In using these terms, the Federal Advisory Committee has taken into consideration a wide range of information, including the strength and consistency of the observed evidence, the range and consistency of model projections, the reliability of particular models as tested by various methods, and most importantly, the body of work addressed in earlier synthesis and assessment reports. Key sources of information used to develop these characterizations of uncertainty are referenced in endnotes.

How does this report address incomplete scientific understanding?

This assessment identifies areas in which scientific uncertainty limits our ability to estimate future climate change and its impacts. The section on *An Agenda for Climate Impacts Science* at the end of this report highlights some of these areas.

Executive Summary

Observations show that warming of the climate is unequivocal. The global warming observed over the past 50 years is due primarily to human-induced emissions of heat-trapping gases. These emissions come mainly from the burning of fossil fuels (coal, oil, and gas), with important contributions from the clearing of forests, agricultural practices, and other activities.

Warming over this century is projected to be considerably greater than over the last century. The global average temperature since 1900 has risen by about 1.5ºF. By 2100, it is projected to rise another 2 to 11.5ºF. The U.S. average temperature has risen by a comparable amount and is very likely to rise more than the global average over this century, with some variation from place to place. Several factors will determine future temperature increases. Increases at the lower end of this range are more likely if global heat-trapping gas emissions are cut substantially. If emissions continue to rise at or near current rates, temperature increases are more likely to be near the upper end of the range. Volcanic eruptions or other natural variations could temporarily counteract some of the human-induced warming, slowing the rise in global temperature, but these effects would only last a few years.

Reducing emissions of carbon dioxide would lessen warming over this century and beyond. Sizable early cuts in emissions would significantly reduce the pace and the overall amount of climate change. Earlier cuts in emissions would have a greater effect in reducing climate change than comparable reductions made later. In addition, reducing emissions of some shorter-lived heat-trapping gases, such as methane, and some types of particles, such as soot, would begin to reduce warming within weeks to decades.

Climate-related changes have already been observed globally and in the United States. These include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice. A longer ice-free period on lakes and rivers, lengthening of the growing season, and increased water vapor in the atmosphere have also been observed. Over the past 30 years, temperatures have risen faster in winter than in any other season, with average winter temperatures in the Midwest and northern Great Plains increasing more than 7ºF. Some of the changes have been faster than previous assessments had suggested.

These climate-related changes are expected to continue while new ones develop. Likely future changes for the United States and surrounding coastal waters include more intense hurricanes with related increases in wind, rain, and storm surges (but not necessarily an increase in the number of these storms that make landfall), as well as drier conditions in the Southwest and Caribbean. These changes will affect human health, water supply, agriculture, coastal areas, and many other aspects of society and the natural environment.

This report synthesizes information from a wide variety of scientific assessments (see page 7) and recently published research to summarize what is known about the observed and projected consequences of climate change on the United States. It combines analysis of impacts on various sectors

such as energy, water, and transportation at the national level with an assessment of key impacts on specific regions of the United States. For example, sea-level rise will increase risks of erosion, storm surge damage, and flooding for coastal communities, especially in the Southeast and parts of Alaska. Reduced snowpack and earlier snow melt will alter the timing and amount of water supplies, posing significant challenges for water resource management in the West.

Society and ecosystems can adjust to some climatic changes, but this takes time. The projected rapid rate and large amount of climate change over this century will challenge the ability of society and natural systems to adapt. For example, it is difficult and expensive to alter or replace infrastructure designed to last for decades (such as buildings, bridges, roads, airports, reservoirs, and ports) in response to continuous and/or abrupt climate change.

Impacts are expected to become increasingly severe for more people and places as the amount of warming increases. Rapid rates of warming would lead to particularly large impacts on natural ecosystems and the benefits they provide to humanity. Some of the impacts of climate change will be irreversible, such as species extinctions and coastal land lost to rising seas.

Unanticipated impacts of increasing carbon dioxide and climate change have already occurred and more are possible in the future. For example, it has recently been observed that the increase in atmospheric carbon dioxide concentration is causing an increase in ocean acidity. This reduces the ability of corals and other sea life to build shells and skeletons out of calcium carbonate. Additional impacts in the future might stem from unforeseen changes in the climate system, such as major alterations in oceans, ice, or storms; and unexpected consequences of ecological changes, such as massive dislocations of species or pest outbreaks. Unexpected social or economic changes, including major shifts in wealth, technology, or societal priorities would also affect our ability to respond to climate change. Both anticipated and unanticipated impacts become more challenging with increased warming.

Projections of future climate change come from careful analyses of outputs from global climate models run on the world's most advanced computers. The model simulations analyzed in this report used plausible scenarios of human activity that generally lead to further increases in heat-trapping emissions. None of the scenarios used in this report assumes adoption of policies explicitly designed to address climate change. However, the level of emissions varies among scenarios because of differences in assumptions about population, economic activity, choice of energy technologies, and other factors. Scenarios cover a range of emissions of heat-trapping gases, and the associated climate projections illustrate that lower emissions result in less climate change and thus reduced impacts over this century and beyond. Under all scenarios considered in this report, however, relatively large and sustained changes in many aspects of climate are projected by the middle of this century, with even larger changes by the end of this century, especially under higher emissions scenarios.

In projecting future conditions, there is always some level of uncertainty. For example, there is a high degree of confidence in projections that future temperature increases will be greatest in the Arctic and in the middle of continents. For precipitation, there is high confidence in projections of continued increases in the Arctic and sub-Arctic (including Alaska) and decreases in the regions just outside the tropics, but the precise location of the transition between these is less certain. At local to regional scales and on time frames up to a few years, natural climate variations can be relatively large and can temporarily mask the progressive nature of global climate change. However, the science of making skillful projections at these scales has progressed considerably, allowing useful information to be drawn from regional climate studies such as those highlighted in this report.

This report focuses on observed and projected climate change and its impacts on the United States. However, a discussion of these issues would be incomplete without mentioning some of the actions society can take to respond to the climate challenge. The two major categories are "mitigation" and "adaptation." Mitigation refers to options for limiting climate change by, for example, reducing

heat-trapping emissions such as carbon dioxide, methane, nitrous oxide, and halocarbons, or removing some of the heat-trapping gases from the atmosphere. Adaptation refers to changes made to better respond to present or future climatic and other environmental conditions, thereby reducing harm or taking advantage of opportunity. Effective mitigation measures reduce the need for adaptation. Mitigation and adaptation are both essential parts of a comprehensive climate change response strategy.

Carbon dioxide emissions are a primary focus of mitigation strategies. These include improving energy efficiency, using energy sources that do not produce carbon dioxide or produce less of it, capturing and storing carbon dioxide from fossil fuel use, and so on. Choices made about emissions reductions now and over the next few decades will have far-reaching consequences for climate-change impacts. The importance of mitigation is clear in comparisons of impacts resulting from higher versus lower emissions scenarios considered in this report. Over the long term, lower emissions will lessen both the magnitude of climate-change impacts and the rate at which they appear. Smaller climate changes that come more slowly make the adaptation challenge more tractable.

However, no matter how aggressively heat-trapping emissions are reduced, some amount of climate change and resulting impacts will continue due to the effects of gases that have already been released. This is true for several reasons. First, some of these gases are very long-lived and the levels of atmospheric heat-trapping gases will remain elevated for hundreds of years or more. Second, the Earth's vast oceans have absorbed much of the heat added to the climate system due to the increase in heat-trapping gases, and will retain that heat for many decades. In addition, the factors that determine emissions, such as energy-supply systems, cannot be changed overnight. Consequently, there is also a need for adaptation.

Adaptation can include a wide range of activities. Examples include a farmer switching to growing a different crop variety better suited to warmer or drier conditions; a company relocating key business centers away from coastal areas vulnerable to sea-level rise and hurricanes; and a community altering its zoning and building codes to place fewer structures in harm's way and making buildings less vulnerable to damage from floods, fires, and other extreme events. Some adaptation options that are currently being pursued in various regions and sectors to deal with climate change and/or other environmental issues are identified in this report. However, it is clear that there are limits to how much adaptation can achieve.

Humans have adapted to changing climatic conditions in the past, but in the future, adaptations will be particularly challenging because society won't be adapting to a new steady state but rather to a rapidly moving target. Climate will be continually changing, moving at a relatively rapid rate, outside the range to which society has adapted in the past. The precise amounts and timing of these changes will not be known with certainty.

In an increasingly interdependent world, U.S. vulnerability to climate change is linked to the fates of other nations. For example, conflicts or mass migrations of people resulting from food scarcity and other resource limits, health impacts, or environmental stresses in other parts of the world could threaten U.S. national security. It is thus difficult to fully evaluate the impacts of climate change on the United States without considering the consequences of climate change elsewhere. However, such analysis is beyond the scope of this report.

Finally, this report identifies a number of areas in which inadequate information or understanding hampers our ability to estimate future climate change and its impacts. For example, our knowledge of changes in tornadoes, hail, and ice storms is quite limited, making it difficult to know if and how such events have changed as climate has warmed, and how they might change in the future. Research on ecological responses to climate change is also limited, as is our understanding of social responses. The section titled *An Agenda for Climate Impacts Science* at the end of this report offers some thoughts on the most important ways to improve our knowledge. Results from such efforts would inform future assessments that continue building our understanding of humanity's impacts on climate, and climate's impacts on us.

Key Findings

1. Global warming is unequivocal and primarily human-induced.

Global temperature has increased over the past 50 years. This observed increase is due primarily to human-induced emissions of heat-trapping gases. (p. 13)

2. Climate changes are underway in the United States and are projected to grow.

Climate-related changes are already observed in the United States and its coastal waters. These include increases in heavy downpours, rising temperature and sea level, rapidly retreating glaciers, thawing permafrost, lengthening growing seasons, lengthening ice-free seasons in the ocean and on lakes and rivers, earlier snowmelt, and alterations in river flows. These changes are projected to grow. (p. 27)

3. Widespread climate-related impacts are occurring now and are expected to increase.

Climate changes are already affecting water, energy, transportation, agriculture, ecosystems, and health. These impacts are different from region to region and will grow under projected climate change. (p. 41-106, 107-152)

4. Climate change will stress water resources.

Water is an issue in every region, but the nature of the potential impacts varies. Drought, related to reduced precipitation, increased evaporation, and increased water loss from plants, is an important issue in many regions, especially in the West. Floods and water quality problems are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage. (p. 41, 129, 135, 139)

5. Crop and livestock production will be increasingly challenged.

Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields. Increased pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production. (p. 71)

6. Coastal areas are at increasing risk from sea-level rise and storm surge.

Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf Coasts, Pacific Islands, and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected. (p. 111, 139, 145, 149)

7. Risks to human health will increase.

Harmful health impacts of climate change are related to increasing heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents. Reduced cold stress provides some benefits. Robust public health infrastructure can reduce the potential for negative impacts. (p. 89)

8. Climate change will interact with many social and environmental stresses.

Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone. (p. 99)

9. Thresholds will be crossed, leading to large changes in climate and ecosystems.

There are a variety of thresholds in the climate system and ecosystems. These thresholds determine, for example, the presence of sea ice and permafrost, and the survival of species, from fish to insect pests, with implications for society. With further climate change, the crossing of additional thresholds is expected. (p. 76, 82, 115, 137, 142)

10. Future climate change and its impacts depend on choices made today.

The amount and rate of future climate change depend primarily on current and future human-caused emissions of heat-trapping gases and airborne particles. Responses involve reducing emissions to limit future warming, and adapting to the changes that are unavoidable. (p. 25, 29)

Global Climate Change

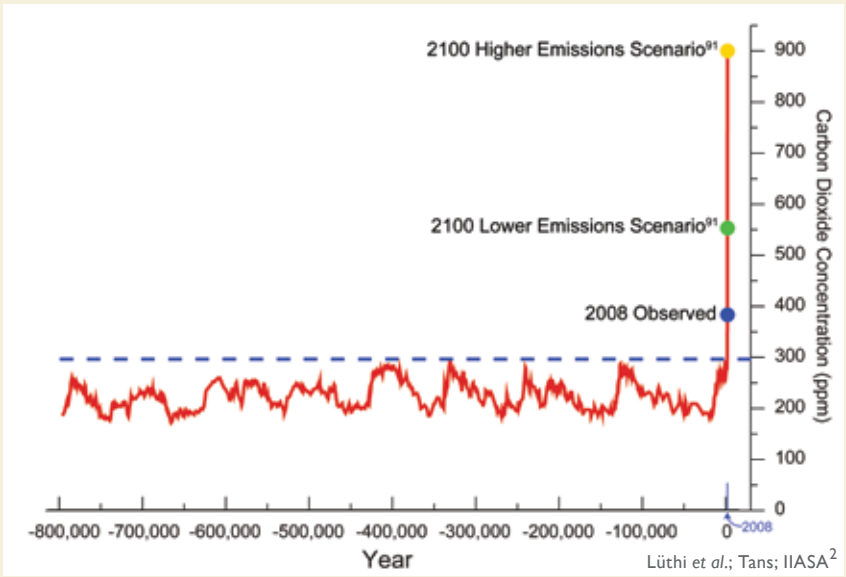
Key Messages:

- Human activities have led to large increases in heat-trapping gases over the past century.
- Global average temperature and sea level have increased, and precipitation patterns have changed.
- The global warming of the past 50 years is due primarily to human-induced increases in heat-trapping gases. Human "fingerprints" also have been identified in many other aspects of the climate system, including changes in ocean heat content, precipitation, atmospheric moisture, and Arctic sea ice.
- Global temperatures are projected to continue to rise over this century; by how much and for how long depends on a number of factors, including the amount of heat-trapping gas emissions and how sensitive the climate is to those emissions.

This introduction to global climate change explains very briefly what has been happening to the world's climate and why, and what is projected to happen in the future. While this report focuses on climate change impacts in the United States, understanding these changes and their impacts requires an understanding of the global climate system.

Many changes have been observed in global climate over the past century. The nature and causes of these changes have been comprehensively chronicled in a variety of recent reports, such as those by the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Climate Change Science Program (CCSP). This section does not intend to duplicate these comprehensive efforts, but rather to provide a brief synthesis, and to integrate more recent work with the assessments of the IPCC, CCSP, and others.

800,000 Year Record of Carbon Dioxide Concentration



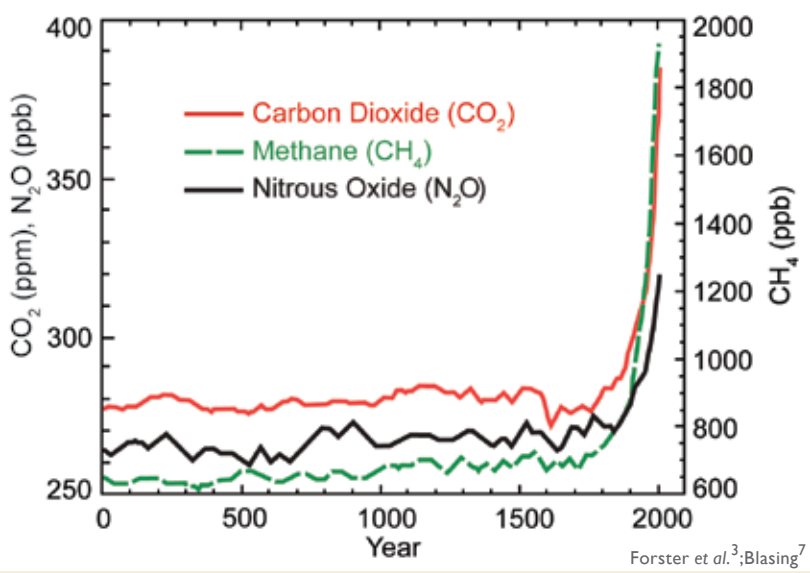
Analysis of air bubbles trapped in an Antarctic ice core extending back 800,000 years documents the Earth's changing carbon dioxide concentration. Over this long period, natural factors have caused the atmospheric carbon dioxide concentration to vary within a range of about 170 to 300 parts per million (ppm). Temperature-related data make clear that these variations have played a central role in determining the global climate. As a result of human activities, the present carbon dioxide concentration of about 385 ppm is about 30 percent above its highest level over at least the last 800,000 years. In the absence of strong control measures, emissions projected for this century would result in the carbon dioxide concentration increasing to a level that is roughly 2 to 3 times the highest level occurring over the glacial-interglacial era that spans the last 800,000 or more years.

Human activities have led to large increases in heat-trapping gases over the past century.

The Earth's climate depends on the functioning of a natural "greenhouse effect." This effect is the result of heat-trapping gases (also known as greenhouse gases) like water vapor, carbon dioxide, ozone, methane, and nitrous oxide, which absorb heat radiated from the Earth's surface and lower atmosphere and then radiate much of the energy back toward the surface. Without this natural greenhouse effect, the average surface temperature of the Earth would be about 60°F colder. However, human activities have been releasing additional heat-trapping gases, intensifying the natural greenhouse effect, thereby changing the Earth's climate.

Climate is influenced by a variety of factors, both human-induced and natural. The increase in the carbon dioxide concentration has been the principal factor causing warming over the past 50 years. Its concentration has been building up in the Earth's atmosphere since the beginning of the industrial era in the mid-1700s, primarily due to the burning of fossil fuels (coal, oil, and natural gas) and the clearing of forests. Human activities have also increased the emissions of other greenhouse gases, such as methane, nitrous oxide, and halocarbons.[3]

2,000 Years of Greenhouse Gas Concentrations



Forster *et al.*[3];Blasing[7]

Increases in concentrations of these gases since 1750 are due to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion molecules of air.

These emissions are thickening the blanket of heat-trapping gases in Earth's atmosphere, causing surface temperatures to rise.

Heat-trapping gases

Carbon dioxide concentration has increased due to the use of fossil fuels in electricity generation, transportation, and industrial and household uses. It is also produced as a by-product during the manufacturing of cement. Deforestation provides a source of carbon dioxide and reduces its uptake by trees and other plants. Globally, over the past several decades, about 80 percent of human-induced carbon dioxide emissions came from the burning of fossil fuels, while about 20 percent resulted from deforestation and associated agricultural practices. The concentration of carbon dioxide in the atmosphere has increased by roughly 35 percent since the start of the industrial revolution.[3]

Methane concentration has increased mainly as a result of agriculture; raising livestock (which produce methane in their digestive tracts); mining, transportation, and use of certain fossil fuels; sewage; and decomposing garbage in landfills. About 70 percent of the emissions of atmospheric methane are now related to human activities.[4]

Nitrous oxide concentration is increasing as a result of fertilizer use and fossil fuel burning.

Halocarbon emissions come from the release of certain manufactured chemicals to the atmosphere. Examples include chlorofluorocarbons (CFCs), which were used extensively in refrigeration and for other industrial processes before their presence in the atmosphere was found to cause stratospheric ozone depletion. The abundance of these gases in the atmosphere is now decreasing as a result of international regulations designed to protect the ozone layer. Continued decreases in ozone-depleting halocarbon emissions are expected to reduce their relative influence on climate change in the future.[3,5] Many halocarbon replacements, however, are potent greenhouse gases, and their concentrations are increasing.[6]

Ozone is a greenhouse gas, and is continually produced and destroyed in the atmosphere by chemical reactions. In the troposphere, the lowest 5 to 10 miles of the atmosphere near the surface, human activities have increased the ozone concentration through the release of gases such as carbon monoxide, hydrocarbons, and nitrogen oxides. These gases undergo chemical reactions to produce ozone in the presence of sunlight. In addition to trapping heat, excess ozone in the troposphere causes respiratory illnesses and other human health problems.

In the stratosphere, the layer above the troposphere, ozone exists naturally and protects life on Earth from exposure to excessive ultraviolet radiation from the Sun. As mentioned previously, halocarbons released by human activities destroy ozone in the stratosphere and have caused the ozone hole over Antarctica.[8] Changes in the stratospheric ozone layer have contributed to changes in wind patterns and regional climates in Antarctica.[9]

Water vapor is the most important and abundant greenhouse gas in the atmosphere. Human activities produce only a very small increase in water vapor through irrigation and combustion processes.[3] However, the surface warming caused by human-produced increases in other greenhouse gases leads to an increase in atmospheric water vapor, since a warmer climate increases evaporation and allows the atmosphere to hold more moisture. This creates an amplifying "feedback loop," leading to more warming.

Other human influences

In addition to the global-scale climate effects of heat-trapping gases, human activities also produce additional local and regional effects. Some of these activities partially offset the warming caused by greenhouse gases, while others increase the warming. One such influence on climate is caused by tiny particles called "aerosols" (not to be confused with aerosol spray cans). For example, the burning of coal produces emissions of sulfur-containing compounds. These compounds form "sulfate aerosol" particles, which reflect some of the incoming sunlight away from the Earth, causing a cooling influence at the surface. Sulfate aerosols also tend to make clouds more efficient at reflecting sunlight, causing an additional indirect cooling effect. Another type of aerosol, often referred to as soot or black carbon, absorbs incoming sunlight and traps heat in the atmosphere. Thus, depending on their type, aerosols can either mask or increase the warming caused by increased levels of greenhouse gases.[13] On a globally averaged basis, the sum of these aerosol effects offsets some of the warming caused by heat-trapping gases.[10]

The effects of various greenhouse gases and aerosol particles on Earth's climate depend in part on how long these gases and particles remain in the atmosphere. After emission, the atmospheric concentration of carbon dioxide remains elevated for thousands of years, and that of methane for decades, while the elevated concentrations of aerosols only persist for days to weeks.[11,12] The climate effects of reductions in emissions of carbon dioxide and other long-lived gases do not become apparent for at least several decades. In contrast, reductions in emissions of short-lived compounds can have a rapid, but complex effect since the geographic patterns of their climatic influence and the resulting surface temperature responses are quite different. One modeling study found that while the greatest emissions of short-lived pollutants in summertime by late this century are projected to come from Asia, the strongest climate response is projected to be over the central United States.[13]

Human activities have also changed the land surface in ways that alter how much heat is reflected or absorbed by the surface. Such changes include the cutting and burning of forests, the replacement of other areas of natural vegetation with agriculture and cities, and large-scale irrigation. These transformations of the land surface can cause local (and even regional) warming or cooling. Globally, the net effect of these changes has probably been a slight cooling of the Earth's surface over the past 100 years.[14,15]

Natural influences

Two important natural factors also influence climate: the Sun and volcanic eruptions. Over the past three decades, human influences on climate have become increasingly obvious, and global temperatures have risen sharply. During the same period, the Sun's energy output (as measured by satellites since 1979) has followed its historical 11-year cycle

of small ups and downs, but with no net increase (see figure page 20).[16] The two major volcanic eruptions of the past 30 years have had short-term cooling effects on climate, lasting 2 to 3 years.[17] Thus, these natural factors cannot explain the warming of recent decades; in fact, their net effect on climate has probably been a slight cooling influence over this period. Slow changes in Earth's orbit around the Sun and its tilt toward or away from the Sun are also a purely natural influence on climate, but are only important on timescales from thousands to many tens of thousands of years.

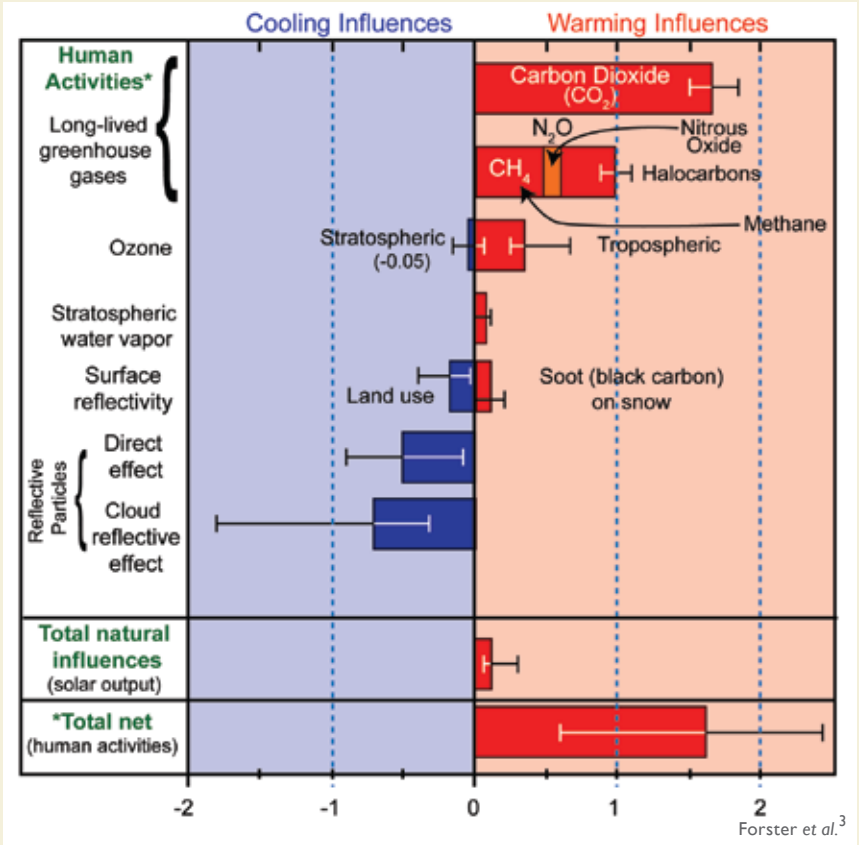
The climate changes that have occurred over the last century are not solely caused by the human and natural factors described above. In addition to these influences, there are also fluctuations in climate that occur even in the absence of changes in human activities, the Sun, or volcanoes. One example is the El Niño phenomenon, which has important influences on many aspects of regional and global climate. Many other modes of variability have been identified by climate scientists and their effects on climate occur at the same time as the effects of human activities, the Sun, and volcanoes.

Carbon release and uptake

Once carbon dioxide is emitted to the atmosphere, some of it is absorbed by the oceans and taken up by vegetation, although this storage may be temporary. About 45 percent of the carbon dioxide emitted by human activities in the last 50 years is now stored in the oceans and vegetation. The rest has remained in the air, increasing the atmospheric concentration.[2,3,18] It is thus important to understand not only how much carbon dioxide is emitted, but also how much is taken up, over what time scales, and how these sources and "sinks" of carbon dioxide might change as climate continues to warm. For example, it is known from long records of Earth's climate history that under warmer conditions, carbon tends to be released, for instance, from thawing permafrost, initiating a feedback loop in which more carbon release leads to more warming which leads to further release, and so on.[19,20]

Global emissions of carbon dioxide have been accelerating. The growth rate increased from 1.3 percent per year in the 1990s to 3.3 percent per year between 2000 and 2006.[21] The increasing emissions of carbon dioxide are the primary cause of the increased concentration of carbon dioxide observed in the atmosphere. There is also evidence that a smaller fraction of the annual human-induced emissions is now being taken up than in the past, leading to a greater fraction remaining in the atmosphere and an accelerating rate of increase in the carbon dioxide concentration.[21]

Major Warming and Cooling Influences on Climate
1750-2005



The figure above shows the amount of warming influence (red bars) or cooling influence (blue bars) that different factors have had on Earth's climate over the industrial age (from about 1750 to the present). Results are in watts per square meter. The longer the bar, the greater the influence on climate. The top part of the box includes all the major human-induced factors, while the second part of the box includes the Sun, the only major natural factor with a long-term effect on climate. The cooling effect of individual volcanoes is also natural, but is relatively short-lived (2 to 3 years), thus their influence is not included in this figure. The bottom part of the box shows that the total net effect (warming influences minus cooling influences) of human activities is a strong warming influence. The thin lines on each bar provide an estimate of the range of uncertainty.

Ocean acidification

As the ocean absorbs carbon dioxide from the atmosphere, seawater is becoming less alkaline (its pH is decreasing) through a process generally referred to as ocean acidification. The pH of seawater has decreased significantly since 1750,[22,23] and is projected to drop much more dramatically by the end of the century if carbon dioxide concentrations continue to increase.[24] Such ocean acidification is essentially irreversible over a time scale of centuries. As discussed in the *Ecosystems* sector and *Coasts* region, ocean acidification affects the process of calcification by which living things create shells and skeletons, with substantial negative consequences for coral reefs, mollusks, and some plankton species important to ocean food chains.[25]

Global average temperature and sea level have increased, and precipitation patterns have changed.

Temperatures are rising

Global average surface air temperature has increased substantially since 1970.[26] The estimated change in the average temperature of Earth's surface is based on measurements from thousands of weather stations, ships, and buoys around the world, as well as from satellites. These measurements are independently compiled, analyzed, and processed by different research groups. There are a number of important steps in the data processing. These include identifying and adjusting for the effects of changes in the instruments used to measure temperature, the measurement times and locations, the local environment around the measuring site, and such factors as satellite orbital drift. For instance, the growth of cities can cause localized "urban heat island" effects.

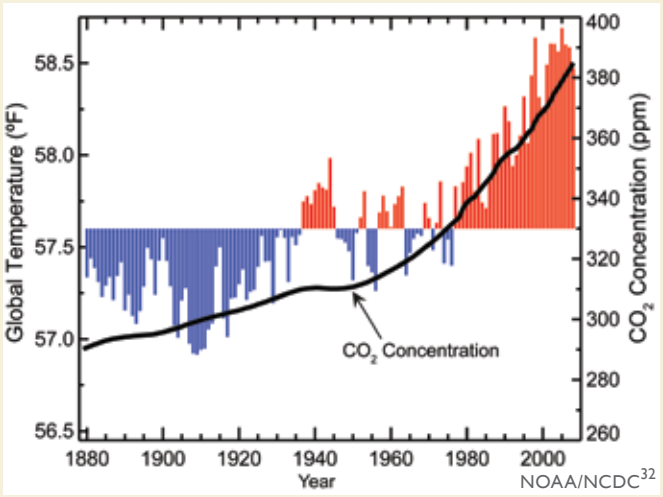
A number of research groups around the world have produced estimates of global-scale changes in surface temperature. The warming trend that is apparent in all of these temperature records is confirmed by other independent observations, such as the melting of Arctic sea ice, the retreat of mountain glaciers on every continent,[27] reductions in the extent of snow cover, earlier blooming of plants in spring, and increased melting of the Greenland and Antarctic ice sheets.[28,29] Because snow and ice reflect the Sun's heat, this melting causes more heat to be absorbed, which causes more melting, resulting in another feedback loop.[20]

Additionally, temperature measurements above the surface have been made by weather balloons since the late 1940s, and from satellites since 1979. These measurements show warming of the troposphere, consistent with the surface warming.[30,31] They also reveal cooling in the stratosphere.[30] This pattern of tropospheric warming and stratospheric cooling agrees with our understanding of how atmospheric temperature would be expected to change in response to increasing greenhouse gas concentrations and the observed depletion of stratospheric ozone.[14]

Precipitation patterns are changing

Precipitation is not distributed evenly over the globe. Its average distribution is governed primarily by atmospheric circulation patterns, the availability of moisture, and surface terrain effects. The first two of these factors are influenced by temperature. Thus, human-caused changes in temperature are expected to alter precipitation patterns.

Global Temperature and Carbon Dioxide



Global annual average temperature (as measured over both land and oceans). Red bars indicate temperatures above and blue bars indicate temperatures below the average temperature for the period 1901-2000. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, each individual year does not show a temperature increase relative to the previous year, and some years show greater changes than others.[33] These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and the eruption of large volcanoes.

Observations show that such shifts are occurring. Changes have been observed in the amount, intensity, frequency, and type of precipitation. Pronounced increases in precipitation over the past 100 years have been observed in eastern North America, southern South America, and northern Europe. Decreases have been seen in the Mediterranean, most of Africa, and southern Asia. Changes in the geographical distribution of droughts and flooding have been complex. In some regions, there have been increases in the occurrences of both droughts and floods.[28] As the world warms, northern regions and mountainous areas are experiencing more precipitation falling as rain rather than snow.[34] Widespread increases in heavy precipitation events have occurred, even in places where total rain amounts have decreased. These changes are associated with the fact that warmer air holds more water vapor evaporating from the world's oceans and land surface.[31] This increase in atmospheric water vapor has been observed from satellites, and is primarily due to human influences.[35,36]

Sea level is rising

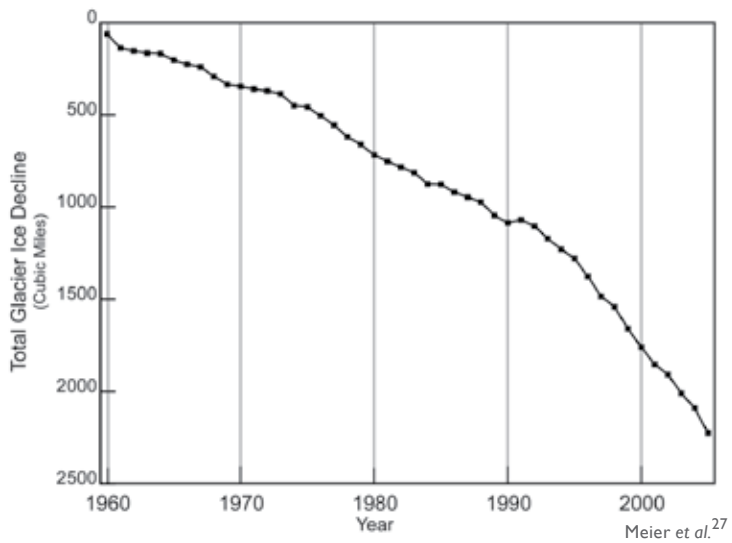
After at least 2,000 years of little change, sea level rose by roughly 8 inches over the past century. Satellite data available over the past 15 years show sea level rising at a rate roughly double the rate observed over the past century.[37]

There are two principal ways in which global warming causes sea level to rise. First, ocean water expands as it warms, and therefore takes up more space. Warming has been observed in each of the world's major ocean basins, and has been directly linked to human influences.[38,39]

Second, warming leads to the melting of glaciers and ice sheets, which raises sea level by adding water to the oceans. Glaciers have been retreating worldwide for at least the last century, and the rate of retreat has increased in the past decade.[29,40] Only a few glaciers are actually advancing (in locations that were well below freezing, and where increased precipitation has outpaced melting). The total volume of glaciers on Earth is declining sharply. The progressive disappearance of glaciers has implications not only for the rise in global sea level, but also for water supplies in certain densely populated regions of Asia and South America.

The Earth has major ice sheets on Greenland and Antarctica. These ice sheets are currently losing ice volume by increased melting and calving of icebergs, contributing to sea-level rise. The Greenland Ice Sheet has also been experiencing record amounts of surface melting, and a large increase in the rate of mass loss in the past decade.[41] If the entire Greenland Ice Sheet melted, it would raise sea level by about 20 feet. The Antarctic Ice Sheet consists of two portions, the West Antarctic Ice Sheet and the East Antarctic Ice Sheet. The West Antarctic Ice Sheet, the more vulnerable to melting of the two, contains enough water to raise global sea levels by about 16 to 20 feet.[29] If the East Antarctic Ice Sheet melted entirely, it would raise global sea level by about 200 feet. Complete melting of these ice sheets over this century or the next is thought to be virtually impossible, although past climate records provide precedent for very significant decreases in ice volume, and therefore increases in sea level.[42,43]

Cumulative Decrease in Global Glacier Ice



As temperatures have risen, glaciers around the world have shrunk. The graph shows the cumulative decline in glacier ice worldwide.

The global warming of the past 50 years is due primarily to human-induced increases in heat-trapping gases. Human "fingerprints" also have been identified in many other aspects of the climate system, including changes in ocean heat content, precipitation, atmospheric moisture, and Arctic sea ice.

In 1996, the IPCC Second Assessment Report[44] cautiously concluded that "the balance of evidence suggests a discernible human influence on global climate." Since then, a number of national and international assessments have come to much stronger conclusions about the reality of human effects on climate. Recent scientific assessments find that most of the warming of the Earth's surface over the past 50 years has been caused by human activities.[45,46]

This conclusion rests on multiple lines of evidence. Like the warming "signal" that has gradually emerged from the "noise" of natural climate variability, the scientific evidence for a human influence on global climate has accumulated over the past several decades, from many hundreds of studies. No single study is a "smoking gun." Nor has any single study or combination of studies undermined the large body of evidence supporting the conclusion that human activity is the primary driver of recent warming.

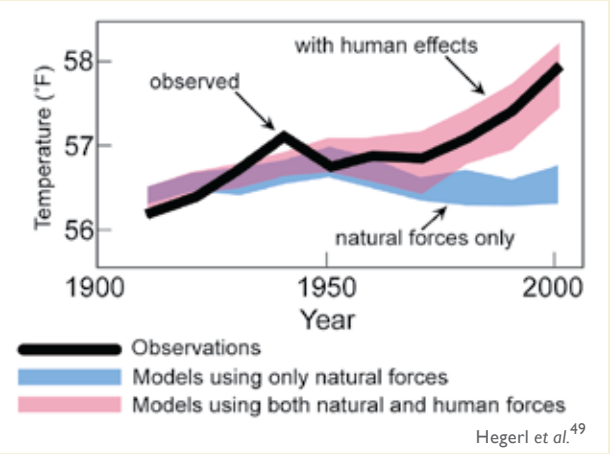
The first line of evidence is our basic physical understanding of how greenhouse gases trap heat, how the climate system responds to increases in greenhouse gases, and how other human and natural factors influence climate. The second line of evidence is from indirect estimates of climate changes over the last 1,000 to 2,000 years. These records are obtained from living things and their remains (like tree rings and corals) and from physical quantities (like the ratio between lighter and heavier isotopes of oxygen in ice cores) which change in measurable ways as climate changes. The lesson from these data is that global surface temperatures over the last several decades are clearly unusual, in that they were higher than at any time during at least the past 400 years.[47] For the Northern Hemisphere, the recent temperature rise is clearly unusual in at least the last 1,000 years.[47,48]

The third line of evidence is based on the broad, qualitative consistency between observed changes in climate and the computer model simulations of how climate would be expected to change in response to human activities. For example, when climate models are run with historical increases in greenhouse gases, they show gradual warming of the Earth and ocean surface, increases in ocean heat content and the temperature of the lower atmosphere, a rise in global sea level, retreat of sea ice and snow cover, cooling of the stratosphere, an increase in the amount of atmospheric water vapor, and changes in large-scale precipitation and pressure patterns. These and other aspects of modeled climate change are in agreement with observations.[14,49]

Finally, there is extensive statistical evidence from so-called "fingerprint" studies. Each factor that affects climate produces a unique pattern of climate response, much as each person has a unique fingerprint. Fingerprint studies exploit these unique signatures, and allow detailed comparisons of modeled and observed climate change patterns.[44] Scientists rely on such studies to attribute observed changes in climate to a particular cause or set of causes. In the real world, the climate changes that have occurred since the start of the Industrial Revolution are due to a complex mixture of human and natural causes. The importance of each individual influence in this mixture changes over time. Of course, there are not multiple Earths, which would allow an experimenter to change one factor at a time on each Earth, thus helping to isolate different fingerprints. Therefore, climate models are used to study how individual factors affect climate. For example, a single factor (like greenhouse gases) or a set of factors can be varied, and the response of the modeled climate system to these individual or combined changes can thus be studied.[50]

For example, when climate model simulations of the last century include all of the major influences on climate, both human-induced and natural, they can reproduce many important features of observed climate change patterns. When human influences are removed from the model experiments, results suggest that the surface of the Earth would actually have cooled slightly over the last 50 years. The clear message from fingerprint studies is that the

Separating Human and Natural Influences on Climate



The blue band shows how global average temperatures would have changed due to natural forces only, as simulated by climate models. The red band shows model projections of the effects of human and natural forces combined. The black line shows actual observed global average temperatures. As the blue band indicates, without human influences, temperature over the past century would actually have first warmed and then cooled slightly over recent decades.[58]

observed warming over the last half-century cannot be explained by natural factors, and is instead caused primarily by human factors.[14,50]

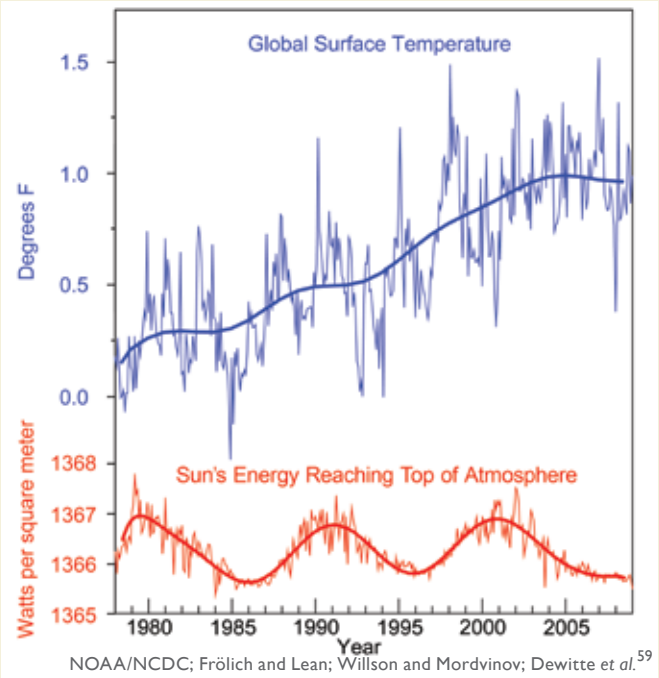
Another fingerprint of human effects on climate has been identified by looking at a slice through the layers of the atmosphere, and studying the pattern of temperature changes from the surface up through the stratosphere. In all climate models, increases in carbon dioxide cause warming at the surface and in the troposphere, but lead to cooling of the stratosphere. For straightforward physical reasons, models also calculate that the human-caused depletion of stratospheric ozone has had a strong cooling effect in the stratosphere. There is a good match between the model fingerprint in response to combined carbon dioxide and ozone changes and the observed pattern of tropospheric warming and stratospheric cooling (see figure on next page).[14]

In contrast, if most of the observed temperature change had been due to an increase in solar output rather than an increase in greenhouse gases, Earth's atmosphere would have warmed throughout its full vertical extent, including the stratosphere.[9] The observed pattern of atmospheric temperature changes, with its pronounced cooling in the stratosphere, is therefore inconsistent with the hypothesis that changes in the Sun can explain the warming of recent decades. Moreover, direct satellite measurements of solar output show slight decreases during the recent period of warming.

The earliest fingerprint work[51] focused on changes in surface and atmospheric temperature. Scientists then applied fingerprint methods to a whole range of climate variables,[50,52] identifying human-caused climate signals in the heat content of the oceans,[38,39] the height of the tropopause[53] (the boundary between the troposphere and stratosphere, which has shifted upward by hundreds of feet in recent decades), the geographical patterns of precipitation,[54] drought,[55] surface pressure,[56] and the runoff from major river basins.[57]

Studies published after the appearance of the IPCC Fourth Assessment Report in 2007 have also found human fingerprints in the increased levels of atmospheric moisture[35,36] (both close to the surface and over the full extent of the atmosphere), in the

Measurements of Surface Temperature and Sun's Energy



The Sun's energy received at the top of Earth's atmosphere has been measured by satellites since 1978. It has followed its natural 11-year cycle of small ups and downs, but with no net increase (bottom). Over the same period, global temperature has risen markedly (top).[60]

decline of Arctic sea ice extent,[61] and in the patterns of changes in Arctic and Antarctic surface temperatures.[62]

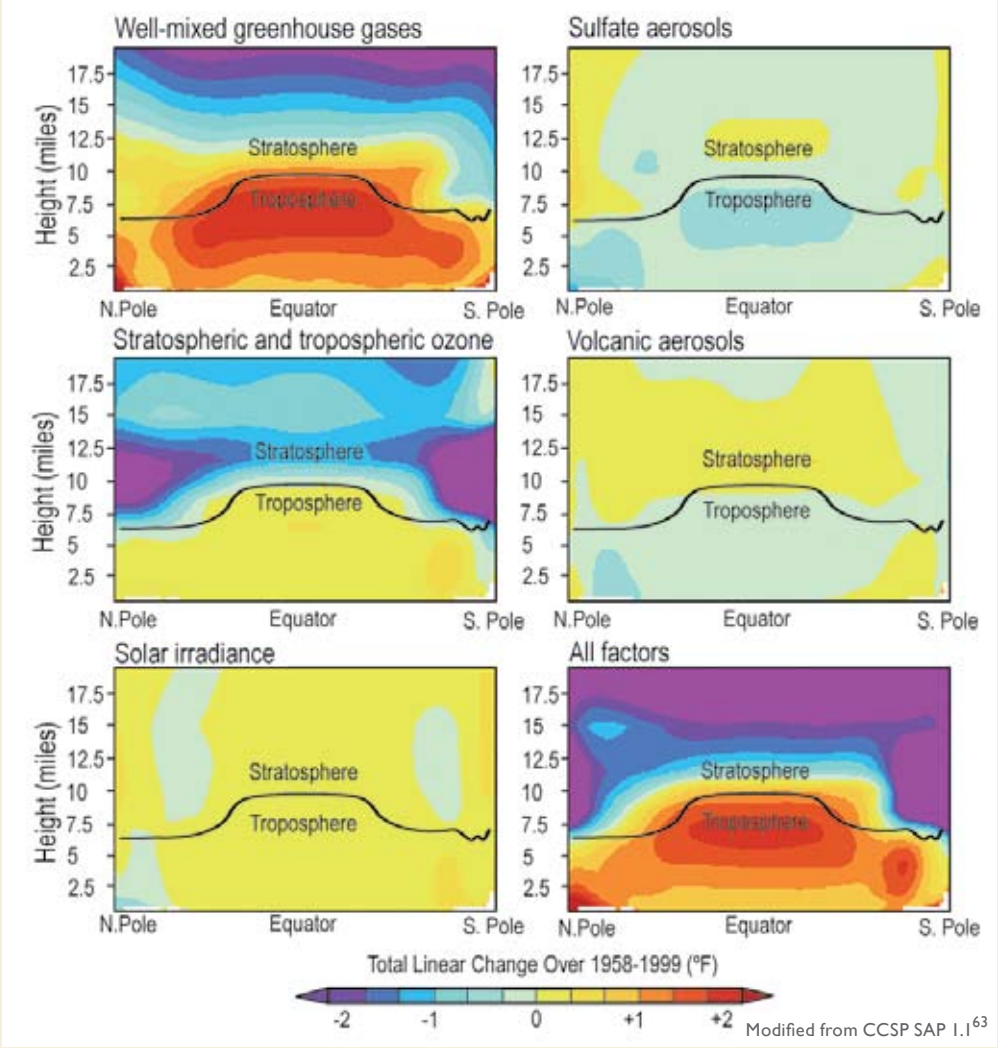
The message from this entire body of work is that the climate system is telling a consistent story of increasingly dominant human influence – the changes in temperature, ice extent, moisture, and circulation patterns fit together in a physically consistent way, like pieces in a complex puzzle.

Increasingly, this type of fingerprint work is shifting its emphasis. As noted, clear and compelling scientific evidence supports the case for a pronounced human influence on global climate. Much of the recent attention is now on climate changes at continental and regional scales,[64,65] and on variables that can have large impacts on societies. For example, scientists have established causal links between human activities and the changes in snowpack, maximum and minimum temperature, and the seasonal timing of runoff over mountainous regions of the western United States.[34] Human activity is likely to have made a substantial contribution to ocean surface temperature changes in hurricane formation regions.[66-68] Researchers are also looking beyond the physical climate system, and are beginning to tie changes in the distribution and seasonal behavior of plant and animal species to human-caused changes in temperature and precipitation.[69,70]

For over a decade, one aspect of the climate change story seemed to show a significant difference between models and observations.[14]

In the tropics, all models predicted that with a rise in greenhouse gases, the troposphere would be expected to warm more rapidly than the surface. Observations from weather balloons, satellites, and surface thermometers seemed to show the opposite behavior (more rapid warming of the surface than the troposphere). This issue was a stumbling block in our understanding of the causes of climate change. It is now largely resolved.[71] Research showed that there were large uncertainties in the satellite and weather balloon data. When uncertainties in models and observations are properly accounted for, newer observational data sets (with better treatment of known problems) are in agreement with climate model results.[31,72-75]

Patterns of Temperature Change Produced by Various Atmospheric Factors, 1958-1999



Climate simulations of the vertical profile of temperature change due to various factors, and the effect due to all factors taken together. The panels above represent a cross-section of the atmosphere from the north pole to the south pole, and from the surface up into the stratosphere. The black lines show the location of the tropopause, the boundary between the lower atmosphere (troposphere) and the stratosphere.

This does not mean, however, that all remaining differences between models and observations have been resolved. The observed changes in some climate variables, such as Arctic sea ice,[61,76] some aspects of precipitation,[54,77] and patterns of surface pressure,[56] appear to be proceeding much more rapidly than models have projected. The reasons for these differences are not well understood. Nevertheless, the bottom-line conclusion from climate fingerprinting is that most of the observed changes studied to date are consistent with each other, and are also consistent with our scientific understanding of how the climate system would be expected to respond to the increase in heat-trapping gases resulting from human activities.[14,49]

Scientists are sometimes asked whether extreme weather events can be linked to human activities.[24] Scientific research has concluded that human influences on climate are indeed changing the likelihood of certain types of extreme events. For example, an analysis of the European summer heat wave of 2003 found that the risk of such a heat wave is now roughly four times greater than it would have been in the absence of human-induced climate change.[68,78]

Like fingerprint work, such analyses of human-caused changes in the risks of extreme events rely on information from climate models, and on our understanding of the physics of the climate system. All of the models used in this work have imperfections in their representation of the complexities of the "real world" climate system.[79,80] These are due to both limits in our understanding of the climate system, and in our ability to represent its complex behavior with available computer resources. Despite this, models are extremely useful, for a number of reasons.

First, despite remaining imperfections, the current generation of climate models accurately portrays many important aspects of today's weather patterns and climate.[79,80] Models are constantly being improved, and are routinely tested against many observations of Earth's climate system. Second, the fingerprint work shows that models capture not only our present-day climate, but also key features of the observed climate changes over the past century.[47] Third, many of the large-scale observed climate changes (such as the warming of the surface and troposphere, and the increase in the amount of moisture in the atmosphere) are driven by very basic physics, which is well-represented in models.[35] Fourth, climate models can be used to predict changes in climate that can be verified in the real world. Examples include the short-term global cooling subsequent to the eruption of Mount Pinatubo and the stratospheric cooling with increasing carbon dioxide. Finally, models are the only tools that exist for trying to understand the climate changes likely to be experienced over the course of this century. No period in Earth's geological history provides an exact analogue for the climate conditions that will unfold in the coming decades.[20]

Global temperatures are projected to continue to rise over this century; by how much and for how long depends on a number of factors, including the amount of heat-trapping gas emissions and how sensitive the climate is to those emissions.

Some continued warming of the planet is projected over the next few decades due to past emissions. Choices made now will influence the amount of future warming. Lower levels of heat-trapping emissions will yield less future warming, while higher levels will result in more warming, and more severe impacts on society and the natural world.

Emissions scenarios

The IPCC developed a set of scenarios in a Special Report on Emissions Scenarios (SRES).[81] These have been extensively used to explore the potential for future climate change. None of these scenarios, not even the one called "lower", includes implementation of policies to limit climate change or to stabilize atmospheric concentrations of heat-trapping gases. Rather, differences among these scenarios are due to different assumptions about changes in population, rate of adoption of new technologies, economic growth, and other factors.

The IPCC emission scenarios also do not encompass the full range of possible futures: emissions can change less than those scenarios imply, or they can change more. Recent carbon dioxide emissions

are, in fact, above the highest emissions scenario developed by the IPCC[82] (see figure below). Whether this will continue is uncertain.

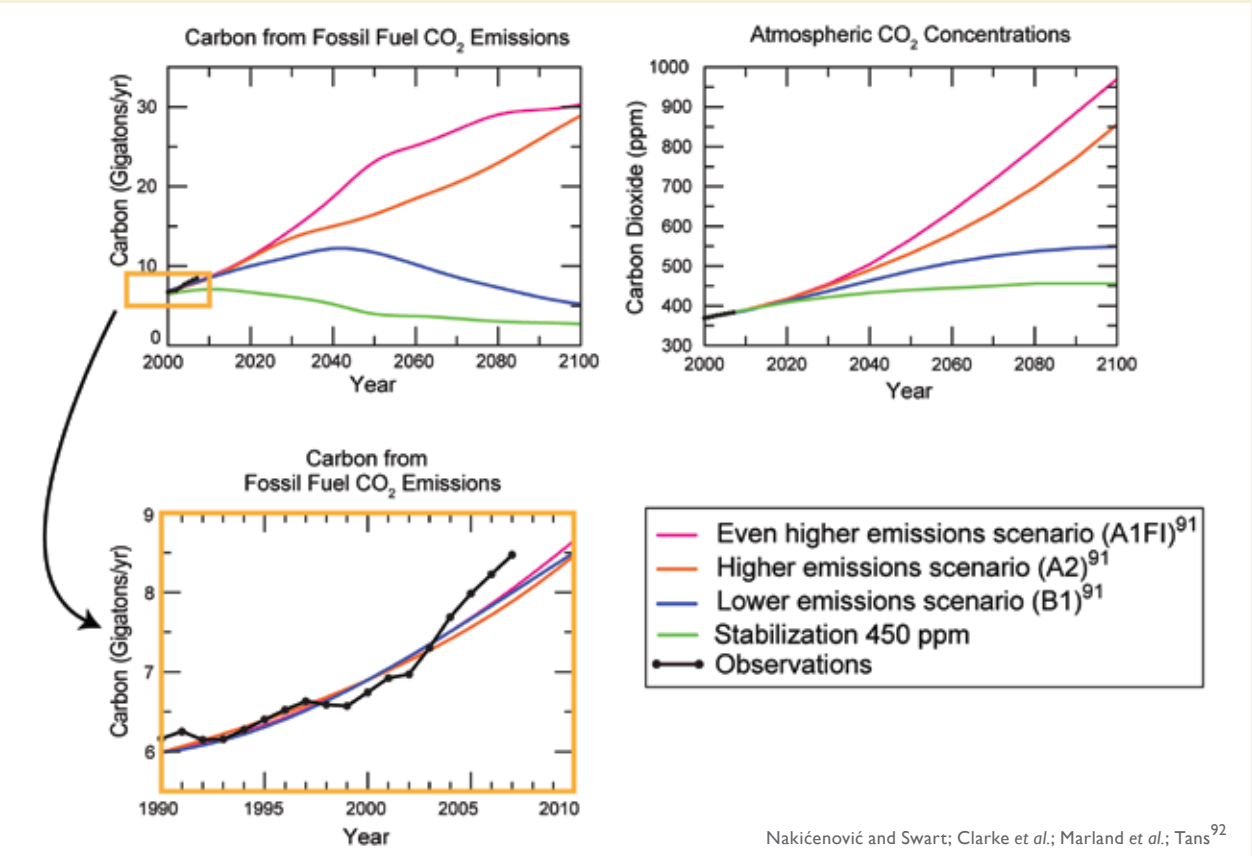
There are also lower possible emissions paths than those put forth by the IPCC. The Framework Convention on Climate Change, to which the United States and 191 other countries are signatories, calls for stabilizing concentrations of greenhouse gases in the atmosphere at a level that would avoid dangerous human interference with the climate system. What exactly constitutes such interference is subject to interpretation.

A variety of research studies suggest that a further 2°F increase (relative to the 1980-1999 period) would lead to severe, widespread, and irreversible impacts.[83-85] To have a good chance (but not a guarantee) of avoiding temperatures above those levels, it has been estimated that atmospheric concentration of carbon dioxide would need to stabilize in the long term at around today's levels.[86-89]

Reducing emissions of carbon dioxide would reduce warming over this century and beyond. Implementing sizable and sustained reductions in carbon dioxide emissions as soon as possible would significantly reduce the pace and the overall amount of climate change, and would be more effective than reductions of the same size initiated later. Reducing emissions of some shorter-lived greenhouse gases, such as methane, and some types of particles, such as soot, would begin to reduce the warming influence within weeks to decades.[13]

The graphs below show emissions scenarios and resulting carbon dioxide concentrations for three IPCC scenarios[90,91] and one stabilization scenario.[25]

Scenarios of Future Carbon Dioxide Global Emissions and Concentrations



Nakićenović and Swart; Clarke *et al.*; Marland *et al.*; Tans[92]

The graphs show recent and projected global emissions of carbon dioxide in gigatons of carbon, on the left, and atmospheric concentrations on the right under five emissions scenarios. The top three in the key are IPCC scenarios that assume no explicit climate policies (these are used in model projections that appear throughout this report). The bottom line is a "stabilization scenario," designed to stabilize atmospheric carbon dioxide concentration at 450 parts per million. The inset expanded below these charts shows emissions for 1990-2010 under the three IPCC scenarios along with actual emissions to 2007 (in black).

The stabilization scenario is aimed at stabilizing the atmospheric carbon dioxide concentration at roughly 450 parts per million (ppm); this is 70 ppm above the 2008 concentration of 385 ppm. Resulting temperature changes depend on atmospheric concentrations of greenhouse gases and particles and the climate's sensitivity to those concentrations.[87] Of those shown on the previous page, only the 450 ppm stabilization target has the potential to keep the global temperature rise at or below about 3.5°F from pre-industrial levels and 2°F above the current average temperature, a level beyond which many concerns have been raised about dangerous human interference with the climate system.[88,89] Scenarios that stabilize carbon dioxide below 450 ppm (not shown in the figure) offer an increased chance of avoiding dangerous climate change.[88,89]

Carbon dioxide is not the only greenhouse gas of concern. Concentrations of other heat-trapping gases like methane and nitrous oxide and particles like soot will also have to be stabilized at low enough levels to prevent global temperatures from rising higher than the level mentioned above. When these other gases are added, including the offsetting cooling effects of sulfate aerosol particles, analyses suggest that stabilizing concentrations around 400 parts per million of "equivalent carbon dioxide" would yield about an 80 percent chance of avoiding exceeding the 2°F above present temperature threshold. This would be true even if concentrations temporarily peaked as high as 475 parts per million and then stabilized at 400 parts per million roughly a century later.[72,88,89,93-95] Reductions in sulfate aerosol particles would necessitate lower equivalent carbon dioxide targets.

Rising global temperature

All climate models project that human-caused emissions of heat-trapping gases will cause further warming in the future. Based on scenarios that do not assume explicit climate policies to reduce greenhouse gas emissions, global average temperature is projected to rise by 2 to 11.5°F by the end of this century[90] (relative to the 1980-1999 time period). Whether the actual warming in 2100 will be closer to the low or the high end of this range depends primarily on two factors: first, the future level of emissions of heat-trapping gases, and second, how sensitive climate is to past and future emissions. The range of possible outcomes has been explored using a range of different emissions scenarios, and a variety of climate models that encompass the known range of climate sensitivity.

Changing precipitation patterns

Projections of changes in precipitation largely follow recently observed patterns of change, with overall increases in the global average but substantial shifts in where and how precipitation falls.[90] Generally, higher latitudes are projected to receive more precipitation, while the dry belt that lies just outside the tropics expands further poleward,[96,97] and also receives less rain. Increases in tropical precipitation are projected during rainy seasons (such as monsoons), and especially over the tropical Pacific. Certain regions, including the U.S. West (especially the Southwest) and the Mediterranean, are expected to become drier. The widespread trend toward more heavy downpours is expected to continue, with precipitation becoming less frequent but more intense.[90] More precipitation is expected to fall as rain rather than snow.

Currently rare extreme events are becoming more common

In a warmer future climate, models project there will be an increased risk of more intense, more frequent, and longer-lasting heat waves.[90] The European heat wave of 2003 is an example of the type of extreme heat event that is likely to become much more common.[90] If greenhouse gas emissions continue to increase, by the 2040s more than half of European summers will be hotter than the summer of 2003, and by the end of this century, a summer as hot as that of 2003 will be considered unusually cool.[78]

Increased extremes of summer dryness and winter wetness are projected for much of the globe, meaning a generally greater risk of droughts and floods. This has already been observed,[55] and is projected to continue. In a warmer world, precipitation tends to be concentrated into heavier events, with longer dry periods in between.[90]

Models project a general tendency for more intense but fewer storms overall outside the tropics, with more extreme wind events and higher ocean waves in a number of regions in association with those

storms. Models also project a shift of storm tracks toward the poles in both hemispheres.[90]

Changes in hurricanes are difficult to project because there are countervailing forces. Higher ocean temperatures lead to stronger storms with higher wind speeds and more rainfall.[98] But changes in wind speed and direction with height are also projected to increase in some regions, and this tends to work against storm formation and growth.[99-101] It currently appears that stronger, more rain-producing tropical storms and hurricanes are generally more likely, though more research is required on these issues.[68] More discussion of Atlantic hurricanes, which most affect the United States, appears on page 34 in the *National Climate Change* section.

Sea level will continue to rise

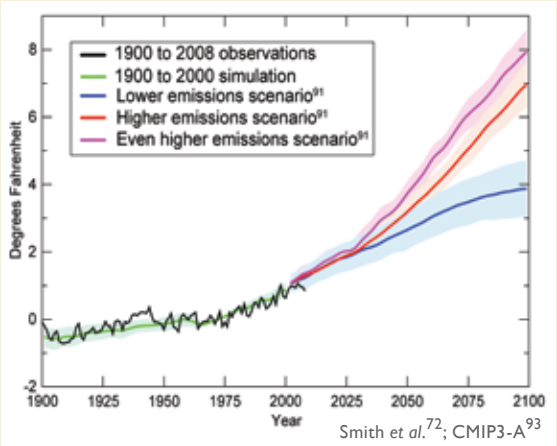
Projecting future sea-level rise presents special challenges. Scientists have a well-developed understanding of the contributions of thermal expansion and melting glaciers to sea-level rise, so the models used to project sea-level rise include these processes. However, the contributions to past and future sea-level rise from ice sheets are less well understood. Recent observations of the polar ice sheets show that a number of complex processes control the movement of ice to the sea, and thus affect the contributions of ice sheets to sea-level rise.[29] Some of these processes are already producing substantial loss of ice mass. Because these processes are not well understood it is difficult to predict their future contributions to sea-level rise.[102]

Because of this uncertainty, the 2007 assessment by the IPCC could not quantify the contributions to sea-level rise due to changes in ice sheet dynamics, and thus projected a rise of the world's oceans from 8 inches to 2 feet by the end of this century.[90]

More recent research has attempted to quantify the potential contribution to sea-level rise from the accelerated flow of ice sheets to the sea[27,42] or to estimate future sea level based on its observed relationship to temperature.[103] The resulting estimates exceed those of the IPCC, and the average estimates under higher emissions scenarios are for sea-level rise between 3 and 4 feet by the end of this century. An important question that is often asked is, what is the upper bound of sea-level rise expected over this century? Few analyses have focused on this question. There is some evidence to suggest that it would be virtually impossible to have a rise of sea level higher than about 6.5 feet by the end of this century.[42]

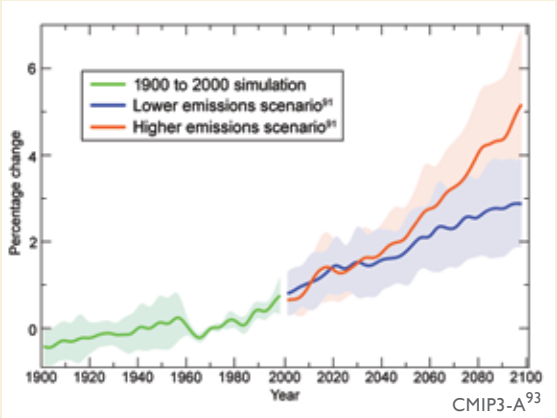
The changes in sea level experienced at any particular location along the coast depend not only on the increase in the global average sea level, but also on changes in regional currents and winds, proximity to the mass of melting ice sheets, and on the vertical movements of the land due to geological

Global Average Temperature
1900 to 2100



Observed and projected changes in the global average temperature under three IPCC no-policy emissions scenarios. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. A wider range of model types shows outcomes from 2 to 11.5°F.[90] Changes are relative to the 1960-1979 average.

Global Increase in Heavy Precipitation
1900 to 2100



Simulated and projected changes in the amount of precipitation falling in the heaviest 5 percent of daily events. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. Changes are relative to the 1960-1979 average.

forces.[104] The consequences of sea-level rise at any particular location depend on the amount of sea-level rise relative to the adjoining land. Although some parts of the U.S. coast are undergoing uplift (rising), most shorelines are subsiding (sinking) to various degrees – from a few inches to over 2 feet per century.

Abrupt climate change

There is also the possibility of even larger changes in climate than current scenarios and models project. Not all changes in the climate are gradual. The long record of climate found in ice cores, tree rings, and other natural records show that Earth's climate patterns have undergone rapid shifts from one stable state to another within as short a period as a decade. The occurrence of abrupt changes in climate becomes increasingly likely as the human disturbance of the climate system grows.[90] Such changes can occur so rapidly that they would challenge the ability of human and natural systems to adapt.[105] Examples of such changes are abrupt shifts in drought frequency and duration. Ancient climate records suggest that in the United States, the Southwest may be at greatest risk for this kind of change, but that other regions including the Midwest and Great Plains have also had these kinds of abrupt shifts in the past and could experience them again in the future.

Rapid ice sheet collapse with related sea-level rise is another type of abrupt change that is not well understood or modeled and that poses a risk for the future. Recent observations show that melting on the surface of an ice sheet produces water that flows down through large cracks that create conduits through the ice to the base of the ice sheet where it lubricates ice previously frozen to the rock below.[29] Further, the interaction with warm ocean water, where ice meets the sea, can lead to sudden losses in ice mass and accompanying rapid global sea-level rise. Observations indicate that ice loss has increased dramatically over the last decade, though scientists are not yet confident that they can project how the ice sheets will respond in the future.

There are also concerns regarding the potential for abrupt release of methane from thawing of frozen soils, from the sea floor, and from wetlands in the tropics and the Arctic. While analyses suggest that an abrupt release of methane is very unlikely to occur within 100 years, it is very likely that warming will accelerate the pace of chronic methane emissions from these sources, potentially increasing the rate of global temperature rise.[106]

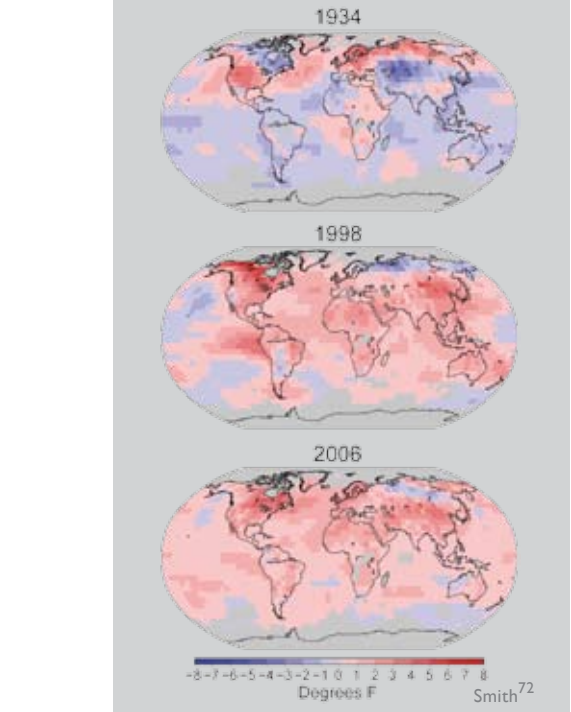
A third major area of concern regarding possible abrupt change involves the operation of the ocean currents that transport vast quantities of heat around the globe. One branch of the ocean circulation is in the North Atlantic. In this region, warm water flows northward from the tropics to the North Atlantic in the upper layer of the ocean, while cold water flows back from the North Atlantic to the tropics in the ocean's deep layers, creating a "conveyor belt" for heat. Changes in this circulation have profound impacts on the global climate system, from changes in African and Indian monsoon rainfall, to atmospheric circulation relevant to hurricanes, to changes in climate over North America and Western Europe.

Recent findings indicate that it is very likely that the strength of this North Atlantic circulation will decrease over the course of this century in response to increasing greenhouse gases. This is expected because warming increases the melting of glaciers and ice sheets and the resulting runoff of freshwater to the sea. This additional water is virtually salt-free, which makes it less dense than sea water. Increased precipitation also contributes fresh, less-dense water to the ocean. As a result, less surface water is dense enough to sink, thereby reducing the conveyor belt's transport of heat. The best estimate is that the strength of this circulation will decrease 25 to 30 percent in this century, leading to a reduction in heat transfer to the North Atlantic. It is considered very unlikely that this circulation would collapse entirely during the next 100 years or so, though it cannot be ruled out. While very unlikely, the potential consequences of such an abrupt event would be severe. Impacts would likely include sea-level rise around the North Atlantic of up to 2.5 feet (in addition to the rise expected from thermal expansion and melting glaciers and ice sheets), changes in atmospheric circulation conditions that influence hurricane activity, a southward shift of tropical rainfall belts with resulting agricultural impacts, and disruptions to marine ecosystems.[76]

National Climate Change

Key Messages:

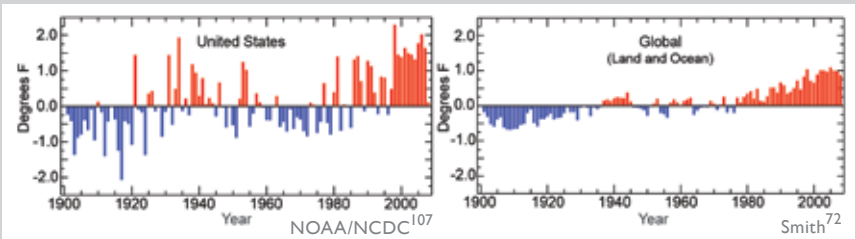
- U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heat-trapping gases emitted globally and how sensitive the climate is to those emissions.
- Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier.
- The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places.
- Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.
- The destructive energy of Atlantic hurricanes has increased in recent decades. The intensity of these storms is likely to increase in this century.
- In the eastern Pacific, the strongest hurricanes have become stronger since the 1980s, even while the total number of storms has decreased.
- Sea level has risen along most of the U.S. coast over the last 50 years, and will rise more in the future.
- Cold-season storm tracks are shifting northward and the strongest storms are likely to become stronger and more frequent.
- Arctic sea ice is declining rapidly and this is very likely to continue.



The maps show annual temperature difference from the 1961-1990 average for the 3 years that were the hottest on record in the United States: 1998, 1934 and 2006 (in rank order). Red areas were warmer than average, blue were cooler than average. The 1930s were very warm in much of the United States, but they were not unusually warm globally. On the other hand, the warmth of 1998 and 2006, as for most years in recent decades, has been global in extent.

Like the rest of the world, the United States has been warming significantly over the past 50 years in response to the build up of heat-trapping gases in the atmosphere. When looking at national climate, however, it is important to recognize that climate responds to local, regional, and global factors. Therefore, national climate varies more than the average global climate. While various parts of the world have had particularly hot or cold periods earlier in the historical record, these periods have not been global in scale, whereas the warming of recent decades has been global in scale – hence the term *global* warming. It is also important to recognize that at both the global and national scales, year-to-year fluctuations in natural weather and climate patterns can produce a period that does not follow the long-term trend. Thus, each year will not necessarily be warmer than every year before it, though the warming trend continues.

Annual Average Temperature
(Departure from the 1901-2000 Average)



From 1901 to 2008, each year's temperature departure from the long-term average is one bar, with blue bars representing years cooler than the long-term average and red bars representing years warmer than that average. National temperatures vary much more than global temperatures, in part because of the moderating influence of the oceans on global temperatures.

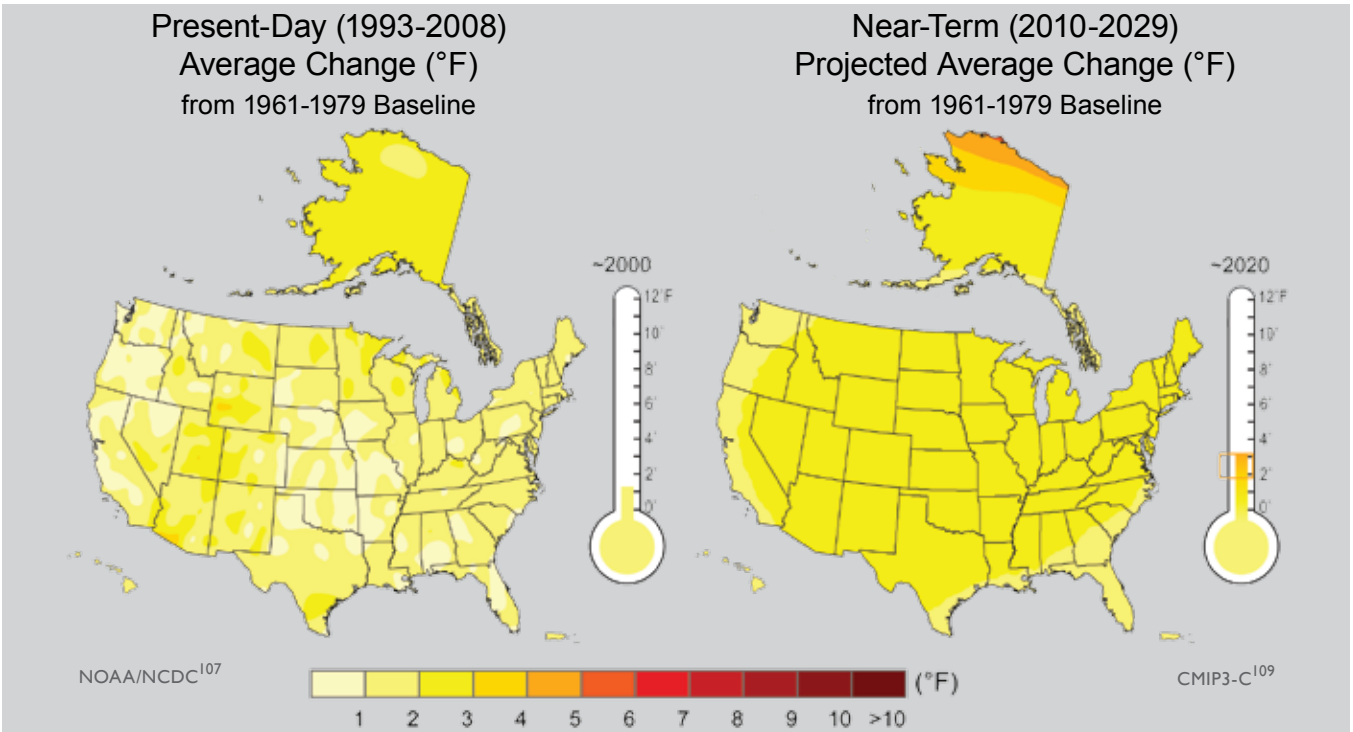
U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heat-trapping gases emitted globally and how sensitive the climate is to those emissions.

The series of maps and thermometers on these two pages shows the magnitude of the observed and projected changes in annual average temperature. The map for the period around 2000 shows that most areas of the United States have warmed 1 to 2°F compared to the 1960s and 1970s. Although not reflected in these maps of annual average temperature, this warming has generally resulted in longer warm seasons and shorter, less intense cold seasons.

The remaining maps show projected warming over the course of this century under a lower emissions scenario and a higher emissions scenario[91] (see *Global Climate Change* section, page 23). Temperatures will continue to rise throughout the century under both emissions scenarios,[91] although higher emissions result in more warming by the middle of the century and significantly more by the end of the century.

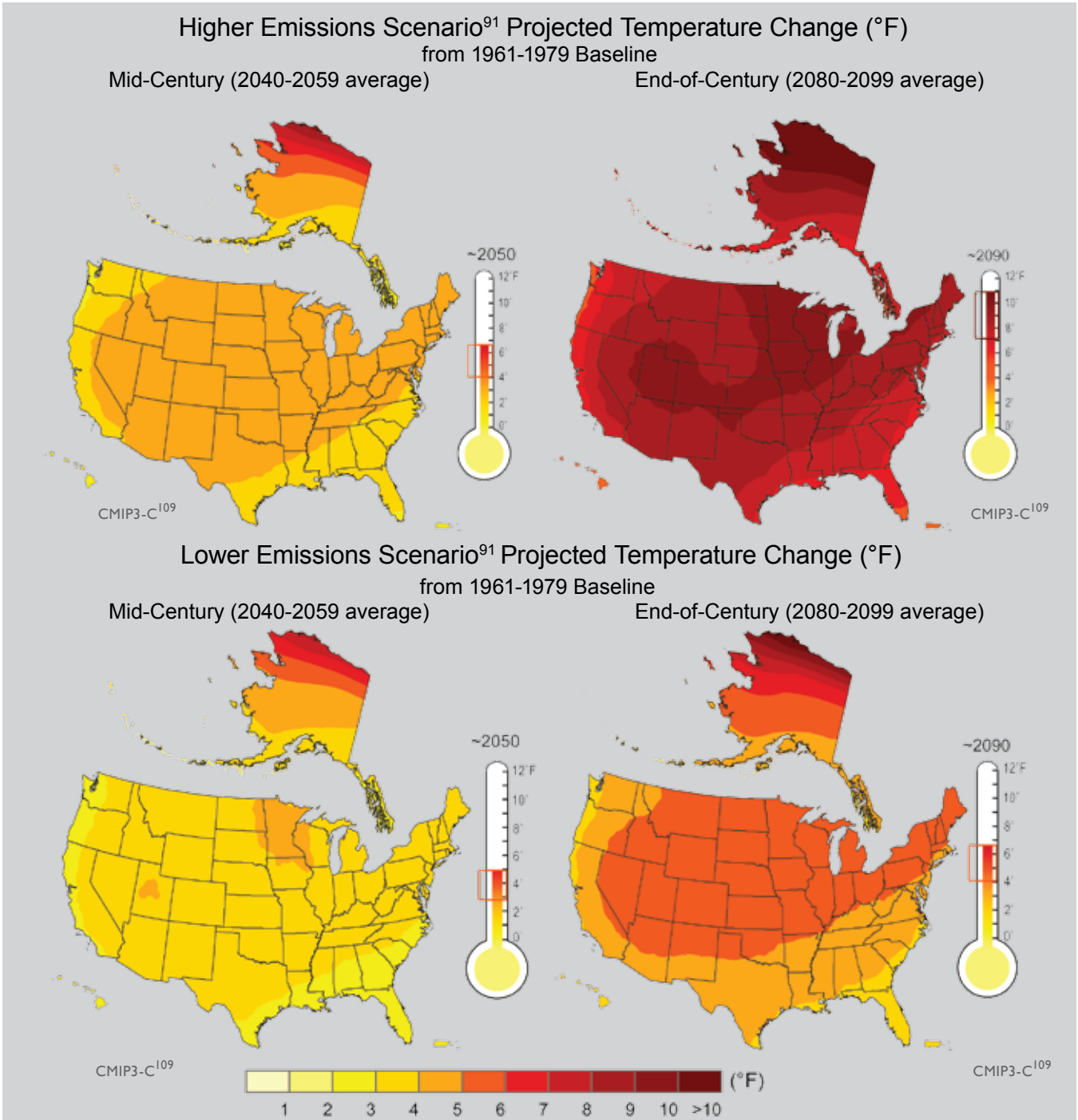
Temperature increases in the next couple of decades will be primarily determined by past emissions of heat-trapping gases. As a result, there is little difference in projected temperature between the higher and lower emissions scenarios[91] in the near-term (around 2020), so only a single map is shown for this timeframe. Increases after the next couple of decades will be primarily determined by future emissions.[90] This is clearly evident in greater projected warming in the higher emissions scenario[91] by the middle (around 2050) and end of this century (around 2090).

On a seasonal basis, most of the United States is projected to experience greater warming in summer than in winter, while Alaska experiences far more warming in winter than summer.[108]



The maps and thermometers on this page and the next page show temperature differences (either measured or projected) from conditions as they existed during the period from 1961-1979. Comparisons to this period are made because the influence on climate from increasing greenhouse gas emissions has been greatest during the past five decades. The present-day map is based on the average observed temperatures from 1993-2008 minus the average from 1961-1979. Projected temperatures are based on results from 16 climate models for the periods 2010-2029, 2040-2059, and 2080-2099. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. The mid-century and end-of-century maps show projections for both the higher and lower emission scenarios.[91] The projection for the near-term is the average of the higher and lower emission scenarios[91] because there is little difference in that timeframe.

The average warming for the country as a whole is shown on the thermometers adjacent to each map. By the end of the century, the average U.S. temperature is projected to increase by approximately 7 to 11°F under the higher emissions scenario[91] and by approximately 4 to 6.5°F under the lower emissions scenario.[91] These ranges are due to differences among climate model results for the same emissions scenarios. Emissions scenarios even lower than the lower scenario shown here, such as the 450 ppm stabilization scenario described on pages 23-24, would yield lower temperature increases than those shown below.[25]



The maps on this page and the previous page are based on projections of future temperature by 16 of the Coupled Model Intercomparison Project Three (CMIP3) climate models using two emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC), *Special Report on Emission Scenarios* (SRES).[91] The "lower" scenario here is B1, while the "higher" is A2.[91] The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. Additional information on these scenarios is on pages 22 and 23 in the previous section, *Global Climate Change*. These maps, and others in this report, show projections at national, regional, and sub-regional scales, using well-established techniques.[110]

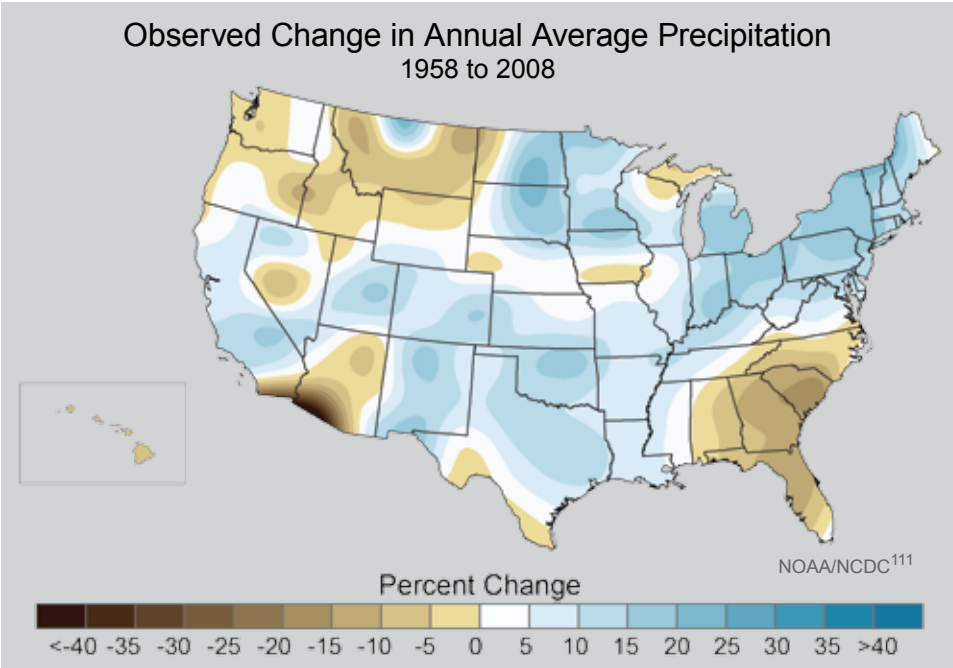
Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier.

While precipitation over the United States as a whole has increased, there have been important regional and seasonal differences. Increasing trends throughout much of the year have been predominant in the Northeast and large parts of the Plains and Midwest. Decreases occurred in much of the Southeast in all but the fall season and in the Northwest in all seasons except spring. Precipitation also generally decreased during the summer and fall in the Southwest, while winter and spring, which are the wettest seasons in states such as California and Nevada, have had increases in precipitation.[111]

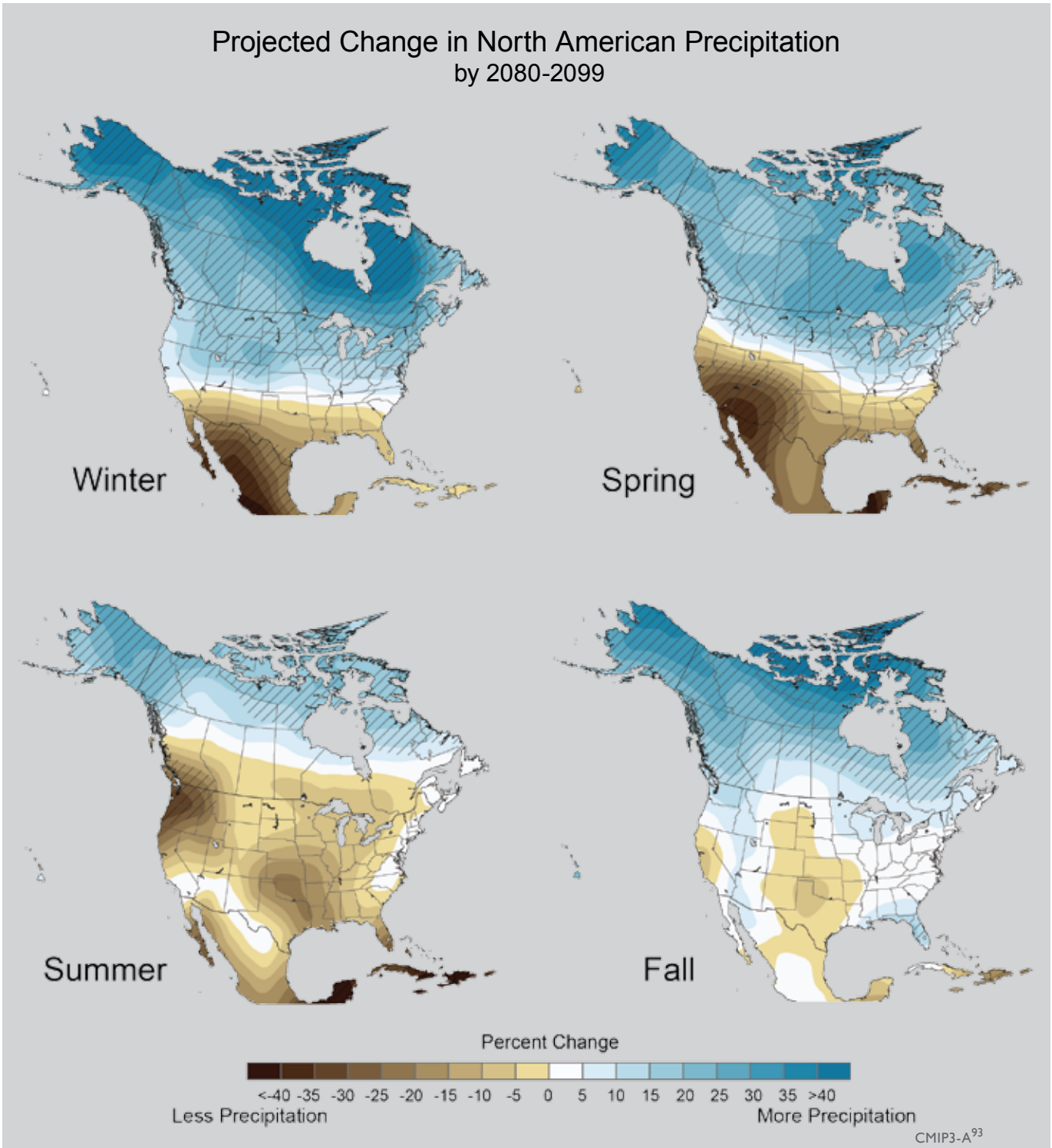
Future changes in total precipitation due to human-induced warming are more difficult to project than changes in temperature. In some seasons, some areas will experience an increase in precipitation, other areas will experience a decrease, and others will see little discernible change. The difficulty arises in predicting the extent of those areas and the amount of change. Model projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier.[97,108]

Confidence in projected changes is higher for winter and spring than for summer and fall. In winter and spring, northern areas are expected to receive significantly more precipitation than they do now, because the interaction of warm and moist air coming from the south with colder air from the north is projected to occur farther north than it did on average in the last century. The more northward incursions of warmer and moister air masses are expected to be particularly noticeable in northern regions that will change from very cold and dry atmospheric conditions to warmer but moister conditions.[68] Alaska, the Great Plains, the upper Midwest, and the Northeast are beginning to experience such changes for at least part of the year, with the likelihood of these changes increasing over time.

In some northern areas, warmer conditions will result in more precipitation falling as rain and less as snow. In addition, potential water resource benefits from increasing precipitation could be countered by the competing influences of increasing evaporation and runoff. In southern areas, significant reductions in precipitation are projected in winter and spring as the subtropical dry belt expands.[108] This is particularly pronounced in the Southwest, where it would have serious ramifications for water resources.

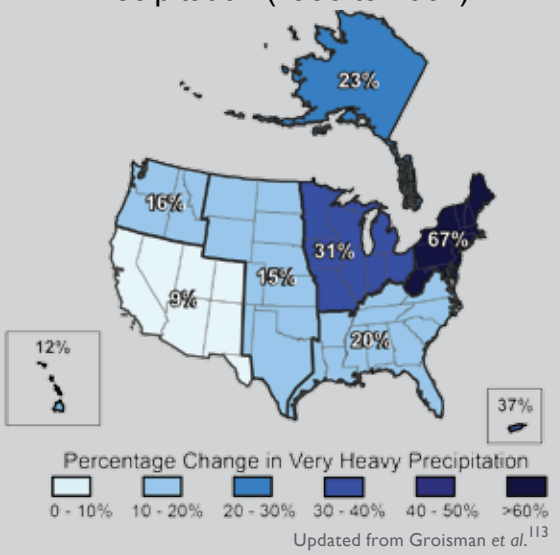


While U.S. annual average precipitation has increased about 5 percent over the past 50 years, there have been important regional differences as shown above.



The maps show projected future changes in precipitation relative to the recent past as simulated by 15 climate models. The simulations are for late this century, under a higher emissions scenario.[91] For example, in the spring, climate models agree that northern areas are likely to get wetter, and southern areas drier. There is less confidence in exactly where the transition between wetter and drier areas will occur. Confidence in the projected changes is highest in the hatched areas.

Increases in Amounts of Very Heavy Precipitation (1958 to 2007)



Updated from Groisman *et al.*[113]

The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places.

One of the clearest precipitation trends in the United States is the increasing frequency and intensity of heavy downpours. This increase was responsible for most of the observed increase in overall precipitation during the last 50 years. In fact, there has been little change or a decrease in the frequency of light and moderate precipitation during the past 30 years, while heavy precipitation has increased. In addition, while total average precipitation over the nation as a whole increased by about 7 percent over the past century, the amount of precipitation falling in the heaviest 1 percent of rain events increased nearly 20 percent.[112]

During the past 50 years, the greatest increases in heavy precipitation occurred in the Northeast and the Midwest. There have also been increases in heavy downpours in the other regions of the continental United States, as well as Alaska, Hawaii, and Puerto Rico.[112]

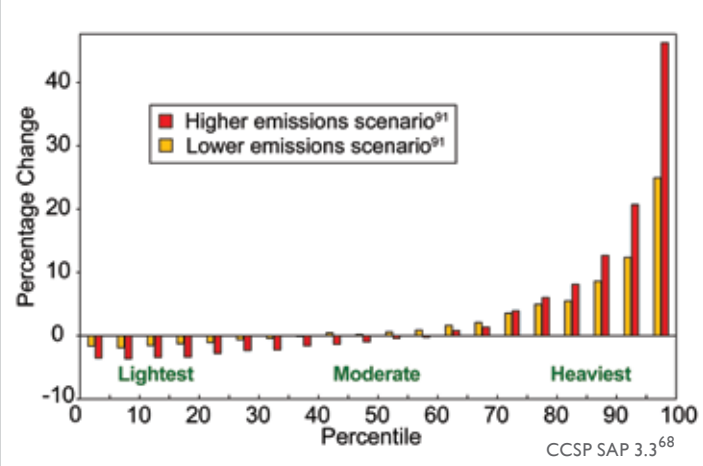
Climate models project continued increases in the heaviest downpours during this century, while the lightest precipitation is projected to decrease. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase. The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now.[112]

Changes in these kinds of extreme weather and climate events are among the most serious challenges to our nation in coping with a changing climate.

Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.

Many extremes and their associated impacts are now changing. For example, in recent decades most of North America has been experiencing more unusually hot days and nights, fewer unusually cold days and nights, and fewer frost days. Droughts are becoming more severe in some regions. The power and frequency of Atlantic hurricanes have increased substantially in recent decades. The number of North American mainland landfalling hurricanes does

Projected Changes in Light, Moderate, and Heavy Precipitation (by 2090s)



The figure shows projected changes from the 1990s average to the 2090s average in the amount of precipitation falling in light, moderate, and heavy events in North America. Projected changes are displayed in 5 percent increments from the lightest drizzles to the heaviest downpours. As shown here, the lightest precipitation is projected to decrease, while the heaviest will increase, continuing the observed trend. The higher emission scenario[91] yields larger changes. Projections are based on the models used in the IPCC 2007 Fourth Assessment Report.

not appear to have increased over the past century. Outside the tropics, cold-season storm tracks are shifting northward and the strongest storms are becoming even stronger. These trends in storms outside the tropics are projected to continue throughout this century.[68,112,114]

Drought

Like precipitation, trends in drought have strong regional variations. In much of the Southeast and large parts of the West, the frequency of drought has increased coincident with rising temperatures over the past 50 years. In other regions, such as the Midwest and Great Plains, there has been a reduction in drought frequency.

Although there has been an overall increase in precipitation and no clear trend in drought for the nation as a whole, increasing temperatures have made droughts more severe and widespread than they would have otherwise been. Without the observed increase in precipitation, higher temperatures would have led to an increase in the area of the contiguous United States in severe to extreme drought, with some estimates of a 30 percent increase.[112] In the future, droughts are likely to become more frequent and severe in some regions.[68] The Southwest, in particular, is expected to experience increasing drought as changes in atmospheric circulation patterns cause the dry zone just outside the tropics to expand farther northward into the United States.[97]

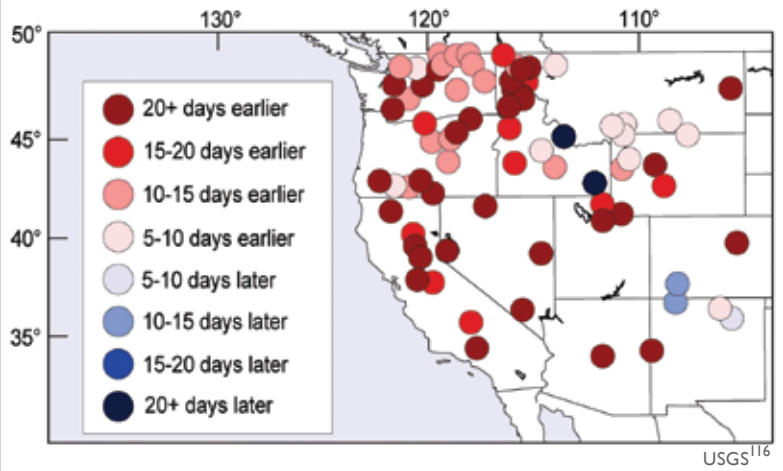
Rising temperatures have also led to earlier melting of the snowpack in the western United States.[40] Because snowpack runoff is critical to the water resources in the western United States, changes in the timing and amount of runoff can exacerbate problems with already limited water supplies in the region.

Heat waves

A heat wave is a period of several days to weeks of abnormally hot weather, often with high humidity. During the 1930s, there was a high frequency of heat waves due to high daytime temperatures resulting in large part from an extended multi-year period of intense drought. By contrast, in the past 3 to 4 decades, there has been an increasing trend in high-humidity heat waves, which are characterized by the persistence of extremely high nighttime temperatures.[112]

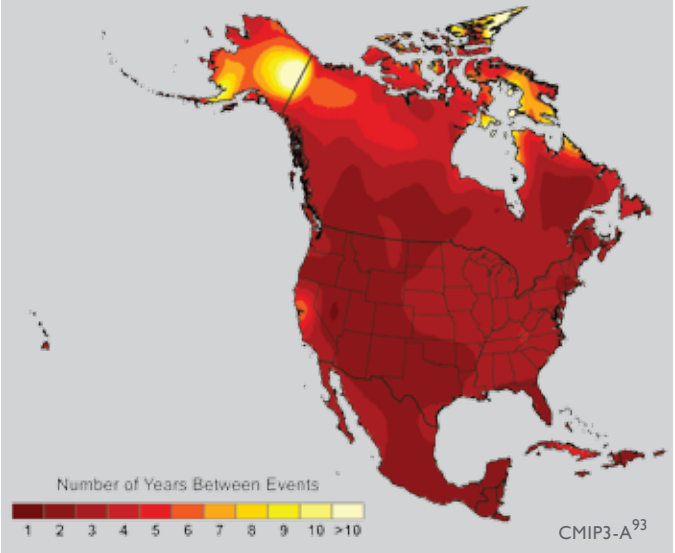
As average temperatures continue to rise throughout this century, the frequency of cold extremes will decrease and the frequency and intensity of high temperature extremes will increase.[115] The number of days with high temperatures above

Observed Spring Snowmelt Dates

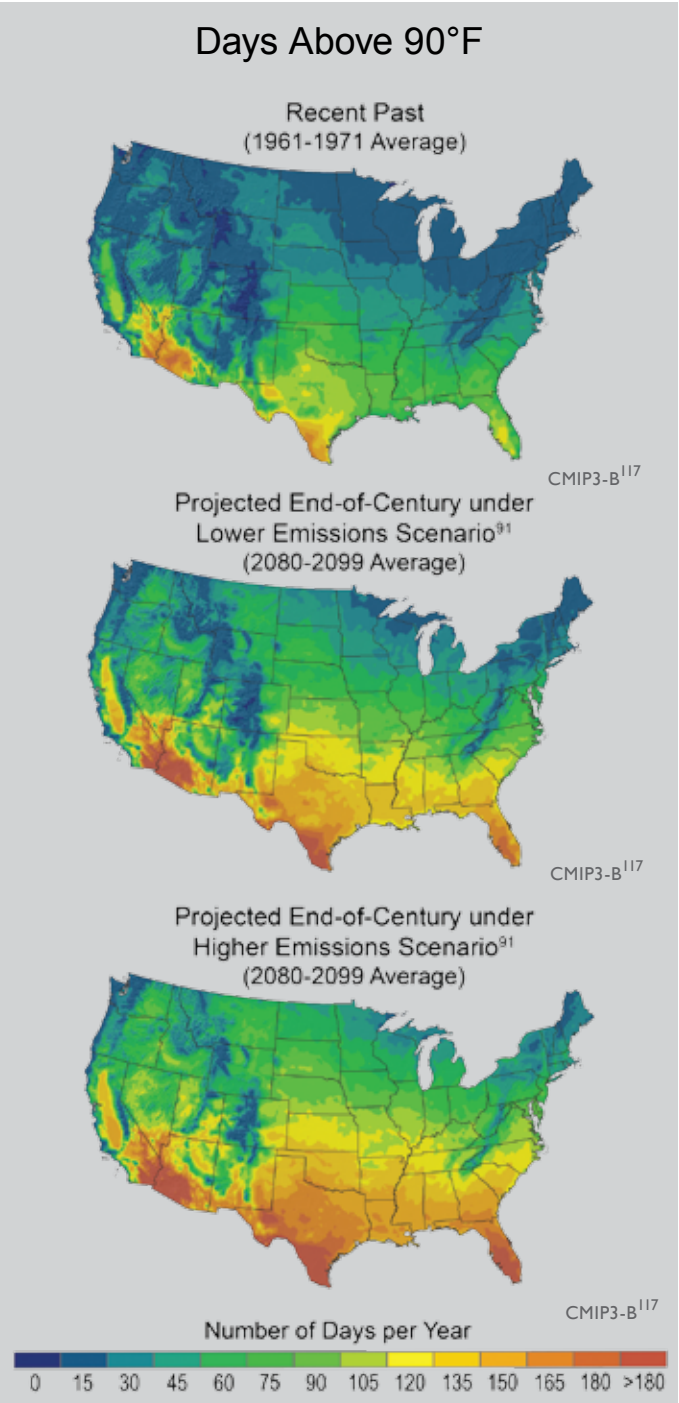


Date of onset of spring runoff pulse. Reddish-brown circles indicate significant trends toward onsets more than 20 days earlier. Lighter circles indicate less advance of the onset. Blue circles indicate later onset. The changes depend on a number of factors in addition to temperature, including altitude and timing of snowfall.

Projected Frequency of Extreme Heat
(2080-2099 Average)



Simulations for 2080-2099 indicate how currently rare extremes (a 1-in-20-year event) are projected to become more commonplace. A day so hot that it is currently experienced once every 20 years would occur every other year or more frequently by the end of the century under the higher emissions scenario.[91]



The average number of days per year when the maximum temperature exceeded 90°F from 1961-1979 (top) and the projected number of days per year above 90°F by the 2080s and 2090s for lower emissions (middle) and higher emissions (bottom).[91] Much of the southern United States is projected to have more than twice as many days per year above 90°F by the end of this century.

90°F is projected to increase throughout the country as illustrated in the maps on the left. Parts of the South that currently have about 60 days per year with temperatures over 90°F are projected to experience 150 or more days a year above 90°F by the end of this century, under a higher emissions scenario.[91] There is higher confidence in the regional patterns than in results for any specific location (see *An Agenda for Climate Impacts Science* section).

With rising high temperatures, extreme heat waves that are currently considered rare will occur more frequently in the future. Recent studies using an ensemble of models show that events that now occur once every 20 years are projected to occur about every other year in much of the country by the end of this century. In addition to occurring more frequently, at the end of this century these very hot days are projected to be about 10°F hotter than they are today.[68]

The destructive energy of Atlantic hurricanes has increased in recent decades. The intensity of these storms is likely to increase in this century.

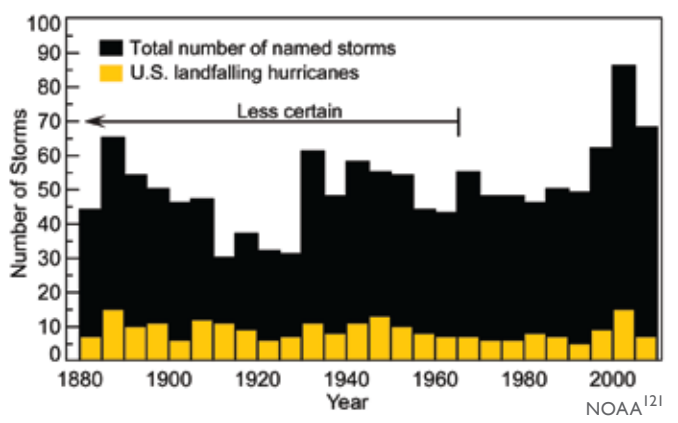
Of all the world's tropical storm and hurricane basins, the North Atlantic has been the most thoroughly monitored and studied. The advent of routine aircraft monitoring in the 1940s and the use of satellite observations since the 1960s have greatly aided monitoring of tropical storms and hurricanes. In addition, observations of tropical storm and hurricane strength made from island and mainland weather stations and from ships at sea began in the 1800s and continue today. Because of new and evolving observing techniques and technologies, scientists pay careful attention to ensuring consistency in tropical storm and hurricane records from the earliest manual observations to today's automated measurements. This is accomplished through collection, analysis, and cross-referencing of data from numerous sources and, where necessary, the application of adjustment techniques to account for differences in observing and reporting methodologies through time. Nevertheless, data uncertainty is larger in the early part of the record. Confidence in the tropical storm and hurricane record increases after 1900 and is greatest during the satellite era, from 1965 to the present.[112]

The total number of hurricanes and strongest hurricanes (Category 4 and 5) observed from 1881 through 2008 shows multi-decade periods of above average activity in the 1800s, the mid-1900s, and since 1995. The power and frequency of Atlantic hurricanes have increased substantially in recent decades.[112] There has been little change in the total number of landfalling hurricanes, in part because a variety of factors affect whether a hurricane will make landfall. These include large-scale steering winds, atmospheric stability, wind shear, and ocean heat content. This highlights the importance of understanding the broader changes occurring throughout the Atlantic Basin beyond the storms making landfall along the U.S. coast.[112]

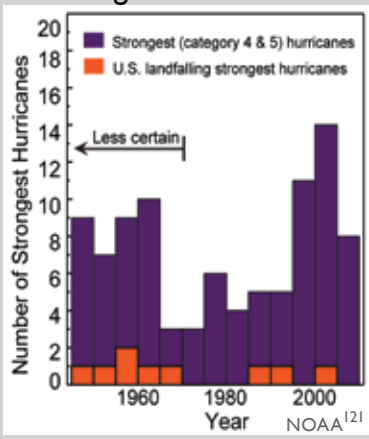
Tropical storms and hurricanes develop and gain strength over warm ocean waters. As oceans warm, they provide a source of energy for hurricane growth. During the past 30 years, annual sea surface temperatures in the main Atlantic hurricane development region increased nearly 2°F. This warming coincided with an increase in the destructive energy (as defined by the Power Dissipation Index, a combination of intensity, duration, and frequency) of Atlantic tropical storms and hurricanes. The strongest hurricanes (Category 4 and 5) have, in particular, increased in intensity.[112] The graph below shows the strong correlation between hurricane power and sea surface temperature in the Atlantic and the overall increase in both during the past 30 years. Climate models project that hurricane intensity will continue to increase, though at a lesser rate than that observed in recent decades.[100]

New evidence has emerged recently for other temperature related linkages that can help

Atlantic Tropical Storms and Hurricanes

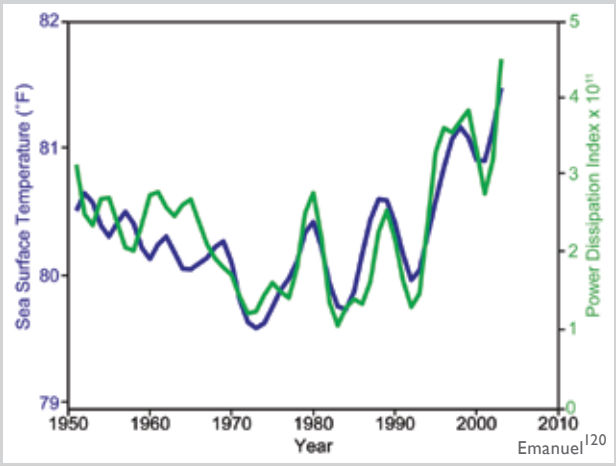


Atlantic Basin Strongest Hurricanes



Top: Total numbers of North Atlantic named storms (tropical storms and hurricanes) (black) and total U.S. landfalling hurricanes (yellow) in 5-year periods based on annual data from 1881 to 2008. The bar for the last 5-year period is based on the assumption that the level of activity from 2006 to 2008 persists through 2010. In the era before satellites, indicated by the arrow above, the total number of named storms is less certain and has been adjusted upward to account for missing storms. Adjustments are based on relationships established during the satellite era between the number of observed storms and the number that would have been missed if satellite data had not been available.
Bottom: Total number of strongest (Category 4 and 5) North Atlantic basin hurricanes (purple) and strongest U.S. landfalling hurricanes (orange) in 5-year periods based on annual data from 1946 to 2008. The bar for the last 5-year period is based on the assumption that the level of activity from 2006 to 2008 persists through 2010. From 1946 to the mid-1960s, as indicated by the arrow above, hurricane intensity was measured primarily by aircraft reconnaissance. Data prior to aircraft reconnaissance are not shown due to the greater uncertainty in estimates of a hurricane's maximum intensity. Satellites have increased the reliability of hurricane intensity estimates since the mid-1960s.

Observed Relationship Between Sea Surface Temperatures and Hurricane Power in the North Atlantic Ocean



Observed sea surface temperature (blue) and the Power Dissipation Index (green), which combines frequency, intensity and duration for North Atlantic hurricanes.[120] Hurricane rainfall and wind speeds are likely to increase in response to human-caused warming. Analyses of model simulations suggest that for each 1.8°F increase in tropical sea surface temperatures, rainfall rates will increase by 6 to 18 percent.[68]

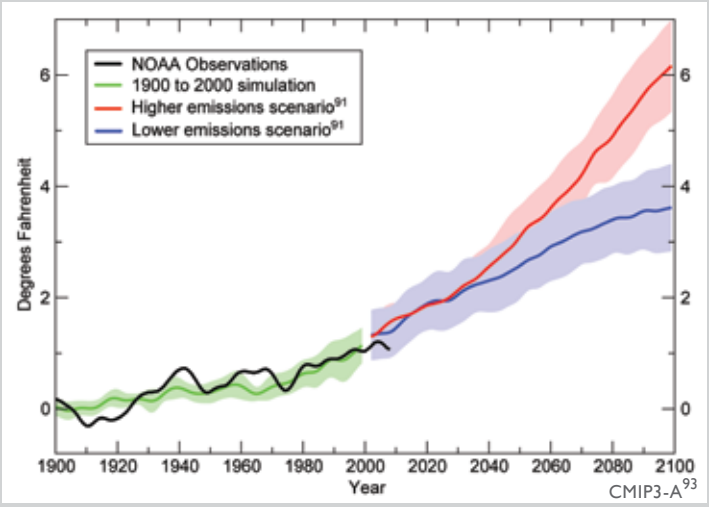
explain the increase in Atlantic hurricane activity. This includes the contrast in sea surface temperature between the main hurricane development region and the broader tropical ocean.[99,118,119] Other causes beyond the rise in ocean temperature, such as atmospheric stability and circulation, can also influence hurricane power. For these and other reasons, a confident assessment requires further study.[68]

Evidence of increasing hurricane strength in the Atlantic and other oceans with linkages to rising sea surface temperatures is also supported by satellite records dating back to 1981. An increase in the maximum wind speeds of the strongest hurricanes has been documented and linked to increasing sea surface temperatures.[122]

Projections are that sea surface temperatures in the main Atlantic hurricane development region will increase at even faster rates during the second half of this century under higher emissions scenarios. This highlights the need to better understand the relationship between increasing temperatures and hurricane intensity. As ocean temperatures continue to increase in the future, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming.[68] Analyses of model simulations suggest that for each 1.8°F increase in tropical sea surface temperatures, core rainfall rates will increase by 6 to 18 percent and the surface wind speeds of the strongest hurricanes will increase by about 1 to 8 percent.[114] Even without further coastal development, storm surge levels and hurricane damages are likely to increase because of increasing hurricane intensity coupled with sea-level rise, the latter being a virtually certain outcome of the warming global climate.[68]

Observed and Projected Sea Surface Temperature Change

Atlantic Hurricane Formation Region



Observed (black) and projected temperatures (blue = lower scenario; red = higher scenario) in the Atlantic hurricane formation region. Increased intensity of hurricanes is linked to rising sea surface temperatures in the region of the ocean where hurricanes form. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models.

In the eastern Pacific, the strongest hurricanes have become stronger since the 1980s, even while the total number of storms has decreased.

Although on average more hurricanes form in the eastern Pacific than the Atlantic each year, cool ocean waters along the U.S. West Coast and atmospheric steering patterns help protect the contiguous U.S. from landfalls. Threats to the Hawaiian Islands are greater, but landfalling storms are rare in comparison to those of the U.S. East and Gulf Coasts. Nevertheless, changes in hurricane intensity and frequency could influence the impact of landfalling Pacific hurricanes in the future.

The total number of tropical storms and hurricanes in the eastern Pacific on seasonal to multi-decade time periods is generally opposite to that observed in the Atlantic. For example, during El Niño events it is common for hurricanes in the Atlantic to be suppressed while the eastern Pacific is more active. This reflects the large-scale atmospheric circulation patterns that extend across both the Atlantic and the Pacific oceans.[123,124]

Within the past three decades the total number of tropical storms and hurricanes and their destructive energy have decreased in the eastern Pacific.[68,124] However, satellite observations have shown that like the Atlantic, the strongest hurricanes (the top 5 percent), have gotten stronger since the early 1980s.[122,125] As ocean temperatures rise, the strongest hurricanes are likely to increase in both the eastern Pacific and the Atlantic.[68]

Sea level has risen along most of the U.S. coast over the past 50 years, and will rise more in the future.

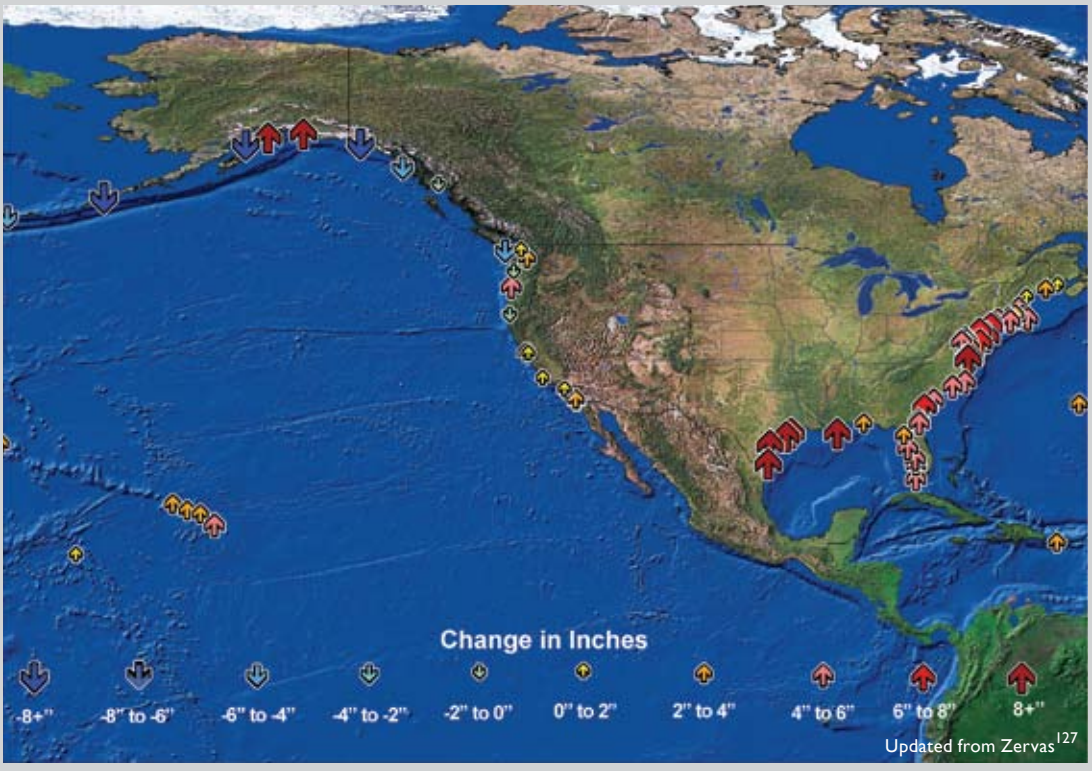
Recent global sea-level rise has been caused by the warming-induced expansion of the oceans, accelerated melting of most of the world's glaciers, and loss of ice on the Greenland and Antarctic ice sheets.[37] There is strong evidence that global sea level is currently rising at an increased rate.[37,126] A warming global climate will cause further sea-level rise over this century and beyond.[90,105]

During the past 50 years, sea level has risen up to 8 inches or more along some coastal areas of the United States, and has fallen in other locations. The amount of relative sea-level rise experienced along different parts of the U.S. coast depends on the changes in elevation of the land that occur as a result of subsidence (sinking) or uplift (rising), as well as increases in global sea level due to warming. In addition, atmospheric and oceanic circulation, which will be affected by climate change, will influence regional sea level. Regional differences in sea-level rise are also expected to be related to where the meltwater originates.[104]

Human-induced sea-level rise is occurring globally. Large parts of the Atlantic Coast and Gulf of Mexico Coast have experienced significantly higher rates of relative sea-level rise than the global average during the last 50 years, with the local differences mainly due to land subsidence.[127] Portions of the Northwest and Alaska coast have, on the other hand, experienced slightly falling sea level as a result of long-term uplift as a consequence of glacier melting and other geological processes.

Regional variations in relative sea-level rise are expected in the future. For example, assuming historical geological forces continue, a 2-foot rise in global sea level (which is within the range of recent estimates) by the end of this century would result in a relative sea-level rise of 2.3 feet at New York City, 2.9 feet at Hampton Roads, Virginia, 3.5 feet at Galveston, Texas, and 1 foot at Neah Bay in Washington state.[128]

Relative Sea-Level Changes on U.S. Coastlines, 1958 to 2008



Observed changes in relative sea level from 1958 to 2008 for locations on the U.S. coast. Some areas along the Atlantic and Gulf coasts saw increases greater than 8 inches over the past 50 years.

Cold-season storm tracks are shifting northward and the strongest storms are likely to become stronger and more frequent.

Large-scale storm systems are the dominant weather phenomenon during the cold season in the United States. Although the analysis of these storms is complicated by a relatively short length of most observational records and by the highly variable nature of strong storms, some clear patterns have emerged.[112]

Storm tracks have shifted northward over the last 50 years as evidenced by a decrease in the frequency of storms in mid-latitude areas of the Northern Hemisphere, while high-latitude activity has increased. There is also evidence of an increase in the intensity of storms in both the mid- and high-latitude areas of the Northern Hemisphere, with greater confidence in the increases occurring in high latitudes.[112] The northward shift is projected to continue, and strong cold season storms are likely to become stronger and more frequent, with greater wind speeds and more extreme wave heights.[68]

Snowstorms

The northward shift in storm tracks is reflected in regional changes in the frequency of snowstorms. The South and lower Midwest saw reduced snowstorm frequency during the last century. In contrast, the Northeast and upper Midwest saw increases in snowstorms, although considerable decade-to-decade variations were present in all regions, influenced, for example, by the frequency of El Niño events.[112]

There is also evidence of an increase in lake-effect snowfall along and near the southern and eastern shores of the Great Lakes since 1950.[97] Lake-effect snow is produced by the strong flow of cold air across large areas of relatively warmer ice-free water. As the climate has warmed, ice coverage on the Great Lakes has fallen. The maximum seasonal coverage of Great Lakes ice decreased at a rate of 8.4 percent per decade from 1973 through 2008, amounting to a roughly 30 percent decrease in ice coverage (see *Midwest* region). This has created conditions conducive to greater evaporation of moisture and thus heavier snowstorms. Among recent extreme lake-effect snow events was a February 2007 10-day storm total of over 10 feet of snow in western New York state. Climate models suggest that lake-effect snowfalls are likely to increase over the next few decades.[130] In the longer term, lake-effect snows are likely to decrease as temperatures continue to rise, with the precipitation then falling as rain.[129]

Areas in New York state east of Lake Ontario received over 10 feet of lake-effect snow during a 10-day period in early February 2007.

Tornadoes and severe thunderstorms

Reports of severe weather including tornadoes and severe thunderstorms have increased during the past 50 years. However, the increase in the number of reports is widely believed to be due to improvements in monitoring technologies such as Doppler radars combined with changes in population and increasing public awareness. When adjusted to account for these factors, there is no clear trend in the frequency or strength of tornadoes since the 1950s for the United States as a whole.[112]

The distribution by intensity for the strongest 10 percent of hail and wind reports is little changed, providing no evidence of an observed increase in the severity of events.[112] Climate models project future increases in the frequency of environmental conditions favorable to severe thunderstorms.[131] But the inability to adequately model the small-scale conditions involved in thunderstorm development remains a limiting factor in projecting the future character of severe thunderstorms and other small-scale weather phenomena.[68]

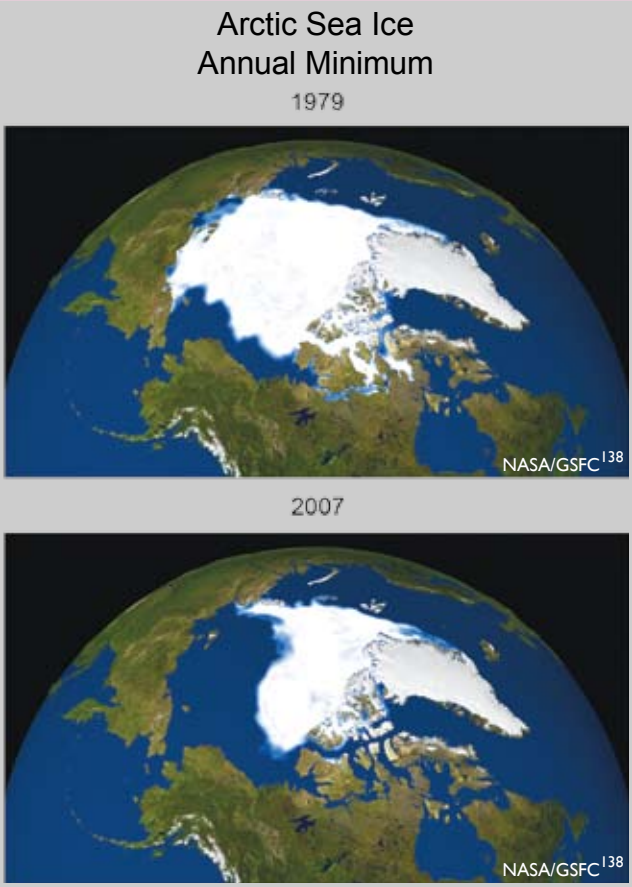
Arctic sea ice is declining rapidly and this is very likely to continue.

Sea ice is a very important part of the climate system. In addition to direct impacts on coastal areas of Alaska, it more broadly affects surface reflectivity, ocean currents, cloudiness, humidity, and the exchange of heat and moisture at the ocean's surface. Open ocean water is darker in color than sea ice, which causes it to absorb more of the Sun's heat, which increases the warming of the water even more.[40,132]

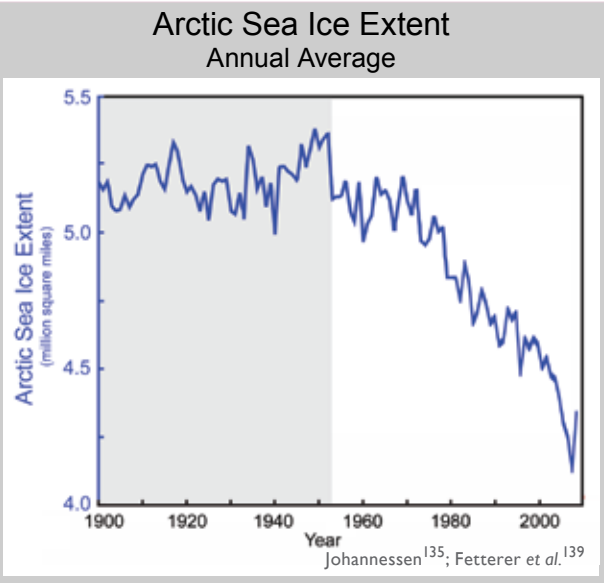
The most complete record of sea ice is provided by satellite observations of sea ice extent since the 1970s. Prior to that, aircraft, ship, and coastal observations in the Arctic make it possible to extend the record of Northern Hemisphere sea ice extent back to at least 1900, although there is a lower level of confidence in the data prior to 1953.[40]

Arctic sea ice extent has fallen at a rate of 3 to 4 percent per decade over the last three decades. End-of-summer Arctic sea ice has fallen at an even faster rate of more than 11 percent per decade in that time. The observed decline in Arctic sea ice has been more rapid than projected by climate models.[133] Year-to-year changes in sea ice extent and record low amounts are influenced by natural variations in atmospheric pressure and wind patterns.[134] However, clear linkages between rising greenhouse gas concentrations and declines in Arctic sea ice have been identified in the climate record as far back as the early 1990s.[61] The extreme loss in Arctic sea ice that occurred in 2007 would not have been possible without the long-term reductions that have coincided with a sustained increase in the atmospheric concentration of carbon dioxide and the rapid rise in global temperatures that have occurred since the mid-1970s.[135] Although the 2007 record low was not eclipsed in 2008, the 2008 sea ice extent is well below the long-term average, reflecting a continuation of the long-term decline in Arctic sea ice. In addition, the total volume of Arctic sea ice in 2008 was likely a record low because the ice was unusually thin.[136]

It is expected that declines in Arctic sea ice will continue in the coming decades with year-to-year fluctuations influenced by natural atmospheric variability. The overall rate of decline will be influenced mainly by the rate at which carbon dioxide and other greenhouse gas concentrations increase.[137]



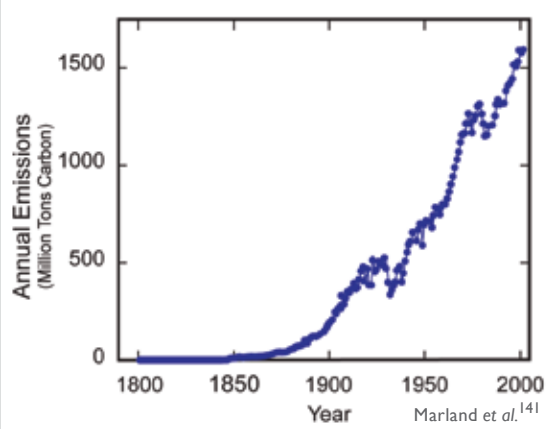
Arctic sea ice reaches its annual minimum in September. The satellite images above show September Arctic sea ice in 1979, the first year these data were available, and 2007.



Observations of annual average Arctic sea ice extent for the period 1900 to 2008. The gray shading indicates less confidence in the data before 1953.

U.S. Emission and Absorption of Heat-Trapping Gases

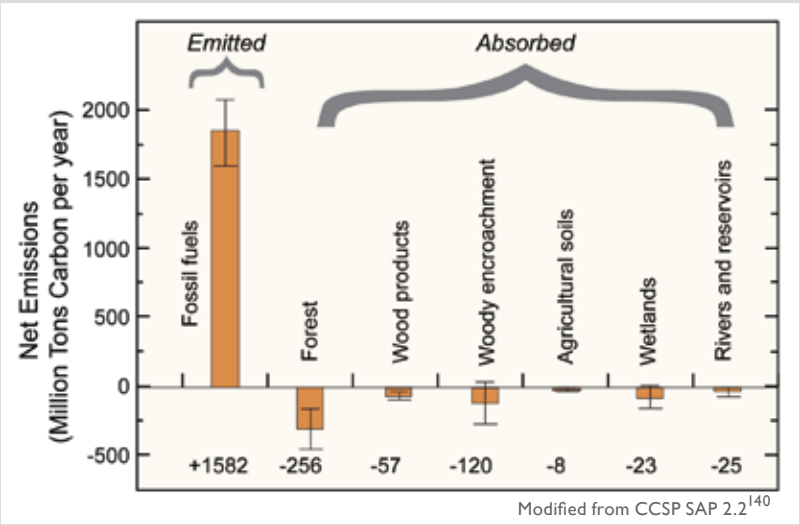
Since the industrial revolution, the United States has been the world's largest emitter of heat-trapping gases. With 4.5 percent of world's population, the United States is responsible for about 28 percent of the human-induced heat-trapping gases in the atmosphere today.[136] Although China has recently surpassed the United States in current total annual emissions, per capita emissions remain much higher in the United States. Carbon dioxide, the most important of the heat-trapping gases produced directly by human activities, is a cumulative problem because it has a long atmospheric lifetime. Roughly one-half of the carbon dioxide released from fossil fuel burning remains in the atmosphere after 100 years, and roughly one-fifth of it remains after 1,000 years.[90]



U.S. annual emissions of CO_2 from fossil-fuel use.[141]

U.S. carbon dioxide emissions grew dramatically over the past century. These emissions come almost entirely from burning fossil fuels. These sources of carbon dioxide are one side of the equation and on the other side are "sinks" that take up carbon dioxide. The growth of trees and other plants is an important natural carbon sink. In recent years, it is estimated that about 20 percent of U.S. carbon dioxide emissions have been offset by U.S. forest growth and other sinks (see figure below).[140] It is not known whether U.S. forests and other sinks will continue to take up roughly this amount of carbon dioxide in the future as climate change alters carbon release and uptake. For example, a warming-induced lengthening of the growing season would tend to increase carbon uptake. On the other hand, the increases in forest fires and in the decomposition rate of dead plant matter would decrease uptake, and might convert the carbon sink into a source.[140]

The amount of carbon released and taken up by natural sources varies considerably from year to year depending on climatic and other conditions. For example, fires release carbon dioxide, so years with many large fires result in more carbon release and less uptake as natural sinks (the vegetation) are lost. Similarly, the trees destroyed by intense storms or droughts release carbon dioxide as they decompose, and the loss results in reduced strength of natural sinks until regrowth is well underway. For example, Hurricane Katrina killed or severely damaged over 320 million large trees. As these trees decompose over the next few years, they will release an amount of carbon dioxide equivalent to that taken up by all U.S. forests in a year.[112] The net change in carbon storage in the long run will depend on how much is taken up by the regrowth as well as how much was released by the original disturbance.



U.S. carbon dioxide emissions and uptake in millions of tons of carbon per year in 2003. The bar marked "Emitted" indicates the amount of carbon as carbon dioxide added to the atmosphere from U.S. emissions. The bars marked "Absorbed" indicate amounts of carbon as carbon dioxide removed from the atmosphere. The thin lines on each bar indicate estimates of uncertainty.

Water Resources

Key Messages:

- Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses.
- Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between).
- Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer.
- In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer.
- Surface water quality and groundwater quantity will be affected by a changing climate.
- Climate change will place additional burdens on already stressed water systems.
- The past century is no longer a reasonable guide to the future for water management.

Changes in the water cycle, which are consistent with the warming observed over the past several decades, include:

- changes in precipitation patterns and intensity
- changes in the incidence of drought
- widespread melting of snow and ice
- increasing atmospheric water vapor
- increasing evaporation
- increasing water temperatures
- reductions in lake and river ice
- changes in soil moisture and runoff

For the future, marked regional differences are projected, with increases in annual precipitation, runoff, and soil moisture in much of the Midwest and Northeast, and declines in much of the West, especially the Southwest.

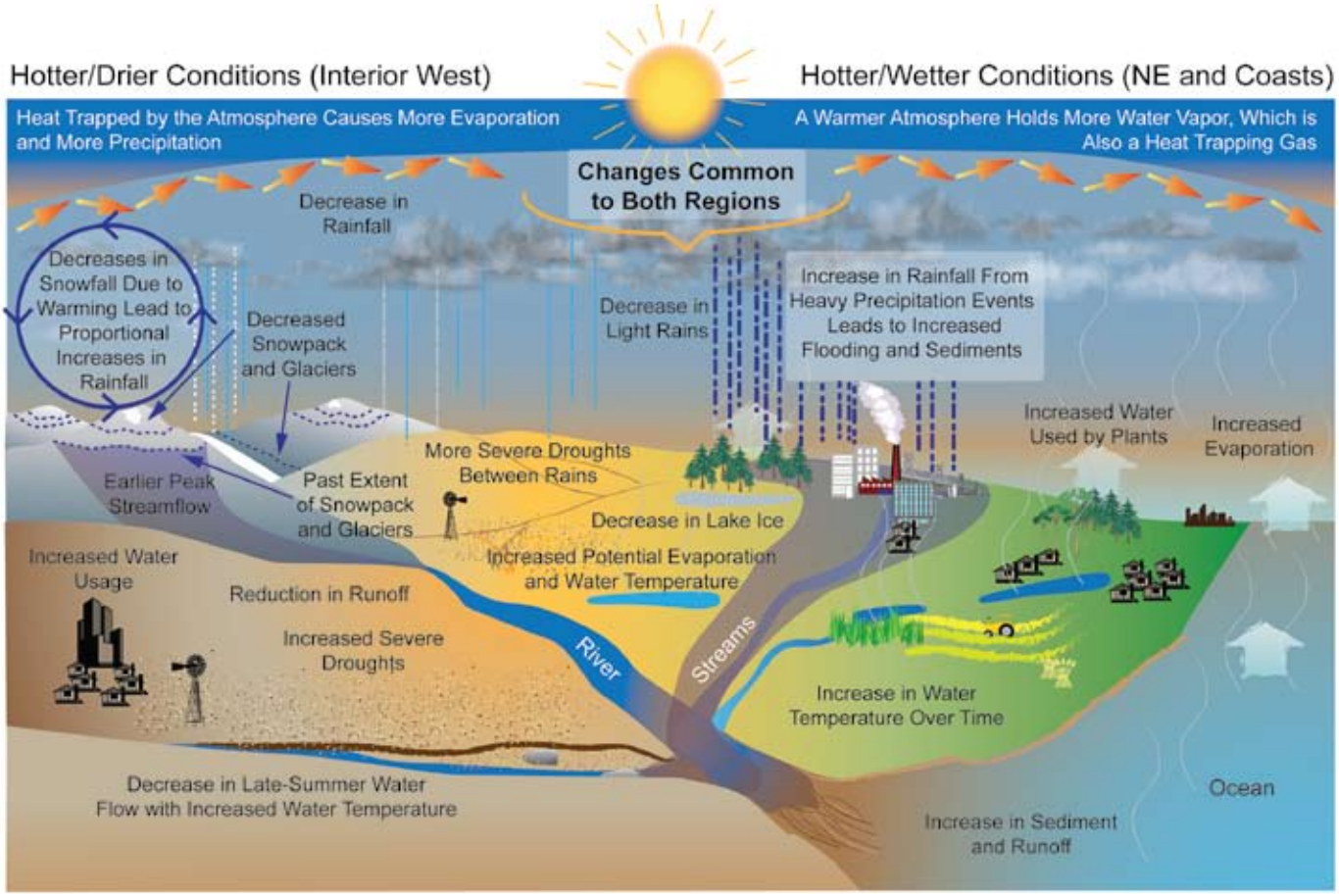
Skagit River and surrounding mountains in the Northwest

The impacts of climate change include too little water in some places, too much water in other places, and degraded water quality. Some locations are expected to be subject to all of these conditions during different times of the year. Water cycle changes are expected to continue and to adversely affect energy production and use, human health, transportation, agriculture, and ecosystems (see table on page 50).[142]

Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses.

Substantial changes to the water cycle are expected as the planet warms because the movement of water in the atmosphere and oceans is one of the primary mechanisms for the redistribution of heat around the world. Evidence is mounting that human-induced climate change is already altering many of the existing patterns of precipitation in the United States, including when, where, how much, and what kind of precipitation falls.[68,142] A warmer climate increases evaporation of water from land and sea, and allows more moisture to be held in the atmosphere. For every 1°F rise in temperature, the water holding capacity of the atmosphere increases by about 4 percent.[49]

Projected Changes in the Water Cycle



The water cycle exhibits many changes as the Earth warms. Wet and dry areas respond differently. NOAA/NCDC

In addition, changes in atmospheric circulation will tend to move storm tracks northward with the result that dry areas will become drier and wet areas wetter. Hence, the arid Southwest is projected to experience longer and more severe droughts from the combination of increased evaporation and reductions in precipitation.[108]

Changes in Snowfall Contributions to Wintertime Precipitation

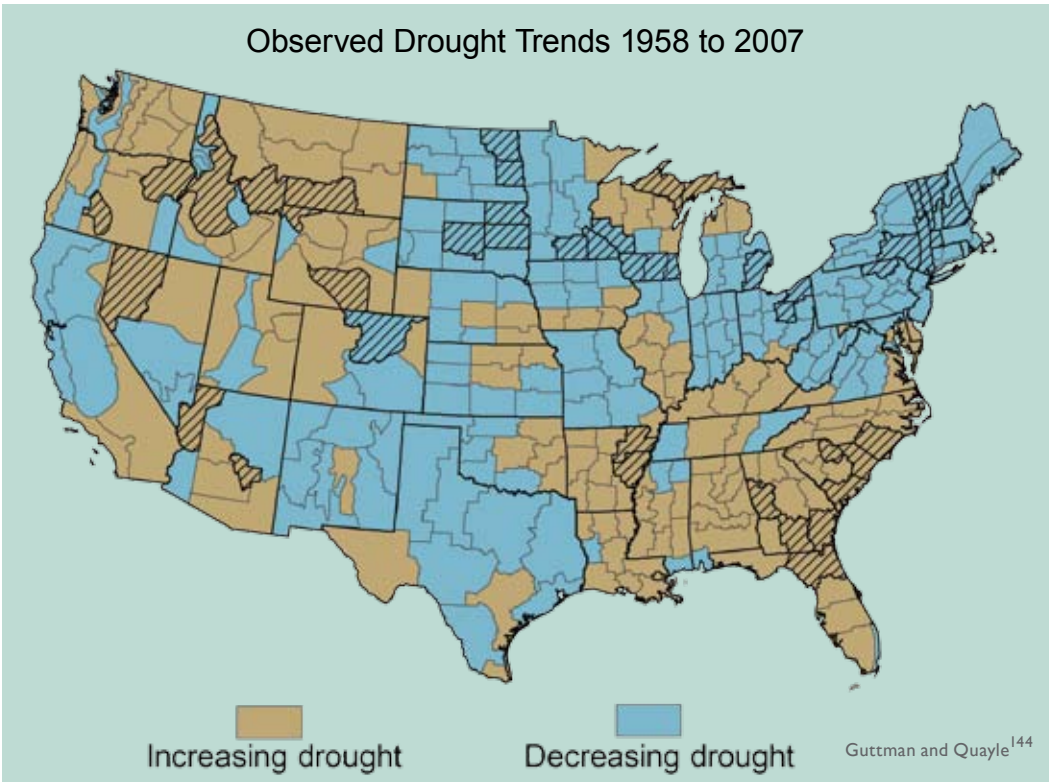
1949 to 2005

Trends in winter snow-to-total precipitation ratio from 1949 to 2005. Red circles indicate less snow, while blue squares indicate more snow. Large circles and squares indicate the most significant trends.[143] Areas south of 37°N latitude were excluded from the analysis because most of that area receives little snowfall. White areas above that line have inadequate data for this analysis.

The additional atmospheric moisture contributes to more overall precipitation in some areas, especially in much of the Northeast, Midwest, and Alaska. Over the past 50 years, precipitation and streamflow have increased in much of the Northeast and Midwest, with a reduction in drought duration and severity. Much of the Southeast and West has had reductions in precipitation and increases in drought severity and duration, especially in the Southwest.

In most areas of the country, the fraction of precipitation falling as rain versus snow has increased during the last 50 years. Despite this general shift from snow to rain, snowfalls

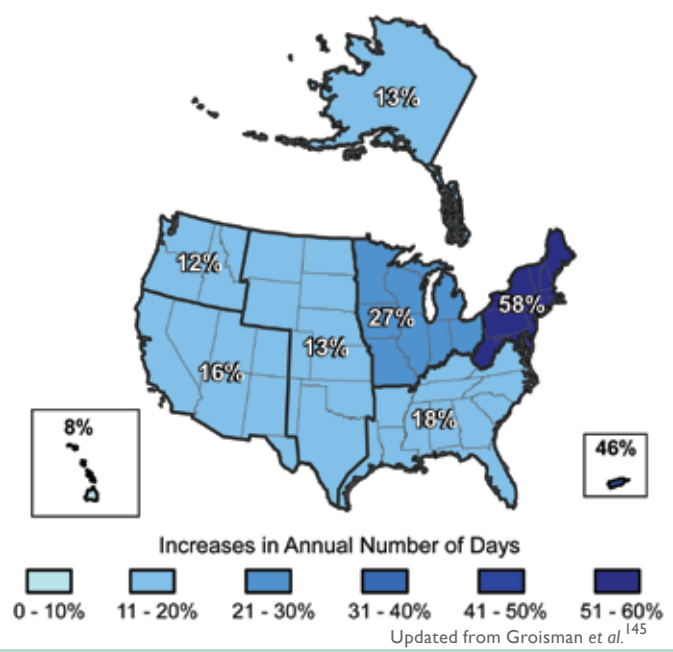
Observed Water-Related Changes During the Last Century[142]		
Observed Change	**Direction of Change**	**Region Affected**
One to four week earlier peak streamflow due to earlier warming-driven snowmelt	Earlier	West and Northeast
Proportion of precipitation falling as snow	Decreasing	West and Northeast
Duration and extent of snow cover	Decreasing	Most of the United States
Mountain snow water equivalent	Decreasing	West
Annual precipitation	Increasing	Most of the United States
Annual precipitation	Decreasing	Southwest
Frequency of heavy precipitation events	Increasing	Most of the United States
Runoff and streamflow	Decreasing	Colorado and Columbia River Basins
Streamflow	Increasing	Most of East
Amount of ice in mountain glaciers	Decreasing	U.S. western mountains, Alaska
Water temperature of lakes and streams	Increasing	Most of the United States
Ice cover on lakes and rivers	Decreasing	Great Lakes and Northeast
Periods of drought	Increasing	Parts of West and East
Salinization of surface waters	Increasing	Florida, Louisiana
Widespread thawing of permafrost	Increasing	Alaska



Trends in end-of-summer drought as measured by the Palmer Drought Severity Index from 1958 to 2007 in each of 344 U.S. climate divisions.[144] Hatching indicates significant trends.

along the downwind coasts of the Great Lakes have increased. Factors contributing to this increase include reduced ice cover due to warming, which lengthens the period of open water. In addition, cold air moving over relatively warm, open lake water induces strong evaporation, often causing heavy lake-effect snow. Heavy snowfall and snowstorm frequency have increased in many northern parts of the United States. In the South however, where temperatures are already marginal for heavy snowfall, climate warming has led to a reduction in heavy snowfall and snowstorm frequency. These trends suggest a northward shift in snowstorm occurrence.[68]

Increases in the Number of Days with Very Heavy Precipitation (1958 to 2007)



Updated from Groisman *et al.*[145]

The map shows the percentage increases in the average number of days with very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more days with very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between).

While it sounds counterintuitive, a warmer world produces both wetter and drier conditions. Even though total global precipitation increases, the regional and seasonal distribution of precipitation changes, and more precipitation comes in heavier rains (which can cause flooding) rather than light events. In the past century, averaged over the United States, total precipitation has increased by about 7 percent, while the heaviest 1 percent of rain events increased by nearly 20 percent.[68] This has been especially noteworthy in the Northeast, where the annual number of days with very heavy precipitation has increased most in the past 50 years, as shown in the adjacent figure. Flooding often occurs when heavy precipitation persists for weeks to months in large river basins. Such extended periods of heavy precipitation have also been increasing over the past century, most notably in the past two to three decades in the United States.[112]

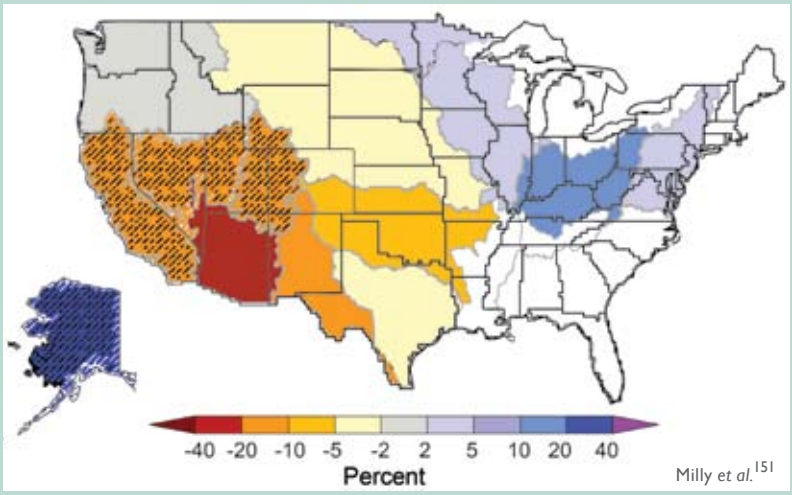
Observations also show that over the past several decades, extended dry periods have become more frequent in parts of the United States, especially the Southwest and the eastern United States.[146,147] Longer periods between rainfalls, combined with higher air temperatures, dry out soils and vegetation, causing drought.

For the future, precipitation intensity is projected to increase everywhere, with the largest increases occurring in areas in which average precipitation increases the most. For example, the Midwest and Northeast, where total precipitation is expected to increase the most, would also experience the largest increases in heavy precipitation events. The number of dry days between precipitation events is also projected to increase, especially in the more arid areas. Mid-continental areas and the Southwest are particularly threatened by future drought. The magnitude of the projected changes in extremes is expected to be greater than changes in averages, and hence detectable sooner.[49,68,90,142,148]

Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer.

Runoff, which accumulates as streamflow, is the amount of precipitation that is not evaporated, stored as snowpack or soil moisture, or filtered down to groundwater. The proportion of precipitation that runs off is determined by a variety of factors including temperature, wind speed, humidity, solar intensity at the ground, vegetation, and soil moisture. While runoff generally tracks precipitation, increases and decreases in precipitation do not necessarily lead to equal increases and decreases in runoff. For example, droughts cause soil moisture reductions that can reduce expected runoff until soil moisture is replenished. Conversely, water-saturated soils can generate floods with only moderate additional precipitation. During the last century, consistent increases in precipitation have been found in the Midwest and Northeast along with increased runoff.[149,150] Climate models consistently project that the East will experience increased runoff, while there will be substantial declines in the interior West, especially the Southwest. Projections for runoff in California and other parts of the West also show reductions, although less than in the interior West. In short, wet areas are projected to get wetter and dry areas drier. Climate models also consistently project heat-related summer soil moisture reductions in the middle of the continent.[115,142,146,149]

Projected Changes in Annual Runoff

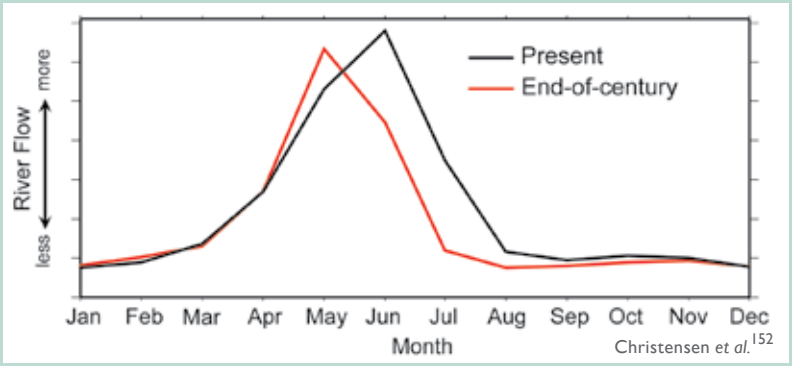


Projected changes in median runoff for 2041-2060, relative to a 1901-1970 baseline, are mapped by water-resource region. Colors indicate percentage changes in runoff. Hatched areas indicate greater confidence due to strong agreement among model projections. White areas indicate divergence among model projections. Results are based on emissions in between the lower and higher emissions scenarios.[91]

In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer.

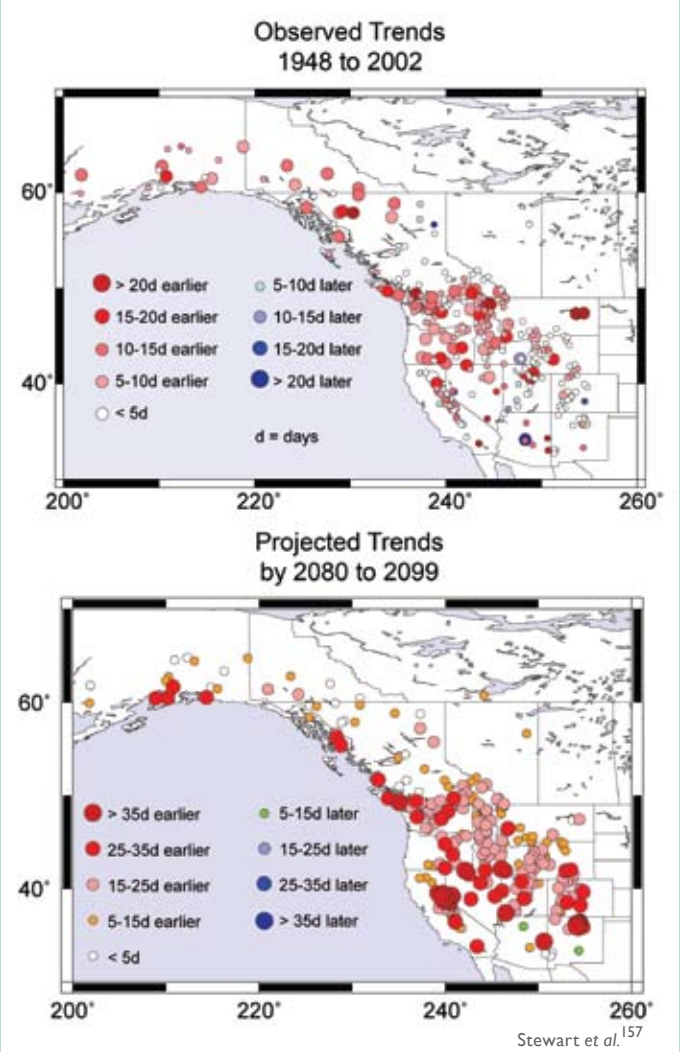
Large portions of the West and some areas in the Northeast rely on snowpack as a natural reservoir to hold winter precipitation until it later runs off as streamflow in spring, summer, and fall. Over the last 50 years, there have been widespread temperature-related reductions in snowpack in the West, with the largest reductions occurring in lower elevation mountains in the Northwest and California where snowfall occurs at temperatures close to the freezing point.[142,153] The Northeast has also experienced snowpack reductions during a similar period. Observations indicate a transition to more rain and less snow in both the West and Northeast in the last 50 years.[143,154-156] Runoff in snowmelt-dominated areas is occurring up to 20 days earlier in the West, and up to 14 days earlier in the Northeast.[157,158] Future projections for most snowmelt-dominated basins in the West consistently indicate earlier spring

Simulated Changes in Annual Runoff Pattern



General schematic of changes in the annual pattern of runoff for snowmelt-dominated streams. Compared to the historical pattern, runoff peak is projected to shift to earlier in the spring and late summer flows are expected to be lower. The above example is for the Green River, which is part of the Colorado River watershed.

Trends in Peak Streamflow Timing



Top map shows changes in runoff timing in snowmelt-driven streams from 1948 to 2002 with red circles indicating earlier runoff, and blue circles indicating later runoff. Bottom map shows projected changes in snowmelt-driven streams by 2080-2099, compared to 1951-1980, under a higher emissions scenario.[91]

runoff, in some cases up to 60 days earlier.[157,159] For the Northeast, projections indicate spring runoff will advance by up to 14 days.[150] Earlier runoff produces lower late-summer streamflows, which stress human and environmental systems through less water availability and higher water temperatures.[145] Scientific analyses to determine the causes of recent changes in snowpack, runoff timing, and increased winter temperatures have attributed these changes to human-caused climate change.[34,160,161]

Surface water quality and groundwater quantity will be affected by a changing climate.

Changes in water quality

Increased air temperatures lead to higher water temperatures, which have already been detected in many streams, especially during low-flow periods. In lakes and reservoirs, higher water temperatures lead to longer periods of summer stratification (when surface and bottom waters do not mix). Dissolved oxygen is reduced in lakes, reservoirs, and rivers at higher temperatures. Oxygen is an essential resource for many living things, and its availability is reduced at higher temperatures both because the amount that can be dissolved in water is lower and because respiration rates of living things are higher. Low oxygen stresses aquatic animals such as coldwater fish and the insects and crustaceans on which they feed.[142] Lower oxygen levels also decrease the self-purification capabilities of rivers.

The negative effects of water pollution, including sediments, nitrogen from agriculture, disease pathogens, pesticides, herbicides, salt, and thermal pollution, will be amplified by observed and projected increases in precipitation intensity and longer periods when streamflows are low.[146] The U.S. Environmental Protection Agency expects the number of waterways considered "impaired" by water pollution to increase.[162] Heavy downpours lead to increased sediment in runoff and outbreaks of waterborne diseases.[163,164] Increases in pollution carried to lakes, estuaries, and the coastal ocean, especially when coupled with increased temperature, can result in blooms of harmful algae and bacteria. However, pollution has the potential of being diluted in regions that experience increased streamflow.

Water-quality changes during the last century were probably due to causes other than climate change, primarily changes in pollutants.[149]

Changes in groundwater

Many parts of the United States are heavily dependent on groundwater for drinking, residential, and agricultural water supplies.[164] How climate change will affect groundwater is not well known,

Heavy rain can cause sediments to become suspended in water, reducing its quality, as seen in the brown swath above in New York City's Ashokan reservoir following Hurricane Floyd in September 1999.

but increased water demands by society in regions that already rely on groundwater will clearly stress this resource, which is often drawn down faster than it can be recharged.[164] In many locations, groundwater is closely connected to surface water and thus trends in surface water supplies over time affect groundwater. Changes in the water cycle that reduce precipitation or increase evaporation and runoff would reduce the amount of water available for recharge. Changes in vegetation and soils that occur as temperature changes or due to fire or pest outbreaks are also likely to affect recharge by altering evaporation and infiltration rates. More frequent and larger floods are likely to increase groundwater recharge in semi-arid and arid areas, where most recharge occurs through dry streambeds after heavy rainfalls and floods.[142]

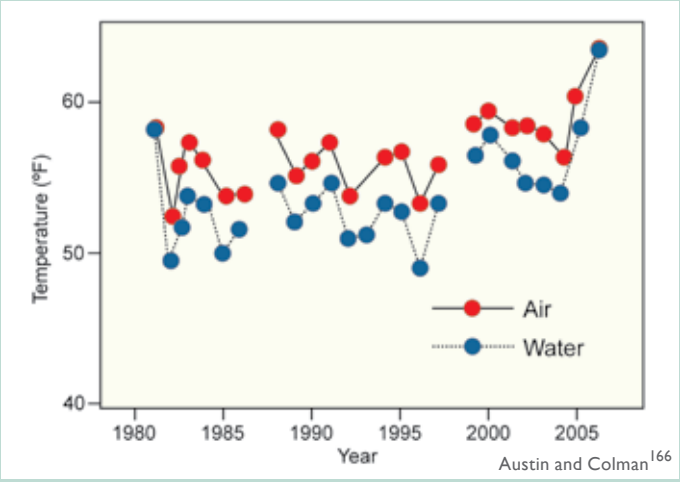
Sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination.[146] Increased evaporation or reduced recharge into coastal aquifers exacerbates saltwater intrusion. Shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to climate change. Small reductions in groundwater levels can lead to large reductions in streamflow and increases in groundwater levels can increase streamflow.[165] Further, the interface between streams and groundwater is an important site for pollution removal by microorganisms. Their activity will change in response to increased temperature and increased or decreased streamflow as climate changes, and this will affect water quality. Like water quality, research on the impacts of climate change on groundwater has been minimal.[149]

Climate change will place additional burdens on already stressed water systems.

In many places, the nation's water systems are already taxed due to aging infrastructure, population increases, and competition among water needs for farming, municipalities, hydropower, recreation, and ecosystems.[167-169] Climate change will add another factor to existing water management challenges, thus increasing vulnerability.[170] The U.S. Bureau of Reclamation has identified many areas in the West that are already at risk for serious conflict over water, even in the absence of climate change[171] (see figure next page).

Adapting to gradual changes, such as changes in average amounts of precipitation, is less difficult than adapting to changes in extremes. Where extreme events, such as droughts or floods, become more intense or more frequent with climate change, the economic and social costs of these events will increase.[172] Water systems have life spans of many years and are designed with spare

Lake Superior Summer Air and Water Temperatures
1979 to 2006



Austin and Colman[166]

The recent large jump in summer water temperature is related to the recent large reduction in ice cover (see *Midwest* region).

capacity. These systems are thus able to cope with small changes in average conditions.[172] Water resource planning today considers a broad range of stresses and hence adaptation to climate change will be one factor among many in deciding what actions will be taken to minimize vulnerability.[172-174]

Rapid regional population growth

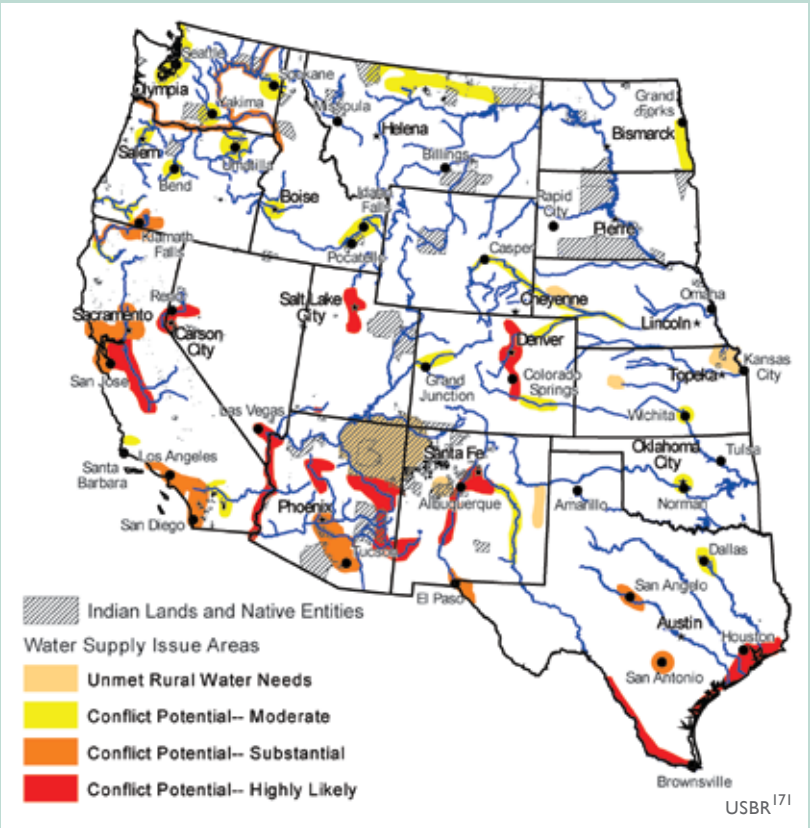
The U.S. population is estimated to have grown to more than 300 million people, nearly a 7 percent increase since the 2000 Census. Current Census Bureau projections are for this growth rate to continue, with the national population projected to reach 350 million by 2025 and 420 million by 2050. The highest rates of population growth to 2025 are projected to occur in areas such as the Southwest that are at risk for reductions in water supplies due to climate change.[167]

Damage to the city water system in Asheville, North Carolina, due to heavy rain in 2004.

Aging water infrastructure

The nation's drinking water and wastewater infrastructure is aging. In older cities, some buried water mains are over 100 years old and breaks of these lines are a significant problem. Sewer overflows resulting in the discharge of untreated wastewater also occur frequently. Heavier downpours will exacerbate existing problems in many cities, especially where stormwater catchments and sewers are combined. Drinking water and sewer infrastructure is very expensive to install and maintain. Climate change will present a new set of challenges for designing upgrades to the nation's water delivery and sewage removal infrastructure.[168]

Potential Water Supply Conflicts by 2025



The map shows regions in the West where water supply conflicts are likely to occur by 2025 based on a combination of factors including population trends and potential endangered species' needs for water. The red zones are where the conflicts are most likely to occur. This analysis does not factor in the effects of climate change, which is expected to exacerbate many of these already-identified issues.[171]

Existing water disputes across the country

Many locations in the United States are already undergoing water stress. The Great Lakes states are establishing an interstate compact to protect against reductions in lake levels and potential water exports. Georgia, Alabama, and Florida are in a dispute over water for drinking, recreation, farming, environmental purposes, and hydropower in the Apalachicola–Chattahoochee–Flint River system.[175,176]

The State Water Project in California is facing a variety of problems in the Sacramento Delta, including endangered species, saltwater intrusion, and potential loss of islands due to flood- or earthquake-caused levee failures.[177-182] A dispute over endangered fish in the Rio Grande has been ongoing for many years.[183] The Klamath River in Oregon and California has been the location of a multi-year disagreement over native fish, hydropower, and farming.[184,185] The Colorado River has been the site of numerous interstate quarrels over the last century.[186,187] Large, unquantified Native

American water rights challenge existing uses in the West (see *Southwest* region).[188] By changing the existing patterns of precipitation and runoff, climate change will add another stress to existing problems.

Changing water demands

Water demands are expected to change with increased temperatures. Evaporation is projected to increase over most of the United States as temperatures rise. Higher temperatures and longer dry periods are expected to lead to increased water demand for irrigation. This may be partially offset by more efficient use of water by plants due to rising atmospheric carbon dioxide. Higher temperatures are projected to increase cooling water withdrawals by electrical generating stations. In addition, greater cooling requirements in summer will increase electricity use, which in turn will require more cooling water for power plants. Industrial and municipal demands are expected to increase slightly.[146]

The past century is no longer a reasonable guide to the future for water management.

Water planning and management have been based on historical fluctuations in records of stream flows, lake levels, precipitation, temperature, and water demands. All aspects of water management including reservoir sizing, reservoir flood operations, maximum urban stormwater runoff amounts, and projected water demands have been based on these records. Water managers have proven adept at balancing supplies and demand through the significant climate variability of the past century.[142] Because climate change will significantly modify many aspects of the water cycle, the assumption of an unchanging climate is no longer appropriate for many aspects of water planning. Past assumptions derived from the historical record about supply and demand will need to be revisited for existing and proposed water projects.[142,151,174]

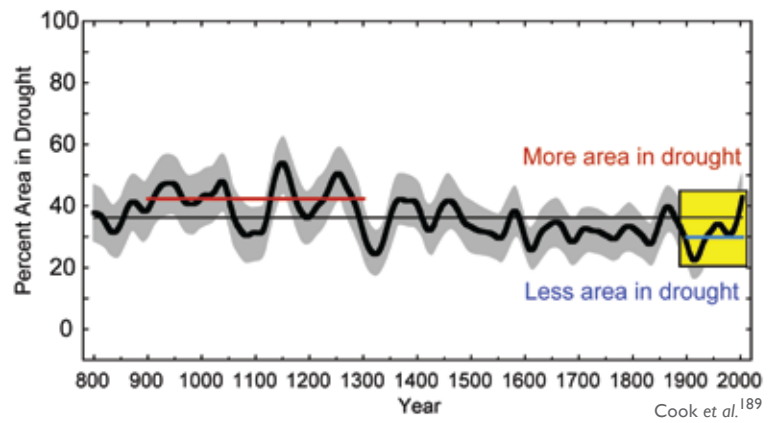
Drought studies that consider the past 1,200 years indicate that in the West, the last century was significantly wetter than most other centuries. Multi-decade "megadroughts" in the years 900 to 1300 were substantially worse than the worst droughts of the last century, including the Dust Bowl era. The causes of these events are only partially known; if they were to reoccur, they would clearly stress water management, even in the absence of climate change (see figure below).[97,149,189]

The intersection of substantial changes in the water cycle with multiple stresses such as population growth and competition for water supplies means that water planning will be doubly challenging. The ability to modify operational rules and water allocations is likely to be critical for the protection of infrastructure, for public safety, to ensure reliability of water delivery, and to protect the environment. There are, however, many institutional and legal barriers to such changes in both the short and long term.[190] Four examples:

- The allocation of the water in many interstate rivers is governed by compacts, international treaties, federal laws, court decrees, and other agreements that are difficult to modify.

- Reservoir operations are governed by "rule curves" that require a certain amount of space to be saved in a reservoir at certain times of

Long-Term Aridity Changes in the West



The black line shows the percentage of the area affected by drought (Palmer Drought Severity Index less than –1) in the West over the past 1,200 years. The red line indicates the average drought area in the years 900 to 1300. The blue horizontal line in the yellow box indicates the average during the period from 1900 to 2000, illustrating that the most recent period, during which population and water infrastructure grew rapidly in the West, was wetter than the long-term average (thin horizontal black line).[189] Droughts shown in the period 1100-1300 significantly exceed those that have occurred over the past 100 years.

year to capture a potential flood. Developed by the U.S. Army Corps of Engineers based on historical flood data, many of these rule curves have never been modified, and modifications might require Environmental Impact Statements.[151]

Highlights of Water-Related Impacts by Sector	
Sector	**Examples of Impacts**
Human Health	Heavy downpours increase incidence of waterborne disease and floods, resulting in potential hazards to human life and health.[163]
Energy Supply and Use	Hydropower production is reduced due to low flows in some regions. Power generation is reduced in fossil fuel and nuclear plants due to increased water temperatures and reduced cooling water availability.[191]
Transportation	Floods and droughts disrupt transportation. Heavy downpours affect harbor infrastructure and inland waterways. Declining Great Lakes levels reduce freight capacity.[192]
Agriculture and Forests	Intense precipitation can delay spring planting and damage crops. Earlier spring snowmelt leads to increased number of forest fires.[193]
Ecosystems	Coldwater fish threatened by rising water temperatures. Some warmwater fish will expand ranges.[70]

- In most parts of the West, water is allocated based on a "first in time means first in right" system, and because agriculture was developed before cities were established, large volumes of water typically are allocated to agriculture. Transferring agricultural rights to municipalities, even for short periods during drought, can involve substantial expense and time and can be socially divisive.

- Conserving water does not necessarily lead to a right to that saved water, thus creating a disincentive for conservation.

Total U.S. water diversions peaked in the 1980s, which implies that expanding supplies in many areas to meet new needs are unlikely to be a viable option, especially in arid areas likely to experience less precipitation. However, over the last 30 years, per capita water use has decreased significantly (due, for example, to more efficient technologies such as drip irrigation) and it is anticipated that per capita use will continue to decrease, thus easing stress.[149]

Adaptation: New York City Begins Planning for Climate Change

The New York City Department of Environmental Protection (DEP), the agency in charge of providing the city's drinking water and wastewater treatment, is beginning to alter its planning to take into account the effects of climate change – sea-level rise, higher temperatures, increases in extreme events, and changing precipitation patterns – on the city's water systems. In partnership with Columbia University, DEP is evaluating climate change projections, impacts, indicators, and adaptation and mitigation strategies.

City planners have begun to address these issues by defining risks using probabilistic climate scenarios and considering potential adaptations that relate to operations/management, infrastructure, and policy. For example, DEP is examining the feasibility of relocating critical control systems to higher floors in low-lying buildings or to higher ground, building flood walls, and modifying design criteria to reflect changing hydrologic processes.

Important near-term goals of the overall effort include updating the existing 100-year flood elevations using climate model projections and identifying additional monitoring stations needed to track changes. DEP will also establish a system for reporting the impacts of extreme weather events on the City's watershed and infrastructure. In the immediate future, DEP will evaluate flood protection measures for three existing water pollution control plants that are scheduled for renovation.[194]

Spotlight on the Colorado River

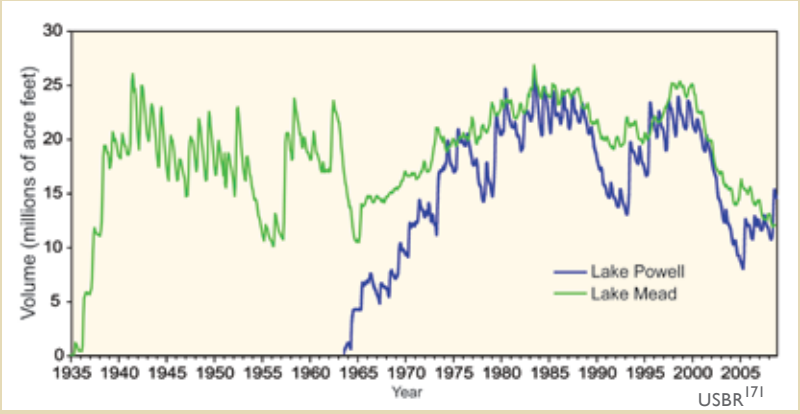
The Colorado River system supplies water to over 30 million people in the Southwest including Los Angeles, Phoenix, Las Vegas, and Denver. Reservoirs in the system, including the giant lakes Mead and Powell, were nearly full in 1999, with almost four times the annual flow of the river stored. By 2007, the system had lost approximately half of that storage after enduring the worst drought in 100 years of record keeping.[29] Runoff was reduced due to low winter precipitation, and warm, dry, and windy spring seasons that substantially reduced snowpack.

Matching photographs taken 18 months apart during the most serious period of recent drought show a significant decrease in Lake Powell.

Numerous studies over the last 30 years have indicated that the river is likely to experience reductions in runoff due to climate change. In addition, diversions from the river to meet the needs of cities and agriculture are approaching its average flow. Under current conditions, even without climate change, large year-to-year fluctuations in reservoir storage are possible.[152] If reductions in flow projected to accompany global climate change occur, water managers will be challenged to satisfy all existing demands, let alone the increasing demands of a rapidly growing population.[167,195]

Efforts are underway to address these challenges. In 2005, the Department of Interior's Bureau of Reclamation began a process to formalize operating rules for lakes Mead and Powell during times of low flows and to apportion limited water among the states.[196]

Change in Water Volume of Lakes Mead and Powell

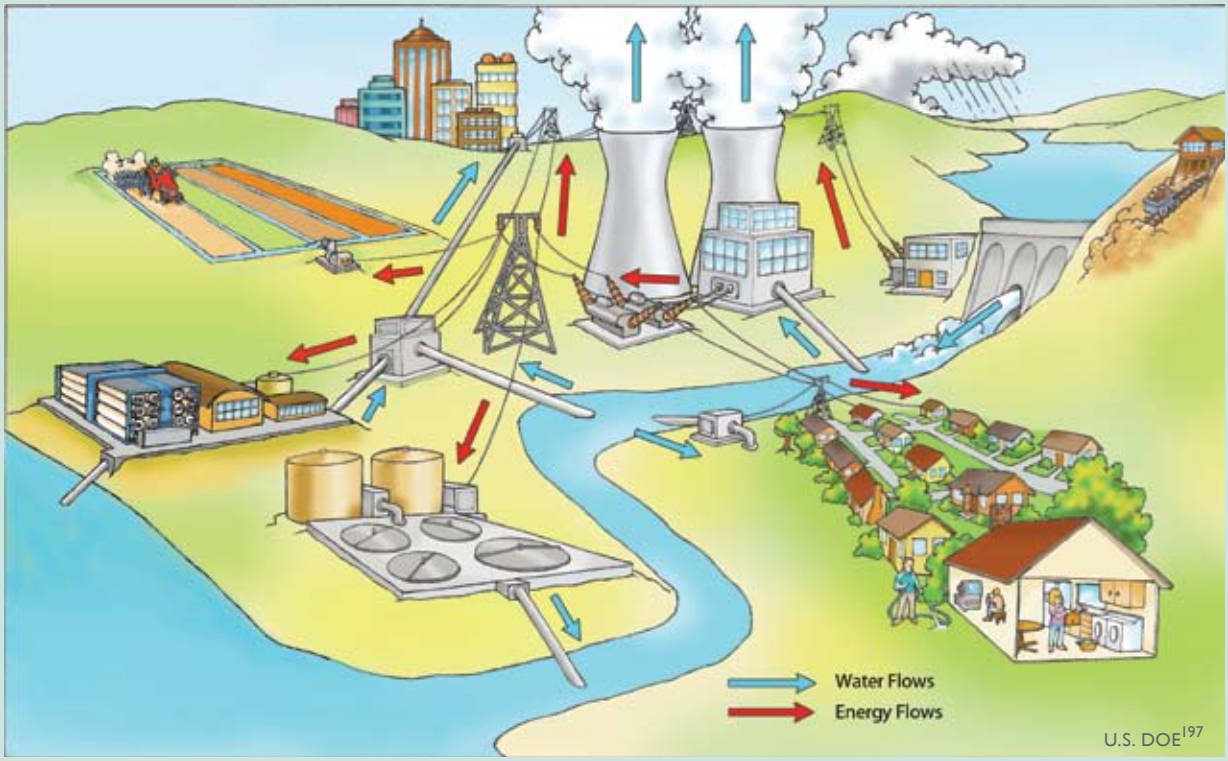


The filling of Lake Mead (green) was initiated in 1935, and that of Lake Powell (blue) in 1963. In 1999, the lakes were nearly full, but by 2007, the lakes had lost nearly half of their storage water after the worst drought in 100 years.

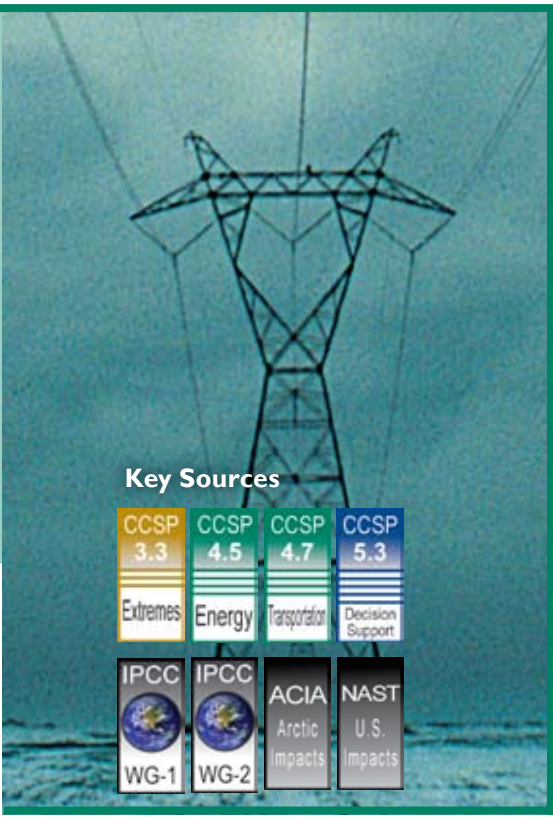
Water and Energy Connections

Water and energy are tightly interconnected; water systems use large amounts of energy, and energy systems use large amounts of water. Both are expected to be under increasing pressure in the future and both will be affected by a changing climate. In the energy sector, water is used directly for hydropower, and cooling water is critical for nearly all other forms of electrical power generation. Withdrawals of freshwater used to cool power plants that use heat to generate electricity are very large, nearly equaling the water withdrawn for irrigation. Water consumption by power plants is about 20 percent of all non-agricultural uses, or half that of all domestic use.[197]

In the water sector, two very unusual attributes of water, significant weight due to its relatively high density, and high heat capacity, make water use energy intensive. Large amounts of energy are needed for pumping, heating, and treating drinking water and wastewater. Water supply and treatment consumes roughly 4 percent of the nation's power supply, and electricity accounts for about 75 percent of the cost of municipal water processing and transport. In California, 30 percent of all non-power plant natural gas is used for water-related activities.[198,199] The energy required to provide water depends on its source (groundwater, surface water, desalinated water, treated wastewater, or recycled water), the distance the water is conveyed, the amount of water moved, and the local topography. Surface water often requires more treatment than groundwater. Desalination requires large amounts of energy to produce freshwater. Treated wastewater and recycled water (used primarily for agriculture and industry) require energy for treatment, but little energy for supply and conveyance. Conserving water has the dual benefit of conserving energy and potentially reducing greenhouse gas emissions if fossil fuels are the predominant source of that energy.



Water and energy are intimately connected. Water is used by the power generation sector for cooling, and energy is used by the water sector for pumping, drinking water treatment, and wastewater treatment. Without energy, there would be limited water distribution, and without water, there would be limited energy production.



Energy Supply and Use

Key Messages:

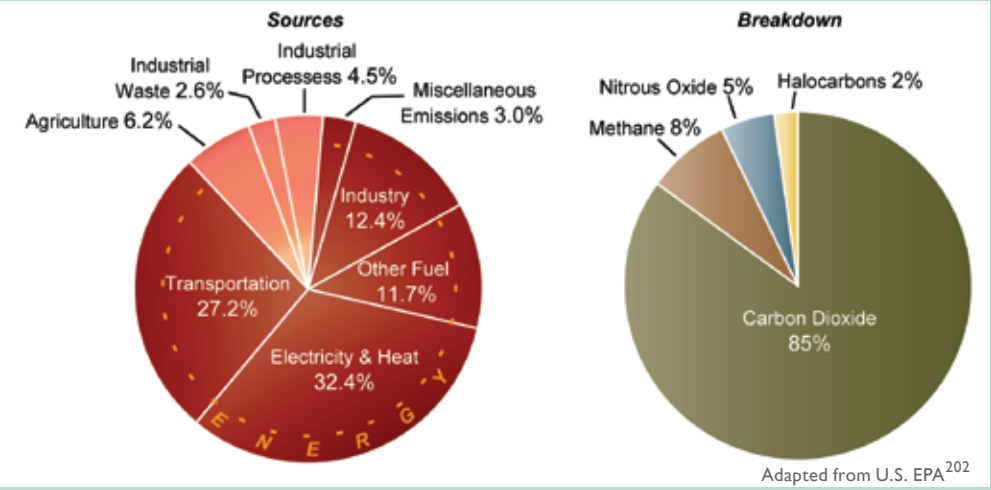
- Warming will be accompanied by decreases in demand for heating energy and increases in demand for cooling energy. The latter will result in significant increases in electricity use and higher peak demand in most regions.
- Energy production is likely to be constrained by rising temperatures and limited water supplies in many regions.
- Energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions.
- Climate change is likely to affect some renewable energy sources across the nation, such as hydropower production in regions subject to changing patterns of precipitation or snowmelt.

Energy is at the heart of the global warming challenge.[3] It is humanity's production and use of energy that is the primary cause of global warming, and in turn, climate change will eventually affect our production and use of energy. The vast majority of U.S. greenhouse gas emissions, about 87 percent, come from energy production and use.[200]

At the same time, other U.S. trends are increasing energy use: population shifts to the South, especially the Southwest, where air conditioning use is high, an increase in the square footage built per person, increased electrification of the residential and commercial sectors, and increased market penetration of air conditioning.[201]

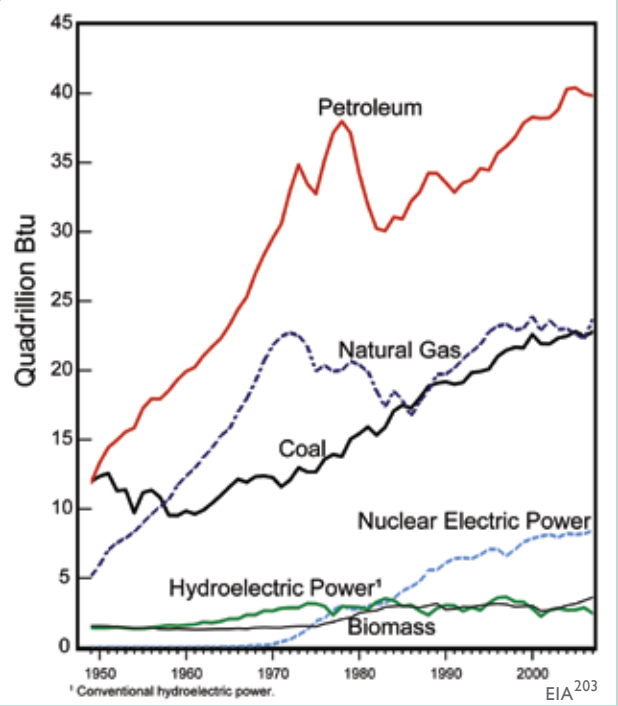
Many of the effects of climate change on energy production and use in the United States are not well studied. Some of the effects of climate change, however, have clear implications for energy production and use. For instance, rising temperatures are expected to increase energy requirements for cooling and reduce energy requirements for heating.[164,201] Changes in precipitation have the potential to affect prospects for hydropower, positively or negatively.[201] Increases in hurricane intensity are likely to cause further disruptions to oil and gas operations in the Gulf, like those experienced in 2005 with Hurricane Katrina and in 2008 with Hurricane Ike.[201] Concerns about climate

Sources of U.S. Greenhouse Emissions (2003)



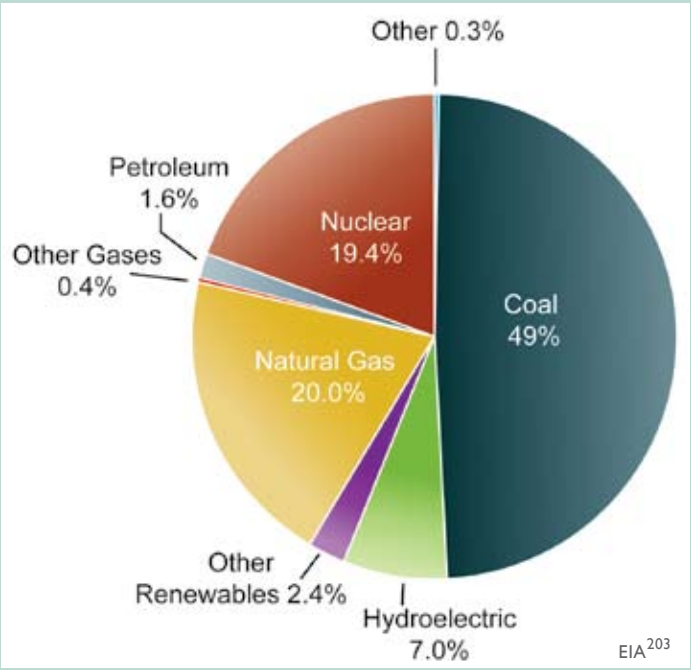
About 87 percent of U.S. greenhouse gas emissions come from energy production and use, as shown in the left pie chart. The right pie chart breaks down these emissions by greenhouse gas.

Primary Energy Consumption by Major Source (1949 to 2007)



U.S. energy supply is dominated by fossil fuels. Petroleum, the top source of energy shown above, is primarily used for transportation (70 percent of oil use). Natural gas is used in roughly equal parts to generate electricity, power industrial processes, and heat water and buildings. Coal is primarily used to generate electricity (91 percent of coal use). Nuclear power is used entirely for electricity generation.

U.S. Electricity Sources (2007)



Coal, natural gas, and nuclear power plants together account for about 90 percent of current U.S. electricity production.

change impacts will almost certainly alter perceptions and valuations of energy technology alternatives. These effects are very likely to be relevant for energy policies, decisions, and institutions in the United States, affecting courses of action and appropriate strategies for risk management.[201]

The overall scale of the national energy economy is very large, and the energy industry has both the financial and the managerial resources to be adaptive. Impacts due to climate change are likely to be most apparent at sub-national scales, such as regional effects of extreme weather events and reduced water availability, and effects of increased cooling demands on especially vulnerable places and populations.[204]

Warming will be accompanied by decreases in demand for heating energy and increases in demand for cooling energy. The latter will result in significant increases in electricity use and higher peak demand in most regions.

Research on the effects of climate change on energy production and use has largely been limited to impacts on energy use in buildings. These studies have considered effects of global warming on energy requirements for heating and cooling in buildings in the United States.[205] They find that the demand for cooling energy increases from 5 to 20 percent per 1.8°F of warming, and the demand for heating energy drops by 3 to 15 percent per 1.8°F of warming.[205] These ranges reflect different assumptions about factors such as the rate of market penetration of improved building equipment technologies.[205]

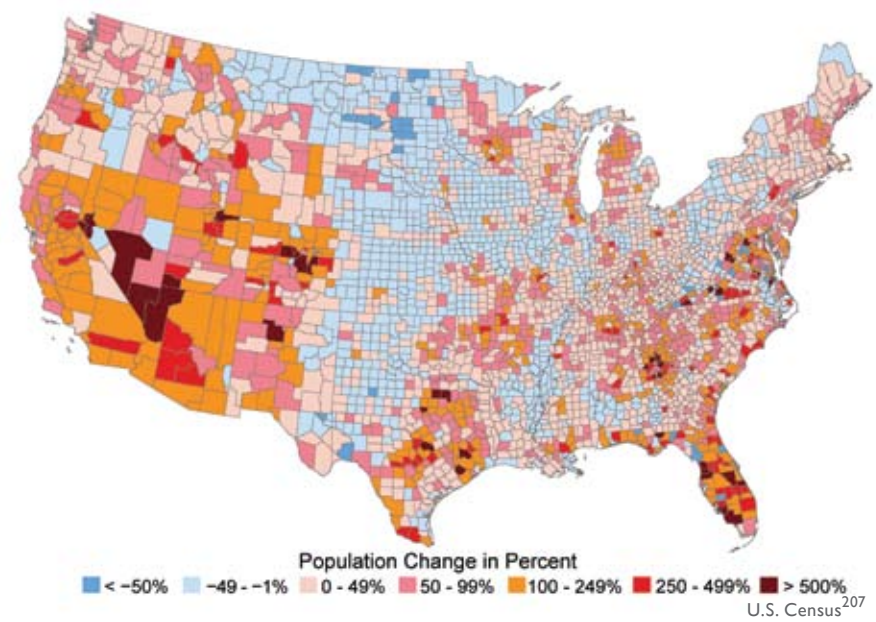
Studies project that temperature increases due to global warming are very likely to increase peak demand for electricity in most regions of the country.[205] An increase in peak demand can lead to a disproportionate increase in energy infrastructure investment.[205]

Since nearly all of the cooling of buildings is provided by electricity use, whereas the vast majority of the heating of buildings is provided by natural gas and fuel oil,[201,206] the projected

changes imply increased demands for electricity. This is especially the case where climate change would result in significant increases in the heat index in summer, and where relatively little space cooling has been needed in the past, but demands are likely to increase in the future.[205] The increase in electricity demand is likely to be accelerated by population movements to the South and Southwest, which are regions of especially high per capita electricity use, due to demands for cooling in commercial buildings and households.[205] Because nearly half of the nation's electricity is currently generated from coal, these factors have the potential to increase total national carbon dioxide emissions in the absence of improved energy efficiency, development of non-carbon energy sources, and/or carbon capture and storage.[205]

Other effects of climate change on energy consumption are less clear, because little research has been done.[205] For instance, in addition to cooling, air conditioners also remove moisture from the air; thus the increase in humidity projected to accompany global warming is likely to increase electricity consumption by air conditioners even further.[205] As other examples, warming would increase the use of air conditioners in highway vehicles, and water scarcity in some regions has the potential to increase energy demands for water pumping. It is important to improve the information available about these other kinds of effects.

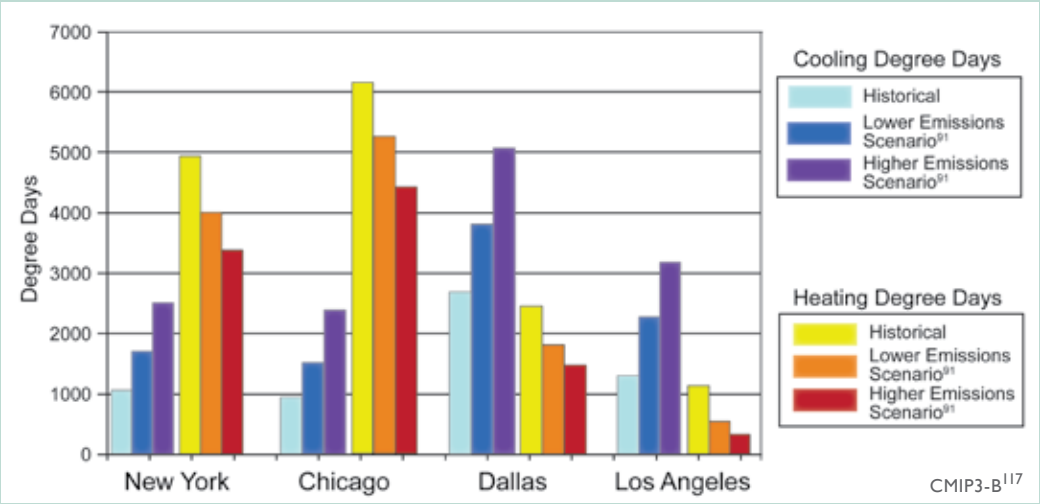
Change in Population from 1970 to 2008



U.S. Census[207]

The map above, showing percentage changes in county population between 1970 and 2008, graphically illustrates the large increases in places that require air conditioning. Areas with very large increases are shown in orange, red, and maroon. Some places had enormous growth, in the hundreds of thousands of people. For example, counties in the vicinity of South Florida, Atlanta, Los Angeles, Phoenix, Las Vegas, Denver, Dallas, and Houston all had very large increases.

Shifting Energy Demand in the United States by 2080-2099



CMIP3-B[117]

"Degree days" are a way of measuring the energy needed for heating and cooling by adding up how many degrees hotter or colder each day's average temperature is from 65°F over the course of a year. Colder locations have high numbers of heating degree days and low numbers of cooling degree days, while hotter locations have high numbers of cooling degree days and low numbers of heating degree days. Nationally, the demand for energy will increase in summer and decrease in winter. Cooling uses electricity while heating uses a combination of energy sources, so the overall effect nationally and in most regions will be an increased need for electricity. The projections shown in the chart are for late this century. The higher emissions scenario[91] used here is referred to as "even higher" on page 23.

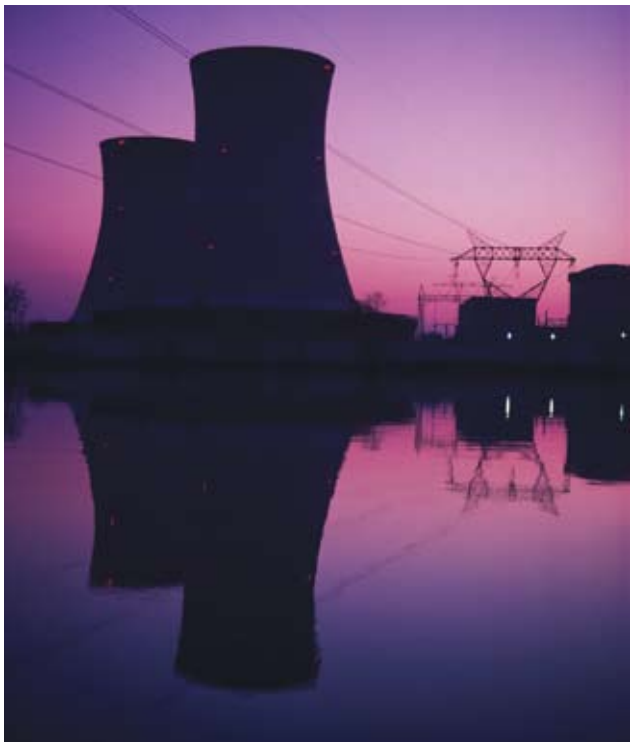
Energy production is likely to be constrained by rising temperatures and limited water supplies in many regions.

In some regions, reductions in water supply due to decreases in precipitation and/or water from melting snowpack are likely to be significant, increasing the competition for water among various sectors including energy production (see *Water Resources* sector).[191,208]

The production of energy from fossil fuels (coal, oil, and natural gas) is inextricably linked to the availability of adequate and sustainable supplies of water.[191,208] While providing the United States with the majority of its annual energy needs, fossil fuels also place a high demand on the nation's water resources in terms of both quantity and quality impacts.[191,208] Generation of electricity in thermal power plants (coal, nuclear, gas, or oil) is water intensive. Power plants rank only slightly behind irrigation in terms of freshwater withdrawals in the United States.[191]

There is a high likelihood that water shortages will limit power plant electricity production in many regions. Future water constraints on electricity production in thermal power plants are projected for Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington state by 2025.[191] Additional parts of the United States could face similar constraints as a result of drought, growing populations, and increasing demand for water for various uses, at least seasonally.[209] Situations where the development of new power plants is being slowed down or halted due to inadequate cooling water are becoming more frequent throughout the nation.[191]

The issue of competition among various water uses is dealt with in more detail in the *Water Resources* sector. In connection with these issues and other regional water scarcity impacts, energy is likely to be needed to move and manage water. This is one of many examples of interactions among the impacts of climate change on various sectors that, in this case, affects energy requirements.



Nuclear, coal, and natural gas power plants require large amounts of water for cooling.[191]

In addition to the problem of water availability, there are issues related to an increase in water temperature. Use of warmer water reduces the efficiency of thermal power plant cooling technologies. And, warmer water discharged from power plants can alter species composition in aquatic ecosystems.[210] Large coal and nuclear plants have been limited in their operations by reduced river levels caused by higher temperatures and thermal limits on water discharge.[191]

The efficiency of thermal power plants, fossil or nuclear, is sensitive to ambient air and water temperatures; higher temperatures reduce power outputs by affecting the efficiency of cooling.[191] Although this effect is not large in percentage terms, even a relatively small change could have significant implications for total national electric power supply.[191] For example, an average reduction of 1 percent in electricity generated by thermal power plants nationwide would mean a loss of 25 billion kilowatt-hours per year,[211] about the amount of electricity consumed by 2 million Americans, a loss that would need to be supplied in some other way or offset through measures that improve energy efficiency.

Energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions.

Sea-level rise

A significant fraction of America's energy infrastructure is located near the coasts, from power plants, to oil refineries, to facilities that receive oil and gas deliveries.[191] Rising sea levels are likely to lead to direct losses, such as equipment damage from flooding or erosion, and indirect effects, such as the costs of raising vulnerable assets to higher levels or building new facilities farther inland, increasing transportation costs.[191] The U.S. East Coast and Gulf Coast have been identified as particularly vulnerable to sea-level rise because the land is relatively flat and also sinking in many places.[191]

Extreme events

Observed and projected increases in a variety of extreme events will have significant impacts on the energy sector. As witnessed in 2005, hurricanes can have a debilitating impact on energy infrastructure. Direct losses to the energy industry in 2005 are estimated at $15 billion,[191] with millions more in restoration and recovery costs. As one example, the Yscloskey Gas Processing Plant (located on the Louisiana coast) was forced to close for six months following Hurricane Katrina, resulting in lost revenues to the plant's owners and employees, and higher prices to consumers, as gas had to be procured from other sources.[191]

The impacts of an increase in severe weather are not limited to hurricane-prone areas. For example, rail transportation lines, which carry approximately two-thirds of the coal to the nation's power plants,[212] often follow riverbeds, especially in the Appalachian region.[191] More intense rainstorms, which have been observed and projected,[68,112] can lead to rivers flooding, which can "wash out" or degrade nearby railbeds and roadbeds.[191] This is also a problem in the Midwest, which experienced major flooding of the Mississippi River in 1993 and 2008.[213]

Development of new energy facilities could be restricted by siting concerns related to sea-level rise, exposure to extreme events, and increased capital costs resulting from a need to provide greater protection from extreme events.[191]

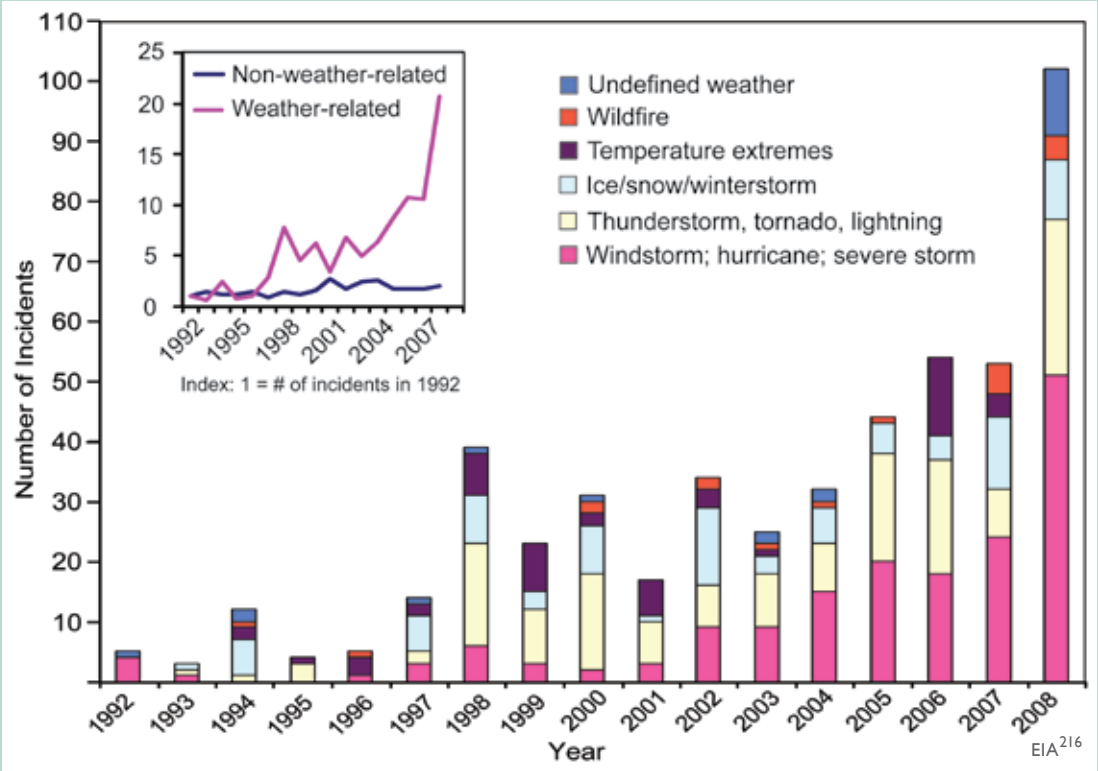
The electricity grid is also vulnerable to climate change effects, from temperature changes to severe weather events.[191] The most familiar example is

Regional Spotlight: Gulf Coast Oil and Gas

The Gulf Coast is home to the U.S. oil and gas industries, representing nearly 30 percent of the nation's crude oil production and approximately 20 percent of its natural gas production. One-third of the national refining and processing capacity lies on coastal plains adjacent to the Gulf of Mexico. Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea-level rise and the high winds and storm surge associated with hurricanes and other tropical storms. For example, hurricanes Katrina and Rita halted all oil and gas production from the Gulf, disrupted nearly 20 percent of the nation's refinery capacity, and closed many oil and gas pipelines.[214] Relative sea-level rise in parts of the Gulf Coast region (Louisiana and East Texas) is projected to be as high as 2 to 4 feet by 2050 to 2100, due to the combination of global sea-level rise caused by warming oceans and melting ice and local land sinking.[215] Combined with onshore and offshore storm activity, this would represent an increased threat to this regional energy infrastructure. Some adaptations to these risks are beginning to emerge (see Adaptation box, page 58).

Offshore oil production is particularly susceptible to extreme weather events. Hurricane Ivan in 2004 destroyed seven platforms in the Gulf of Mexico, significantly damaged 24 platforms, and damaged 102 pipelines. Hurricanes Katrina and Rita in 2005 destroyed more than 100 platforms and damaged 558 pipelines. For example, Chevron's $250 million "Typhoon" platform was damaged beyond repair. Plans are being made to sink its remains to the seafloor.

Significant Weather-Related U.S. Electric Grid Disturbances



The number of incidents caused by extreme weather has increased tenfold since 1992. The portion of all events that are caused by weather-related phenomena has more than tripled from about 20 percent in the early 1990s to about 65 percent in recent years. The weather-related events are more severe, with an average of about 180,000 customers affected per event compared to about 100,000 for non-weather-related events (and 50,000 excluding the massive blackout of August 2003).[201] The data shown include disturbances that occurred on the nation's large-scale "bulk" electric transmission systems. Most outages occur in local distribution networks and are not included in the graph. Although the figure does not demonstrate a cause-effect relationship between climate change and grid disruption, it does suggest that weather and climate extremes often have important effects on grid disruptions. We do know that more frequent weather and climate extremes are likely in the future,[68] which poses unknown new risks for the electric grid.

Adaptation: Addressing Oil Infrastructure Vulnerabilities in the Gulf Coast

Port Fourchon, Louisiana, supports 75 percent of deepwater oil and gas production in the Gulf of Mexico, and its role in supporting oil production in the region is increasing. The Louisiana Offshore Oil Port, located about 20 miles offshore, links daily imports of 1 million barrels of oil and production of 300,000 barrels in the Gulf of Mexico to 50 percent of national refining capacity. One road, Louisiana Highway 1, connects Port Fourchon with the nation. It transports machinery, supplies, and workers and is the evacuation route for onshore and offshore workers. Responding to threats of storm surge and flooding, related in part to concerns about climate change, Louisiana is currently upgrading Highway 1, including elevating it above the 500-year flood level and building a higher bridge over Bayou LaFourche and the Boudreaux Canal.[217]

Regional Spotlight: Florida's Energy Infrastructure

Florida's energy infrastructure is particularly vulnerable to sea-level rise and storm impacts. Most of the petroleum products consumed in Florida are delivered by barge to three ports, two on the east coast and one on the west coast. The interdependencies of natural gas distribution, transportation fuel distribution and delivery, and electrical generation and distribution were found to be major issues in Florida's recovery from recent major hurricanes.[191]

effects of severe weather events on power lines, such as from ice storms, thunderstorms, and hurricanes. In the summer heat wave of 2006, for example, electric power transformers failed in several areas (including St. Louis, Missouri, and Queens, New York) due to high temperatures, causing interruptions of electric power supply. It is not yet possible to project effects of climate change on the grid, because so many of the effects would be more localized than current climate change models can depict; but, weather-related grid disturbances are recognized as a challenge for strategic planning and risk management.

Climate change is likely to affect some renewable energy sources across the nation, such as hydropower production in regions subject to changing patterns of precipitation or snowmelt.

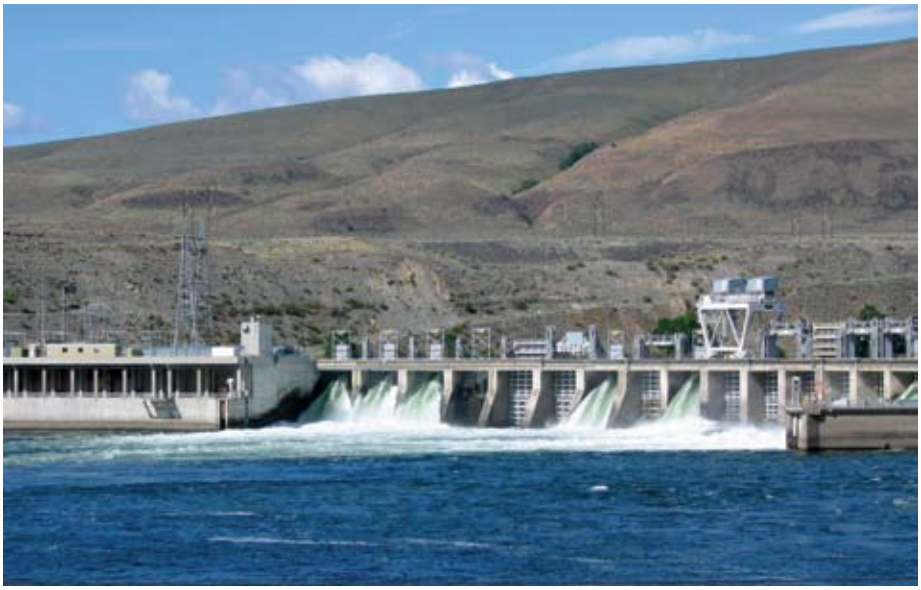
Renewable sources currently account for about 9 percent of electricity production in the United States.[203] Hydroelectric power is by far the largest renewable contributor to electricity generation,[191] accounting for about 7 percent of total U.S. electricity.[218] Like many things discussed in this report, renewable energy resources have strong interrelationships with climate change; using renewable energy can reduce the magnitude of climate change, while climate change can affect the prospects for using some renewable energy sources.

Hydropower is a major source of electricity in some regions of the United States, notably in the Northwest.[191] It is likely to be significantly affected by climate change in regions subject to reduced precipitation and/or water from melting snowpack. Significant changes are already being detected in the timing and amount of streamflows in many western rivers,[164] consistent with the predicted effects of global warming. More precipitation coming as rain rather than snow, reduced snowpack, earlier peak runoff, and related effects are beginning to affect hydropower availability.[164]

Hydroelectric generation is very sensitive to changes in precipitation and river discharge. For example, every 1 percent decrease in precipitation results in a 2 to 3 percent drop in streamflow;[219] every 1 percent decrease in streamflow in the Colorado River Basin results in a 3 percent drop in power generation.[191] Such magnifying sensitivities occur because water flows through multiple power plants in a river basin.[191]

Climate impacts on hydropower occur when either the total amount or the timing of runoff is altered, such as when natural water storage in snowpack and glaciers is reduced under hotter conditions. Glaciers, snowpack, and their associated runoff are already declining in the West, and larger declines are projected.[164]

Hydropower operations are also affected by changes to air temperatures, humidity, or wind patterns due to climate change.[191] These variables cause changes in water quantity and quality, including water temperature. Warmer air and water generally increase the evaporation of water from the surface



Hydroelectric dam in the Northwest

of reservoirs, reducing the amount of water available for power production and other uses. Huge reservoirs with large surface areas, located in arid, sunny parts of the country, such as Lake Mead (located on Arizona-Nevada border on the Colorado River), are particularly susceptible to increased evaporation due to warming, meaning less water will be available for all uses, including hydropower.[191] And, where hydropower dams flow into waterways that support trout, salmon or other coldwater fisheries, warming of reservoir releases might have detrimental consequences that require changes in operations that reduce power production.[191] Such impacts will increasingly translate into competition for water resources.

Climate change is also likely to affect other renewable energy sources. For example, changing cloud cover affects solar energy resources, changes in winds affect wind power, and temperature and water availability affect biomass production (particularly related to water requirements for biofuels).[191] The limited research to date on these important issues does not support firm conclusions about where such impacts would occur and how significant they would be.[205] This is an area that calls for much more study (see *An Agenda for Climate Impacts Science* section, Recommendation 2).

Regional Spotlight: Energy Impacts of Alaska's Rapid Warming

Significant impacts of warming on the energy sector can already be observed in Alaska, where temperatures have risen about twice as much as the rest of the nation. In Alaska, frozen ground and ice roads are an important means of winter travel, and warming has resulted in a much shorter cold season. Impacts on the oil and natural gas industries on Alaska's North Slope have been one of the results. For example, the season during which oil and gas exploration and extraction equipment can be operated on the tundra has been shortened due to warming. In addition, the thawing of permafrost, on which buildings, pipelines, airfields, and coastal installations supporting oil and gas development are located, adversely affects these structures and increases the cost of maintaining them.[191]

Different energy impacts are expected in the marine environment as sea ice continues to retreat and thin. These trends are expected to improve shipping accessibility, including oil and gas transport by sea, around the margins of the Arctic Basin, at least in the summer. The improved accessibility, however, will not be uniform throughout the different regions. Offshore oil exploration and extraction might benefit from less extensive and thinner sea ice, although equipment will have to be designed to withstand increased wave forces and ice movement.[191,220]

Transportation

Key Messages:

- Sea-level rise and storm surge will increase the risk of major coastal impacts, including both temporary and permanent flooding of airports, roads, rail lines, and tunnels.
- Flooding from increasingly intense downpours will increase the risk of disruptions and delays in air, rail, and road transportation, and damage from mudslides in some areas.
- The increase in extreme heat will limit some transportation operations and cause pavement and track damage. Decreased extreme cold will provide some benefits such as reduced snow and ice removal costs.
- Increased intensity of strong hurricanes would lead to more evacuations, infrastructure damage and failure, and transportation interruptions.
- Arctic warming will continue to reduce sea ice, lengthening the ocean transport season, but also resulting in greater coastal erosion due to waves. Permafrost thaw in Alaska will damage infrastructure. The ice road season will become shorter.

The U.S. transport sector is a significant source of greenhouse gases, accounting for 27 percent of U.S. emissions.[221] While it is widely recognized that emissions from transportation have a major impact on climate, climate change will also have a major impact on transportation.

Climate change impacts pose significant challenges to our nation's multi-modal transportation system and cause disruptions in other sectors across the economy. For example, major flooding in the Midwest in 1993 and 2008 restricted regional travel of all types, and disrupted freight and rail shipments across the country, such as those bringing coal to power plants and chlorine to water treatment systems. The U.S. transportation network is vital to the nation's economy, safety, and quality of life.

Buildings and debris float up against a railroad bridge on the Cedar River during record flooding in June 2008, in Cedar Rapids, Iowa.

Extreme events present major challenges for transportation, and such events are becoming more frequent and intense. Historical weather patterns are no longer a reliable predictor of the future.[222] Transportation planners have not typically accounted for climate change in their long-term planning and project development. The longevity of transportation infrastructure, the long-term nature of climate change, and the potential impacts identified by recent studies warrant serious attention to climate change in planning new or rehabilitated transportation systems.[223]

The strategic examination of national, regional, state, and local networks is an important step toward understanding the risks posed by climate change. A range of adaptation responses can be employed to reduce risks through redesign or relocation of infrastructure, increased redundancy of critical services, and operational improvements. Adapting to climate change is an evolutionary process. Through adoption of longer planning horizons, risk management, and adaptive responses, vulnerable transportation infrastructure can be made more resilient.[215]

Sea-level rise and storm surge will increase the risk of major coastal impacts, including both temporary and permanent flooding of airports, roads, rail lines, and tunnels.

Sea-level rise

Transportation infrastructure in U.S. coastal areas is increasingly vulnerable to sea-level rise. Given the high population density near the coasts, the potential exposure of transportation infrastructure to flooding is immense. Population swells in these areas during the summer months because beaches are very important tourist destinations.[222]

In the Gulf Coast area alone, an estimated 2,400 miles of major roadway and 246 miles of freight rail lines are at risk of permanent flooding within 50 to 100 years as global warming and land subsidence (sinking) combine to produce an anticipated relative sea-level rise in the range of 4 feet.[217] Since the Gulf Coast region's transportation network is interdependent and relies on minor roads and other low-lying infrastructure, the risks of service disruptions due to sea-level rise are likely to be even greater.[217]

Coastal areas are also major centers of economic activity. Six of the nation's top 10 freight gateways (measured by the value of shipments) will be threatened by sea-level rise.[222] Seven of the 10 largest ports (by tons of traffic) are located on the Gulf Coast.[222] The region is also home to the U.S. oil and gas industry, with its offshore drilling platforms, refineries, and pipelines. Roughly two-thirds of all U.S. oil imports are transported through this region[224] (see *Energy* sector). Sea-level rise would potentially affect commercial transportation activity valued in the hundreds of billions of dollars annually through inundation of area roads, railroads, airports, seaports, and pipelines.[217]

Storm surge

More intense storms, especially when coupled with sea-level rise, will result in far-reaching and damaging storm surges. An estimated 60,000 miles of coastal highway are already exposed to periodic flooding from coastal storms and high waves.[222] Some of these highways currently serve as evacuation routes during hurricanes and other coastal storms, and these routes could become seriously compromised in the future.

Gulf Coast Area Roads at Risk from Sea-Level Rise

Within 50 to 100 years, 2,400 miles of major roadway are projected to be inundated by sea-level rise in the Gulf Coast region. The map shows roadways at risk in the event of a sea-level rise of about 4 feet, within the range of projections for this region in this century under medium- and high-emissions scenarios.[91] In total, 24 percent of interstate highway miles and 28 percent of secondary road miles in the Gulf Coast region are at elevations below 4 feet.[217]

Regional Spotlight: Gulf Coast

Sea-level rise, combined with high rates of subsidence in some areas, will make much of the existing infrastructure more prone to frequent or permanent inundation; 27 percent of the major roads, 9 percent of the rail lines, and 72 percent of the ports in the area shown on the map on the previous page are built on land at or below 4 feet in elevation, a level within the range of projections for relative sea-level rise in this region in this century. Increased storm intensity may lead to increased service disruption and infrastructure damage. More than half of the area's major highways (64 percent of interstates, 57 percent of arterials), almost half of the rail miles, 29 airports, and virtually all of the ports, are below 23 feet in elevation and subject to flooding and damage due to hurricane storm surge. These factors merit consideration in today's transportation decisions and planning processes.[217]

Coastal areas are projected to experience continued development pressures as both retirement and tourist destinations. Many of the most populous counties of the Gulf Coast, which already experience the effects of tropical storms, are expected to grow rapidly in the coming decades.[222] This growth will generate demand for more transportation infrastructure and services, challenging transportation planners to meet the demand, address current and future flooding, and plan for future conditions.[223]

Land

More frequent inundation and interruptions in travel on coastal and low-lying roadways and rail lines due to storm surge are projected, potentially requiring changes to minimize disruptions. More frequent evacuations due to severe storm surges are also likely. Across the United States, many coastal cities have subways, tunnels, parking lots, and other transportation infrastructure below ground. Underground tunnels and other low-lying infrastructure will experience more frequent and severe flooding. Higher sea levels and storm surges will also erode road base and undermine bridge supports. The loss of coastal wetlands and barrier islands will lead to further coastal erosion due to the loss of natural protection from wave action.

Water

Impacts on harbor infrastructure from wave damage and storm surges are projected to increase. Changes will be required in harbor and port facilities to accommodate higher tides and storm surges. There will be reduced clearance under some waterway bridges for boat traffic. Changes in the navigability of channels are expected; some will become more accessible (and extend farther inland) because of deeper waters, while others will be restricted because of changes in sedimentation rates and sandbar locations. In some areas, waterway systems will become part of open water as barrier islands disappear. Some channels are likely to have to be dredged more frequently as has been done across large open-water bodies in Texas.[222]

Regional Spotlight: New York Metropolitan Area

With the potential for significant sea-level rise estimated under continued high levels of emissions, the combined effects of sea-level rise and storm surge are projected to increase the frequency of flooding. What is currently called a 100-year storm is projected to occur as often as every 10 years by late this century. Portions of lower Manhattan and coastal areas of Brooklyn, Queens, Staten Island, and Nassau County, would experience a marked increase in flooding frequency. Much of the critical transportation infrastructure, including tunnels, subways, and airports, lies well within the range of projected storm surge and would be flooded during such events.[222,225,369]

Air

Airports in coastal cities are often located adjacent to rivers, estuaries, or open ocean. Airport runways in coastal areas face inundation unless effective protective measures are taken. There is the potential for closure or restrictions for several of the nation's busiest airports that lie in coastal zones, affecting service to the highest density populations in the United States.

Flooding from increasingly intense downpours will increase the risk of disruptions and delays in air, rail, and road transportation, and damage from mudslides in some areas.

Heavy downpours have already increased substantially in the United States; the heaviest 1 percent of precipitation events increased by 20 percent, while total precipitation increased by only 7 percent over the past century.[112] Such intense precipitation is likely to increase the frequency and severity of events such as the Great Flood of 1993, which caused catastrophic flooding along 500 miles of the Mississippi and Missouri river system, paralyzing surface transportation systems, including rail, truck, and marine traffic. Major east-west traffic was halted for roughly six weeks in an area stretching from St. Louis, Missouri, west to Kansas City, Missouri and north to Chicago, Illinois, affecting one-quarter of all U.S. freight, which either originated or terminated in the flood-affected region.[222]

The June 2008 Midwest flood was the second record-breaking flood in the past 15 years. Dozens of levees were breached or overtopped in Iowa, Illinois, and Missouri, flooding huge areas, including nine square miles in and around Cedar Rapids, Iowa. Numerous highway and rail bridges were impassable due to flooding of approaches and transport was shut down along many stretches of highway, rail lines, and normally navigable waterways.

Planners have generally relied on weather extremes of the past as a guide to the future, planning, for example, for a "100-year flood," which is now likely to come more frequently as a result of climate change. Historical analysis of weather data has thus become less reliable as a forecasting tool. The accelerating changes in climate make it more difficult to predict the frequency and intensity of weather events that can affect transportation.[222]

Land

The increase in heavy precipitation will inevitably cause increases in weather-related accidents, delays, and traffic disruptions in a network already challenged by increasing congestion.[215] There will be increased flooding of evacuation routes, and construction activities will be disrupted. Changes in rain, snowfall, and seasonal flooding will impact safety and maintenance operations on the nation's roads and railways. For example, if more precipitation falls as rain rather than snow in winter and spring, there will be an increased risk of landslides, slope failures, and floods from the runoff, causing road closures as well as the need for road repair and reconstruction[222] (see *Water Resources* sector).

Increased flooding of roadways, rail lines, and underground tunnels is expected. Drainage systems will be overloaded more frequently and severely, causing backups and street flooding. Areas where flooding is already common will face more frequent and severe problems. For example, Louisiana Highway 1, a critical link in the transport of oil from the Gulf of Mexico, has recently experienced increased flooding, prompting authorities to elevate the road (see Adaptation Box page 58).[217] Increases in road washouts, damage to railbed support structures, and landslides and mudslides that damage roads and other infrastructure are expected. If soil moisture levels become too high, the structural integrity of roads, bridges, and tunnels, which in some cases are already under age-related stress and in need of repair, could be compromised. Standing water will have adverse impacts on road base. For example, damage due to long term submersion of roadways in Louisiana was estimated to be $50 million for just 200 miles of state-owned highway. The Louisiana Department of Transportation and Development noted that a total of 1,800 miles of roads were under water for long periods, requiring costly repairs.[217] Pipelines are likely to be damaged because intense precipitation can cause the ground to sink underneath the pipeline; in shallow river-

Adaptation: Climate Proofing a Road

Completion of a road around the 42-square mile island of Kosrae in the U.S.-affiliated Federated States of Micronesia provides a good example of adaptation to climate change. A road around the island's perimeter existed, except for a 10-mile gap. Filling this gap would provide all-weather land access to a remote village and allow easier access to the island's interior.

In planning this new section of road, authorities decided to "climate-proof" it against projected increases in heavy downpours and sea-level rise. This led to the section of road being placed higher above sea level and with an improved drainage system to handle the projected heavier rainfall. While there were additional capital costs for incorporating this drainage system, the accumulated costs, including repairs and maintenance, would be lower after about 15 years, equating to a good rate of return on investment. Adding this improved drainage system to roads that are already built is more expensive than on new construction, but still has been found to be cost effective.[226]

beds, pipelines are more exposed to the elements and can be subject to scouring and shifting due to heavy precipitation.[217]

Water

Facilities on land at ports and harbors will be vulnerable to short term flooding from heavy downpours, interrupting shipping service. Changes in silt and debris buildup resulting from extreme precipitation events will affect channel depth, increasing dredging costs. The need to expand stormwater treatment facilities, which can be a significant expense for container and other terminals with large impermeable surfaces, will increase.

Air

Increased delays due to heavy downpours are likely to affect operations, causing increasing flight delays and cancellations.[222] Stormwater runoff that exceeds the capacity of collection and drainage systems will cause flooding, delays, and airport closings. Heavy downpours will affect the structural integrity of airport facilities, such as through flood damage to runways and other infrastructure. All of these impacts have implications for emergency evacuation planning, facility maintenance, and safety.[222]

The increase in extreme heat will limit some transportation operations and cause pavement and track damage. Decreased extreme cold will provide some benefits such as reduced snow and ice removal costs.

Land

Longer periods of extreme heat in summer can damage roads in several ways, including softening of asphalt that leads to rutting from heavy traffic.[164] Sustained air temperature over 90°F is a significant threshold for such problems (see maps page 34). Extreme heat can cause deformities in rail tracks, at minimum resulting in speed restrictions and, at worst, causing derailments. Air temperatures above 100°F can lead to equipment failure (see maps page 90). Extreme heat also causes thermal expansion of bridge joints, adversely affecting bridge operations and increasing maintenance costs. Vehicle overheating and tire deterioration are additional concerns.[222] Higher temperatures will also increase refrigeration needs for goods during transport, particularly in the South, raising transportation costs.[217]

Increases in very hot days and heat waves are expected to limit construction activities due to health and safety concerns for highway workers. Guid-

Regional Spotlight: the Midwest

An example of intense precipitation affecting transportation infrastructure was the record-breaking 24-hour rainstorm in July 1996, which resulted in flash flooding in Chicago and its suburbs, with major impacts. Extensive travel delays occurred on metropolitan highways and railroads, and streets and bridges were damaged. Commuters were unable to reach Chicago for up to three days, and more than 300 freight trains were delayed or rerouted.[222]

The June 2008 Midwest floods caused I-80 in eastern Iowa to be closed for more than five days, disrupting major east-west shipping routes for trucks and the east-west rail lines through Iowa. These floods exemplify the kind of extreme precipitation events and their direct impacts on transportation that are likely to become more frequent in a warming world. These extremes create new and more difficult problems that must be addressed in the design, construction, rehabilitation, and operation of the nation's transportation infrastructure.

ance from the U.S. Occupational Safety and Health Administration states that concern for heat stress for moderate to heavy work begins at about 80°F as measured by an index that combines temperature, wind, humidity, and direct sunlight. For dry climates, such as Phoenix and Denver, National Weather Service heat indices above 90°F might allow work to proceed, while higher humidity areas such as New Orleans or Miami should consider 80 to 85°F as an initial level for work restrictions.[227] These trends and associated impacts will be exacerbated in many places by urban heat island effects (see *Human Health* and *Society* sectors).

Wildfires are projected to increase, especially in the Southwest (see *Southwest* region), threatening communities and infrastructure directly and bringing about road and rail closures in affected areas.

In many northern states, warmer winters will bring about reductions in snow and ice removal costs, lessen adverse environmental impacts from the use of salt and chemicals on roads and bridges, extend the construction season, and improve the mobility and safety of passenger and freight travel through reduced winter hazards. On the other hand, more freeze-thaw conditions are projected to occur in northern states, creating frost heaves and potholes on road and bridge surfaces and resulting in load restrictions on certain roads to minimize the damage. With the expected earlier onset of seasonal warming, the period of springtime load restrictions might be reduced in some areas, but it is likely to expand in others with shorter winters but longer thaw seasons. Longer construction seasons will be a benefit in colder locations.[222]

Water

Warming is projected to mean a longer shipping season but lower water levels for the Great Lakes and St. Lawrence Seaway. Higher temperatures, reduced lake ice, and increased evaporation are expected to combine to produce lower water levels as climate warming proceeds (see *Midwest* region). With lower lake levels, ships will be unable to carry as much cargo and hence shipping costs will increase. A recent study, for example, found that the projected reduction in Great Lakes water levels would result in an estimated 13 to 29 percent increase in shipping costs for Canadian commercial navigation by 2050, all else remaining equal.[222]

If low water levels become more common because of drier conditions due to climate change, this could create problems for river traffic, reminiscent of the stranding of more than 4,000 barges on the Mississippi River during the drought in 1988. Freight movements in the region could be seriously impaired, and extensive dredging could be required to keep shipping channels open. On the other hand, a longer shipping season afforded by a warmer climate could offset some of the resulting adverse economic effects.

Navigable Inland Waterways

CCSP SAP 4.7[217]

Inland waterways are an important part of the transportation network in various parts of the United States. For example, these waterways provide 20 states with access to the Gulf of Mexico.[217] As conditions become drier, these main transportation pathways are likely to be adversely affected by the resulting lower water levels, creating problems for river traffic. Names of navigable rivers are shown above.

In cold areas, the projected decrease in very cold days will mean less ice accumulation on vessels, decks, riggings, and docks; less ice fog; and fewer ice jams in ports.[222]

Air

Rising temperatures will affect airport ground facilities, runways in particular, in much the same way they affect roads. Airports in some areas are likely to benefit from reduction in the cost of snow and ice removal and the impacts of salt and chemical use, though some locations have seen increases in snowfall. Airlines could benefit from reduced need to de-ice planes.

More heat extremes will create added operational difficulties, for example, causing greater energy consumption by planes on the ground. Extreme heat also affects aircraft lift; because hotter air is less dense, it reduces the lift produced by the wing and the thrust produced by the engine – problems exacerbated at high altitudes and high temperatures. As a result, planes need to take off faster, and if runways are not sufficiently long for aircraft to build up enough speed to generate lift, aircraft weight must be reduced. Thus, increases in extreme heat will result in payload restrictions, could cause flight cancellations and service disruptions at affected airports, and could require some airports to lengthen runways. Recent hot summers have seen flights cancelled due to heat, especially in high altitude locations. Economic losses are expected at affected airports. A recent illustrative analysis projects a 17 percent reduction in freight carrying capacity for a single Boeing 747 at the Denver airport by 2030 and a 9 percent reduction at the Phoenix airport due to increased temperature and water vapor.[222]

Drought

Rising air temperatures increase evaporation, contributing to dry conditions, especially when accompanied by decreasing precipitation. Even where total annual precipitation does not decrease, precipitation is projected to become less frequent in many parts of the country.[68] Drought is expected to be an increasing problem in some regions; this, in turn, has impacts on transportation. For example, increased susceptibility to wildfires during droughts could threaten roads and other transportation infrastructure directly, or cause road closures due to fire threat or reduced visibility such as has occurred in Florida and California in recent years. There is also increased susceptibility to mudslides in areas deforested by wildfires. Airports could suffer from decreased visibility due to wildfires. River transport is seriously affected by drought, with reductions in the routes available, shipping season, and cargo carrying capacity.

Increased intensity of strong hurricanes would lead to more evacuations, infrastructure damage and failure, and transportation interruptions.

More intense hurricanes in some regions are a projected effect of climate change. Three aspects of tropical storms are relevant to transportation: precipitation, winds, and wind-induced storm surge. Stronger hurricanes have longer periods of intense precipitation, higher wind speeds (damage increases exponentially with wind speed[228]),

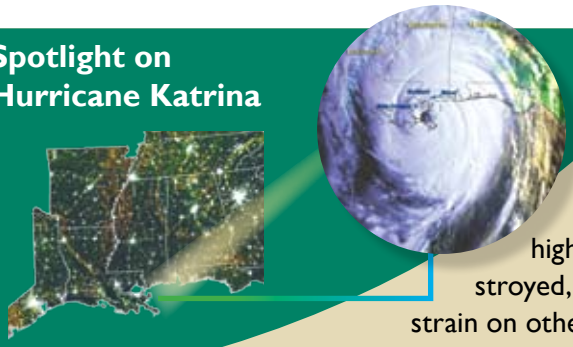
and higher storm surge and waves. Transportation planners, designers, and operators may need to adopt probabilistic approaches to developing transportation projects rather than relying on standards and the deterministic approaches of the past. The uncertainty associated with projecting impacts over a 50- to 100-year time period makes risk management a reasonable approach for realistically incorporating climate change into decision making and investment.[215]

Land

There will be a greater probability of infrastructure failures such as highway and rail bridge decks being displaced and railroad tracks being washed away. Storms leave debris on roads and rail lines, which can damage the infrastructure and interrupt travel and shipments of goods. In Louisiana, the Department of Transportation and Development spent $74 million for debris removal alone in the wake of hurricanes Katrina and Rita. The Mississippi Department of Transportation expected to spend in excess of $1 billion to replace the Biloxi and Bay St. Louis bridges, repair other portions of roadway, and remove debris. As of June 2007, more than $672 million had been spent.

There will be more frequent and potentially more extensive emergency evacuations. Damage to signs, lighting fixtures, and supports will increase. The lifetime of highways that have been exposed to flooding is expected to decrease. Road and rail infrastructure for passenger and freight services are likely to face increased flooding by strong hurricanes. In the Gulf Coast, more than one-third of the rail miles are likely to flood when subjected to a storm surge of 18 feet.[217]

Spotlight on Hurricane Katrina



Hurricane Katrina was one of the most destructive and expensive natural disasters in U.S. history, claiming more than 1,800 lives and causing an estimated $134 billion in damage.[217,229] It also seriously disrupted transportation systems as key highway and railroad bridges were heavily damaged or destroyed, necessitating rerouting of traffic and placing increased strain on other routes, particularly other rail lines. Replacement of major infrastructure took from months to years. The CSX Gulf Coast line was re-opened after five months and $250 million in reconstruction costs, while the Biloxi-Ocean Springs Bridge took more than two years to reopen. Barge shipping was halted, as was grain export out of the Port of New Orleans, the nation's largest site of grain exports. The extensive oil and gas pipeline network was shut down by the loss of electrical power, producing shortages of natural gas and petroleum products. Total recovery costs for the roads, bridges, and utilities as well as debris removal have been estimated at $15 billion to $18 billion.[217]

Hurricane Katrina damage to bridge

Redundancies in the transportation system, as well as the storm timing and track, helped keep the storm from having major or long-lasting impacts on national-level freight flows. For example, truck traffic was diverted from the collapsed bridge that carries highway I-10 over Lake Pontchartrain to highway I-12, which parallels I-10 well north of the Gulf Coast. The primary north-south highways that connect the Gulf Coast with major inland transportation hubs were not damaged and were open for nearly full commercial freight movement within days. The railroads were able to route some traffic not bound directly for New Orleans through Memphis and other Midwest rail hubs. While a disaster of historic proportions, the effects of Hurricane Katrina could have been even worse if not for the redundancy and resilience of the transportation network in the area.

Water

All aspects of shipping are disrupted by major storms. For example, freight shipments need to be diverted from the storm region. Activities at offshore drilling sites and coastal pumping facilities are generally suspended and extensive damage to these facilities can occur, as was amply demonstrated during the 2005 hurricane season. Refineries and pipelines are also vulnerable to damage and disruption due to the high winds and storm surge associated with hurricanes and other tropical storms (see *Energy* sector). Barges that are unable to get to safe harbors can be destroyed or severely damaged. Waves and storm surge will damage harbor infrastructure such as cranes, docks, and other terminal facilities. There are implications for emergency evacuation planning, facility maintenance, and safety management.

Air

More frequent interruptions in air service and airport closures can be expected. Airport facilities including terminals, navigational equipment, perimeter fencing, and signs are likely to sustain increased wind damage. Airports are frequently located in low-lying areas and can be expected to flood with more intense storms. As a response to this vulnerability, some airports, such as LaGuardia in New York City, are already protected by levees. Eight airports in the Gulf Coast region of Louisiana and Texas are located in historical 100-year flood plains; the 100-year flood events will be more frequent in the future, creating the likelihood of serious costs and disruption.[217]

Arctic warming will continue to reduce sea ice, lengthening the ocean transport season, but also resulting in greater coastal erosion due to waves. Permafrost thaw in Alaska will damage infrastructure. The ice road season will become shorter.

Special issues in Alaska

Warming has been most rapid in high northern regions. As a result, Alaska is warming at twice the rate of the rest of the nation, bringing both major opportunities and major challenges. Alaska's transportation infrastructure differs sharply from that of the lower 48 states. Although Alaska is twice the size of Texas, its population and road mileage are more like Vermont's. Only 30 percent of Alaska's roads are paved. Air travel is much more common than in other states. Alaska has 84 commercial airports and more than 3,000 airstrips, many of which are the only means of transport for rural communities. Unlike other states, over much of Alaska, the land is generally more accessible in winter, when the ground is frozen and ice roads and bridges formed by frozen rivers are available.

Sea ice decline

The striking thinning and downward trend in the extent of Arctic sea ice is regarded as a considerable opportunity for shippers. Continued reduction in sea ice should result in opening of additional ice-free ports, improved access to ports and natural resources in remote areas, and longer shipping seasons, but it is likely to increase erosion rates on land as well, raising costs for maintaining ports and other transportation infrastructure.[132,220]

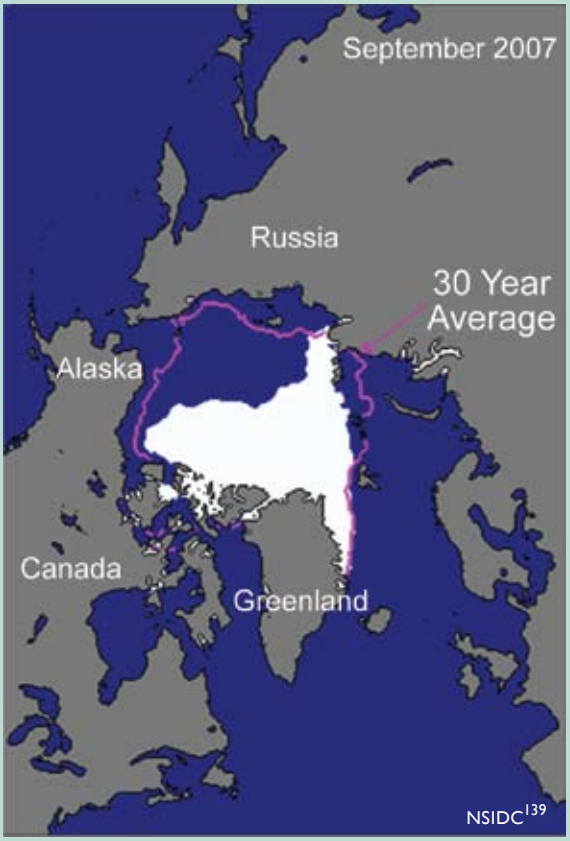
Later this century and beyond, shippers are looking forward to new Arctic shipping routes, including the fabled Northwest Passage, which could provide significant costs savings in shipping times and distances. However, the next few decades are likely to be very unpredictable for shipping through these new routes. The past three decades have seen very high year-to-year variability of sea ice extent in the Canadian Arctic, despite the overall decrease in September sea ice extent. The loss of sea ice from the shipping channels of the Canadian Archipelago might actually allow more frequent intrusions of icebergs, which would continue to impede shipping through the Northwest Passage.

Lack of sea ice, especially on the northern shores of Alaska, creates conditions whereby storms produce waves that cause serious coastal erosion.[137,219] Already a number of small towns, roads, and airports are threatened by retreating coastlines, necessitating the planned relocation of these communities (see *Alaska* region).[132,220]

Thawing ground

The challenges warming presents for transportation on land are considerable.[164] For highways, thawing of permafrost causes settling of the roadbed and

Arctic Sea Ice Decline



The pink line shows the average September sea ice extent from 1979 through the present. The white area shows September 2007 sea ice extent. In 2008, the extent was slightly larger than 2007, but the ice was thinner, resulting in a lower total volume of sea ice. In addition, recent years have had less ice that persisted over numerous years and more first-year ice, which melts more quickly.[139]

frost heaves that adversely affect the integrity of the road structure and its load-carrying capacity. The majority of Alaska's highways are located in areas where permafrost is discontinuous, and dealing with thaw settlement problems already claims a significant portion of highway maintenance dollars.

Bridges and large culverts are particularly sensitive to movement caused by thawing permafrost and are often much more difficult than roads to repair and modify for changing site conditions. Thus, designing these facilities to take climate change into account is even more critical than is the case for roads.

Another impact of climate change on bridges is increased scouring. Hotter, drier summers in Alaska have led to increased glacial melting and longer periods of high streamflows, causing both increased sediment in rivers and scouring of bridge supporting piers and abutments. Temporary ice roads and bridges are commonly used in many parts of Alaska to access northern communities and provide support for the mining and oil and gas industries. Rising temperatures have already shortened the season during which these critical facilities can be used. Like the highway system, the Alaska Railroad crosses permafrost terrain, and frost heave and settlement from thawing affect some portions of the track, increasing maintenance costs.[28,132,220]

A significant number of Alaska's airstrips in the southwest, northwest, and interior of the state are built on permafrost. These airstrips will require major repairs or relocation if their foundations are compromised by thawing.

The cost of maintaining Alaska's public infrastructure is projected to increase 10 to 20 percent by 2030 due to warming, costing the state an additional $4 billion to $6 billion, with roads and airports accounting for about half of this cost.[230] Private infrastructure impacts have not been evaluated.[217]

The Trans-Alaska Pipeline System, which stretches from Prudhoe Bay in the north to the ice-free port of Valdez in the south, crosses a wide range of permafrost types and varying temperature conditions. More than half of the 800-mile pipeline is elevated on vertical supports over potentially unstable permafrost. Because the system was designed in the early 1970s on the basis of permafrost and climate conditions of the 1950 to 1970 period, it requires continuous monitoring and some supports have had to be replaced.

Travel over the tundra for oil and gas exploration and extraction is limited to the period when the ground is sufficiently frozen to avoid damage to the fragile tundra. In recent decades, the number of days that exploration and extraction equipment could be used has dropped from 200 days to 100 days per year due to warming.[220] With continued warming, the number of exploration days is expected to decline even more.

Agriculture

Key Messages:

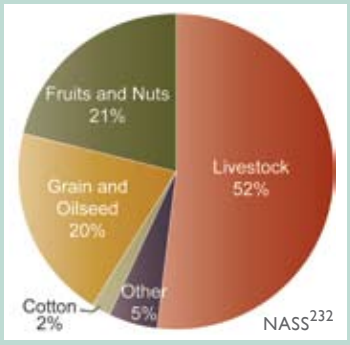
- Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields.
- Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth.
- Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control.
- Forage quality in pastures and rangelands generally declines with increasing carbon dioxide concentration because of the effects on plant nitrogen and protein content, reducing the land's ability to supply adequate livestock feed.
- Increased heat, disease, and weather extremes are likely to reduce livestock productivity.

Agriculture in the United States is extremely diverse in the range of crops grown and animals raised, and produces over $200 billion a year in food commodities, with livestock accounting for more than half. Climate change will increase productivity in certain crops and regions and reduce productivity in others (see for example *Midwest* and *Great Plains* regions).[193]

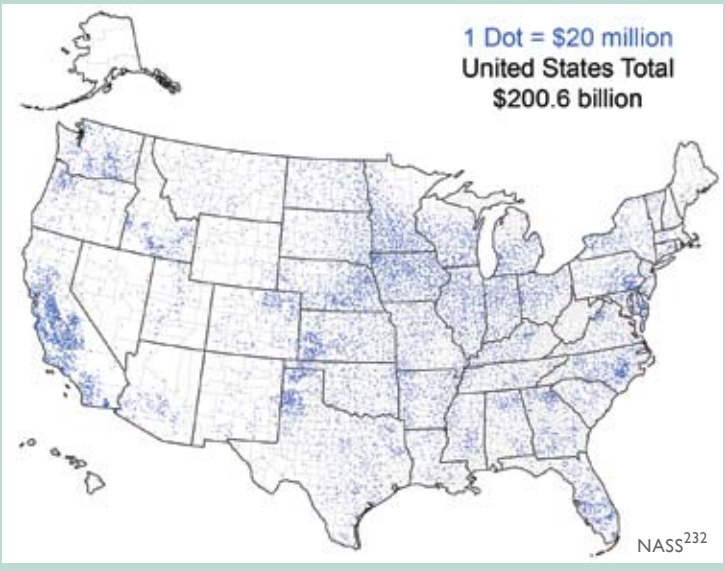
While climate change clearly affects agriculture, climate is also affected by agriculture, which contributes 13.5 percent of all human-induced greenhouse gas emissions globally. In the United States, agriculture represents 8.6 percent of the nation's total greenhouse gas emissions, including 80 percent of its nitrous oxide emissions and 31 percent of its methane emissions.[231]

Increased agricultural productivity will be required in the future to supply the needs of an increasing population. Agricultural productivity is dependent upon the climate and land resources. Climate change can have both beneficial and detrimental impacts on plants. Throughout history, agricultural enterprises have coped with changes in climate through changes in management and in crop or animal selection. However, under higher heat-trapping gas emissions scenarios, the projected climate changes are likely to increasingly challenge U.S. capacity to as efficiently produce food, feed, fuel, and livestock products.

Relative Contributions to Agricultural Products, 2002



Market Value of Agricultural Products Sold, 2002



Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields.

Crop responses in a changing climate reflect the interplay among three factors: rising temperatures, changing water resources, and increasing carbon dioxide concentrations. Warming generally causes plants that are below their optimum temperature to grow faster, with obvious benefits. For some plants, such as cereal crops, however, faster growth means there is less time for the grain itself to grow and mature, reducing yields.[193] For some annual crops, this can be compensated for by adjusting the planting date to avoid late season heat stress.[164]

The grain-filling period (the time when the seed grows and matures) of wheat and other small grains shortens dramatically with rising temperatures. Analysis of crop responses suggests that even moderate increases in temperature will decrease yields of corn, wheat, sorghum, bean, rice, cotton, and peanut crops.[193]

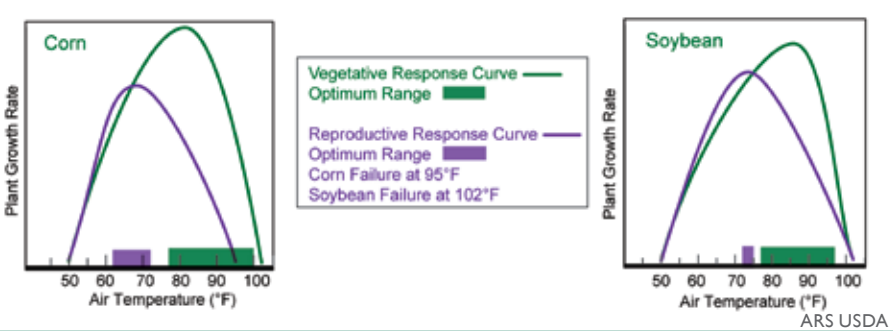
Some crops are particularly sensitive to high nighttime temperatures, which have been rising even faster than daytime temperatures.[68] Nighttime temperatures are expected to continue to rise in the future. These changes in temperature are especially critical to the reproductive phase of growth because warm nights increase the respiration rate and reduce the amount of carbon that is captured during the day by photosynthesis to be retained in the fruit or grain. Further, as temperatures continue to rise and drought periods increase, crops will be more frequently exposed to temperature thresholds at which pollination and grain-set processes begin to fail and quality of vegetable crops decreases. Grain, soybean, and canola crops have relatively low optimal temperatures, and thus will have reduced yields and will increasingly begin to experience failure as warming proceeds.[193] Common snap beans show substantial yield reduction when nighttime temperatures exceed 80°F.

Higher temperatures will mean a longer growing season for crops that do well in the heat, such as melon, okra, and sweet potato, but a shorter growing season for crops more suited to cooler conditions, such as potato, lettuce, broccoli, and spinach.[193] Higher temperatures also cause plants to use more water to keep cool. This is one example of how the interplay between rising temperatures and water availability is critical to how plants respond to climate change. But fruits, vegetables, and grains can suffer even under well-watered conditions if temperatures exceed the maximum level for pollen viability in a particular plant; if temperatures exceed the threshold for that plant, it won't produce seed and so it won't reproduce.[193]

Temperature increases will cause the optimum latitude for crops to move northward; decreases in temperature would cause shifts toward the equator. Where plants can be efficiently grown depends upon climate conditions, of which temperature is one of the major factors.

Plants need adequate water to maintain their temperature within an optimal range. Without water for cooling, plants will suffer heat stress. In many regions, irrigation water is used to maintain adequate temperature conditions for the growth of cool season plants (such as many vegetables), even in warm environments. With increasing demand and competition for freshwater supplies, the water needed for these crops might be increasingly limited. If water supply variability increases, it will affect plant growth and cause

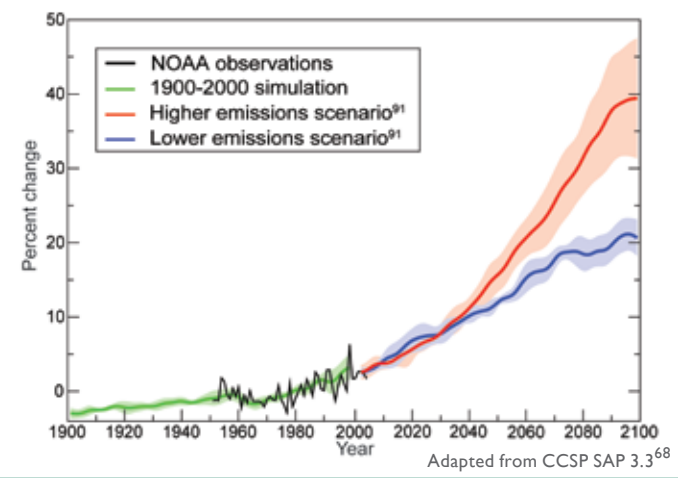
Corn and Soybean Temperature Response



ARS USDA

For each plant variety, there is an optimal temperature for vegetative growth, with growth dropping off as temperatures increase or decrease. Similarly, there is a range of temperatures at which a plant will produce seed. Outside of this range, the plant will not reproduce. As the graphs show, corn will fail to reproduce at temperatures above 95°F and soybean above 102°F.

Increase in Percent of Very Warm Nights



The graph shows the observed and projected change in percent of very warm nights from the 1950-1990 average in the United States. Under the lower emissions scenario,[91] the percentage of very warm nights is projected to increase about 20 percent by 2100. Under the higher emissions scenario,[91] it is projected to increase by about 40 percent.[68] The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. The projections appear smooth because they show the calculated average of many models.

reduced yields. The amount and timing of precipitation during the growing season are also critical, and will be affected by climate change. Changes in season length are also important and affect crops differently.[193]

Higher carbon dioxide levels generally cause plants to grow larger. For some crops, this is not necessarily a benefit because they are often less nutritious, with reduced nitrogen and protein content. Carbon dioxide also makes some plants more water-use efficient, meaning they produce more plant material, such as grain, on less water.[193] This is a benefit in water-limited areas and in seasons with less than normal rainfall amounts.

In some cases, adapting to climate change could be as simple as changing planting dates, which can be an effective no- or low-cost option for taking advantage of a longer growing season or avoiding crop exposure to adverse climatic conditions such as high temperature stress or low rainfall periods. Effectiveness will depend on the region, crop, and the rate and amount of warming. It is unlikely to be effective if a farmer goes to market when the supply-demand balance drives prices down. Predicting the optimum planting date for maximum profits will be more challenging in a future with increased uncertainty regarding climate effects on not only local productivity, but also on supply from competing regions.[193]

Another adaptation strategy involves changing to crop varieties with improved tolerance to heat or drought, or those that are adapted to take advantage of a longer growing season. This is less likely to be cost-effective for perennial crops, for which changing varieties is extremely expensive and new plantings take several years to reach maximum productivity. Even for annual crops, changing varieties is not always a low-cost option. Seed for new stress-tolerant varieties can be expensive, and new varieties often require investments in new planting equipment or require adjustments in a wide range of farming practices. In some cases, it is difficult to breed for genetic tolerance to elevated temperature or to identify an alternative variety that is adapted to the new climate and to local soils, practices, and market demands.

Fruits that require long winter chilling periods will experience declines. Many varieties of fruits (such as popular varieties of apples and berries) require between 400 and 1,800 cumulative hours below 45°F each winter to produce abundant yields the following summer and fall. By late this century, under higher emissions scenarios,[91] winter temperatures in many important fruit-producing regions such as the Northeast will be too consistently warm to meet these requirements. Cranberries have a particularly high chilling requirement, and there are no known low-chill varieties. Massachusetts and New Jersey supply nearly half the nation's cranberry crop. By the middle of this century, under higher emissions scenarios,[91] it is unlikely that these areas will support cranberry production due to a lack of the winter chilling they need.[233,234] Such impacts will vary by region. For example, though there will still be risks of early-season frosts and damaging winter thaws, warming is expected to improve the climate for fruit production in the Great Lakes region.[164]

A seemingly paradoxical impact of warming is that it appears to be increasing the risk of plant frost

Effects of Increased Air Pollution on Crop Yields

Ground-level ozone (a component of smog) is an air pollutant that is formed when nitrogen oxides emitted from fossil fuel burning interact with other compounds, such as unburned gasoline vapors, in the atmosphere,[237] in the presence of sunlight. Higher air temperatures result in greater concentrations of ozone. Ozone levels at the land surface have risen in rural areas of the United States over the past 50 years, and they are forecast to continue increasing with warming, especially under higher emissions scenarios.[91] Plants are sensitive to ozone, and crop yields are reduced as ozone levels increase. Some crops that are particularly sensitive to ozone pollution include soybeans, wheat, oats, green beans, peppers, and some types of cotton.[193]

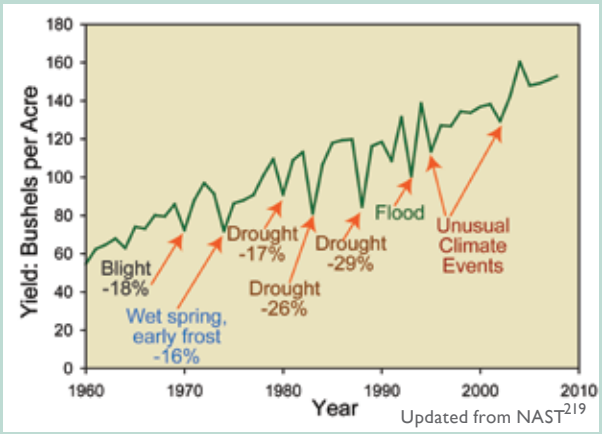
damage. Mild winters and warm, early springs, which are beginning to occur more frequently as climate warms, induce premature plant development and blooming, resulting in exposure of vulnerable young plants and plant tissues to subsequent late-season frosts. For example, the 2007 spring freeze in the eastern United States caused widespread devastation of crops and natural vegetation because the frost occurred during the flowering period of many trees and during early grain development on wheat plants.[235] Another example is occurring in the Rocky Mountains where in addition to the process described above, reduced snow cover leaves young plants unprotected from spring frosts, with some plant species already beginning to suffer as a result[236] (see *Ecosystems* sector).

Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth.

One of the most pronounced effects of climate change is the increase in heavy downpours. Precipitation has become less frequent but more intense, and this pattern is projected to continue across the United States.[112] One consequence of excessive rainfall is delayed spring planting, which jeopardizes profits for farmers paid a premium for early season production of high-value crops such as melon, sweet corn, and tomatoes. Field flooding during the growing season causes crop losses due to low oxygen levels in the soil, increased susceptibility to root diseases, and increased soil compaction due to the use of heavy farm equipment on wet soils. In spring 2008, heavy rains caused the Mississippi River to rise to about 7 feet above flood stage, inundating hundreds of thousands of acres of cropland. The flood hit just as farmers were preparing to harvest wheat and plant corn, soybeans, and cotton. Preliminary estimates of agricultural losses are around $8 billion.[213] Some farmers were put out of business and others will be recovering for years to come. The flooding caused severe erosion in some areas and also caused an increase in runoff and leaching of agricultural chemicals into surface water and groundwater.[233]

Another impact of heavy downpours is that wet conditions at harvest time result in reduced quality of many crops. Storms with heavy rainfall often are accompanied by wind gusts, and both strong winds and rain can flatten crops, causing significant damage. Vegetable and fruit crops are sensitive to even short-term, minor stresses, and as such are par-

U.S. Corn Yields 1960 to 2008



While technological improvements have resulted in a general increase in corn yields, extreme weather events have caused dramatic reductions in yields in particular years. Increased variation in yield is likely to occur as temperatures increase and rainfall becomes more variable during the growing season. Without dramatic technological breakthroughs, yields are unlikely to continue their historical upward trend as temperatures rise above the optimum level for vegetative and reproductive growth.

ticularly vulnerable to weather extremes.[193] More rainfall concentrated into heavy downpours also increases the likelihood of water deficiencies at other times because of reductions in rainfall frequency.

Drought frequency and severity are projected to increase in the future over much of the United States, particularly under higher emissions scenarios.[90,91] Increased drought will be occurring at a time when crop water requirements also are increasing due to rising temperatures. Water deficits are detrimental for all crops.[233]

Temperature extremes will also pose problems. Even crop species that are well-adapted to warmth, such as tomatoes, can have reduced yield and/or quality when daytime maximum temperatures exceed 90°F for even short periods during critical reproductive stages (see maps page 34).[112] For many high-value crops, just hours or days of moderate heat stress at critical growth stages can reduce grower profits by negatively affecting visual or flavor quality, even when total yield is not reduced.[238]

Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control.

Weeds benefit more than cash crops from higher temperatures and carbon dioxide levels.[193] One concern with continued warming is the northward expansion of invasive weeds. Southern farmers currently lose more of their crops to weeds than do northern farmers. For example, southern farmers lose 64 percent of the soybean crop to weeds, while northern farmers lose 22 percent.[239] Some extremely aggressive weeds plaguing the South (such as kudzu) have historically been confined to areas where winter temperatures do not drop below specific thresholds. As temperatures continue to rise, these weeds will expand their ranges northward into important agricultural areas.[240] Kudzu currently has invaded 2.5 million acres of the Southeast and is a carrier of the fungal disease soybean rust, which represents a major and expanding threat to U.S. soybean production.[234]

Controlling weeds currently costs the United States more than $11 billion a year, with the majority spent on herbicides;[241] so both herbicide use and costs are likely to increase as temperatures and carbon dioxide levels rise. At the same time, the most widely used herbicide in the United States, glyphosate (RoundUp®), loses its efficacy on weeds grown at carbon dioxide levels that are projected to occur in the coming decades (see photos below). Higher concentrations of the chemical and more frequent spraying thus will be needed, increasing economic and environmental costs associated with chemical use.[233]

Many insect pests and crop diseases thrive due to warming, increasing losses and necessitating greater pesticide use. Warming aids insects and diseases in several ways. Rising temperatures allow both insects and pathogens to expand their ranges northward. In addition, rapidly rising winter temperatures allow more insects to survive over the winter, whereas cold winters once controlled their populations. Some of these insects, in addition to directly

Herbicide Loses Effectiveness at Higher CO_2

Current CO_2 (380 ppm) Potential Future CO_2 (680 ppm)

The left photo shows weeds in a plot grown at a carbon dioxide (CO_2) concentration of about 380 parts per million (ppm), which approximates the current level. The right photo shows a plot in which the CO_2 level has been raised to about 680 ppm. Both plots were equally treated with herbicide.[233]

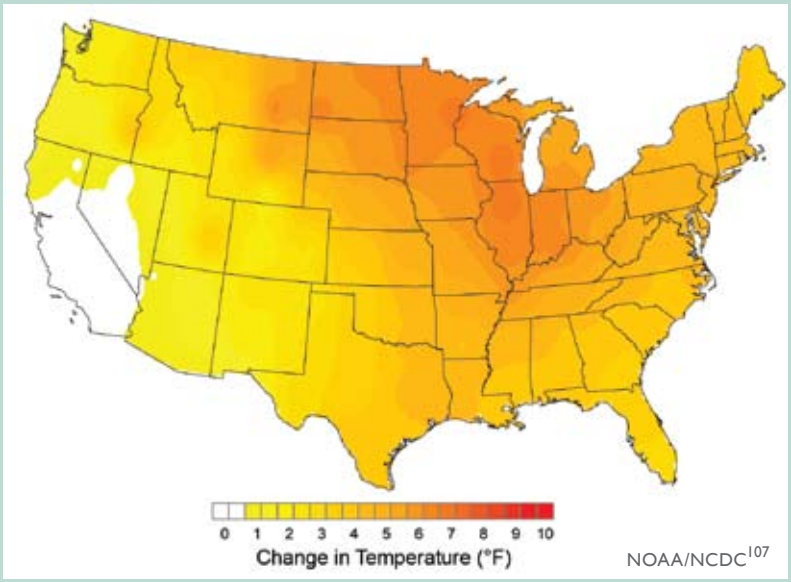
damaging crops, also carry diseases that harm crops. Crop diseases in general are likely to increase as earlier springs and warmer winters allow proliferation and higher survival rates of disease pathogens and parasites.[193,234] The longer growing season will allow some insects to produce more generations in a single season, greatly increasing their populations. Finally, plants grown in higher carbon dioxide conditions tend to be less nutritious, so insects must eat more to meet their protein requirements, causing greater destruction to crops.[193]

Due to the increased presence of pests, spraying is already much more common in warmer areas than in cooler areas. For example, Florida sweet corn growers spray their fields 15 to 32 times a year to fight pests such as corn borer and corn earworm, while New York farmers average zero to five times.[193] In addition, higher temperatures are known to reduce the effectiveness of certain classes of pesticides (pyrethroids and spinosad).

A particularly unpleasant example of how carbon dioxide tends to favor undesirable plants is found in the response of poison ivy to rising carbon dioxide concentrations. Poison ivy thrives in air with extra carbon dioxide in it, growing bigger and producing a more toxic form of the oil, urushiol, which causes painful skin reactions in 80 percent of people. Contact with poison ivy is one of the most widely reported ailments at poison centers in the United States, causing more than 350,000 cases of contact dermatitis each year. The growth stimulation of poison ivy due to increasing carbon dioxide concentration exceeds that of most other woody species. Given continued increases in carbon dioxide emissions, poison ivy is expected to become more abundant and more toxic in the future, with implications for forests and human health.[234]

Higher temperatures, longer growing seasons, and increased drought will lead to increased agricultural water use in some areas. Obtaining the maximum "carbon dioxide fertilization" benefit often requires more efficient use of water and fertilizers that better synchronize plant demand with supply. Farmers are likely to respond to more aggressive and invasive weeds, insects, and pathogens with increased use of herbicides, insecticides, and fungicides. Where increases in water and chemical inputs become necessary, this will increase costs for the farmer, as well as having society-wide impacts by depleting water supply, increasing reactive nitrogen and pesticide loads to the environment, and increasing risks to food safety and human exposure to pesticides.

Winter Temperature Trends, 1975 to 2007



Temperatures are rising faster in winter than in any other season, especially in many key agricultural regions. This allows many insect pests and crop diseases to expand and thrive, creating increasing challenges for agriculture. As indicated by the map, the Midwest and northern Great Plains have experienced increases of more than 7°F in average winter temperatures over the past 30 years.

Forage quality in pastures and rangelands generally declines with increasing carbon dioxide concentration because of the effects on plant nitrogen and protein content, reducing the land's ability to supply adequate livestock feed.

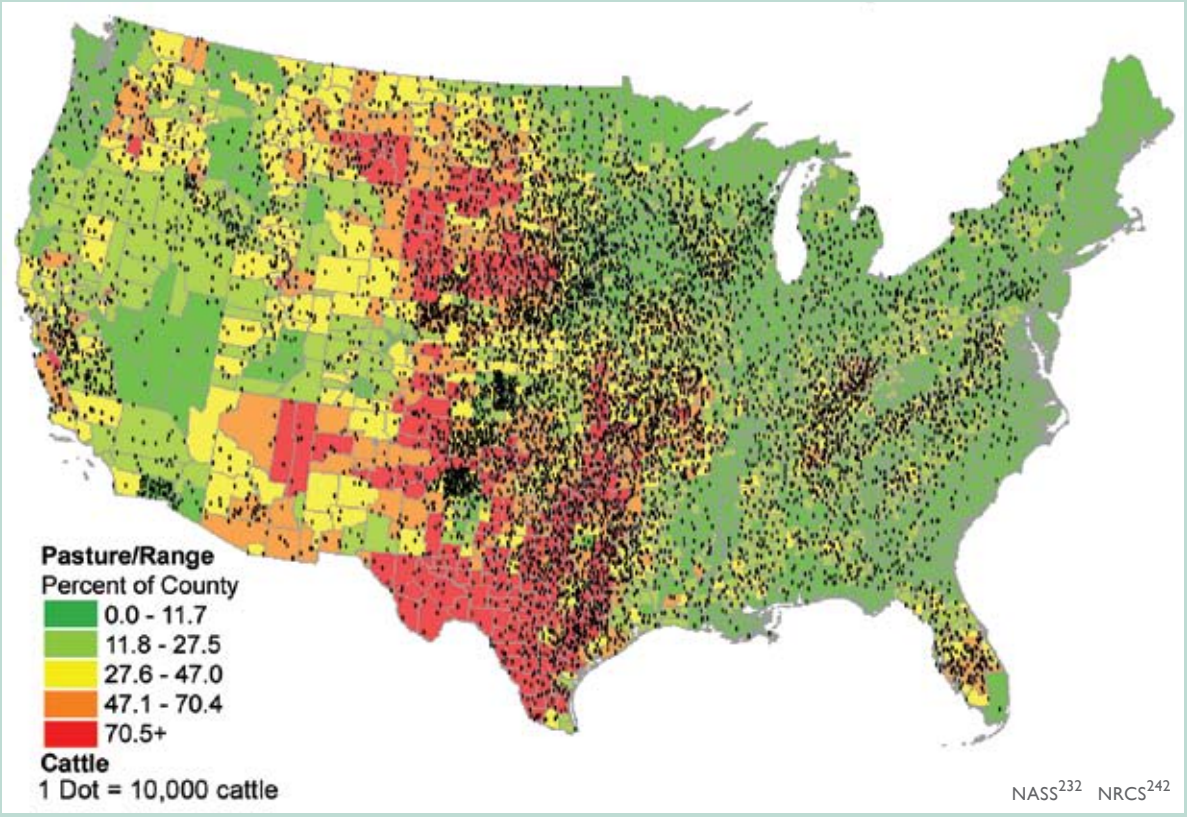
Beef cattle production takes place in every state in the United States, with the greatest number raised in regions that have an abundance of native or planted pastures for grazing. Generally, eastern pasturelands are planted and managed, whereas western rangelands are native pastures, which are

not seeded and receive much less rainfall. There are transformations now underway in many semi-arid rangelands as a result of increasing atmospheric carbon dioxide concentration and the associated climate change. These transformations include which species of grasses dominate, as well as the forage quality of the dominant grasses. Increases in carbon dioxide are generally reducing the quality of the forage, so that more acreage is needed to provide animals with the same nutritional value, resulting in an overall decline in livestock productivity. In addition, woody shrubs and invasive cheatgrass are encroaching into grasslands, further reducing their forage value.[193] The combination of these factors leads to an overall decline in livestock productivity.

While rising atmospheric carbon dioxide concentration increases forage quantity, it has negative impacts on forage quality because plant nitrogen and protein concentrations often decline with higher concentrations of carbon dioxide.[193] This reduction in protein reduces forage quality and counters the positive effects of carbon dioxide enrichment on carbohydrates. Rising carbon dioxide concentration also has the potential to reduce the digestibility of forages that are already of poor quality. Reductions in forage quality could have pronounced detrimental effects on animal growth, reproduction, and survival, and could render livestock production unsustainable unless animal diets are supplemented with protein, adding more costs to production. On shortgrass prairie, for example, a carbon dioxide enrichment experiment reduced the protein concentration of autumn forage below critical maintenance levels for livestock in 3 out of 4 years and reduced the digestibility of forage by 14 percent in mid-summer and by 10 percent in autumn. Significantly, the grass type that thrived the most under excess carbon dioxide conditions also had the lowest protein concentration.[193]

At the scale of a region, the composition of forage plant species is determined mostly by climate and soils. The primary factor controlling the distribution and abundance of plants is water: both the

Distribution of Beef Cattle and Pasture/Rangeland in Continental U.S.



The colors show the percent of the county that is cattle pasture or rangeland, with red indicating the highest percentage. Each dot represents 10,000 cattle. Livestock production occurs in every state. Increasing concentration of carbon dioxide reduces the quality of forage, necessitating more acreage and resulting in a decline in livestock productivity.

amount of water plants use and water availability over time and space. The ability to anticipate vegetation changes at local scales and over shorter periods is limited because at these scales the response of vegetation to global-scale changes depends on a variety of local processes including the rate of disturbances such as fire and grazing, and the rate at which plant species can move across sometimes-fragmented landscapes. Nevertheless, some general patterns of vegetation change are beginning to emerge. For example, experiments indicate that a higher carbon dioxide concentration favors weeds and invasive plants over native species because invasives have traits (such as rapid growth rate and prolific seed production) that allow a larger growth response to carbon dioxide. In addition, the effect of a higher carbon dioxide concentration on plant species composition appears to be greatest where the land has been disturbed (such as by fire or grazing) and nutrient and light availability are high.[193]

Increases in temperature lengthen the growing season, and thus are likely to extend forage production into the late fall and early spring. However, overall productivity remains dependent on precipitation during the growing season.[193]

Increased heat, disease, and weather extremes are likely to reduce livestock productivity.

Like human beings, cows, pigs, and poultry are warm-blooded animals that are sensitive to heat. In terms of production efficiency, studies show that the negative effects of hotter summers will outweigh the positive effects of warmer winters. The more the U.S. climate warms, the more production will fall. For example, an analysis projected that a warming in the range of 9 to 11°F (as in the higher emissions scenarios[91]) would cause a 10 percent decline in livestock yields in cow/calf and dairy operations in Appalachia, the Southeast (including the Mississippi Delta), and southern Plains regions, while a warming of 2.7°F would cause less than a 1 percent decline.

Temperature and humidity interact to cause stress in animals, just as in humans; the higher the heat and humidity, the greater the stress and discomfort, and the larger the reduction in the animals' ability to produce milk, gain weight, and reproduce. Milk production declines in dairy operations, the number of days it takes for cows to reach their target weight grows longer in meat operations, conception rate in cattle falls, and swine growth rates decline due to heat. As a result, swine, beef, and milk production are all projected to decline in a warmer world.[193]

The projected increases in air temperatures will negatively affect confined animal operations (dairy, beef, and swine) located in the central United States, increasing production costs as a result of reductions in performance associated with lower feed intake and increased requirements for energy to maintain healthy livestock. These costs do not account for the increased death of livestock associated with extreme weather events such as heat waves. Nighttime recovery is an essential element of survival when livestock are stressed by extreme heat. A feature of recent heat waves is the lack of nighttime relief. Large numbers of deaths have occurred in recent heat waves, with individual states reporting losses of 5,000 head of cattle in a single heat wave in one summer.[193]

Warming also affects parasites and disease pathogens. The earlier arrival of spring and warmer winters allow greater proliferation and survival of parasites and disease pathogens.[193] In addition, changes in rainfall distributions are likely to lead to changes in diseases sensitive to moisture. Heat stress reduces animals' ability to cope with other stresses, such as diseases and parasites. Furthermore, changes in rainfall distributions could lead to changes in diseases sensitive to relative humidity.

Maintaining livestock production would require modifying facilities to reduce heat stress on animals, using the best understanding of the chronic and acute stresses that livestock will encounter to determine the optimal modification strategy.[193]

Changing livestock species as an adaptation strategy is a much more extreme, high-risk, and, in most cases, high-cost option than changing crop varieties. Accurate predictions of climate trends and development of the infrastructure and market for the new livestock products are essential to making this an effective response.

Ecosystems

Key Messages:

- Ecosystem processes, such as those that control growth and decomposition, have been affected by climate change.
- Large-scale shifts have occurred in the ranges of species and the timing of the seasons and animal migration, and are very likely to continue.
- Fires, insect pests, disease pathogens, and invasive weed species have increased, and these trends are likely to continue.
- Deserts and drylands are likely to become hotter and drier, feeding a self-reinforcing cycle of invasive plants, fire, and erosion.
- Coastal and near-shore ecosystems are already under multiple stresses. Climate change and ocean acidification will exacerbate these stresses.
- Arctic sea ice ecosystems are already being adversely affected by the loss of summer sea ice and further changes are expected.
- The habitats of some mountain species and coldwater fish, such as salmon and trout, are very likely to contract in response to warming.
- Some of the benefits ecosystems provide to society will be threatened by climate change, while others will be enhanced.

The natural functioning of the environment provides both goods – such as food and other products that are bought and sold – and services, which our society depends upon. For example, ecosystems store large amounts of carbon in plants and soils; they regulate water flow and water quality; and they stabilize local climates. These services are not assigned a financial value, but society nonetheless depends on them. Ecosystem processes are the underpinning of these services: photosynthesis, the process by which plants capture carbon dioxide from the atmosphere and create new growth; the plant and soil processes that recycle nutrients from decomposing matter and maintain soil fertility; and the processes by which plants draw water from soils and return water to the atmosphere. These ecosystem processes are affected by climate and by the concentration of carbon dioxide in the atmosphere.[70]

The diversity of living things (biodiversity) in ecosystems is itself an important resource that maintains the ability of these systems to provide the services upon which society depends. Many factors affect biodiversity including: climatic conditions; the influences of competitors, predators, parasites, and diseases; disturbances such as fire; and other physical factors. Human-induced climate change, in conjunction with other stresses, is exerting major influences on natural environments and biodiversity, and these influences are generally expected to grow with increased warming.[70]

Ecosystem processes, such as those that control growth and decomposition, have been affected by climate change.

Climate has a strong influence on the processes that control growth and development in ecosystems. Temperature increases generally speed up plant growth, rates of decomposition, and how rapidly the cycling of nutrients occurs, though other factors, such as whether sufficient water is available, also influence these rates. The growing season is lengthening as higher temperatures occur earlier in the spring. Forest growth has risen over the past several decades as a consequence of a number of factors – young forests reaching maturity, an increased concentration of carbon dioxide in the atmosphere, a longer growing season, and increased deposition of nitrogen from the atmosphere. Based on the current understanding of these processes, the individual effects are difficult to disentangle.[243]

Butterfly Range Shifts Northward

As climate warms, many species in the United States are shifting their ranges northward and to higher elevations. The map shows the response of Edith's checkerspot butterfly populations to a warming climate over the past 136 years in the American West. Over 70 percent of the southernmost populations (shown in yellow) have gone extinct. The northernmost populations and those above 8,000 feet elevation in the cooler climate of California's Sierra Nevada (shown in green) are still thriving. These differences in numbers of population extinctions across the geographic range of the butterfly have resulted in the average location shifting northward and to higher elevations over the past century, illustrating how climate change is altering the ranges of many species. Because their change in range is slow, most species are not expected to be able to keep up with the rapid climate change projected in the coming decades.[244]

A higher atmospheric carbon dioxide concentration causes trees and other plants to capture more carbon from the atmosphere, but experiments show that trees put much of this extra carbon into producing fine roots and twigs, rather than new wood. The effect of carbon dioxide in increasing growth thus seems to be relatively modest, and generally is seen most strongly in young forests on fertile soils where there is also sufficient water to sustain this growth. In the future, as atmospheric carbon dioxide continues to rise, and as climate continues to change, forest growth in some regions is projected to increase, especially in relatively young forests on fertile soils.[243]

Forest productivity is thus projected to increase in much of the East, while it is projected to decrease in much of the West where water is scarce and projected to become more so. Wherever droughts increase, forest productivity will decrease and tree death will increase. In addition to occurring in much of the West, these conditions are projected to occur in parts of Alaska and in the eastern part of the Southeast.[243]

Large-scale shifts have occurred in the ranges of species and the timing of the seasons and animal migration, and are very likely to continue.

Climate change is already having impacts on animal and plant species throughout the United States. Some of the most obvious changes are related to the timing of the seasons: when plants bud in spring, when birds and other animals migrate, and so on. In the United States, spring now arrives an average of 10 days to two weeks earlier than it did 20 years ago. The growing season is lengthening over much of the continental United States. Many migratory bird species are arriving earlier. For example, a study of northeastern birds that migrate long distances found that birds wintering in the southern United States now arrive back in the Northeast an average of 13 days earlier than they did during the first half of the last century. Birds wintering in South America arrive back in the Northeast an average of four days earlier.[70]

Another major change is in the geographic distribution of species. The ranges of many species in the United States have shifted northward and upward in elevation. For example, the ranges of many butterfly species have expanded northward, contracted at the southern edge, and shifted to higher elevations as warming has continued. A study of Edith's checkerspot butterfly showed that 40 percent of the populations below 2,400 feet have gone extinct, despite the availability of otherwise suitable habitat and food supply. The checkerspot's most southern populations also have gone extinct, while new populations have been established north of the previous northern boundary for the species.[70]

For butterflies, birds, and other species, one of the concerns with such changes in geographic range and timing of migration is the potential for mismatches between species and the resources they need to survive. The rapidly changing landscape, such as new highways and expanding urban areas, can create barriers that limit habitat and increase species loss. Failure of synchronicity between butterflies and the resources they depend

upon has led to local population extinctions of the checkerspot butterfly during extreme drought and low-snowpack years in California.[70]

Tree species shifts

Forest tree species also are expected to shift their ranges northward and upslope in response to climate change, although specific quantitative predictions are very difficult to make because of the complexity of human land use and many other factors. This would result in major changes in the character of U.S. forests and the types of forests that will be most prevalent in different regions. In the United States, some common forests types are projected to expand, such as oak-hickory; others are projected to contract, such as maple-beech-birch. Still others, such as spruce-fir, are likely to disappear from the United States altogether.[243]

In Alaska, vegetation changes are already underway due to warming. Tree line is shifting northward into tundra, encroaching on the habitat for many migratory birds and land animals such as caribou that depend on the open tundra landscape.[245]

Marine species shifts and effects on fisheries

The distribution of marine fish and plankton are predominantly determined by climate, so it is not surprising that marine species in U.S. waters are moving northward and that the timing of plankton blooms is shifting. Extensive shifts in the ranges and distributions of both warmwater and coldwater species of fish have been documented.[70] For example, in the waters around Alaska, climate change already is causing significant alterations in marine ecosystems with important implications for fisheries and the people who depend on them (see *Alaska* region).

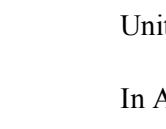
In the Pacific, climate change is expected to cause an eastward shift in the location of tuna stocks.[246] It is clear that such shifts are related to climate, including natural modes of climate variability such as the cycles of El Niño and La Niña. However, it is unclear how these modes of ocean variability will change as global climate continues to change, and therefore it is very difficult to predict quantitatively how marine fish and plankton species' distributions might shift as a function of climate change.[70]

Breaking up of existing ecosystems

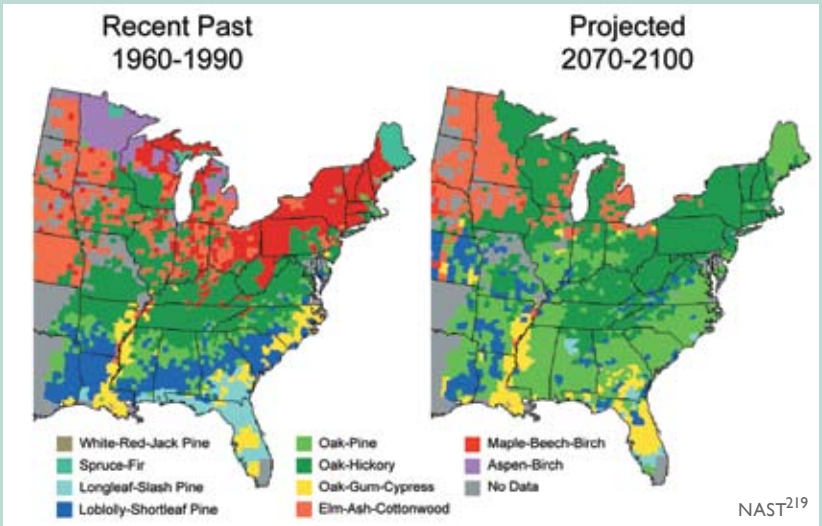
As warming drives changes in timing and geographic ranges for various species, it is important to note that entire communities of species do not shift intact. Rather, the range and timing of each species shifts in response to its sensitivity to climate change, its mobility, its lifespan, and the availability of the resources it needs (such as soil, moisture, food, and shelter). The speed with which species can shift their ranges is influenced by factors including their size, lifespan, and seed dispersal techniques in plants. In addition, migratory pathways must be available, such as northward flowing rivers which serve as conduits for fish. Some migratory pathways may be blocked by development and habitat fragmentation. All of these variations result in the breakup of existing ecosystems and formation of new ones, with unknown consequences.[220]

Extinctions and climate change

Interactions among impacts of climate change and other stressors can increase the risk of species extinction. Extinction rates of plants and animals have already risen considerably, with the vast majority of these extinctions attributed to loss of habitat or over-exploitation.[247] Climate change has been identified as a serious risk factor for the fu-



Projected Shifts in Forest Types



The maps show current and projected forest types. Major changes are projected for many regions. For example, in the Northeast, under a mid-range warming scenario, the currently dominant maple-beech-birch forest type is projected to be completely displaced by other forest types in a warmer future.[243]

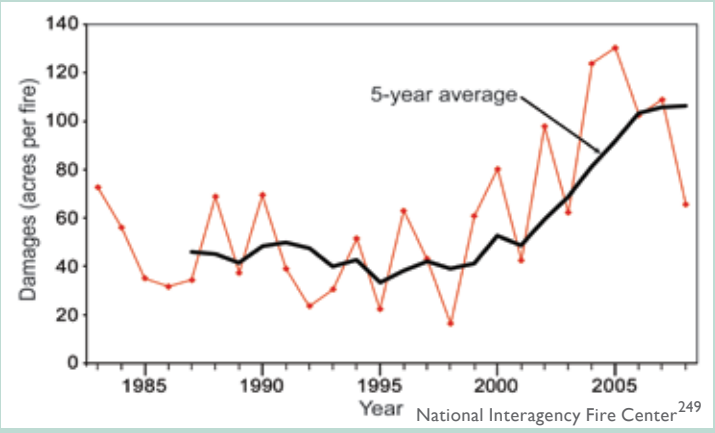
ture, however, since it is one of the environmental stresses on species and ecosystems that is continuing to increase.[247] The Intergovernmental Panel on Climate Change has estimated that if a warming of 3.5 to 5.5°F occurs, 20 to 30 percent of species that have been studied would be in climate zones that are far outside of their current ranges, and would therefore likely be at risk of extinction.[248] One reason this percentage is so high is that climate change would be superimposed on other stresses including habitat loss and continued overharvesting of some species, resulting in considerable stress on populations and species.

Fires, insect pests, disease pathogens, and invasive weed species have increased, and these trends are likely to continue.

Forest fires

In the western United States, both the frequency of large wildfires and the length of the fire season have increased substantially in recent decades, due primarily to earlier spring snowmelt and higher spring and summer temperatures.[294] These changes in climate have reduced the availability of moisture, drying out the vegetation that provides the fuel for fires. Alaska also has experienced large increases in fire, with the area burned more than doubling in recent decades. As in the western United States, higher air temperature is a key factor. In Alaska, for example, June air temperatures alone explained approximately 38 percent of the increase in the area burned annually from 1950 to 2003.[243]

Size of U.S. Wildfires, 1983 to 2008



Data on wildland fires in the United States show that the number of acres burned per fire has increased since the 1980s.

Insect pests

Insect pests are economically important stresses on forest ecosystems in the United States. Coupled with pathogens, they cost $1.5 billion in damage per year. Forest insect pests are sensitive to climatic variations in many stages of their lives. Changes in climate have contributed significantly to several major insect pest outbreaks in the United States and Canada over the past several decades. The mountain pine beetle has infested lodgepole pine in British Columbia. Over 33 million acres of forest have been affected, by far the largest such outbreak in recorded history. Another 1.5 million acres have been infested by pine beetle in Colorado. Spruce beetle has affected more than 2.5 million acres in Alaska (see *Alaska* region) and western Canada. The combination of drought and high temperatures also has led to serious insect infestations and death of piñon pine in the Southwest, and to various insect pest attacks throughout the forests of the eastern United States.[243]

Rising temperatures increase insect outbreaks in a number of ways. First, winter temperatures above a certain threshold allow more insects to survive the cold season that normally limits their numbers. Second, the longer warm season allows them to develop faster, sometimes completing two life cycles instead of one in a single growing season. Third, warmer conditions help expand their ranges northward. And fourth, drought stress reduces trees' ability to resist insect attack (for example, by pushing back against boring insects with the pressure of their sap). Spruce beetle, pine beetle, spruce budworm, and woolly adelgid (which attacks eastern hemlocks) are just some of the insects that are proliferating in the United States, devastating many forests. These outbreaks are projected to increase with ongoing warming. Trees killed by insects also provide more dry fuel for wildfires.[70,243,250]

Disease pathogens and their carriers

One consequence of a longer, warmer growing season and less extreme cold in winter is that opportunities are created for many insect pests and disease pathogens to flourish. Accumulating evidence links the spread of disease pathogens to a warming climate. For example, a recent study showed that widespread amphibian extinctions in the mountains of Costa Rica are linked to changes in climatic

conditions which are thought to have enabled the proliferation of an amphibian disease.[70,251]

Diseases that affect wildlife and the living things that carry these diseases have been expanding their geographic ranges as climate heats up. Depending on their specific adaptations to current climate, many parasites, and the insects, spiders, and scorpions that carry and transmit diseases, die or fail to develop below threshold temperatures. Therefore, as temperatures rise, more of these disease-carrying creatures survive. For some species, rates of reproduction, population growth, and biting, tend to increase with increasing temperatures, up to a limit. Some parasites' development rates and infectivity periods also increase with temperature.[70] An analysis of diseases among marine species found that diseases were increasing for mammals, corals, turtles, and mollusks, while no trends were detected for sharks, rays, crabs, and shrimp.[70]

Invasive plants

Problems involving invasive plant species arise from a mix of human-induced changes, including disturbance of the land surface (such as through over grazing or clearing natural vegetation for development), deliberate or accidental transport of non-native species, the increase in available nitrogen through over-fertilization of crops, and the rising carbon dioxide concentration and the resulting climate change.[243] Human-induced climate change is not generally the initiating factor, nor the most important one, but it is becoming a more important part of the mix.

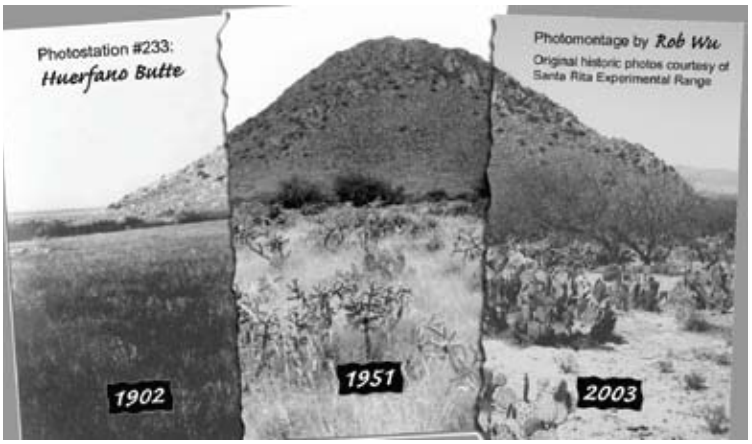
The increasing carbon dioxide concentration stimulates the growth of most plant species, and some invasive plants respond with greater growth rates than native plants. Beyond this, invasive plants appear to better tolerate a wider range of environmental conditions and may be more successful in a warming world because they can migrate and establish themselves in new sites more rapidly than native plants.[70] They are also not usually dependent on external pollinators or seed dispersers to reproduce. For all of these reasons, invasive plant species present a growing problem that is extremely difficult to control once unleashed.[70]

Deserts and drylands are likely to become hotter and drier, feeding a self-reinforcing cycle of invasive plants, fire, and erosion.

The arid Southwest is projected to become even drier in this century. There is emerging evidence that this is already underway.[34] Deserts in the United States are also projected to expand to the north, east, and upward in elevation in response to projected warming and associated changes in climate.

Increased drying in the region contributes to a variety of changes that exacerbate a cycle of desertification. Increased drought conditions cause perennial plants to die due to water stress and increased susceptibility to plant diseases. At the same time, non-native grasses have invaded the region. As these grasses increase in abundance, they provide more fuel for fires, causing fire frequency to increase in a self-reinforcing cycle that leads to further losses of vegetation. When it does rain, the rain tends to come in heavy downpours, and since there is less vegetation to protect the soil, water erosion increases. Higher air temperatures and decreased soil moisture reduce soil stability, further exacerbating erosion. And with a growing population needing water for urban uses, hydroelectric generation, and agriculture, there is increasing pressure on mountain water sources that would otherwise flow to desert river areas.[70,149]

Desertification of Arid Grassland
near Tucson, Arizona, 1902 to 2003



CCSP SAP 4.3[243]

The photo series shows the progression from arid grassland to desert (desertification) over a 100-year period. The change is the result of grazing management and reduced rainfall in the Southwest.[250,252,253]

The response of arid lands to climate change also depends on how other factors interact with climate at local scales. Large-scale, unregulated livestock grazing in the Southwest during the late 1800s and early 1900s is widely regarded as having contributed to widespread desertification. Grazing peaked around 1920 on public lands in the West. By the 1970s, grazing had been reduced by about 70 percent, but the arid lands have been very slow to recover from its impacts. Warmer and drier climate conditions are expected to slow recovery even more. In addition, the land resource in the Southwest is currently managed more for providing water for people than for protecting the productivity of the landscape. As a result, the land resource is likely to be further degraded and its recovery hampered.[243]

Coastal and near-shore ecosystems are already under multiple stresses. Climate change and ocean acidification will exacerbate these stresses.

Coastal and near-shore marine ecosystems are vulnerable to a host of climate change-related effects including increasing air and water temperatures, ocean acidification, changes in runoff from the land, sea-level rise, and altered currents. Some of these changes have already led to coral bleaching, shifts in species ranges, increased storm intensity in some regions, dramatic reductions in sea ice extent and thickness along the Alaskan coast,[137] and other significant changes to the nation's coastlines and marine ecosystems.[70]

The interface between land and sea is important, as many species, including many endangered species, depend on it at some point in their life cycle. In addition, coastal areas buffer inland areas from the effects of wave action and storms.[247] Coastal wetlands, intertidal areas, and other near-shore ecosystems are subject to a variety of environmental stresses.[254,255] Sea-level rise, increased coastal storm intensity, and rising temperatures contribute to increased vulnerability of coastal wetland ecosystems. It has been estimated that 3 feet of sea-level rise (within the range of projections for this century) would inundate about 65 percent of the coastal marshlands and swamps in the contiguous United States.[256] The combination of sea-level rise, local land sinking, and related factors already have resulted in substantially higher relative sea-level rise along the Gulf of Mexico and the mid-Atlantic coast, more so than on the Pacific Coast.[43,254] In Louisiana alone, over one-third of the coastal plain that existed a century ago has since been lost,[254] which is mostly due to local land sinking.[70] Barrier islands are also losing land at an increasing rate[257] (see *Southeast* region), and they are particularly important in protecting the coastline in some regions vulnerable to sea-level rise and storm surge.

Coral reefs

Coral reefs are very diverse ecosystems that support many other species by providing food and habitat. In addition to their ecological value, coral reefs provide billions of dollars in services including tourism, fish breeding habitat, and protection of coastlines. Corals face a host of challenges associated with human activities such as poorly regulated tourism, destructive fishing, and pollution, in addition to climate change-related stresses.[70]

Corals are marine animals that host symbiotic algae which help nourish the animals and give the corals their color. When corals are stressed by increases in water temperatures or ultraviolet light, they lose their algae and turn white, a process called coral bleaching. If the stress persists, the corals die. Intensities and frequencies of bleaching events, clearly driven by warming in surface water, have increased substantially over the past 30 years, leading to the death or severe damage of about one-third of the world's corals.[70]

The United States has extensive coral reef ecosystems in the Caribbean, Atlantic, and Pacific oceans. In 2005, the Caribbean basin experienced unprecedented water temperatures that resulted in dramatic coral bleaching with some sites in the U.S. Virgin Islands seeing 90 percent of the coral bleached. Some corals began to recover when water temperatures decreased, but later that year disease appeared, striking the previously bleached and weakened coral. To date, 50 percent of the corals in Virgin Islands National Park have died from the bleaching and disease events. In the Florida Keys, summer bleaching in 2005 was also followed by disease in September.[70]

But rising temperature is not the only stress coral reefs face. As the carbon dioxide concentration in the air increases, more carbon dioxide is absorbed into the world's oceans, leading to their acidification. This makes less calcium carbonate available for corals and other sea life to build their skeletons and shells.[258] If carbon dioxide concentrations continue to rise and the resulting acidification proceeds, eventually, corals and other ocean life that rely on calcium carbonate will not be able to build these skeletons and shells at all. The implications of such extreme changes in ocean ecosystems are not clear, but there is now evidence that in some ocean areas, such as along the Northwest coast, acidification is already occurring[70,259] (see *Coasts* region for more discussion of ocean acidification).

Arctic sea ice ecosystems are already being adversely affected by the loss of summer sea ice and further changes are expected.

Perhaps most vulnerable of all to the impacts of warming are Arctic ecosystems that rely on sea ice, which is vanishing rapidly and is projected to disappear entirely in summertime within this century. Algae that bloom on the underside of the sea ice form the base of a food web linking microscopic animals and fish to seals, whales, polar bears, and people. As the sea ice disappears, so too do these algae. The ice also provides a vital platform for ice-dependent seals (such as the ringed seal) to give birth, nurse their pups, and rest. Polar bears use the ice as a platform from which to hunt their prey. The walrus rests on the ice near the continental shelf between its dives to eat clams and other shellfish. As the ice edge retreats away from the shelves to deeper areas, there will be no clams nearby.[70,132,220]

The Bering Sea, off the west coast of Alaska, produces our nation's largest commercial fish harvests as well as providing food for many Native Alaskan peoples. Ultimately, the fish populations (and animals including seabirds, seals, walruses, and whales) depend on plankton blooms regulated by the extent and location of the ice edge in spring. As the sea ice continues to decline, the location, timing, and species composition of the blooms is changing. The spring melt of sea ice in the Bering Sea has long provided material that feeds the clams, shrimp, and other life forms on the ocean floor that, in turn, provide food for the walruses, gray whales, bearded seals, eider ducks, and many fish. The earlier ice melt resulting from warming, however, leads to later phytoplankton blooms that are largely consumed by microscopic animals near the sea surface, vastly decreasing the amount of food reaching the living things on the ocean floor. This will radically change the species composition of the fish and other creatures, with significant repercussions for both subsistence and commercial fishing.[70]

Ringed seals give birth in snow caves on the sea ice, which protect their pups from extreme cold and predators. Warming leads to earlier snow melt, which causes the snow caves to collapse before the pups are weaned. The small, exposed pups may die of hypothermia or be vulnerable to predation by arctic foxes, polar bears, gulls, and ravens. Gulls and ravens are arriving in the Arctic earlier as springs become warmer, increasing the birds' opportunity to prey on the seal pups.[70]

Polar bears are the top predators of the sea ice ecosystem. Because they prey primarily on ice-associated seals, they are especially vulnerable to the disappearance of sea ice. The bears' ability to catch seals depends on the presence of sea ice. In that habitat, polar bears take advantage of the fact that seals must surface to breathe in limited openings in the ice cover. In the open ocean, bears lack a hunting platform, seals are not restricted in where they can surface, and successful hunting is very rare. On shore, polar bears feed little, if at all.

About two-thirds of the world's polar bears are projected to be gone by the middle of this century. It is projected that there will be no wild polar bears in Alaska in 75 years.[70]

In addition, the rapid rate of warming in Alaska and the rest of the Arctic in recent decades is sharply reducing the snow cover in which polar bears build dens and the sea ice they use as foraging habitat. Female polar bears build snow dens in which they hibernate for four to five months each year and in which they give birth to their cubs. Born weighing only about 1 pound, the tiny cubs depend on the snow den for warmth.

About two-thirds of the world's polar bears are projected to be gone by the middle of this century. It is projected that there will be no wild polar bears left in Alaska in 75 years.[70]

Continued warming will inevitably entail major changes in the sea ice ecosystem, to the point that its viability is in jeopardy. Some species will become extinct, while others might adapt to new habitats. The chances of species surviving the current changes may depend critically on the rate of change. The current rates of change in the sea ice ecosystem are very rapid relative to the life spans of animals including seals, walruses, and polar bears, and as such, are a major threat to their survival.[70]

Forest Species Shift Upslope

Beckage *et al.*[260]/Adapted from Boston Globe/Landov

As climate warms, hardwood trees out-compete evergreen trees that are adapted to colder conditions.

The pika, pictured above, is a small mammal whose habitat is limited to cold areas near the tops of mountains. As climate warms, little suitable habitat is left. Of 25 pika populations studied in the Great Basin between the Rocky Mountains and the Sierra Nevada, more than one-third have gone extinct in recent decades.[261,262]

The habitats of some mountain species and coldwater fish, such as salmon and trout, are very likely to contract in response to warming.

Animal and plant species that live in the mountains are among those particularly sensitive to rapid climate change. They include animal species such as the grizzly bear, bighorn sheep, pika, mountain goat, and wolverine. Major changes have already been observed in the pika as previously reported populations have disappeared entirely as climate has warmed over recent decades.[70] One reason mountain species are so vulnerable is that their suitable habitats are being compressed as climatic zones shift upward in elevation. Some species try to shift uphill with the changing climate, but may face constraints related to food, other species present, and so on. In addition, as species move up the mountains, those near the top simply run out of habitat.[70]

Fewer wildflowers are projected to grace the slopes of the Rocky Mountains as global warming causes earlier spring snowmelt. Larkspur, aspen fleabane, and aspen sunflower grow at an altitude of about 9,500 feet where the winter snows are deep. Once the snow melts, the flowers form buds and prepare to bloom. But warmer springs mean that the snow melts earlier, leaving the buds exposed to frost. (The percentage of buds that were frosted has doubled over the past decade.) Frost does not kill the plants, but it does make them unable to seed and reproduce, meaning there will be no next generation. Insects and other animal species depend on the flowers for food, and other species depend on those species, so the loss is likely to propagate through the food chain.[236]

Shifts in tree species on mountains in New England, where temperatures have risen 2 to 4°F in the last 40 years, offer another example. Some mountain tree species have shifted uphill by 350

feet in the last 40 years. Tree communities were relatively unchanged at low and high elevations, but in the transition zone in between (at about 2,600 feet elevation) the changes have been dramatic. Cold-loving tree species declined from 43 to 18 percent, while warmer-loving trees increased from 57 to 82 percent. Overall, the transition zone has shifted about 350 feet uphill in just a few decades, a surprisingly rapid rate since these are trees that live for hundreds of years. One possibility is that as trees were damaged or killed by air pollution, it left an opportunity for the warming-induced transition to occur more quickly. These results indicate that the composition of high elevation forests is changing rapidly.[260]

Coldwater fish

Salmon and other coldwater fish species in the United States are at particular risk from warming. Salmon are under threat from a variety of human activities, but global warming is a growing source of stress. Rising temperatures affect salmon in several important ways. As precipitation increasingly falls as rain rather than snow, it feeds floods that wash away salmon eggs incubating in the streambed. Warmer water leads eggs to hatch earlier in the year, so the young are smaller and more vulnerable to predators. Warmer conditions increase the fish's metabolism, taking energy away from growth and forcing the fish to find more food, but earlier hatching of eggs could put them out of sync with the insects they eat. Earlier melting of snow leaves rivers and streams warmer and shallower in summer and fall. Diseases and parasites tend to flourish in warmer water. Studies suggest that up to 40 percent of Northwest salmon populations may be lost by 2050.[263]

Large declines in trout populations are also projected to occur around the United States. Over half of the wild trout populations are likely to disappear from the southern Appalachian Mountains because of the effects of rising stream temperatures. Losses of western trout populations may exceed 60 percent in certain regions. About 90 percent of bull trout, which live in western rivers in some of the country's most wild places, are projected to be lost due to warming. Pennsylvania is predicted to lose 50 percent of its trout habitat in the coming decades. Projected losses of trout habitat for some warmer states, such as North Carolina and Virginia, are up to 90 percent.[264]

Some of the benefits ecosystems provide to society will be threatened by climate change, while others will be enhanced.

Human well-being depends on the Earth's ecosystems and the services that they provide to sustain and fulfill human life.[265] These services are important to human well-being because they contribute to basic material needs, physical and psychological health, security, and economic activity. A recent assessment reported that of 24 vital ecosystem services, 15 were being degraded by human activity.[247] Climate change is one of several human-induced stresses that threaten to intensify and extend these adverse impacts to biodiversity, ecosystems, and the services they provide. Two of many possible examples follow.

Forests and carbon storage

Forests provide many services important to the well-being of Americans: air and water quality maintenance, water flow regulation, and watershed protection; wildlife habitat and biodiversity conservation; recreational opportunities and aesthetic and spiritual fulfillment; raw materials for wood and paper products; and climate regulation and carbon storage. A changing climate will alter forests and the services they provide. Most of these changes are likely to be detrimental.

In the United States, forest growth and long-lived forest products currently offset about 20 percent of U.S. fossil fuel carbon emissions.[140,257] This carbon "sink" is an enormous service provided by forests and its persistence or growth will be important to limiting the atmospheric carbon dioxide concentration. The scale of the challenge of increasing this sink is very large. To offset an additional 10 percent of U.S. emissions through tree planting would require converting one-third of current croplands to forests.[243]

Recreational opportunities

Tourism is one of the largest economic sectors in the world, and it is also one of the fastest

growing;[266] the jobs created by recreational tourism provide economic benefits not only to individuals but also to communities. Slightly more than 90 percent of the U.S. population participates in some form of outdoor recreation, representing nearly 270 million participants,[267] and several billion days spent each year in a wide variety of outdoor recreation activities.

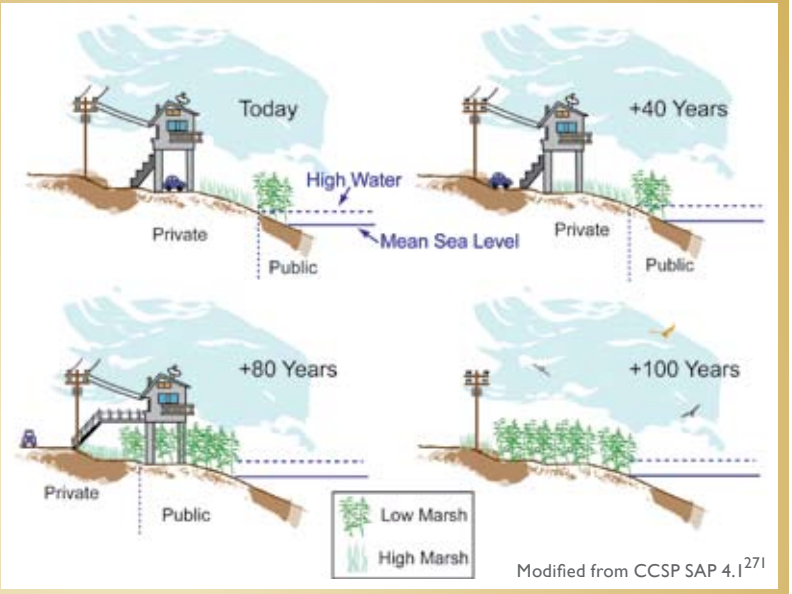
Since much recreation and tourism occurs outside, increased temperature and precipitation have a direct effect on the enjoyment of these activities, and on the desired number of visitor days and associated level of visitor spending as well as tourism employment. Weather conditions are an important factor influencing tourism visits. In addition, outdoor recreation and tourism often depends on the availability and quality of natural resources,[268] such as beaches, forests, wetlands, snow, and wildlife, all of which will be affected by climate change.

Thus, climate change can have direct effects on the natural resources that people enjoy. The length of the season for, and desirability of, several of the most popular activities – walking; visiting a beach, lakeshore, or river; sightseeing; swimming; and picnicking[267] – are likely to be enhanced by small near-term increases in temperature. Other activities are likely to be harmed by even small increases in warming, such as snow- and ice-dependent activities including skiing, snowmobiling, and ice fishing.

The net economic effect of near-term climate change on recreational activities is likely to be positive. In the longer term, however, as climate change effects on ecosystems and seasonality become more pronounced, the net economic effect on tourism and recreation is not known with certainty.[172]

Adaptation: Preserving Coastal Wetlands

Coastal wetlands are rich ecosystems that protect the shore from damage during storm surges and provide society with other services. One strategy designed to preserve coastal wetlands as sea level rises is the "rolling easement." Rolling easements allow some development near the shore, but prohibit construction of seawalls or other armoring to protect buildings; they recognize nature's right-of-way to advance inland as sea level rises. Massachusetts and Rhode Island prohibit shoreline armoring along the shores of some estuaries so that ecosystems can migrate inland, and several states limit armoring along ocean shores.[269,270]



Modified from CCSP SAP 4.1[271]

In the case shown here, the coastal marsh would reach the footprint of the house 40 years in the future. Because the house is on pilings, it could still be occupied if it is connected to a community sewage treatment system; a septic system would probably fail due to proximity to the water table. After 80 years, the marsh would have taken over the yard, and the footprint of the house would extend onto public property. The house could still be occupied but reinvestment in the property would be unlikely. After 100 years, this house would be removed, although some other houses in the area could still be occupied. Eventually, the entire area would return to nature. A home with a rolling easement would depreciate in value rather than appreciate like other coastal real estate. But if the loss were expected to occur 100 years from now, it would only reduce the current property value by 1 to 5 percent, for which the owner could be compensated.[271]

Human Health

Key Messages:

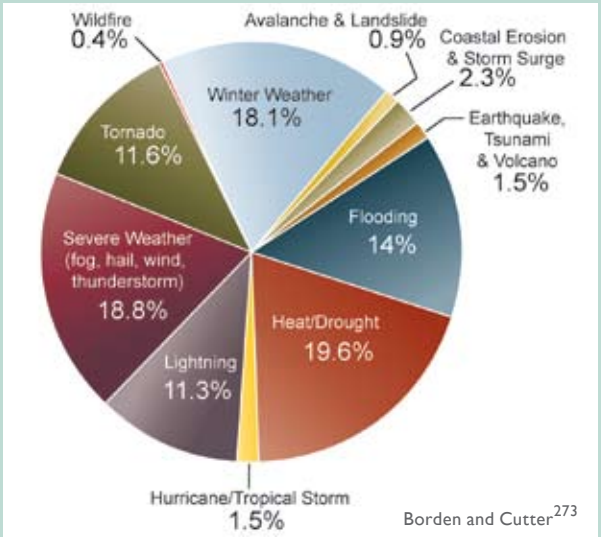
- Increases in the risk of illness and death related to extreme heat and heat waves are very likely. Some reduction in the risk of death related to extreme cold is expected.
- Warming is likely to make it more challenging to meet air quality standards necessary to protect public health.
- Extreme weather events cause physical and mental health problems. Some of these events are projected to increase.
- Some diseases transmitted by food, water, and insects are likely to increase.
- Rising temperature and carbon dioxide concentration increase pollen production and prolong the pollen season in a number of plants with highly allergenic pollen, presenting a health risk.
- Certain groups, including children, the elderly, and the poor, are most vulnerable to a range of climate-related health effects.

Climate change poses unique challenges to human health. Unlike health threats caused by a particular toxin or disease pathogen, there are many ways that climate change can lead to potentially harmful health effects. There are direct health impacts from heat waves and severe storms, ailments caused or exacerbated by air pollution and airborne allergens, and many climate-sensitive infectious diseases.[163]

Realistically assessing the potential health effects of climate change must include consideration of the capacity to manage new and changing climate conditions.[163] Whether or not increased health risks due to climate change are realized will depend largely on societal responses and underlying vulnerability. The probability of exacerbated health risks due to climate change points to a need to maintain a strong public health infrastructure to help limit future impacts.[163]

Increased risks associated with diseases originating outside the United States must also be considered because we live in an increasingly globalized world. Many poor nations are expected to suffer even greater health consequences from climate change.[272] With global trade and travel, disease flare-ups in any part of the world can potentially reach the United States. In addition, weather and climate extremes such as severe storms and drought can undermine public health infrastructure, further stress environmental resources, destabilize economies, and potentially create security risks both within the United States and internationally.[219]

Hazard-Related Deaths in the U.S.



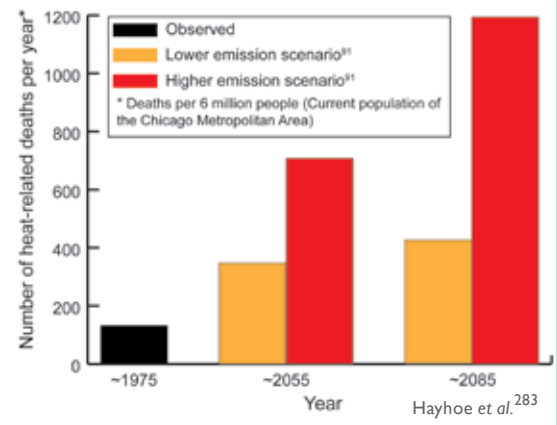
The pie chart shows the distribution of deaths for 11 hazard categories as a percent of the total 19,958 deaths due to these hazards from 1970 to 2004. Heat/drought ranks highest, followed by severe weather, which includes events with multiple causes such as lightning, wind, and rain.[273] This analysis ended prior to the 2005 hurricane season which resulted in approximately 2,000 deaths.[229]

Increases in the risk of illness and death related to extreme heat and heat waves are very likely. Some reduction in the risk of death related to extreme cold is expected.

Temperatures are rising and the probability of severe heat waves is increasing. Analyses suggest that currently rare extreme heat waves will become much more common in the future (see *National Climate Change*).[68] At the same time, the U.S. population is aging, and older people are more vulnerable to hot weather and heat waves. The percentage of the U.S. population over age 65 is currently 12 percent and is projected to be 21 percent by 2050 (over 86 million people).[163,274] Diabetics are also at greater risk of heat-related death, and the prevalence of obesity and diabetes is increasing. Heat-related illnesses range from heat exhaustion to kidney stones.[275,276]

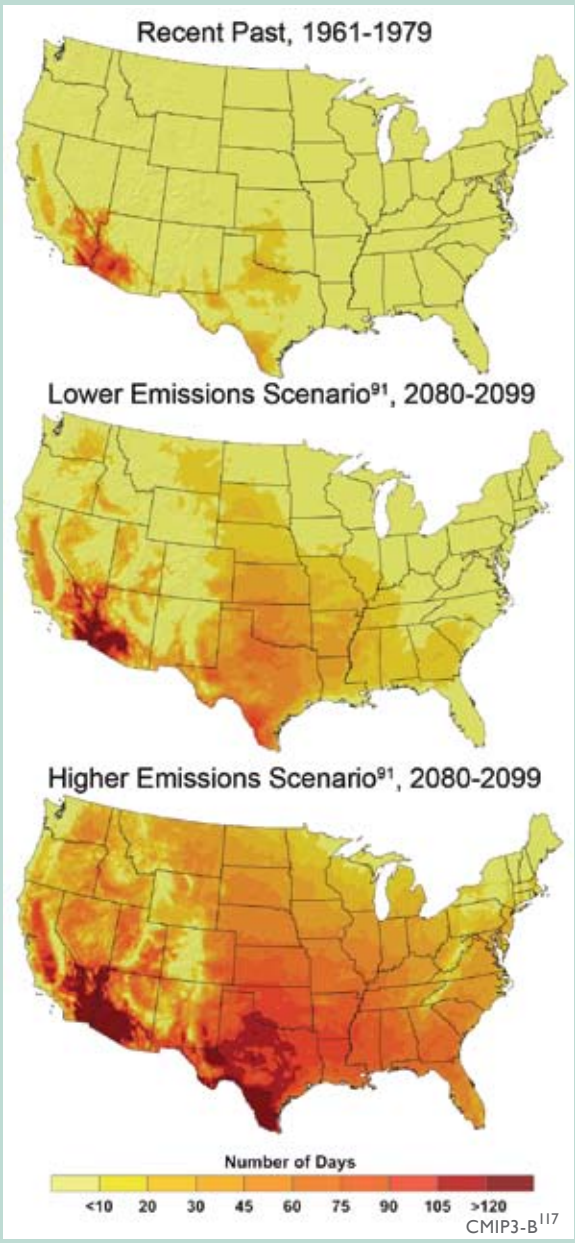
Heat is already the leading cause of weather-related deaths in the United States. More than 3,400 deaths between 1999 and 2003 were reported as resulting from exposure to excessive heat.[277] An analysis of nine U.S. cities shows that deaths due to heat increase with rising temperature and humidity.[278] From the 1970s to the 1990s, however, heat-related deaths declined.[279] This likely resulted from a rapid increase in the use of air conditioning. In 1978, 44 percent of households were without air conditioning, whereas in 2005, only 16 percent of the U.S. population lived without it (and only 3 percent did not have it in the South).[280,281] With air conditioning reaching near saturation, a recent study found that the general decline in heat-related deaths seems to have leveled off since the mid-1990s.[282]

Projected Increase in Heat-Related Deaths in Chicago



Increases in heat-related deaths are projected in cities around the nation, especially under higher emissions scenarios.[91] This analysis included some, but not all possible, adaptation measures. The graph shows the projected number of deaths per year, averaged over a three-decade period around 1975, 2055, and 2085 for the City of Chicago under lower and higher emissions.[91]

Number of Days Over 100°F



The number of days in which the temperature exceeds 100°F by late this century, compared to the 1960s and 1970s, is projected to increase strongly across the United States. For example, parts of Texas that recently experienced about 10 to 20 days per year over 100°F are expected to experience more than 100 days per year in which the temperature exceeds 100°F by the end of the century under the higher emissions scenario.[91]

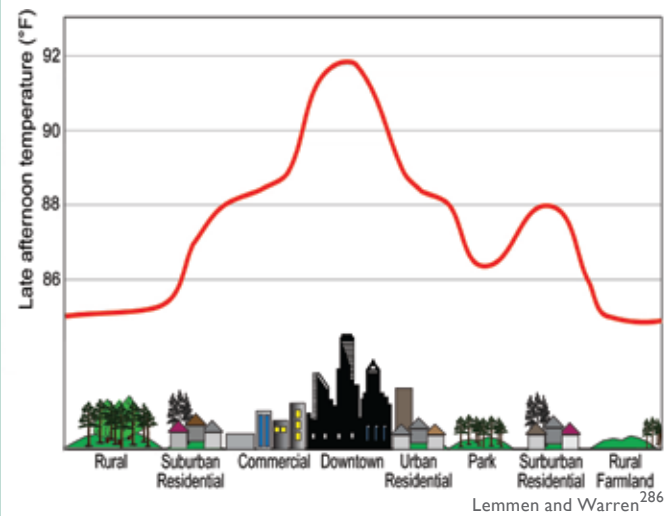
As human-induced warming is projected to raise average temperatures by about 6 to 11°F in this century under a higher emissions scenario,[91] heat waves are expected to continue to increase in frequency, severity, and duration.[68,112] For example, by the end of this century, the number of heat-wave days in Los Angeles is projected to double,[284] and the number in Chicago to quadruple,[285] if emissions are not reduced.

Projections for Chicago suggest that the average number of deaths due to heat waves would more than double by 2050 under a lower emissions scenario[91] and quadruple under a high emissions scenario[91] (see figure page 90).[283]

A study of climate change impacts in California projects that, by the 2090s, annual heat-related deaths in Los Angeles would increase by two to three times under a lower emissions scenario and by five to seven times under a higher emissions scenario, compared to a 1990s baseline of about 165 deaths. These estimates assume that people will have become somewhat more accustomed to higher temperatures. Without such acclimatization, these estimates are projected to be about 20 to 25 percent higher.[284]

The full effect of global warming on heat-related illness and death involves a number of factors including actual changes in temperature (averages, highs, and lows); and human population characteristics, such as age, wealth, and fitness. In addition, adaptation at the scale of a city includes options such as heat wave early warning systems, urban design to reduce heat loads, and enhanced services during heat waves.[163]

Urban Heat Island Effect



Lemmen and Warren[286]

Large amounts of concrete and asphalt in cities absorb and hold heat. Tall buildings prevent heat from dissipating and reduce air flow. At the same time, there is generally little vegetation to provide shade and evaporative cooling. As a result, parts of cities can be up to 10°F warmer than the surrounding rural areas, compounding the temperature increases that people experience as a result of human-induced warming.[313]

Reduced extreme cold

In a warmer world, the number of deaths caused by extremely low temperatures would be expected to drop, although in general, it is uncertain how climate change will affect net mortality.[163] Nevertheless, a recent study that analyzed daily mortality and weather data with regard to 6,513,330 deaths in 50 U.S. cities between 1989 and 2000 shows a marked difference between deaths resulting from hot and cold temperatures. The researchers found that, on average, cold snaps increased death rates

Adaptation: Reducing Deaths During Heat Waves

In the mid-1990s, Philadelphia became the first U.S. city to implement a system for reducing the risk of death during heat waves. The city focuses its efforts on the elderly, homeless, and poor. During a heat wave, a heat alert is issued and news organizations are provided with tips on how vulnerable people can protect themselves. The health department and thousands of block captains use a buddy system to check on elderly residents in their homes; electric utilities voluntarily refrain from shutting off services for non-payment; and public cooling places extend their hours. The city operates a "Heatline" where nurses are standing by to assist callers experiencing health problems; if callers are deemed "at risk," mobile units are dispatched to the residence. The city has also implemented a "Cool Homes Program" for elderly, low-income residents, which provides measures such as roof coatings and roof insulation that save energy and lower indoor temperatures. Philadelphia's system is estimated to have saved 117 lives over its first 3 years of operation.[287,288]

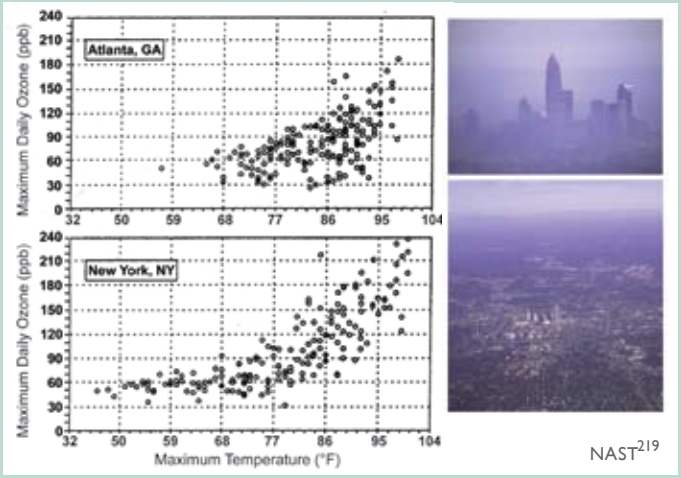
by 1.6 percent, while heat waves triggered a 5.7 percent increase in death rates.[289] The analysis found that the reduction in deaths as a result of relatively milder winters attributable to global warming will be substantially less than the increase in deaths due to summertime heat extremes.

Many factors contribute to winter deaths, including highly seasonal diseases such as influenza and pneumonia. It is unclear how these diseases are affected by temperature.[163]

Warming is likely to make it more challenging to meet air quality standards necessary to protect public health.

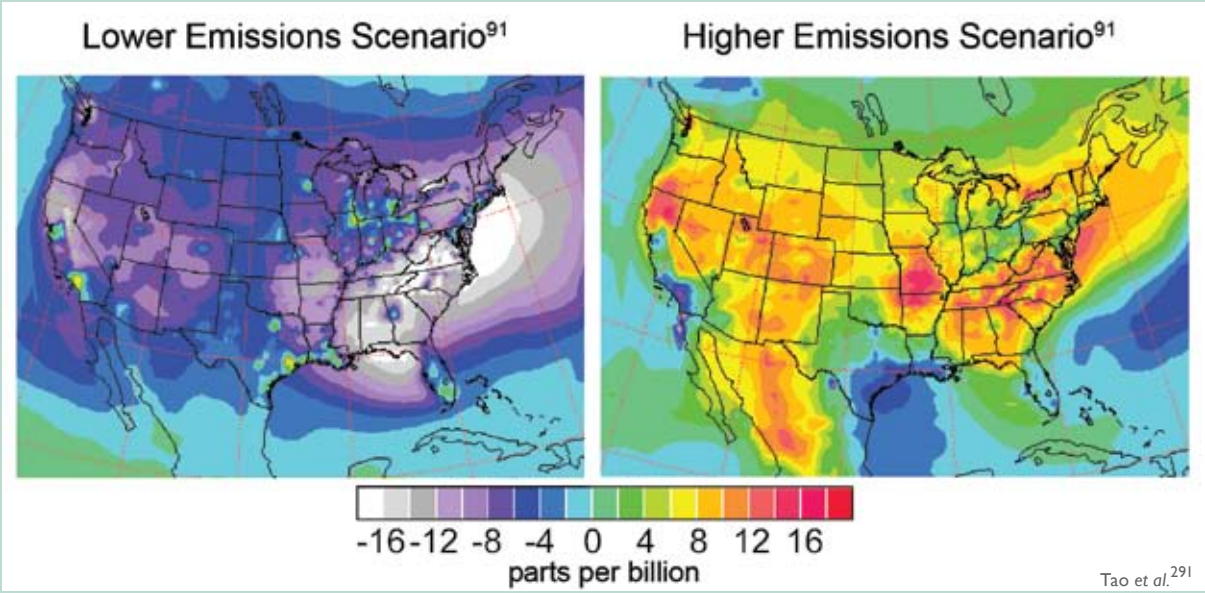
Poor air quality, especially in cities, is a serious concern across the United States. Half of all Americans, 158 million people, live in counties where air pollution exceeds national health standards.[290] While the Clean Air Act has improved air quality, higher temperatures and associated stagnant air masses are expected to make it more challenging to meet air quality standards, particularly for ground-level ozone (a component of smog).[13] It

Temperature and Ozone



The graphs illustrate the observed association between ground-level ozone (a component of smog) concentration in parts per billion (ppb) and temperature in Atlanta and New York City (May to October 1988 to 1990).[219] The projected higher temperatures across the United States in this century are likely to increase the occurrence of high ozone concentrations, although this will also depend on emissions of ozone precursors and meteorological factors. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function.

Projected Change in Ground-Level Ozone, 2090s

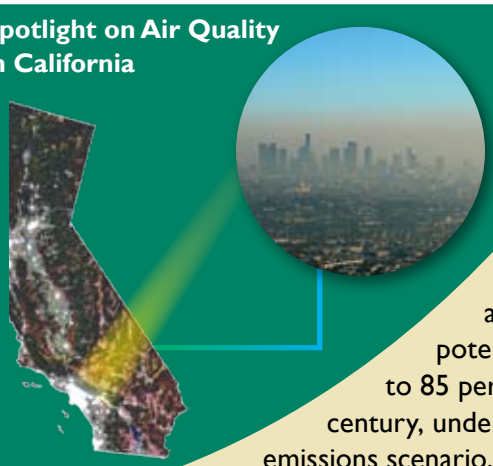


The maps show projected changes in ground-level ozone (a component of smog) for the 2090s, averaged over the summer months (June through August), relative to 1996-2000, under lower and higher emissions scenarios, which include both greenhouse gases and emissions that lead to ozone formation (some of which decrease under the lower emissions scenario).[91] By themselves, higher temperatures and other projected climate changes would increase ozone levels under both scenarios. However, the maps indicate that future projections of ozone depend heavily on emissions, with the higher emissions scenario[91] increasing ozone by large amounts, while the lower emissions scenario[91] results in an overall decrease in ground-level ozone by the end of the century.[291]

has been firmly established that breathing ozone results in short-term decreases in lung function and damages the cells lining the lungs. It also increases the incidence of asthma-related hospital visits and premature deaths.[272] Vulnerability to ozone effects is greater for those who spend time outdoors, especially with physical exertion, because this results in a higher cumulative dose to their lungs. As a result, children, outdoor workers, and athletes are at higher risk for these ailments.[163]

Ground-level ozone concentrations are affected by many factors including weather conditions, emissions of gases from vehicles and industry that lead

Spotlight on Air Quality in California



Californians currently experience the worst air quality in the nation. More than 90 percent of the population lives in areas that violate state air quality standards for ground-level ozone or small particles. These pollutants cause an estimated 8,800 deaths and over a billion dollars in health care costs every year in California.[292] Higher temperatures are projected to increase the frequency, intensity, and duration of conditions conducive to air pollution formation, potentially increasing the number of days conducive to air pollution by 75 to 85 percent in Los Angeles and the San Joaquin Valley, toward the end of this century, under a higher emissions scenario, and by 25 to 35 percent under a lower emissions scenario.[293] Air quality could be further compromised by wildfires, which are already increasing as a result of warming.[252,294]

Adaptation: Improving Urban Air Quality

Because ground-level ozone is related to temperature (see figure at top of previous page), air quality is projected to become worse with human-induced climate change. Many areas in the country already have plans in place for responding to air quality problems. For example, the Air Quality Alert program in Rhode Island encourages residents to reduce air pollutant emissions by limiting car travel and the use of small engines, lawn mowers, and charcoal lighter fluids on days when ground-level ozone is high. Television weather reports include alerts when ground-level ozone is high, warning especially susceptible people to limit their time outdoors. To help cut down on the use of cars, all regular bus routes are free on Air Quality Alert days.[295]

Pennsylvania offers the following suggestions for high ozone days:

- Refuel vehicles after dark. Avoid spilling gasoline and stop fueling when the pump shuts off automatically.
- Conserve energy. Do not overcool homes. Turn off lights and appliances that are not in use. Wash clothes and dishes only in full loads.
- Limit daytime driving. Consider carpooling or taking public transportation. Properly maintain vehicles, which also helps to save fuel.
- Limit outdoor activities, such as mowing the lawn or playing sports, to the evening hours.
- Avoid burning leaves, trash, and other materials.

Traffic restrictions imposed during the 1996 summer Olympics in Atlanta quantified the direct respiratory health benefits of reducing the number of cars and the amount of their tailpipe emissions from an urban environment. Peak morning traffic decreased by 23 percent, and peak ozone levels dropped by 28 percent. As a result, childhood asthma-related emergency room visits fell by 42 percent.[296]

to ozone formation (especially nitrogen oxides and volatile organic compounds [VOCs]), natural emissions of VOCs from plants, and pollution blown in from other places.[290,297] A warmer climate is projected to increase the natural emissions of VOCs, accelerate ozone formation, and increase the frequency and duration of stagnant air masses that allow pollution to accumulate, which will exacerbate health symptoms.[298] Increased temperatures and water vapor due to human-induced carbon dioxide emissions have been found to increase ozone more in areas with already elevated concentrations, meaning that global warming tends to exacerbate ozone pollution most in already polluted areas. Under constant pollutant emissions, by the middle of this century, Red Ozone Alert Days (when the air is unhealthy for everyone) in the 50 largest cities in the eastern United States are projected to increase by 68 percent due to warming alone.[298] Such conditions would challenge the ability of communities to meet health-based air quality standards such as those in the Clean Air Act.

Health risks from heat waves and air pollution are not necessarily independent. The formation of ground-level ozone occurs under hot and stagnant conditions – essentially the same weather conditions accompanying heat waves (see box page 102). Such interactions among risk factors are likely to increase as climate change continues.

Extreme weather events cause physical and mental health problems. Some of these events are projected to increase.

Injury, illness, emotional trauma, and death are known to result from extreme weather events.[68] The number and intensity of some of these events are already increasing and are projected to increase further in the future.[68,112] Human health impacts in the United States are generally expected to be less severe than in poorer countries where the emergency preparedness and public health infrastructure is less developed. For example, early warning and evacuation systems and effective sanitation lessen the health impacts of extreme events.[68]

This assumes that medical and emergency relief systems in the United States will function well and that timely and effective adaptation measures will be developed and deployed. There have already been serious failures of these systems in the aftermath of hurricanes Katrina and Rita, so coping with future impacts will require significant improvements.

Extreme storms

Over 2,000 Americans were killed in the 2005 hurricane season, more than double the average number of lives lost to hurricanes in the United States over the previous 65 years.[163] But the human health impacts of extreme storms go beyond direct injury and death to indirect effects such as carbon monoxide poisoning from portable electric generators in use following hurricanes, an increase in stomach and intestinal illness among evacuees, and mental health impacts such as depression and post-traumatic stress disorder.[163] Failure to fully account for both direct and indirect health impacts might result in inadequate preparation for and response to future extreme weather events.[163]

Floods

Heavy downpours have increased in recent decades and are projected to increase further as the world continues to warm.[68,112] In the United States, the amount of precipitation falling in the heaviest 1 percent of rain events increased by 20 percent in the past century, while total precipitation increased by 7 percent. Over the last century, there was a 50 percent increase in the frequency of days with precipitation over 4 inches in the upper Midwest.[112] Other regions, notably the South, have also seen strong increases in heavy downpours, with most of these coming in the warm season and almost all of the increase coming in the last few decades.

Heavy rains can lead to flooding, which can cause health impacts including direct injuries as well as increased incidence of waterborne diseases due to pathogens such as *Cryptosporidium* and *Giardia*.[163] Downpours can trigger sewage overflows, contaminating drinking water and endangering beachgoers. The consequences will be particularly severe in the roughly 770 U.S. cities and towns, including New York, Chicago, Washington DC, Milwaukee, and Philadelphia, that have "combined sewer systems;" an older design that carries storm water and sewage in the same pipes.[299] During heavy rains, these

systems often cannot handle the volume, and raw sewage spills into lakes or waterways, including drinking-water supplies and places where people swim.[252]

In 1994, the Environmental Protection Agency (EPA) established a policy that mandates that communities substantially reduce or eliminate their combined sewer overflow, but this mandate remains unfulfilled.[300] In 2004, the EPA estimated it would cost $55 billion to correct combined sewer overflow problems in publicly owned wastewater treatment systems.[301]

Using 2.5 inches of precipitation in one day as the threshold for initiating a combined sewer overflow event, the frequency of these events in Chicago is expected to rise by 50 percent to 120 percent by the end of this century,[302] posing further risks to drinking and recreational water quality.

Wildfires

Wildfires in the United States are already increasing due to warming. In the West, there has been a nearly fourfold increase in large wildfires in recent decades, with greater fire frequency, longer fire durations, and longer wildfire seasons. This increase is strongly associated with increased spring and summer temperatures and earlier spring snowmelt, which have caused drying of soils and vegetation.[163,252,294] In addition to direct injuries and deaths due to burns, wildfires can cause eye and respiratory illnesses due to fire-related air pollution.[163]

Some diseases transmitted by food, water, and insects are likely to increase.

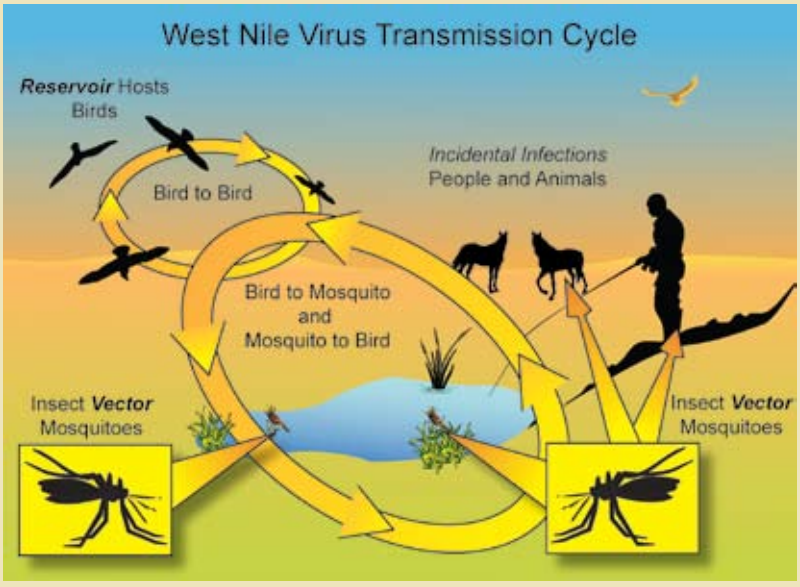
A number of important disease-causing agents (pathogens) commonly transmitted by food, water,

Spotlight on West Nile Virus

The first outbreak of West Nile virus in the United States occurred in the summer of 1999, likely a result of international air transport. Within five years, the disease had spread across the continental United States, transmitted by mosquitoes that acquire the virus from infected birds. While bird migrations were the primary mode of disease spread, during the epidemic summers of 2002 to 2004, epicenters of West Nile virus were linked to locations with either drought or above average temperatures.

Since 1999, West Nile virus has caused over 28,000 reported cases, and over 1,100 Americans have died from it.[303] During 2002, a more virulent strain of West Nile virus emerged in the United States. Recent analyses indicate that this mutated strain responds strongly to higher temperatures, suggesting that greater risks from the disease may result from increases in the frequency of heatwaves,[304] though the risk will also depend on the effectiveness of mosquito control programs.

While West Nile virus causes mild flu-like symptoms in most people, about one in 150 infected people develop serious illness, including the brain inflammation diseases encephalitis and meningitis.



or animals are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events.[163]

- Cases of food poisoning due to *Salmonella* and other bacteria peak within one to six weeks of the highest reported ambient temperatures.[163]
- Cases of waterborne *Cryptosporidium* and *Giardia* increase following heavy downpours. These parasites can be transmitted in drinking water and through recreational water use.[163]
- Climate change affects the life cycle and distribution of the mosquitoes, ticks, and rodents that carry West Nile virus, equine encephalitis, Lyme disease, and hantavirus. However, moderating factors such as housing quality, land use patterns, pest control programs, and a robust public health infrastructure are likely to prevent the large-scale spread of these diseases in the United States.[163,305]
- Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals, increasing the likelihood of food-borne disease associated with fresh produce.[163]
- *Vibrio* sp. (shellfish poisoning) accounts for 20 percent of the illnesses and 95 percent of the deaths associated with eating infected shellfish, although the overall incidence of illness from *Vibrio* infection remains low. There is a close association between temperature, *Vibrio* sp. abundance, and clinical illness. The U.S. infection rate increased 41 percent from 1996 to 2006,[163] concurrent with rising temperatures.
- As temperatures rise, tick populations that carry Rocky Mountain spotted fever are projected to shift from south to north.[306]
- The introduction of disease-causing agents from other regions of the world is an additional threat.[163]

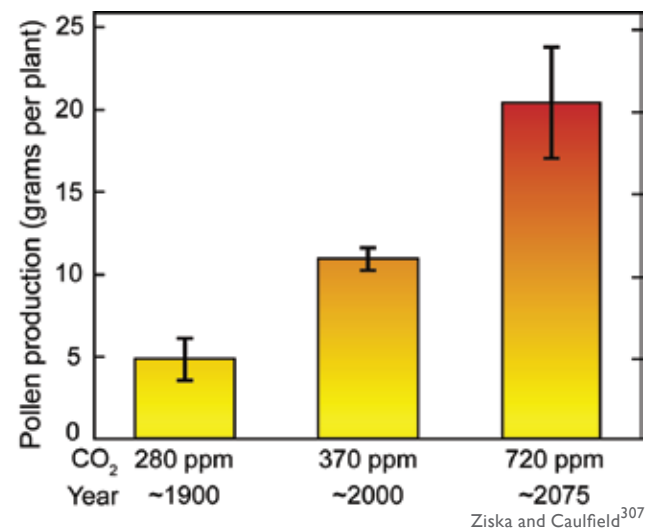
While the United States has programs such as the Safe Drinking Water Act that help protect against some of these problems, climate change will present new challenges.

Rising temperature and carbon dioxide concentration increase pollen production and prolong the pollen season in a number of plants with highly allergenic pollen, presenting a health risk.

Rising carbon dioxide levels have been observed to increase the growth and toxicity of some plants that cause health problems. Climate change has caused an earlier onset of the spring pollen season in the United States.[272] It is reasonable to conclude that allergies caused by pollen have also experienced associated changes in seasonality.[272] Several laboratory studies suggest that increasing carbon dixoide concentrations and temperatures increase ragweed pollen production and prolong the ragweed pollen season.[163,272]

Poison ivy growth and toxicity is also greatly increased by carbon dioxide, with plants growing larger and more allergenic. These increases exceed those of most beneficial plants. For example, poison ivy vines grow twice as much per year in air with a doubled preindustrial carbon dioxide concentration as they do in unaltered air; this is nearly five times the increase reported for tree species in

Pollen Counts Rise with Increasing Carbon Dioxide



Pollen production from ragweed grown in chambers at the carbon dioxide concentration of a century ago (about 280 parts per million [ppm]) was about 5 grams per plant; at today's approximate carbon dioxide level, it was about 10 grams; and at a level projected to occur about 2075 under the higher emissions scenario,[91] it was about 20 grams.[307]

Poison ivy

other analyses.[308] Recent and projected increases in carbon dioxide also have been shown to stimulate the growth of stinging nettle and leafy spurge, two weeds that cause rashes when they come into contact with human skin.[309,310]

Certain groups, including children, the elderly, and the poor, are most vulnerable to a range of climate-related health effects.

Infants and children, pregnant women, the elderly, people with chronic medical conditions, outdoor workers, and people living in poverty are especially at risk from a variety of climate related health effects. Examples of these effects include increasing heat stress, air pollution, extreme weather events, and diseases carried by food, water, and insects.[163]

Children's small ratio of body mass to surface area and other factors make them vulnerable to heat-related illness and death. Their increased breathing rate relative to body size, additional time spent outdoors, and developing respiratory tracts, heighten their sensitivity to air pollution. In addition, children's immature immune systems increase their risk of serious consequences from waterborne and food-borne diseases, while developmental factors make them more vulnerable to complications from severe infections such as *E. coli* or *Salmonella*.[163]

The greatest health burdens related to climate change are likely to fall on the poor, especially those lacking adequate shelter and access to other resources such as air conditioning.[163]

Elderly people are more likely to have debilitating chronic diseases or limited mobility. The elderly are also generally more sensitive to extreme heat for several reasons. They have a reduced ability to regulate their own body temperature or sense when they are too hot. They are at greater risk of heart failure, which is further exacerbated when cardiac demand increases in order to cool the body during a heat wave.[318] Also, people taking medications, such as diuretics for high blood pressure, have a higher risk of dehydration.[163]

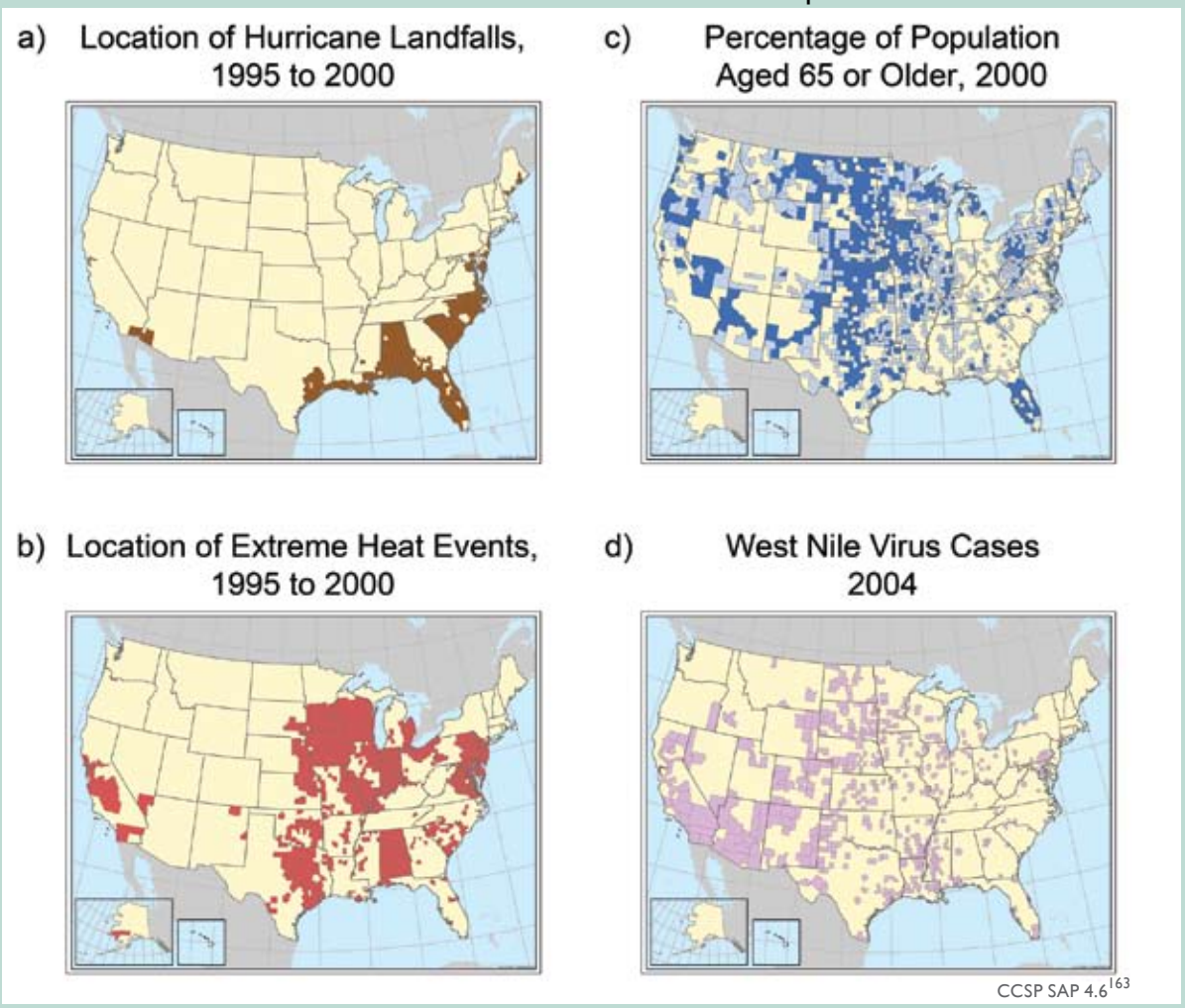
The multiple health risks associated with diabetes will increase the vulnerability of the U.S. population to increasing temperatures. The number of Americans with diabetes has grown to about 24 million people, or roughly 8 percent of the U.S. population. Almost 25 percent of the population 60 years and older had diabetes in 2007.[311] Fluid imbalance and dehydration create higher risks for diabetics during heat waves. People with diabetes-related heart disease are at especially increased risk of dying in heat waves.[318]

High obesity rates in the United States are a contributing factor in currently high levels of diabetes. Similarly, a factor in rising obesity rates is a sedentary lifestyle and automobile dependence; 60 percent of Americans do not meet minimum daily exercise requirements. Making cities more walkable and bikeable would thus have multiple benefits: improved personal fitness and weight loss;

reduced local air pollution and associated respiratory illness; and reduced greenhouse gas emissions.[312]

The United States has considerable capacity to adapt to climate change, but during recent extreme weather and climate events, actual practices have not always protected people and property. Vulnerability to extreme events is highly variable, with disadvantaged groups and communities (such as the poor, infirm, and elderly) experiencing considerable damage and disruptions to their lives. Adaptation tends to be reactive, unevenly distributed, and focused on coping rather than preventing problems. Future reduction in vulnerability will require consideration of how best to incorporate planned adaptation into long-term municipal and public service planning, including energy, water, and health services, in the face of changing climate-related risks combined with ongoing changes in population and development patterns.[163,164]

Geographic Vulnerability of U.S. Residents to Selected Climate-Related Health Impacts



Maps indicating U.S. counties, or in some cases states, with existing vulnerability to climate-sensitive health outcomes: a) location of hurricane landfalls; b) extreme heat events (defined by the Centers for Disease Control as temperatures 10 or more degrees F above the average high temperature for the region and lasting for several weeks); c) percentage of population over age 65 (dark blue indicates that percentage is over 17.6 percent, light blue 14.4 to 17.5 percent); d) locations of West Nile virus cases reported in 2004. These examples demonstrate both the diversity of climate-sensitive health outcomes and the geographic variability of where they occur. Events over short time spans, in particular West Nile virus cases, are not necessarily predictive of future vulnerability.

Society

Key Messages:

- Population shifts and development choices are making more Americans vulnerable to the expected impacts of climate change.
- Vulnerability is greater for those who have few resources and few choices.
- City residents and city infrastructure have unique vulnerabilities to climate change.
- Climate change affects communities through changes in climate-sensitive resources that occur both locally and at great distances.
- Insurance is one of the industries particularly vulnerable to increasing extreme weather events such as severe storms, but it can also help society manage the risks.
- The United States is connected to a world that is unevenly vulnerable to climate change and thus will be affected by impacts in other parts of the world.

Climate change will affect society through impacts on the necessities and comforts of life: water, energy, housing, transportation, food, natural ecosystems, and health. This section focuses on some characteristics of society that make it vulnerable to the potential impacts of climate change and how the risks and costs may be distributed. Many impacts of climate change on society, for example, sea-level rise and increased water scarcity, are covered in other sections of this report. This section is not a comprehensive analysis of societal vulnerabilities, but rather highlights key examples.

Because societies and their built environments have developed under a climate that has fluctuated within a relatively confined range of conditions, most impacts of a rapidly changing climate will present challenges. Society is especially vulnerable to extremes, such as heat waves and floods, many of which are increasing as climate changes.[313] And while there are likely to be some benefits and opportunities in the early stages of warming, as climate continues to change, negative impacts are projected to dominate.[164]

Climate change will affect different segments of society differently because of their varying exposures and adaptive capacities. The impacts of climate change also do not affect society in isolation. Rather, impacts can be exacerbated when climate change occurs in combination with the effects of an aging and growing population, pollution, poverty, and natural environmental fluctuations.[164,172,274] Unequal adaptive capacity in the world as a whole also will pose challenges to the United States. Poorer countries are projected to be disproportionately affected by the impacts of climate change and the United States is strongly connected to the world beyond its borders through markets, trade, investments, shared resources, migrating species, health, travel and tourism, environmental refugees (those fleeing deteriorating environmental conditions), and security.

Cedar Rapids, Iowa, June 12, 2008

Population shifts and development choices are making more Americans vulnerable to the expected impacts of climate change.

Climate is one of the key factors in Americans' choices of where to live. As the U.S. population grows, ages, and becomes further concentrated in cities and coastal areas, society is faced with additional challenges. Climate change is likely to exacerbate these challenges as changes in temperature, precipitation, sea levels, and extreme weather events increasingly affect homes, communities, water supplies, land resources, transportation, urban infrastructure, and regional characteristics that people have come to value and depend on.

Population growth in the United States over the past century has been most rapid in the South, near the coasts, and in large urban areas (see figure on page 55 in the *Energy* sector). The four most populous states in 2000 – California, Texas, Florida, and New York – accounted for 38 percent of the total growth in U.S. population during that time, and share significant vulnerability to coastal storms, severe drought, sea-level rise, air pollution, and urban heat island effects.[313] But migration patterns are now shifting: the population of the Mountain West (Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico) is projected to increase by 65 percent from 2000 to 2030, representing one-third of all U.S. population growth.[274,314] Southern coastal areas on both the Atlantic and the Gulf of Mexico are projected to continue to see population growth.[313]

Overlaying projections of future climate change and its impacts on expected changes in U.S. population and development patterns reveals a critical insight: more Americans will be living in the areas that are most vulnerable to the effects of climate change.[274]

America's coastlines have seen pronounced population growth in regions most at risk of hurricane activity, sea-level rise, and storm surge – putting more people and property in harm's way as the probability of harm increases.[274] On the Atlantic and Gulf coasts where hurricane activity is prevalent, the coastal land in many areas is sinking while sea level is rising. Human activities are exacerbating the loss of coastal wetlands that once helped buffer the coastline from erosion due to storms. The devastation caused by recent hurricanes highlights the vulnerability of these areas.[224]

The most rapidly growing area of the country is the Mountain West, a region projected to face more frequent and severe wildfires and have less water available, particularly during the high-demand period of summer. Continued population growth in these arid and semi-arid regions would stress water supplies. Because of high demand for irrigating agriculture, overuse of rivers and streams is common in the arid West, particularly along the Front Range of the Rocky Mountains in Colorado, in Southern California, and in the Central Valley of California. Rapid population and economic growth in these arid and semi-arid regions has dramatically increased vulnerability to water shortages (see *Water Resources* sector and *Southwest* region).[274]

Many questions are raised by ongoing development patterns in the face of climate change. Will growth continue as projected in vulnerable areas, despite the risks? Will there be a retreat from the coastline as it becomes more difficult to insure vulnerable properties? Will there be pressure for the government to insure properties that private insurers have rejected? How can the vulnerability of new development be minimized? How can we ensure that communities adopt measures to manage the significant changes that are projected in sea level, temperature, rainfall, and extreme weather events?

Development choices are based on people's needs and desires for places to live, economies that provide employment, ecosystems that provide services, and community-based social activities. Thus, the future vulnerability of society will be influenced by how and where people choose to live. Some choices, such as expanded development in coastal regions, can increase vulnerabilities to climate-related events, even without any change in climate.

Vulnerability is greater for those who have few resources and few choices.

Vulnerabilities to climate change depend not only on where people are but also on their circumstanc-

es. In general, groups that are especially vulnerable include the very young, the very old, the sick, and the poor. These groups represent a more significant portion of the total population in some regions and localities than others. For example, the elderly more often cite a warm climate as motivating their choice of where to live and thus make up a larger share of the population in warmer areas.[305]

In the future (as in the past), the impacts of climate change are likely to fall disproportionately on the disadvantaged.[313] People with few resources often live in conditions that increase their vulnerability to the effects of climate change.[172] For example, the experience with Hurricane Katrina showed that the poor and elderly were the most vulnerable because of where they lived and their limited ability to get out of harm's way. Thus, those who had the least proportionately lost the most. And it is clear that people with access to financial resources, including insurance, have a greater capacity to adapt to, recover, or escape from adverse impacts of climate change than those who do not have such access.[305, 316] The fate of the poor can be permanent dislocation, leading to the loss of social relationships and community support networks provided by schools, churches, and neighborhoods.

Native American communities have unique vulnerabilities. Native Americans who live on established reservations are restricted to reservation boundaries and therefore have limited relocation options.[219] In Alaska, over 100 villages on the coast and in low-lying areas along rivers are subject to increased flooding and erosion due to warming.[315] Warming also reduces the availability and accessibility of many traditional food sources for Native Alaskans, such as seals that live on ice and caribou whose migration patterns depend on being able to cross frozen rivers and wetlands. These vulnerable people face losing their current livelihoods, their communities, and in some cases, their culture, which depends on traditional ways of collecting and sharing food.[132,220] Native cultures in the Southwest are particularly vulnerable to impacts of climate change on water quality and availability.

Chalmette, Louisiana after Hurricane Katrina

City residents and city infrastructure have unique vulnerabilities to climate change.

Over 80 percent of the U.S. population resides in urban areas, which are among the most rapidly changing environments on Earth. In recent decades, cities have become increasingly spread out, complex, and interconnected with regional and national economies and infrastructure.[319] Cities also experience a host of social problems, including neighborhood degradation, traffic congestion, crime, unemployment, poverty, and inequities in health and well-being.[320] Climate-related changes such as increased heat, water shortages, and extreme weather events will add further stress to existing problems. The impacts of climate change on cities are compounded by aging infrastructure, buildings, and populations, as well as air pollution and population growth. Further, infrastructure designed to handle past variations in climate can instill a false confidence in its ability to handle future changes. However, urban areas also present opportunities for adaptation through technology, infrastructure, planning, and design.[313]

As cities grow, they alter local climates through the urban heat island effect. This effect occurs because cities absorb, produce, and retain more heat than the surrounding countryside. The urban heat island

effect has raised average urban air temperatures by 2 to 5°F more than surrounding areas over the past 100 years, and by up to 20°F more at night.[321] Such temperature increases, on top of the general increase caused by human-induced warming, affect urban dwellers in many ways, influencing health, comfort, energy costs, air quality, water quality and availability, and even violent crime (which increases at high temperatures) (see *Human Health, Energy,* and *Water Resources* sectors).[172,313,322,323]

More frequent heavy downpours and floods in urban areas will cause greater property damage, a heavier burden on emergency management, increased clean-up and rebuilding costs, and a growing financial toll on businesses and homeowners. The Midwest floods of 2008 provide a recent vivid example of such tolls. Heavy downpours and urban floods can also overwhelm combined sewer and storm-water systems and release pollutants to waterways.[313] Unfortunately, for many cities, current planning and existing infrastructure are designed for the historical one-in-100 year event, whereas cities are likely to experience this same flood level much more frequently as a result of the climate change projected over this century.[146,164,324]

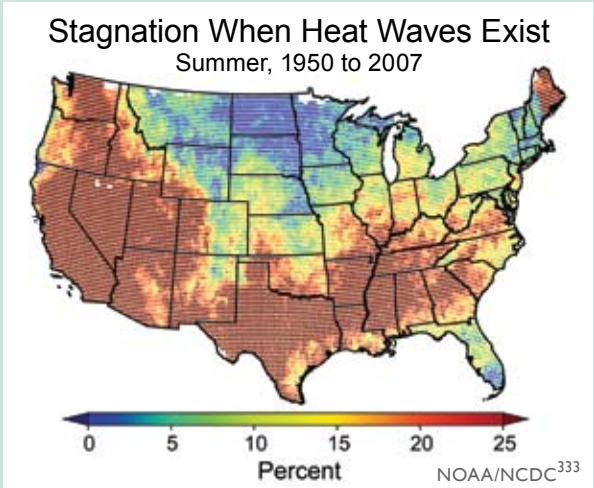
Cities are also likely to be affected by climate change in unforeseen ways, necessitating diversion of city funds for emergency responses to extreme weather.[313] There is the potential for increased summer electricity blackouts owing to greater demand for air conditioning.[325] For example, there were widespread power outages in Chicago during the 1995 heat wave and in some parts of New York City during the 1999 heat wave. In southern California's cities, additional summer electricity demand will intensify conflicts between hydropower and flood-control objectives.[164] Increased costs of repairs and maintenance are projected for transportation systems, including roads, railways, and airports, as they are negatively affected by heavy downpours

Heat, Drought, and Stagnant Air Degrade Air Quality and Quality of Life

Heat waves and poor air quality already threaten the lives of thousands of people each year.[292] Experience and research have shown that these events are interrelated as the atmospheric conditions that produce heat waves are often accompanied by stagnant air and poor air quality.[326] The simultaneous occurrence of heat waves, drought, and stagnant air negatively affects quality of life, especially in cities.

One such event occurred in the United States during the summer of 1988, causing 5,000 to 10,000 deaths and economic losses of more than $70 billion (in 2002 dollars).[229,327] Half of the nation was affected by drought, and 5,994 all-time daily high temperature records were set around the country in July alone (more than three times the most recent 10-year average).[328,329] Poor air quality resulting from the lack of rainfall, high temperatures, and stagnant conditions led to an unprecedented number of unhealthy air quality days throughout large parts of the country.[327,329] Continued climate change is projected to increase the likelihood of such episodes.[68,330]

Interactions such as those between heat wave and drought will affect adaptation planning. For example, electricity use increases during heat waves due to increased air conditioning demand.[330,331] During droughts, cooling water availability is at its lowest. Thus, during a simultaneous heat wave and drought, electricity demand for cooling will be high when power plant cooling water availability is at its lowest.[340]



The map shows the frequency of occurrence of stagnant air conditions when heat wave conditions were also present. Since 1950, across the Southeast, southern Great Plains, and most of the West, the air was stagnant more than 25 percent of the time during heat waves.

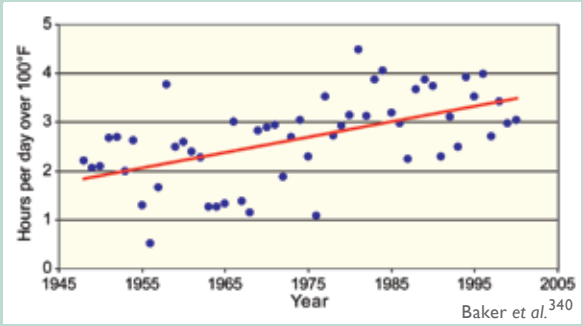
and extreme heat[190] (see *Transportation* sector). Coping with increased flooding will require replacement or improvements in storm drains, flood channels, levees, and dams.

In addition, coastal cities are also vulnerable to sea-level rise, storm surge, and increased hurricane intensity. Cities such as New Orleans, Miami, and New York are particularly at risk, and would have difficulty coping with the sea-level rise projected by the end of the century under a higher emissions scenario.[91,164] Remnants of hurricanes moving inland also threaten cities of the Appalachian Mountains, which are vulnerable if hurricane frequency or intensity increases. Since most large U.S. cities are on coasts, rivers, or both, climate change will lead to increased potential flood damage. The largest impacts are expected when sea-level rise, heavy runoff, high tides, and storms coincide.[313] Analyses of New York and Boston indicate that the potential impacts of climate change are likely to be negative, but that vulnerability can be reduced by behavioral and policy changes.[313,334-336]

Urban areas concentrate the human activities that are largely responsible for heat-trapping emissions. The demands of urban residents are also associated with a much larger footprint on areas far removed from these population centers.[337] On the other hand, concentrating activities such as transportation can make them more efficient. Cities have a large role to play in reducing heat-trapping emissions, and many are pursuing such actions. For example, over 900 cities have committed to the U.S. Mayors' Climate Protection Agreement to advance emissions reduction goals.[317]

Cities also have considerable potential to adapt to climate change through technological, institutional, structural, and behavioral changes. For example, a number of cities have warning programs in place to reduce heat-related illness and death (see *Human Health* sector). Relocating development away from low-lying areas, building new infrastructure with future sea-level rise in mind, and promoting water conservation are examples of structural and institutional strategies. Choosing road materials that can handle higher temperatures is an adaptation option that relies on new technology (see *Transportation* sector). Cities can reduce heat loads by increasing reflective surfaces and green spaces. Some actions have multiple benefits. For example, increased planting of trees and other vegetation in cities has been shown to be associated with a reduction in crime,[338] in addition to reducing local temperatures, and thus energy demand for air conditioning.

Rising Heat Index in Phoenix



The average number of hours per summer day in Phoenix that the temperature was over 100°F has doubled over the past 50 years, in part as a result of the urban heat island effect. Hot days take a toll on both quality of life and loss of life. Arizona's heat-related deaths are the highest of any state, at three to seven times the national average.[340,341]

Human well-being is influenced by economic conditions, natural resources and amenities, public health and safety, infrastructure, government, and social and cultural resources. Climate change will influence all of these, but an understanding of the many interacting impacts, as well as the ways society can adapt to them, remains in its infancy.[305,339]

Climate change affects communities through changes in climate-sensitive resources that occur both locally and at great distances.

Human communities are intimately connected to resources beyond their geographical boundaries. Thus, communities will be vulnerable to the potential impacts of climate change on sometimes-distant resources. For example, communities that have developed near areas of agricultural production, such as the Midwest corn belt or the wine-producing regions of California and the Northwest, depend on the continued productivity of those regions, which would be compromised by increased temperature or severe weather.[313] Some agricultural production that is linked to cold climates is likely to disappear entirely: recent warming has altered the required temperature patterns for maple syrup production,

shifting production northward from New England into Canada. Similarly, cranberries require a long winter chill period, which is shrinking as climate warms[234] (see *Northeast* region). Most cities depend on water supplies from distant watersheds, and those depending on diminishing supplies (such as the Sierra Nevada snowpack) are vulnerable. Northwest communities also depend upon forest resources for their economic base, and many island, coastal, and "sunbelt" communities depend on tourism.

Recreation and tourism play important roles in the economy and quality of life of many Americans. In some regions tourism and recreation are major job creators, bringing billions of dollars to regional economies. Across the nation, fishing, hunting, skiing, snowmobiling, diving, beach-going, and other outdoor activities make important economic contributions and are a part of family traditions that have value that goes beyond financial returns. A changing climate will mean reduced opportunities for some activities and locations and expanded opportunities for others.[305,342] Hunting and fishing will change as animals' habitats shift and as relationships among species in natural communities are disrupted by their different responses to rapid climate change. Water-dependent recreation in areas projected to get drier, such as the Southwest, and beach recreation in areas that are expected to see rising sea levels, will suffer. Some regions will see an expansion of the season for warm weather recreation such as hiking and bicycle riding.

Examples of Impacts On Recreation

Recreational Activity	Potential Impacts of Climate Change	Estimated Economic Impacts
Skiing, Northeast	20 percent reduction in ski season length	$800 million loss per year, potential resort closures[234]
Snowmobiling, Northeast	Reduction of season length under higher emissions scenario[91]	Complete loss of opportunities in New York and Pennsylvania within a few decades, 80 percent reduction in season length for region by end of century[234,342]
Beaches, North Carolina	Many beaches are eroded, and some lost by 2080[343]	Reduced opportunities for beach and fishing trips,[343] without additional costs for adaptation measures

Insurance is one of the industries particularly vulnerable to increasing extreme weather events such as severe storms, but it can also help society manage the risks.

Insurance – the world's largest industry – is one of the primary mechanisms through which the costs of climate change are distributed across society.[344,351]

Most of the climate change impacts described in this report have economic consequences. A significant portion of these flow through public and private insurance markets, which essentially aggregate and distribute society's risk. Insurance thus provides a window into the myriad ways in which the costs of climate change will manifest, and serves as a form of economic adaptation and a messenger of these impacts through the terms and price signals it sends its customers.[344]

In an average year, about 90 percent of insured catastrophe losses worldwide are weather-related. In the United States, about half of all these losses are insured, which amounted to $320 billion between 1980 and 2005 (inflation-adjusted to 2005 dollars). While major events such as hurricanes grab headlines, the aggregate effect of smaller events accounts for at least 60 percent of total insured losses on average.[344] Many of the smallest scale property losses and weather-related life/health losses are unquantified.[345]

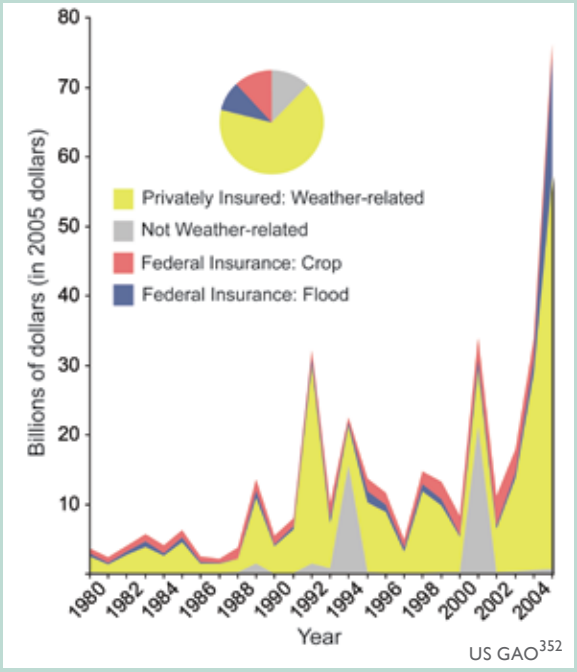
Escalating exposures to catastrophic weather events, coupled with private insurers' withdrawal from various markets, are placing the federal government at increased financial risk as insurer of last resort. The National Flood Insurance Program would have gone bankrupt after the storms of 2005 had they not been given the ability to borrow about $20 billion from the U.S. Treasury.[172] For public and private insurance programs alike, rising losses require a combination of risk-based premiums and improved loss prevention.

While economic and demographic factors have no doubt contributed to observed increases in losses,[346] these factors do not fully explain the upward trend in costs or numbers of events.[344,347] For example, during the time period covered in the figure to the right, population increased by a factor of 1.3 while losses increased by a factor of 15 to 20 in inflation-corrected dollars. Analyses asserting little or no role of climate change in increasing the risk of losses tend to focus on a highly limited set of hazards and locations. They also often fail to account for the vagaries of natural cycles and inflation adjustments, or to normalize for countervailing factors such as improved pre- and post-event loss prevention (such as dikes, building codes, and early warning systems).[348]

What is known with far greater certainty is that future increases in losses will be attributable to climate change as it increases the frequency and intensity of many types of extreme weather, such as severe thunderstorms and heat waves.[131,350]

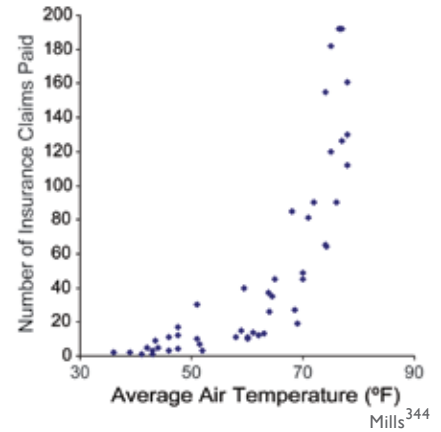
Insurance is emblematic of the increasing globalization of climate risks. Because large U.S.-based companies operate around the world, their customers and assets are exposed to climate impacts wherever they occur. Most of the growth in the insurance industry is in emerging markets, which will structurally increase U.S. insurers' exposure to climate risk because those regions are more vulnerable and are experiencing particularly high rates of population growth and development.[351]

Insured Losses from Catastrophes, 1980 to 2005


[352]

Weather-related insurance losses in the United States are increasing. Typical weather-related losses today are similar to those that resulted from the 9/11 attack (shown in gray at 2001 in the graph). About half of all economic losses are insured, so actual losses are roughly twice those shown on the graph. Data on smaller-scale losses (many of which are weather-related) are significant but are not included in this graph as they are not comprehensively reported by the U.S. insurance industry.

Lightning-Related Insurance Claims


[344]

There is a strong observed correlation between higher temperatures and the frequency of lightning-induced insured losses in the United States. Each marker represents aggregate monthly U.S. lightning-related insurance claims paid by one large national insurer over a five-year period, 1991-1995. All else being equal, these claims are expected to increase with temperature.[344,353,354]

The movement of populations into harm's way creates a rising baseline of insured losses upon which the consequences of climate change will be superimposed. These observations reinforce a recurring theme in this report: the past can no longer be used as the basis for planning for the future.

It is a challenge to design insurance systems that properly price risks, reward loss prevention, and do not foster risk taking (for example by repeatedly rebuilding flooded homes). This challenge is particularly acute in light of insurance market distortions such as prices that inhibit insurers' ability to recover rising losses, combined with information gaps on the impacts of climate change and adaptation strategies. Rising losses[252] are already affecting the availability and affordability of insurance. Several million customers in the United States, no longer able to purchase private insurance coverage, are taking refuge in state-mandated insurance pools, or going without insurance altogether. Offsetting rising insurance costs is one benefit of mitigation and adaptation investments to reduce the impacts of climate change.

Virtually all segments of the insurance industry are vulnerable to the impacts of climate change. Examples include damage to property, crops, forest products, livestock, and transportation infrastructure; business and supply-chain interruptions caused by weather extremes, water shortages, and electricity outages; legal consequences;[355] and compromised health or loss of life. Increasing risks to insurers and their customers are driven by many factors including reduced periods of time between loss events, increasing variability, shifting types and location of events, and widespread simultaneous losses.

In light of these challenges, insurers are emerging as partners in climate science and the formulation of public policy and adaptation strategies.[356] Some have promoted adaptation by providing premium incentives for customers who fortify their properties, engaging in the process of determining building codes and land-use plans, and participating in the development and financing of new technologies and practices. For example, the Federal Emergency Management Agency (FEMA) Community Rating System is a point system that rewards communities that undertake floodplain management activities to reduce flood risk beyond the minimum requirement set by the National Flood Insurance Program. Everyone in these communities is rewarded with lower flood insurance premiums (−5 to −45 percent).[357] Others have recognized that mitigation and adaptation can work hand in hand in a coordinated climate risk-management strategy and are offering "green" insurance products designed to capture these dual benefits.[351,349]

The United States is connected to a world that is unevenly vulnerable to climate change and thus will be affected by impacts in other parts of the world.

American society will not experience the potential impacts of climate change in isolation. In an increasingly connected world, impacts elsewhere will have political, social, economic, and environmental ramifications for the United States. As in the United States, vulnerability to the potential impacts of climate change worldwide varies by location, population characteristics, and economic status.

The rising concentration of people in cities is occurring globally, but is most prevalent in lower-income countries. Many large cities are located in vulnerable areas such as floodplains and coasts. In most of these cities, the poor often live in the most marginal of these environments, in areas that are susceptible to extreme events, and their ability to adapt is limited by their lack of financial resources.[172]

In addition, over half of the world's population – including most of the world's major cities – depends on glacier melt or snowmelt to supply water for drinking and municipal uses. Today, some locations are experiencing abundant water supplies and even frequent floods due to increases in glacier melt rates due to increased temperatures worldwide. Soon, however, this trend is projected to reverse as even greater temperature increases reduce glacier mass and cause more winter precipitation to fall as rain and less as snow.[90]

As conditions worsen elsewhere, the number of people wanting to immigrate to the United States will increase. The direct cause of potential increased migration, such as extreme climatic events, will be difficult to separate from other forces that drive people to migrate. Climate change also has the potential to alter trade relationships by changing the comparative trade advantages of regions or nations. As with migration, shifts in trade can have multiple causes.

Accelerating emissions in economies that are rapidly expanding, such as China and India, pose future threats to the climate system and already are associated with air pollution episodes that reach the United States.[297]

Meeting the challenge of improving conditions for the world's poor has economic implications for the United States, as does intervention and resolution of intra- and intergroup conflicts. Where climate change exacerbates such challenges, for example by limiting access to scarce resources or increasing incidence of damaging weather events, consequences are likely for the U.S. economy and security.[358]

Northeast

The Northeast has significant geographic and climatic diversity within its relatively small area. The character and economy of the Northeast have been shaped by many aspects of its climate including its snowy winters, colorful autumns, and variety of extreme events such as nor'easters, ice storms, and heat waves. This familiar climate has already begun changing in noticeable ways.

Since 1970, the annual average temperature in the Northeast has increased by 2°F, with winter temperatures rising twice this much.[150] Warming has resulted in many other climate-related changes, including:

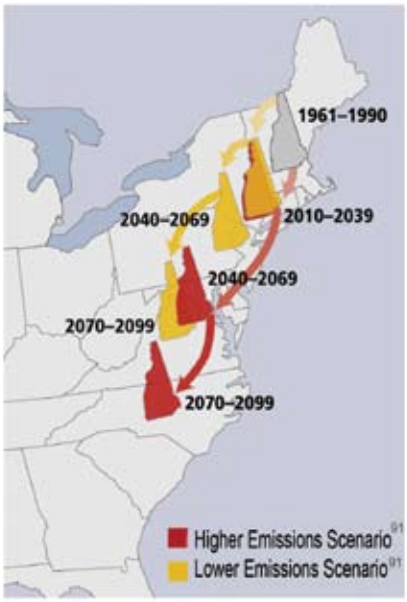
- More frequent days with temperatures above 90°F
- A longer growing season
- Increased heavy precipitation
- Less winter precipitation falling as snow and more as rain
- Reduced snowpack
- Earlier breakup of winter ice on lakes and rivers
- Earlier spring snowmelt resulting in earlier peak river flows
- Rising sea surface temperatures and sea level

Each of these observed changes is consistent with the changes expected in this region from global warming. The Northeast is projected to face continued warming and more extensive climate-related changes, some of which could dramatically alter the region's economy, landscape, character, and quality of life.

Over the next several decades, temperatures in the Northeast are projected to rise an additional 2.5 to 4°F in winter and 1.5 to 3.5°F in summer. By mid-century and beyond, however, today's emissions choices would generate starkly different climate futures; the lower the emissions, the smaller the climatic changes and resulting impacts.[150,359] By late this century, under a higher emissions scenario[91]:

- Winters in the Northeast are projected to be much shorter with fewer cold days and more precipitation.
- The length of the winter snow season would be cut in half across northern New York, Vermont, New Hampshire, and Maine, and reduced to a week or two in southern parts of the region.
- Cities that today experience few days above 100°F each summer would average 20 such days per summer, while certain cities, such as Hartford and Philadelphia, would average nearly 30 days over 100°F.
- Short-term (one- to three-month) droughts are projected to occur as frequently as once each summer in the Catskill and Adirondack Mountains, and across the New England states.
- Hot summer conditions would arrive three weeks earlier and last three weeks longer into the fall.
- Sea level in this region is projected to rise more than the global average, see *Global* and *National Climate Change* and *Coasts* sections for more information on sea-level rise (pages 25, 37, 150).

Climate on the Move:
Changing Summers in New Hampshire



Hayhoe *et al.*[359] Fig. from Frumhoff *et al.*[234]

Yellow arrows track what summers are projected to feel like under a lower emissions scenario,[91] while red arrows track projections for a higher emissions scenario[91] (referred to as "even higher" on page 23). For example, under the higher emission scenario,[91] by late this century residents of New Hampshire would experience a summer climate more like what occurs today in North Carolina.[359]

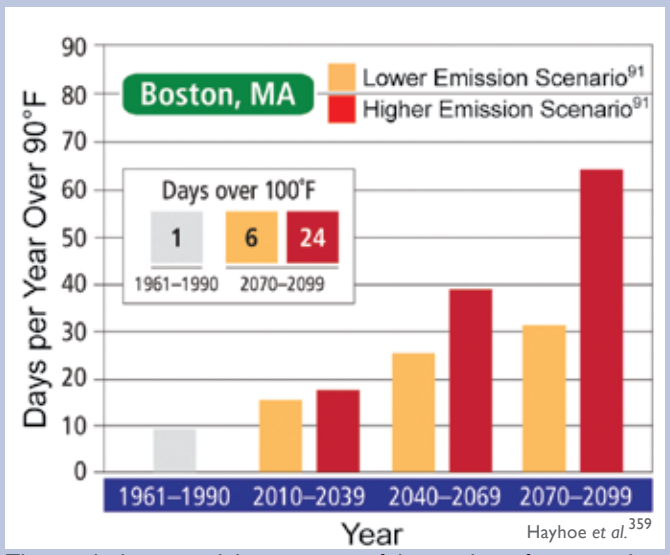
Extreme heat and declining air quality are likely to pose increasing problems for human health, especially in urban areas.

Heat waves, which are currently rare in the region, are projected to become much more commonplace in a warmer future, with major implications for human health (see *Human Health* sector).[163,68]

In addition to the physiological stresses associated with hotter days and nights,[360] for cities that now experience ozone pollution problems, the number of days that fail to meet federal air quality standards is projected to increase with rising temperatures if there are no additional controls on ozone-causing pollutants[163,361] (see *Human Health* sector). Sharp reductions in emissions will be needed to keep ozone within existing standards.

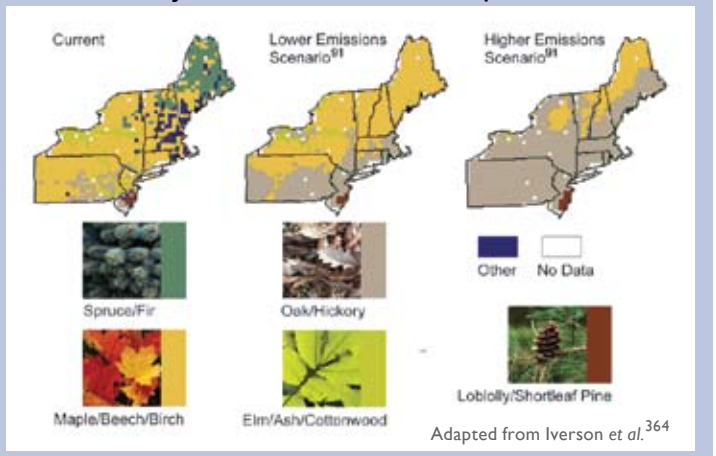
Projected changes in summer heat (see figure below) provide a clear sense of how different the climate of the Northeast is projected to be under lower versus higher emissions scenarios. Changes of this kind will require greater use of air conditioning (see *Energy* sector).

Projected Days per Year over 90°F in Boston



The graph shows model projections of the number of summer days with temperatures over 90°F in Boston, Massachusetts, under lower and higher (referred to as "even higher" on page 23) emissions scenarios.[91] The inset shows projected days over 100°F.[359]

Projected Shifts in Tree Species



Much of the Northeast's forest is composed of the hardwoods maple, beech, and birch, while mountain areas and more northern parts of the region are dominated by spruce/fir forests. As climate changes over this century, suitable habitat for spruce and fir is expected to contract dramatically. Suitable maple/beech/birch habitat is projected to shift significantly northward under a higher emissions scenario (referred to as "even higher" on page 23),[91] but to shift far less under a lower emissions scenario.[91,363] Other studies of tree species shifts suggest even more dramatic changes than those shown here (see page 81).

Agricultural production, including dairy, fruit, and maple syrup, are likely to be adversely affected as favorable climates shift.

Large portions of the Northeast are likely to become unsuitable for growing popular varieties of apples, blueberries, and cranberries under a higher emissions scenario.[91,362,363] Climate conditions suitable for maple/beech/birch forests are projected to shift dramatically northward (see figure above), eventually leaving only a small portion of the Northeast with a maple sugar business.[364]

The dairy industry is the most important agricultural sector in this region, with annual production worth $3.6 billion.[365] Heat stress in dairy cows depresses both milk production and birth rates for periods of weeks to months.[193,366] By late this century, all but the northern parts of Maine, New Hampshire, New York, and Vermont are projected to suffer declines in July milk production under the higher emissions scenario. In parts of Connecticut, Massachusetts, New Jersey, New York, and Pennsylvania, a large decline in milk production, up to 20 percent or greater, is projected. Under the lower emissions scenario, however, reductions in milk production of up to 10 percent remain confined primarily to the southern parts of the region.

This analysis used average monthly temperature and humidity data that do not capture daily variations in heat stress and projected increases in extreme heat. Nor did the analysis directly consider farmer responses, such as installation of potentially costly cooling systems. On balance, these projections are likely to underestimate impacts on the dairy industry.[150]

Severe flooding due to sea-level rise and heavy downpours is likely to occur more frequently.

The densely populated coasts of the Northeast face substantial increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands.[367,369] New York state alone has more than $2.3 trillion in insured coastal property.[368] Much of this coastline is exceptionally vulnerable to sea-level rise and related impacts. Some major insurers have withdrawn coverage from thousands of homeowners in coastal areas of the Northeast, including New York City.

Rising sea level is projected to increase the frequency and severity of damaging storm surges and flooding. Under a higher emissions scenario,[91] what is now considered a once-in-a-century coastal flood in New York City is projected to occur at least twice as often by mid-century, and 10 times as often (or once per decade

Increased Flood Risk in New York City

The light blue area above depicts today's FEMA 100-year flood zone for the city (the area of the city that is expected to be flooded once every 100 years). With rising sea levels, a 100-year flood at the end of this century (not mapped here) is projected to inundate a far larger area of New York City, especially under the higher emissions scenario.[91] Critical transportation infrastructure located in the Battery area of lower Manhattan could be flooded far more frequently unless protected. The increased likelihood of flooding is causing planners to look into building storm-surge barriers in New York Harbor to protect downtown New York City. [234,370,371]

Adaptation: Raising a Sewage Treatment Plant in Boston

Boston's Deer Island sewage treatment plant was designed and built taking future sea-level rise into consideration. Because the level of the plant relative to the level of the ocean at the outfall is critical to the amount of rainwater and sewage that can be treated, the plant was built 1.9 feet higher than it would otherwise have been to accommodate the amount of sea-level rise projected to occur by 2050, the planned life of the facility.

The planners recognized that the future would be different from the past and they decided to plan for the future based on the best available information. They assessed what could be easily and inexpensively changed at a later date versus those things that would be more difficult and expensive to change later. For example, increasing the plant's height would be less costly to incorporate in the original design, while protective barriers could be added at a later date, as needed, at a relatively small cost.

on average) by late this century. With a lower emissions scenario,[91] today's 100-year flood is projected to occur once every 22 years on average by late this century.[369]

The projected reduction in snow cover will adversely affect winter recreation and the industries that rely upon it.

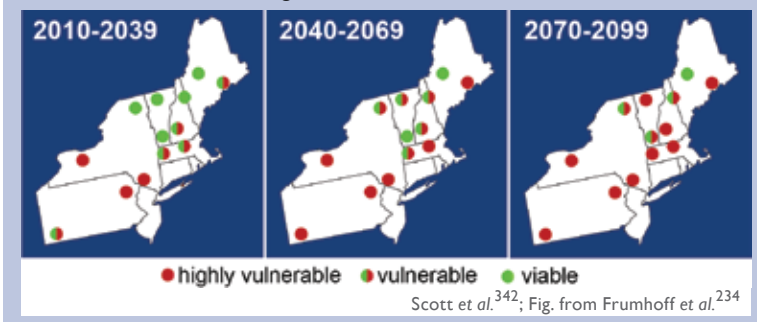
Winter snow and ice sports, which contribute some $7.6 billion annually to the regional economy, will be particularly affected by warming.[342] Of this total, alpine skiing and other snow sports (not including snowmobiling) account for $4.6 billion annually. Snowmobiling, which now rivals skiing as the largest winter recreation industry in the nation, accounts for the remaining $3 billion.[372] Other winter traditions, ranging from skating and ice fishing on frozen ponds and lakes, to cross-country (Nordic) skiing, snowshoeing, and dog sledding, are integral to the character of the Northeast, and for many residents and visitors, its desirable quality of life.

Warmer winters will shorten the average ski and snowboard seasons, increase artificial snowmaking requirements, and drive up operating costs. While snowmaking can enhance the prospects for ski resort success, it requires a great deal of water and energy, as well as very cold nights, which are becoming less frequent. Without the opportunity to benefit from snowmaking, the prospects for the snowmobiling industry are even worse. Most of the region is likely to have a marginal or non-existent snowmobile season by mid-century.

The center of lobster fisheries is projected to continue its northward shift and the cod fishery on Georges Bank is likely to be diminished.

Lobster catch has increased dramatically in the Northeast as a whole over the past three decades, though not uniformly.[374,375] Catches in the southern part of the region peaked in the mid-1990s, and have since declined sharply, beginning with a 1997 die-off in Rhode Island and Buzzards Bay (Massachusetts) associated with the onset of a temperature-sensitive bacterial shell disease, and accelerated by a 1999 lobster die-off in Long Island Sound. Currently, the southern extent of the commercial lobster harvest appears to be limited by this temperature-sensitive shell disease, and these effects are expected to increase as near-shore water temperatures rise above the threshold for this disease. Analyses also suggest that lobster survival and settlement in northern regions of the Gulf of Maine could be increased by warming water, a longer growing season, more rapid growth, an earlier hatching season, an increase in nursery grounds suitable for larvae, and faster development of plankton.[376]

Ski Areas at Risk
under Higher Emissions Scenario[91]



Scott *et al.*[342]; Fig. from Frumhoff *et al.*[234]

The ski resorts in the Northeast have three climate-related criteria that need to be met for them to remain viable: the average length of the ski season must be at least 100 days; there must be a good probability of being open during the lucrative winter holiday week between Christmas and the New Year; and there must be enough nights that are sufficiently cold to enable snowmaking operations. By these standards, only one area in the region (not surprisingly, the one located farthest north) is projected to be able to support viable ski resorts by the end of this century under a higher emissions scenario (referred to as "even higher" on page 23).[91,373]

Cod populations throughout the North Atlantic are adapted to a wide range of seasonal ocean temperatures, including average annual temperatures near the seafloor ranging from 36 to 54°F. Large populations of cod are generally not found above the 54°F threshold.[377] Temperature also influences both the location and timing of spawning, which in turn affects the subsequent growth and survival of young cod. Increases in average annual bottom temperatures above 47°F lead to a decline in growth and survival.[378,379] Projections of warming indicate that both the 47°F and the 54°F thresholds will be met or exceeded in this century under a higher emissions scenario.[234] Climate change will thus introduce an additional stress to an already-stressed fishery.[377]

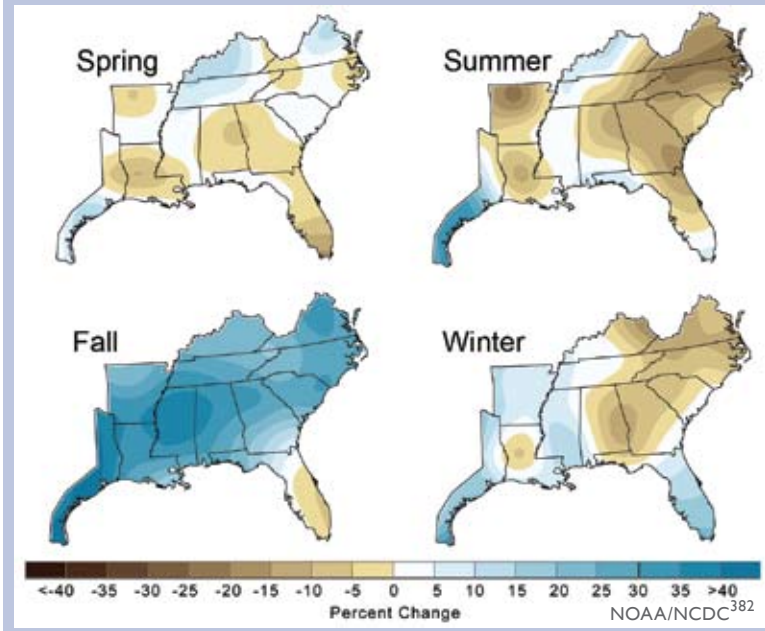
Southeast

The climate of the Southeast is uniquely warm and wet, with mild winters and high humidity, compared with the rest of the continental United States. The average annual temperature of the Southeast did not change significantly over the past century as a whole. Since 1970, however, annual average temperature has risen about 2°F, with the greatest seasonal increase in temperature occurring during the winter months. The number of freezing days in the Southeast has declined by four to seven days per year for most of the region since the mid-1970s.

Average autumn precipitation has increased by 30 percent for the region since 1901. The decline in fall precipitation in South Florida contrasts strongly with the regional average. There has been an increase in heavy downpours in many parts of the region,[380,381] while the percentage of the region experiencing moderate to severe drought increased over the past three decades. The area of moderate to severe spring and summer drought has increased by 12 percent and 14 percent, respectively, since the mid-1970s. Even in the fall months, when precipitation tended to increase in most of the region, the extent of drought increased by 9 percent.

Climate models project continued warming in all seasons across the Southeast and an increase in the rate of warming through the end of this century. The projected rates of warming are more than double those experienced in the Southeast since 1975, with the greatest temperature increases projected to occur in the summer months. The number of very hot days is projected to rise at a greater rate than the average temperature. Under a lower emissions scenario,[91] average temperatures in the region are projected to rise by about 4.5°F by the 2080s, while a higher emissions scenario[91] yields about 9°F of average warming (with about a 10.5°F increase in summer, and a much higher heat index). Spring and summer rainfall is projected to decline in South Florida during this century. Except for indications that the amount of rainfall from individual hurricanes will increase,[68] climate models provide divergent

Observed Changes in Precipitation
1901 to 2007



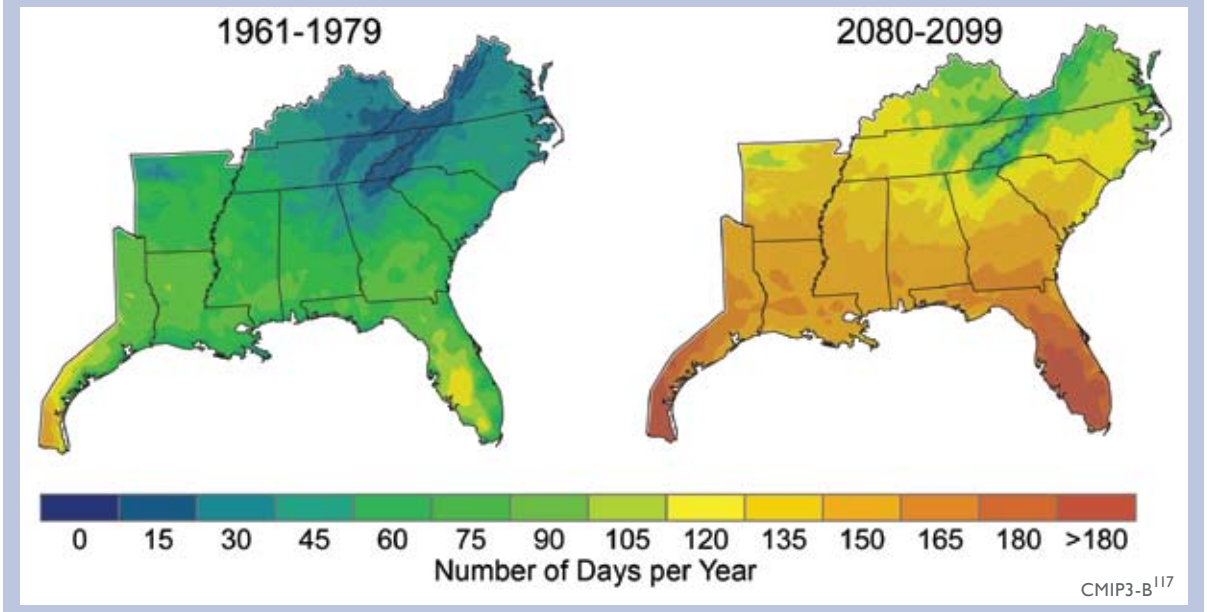
While average fall precipitation in the Southeast increased by 30 percent since the early 1900s, summer and winter precipitation declined by nearly 10 percent in the eastern part of the region. Southern Florida has experienced a nearly 10 percent drop in precipitation in spring, summer, and fall. The percentage of the Southeast region in drought has increased over recent decades.

Average Change in Temperature and Precipitation in the Southeast

	Temperature Change in °F			Precipitation change in %	
	1901-2008	1970-2008		1901-2008	1970-2008
Annual	0.3	1.6	Annual	6.0	-7.7
Winter	0.2	2.7	Winter	1.2	-9.6
Spring	0.4	1.2	Spring	1.7	-29.2
Summer	0.4	1.6	Summer	-4.0	3.6
Fall	0.2	1.1	Fall	27.4	0.1

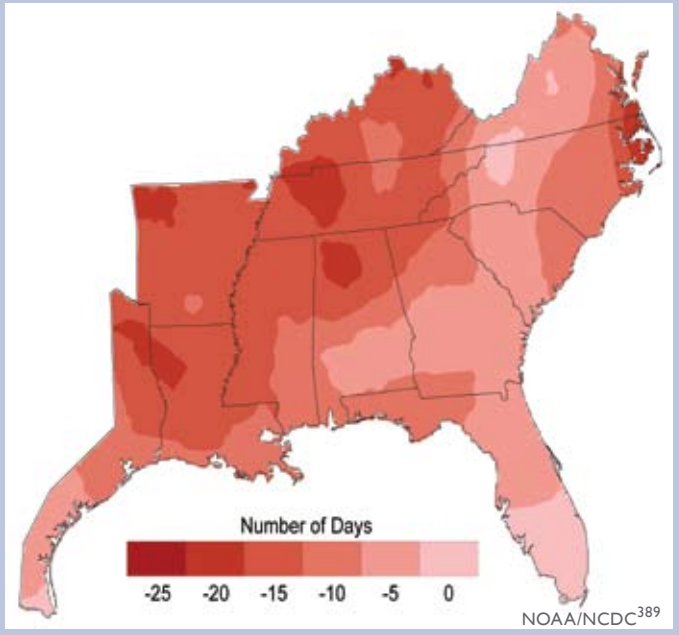
Observed temperature and precipitation changes in the Southeast are summarized above for two different periods.[383] Southeast average temperature declined from 1901 to 1970 and then increased strongly since 1970.

Number of Days per Year with Peak Temperature over 90°F



The number of days per year with peak temperature over 90°F is expected to rise significantly, especially under a higher emissions scenario[91] as shown in the map above. By the end of the century, projections indicate that North Florida will have more than 165 days (nearly six months) per year over 90°F, up from roughly 60 days in the 1960s and 1970s. The increase in very hot days will have consequences for human health, drought, and wildfires.

Change in Freezing Days per Year
1976 to 2007



Since the mid-1970s, the number of days per year in which the temperature falls below freezing has declined by four to seven days over much of the Southeast. Some areas, such as western Louisiana, have experienced more than 20 fewer freezing days. Climate models project continued warming across the region, with the greatest increases in temperature expected in summer, and the number of very hot days increasing at a greater rate than the average temperature.

results for future precipitation for the remainder of the Southeast. Models project that Gulf Coast states will tend to have less rainfall in winter and spring, compared with the more northern states in the region (see map on page 31 in the *National Climate Change* section). Because higher temperatures lead to more evaporation of moisture from soils and water loss from plants, the frequency, duration, and intensity of droughts are likely to continue to increase.

The destructive potential of Atlantic hurricanes has increased since 1970, correlated with an increase in sea surface temperature. A similar relationship with the frequency of landfalling hurricanes has not been established[98,384-387] (see *National Climate Change* section for a discussion of past trends and future projections). An increase in average summer wave heights along the U.S. Atlantic coastline since 1975 has been attributed to a progressive increase in hurricane power.[112,388] The intensity of Atlantic hurricanes is likely to increase during this century with higher peak wind speeds, rainfall intensity, and storm surge height and strength.[90,112] Even with no increase in hurricane intensity, coastal inundation and shoreline retreat would increase as sea-level rise accelerates, which is one of the most certain and most costly consequences of a warming climate.[164]

Projected increases in air and water temperatures will cause heat-related stresses for people, plants, and animals.

The warming projected for the Southeast during the next 50 to 100 years will create heat-related stress for people, agricultural crops, livestock, trees, transportation and other infrastructure, fish, and wildlife. The average temperature change is not as important for all of these sectors and natural systems as the projected increase in maximum and minimum temperatures. Examples of potential impacts include:

- Increased illness and death due to greater summer heat stress, unless effective adaptation measures are implemented.[164]
- Decline in forest growth and agricultural crop production due to the combined effects of thermal stress and declining soil moisture.[390]
- Increased buckling of pavement and railways.[217,222]
- Decline in dissolved oxygen in stream, lakes, and shallow aquatic habitats leading to fish kills and loss of aquatic species diversity.
- Decline in production of cattle and other rangeland livestock.[391] Significant impacts on beef cattle occur at continuous temperatures in the 90 to 100°F range, increasing in danger as the humidity level increases (see *Agriculture* sector).[391] Poultry and swine are primarily raised in indoor operations, so warming would increase energy requirements.[193]

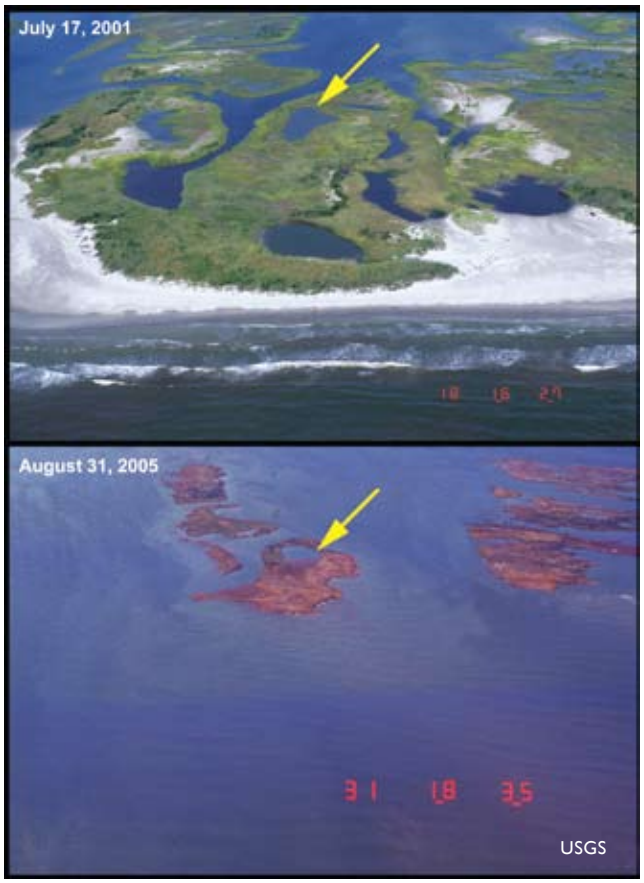
A reduction in very cold days is likely to reduce the loss of human life due to cold-related stress, while heat stress and related deaths in the summer months are likely to increase. The reduction in cold-related deaths is not expected to offset the increase in heat-related deaths (see *Human Health* sector). Other effects of the projected increases in temperature include more frequent outbreaks of shellfish-borne diseases in coastal waters, altered distribution of native plants and animals, local loss of many threatened and endangered species, displacement of native species by invasive species, and more frequent and intense wildfires.

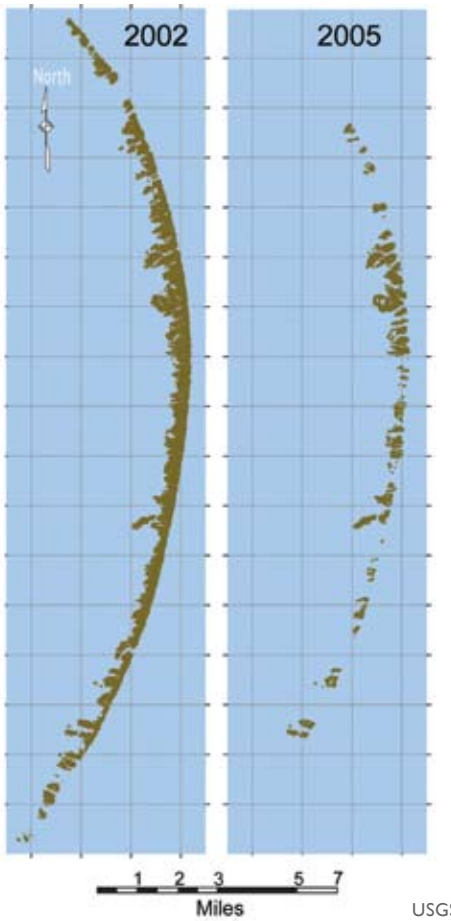
Decreased water availability is very likely to affect the region's economy as well as its natural systems.

Decreased water availability due to increased temperature and longer periods of time between rainfall events, coupled with an increase in societal demand is very likely to affect many sectors of the Southeast's economy. The amount and timing of water available to natural systems is also affected by climate change, as well as by human response strategies such as increasing storage capacity (dams)[142] and increasing acreage of irrigated cropland.[392] The 2007 water shortage in the Atlanta region created serious conflicts between three states, the U.S. Army Corps of Engineers (which operates the dam at Lake Lanier), and the U.S. Fish and Wildlife Service, which is charged with protecting endangered species. As humans seek to adapt to climate change by manipulating water resources, streamflow and biological diversity are likely to be reduced.[142] During droughts, recharge of groundwater will decline as the temperature and spacing between rainfall events increase. Responding by increasing groundwater pumping will further stress or deplete aquifers and place increasing strain on surface water resources. Increasing evaporation and plant water loss rates alter the balance of runoff and groundwater recharge, which is likely to lead to saltwater intrusion into shallow aquifers in many parts of the Southeast.[142]

In Atlanta and Athens, Georgia, 2007 was the second driest year on record. Among the numerous effects of the rainfall shortage were restrictions on water use in some cities and low water levels in area lakes. In the photo, a dock lies on dry land near Aqualand Marina on Lake Lanier (located northeast of Atlanta) in December 2007.

Land Lost During 2005 Hurricanes





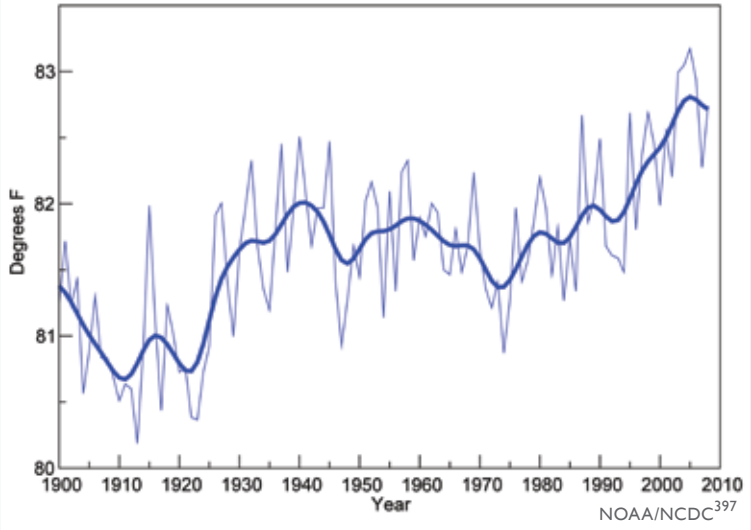
In 2005, 217 square miles of land and wetlands were lost to open water during hurricanes Rita and Katrina. The photos and maps show the Chandeleur Islands, east of New Orleans, before and after the 2005 hurricanes; 85 percent of the islands' above-water land mass was eliminated.

Sea-level rise and the likely increase in hurricane intensity and associated storm surge will be among the most serious consequences of climate change.

An increase in average sea level of up to 2 feet or more and the likelihood of increased hurricane intensity and associated storm surge are likely to be among the most costly consequences of climate change for this region (see *National Climate Change* section). As sea level rises, coastal shorelines will retreat. Wetlands will be inundated and eroded away, and low-lying areas including some communities will be inundated more frequently – some permanently – by the advancing sea. Current buildings and infrastructure were not designed to withstand the intensity of the projected storm surge, which would cause catastrophic damage. As temperature increases and rainfall patterns change, soil moisture and runoff to the coast are likely to be more variable. The salinity of estuaries, coastal wetlands, and tidal rivers is likely to increase in the southeastern coastal zone, thereby altering coastal ecosystems and displacing them farther inland if no barriers exist. More frequent storm surge flooding and permanent inundation of coastal ecosystems and communities is likely in some low-lying areas, particularly along the central Gulf Coast where the land surface is sinking.[393,394] Rapid acceleration in the rate of increase in sea-level rise could threaten a large portion of the Southeast coastal zone. The likelihood of a catastrophic increase in the rate of sea-level rise is dependent upon ice sheet response to warming, which is the subject of much scientific uncertainty (see *Global Climate Change* section).[90] Such rapid rise in sea level is likely to result in the destruction of barrier islands and wetlands.[257,390]

Compared to the present coastal situation, for which vulnerability is quite high, an increase in hurricane intensity will further affect low-lying coastal ecosystems and coastal communities along the Gulf and South Atlantic coastal margin. An increase in intensity is very likely to increase inland and coastal flooding, coastal erosion rates, wind damage to coastal forests, and wetland loss. Major hurricanes also pose a severe risk to people, personal property, and public infrastructure in the Southeast, and this risk is likely to be exacerbated.[393,394] Hurricanes have their greatest impact at the coastal margin where they make landfall, causing storm surge, severe beach erosion, inland flooding, and wind-related casualties for both cultural and natural resources. Some of these impacts extend farther inland, affecting larger areas. Recent examples of societal vulnerability to severe hurricanes include Katrina and Rita in 2005, which were responsible for the loss of more than 1,800 lives and the net loss of 217 square miles of low-lying coastal marshes and barrier islands in southern Louisiana.[390,396]

Sea Surface Temperature
Atlantic Hurricane Main Development Region
August through October, 1900 to 2008



Ocean surface temperature during the peak hurricane season, August through October, in the main development region for Atlantic hurricanes.[397] Higher sea surface temperatures in this region of the ocean have been associated with more intense hurricanes. As ocean temperatures continue to increase in the future, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming (see *National Climate Change* section).[68]

Ecological thresholds are expected to be crossed throughout the region, causing major disruptions to ecosystems and to the benefits they provide to people.

Ecological systems provide numerous important services that have high economic and cultural value in the Southeast. Ecological effects cascade among both living and physical systems, as illustrated in the following examples of ecological disturbances that result in abrupt responses, as opposed to gradual and proportional responses to warming:

- The sudden loss of coastal landforms that serve as a storm-surge barrier for natural resources and as a homeland for coastal communities (such as in a major hurricane).[254,390]
- An increase in sea level can have no apparent effect until an elevation is reached that allows widespread, rapid saltwater intrusion into coastal forests and freshwater aquifers.[398]
- Lower soil moisture and higher temperatures leading to intense wildfires or pest outbreaks (such as the southern pine beetle) in southeastern forests;[399] intense droughts leading to the drying of lakes, ponds, and wetlands; and the local or global extinction of riparian and aquatic species.[142]

Flooding damage in Louisiana due to Hurricane Katrina

- A precipitous decline of wetland-dependent coastal fish and shellfish populations due to the rapid loss of coastal marsh.[400]

Quality of life will be affected by increasing heat stress, water scarcity, severe weather events, and reduced availability of insurance for at-risk properties.

Over the past century, the southeastern "sunbelt" has attracted people, industry, and investment. The population of Florida more than doubled during the past three decades, and growth rates in most other southeastern states were in the range of 45 to 75 percent (see population map, page 55). Future population growth and the quality of life for existing residents is likely to be affected by the many challenges associated with climate change, such as reduced insurance availability, increased insurance cost, and increases in water scarcity, sea-level rise, extreme weather events, and heat stress. Some of these problems, such as increasing heat and declining air quality, will be especially acute in cities.

Adaptation: Reducing Exposure to Flooding and Storm Surge

Three different types of adaptation to sea-level rise are available for low-lying coastal areas.[173,269] One is to move buildings and infrastructure farther inland to get out of the way of the rising sea. Another is to accommodate rising water through changes in building design and construction, such as elevating buildings on stilts. Flood insurance programs even require this in some areas with high probabilities of floods. The third adaptation option is to try to protect existing development by building levees and river flood control structures. This option is being pursued in some highly vulnerable areas of the Gulf and South Atlantic coasts. Flood control structures can be designed to be effective in the face of higher sea level and storm surge. Some hurricane levees and floodwalls were not just replaced after Hurricane Katrina, they were redesigned to withstand higher storm surge and wave action.[401]

Recent upgrades that raised the height of this earthen levee increased protection against storm surge in the New Orleans area.

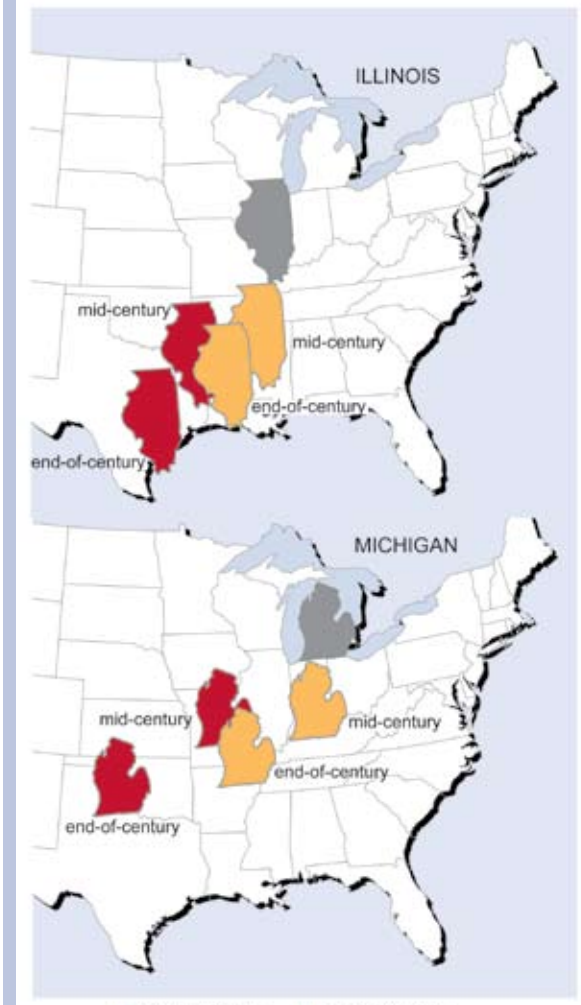
The costs and environmental impacts of building such structures can be significant. Furthermore, building levees can actually increase future risks.[269] This is sometimes referred to as the levee effect or the safe-development paradox. Levees that provide protection from, for example, the storm surge from a Category 3 hurricane, increase real and perceived safety and thereby lead to increased development. This increased development means there will be greater damage if and when the storm surge from a Category 5 hurricane tops the levee than there would have been if no levee had been constructed.[252]

In addition to levees, enhancement of key highways used as hurricane evacuation routes and improved hurricane evacuation planning is a common adaptation underway in all Gulf Coast states.[217] Other protection options that are being practiced along low-lying coasts include the enhancement and protection of natural features such as forested wetlands, saltmarshes, and barrier islands.[390]

Midwest

The Midwest's climate is shaped by the presence of the Great Lakes and the region's location in the middle of the North American continent. This location, far from the temperature-moderating effects of the oceans, contributes to large seasonal swings in air temperature from hot, humid summers to cold winters. In recent decades, a noticeable increase in average temperatures in the Midwest has been observed, despite the strong year-to-year variations. The largest increase has been measured in winter, extending the length of the frost-free or growing season by more than one week, mainly due to earlier dates for the last spring frost. Heavy downpours are now twice as frequent as they were a century ago. Both summer and winter precipitation have been above average for the last three decades, the wettest period in a century. The Midwest has experienced two record-breaking floods in the past 15 years.[213] There has also been a decrease in lake ice, including on the Great Lakes. Since the 1980s, large heat waves have been more frequent in the Midwest than any time in the last century, other than the Dust Bowl years of the 1930s.[112,283,402-404]

Climate on the Move:
Changing Summers in the Midwest



Model projections of summer average temperature and precipitation changes in Illinois and Michigan for mid-century (2040-2059), and end-of-century (2080-2099), indicate that summers in these states are expected to feel progressively more like summers currently experienced in states south and west. Both states are projected to get considerably warmer and have less summer precipitation.

During the summer, public health and quality of life, especially in cities, will be negatively affected by increasing heat waves, reduced air quality, and insect and waterborne diseases. In the winter, warming will have mixed impacts.

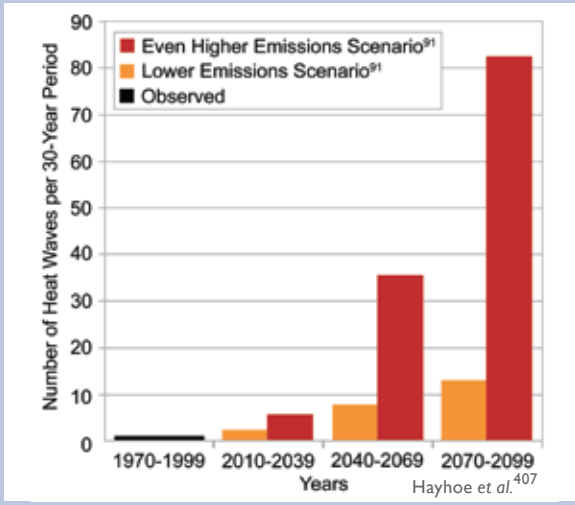
Heat waves that are more frequent, more severe, and longer lasting are projected. The frequency of hot days and the length of the heat-wave season both will be more than twice as great under the higher emissions scenario[91] compared to the lower emissions scenario.[91,283, 402,403,405] Events such as the Chicago heat wave of 1995, which resulted in over 700 deaths, will become more common. Under the lower emissions scenario,[91] such a heat wave is projected to occur every other year in Chicago by the end of the century, while under the higher emissions scenario,[91] there would be about three such heat waves per year. Even more severe heat waves, such as the one that claimed tens of thousands of lives in Europe in 2003, are projected to become more frequent in a warmer world, occurring as often as every other year in the Midwest by the end of this century under the higher emissions scenario.[91,283,403,406] Some health impacts can be reduced by better preparation for such events.[288]

During heat waves, high electricity demand combines with climate-related limitations on energy production capabilities (see *Energy Supply and Use* sector), increasing the likelihood of electricity shortages and resulting in brownouts or even blackouts. This combination can leave people without air conditioning and ventilation when they need it most, as occurred during the 1995 Chicago/Milwaukee heat wave. In general, electricity demand for air conditioning is projected to significantly increase in summer. Improved energy planning could reduce electricity disruptions.

The urban heat island effect can further add to high local daytime and nighttime temperatures (see *Human Health* sector). Heat waves take a greater toll in illness and death when there is little relief from the heat at night.

Another health-related issue arises from the fact that climate change can affect air quality. A warmer climate generally means more ground-level ozone (a component of smog), which can cause respiratory problems, especially for those who are young, old, or have asthma or allergies. Unless the emissions of pollutants that lead to ozone formation are reduced significantly, there will be more ground-level ozone as a result of the projected climate changes in the Midwest due to increased air temperatures, more stagnant air, and increased emissions from vegetation.[283,291,402,403,408-410]

Number of 1995-like Chicago Heat Waves

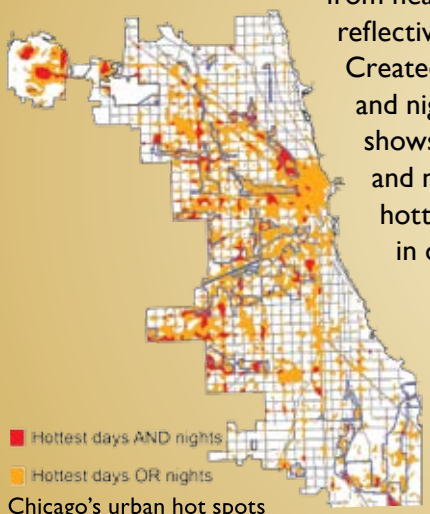


Over the last three decades of this century, heat waves like the one that occurred in Chicago in 1995 are projected to occur about once every three years under the lower emissions scenario.[91] Under the even higher emissions scenario, such events are projected to occur an average of nearly three times a year. In this analysis, heat waves were defined as at least one week of daily maximum temperatures greater than 90°F and nighttime minimum temperatures greater than 70°F, with at least two consecutive days with daily temperatures greater than 100°F and nighttime temperatures greater than 80°F.

Insects such as ticks and mosquitoes that carry diseases will survive winters more easily and produce larger populations in a warmer Midwest.[283,402,403] One potential risk is an increasing incidence of diseases such as West Nile

Adaptation: Chicago Tries to Cool the Urban Heat Island

Efforts to reduce urban heat island effects become even more important in a warming climate. The City of Chicago has produced a map of urban hotspots to use as a planning tool to target areas that could most benefit from heat-island reduction initiatives such as reflective or green roofing, and tree planting. Created using satellite images of daytime and nighttime temperatures, the map shows the hottest 10 percent of both day and night temperatures in red, and the hottest 10 percent of either day or night in orange.



Chicago's urban hot spots

"Green roofs" are cooler than the surrounding conventional roofs.

The City is working to reduce urban heat buildup and the need for air conditioning by using reflective roofing materials. This thermal image shows that the radiating temperature of the City Hall's "green roof" – covered with soil and vegetation – is up to 77°F cooler than the nearby conventional roofs.[411]

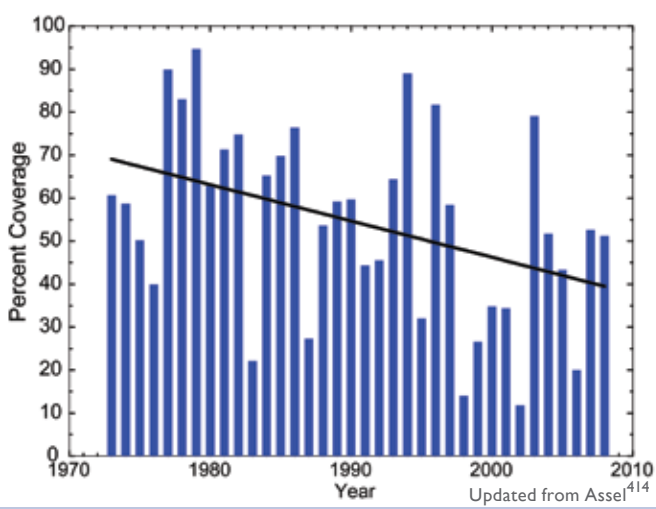
virus. Waterborne diseases will present an increasing risk to public health because many pathogens thrive in warmer conditions.[163]

In winter, oil and gas demand for heating will decline. Warming will also decrease the number of days with snow on the ground, which is expected to improve traffic safety.[222] On the other hand, warming will decrease outdoor winter recreational opportunities such as skiing, snowmobiling, ice skating, and ice fishing.

Significant reductions in Great Lakes water levels, which are projected under higher emissions scenarios, lead to impacts on shipping, infrastructure, beaches, and ecosystems.

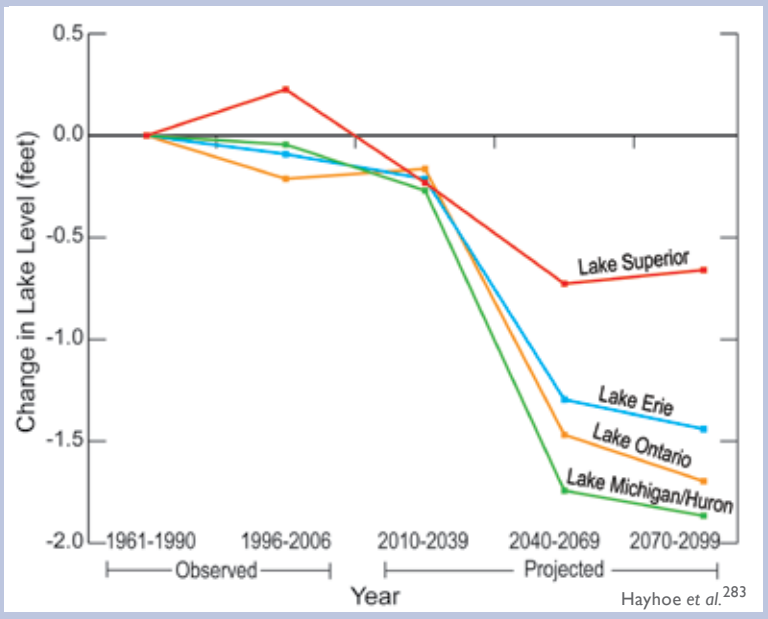
The Great Lakes are a natural resource of tremendous significance, containing 20 percent of the planet's fresh surface water and serving as the dominant feature of the industrial heartland of the nation. Higher temperatures will mean more evaporation and hence a likely reduction in the Great Lakes water levels. Reduced lake ice increases evaporation in winter, contributing to the decline. Under a lower emissions scenario,[91] water levels in the Great Lakes are projected to fall no more than 1 foot by the end of the century, but under a higher emissions scenario,[91] they are projected to fall between 1 and 2 feet.[283] The greater the temperature rise, the higher the likelihood of a larger decrease in lake levels.[412] Even a decrease of 1 foot, combined with normal fluctuations, can result in significant lengthening of the distance to the lakeshore in many places. There are also potential impacts on beaches, coastal ecosystems, dredging requirements, infrastructure, and shipping. For example, lower lake levels reduce "draft," or the distance between the waterline and the bottom of a ship, which lessens a ship's ability to carry freight. Large vessels, sized for passage through the St. Lawrence Seaway, lose up to 240 tons of capacity for each inch of draft lost.[283,402,403,413] These impacts will have costs, including increased shipping, repair and maintenance costs, and lost recreation and tourism dollars.

Observed Changes in Great Lakes Ice Cover
Seasonal Maximum Coverage, 1973 to 2008

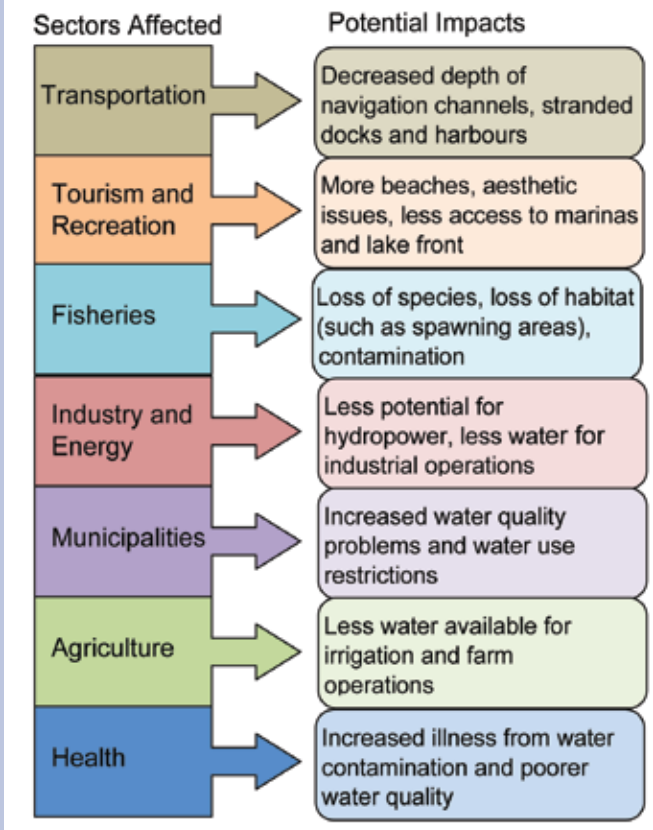


Reductions in winter ice cover lead to more evaporation, causing lake levels to drop even farther. While the graph indicates large year-to-year variations, there is a clear decrease in the extent of Great Lakes ice coverage, as shown by the black trend line.

Projected Changes in Great Lakes Levels
under Higher Emissions Scenario[91]



Average Great Lakes levels depend on the balance between precipitation (and corresponding runoff) in the Great Lakes Basin on one hand, and evaporation and outflow on the other. As a result, lower emissions scenarios[91] with less warming show less reduction in lake levels than higher emissions scenarios.[91] Projected changes in lake levels are based on simulations by the NOAA Great Lakes model for projected climate changes under a higher emissions scenario.[91]



Reduced water levels in the Great Lakes will have interconnected impacts across many sectors, creating mismatches between water supply and demand, and necessitating trade-offs. Regions outside the Midwest will also be affected. For example, a reduction in hydropower potential would affect the Northeast, and a reduction in irrigation water would affect regions that depend on agricultural produce from the Midwest.

The Great Flood of 1993 caused flooding along 500 miles of the Mississippi and Missouri river systems. The photo shows the flood's effects on U.S. Highway 54, just north of Jefferson City, Missouri.

The likely increase in precipitation in winter and spring, more heavy downpours, and greater evaporation in summer would lead to more periods of both floods and water deficits.

Precipitation is projected to increase in winter and spring, and to become more intense throughout the year. This pattern is expected to lead to more frequent flooding, increasing infrastructure damage, and impacts on human health. Such heavy downpours can overload drainage systems and water treatment facilities, increasing the risk of waterborne diseases. Such an incident occurred in Milwaukee in 1993 when the water supply was contaminated with the parasite *Cryptosporidium*, causing 403,000 reported cases of gastrointestinal illness and 54 deaths.[219]

In Chicago, rainfall of more than 2.5 inches per day is an approximate threshold beyond which combined water and sewer systems overflow into Lake Michigan (such events occurred 2.5 times per decade from 1961 to 1990). This generally results in beach closures to reduce the risk of disease transmission. Rainfall above this threshold is projected to occur twice as often by the end of this century under the lower emissions scenario[91] and three times as often under the higher emissions scenario.[91,283,403] Similar increases are expected across the Midwest.

More intense rainfall can lead to floods that cause significant impacts regionally and even nationally. For example, the Great Flood of 1993 caused catastrophic flooding along 500 miles of the Mississippi and Missouri river systems, affecting one-quarter of all U.S. freight (see *Transportation* sector).[222,415-417] Another example was a record-breaking 24-hour rainstorm in July 1996, which resulted in flash flooding in Chicago and its suburbs, causing extensive damage and disruptions, with some commuters not being able to reach Chicago for

three days (see *Transportation* sector).[222] There was also a record-breaking storm in August 2007. Increases in such events are likely to cause greater property damage, higher insurance rates, a heavier burden on emergency management, increased clean-up and rebuilding costs, and a growing financial toll on businesses, homeowners, and insurers.

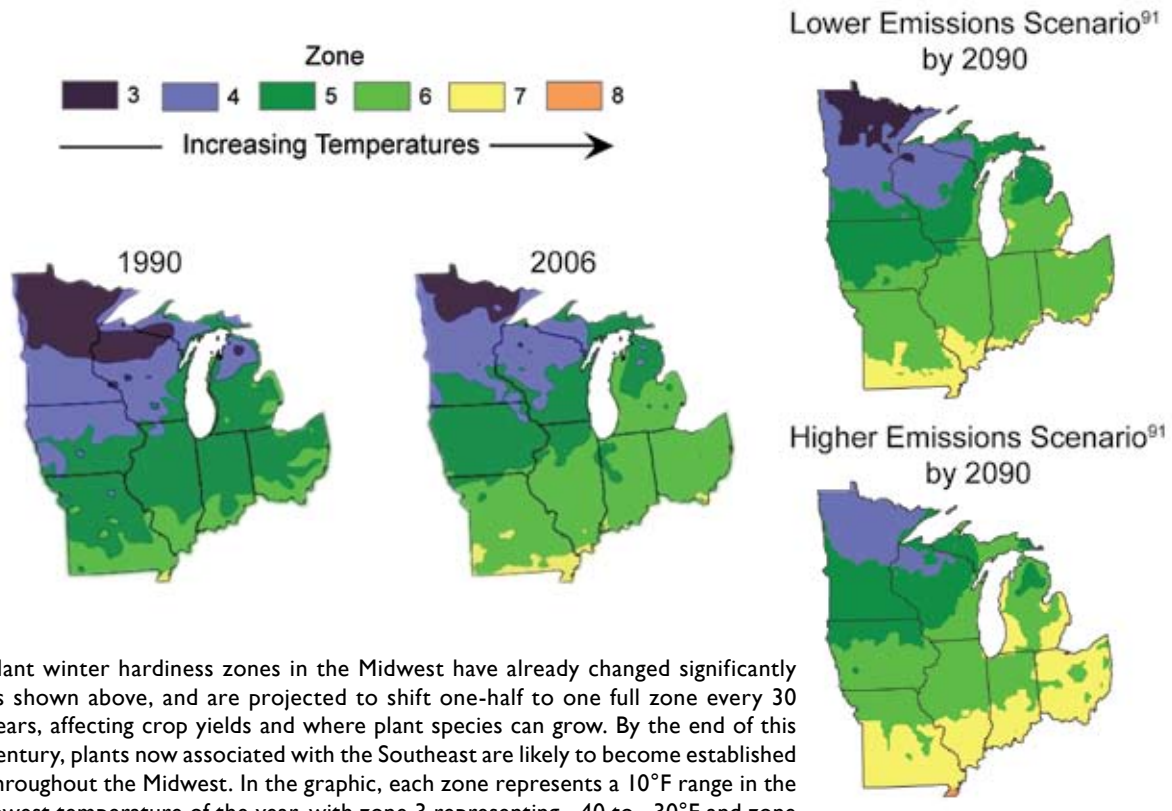
In the summer, with increasing evaporation rates and longer periods between rainfalls, the likelihood of drought will increase and water levels in rivers, streams, and wetlands are likely to decline. Lower water levels also could create problems for river traffic, reminiscent of the stranding of more than 4,000 barges on the Mississippi River during the 1988 drought. Reduced summer water levels are also likely to reduce the recharge of groundwater, cause small streams to dry up (reducing native fish populations), and reduce the area of wetlands in the Midwest.

While the longer growing season provides the potential for increased crop yields, increases in heat waves, floods, droughts, insects, and weeds will present increasing challenges to managing crops, livestock, and forests.

The projected increase in winter and spring precipitation and flooding is likely to delay planting and crop establishment. Longer growing seasons and increased carbon dioxide have positive effects on some crop yields, but this is likely to be counterbalanced in part by the negative effects of additional disease-causing pathogens, insect pests, and weeds (including invasive weeds).[193] Livestock production is expected to become more costly as higher temperatures stress livestock, decreasing productivity and increasing costs associated with the needed ventilation and cooling equipment.[193]

Plant winter hardiness zones (each zone represents a 10°F change in minimum temperature) in the Midwest are likely to shift one-half to one full zone

Observed and Projected Changes in Plant Hardiness Zones



Plant winter hardiness zones in the Midwest have already changed significantly as shown above, and are projected to shift one-half to one full zone every 30 years, affecting crop yields and where plant species can grow. By the end of this century, plants now associated with the Southeast are likely to become established throughout the Midwest. In the graphic, each zone represents a 10°F range in the lowest temperature of the year, with zone 3 representing –40 to –30°F and zone 8 representing 10 to 20°F.

© 2006 by Arbor Day Foundation ®[418]

CMIP3-B[117]

about every 30 years. By the end of the century, plants now associated with the Southeast are likely to become established throughout the Midwest.

Impacts on forests are likely to be mixed, with the positive effects of higher carbon dioxide and nitrogen levels acting as fertilizers potentially negated by the negative effects of decreasing air quality.[243] In addition, more frequent droughts, and hence fire hazards, and an increase in destructive insect pests, such as gypsy moths, hinder plant growth. Insects, historically controlled by cold winters, more easily survive milder winters and produce larger populations in a warmer climate (see *Agriculture* and *Ecosystems* sectors).

Native species are very likely to face increasing threats from rapidly changing climate conditions, pests, diseases, and invasive species moving in from warmer regions.

As air temperatures increase, so will water temperatures. In some lakes, this will lead to an earlier and longer period in summer during which mixing of the relatively warm surface lake water with the colder water below is reduced.[564] In such cases, this stratification can cut off oxygen from bottom layers, increasing the risk of oxygen-poor or oxygen-free "dead zones" that kill fish and other living things. In lakes with contaminated sediment, warmer water and low-oxygen conditions can more readily mobilize mercury and other persistent pollutants.[565] In such cases, where these increasing quantities of contaminants are taken up in the aquatic food chain, there will be additional potential for health hazards for species that eat fish from the lakes, including people.[566]

Populations of coldwater fish, such as brook trout, lake trout, and whitefish, are expected to decline dramatically, while populations of coolwater fish such as muskie, and warmwater species such as smallmouth bass and bluegill, will take their place. Aquatic ecosystem disruptions are likely to be compounded by invasions by non-native species, which tend to thrive under a wide range of environmental conditions. Native species, adapted to a narrower range of conditions, are expected to decline.

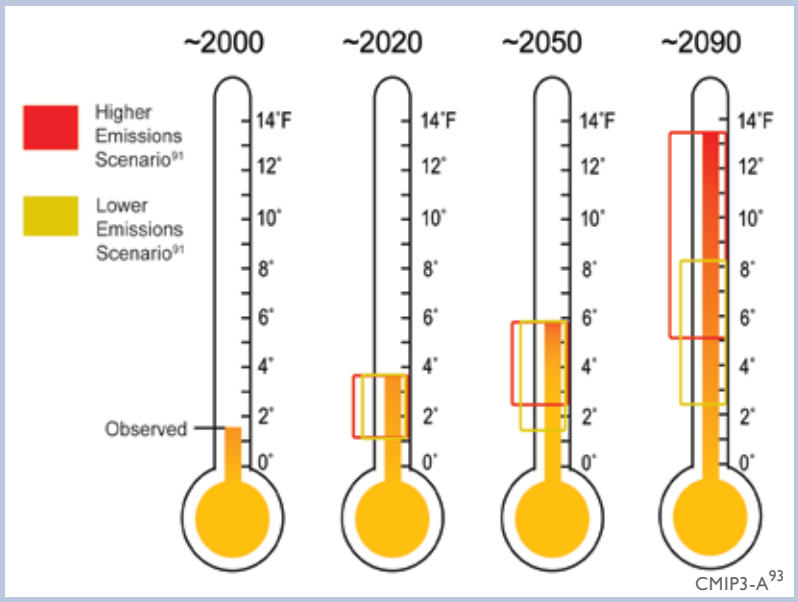
All major groups of animals, including birds, mammals, amphibians, reptiles, and insects, will be affected by impacts on local populations, and by competition from other species moving into the Midwest region.[70] The potential for animals to shift their ranges to keep pace with the changing climate will be inhibited by major urban areas and the presence of the Great Lakes.

Great Plains

The Great Plains is characterized by strong seasonal climate variations. Over thousands of years, records preserved in tree rings, sediments, and sand deposits provide evidence of recurring periods of extended drought (such as the Dust Bowl of the 1930s) alternating with wetter conditions.[97,419]

Today, semi-arid conditions in the western Great Plains gradually transition to a moister climate in the eastern parts of the region. To the north, winter days in North Dakota average 25°F, while it is not unusual to have a West Texas winter day over 75°F. In West Texas, there are between 70 and 100 days per year over 90°F, whereas North Dakota has only 10 to 20 such days on average.

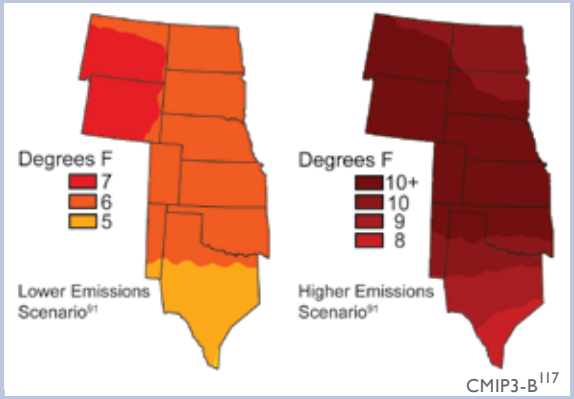
Observed and Projected Temperature Rise



The average temperature in the Great Plains already has increased roughly 1.5°F relative to a 1960s and 1970s baseline. By the end of the century, temperatures are projected to continue to increase by 2.5°F to more than 13°F compared with the 1960 to 1979 baseline, depending on future emissions of heat-trapping gases. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible.

Significant trends in regional climate are apparent over the last few decades. Average temperatures have increased throughout the region, with the largest changes occurring in winter months and over the northern states. Relatively cold days are becoming less frequent and relatively hot days more frequent.[420] Precipitation has also increased over most of the area.[149,421]

Summer Temperature Change by 2080-2099



Temperatures in the Great Plains are projected to increase significantly by the end of this century, with the northern part of the region experiencing the greatest projected increase in temperature.

Temperatures are projected to continue to increase over this century, with larger changes expected under scenarios of higher heat-trapping emissions as compared to lower heat-trapping emissions. Summer changes are projected to be larger than those in winter in the southern and central Great Plains.[108] Precipitation is also projected to change, particularly in winter and spring. Conditions are anticipated to become wetter in the north and drier in the south.

Projected changes in long-term climate and more frequent extreme events such as heat waves, droughts, and heavy rainfall will affect many aspects of life in the Great Plains. These include the region's already threatened water resources, essential agricultural and ranching activities, unique natural and protected areas, and the health and prosperity of its inhabitants.

Projected increases in temperature, evaporation, and drought frequency add to concerns about the region's declining water resources.

Water is the most important factor affecting activities on the Great Plains. Most of the water used in the Great Plains comes from the High Plains aquifer (sometimes referred to by the name of its largest formation, the Ogallala aquifer), which stretches from South Dakota to Texas. The aquifer holds both current recharge from precipitation and so-called "ancient" water, water trapped by silt and soil washed down from the Rocky Mountains during the last ice age.

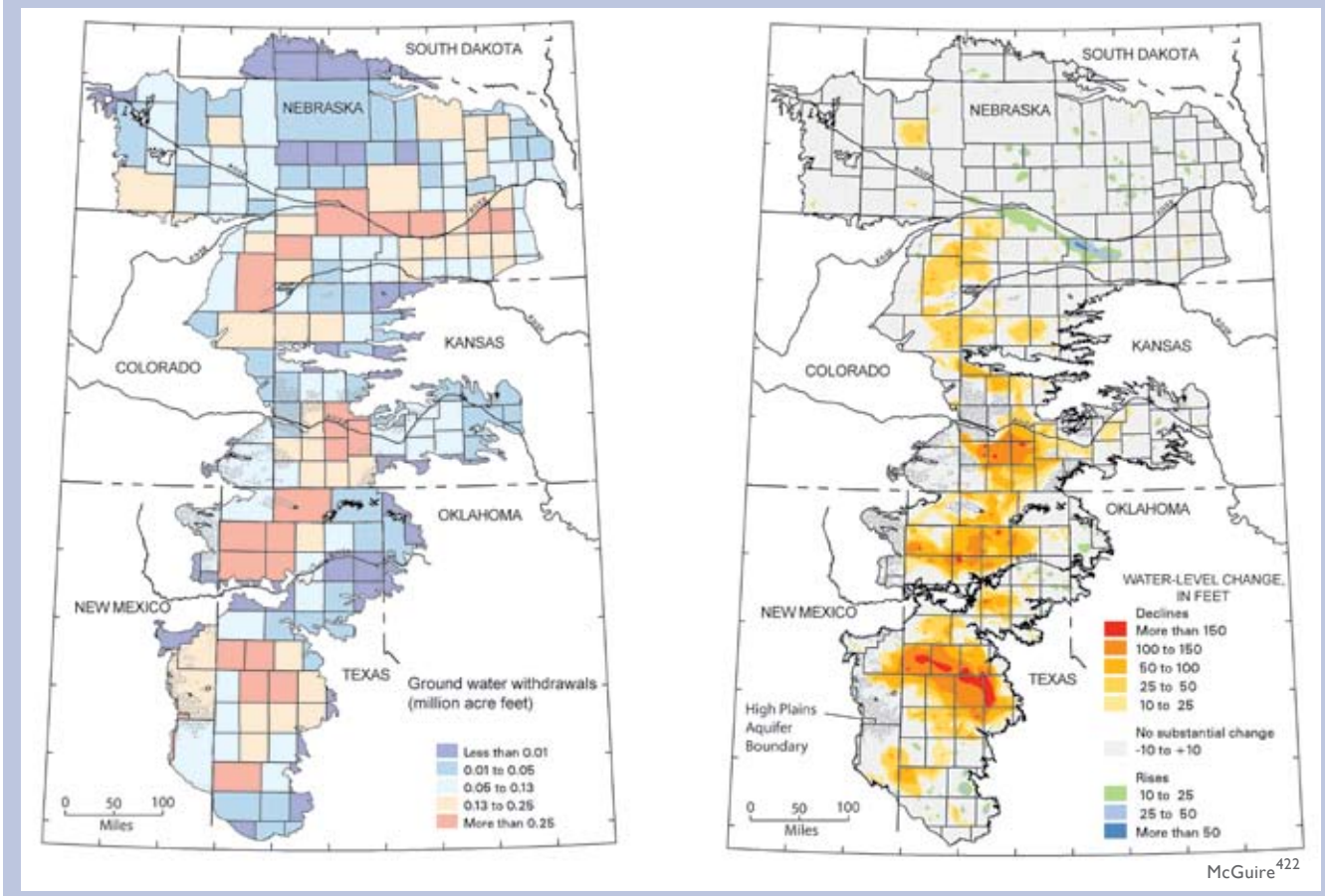
As population increased in the Great Plains and irrigation became widespread, annual water withdrawals began to outpace natural recharge.[422]

Today, an average of 19 billion gallons of groundwater are pumped from the aquifer each day. This water irrigates 13 million acres of land and provides drinking water to over 80 percent of the region's population.[423] Since 1950, aquifer water levels have dropped an average of 13 feet, equivalent to a 9 percent decrease in aquifer storage. In heavily irrigated parts of Texas, Oklahoma, and Kansas, reductions are much larger, from 100 feet to over 250 feet.

Projections of increasing temperatures, faster evaporation rates, and more sustained droughts brought on by climate change will only add more stress to overtaxed water sources.[149,253,424,425] Current water use on the Great Plains is unsustainable, as the High Plains aquifer continues to be tapped faster than the rate of recharge.

Groundwater Withdrawals for Irrigation
1950 to 2005

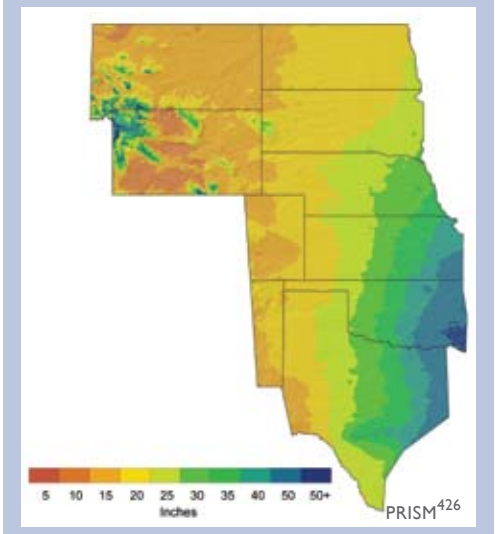
Water Level Changes in the High Plains Aquifer
1950 to 2005



McGuire[422]

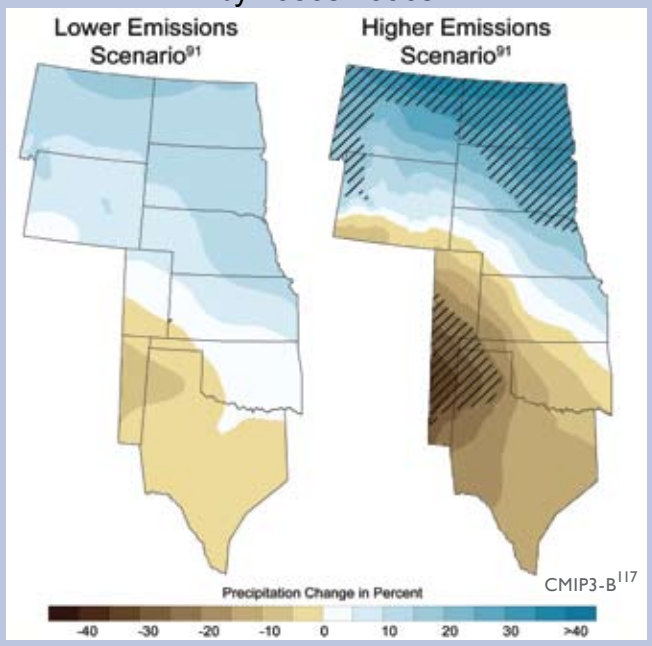
Irrigation is one of the main factors stressing water resources in the Great Plains. In parts of the region, more than 81 trillion gallons of water (pink areas on the left hand map) were withdrawn for irrigation in Texas, Oklahoma, and Kansas from 1950 to 2005. During the same time period, water levels in parts of the High Plains aquifer in those states decreased by more than 150 feet (red areas on the right hand map).

Average Annual Observed Precipitation
1971-2000



The Great Plains currently experiences a sharp precipitation gradient from east to west, from more than 50 inches of precipitation per year in eastern Oklahoma and Texas to less than 10 inches in some of the western parts of the region.

Projected Spring Precipitation Change by 2080s-2090s



Northern areas of the Great Plains are projected to experience a wetter climate by the end of this century, while southern areas are projected to experience a drier climate. The change in precipitation is compared with a 1960-1979 baseline. Confidence in the projected changes is highest in the hatched areas.

The Dust Bowl: Combined Effects of Land Use and Climate

Over the past century, large-scale conversion of grasslands to crops and ranchland has altered the natural environment of the Great Plains.[149] Irrigated fields have increased evaporation rates, reducing summer temperatures, and increasing local precipitation.[427,428]

The Dust Bowl of the 1930s epitomizes what can happen as a result of interactions between climate and human activity. In the 1920s, increasing demand for food encouraged poor agricultural practices. Small-scale producers ploughed under native grasses to plant wheat, removing the protective cover the land required to retain its moisture.

Dust Bowl of 1935 in Stratford, Texas

Variations in ocean temperature contributed to a slight increase in air temperatures, just enough to disrupt the winds that typically draw moisture from the south into the Great Plains. As the intensively tilled soils dried up, topsoil from an estimated 100 million acres of the Great Plains blew across the continent.

The Dust Bowl dramatically demonstrated the potentially devastating effects of poor land-use practices combined with climate variability and change.[429] Today, climate change is interacting with a different set of poor land-use practices. Water is being pumped from the Ogallala aquifer faster than it can recharge. In many areas, playa lakes are poorly managed (see page 127). Existing stresses on water resources in the Great Plains due to unsustainable water usage are likely to be exacerbated by future changes in temperature and precipitation, this time largely due to human-induced climate change.

Agriculture, ranching, and natural lands, already under pressure due to an increasingly limited water supply, are very likely to also be stressed by rising temperatures.

Agricultural, range, and croplands cover more than 70 percent of the Great Plains, producing wheat, hay, corn, barley, cattle, and cotton. Agriculture is fundamentally sensitive to climate. Heat and water stress from droughts and heat waves can decrease yields and wither crops.[430,431] The influence of long-term trends in temperature and precipitation can be just as great.[431]

As temperatures increase over this century, optimal zones for growing particular crops will shift. Pests that were historically unable to survive in the Great Plains' cooler areas are expected to spread northward. Milder winters and earlier springs also will encourage greater numbers and earlier emergence of insects.[149] Rising carbon dioxide levels in the atmosphere can increase crop growth, but also make some types of weeds grow even faster (see *Agriculture* sector).[432]

Projected increases in precipitation are unlikely to be sufficient to offset decreasing soil moisture and water availability in the Great Plains due to rising temperatures and aquifer depletion. In some areas, there is not expected to be enough water for agriculture to sustain even current usage.

With limited water supply comes increased vulnerability of agriculture to climate change. Further stresses on water supply for agriculture and ranching are likely as the region's cities continue to grow, increasing competition between urban and rural users.[433] The largest impacts are expected in heavily irrigated areas in the southern Great Plains, already plagued by unsustainable water use and greater frequency of extreme heat.[149]

Successful adaptation will require diversification of crops and livestock, as well as transitions from irrigated to rain-fed agriculture.[434-436] Producers who can adapt to changing climate conditions are likely to see their businesses survive; some might even thrive. Others, without resources or ability to adapt effectively, will lose out.

Climate change is likely to affect native plant and animal species by altering key habitats such as the wetland ecosystems known as prairie potholes or playa lakes.

Ten percent of the Great Plains is protected lands, home to unique ecosystems and wildlife. The region is a haven for hunters and anglers, with its ample supplies of wild game such as moose, elk, and deer; birds such as goose, quail, and duck; and fish such as walleye and bass.

Climate-driven changes are likely to combine with other human-induced stresses to further increase the vulnerability of natural ecosystems to pests, invasive species, and loss of native species. Changes in temperature and precipitation affect the composition and diversity of native animals and plants through altering their breeding patterns, water and food supply, and habitat availability.[149] In a changing climate, populations of some pests such as red fire ants and rodents, better adapted to a warmer climate, are projected to increase.[437,438] Grassland and plains birds, already besieged by habitat fragmentation, could experience significant shifts and reductions in their ranges.[439]

Urban sprawl, agriculture, and ranching practices already threaten the Great Plains' distinctive wetlands. Many of these are home to endangered and iconic species. In particular, prairie wetland ecosystems provide crucial habitat for migratory waterfowl and shorebirds.

Mallard ducks are one of the many species that inhabit the playa lakes, also known as prairie potholes.

Ongoing shifts in the region's population from rural areas to urban centers will interact with a changing climate, resulting in a variety of consequences.

Inhabitants of the Great Plains include a rising number of urban dwellers, a long tradition of rural communities, and extensive Native American

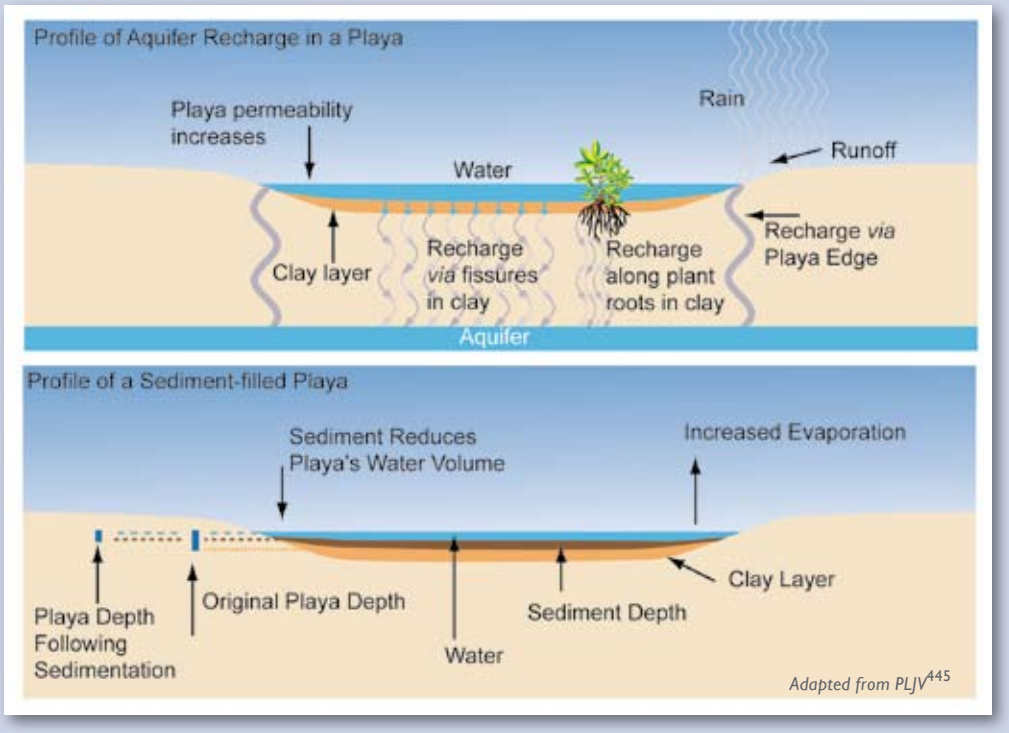
Playa Lakes and Prairie Potholes

Shallow ephemeral lakes dot the Great Plains, anomalies of water in the arid landscape. In the north they are known as prairie potholes; in the south, playa lakes. These lakes create unique microclimates that support diverse wildlife and plant communities. A playa can lie with little or no water for long periods, or have several wet/dry cycles each year. When it rains, what appeared to be only a few clumps of short, dry grasses just a few days earlier suddenly teems with frogs, toads, clam shrimp, and aquatic plants.

Playa lakes in west Texas fill up after a heavy spring rain.

The playas provide a perfect home for migrating birds to feed, mate, and raise their young. Millions of shorebirds and waterfowl, including Canada geese, mallard ducks, and Sandhill cranes, depend on the playas for their breeding grounds. From the prairie potholes of North Dakota to the playa lakes of West Texas, the abundance and diversity of native bird species directly depends on these lakes.[440,441]

Despite their small size, playa lakes and prairie potholes also play a critical role in supplying water to the Great Plains. The contribution of the playa lakes to this sensitively balanced ecosystem needs to be monitored and maintained in order to avoid unforeseen impacts on our natural resources. Before cultivation, water from these lakes was the primary source of recharge to the High Plains aquifer.[442] But many playas are disappearing and others are threatened by growing urban populations, extensive agriculture, and other filling and tilling practices.[443] In recent years, agricultural demands have drawn down the playas to irrigate crops. Agricultural waste and fertilizer residues drain into playas, decreasing the quality of the water, or clogging them so the water cannot trickle down to refill the aquifer. Climate change is expected to add to these stresses, with increasing temperatures and changing rainfall patterns altering rates of evaporation, recharge, and runoff to the playa lake systems.[444]



populations. Although farming and ranching remain primary uses of the land – taking up much of the region's geographical area – growing cities provide housing and jobs for more than two-thirds of the population. For everyone on the Great Plains, though, a changing climate and a limited water supply are likely to challenge their ability to thrive, leading to conflicting interests in the allocation of increasingly scarce water resources.[313,433]

Native American communities

The Great Plains region is home to 65 Native American tribes. Native populations on rural tribal lands have limited capacities to respond to climate change.[313] Many reservations already face severe problems with water quantity and quality – problems likely to be exacerbated by climate change and other human-induced stresses.

Rural communities

As young adults move out of small, rural communities, the towns are increasingly populated by a vulnerable demographic of very old and very young people, placing them more at risk for health issues than urban communities. Combined effects of changing demographics and climate are likely to make it more difficult to supply adequate and efficient public health services and educational opportunities to rural areas. Climate-driven shifts in optimal crop types and increased risk of drought, pests, and extreme events will add more economic stress and tension to traditional communities.[430,433]

Urban populations

Although the Great Plains is not yet known for large cities, many mid-sized towns throughout the region are growing rapidly. One in four of the most rapidly growing cities in the nation is located in the Great Plains[446] (see *Society* sector). Most of these growing centers can be found in the southern parts of the region, where water resources are already seriously constrained. Urban populations, particularly the young, elderly, and economically disadvantaged, may also be disproportionately affected by heat.[447]

New opportunities

There is growing recognition that the enormous wind power potential of the Great Plains could provide new avenues for future employment and land use. Texas already produces the most wind power of any state. Wind energy production is also prominent in Oklahoma. North and South Dakota have rich wind potential.[191]

As climate change creates new environmental conditions, effective adaptation strategies become increasingly essential to ecological and socioeconomic survival. A great deal of the Great Plains' adaptation potential might be realized through agriculture. For example, plant species that mature earlier and are more resistant to disease and pests are more likely to thrive under warmer conditions.

Other emerging adaptation strategies include dynamic cropping systems and increased crop diversity. In particular, mixed cropping-livestock systems maximize available resources while minimizing the need for external inputs such as irrigation that draws down precious water supplies.[436] In many parts of the region, diverse cropping systems and improved water use efficiency will be key to sustaining crop and rangeland systems.[448] Reduced water supplies might cause some farmers to alter the intensive cropping systems currently in use.[193,219]

Adaptation: Agricultural Practices to Reduce Water Loss and Soil Erosion

Conservation of water is critical to efficient crop production in areas where water can be scarce. Following the Dust Bowl in the 1930s, Great Plains farmers implemented a number of improved farming practices to increase the effectiveness of rainfall capture and retention in the soil and protect the soil against water and wind erosion. Examples include rotating crops, retaining crop residues, increasing vegetative cover, and altering plowing techniques.

With observed and projected increases in summer temperatures and in the frequency and intensity of heavy downpours, it will become even more important to protect against increasing loss of water and soil. Across the upper Great Plains, where strong storms are projected to occur more frequently, producers are being encouraged to increase the amount of crop residue left on the soil or to plant cover crops in the fall to protect the soil in the spring before crops are planted.

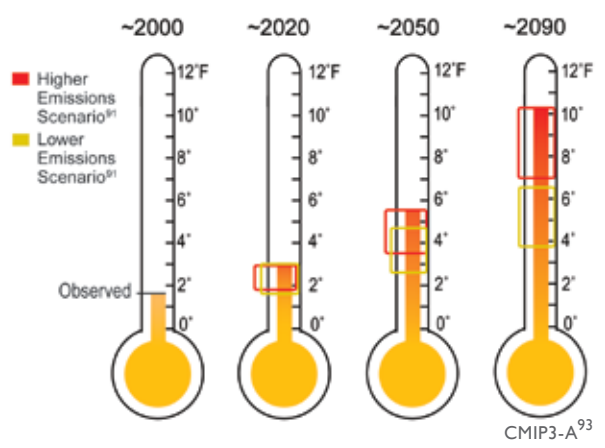
Across the southern Great Plains, some farmers are returning to dryland farming rather than relying on irrigation for their crops. Preserving crop residue helps the soil absorb more moisture from rain and eases the burden on already-stressed groundwater. These efforts have been promoted by the U.S. Department of Agriculture through research and extension efforts such as Kansas State University's Center for Sustainable Agriculture and Alternative Crops.

Southwest

The Southwest region stretches from the southern Rocky Mountains to the Pacific Coast. Elevations range from the lowest in the country to among the highest, with climates ranging from the driest to some of the wettest. Past climate records based on changes in Colorado River flows indicate that drought is a frequent feature of the Southwest, with some of the longest documented "megadroughts" on Earth. Since the 1940s, the region has experienced its most rapid population and urban growth. During this time, there were both unusually wet periods (including much of 1980s and 1990s) and dry periods (including much of 1950s and 1960s).[449] The prospect of future droughts becoming more severe as a result of global warming is a significant concern, especially because the Southwest continues to lead the nation in population growth.

Human-induced climate change appears to be well underway in the Southwest. Recent warming is among the most rapid in the nation, significantly more than the global average in some areas. This is driving declines in spring snowpack and Colorado River flow.[34,160,161] Projections suggest continued strong warming, with much larger increases under higher emissions scenarios[91] compared to lower emissions scenarios. Projected summertime temperature increases are greater than the annual average increases in some parts of the region, and are likely to be exacerbated locally by expanding urban heat island effects.[450] Further water cycle changes are projected, which, combined with increasing temperatures, signal a serious water supply challenge in the decades and centuries ahead.[34,159]

Observed and Projected Temperature Rise



The average temperature in the Southwest has already increased roughly 1.5°F compared to a 1960-1979 baseline period. By the end of the century, average annual temperature is projected to rise approximately 4°F to 10°F above the historical baseline, averaged over the Southwest region. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible.

Water supplies are projected to become increasingly scarce, calling for trade-offs among competing uses, and potentially leading to conflict.

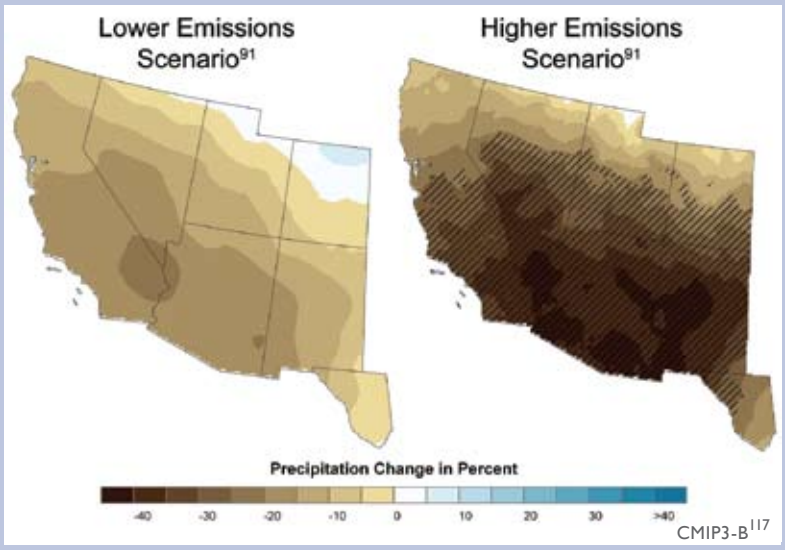
Water is, quite literally, the lifeblood of the Southwest. The largest use of water in the region is associated with agriculture, including some of the nation's most important crop-producing areas in California. Water is also an important source of hydroelectric power, and water is required for the large population growth in the region, particularly that of major cities such as Phoenix and Las Vegas. Water also plays a critical role in supporting healthy ecosystems across the region, both on land and in rivers and lakes.

Water supplies in some areas of the Southwest are already becoming limited, and this trend toward scarcity is likely to be a harbinger of future water shortages.[34,451] Groundwater pumping is lowering water tables, while rising temperatures reduce river flows in vital rivers including the Colorado.[34] Limitations imposed on water supply by projected temperature increases are likely to be made worse by substantial reductions in rain and snowfall in the spring months, when precipitation is most needed to fill reservoirs to meet summer demand.[151]

A warmer and drier future means extra care will be needed in planning the allocation of water for

the coming decades. The Colorado Compact, negotiated in the 1920s, allocated the Colorado River's water among the seven basin states. It was based, however, on unrealistic assumptions about how much water was available because the observations of runoff during the early 1900s turned out to be part of the greatest and longest high-flow period of the last five centuries.[452] Today, even in normal decades, the Colorado River does not have enough water to meet the agreed-upon allocations. During droughts and under projected future conditions, the situation looks even bleaker.

Projected Change in Spring Precipitation, 2080-2099



Percentage change in March-April-May precipitation for 2080-2099 compared to 1961-1979 for a lower emissions scenario[91] (left) and a higher emissions scenario[91] (right). Confidence in the projected changes is highest in the hatched areas.

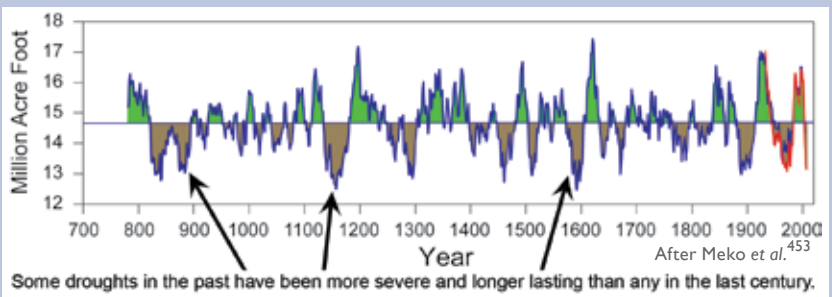
During droughts, water designated for agriculture could provide a temporary back-up supply for urban water needs. Similarly, non-renewable groundwater could be tapped during especially dry periods. Both of these options, however, come at the cost of either current or future agricultural production.

Water is already a subject of contention in the Southwest, and climate change – coupled with rapid population growth – promises to increase the likelihood of water-related

Future of Drought in the Southwest

Droughts are a long-standing feature of the Southwest's climate. The droughts of the last 110 years pale in comparison to some of the decades-long "megadroughts" that the region has experienced over the last 2000 years.[419] During the closing decades of the 1500s, for example, major droughts gripped parts of the Southwest.[189] These droughts sharply reduced the flow of the Colorado River[452,453] and the all-important Sierra Nevada headwaters for California,[454] and dried out the region as a whole. As of 2009, much of the Southwest remains in a drought that began around 1999. This event is the most severe western drought of the last 110 years, and is being exacerbated by record warming.[455]

Over this century, projections point to an increasing probability of drought for the region.[90,115] Many aspects of these projections, including a northward shift in winter and spring storm tracks, are consistent with observed trends over recent decades.[96,456,457] Thus, the most likely future for the Southwest is a substantially drier one (although there is presently no consensus on how the region's summer monsoon [rainy season] might change in the future). Combined with the historical record of severe droughts and the current uncertainty regarding the exact causes and drivers of these past events, the Southwest must be prepared for droughts that could potentially result from multiple causes. The combined effects of natural climate variability and human-induced climate change could turn out to be a devastating "one-two punch" for the region.



Colorado River flow has been reconstructed back over 1200 years based primarily on tree-ring data. These data reveal that some droughts in the past have been more severe and longer lasting than any experienced in the last 100 years. The red line indicates actual measurements of river flow during the last 100 years. Models indicate that, in the future, droughts will continue to occur, but will become hotter, and thus more severe, over time.[90]

conflict. Projected temperature increases, combined with river-flow reductions, will increase the risk of water conflicts between sectors, states, and even nations. In recent years, negotiations regarding existing water supplies have taken place among the seven states sharing the Colorado River and the two states (New Mexico and Texas) sharing the Rio Grande. Mexico and the United States already disagree on meeting their treaty allocations of Rio Grande and Colorado River water.

In addition, many water settlements between the U.S. Government and Native American tribes have yet to be fully worked out. The Southwest is home to dozens of Native communities whose status as sovereign nations means they hold rights to the water for use on their land. However, the amount of water actually available to each nation is determined through negotiations and litigation. Increasing water demand in the Southwest is driving current negotiations and litigation of tribal water rights. While several nations have legally settled their water rights, many other tribal negotiations are either currently underway or pending. Competing demands from treaty rights, rapid development, and changes in agriculture in the region, exacerbated by years of drought and climate change, have the potential to spark significant conflict over an already over-allocated and dwindling resource.

Increasing temperature, drought, wildfire, and invasive species will accelerate transformation of the landscape.

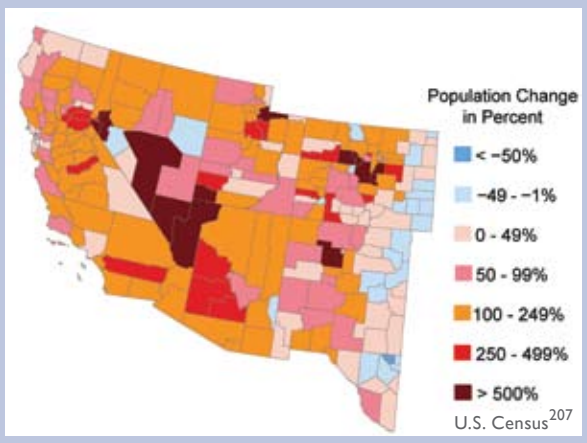
Climate change already appears to be influencing both natural and managed ecosystems of the Southwest.[455,458] Future landscape impacts are likely to be substantial, threatening biodiversity, protected areas, and ranching and agricultural lands. These changes are often driven by multiple factors, including changes in temperature and drought patterns, wildfire, invasive species, and pests.

Conditions observed in recent years can serve as indicators for future change. For example, temperature increases have made the current drought in the region more severe than the natural droughts of the last several centuries. As a result, about 4,600 square miles of piñon-juniper woodland in the Four Corners region of the Southwest have experienced substantial die-off of piñon pine trees.[455] Record wildfires are also being driven by rising temperatures and related reductions in spring snowpack and soil moisture.[458]

How climate change will affect fire in the Southwest varies according to location. In general, total area burned is projected to increase.[459] How this plays out at individual locations, however, depends on regional changes in temperature and precipitation, as well as on whether fire in the area is currently limited by fuel availability or by rainfall.[460] For example, fires in wetter, forested areas are expected to increase in frequency, while areas where fire is limited by the availability of fine fuels experience decreases.[460] Climate changes could also create subtle shifts in fire behavior, allowing more "runaway fires" – fires that are thought to have been brought under control, but then rekindle.[461] The magnitude of fire damages, in terms of economic impacts as well as direct endangerment, also increases as urban development increasingly impinges on forested areas.[460,462]

Climate-fire dynamics will also be affected by changes in the distribution of ecosystems across the Southwest. Increasing temperatures and shifting precipitation patterns will drive declines in high-elevation ecosystems such as alpine forests and tundra.[459,463] Under higher emissions scenarios,[91] high-elevation forests in California, for example, are projected to decline by 60 to 90 percent before the end of the century.[284,459] At the same time, grasslands are projected to expand, another factor likely to increase fire risk.

As temperatures rise, some iconic landscapes of the Southwest will be greatly altered as species shift their ranges northward and upward to cooler climates, and fires attack unaccustomed ecosystems which lack natural defenses. The Sonoran Desert, for example, famous for the saguaro cactus, would look very different if more woody species spread northward from Mexico into areas currently dominated by succulents (such as cacti) or native grasses.[464] The desert is already being invaded by red brome and buffle grasses that do well in high temperatures and are native to Africa and the



The map above of percentage changes in county population between 1970 and 2008 shows that the Southwest has experienced very rapid growth in recent decades (indicated in orange, red, and maroon).

Mediterranean. Not only do these noxious weeds out-compete some native species in the Sonoran Desert, they also fuel hot, cactus-killing fires. With these invasive plant species and climate change, the Saguaro and Joshua Tree national parks could end up with far fewer of their namesake plants.[465] In California, two-thirds of the more than 5,500 native plant species are projected to experience range reductions up to 80 percent before the end of this century under projected warming.[466] In their search for optimal conditions, some species will move uphill, others northward, breaking up present-day ecosystems; those species moving southward to higher elevations might cut off future migration options as temperatures continue to increase.

The potential for successful plant and animal adaptation to coming change is further hampered by existing regional threats such as human-caused fragmentation of the landscape, invasive species, river-flow reductions, and pollution. Given the mountainous nature of the Southwest, and the associated impediments to species shifting their ranges, climate change likely places other species at risk. Some areas have already been identified as possible refuges where species at risk could continue to live if these areas were preserved for this purpose.[466] Other rapidly changing landscapes will require major adjustments, not only from plant and animal species, but also by the region's ranchers, foresters, and other inhabitants.

Increased frequency and altered timing of flooding will increase risks to people, ecosystems, and infrastructure.

Paradoxically, a warmer atmosphere and an intensified water cycle are likely to mean not only a greater likelihood of drought for the Southwest, but also an increased risk of flooding. Winter precipitation in Arizona, for example, is already

A Biodiversity Hotspot

The Southwest is home to two of the world's 34 designated "biodiversity hotspots." These at-risk regions have two special qualities: they hold unusually large numbers of plant and animal species that are endemic (found nowhere else), and they have already lost over 70 percent of their native vegetation.[467,468] About half the world's species of plants and land animals occur only in these 34 locations, though they cover just 2.3 percent of the Earth's land surface.

One of these biodiversity hotspots is the Madrean Pine-Oak Woodlands. Once covering 178 square miles, only isolated patches remain in the United States, mainly on mountaintops in southern Arizona, New Mexico, and West Texas. The greatest diversity of pine species in the world grows in this area: 44 of the 110 varieties,[469] as well as more than 150 species of oak.[470] Some 5,300 to 6,700 flowering plant species inhabit the ecosystem, and over 500 bird species, 23 of which are endemic. More hummingbirds are found here than anywhere else in the United States. There are 384 species of reptiles, 37 of which are endemic, and 328 species of mammals, six of which are endemic. There are 84 fish species, 18 of which are endemic. Some 200 species of butterfly thrive here, of which 45 are endemic, including the Monarch that migrates 2,500 miles north to Canada each year.[471] Ecotourism has become the economic driver in many parts of this region, but logging, land clearing for agriculture, urban development, and now climate change threaten the region's viability.

becoming more variable, with a trend toward both more frequent extremely dry and extremely wet winters.[472] Some water systems rely on smaller reservoirs being filled up each year. More frequent dry winters suggest an increased risk of these systems running short of water. However, a greater potential for flooding also means reservoirs cannot be filled to capacity as safely in years where that is possible. Flooding also causes reservoirs to fill with sediment at a faster rate, thus reducing their water-storage capacities.

On the global and national scales, precipitation patterns are already observed to be shifting, with more rain falling in heavy downpours that can lead to flooding.[90,473] Rapid landscape transformation due to vegetation die-off and wildfire as well as loss of wetlands along rivers is also likely to reduce flood-buffering capacity. Moreover, increased flood risk in the Southwest is likely to result from a combination of decreased snow cover on the lower slopes of high mountains, and an increased fraction of winter precipitation falling as rain and therefore running off more rapidly.[154] The increase in rain on snow events will also result in rapid runoff and flooding.[474]

The most obvious impact of more frequent flooding is a greater risk to human beings and their infrastructure. This applies to locations along major rivers, but also to much broader and highly vulnerable areas such as the Sacramento–San Joaquin River Delta system. Stretching from the San Francisco Bay nearly to the state capital of Sacramento, the Sacramento–San Joaquin River Delta and Suisun Marsh make up the largest estuary on the West Coast of North America. With its rich soils and rapid subsidence rates – in some locations as high as 2 or more feet per decade – the entire Delta region is now below sea level, protected by more than a thousand miles of levees and dams.[475] Projected changes in the timing and amount of river flow, particularly in winter and spring, is estimated to more than double the risk of Delta flooding events by mid-century, and result in an eight-fold increase before the end of the century.[476] Taking into account the additional risk of a major seismic event and increases in sea level due to climate change over this century, the California Bay–Delta Authority has concluded that the Delta and Suisun Marsh are not sustainable under current practices; efforts are underway to identify and implement adaptation strategies aimed at reducing these risks.[476]

Unique tourism and recreation opportunities are likely to suffer.

Tourism and recreation are important aspects of the region's economy. Increasing temperatures will affect important winter activities such as downhill and cross-country skiing, snowshoeing, and snowmobiling, which require snow on the ground. Projections indicate later snow and less snow coverage in ski resort areas, particularly those at lower elevations and in the southern part of the region.[284] Decreases from 40 to almost 90 percent are likely in end-of-season snowpack under a higher emissions scenario[91] in counties with major ski resorts from New Mexico to California.[477] In addition to shorter seasons, earlier wet snow avalanches – more than six weeks earlier by the end of this century under a higher emissions scenario[91] – could force ski areas to shut down affected runs before the season would otherwise end.[478] Resorts require a certain number of days just to break even; cutting the season short by even a few weeks, particularly if those occur during the lucrative holiday season, could easily render a resort unprofitable.

Even in non-winter months, ecosystem degradation will affect the quality of the experience for hikers, bikers, birders, and others who enjoy the Southwest's natural beauty. Water sports that depend on the flows of rivers and sufficient water in lakes and reservoirs are already being affected, and much larger changes are expected.

Cities and agriculture face increasing risks from a changing climate.

Resource use in the Southwest is involved in a constant three-way tug-of-war among preserving natural ecosystems, supplying the needs of rapidly expanding urban areas, and protecting the lucrative agricultural sector, which, particularly in California, is largely based on highly temperature- and water-sensitive specialty crops. Urban areas are also sensitive to temperature-related impacts on air

quality, electricity demand, and the health of their inhabitants.

The magnitude of projected temperature increases for the Southwest, particularly when combined with urban heat island effects for major cities such as Phoenix, Albuquerque, Las Vegas, and many California cities, represent significant stresses to health, electricity, and water supply in a region that already experiences very high summer temperatures.[284,325,450]

If present-day levels of ozone-producing emissions are maintained, rising temperatures also imply declining air quality in urban areas such as those in California which already experience some of the worst air quality in the nation (see *Society* sector).[479] Continued rapid population growth is expected to exacerbate these concerns.

With more intense, longer-lasting heat wave events projected to occur over this century, demands for air conditioning are expected to deplete electricity supplies, increasing risks of brownouts and blackouts.[325] Electricity supplies will also be affected by changes in the timing of river flows and where hydroelectric systems have limited storage capacity and reservoirs (see *Energy* sector).[480,481]

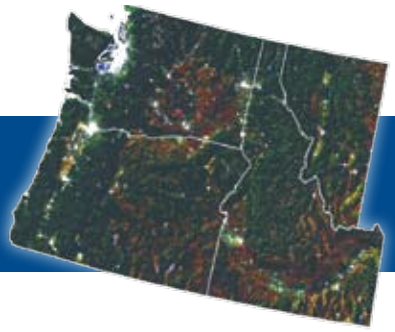
Much of the region's agriculture will experience detrimental impacts in a warmer future, particularly specialty crops in California such as apricots, almonds, artichokes, figs, kiwis, olives, and walnuts.[482,483] These and other specialty crops require a minimum number of hours at a chilling temperature threshold in the winter to become dormant and set fruit for the following year.[482] Accumulated winter chilling hours have already decreased across central California and its coastal valleys. This trend is projected to continue to the point where chilling thresholds for many key crops would no longer be met. A steady reduction in winter chilling could have serious economic impacts on fruit and nut production in the region. California's losses due to future climate change are estimated between zero and 40 percent for wine and table grapes, almonds, oranges, walnuts, and avocadoes, varying significantly by location.[483]

Adaptation strategies for agriculture in California include more efficient irrigation and shifts in cropping patterns, which have the potential to help compensate for climate-driven increases in water demand for agriculture due to rising temperatures.[484] The ability to use groundwater and/or water designated for agriculture as backup supplies for urban uses in times of severe drought is expected to become more important in the future as climate change dries out the Southwest; however, these supplies are at risk of being depleted as urban populations swell (see *Water* sector).

Adaptation: Strategies for Fire

Living with present-day levels of fire risk, along with projected increases in risk, involves actions by residents along the urban-forest interface as well as fire and land management officials. Some basic strategies for reducing damage to structures due to fires are being encouraged by groups like National Firewise Communities, an interagency program that encourages wildfire preparedness measures such as creating defensible space around residential structures by thinning trees and brush, choosing fire-resistant plants, selecting ignition-resistant building materials and design features, positioning structures away from slopes, and working with firefighters to develop emergency plans.

Additional strategies for responding to the increased risk of fire as climate continues to change could include adding firefighting resources[461] and improving evacuation procedures and communications infrastructure. Also important would be regularly updated insights into what the latest climate science implies for changes in types, locations, timing, and potential severity of fire risks over seasons to decades and beyond; implications for related political, legal, economic, and social institutions; and improving predictions for regeneration of burnt-over areas and the implications for subsequent fire risks. Reconsideration of policies that encourage growth of residential developments in or near forests is another potential avenue for adaptive strategies.[462]



Northwest

The Northwest's rapidly growing population, as well as its forests, mountains, rivers, and coastlines, are already experiencing human-induced climate change and its impacts.[34] Regionally averaged temperature rose about 1.5°F over the past century[485] (with some areas experiencing increases up to 4°F) and is projected to increase another 3 to 10°F during this century.[486] Higher emissions scenarios would result in warming in the upper end of the projected range. Increases in winter precipitation and decreases in summer precipitation are projected by many climate models,[487] though these projections are less certain than those for temperature. Impacts related to changes in snowpack, streamflows, sea level, forests, and other important aspects of life in the Northwest are already underway, with more severe impacts expected over coming decades in response to continued and more rapid warming.

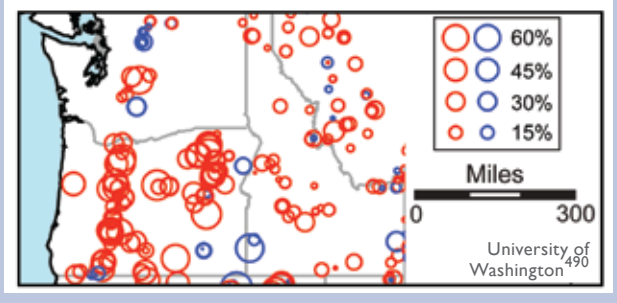
Declining springtime snowpack leads to reduced summer streamflows, straining water supplies.

The Northwest is highly dependent on temperature-sensitive springtime snowpack to meet growing, and often competing, water demands such as municipal and industrial uses, agricultural irrigation, hydropower production, navigation, recreation, and in-stream flows that protect aquatic ecosystems including threatened and endangered species. Higher cool season (October through March) temperatures cause more precipitation to fall as rain rather than snow and contribute to earlier snowmelt. April 1 snowpack, a key indicator of natural water storage available for the warm season, has already declined substantially throughout the region. The average decline in the Cascade Mountains, for example, was about 25 percent over the past 40 to 70 years, with most of this due to the 2.5°F increase in cool season temperatures over that period.[108,488] Further declines in Northwest snowpack are projected to result from additional warming over this century, varying with latitude, elevation, and proximity to the coast. April 1 snowpack is projected to decline as much as 40 percent in the Cascades by the 2040s.[489] Throughout the region, earlier snowmelt will cause a reduction in the amount of water available during the warm season.[68]

In areas where it snows, a warmer climate means major changes in the timing of runoff: streamflow increases in winter and early spring, and then decreases in late spring, summer, and fall. This shift in streamflow timing has already been observed over the past 50 years,[252] with the peak of spring runoff shifting from a few days earlier in some places to as much as 25 to 30 days earlier in others.[157]

This trend is projected to continue, with runoff shifting 20 to 40 days earlier within this century.[157] Reductions in summer water availability will vary with the temperatures experienced in different parts of the region. In relatively warm areas on the western slopes of the Cascade Mountains, for example, reductions in warm season (April through September) runoff of 30 percent or more are projected by mid-century, whereas colder areas in the Rocky Mountains are expected to see reductions of about 10 percent. Areas dominated by rain rather than snow are not expected to see major shifts in the timing of runoff.[492]

Trends in April 1 Snow Water Equivalent
1950 to 2002



April 1 snowpack (a key indicator of natural water storage available for the warm season) has declined throughout the Northwest. In the Cascade Mountains, April 1 snowpack declined by an average of 25 percent, with some areas experiencing up to 60 percent declines. On the map, decreasing trends are in red and increasing trends are in blue.[491]

Extreme high and low streamflows also are expected to change with warming. Increasing winter rainfall (as opposed to snowfall) is expected to lead to more winter flooding in relatively warm watersheds on the west side of the Cascades. The already low flows of late summer are projected to decrease further due to both earlier snowmelt and increased evaporation and water loss from vegetation. Projected decreases in summer precipitation would exacerbate these effects. Some sensitive watersheds are projected to experience both increased flood risk in winter and increased drought risk in summer due to warming.

The region's water supply infrastructure was built based on the assumption that most of the water needed for summer uses would be stored naturally in snowpack. For example, the storage capacity in Columbia Basin reservoirs is only 30 percent of the annual runoff, and many small urban water supply systems on the west side of the Cascades store less than 10 percent of their annual flow.[493] Besides providing water supply and managing flows for hydropower, the region's reservoirs are operated for flood-protection purposes and, as such, might have to release (rather than store) large amounts of runoff during the winter and early spring to maintain enough space for flood protection. Earlier flows would thus place more of the year's runoff into the category of hazard rather than resource. An advance in the timing of snowmelt runoff would also increase the length of the summer dry period, with important consequences for water supply, ecosystems, and wildfire management.[157]

One of the largest demands on water resources in the region is hydroelectric power production. About 70 percent of the Northwest's electricity is provided by hydropower, a far greater percentage than in any other region. Warmer summers will increase electricity demands for air conditioning and refrigeration at the same time of year that lower streamflows will lead to reduced hydropower generation. At the same time, water is needed for irrigated agriculture, protecting fish species, reservoir and river recreation, and urban uses. Conflicts between all of these water uses are expected to increase, forcing complex trade-offs between competing objectives (see *Energy* and *Water* sectors).[487,494]

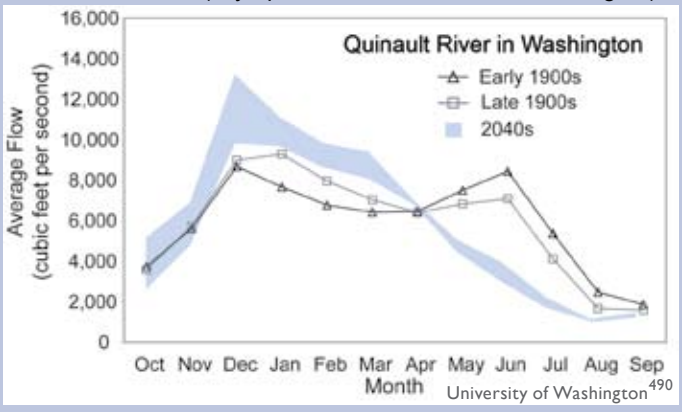
Increased insect outbreaks, wildfires, and changing species composition in forests will pose challenges for ecosystems and the forest products industry.

Higher summer temperatures and earlier spring snowmelt are expected to increase the risk of forest fires in the Northwest by increasing summer moisture deficits; this pattern has already been observed in recent decades. Drought stress and higher temperatures will decrease tree growth in most low- and mid-elevation forests. They will also increase the frequency and intensity of mountain pine beetle and other insect attacks,[243] further increasing fire risk and reducing timber production, an important part of the regional economy. The mountain pine beetle outbreak in British Columbia has destroyed 33 million acres of trees so far, about 40 percent of the marketable pine trees in the province. By 2018, it is projected that the infestation will have run its course and over 78 percent of the mature pines will have been killed; this will affect more than one-third of the total area of British Columbia's forests[495] (see *Ecosystems* sector). Forest and fire management practices are also factors in these insect outbreaks.[252] Idaho's Sawtooth Mountains are also now threatened by pine beetle infestation.

In the short term, high elevation forests on the west side of the Cascade Mountains are expected to

Shift to Earlier Peak Streamflow

Quinault River (Olympic Peninsula, northern Washington)



As precipitation continues to shift from snow to rain, by the 2040s, peak flow on the Quinault River is projected to occur in December, and flows in June are projected to be reduced to about half of what they were over the past century. On the graph, the blue swath represents the range of projected streamflows based on an increase in temperature of 3.6 to 5.4°F. The other lines represent streamflows in the early and late 1900s.[487,494]

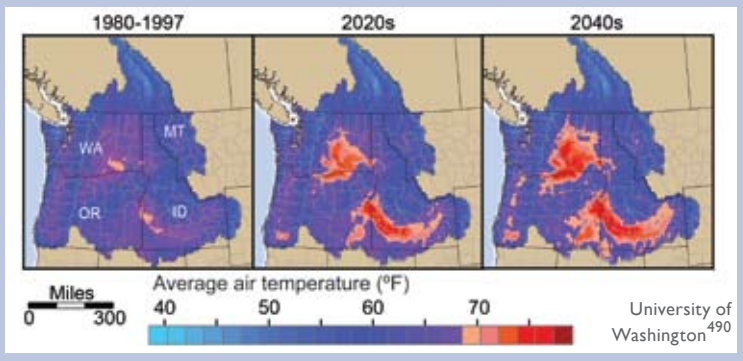
see increased growth. In the longer term, forest growth is expected to decrease as summertime soil moisture deficits limit forest productivity, with low-elevation forests experiencing these changes first. The extent and species composition of forests are also expected to change as tree species respond to climate change. There is also the potential for extinction of local populations and loss of biological diversity if environmental changes outpace species' ability to shift their ranges and form successful new ecosystems.

Agriculture, especially production of tree fruit such as apples, is also an important part of the regional economy. Decreasing irrigation supplies, increasing pests and disease, and increased competition from weeds are likely to have negative effects on agricultural production.

Salmon and other coldwater species will experience additional stresses as a result of rising water temperatures and declining summer streamflows.

Northwest salmon populations are at historically low levels due to stresses imposed by a variety of human activities including dam building, logging, pollution, and over-fishing. Climate change affects salmon throughout their life stages and poses an additional stress. As more winter precipitation falls as rain rather than snow, higher winter streamflows scour streambeds, damaging spawning nests and washing away incubating eggs. Earlier peak streamflows flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses including the risk of being eaten by predators. Lower summer streamflows and warmer water temperatures create less favorable summer stream conditions for salmon and other coldwater fish species in many parts of the Northwest. In addition, diseases and parasites that infect salmon tend to flourish in warmer water. Climate change also impacts the ocean environment, where salmon spend several years of their lives. Historically, warm periods in the coastal ocean have coincided with relatively low abundances of salmon, while cooler ocean periods have coincided with relatively high salmon numbers.[70, 563]

Decreasing Habitat for Coldwater Fish



Increasing air temperatures lead to rising water temperatures, which increase stress on coldwater fish such as trout, salmon, and steelhead. August average air temperature above 70°F is a threshold above which these fish are severely stressed. Projected temperatures for the 2020s and 2040s under a higher emissions scenario suggest that the habitat for these fish is likely to decrease dramatically.[486,497,568,569]

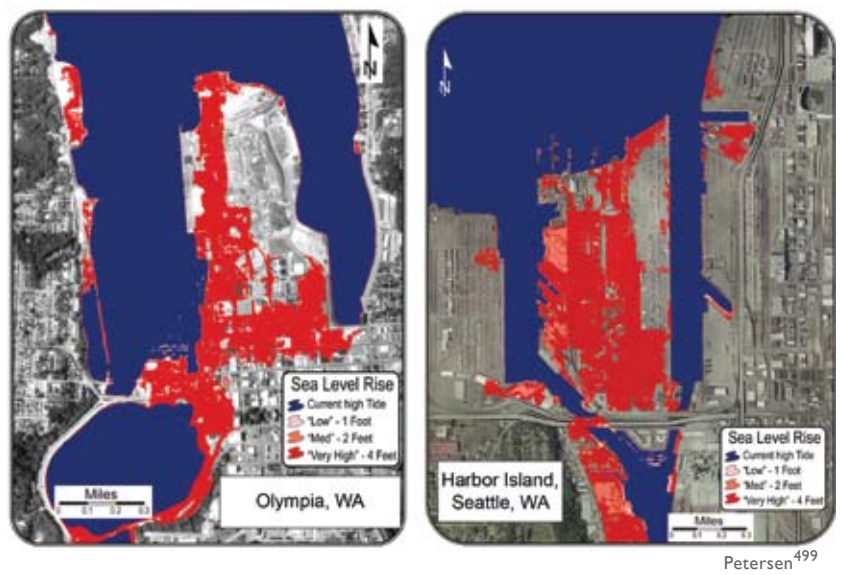
Most wild Pacific salmon populations are extinct or imperiled in 56 percent of their historical range in the Northwest and California,[496] and populations are down more than 90 percent in the Columbia River system. Many species are listed as either threatened or endangered under the Federal Endangered Species Act. Studies suggest that about one-third of the current habitat for the Northwest's salmon and other coldwater fish will no longer be suitable for them by the end of this century as key temperature thresholds are exceeded. Because climate change impacts on their habitat are projected to be negative, climate change is expected to hamper efforts to restore depleted salmon populations.

Sea-level rise along vulnerable coastlines will result in increased erosion and the loss of land.

Climate change is projected to exacerbate many of the stresses and hazards currently facing the coastal zone. Sea-level rise will increase erosion of the Northwest coast and cause the loss of beaches and significant coastal land areas. Among the most vulnerable parts of the coast is the heavily populated south Puget Sound region, which includes the cities of Olympia, Tacoma, and Seattle, Washington. Some climate models project changes in atmospheric pressure patterns that suggest a more southwesterly direction of future winter winds. Combined with higher sea levels, this would accelerate coastal erosion all along the Pacific Coast. Sea-level rise in the Northwest (as elsewhere) is

determined by global rates of sea-level rise, changes in coastal elevation associated with local vertical movement of the land, and atmospheric circulation patterns that influence wind-driven "pile-up" of water along the coast. A mid-range estimate of relative sea-level rise for the Puget Sound basin is about 13 inches by 2100. However, higher levels of up to 50 inches by 2100 in more rapidly subsiding (sinking) portions of the basin are also possible given the large uncertainties about accelerating rates of ice melt from Greenland and Antarctica in recent years (see *Global* and *National Climate Change* sections).[498]

Northwest Cities at Risk to Sea-Level Rise



Highly populated coastal areas throughout Puget Sound, Washington, are vulnerable to sea-level rise. The maps show regions of Olympia and Harbor Island (both located in Puget Sound) that are likely to be lost to sea-level rise by the end of this century based on moderate and high estimates.

An additional concern is landslides on coastal bluffs. The projected heavier winter rainfall suggests an increase in saturated soils and, therefore, an increased number of landslides. Increased frequency and/or severity of landslides is expected to be especially problematic in areas where there has been intensive development on unstable slopes. Within Puget Sound, the cycle of beach erosion and bluff landslides will be exacerbated by sea-level rise, increasing beach erosion, and decreasing slope stability.

Adaptation: Improved Planning to Cope with Future Changes

States, counties, and cities in the Northwest are beginning to develop strategies to adapt to climate change. In 2007, Washington state convened stakeholders to develop adaptation strategies for water, agriculture, forests, coasts, infrastructure, and human health. Recommendations included improved drought planning, improved monitoring of diseases and pests, incorporating sea-level rise in coastal planning, and public education. An implementation strategy is under development.

In response to concerns about increasing flood risk, King County, Washington, approved plans in 2007 to fund repairs to the county's aging levee system. The county also will replace more than 57 "short-span" bridges with wider span structures that allow more debris and floodwater to pass underneath rather than backing up and causing the river to flood. The county has begun incorporating porous concrete and rain gardens into road projects to manage the effects of stormwater runoff during heavy rains, which are increasing as climate changes. King County has also published an adaptation guidebook that is becoming a model that other local governments can refer to in order to organize adaptation actions within their municipal planning processes.[500]

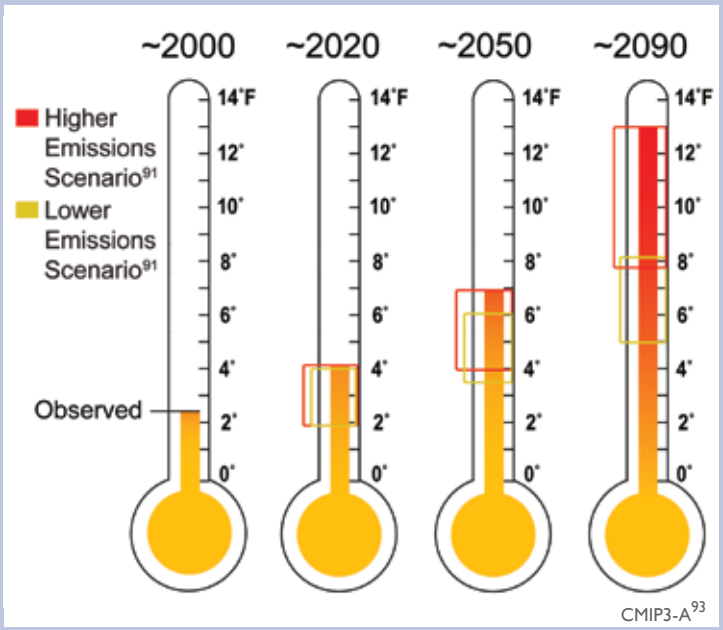
Concern about sea-level rise in Olympia, Washington, contributed to the city's decision to relocate its primary drinking water source from a low-lying surface water source to wells on higher ground. The city adjusted its plans for construction of a new City Hall to locate the building in an area less vulnerable to sea-level rise than the original proposed location. The building's foundation also was raised by 1 foot.

Alaska

Over the past 50 years, Alaska has warmed at more than twice the rate of the rest of the United States' average. Its annual average temperature has increased 3.4°F, while winters have warmed even more, by 6.3°F.[501] As a result, climate change impacts are much more pronounced than in other regions of the United States. The higher temperatures are already contributing to earlier spring snowmelt, reduced sea ice, widespread glacier retreat, and permafrost warming.[220,501] These observed changes are consistent with climate model projections of greater warming over Alaska, especially in winter, as compared to the rest of the country.

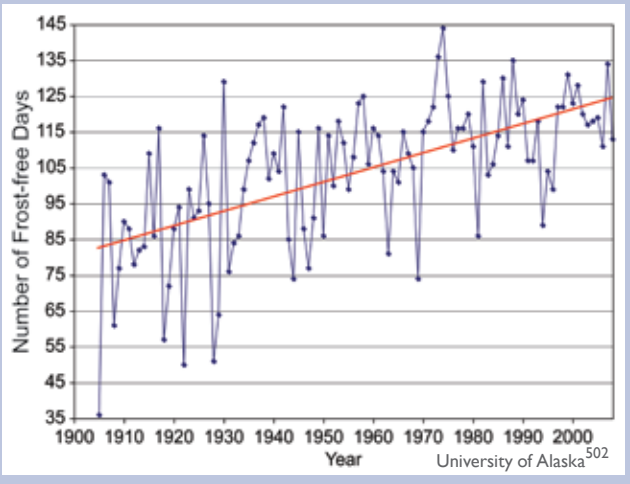
Climate models also project increases in precipitation over Alaska. Simultaneous increases in evaporation due to higher air temperatures, however, are expected to lead to drier conditions overall, with reduced soil moisture.[90] In the future, therefore, model projections suggest a longer summer growing season combined with an increased likelihood of summer drought and wildfires.

Observed and Projected Temperature Rise



Alaska's annual average temperature has increased 3.4°F over the past 50 years. The observed increase shown above compares the average temperature of 1993-2007 with a 1960s-1970s baseline, an increase of over 2°F. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. By the end of this century, the average temperature is projected to rise by 5 to 13°F above the 1960s-1970s baseline.

Fairbanks Frost-Free Season, 1904 to 2008



Over the past 100 years, the length of the frost-free season in Fairbanks, Alaska, has increased by 50 percent. The trend toward a longer frost-free season is projected to produce benefits in some sectors and detriments in others.

Average annual temperatures in Alaska are projected to rise about 3.5 to 7°F by the middle of this century. How much temperatures rise later in the century depends strongly on global emissions choices, with increases of 5 to 8°F projected with lower emissions, and increases of 8 to 13°F with higher emissions.[91] Higher temperatures are expected to continue to reduce Arctic sea ice coverage. Reduced sea ice provides opportunities for increased shipping and resource extraction. At the same time, it increases coastal erosion[522] and flooding associated with coastal storms. Reduced sea ice also alters the timing and location of plankton blooms, which is expected to drive major shifts of marine species such as pollock and other commercial fish stocks.[527]

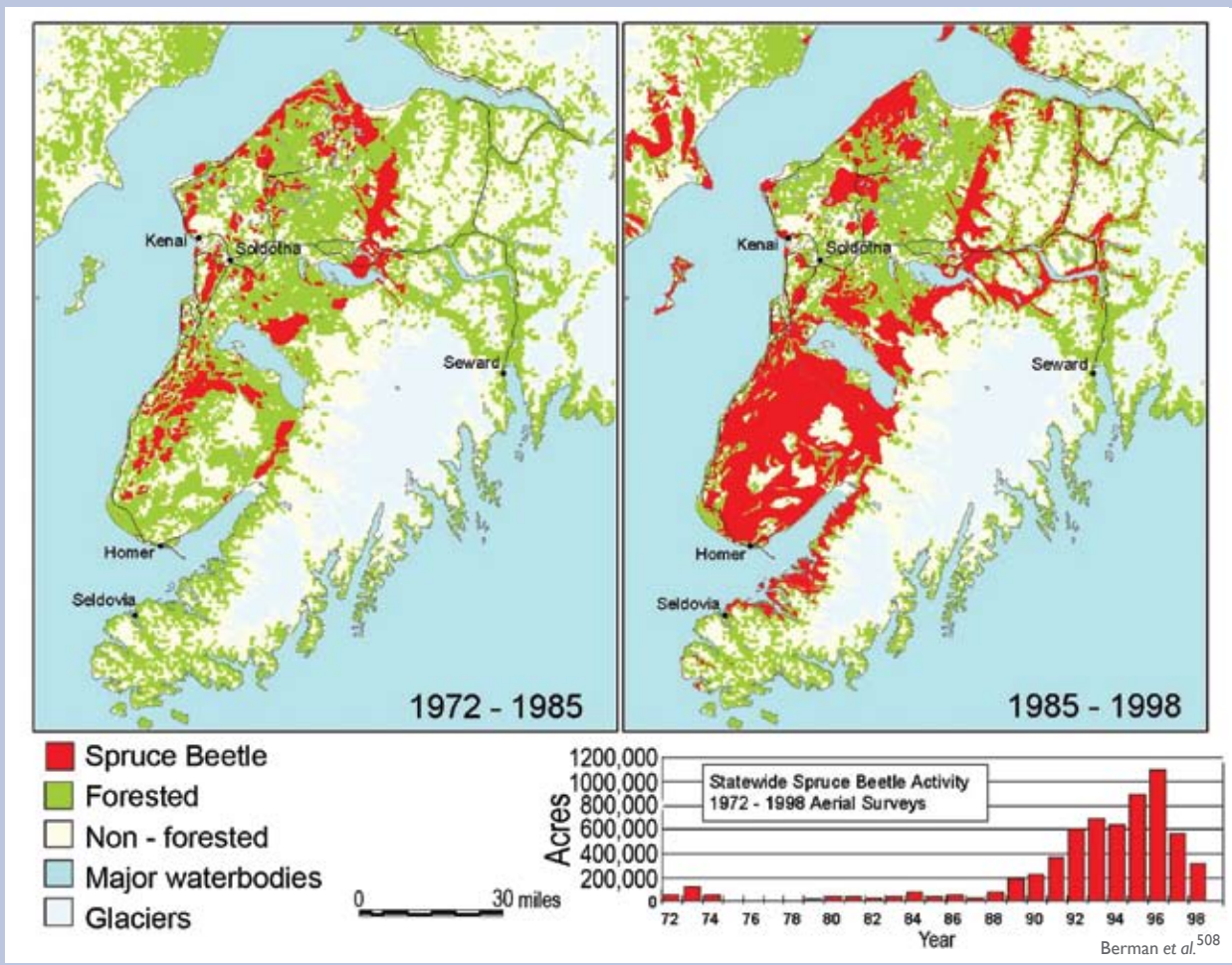
Longer summers and higher temperatures are causing drier conditions, even in the absence of strong trends in precipitation.

Between 1970 and 2000, the snow-free season increased by approximately 10 days across Alaska, primarily due to earlier snowmelt in the spring.[503,504] A longer growing season has potential economic benefits, providing a longer period of outdoor and commercial activity such as tourism. However, there are also downsides. For example, white spruce forests in Alaska's interior are experiencing declining growth due to drought stress[505] and continued warming could lead to widespread death of trees.[506] The decreased soil moisture in Alaska also suggests that agriculture in Alaska might not benefit from the longer growing season.

Insect outbreaks and wildfires are increasing with warming.

Climate plays a key role in determining the extent and severity of insect outbreaks and wildfires.[506,507] During the 1990s, for example, south-central Alaska experienced the largest outbreak of spruce beetles in the world.[243,506] This outbreak occurred because rising temperatures allowed the spruce beetle to survive over the winter and to complete its life cycle in just one year instead of the normal two years. Healthy trees ordinarily defend themselves by pushing back against burrowing beetles with their pitch. From 1989 to 1997, however, the region experienced an extended drought, leaving the trees too stressed to fight off the infestation.

Alaska Spruce Beetle Infestation
Kenai Peninsula, 1972 to 1998



Berman *et al.*[508]

Warming in Alaska has caused insect outbreaks to increase. Red areas indicate spruce beetle infestations on the Kenai Peninsula. Over 5 million acres of Alaska spruce forests were destroyed.

Prior to 1990, the spruce budworm was not able to reproduce in interior Alaska.[506] Hotter, drier summers, however, now mean that the forests there are threatened by an outbreak of spruce budworms.[509] This trend is expected to increase in the future if summers in Alaska become hotter and drier.[506] Large areas of dead trees, such as those left behind by pest infestations, are highly flammable and thus much more vulnerable to wildfire than living trees.

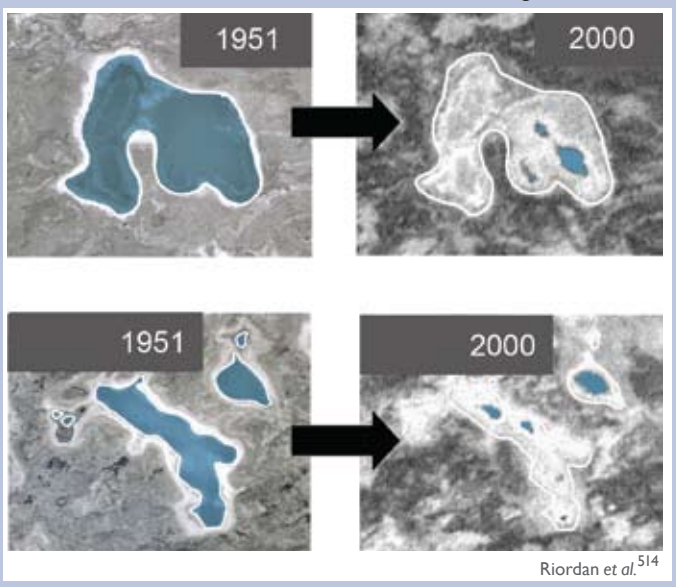
The area burned in North America's northern forest that spans Alaska and Canada tripled from the 1960s to the 1990s. Two of the three most extensive wildfire seasons in Alaska's 56-year record occurred in 2004 and 2005, and half of the most severe fire years on record have occurred since 1990.[510] Under changing climate conditions, the average area burned per year in Alaska is projected to double by the middle of this century.[507] By the end of this century, area burned by fire is projected to triple under a moderate greenhouse gas emissions scenario and to quadruple under a higher emissions scenario.[91] Such increases in area burned would result in numerous impacts, including hazardous air quality conditions such as those suffered by residents of Fairbanks during the summers of 2004 and 2005, as well as increased risks to rural Native Alaskan communities because of reduced availability of the fish and game that make up their diet. This would cause them to adopt a more "Western" diet,[511] known to be associated with increased risk of cancers, diabetes, and cardiovascular disease.[512]

Lakes are declining in area.

Across the southern two-thirds of Alaska, the area of closed-basin lakes (lakes without stream inputs and outputs) has decreased over the past 50 years. This is likely due to the greater evaporation and thawing of permafrost that result from warming.[513,514] A continued decline in the area of surface water would present challenges for the management of natural resources and ecosystems on National Wildlife Refuges in Alaska. These refuges, which cover over 77 million acres (21 percent of Alaska) and comprise 81 percent of the U.S. National Wildlife Refuge System, provide breeding habitat for millions of waterfowl and shorebirds that winter in the lower 48 states. Wetlands are also important to Native peoples who hunt and fish for their food in interior Alaska. Many villages are located adjacent to wetlands that support an abundance of wildlife resources. The sustainability of these traditional lifestyles is thus threatened by a loss of wetlands.

Ponds in Alaska are Shrinking (1951 to 2000)

Yukon Flats National Wildlife Refuge



Riordan *et al.*[514]

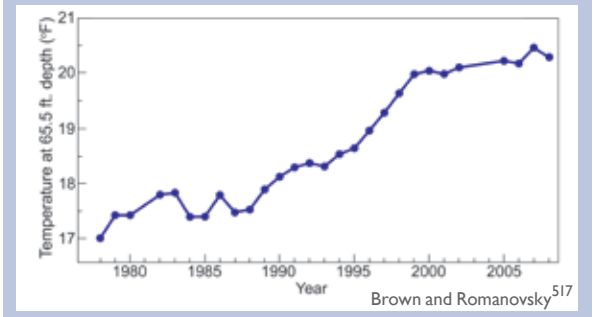
Ponds across Alaska, including those shown above in the northeastern interior of the state, have shrunk as a result of increased evaporation and permafrost thawing. The pond in the top pair of images shrunk from 180 to 10 acres; the larger pond in the bottom pair of images shrunk from 90 to 4 acres.

Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure.

Permafrost temperatures have increased throughout Alaska since the late 1970s.[149] The largest increases have been measured in the northern part of the state.[515] While permafrost in interior Alaska so far has experienced less warming than permafrost in northern Alaska, it is more vulnerable to thawing during this century because it is generally just below the freezing point, while permafrost in northern Alaska is colder.

Land subsidence (sinking) associated with the thawing of permafrost presents substantial challenges to engineers attempting to preserve infrastructure in Alaska.[516] Public infrastructure at risk for damage includes roads, runways, and water and sewer systems. It is estimated that thawing

Permafrost Temperature, 1978 to 2008
Deadhorse, northern Alaska



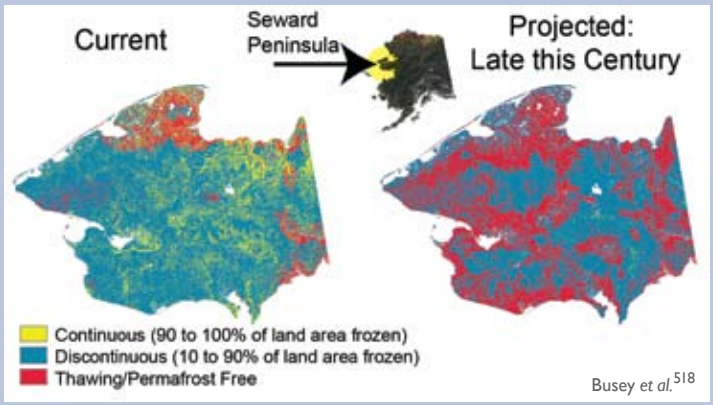
Permafrost temperatures have risen throughout Alaska, with the largest increases in the northern part of the state.

permafrost would add between $3.6 billion and $6.1 billion (10 to 20 percent) to future costs for publicly owned infrastructure by 2030 and between $5.6 billion and $7.6 billion (10 to 12 percent) by 2080.[230] Analyses of the additional costs of permafrost thawing to private property have not yet been conducted.

Thawing ground also has implications for oil and gas drilling. As one example, the number of days per year in which travel on the tundra is allowed under Alaska Department of Natural Resources standards has dropped from more than 200 to about 100 days in the past 30 years. This results in a 50 percent reduction in days that oil and gas exploration and extraction equipment can be used.[220,245]

Thawing permafrost can push natural ecosystems across thresholds. Some forests in Alaska are literally toppling over as the permafrost beneath them thaws, undermining the root systems of trees (see photo next page).

Changing Permafrost Distribution
Moderate Warming Scenario



The maps show projected thawing on the Seward Peninsula by the end of this century under a moderate warming scenario approximately halfway between the lower and higher emissions scenarios[91] described on page 23.

Coastal storms increase risks to villages and fishing fleets.

Alaska has more coastline than the other 49 states combined. Frequent storms in the Gulf of Alaska and the Bering, Chukchi, and Beaufort Seas already affect the coasts during much of the year. Alaska's coastlines, many of which are low in elevation, are increasingly threatened by a combination of the loss of their protective sea ice buffer, increasing storm activity, and thawing coastal permafrost.

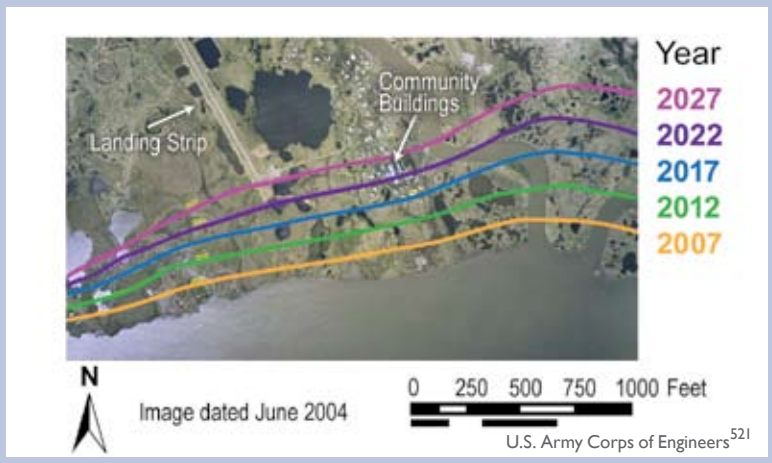
Increasing storm activity in autumn in recent years[520] has delayed or prevented barge operations

Adaptation: Keeping Soil Around the Pipeline Cool

When permafrost thaws, it can cause the soil to sink or settle, damaging structures built upon or within that soil. A warming climate and burial of supports for the Trans-Alaska Pipeline System both contribute to thawing of the permafrost around the pipeline. In locations on the pipeline route where soils were ice-rich, a unique above-ground system was developed to keep the ground cool. Thermal siphons were designed to disperse heat to the air that would otherwise be transferred to the soil, and these siphons were placed on the pilings that support the pipeline. While this unique technology added significant expense to the pipeline construction, it helps to greatly increase the useful lifetime of this structure.[519]

Leaning trees in this Alaska forest tilt because the ground beneath them, which used to be permanently frozen, has thawed. Forests like this are named "drunken forests."

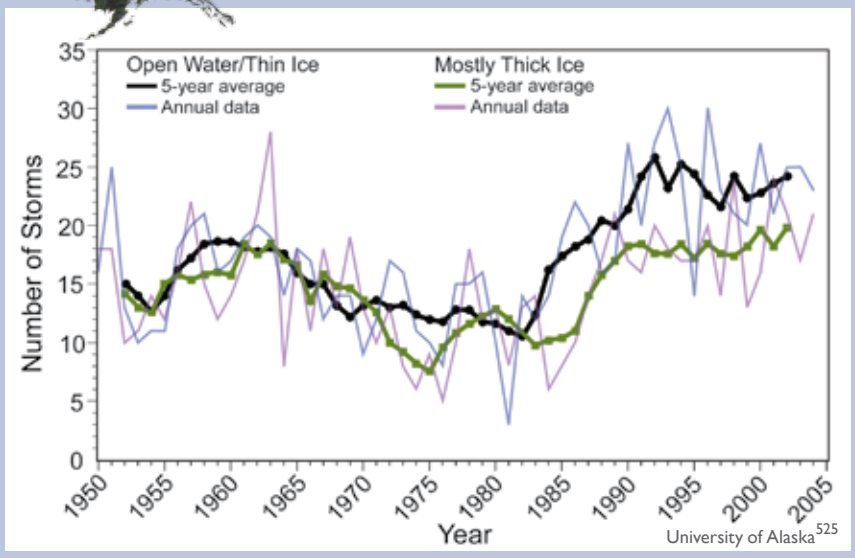
Projected Coastal Erosion, 2007 to 2027
Newtok, western Alaska



Many of Alaska's coastlines are eroding rapidly; the disappearance of coastal land is forcing communities to relocate. The 2007 line on the image indicates where Newtok, Alaska's shoreline had eroded to by 2007. The other lines are projected assuming a conservative erosion rate of 36 to 83 feet per year; however, Newtok residents reported a July 2003 erosion rate of 110 feet per year.

that supply coastal communities with fuel. Commercial fishing fleets and other marine traffic are also strongly affected by Bering Sea storms. High-wind events have become more frequent along the western and northern coasts. The same regions are experiencing increasingly long sea-ice-free seasons and hence longer periods during which coastal areas are especially vulnerable to wind and wave damage. Downtown streets in Nome, Alaska, have flooded in recent years. Coastal erosion is causing the shorelines of some areas to retreat at average rates of tens of feet per year. The ground beneath several native communities is literally crumbling into the sea, forcing residents to confront difficult and expensive choices between relocation and engineering strategies that require continuing investments despite their uncertain effectiveness (see *Society* sector). The rate of erosion along Alaska's northeastern coastline has doubled over the past 50 years.[522]

Annual Number of Storms at Barrow, Alaska, 1950-2004
(northernmost town in the United States)



The number of coastal storms has generally increased as the amount of ice along the coast has decreased. This increase threatens commercial activity and communities in Alaska. The blue line indicates the annual number of open-water storms, those occurring in primarily ice-free water (July to December). The purple line indicates the number of storms occurring when thick sea ice is present (January to June). The black and green lines are smoothed using 5-year averages.

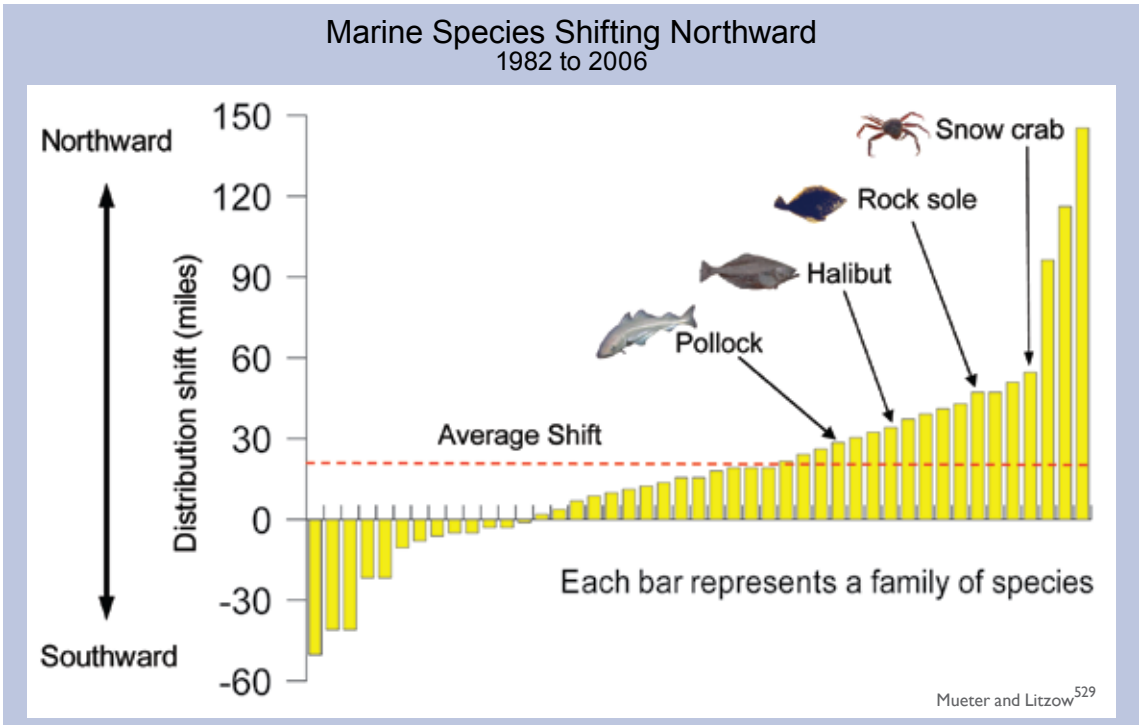
Over this century, an increase of sea surface temperatures and a reduction of ice cover are likely to lead to northward shifts in the Pacific storm track and increased impacts on coastal Alaska.[523,524] Climate models project the Bering Sea to experience the largest decreases in atmospheric pressure in the Northern Hemisphere, suggesting an increase in storm activity in the region.[90] In addition, the longer ice-free season is likely to make more heat and moisture available for storms in the Arctic Ocean, increasing their frequency and/or intensity.

Displacement of marine species will affect key fisheries.

Alaska leads the United States in the value of its commercial fishing catch. Most of the nation's salmon, crab, halibut, and herring come from Alaska. In addition, many Native communities depend on local harvests of fish, walruses, seals, whales, seabirds, and other marine species for their food supply. Climate change causes significant alterations in marine ecosystems with important implications for fisheries. Ocean acidification associated with a rising carbon dioxide concentration represents an additional threat to coldwater marine ecosystems[23,526] (see *Ecosystems* sector and *Coasts* region).

One of the most productive areas for Alaska fisheries is the northern Bering Sea off Alaska's west coast. The world's largest single fishery is the Bering Sea pollock fishery, which has undergone major declines in recent years. Over much of the past decade, as air and water temperatures rose, sea ice in this region declined sharply. Populations of fish, seabirds, seals, walruses, and other species depend on plankton blooms that are regulated by the extent and location of the ice edge in spring. As the sea ice retreats, the location, timing, and species composition of the plankton blooms changes, reducing the amount of food reaching the living things on the ocean floor. This radically changes the species composition and populations of fish and other marine life forms, with significant repercussions for fisheries[527] (see *Ecosystems* sector).

Over the course of this century, changes already observed on the shallow shelf of the northern Bering Sea are likely to affect a much broader portion of the Pacific-influenced sector of the Arctic Ocean. As such changes occur, the most productive commercial fisheries are likely to become more distant from existing fishing ports and processing infrastructure, requiring either relocation or greater investment in transportation time and fuel costs. These changes will also affect the ability of Native Peoples to successfully hunt and fish for the food they need to survive. Coastal communities are already noticing a displacement of walrus and seal populations. Bottom-feeding walrus populations are threatened when their sea ice platform retreats from the shallow coastal feeding grounds on which they depend.[528]



As air and water temperatures rise, marine species are moving northward, affecting fisheries, ecosystems, and coastal communities that depend on the food source. On average, by 2006, the center of the range for the examined species moved 19 miles north of their 1982 locations.

Islands

Climate change presents the Pacific and Caribbean islands with unique challenges. The U.S. affiliated Pacific Islands are home to approximately 1.7 million people in the Hawaiian Islands; Palau; the Samoan Islands of Tutuila, Manua, Rose, and Swains; and islands in the Micronesian archipelago, the Carolines, Marshalls, and Marianas.[530] These include volcanic, continental, and limestone islands, atolls, and islands of mixed geologies.[530] The degree to which climate change and variability will affect each of the roughly 30,000 islands in the Pacific depends upon a variety of factors, including the island's geology, area, height above sea level, extent of reef formation, and the size of its freshwater aquifer.[531]

In addition to Puerto Rico and the U.S. Virgin Islands, there are 40 island nations in the Caribbean that are home to approximately 38 million people.[532] Population growth, often concentrated in coastal areas, escalates the vulnerability of both Pacific and Caribbean island communities to the effects of climate change, as do weakened traditional support systems. Tourism and fisheries, both of which are climate-sensitive, play a large economic role in these communities.[530]

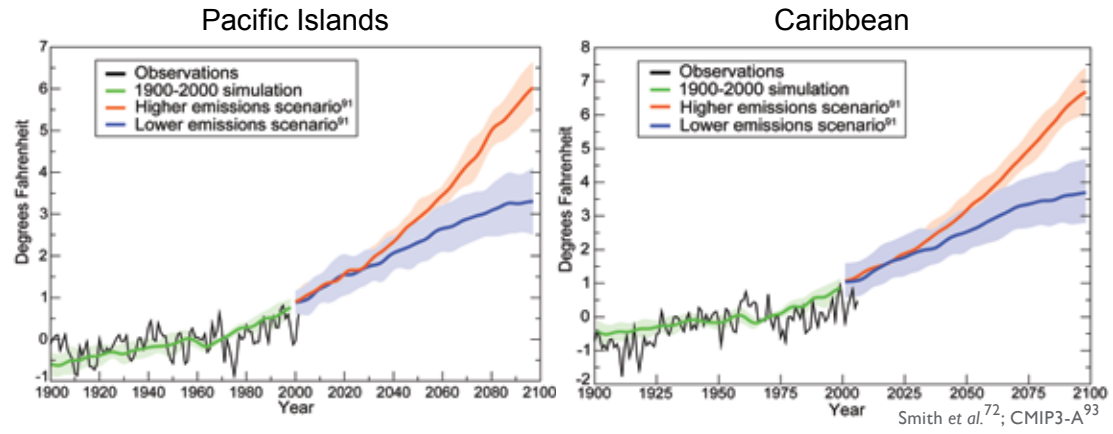
Small islands are considered among the most vulnerable to climate change because extreme events have major impacts on them. Changes in weather patterns and the frequency and intensity of extreme events, sea-level rise, coastal erosion, coral reef bleaching, ocean acidification, and contamination of freshwater resources by salt water are among the impacts small islands face.[533]

Islands have experienced rising temperatures and sea levels in recent decades. Projections for the rest of this century suggest:

- Increases in air and ocean surface temperatures in both the Pacific and Caribbean;[90]
- An overall decrease in rainfall in the Caribbean; and
- An increased frequency of heavy downpours and increased rainfall during summer months (rather than the normal rainy season in winter months) for the Pacific (although the range of projections regarding rainfall in the Pacific is still quite large).

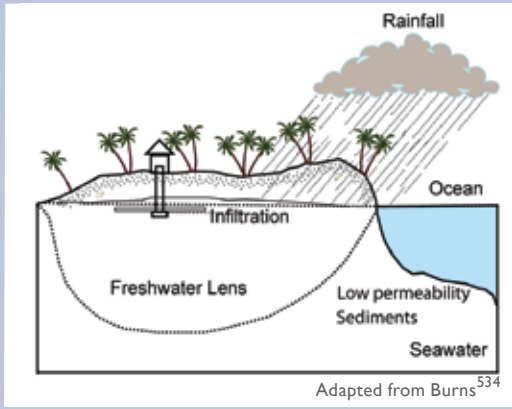
The number of heavy rain events is very likely to increase.[90] Hurricane (typhoon) wind speeds and rainfall rates are likely to increase with continued

Air Temperature Change, Observed and Projected, 1900 to 2100
relative to 1960-1979 average



Air temperatures have increased over the last 100 years in both the Pacific Island and Caribbean regions. Larger increases are projected in the future, with higher emissions scenarios[91] producing considerably greater increases. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models.

Freshwater Lens



Adapted from Burns[534]

Many island communities depend on freshwater lenses, which are recharged by precipitation. The amount of water a freshwater lens contains is determined by the size of the island, the amount of rainfall, rates of water withdrawal, the permeability of the rock beneath the island, and salt mixing due to storm- or tide-induced pressure. Freshwater lenses can be as shallow as 4 to 8 inches or as deep as 65 feet.[534]

warming.[68] Islands and other low-lying coastal areas will be at increased risk from coastal inundation due to sea-level rise and storm surge, with major implications for coastal communities, infrastructure, natural habitats, and resources.

The availability of freshwater is likely to be reduced, with significant implications for island communities, economies, and resources.

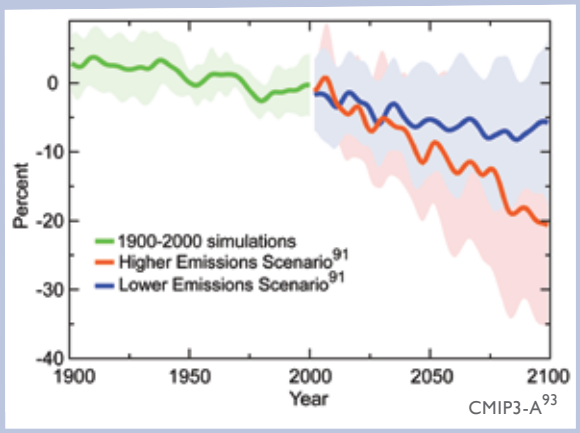
Most island communities in the Pacific and the Caribbean have limited sources of the freshwater needed to support unique ecosystems and biodiversity, public health, agriculture, and tourism. Conventional freshwater resources include rainwater collection, groundwater, and surface water.[534] For drinking and bathing, smaller Pacific islands primarily rely on individual rainwater catchment systems, while groundwater from the freshwater lens is used for irrigation. The size of freshwater lenses in atolls is influenced by factors such as rates of recharge (through precipitation), rates of use, and extent of tidal inundation.[531] Since rainfall triggers the formation of the freshwater lens, changes in precipitation, such as the significant decreases projected for the Caribbean, can significantly affect the availability of water. Because tropical storms replenish water supplies, potential changes in these storms are a great concern.

While it might initially be seen as a benefit, increased rainfall in the Pacific Islands during the summer months is likely to result in increased flooding, which would reduce drinking water quality and crop yields.[534] In addition, many islands have weak distribution systems and old infrastructure, which result in significant water leakage, decreasing their ability to use freshwater efficiently. Water pollution (such as from agriculture or sewage), exacerbated by storms and floods, can contaminate the freshwater supply, affecting public health. Sea-level rise also affects island water supplies by causing salt water to contaminate the freshwater lens and by causing an increased frequency of flooding due to storm high tides.[531] Finally, a rapidly rising population is straining the limited water resources, as would an increased incidence and/or intensity of storms[534] or periods of prolonged drought.

Island communities, infrastructure, and ecosystems are vulnerable to coastal inundation due to sea-level rise and coastal storms.

Sea-level rise will have enormous effects on many island nations. Flooding will become more frequent due to higher storm tides, and coastal land will be permanently lost as the sea inundates low-lying areas and the shorelines erode. Loss of land

Caribbean Precipitation Change
1900 to 2100



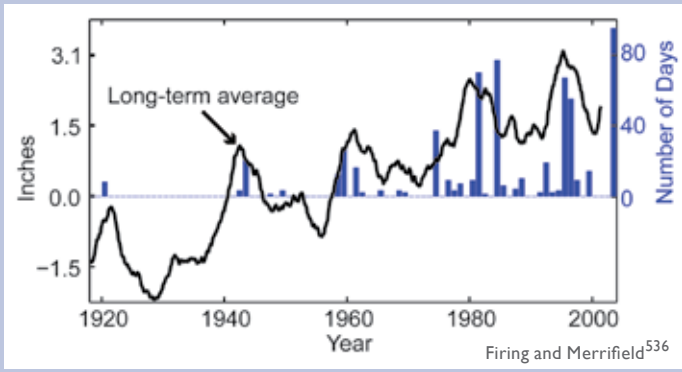
Total annual precipitation has declined in the Caribbean and climate models project stronger declines in the future, particularly under higher emission scenarios.[91] Such decreases threaten island communities that rely on rainfall for replenishing their freshwater supplies. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models.

will reduce freshwater supplies[531] and affect living things in coastal ecosystems. For example, the Northwestern Hawaiian Islands, which are low-lying and therefore at great risk from increasing sea level, have a high concentration of endangered and threatened species, some of which exist nowhere else.[535] The loss of nesting and nursing habitat is expected to threaten the survival of already vulnerable species.[535]

In addition to gradual sea-level rise, extreme high water level events can result from a combination of coastal processes.[271] For example, the harbor in Honolulu, Hawaii, experienced the highest daily average sea level ever recorded in September 2003. This resulted from the combination of long-term sea-level rise, normal seasonal heating (which causes the volume of water to expand and thus the level of the sea to rise), seasonal high tide, and an ocean circulation event which temporarily raised local sea level.[536] The interval between such extreme events has decreased from more than 20 years to approximately 5 years as average sea level has risen.[536]

Hurricanes, typhoons, and other storm events, with their intense precipitation and storm surge, cause major impacts to Pacific and Caribbean island communities, including loss of life, damage to infrastructure and property, and contamination of freshwater supplies.[537] As the climate continues to warm, the peak wind intensities and near-storm precipitation from future tropical cyclones are likely to increase,[90] which, combined with sea-level rise, is expected to cause higher storm surge levels. If such events occur frequently, communities would face challenges in recovering between events, resulting in long-term deterioration of infrastructure, freshwater and agricultural resources, and other impacts.[246]

Extreme Sea-Level Days: Honolulu, Hawaii



Sea-level rise will result in permanent land loss and reductions in freshwater supplies, as well as threaten coastal ecosystems. "Extreme" sea-level days (with a daily average of more than 6 inches above the long-term average[90]) can result from the combined effects of gradual sea-level rise due to warming and other phenomena, including seasonal heating and high tides.

Adaptation: Securing Water Resources

In the islands, "water is gold." Effective adaptation to climate-related changes in the availability of freshwater is thus a high priority. While island communities cannot completely counter the threats to water supplies posed by global warming, effective adaptation approaches can help reduce the damage.

A billboard on Pohnpei, in the Federated States of Micronesia, encourages water conservation in preparation for the 1997 to 1998 El Niño.

When existing resources fall short, managers look to unconventional resources, such as desalinating seawater, importing water by ship, and using treated wastewater for non-drinking uses. Desalination costs are declining, though concerns remain about the impact on marine life, the disposal of concentrated brines that may contain chemical waste, and the large energy use (and associated carbon footprint) of the process.[146] With limited natural resources, the key to successful water resource management in the islands will continue to be "conserve, recover, and reuse."[530]

Pacific Island communities are also making use of the latest science. This effort started during the 1997 to 1998 El Niño, when managers began using seasonal forecasts to prepare for droughts by increasing public awareness and encouraging water conservation. In addition, resource managers can improve infrastructure, such as by fixing water distribution systems to minimize leakage and by increasing freshwater storage capacity.[530]

Coastal houses and an airport in the U.S.-affiliated Federated States of Micronesia rely on mangroves' protection from erosion and damage due to rising sea level, waves, storm surges, and wind.

Critical infrastructure, including homes, airports, and roads, tends to be located along the coast. Flooding related to sea-level rise and hurricanes and typhoons negatively affects port facilities and harbors, and causes closures of roads, airports, and bridges.[538] Long-term infrastructure damage would affect social services such as disaster risk management, health care, education, management of freshwater resources, and economic activity in sectors such as tourism and agriculture.

Climate changes affecting coastal and marine ecosystems will have major implications for tourism and fisheries.

Marine and coastal ecosystems of the islands are particularly vulnerable to the impacts of climate change. Sea-level rise, increasing water temperatures, rising storm intensity, coastal inundation and flooding from extreme events, beach erosion, ocean acidification, increased incidences of coral disease, and increased invasions by non-native species are among the threats that endanger the ecosystems that provide safety, sustenance, economic viability, and cultural and traditional values to island communities.[539]

Tourism is a vital part of the economy for many islands. In 1999, the Caribbean had tourism-based gross earnings of $17 billion, providing 900,000 jobs and making the Caribbean one of the most tourism dependent regions in the world.[532] In the South Pacific, tourism can contribute as much as 47 percent of gross domestic product.[540] In Hawaii, tourism generated $12.4 billion for the state in 2006, with over 7 million visitors.[541]

Sea-level rise can erode beaches, and along with increasing water temperatures, can destroy or degrade natural resources such as mangroves and coral reef ecosystems that attract tourists.[246] Extreme weather events can affect transportation systems and interrupt communications. The availability of freshwater is critical to sustaining tourism, but is subject to the climate-related impacts described on the previous page. Public health concerns about diseases would also negatively affect tourism.

Coral reefs sustain fisheries and tourism, have biodiversity value, scientific and educational value, and form natural protection against wave erosion.[542] For Hawaii alone, net benefits of reefs to the economy are estimated at $360 million annually, and the overall asset value is conservatively estimated to be nearly $10 billion.[542] In the Caribbean, coral reefs provide annual net benefits from fisheries, tourism, and shoreline protection services of between $3.1 billion and $4.6 billion. The loss of income by 2015 from degraded reefs is conservatively estimated at several hundred million dollars annually.[532,543]

Coral reef ecosystems are particularly susceptible to the impacts of climate change, as even small increases in water temperature can cause coral bleaching,[544] damaging and killing corals. Ocean acidification due to a rising carbon dioxide concentration poses an additional threat (see *Ecosystems* sector and *Coasts* region). Coral reef ecosystems are also especially vulnerable to invasive species.[545] These impacts, combined with changes in the occurrence and intensity of El Niño events, rising sea level, and increasing storm damage,[246] will have major negative effects on coral reef ecosystems.

Fisheries feed local people and island economies. Almost all communities within the Pacific Islands derive over 25 percent of their animal protein from fish, with some deriving up to 69 percent.[546] For island fisheries sustained by healthy coral reef and marine ecosystems, climate change impacts exacerbate stresses such as overfishing,[246] affecting both fisheries and tourism that depend on abundant and diverse reef fish. The loss of live corals results in local extinctions and a reduced number of reef fish species.[547]

Nearly 70 percent of the world's annual tuna harvest, approximately 3.2 million tons, comes from the Pacific Ocean.[548] Climate change is projected to cause a decline in tuna stocks and an eastward shift in their location, affecting the catch of certain countries.[246]

Coasts

Approximately one-third of all Americans live in counties immediately bordering the nation's ocean coasts.[549,550] In addition to accommodating major cities, the coasts and the exclusive economic zone extending 200 miles offshore provide enjoyment, recreation, seafood, transportation of goods, and energy. Coastal and ocean activities contribute more than $1 trillion to the nation's gross domestic product and the ecosystems hold rich biodiversity and provide invaluable services.[551] However, intense human uses have taken a toll on coastal environments and their resources. Many fish stocks have been severely diminished by over-fishing, large "dead zones" depleted of oxygen have developed as a result of pollution by excess nitrogen runoff, toxic blooms of algae are increasingly frequent, and coral reefs are badly damaged or becoming overgrown with algae. About half of the nation's coastal wetlands have been lost – and most of this loss has occurred during the past 50 years.

Global climate change imposes additional stresses on coastal environments. Rising sea level is already eroding shorelines, drowning wetlands, and threatening the built environment.[43,224] The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with increasing Atlantic sea surface temperatures, and it is likely that hurricane rainfall and wind speeds will increase in response to global warming.[112] Coastal water temperatures have risen by about 2°F in several regions, and the geographic distributions of marine species have shifted.[37,68,347] Precipitation increases on land have increased river runoff, polluting coastal waters with more nitrogen and phosphorous, sediments, and other contaminants. Furthermore, increasing acidification resulting from the uptake of carbon dioxide by ocean waters threatens corals, shellfish, and other living things that form their shells and skeletons from calcium carbonate[23] (see *Ecosystems* sector). All of these forces converge and interact at the coasts, making these areas particularly sensitive to the impacts of climate change.

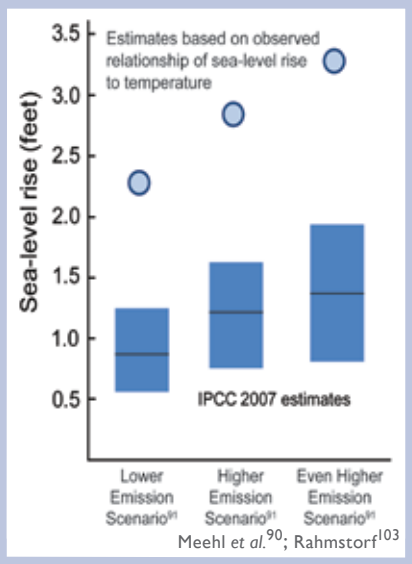
Significant sea-level rise and storm surge will adversely affect coastal cities and ecosystems around the nation; low-lying and subsiding areas are most vulnerable.

The rise in sea level relative to the land surface in any given location is a function of both the amount of global average sea-level rise and the degree to which the land is rising or falling. During the past century in the United States, relative sea level changes ranged from falling several inches to rising as much as 2 feet.[225] High rates of relative sea-level rise, coupled with cutting off the supply of sediments from the Mississippi River and other human alterations, have resulted in the loss of 1,900 square miles of Louisiana's coastal wetlands during the past century, weakening their capacity

Multiple Stresses Confront Coastal Regions

Various forces of climate change at the coasts pose a complex array of management challenges and adaptation requirements. For example, relative sea level is expected to rise at least 2 feet in Chesapeake Bay (located between Maryland and Virginia) where the land is subsiding, threatening portions of cities, inhabited islands, most tidal wetlands, and other low-lying regions. Climate change also will affect the volume of the bay, its salinity distribution and circulation, as will changes in precipitation and freshwater runoff. These changes, in turn, will affect summertime oxygen depletion and efforts to reduce the agricultural nitrogen runoff that causes it. Meanwhile the warming of the bay's waters will make survival there difficult for northern species such as eelgrass and soft clams, while allowing southern species and invaders riding in ships' ballast water to move in and change the mix of species that are caught and must be managed. Additionally, more acidic waters resulting from rising carbon dioxide levels will make it difficult for oysters to build their shells and will complicate the recovery of this key species.[553]

Projected Sea-Level Rise by 2100



Estimates of sea-level rise by the end of the century for three emissions scenarios.[91] Intergovernmental Panel on Climate Change 2007 projections (range shown as bars) exclude changes in ice sheet flow.[90] Light blue circles represent more recent, central estimates derived using the observed relationship of sea-level rise to temperature.[103] Areas where coastal land is sinking, for example by as much as 1.5 feet in this century along portions of the Gulf Coast, would experience that much additional sea-level rise relative to the land.[128]

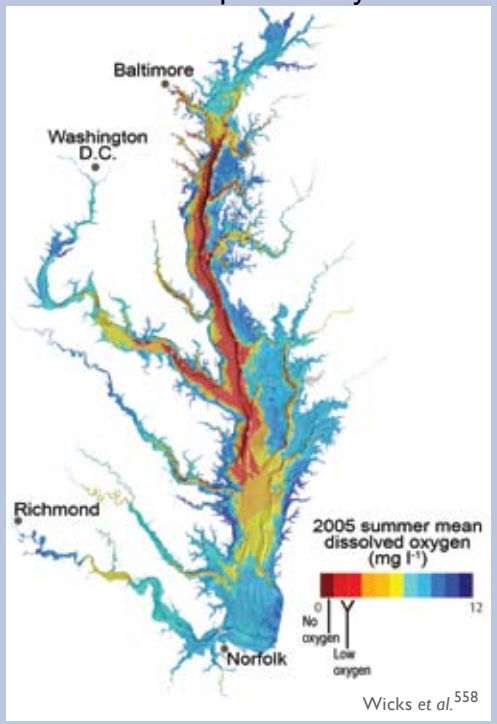
to absorb the storm surge of hurricanes such as Katrina.[552] Shoreline retreat is occurring along most of the nation's exposed shores.

A "ghost swamp" in south Louisiana shows the effects of saltwater intrusion.

The amount of sea-level rise likely to be experienced during this century depends mainly on the expansion of the ocean volume due to warming and the response of glaciers and polar ice sheets. Complex processes control the discharges from polar ice sheets and some are already producing substantial additions of water to the ocean.[554] Because these processes are not well understood, it is difficult to predict their future contributions to sea-level rise.[90,555]

As discussed in the *Global Climate Change* section, recent estimates of global sea-level rise substantially exceed the IPCC estimates, suggesting sea-level rise between 3 and 4 feet in this century. Even a 2-foot rise in relative sea level over a century would result in the loss of a large portion of the nation's remaining coastal wetlands, as they are not able to build new soil at a fast enough rate.[164] Accelerated sea-level rise would affect sea-grasses, coral reefs, and other important habitats. It would also fragment barrier islands, and place into jeopardy existing homes, businesses, and infrastructure, including roads, ports, and water and sewage systems. Portions of major cities, including Boston and New York, would be subject to inundation by ocean water during storm surges or even during regular high tides.[234]

Dead Zones in the Chesapeake Bay



Climate change is likely to expand and intensify "dead zones," areas where bottom water is depleted of dissolved oxygen because of nitrogen pollution, threatening living things.

More spring runoff and warmer coastal waters will increase the seasonal reduction in oxygen resulting from excess nitrogen from agriculture.

Coastal dead zones in places such as the northern Gulf of Mexico[556] and the Chesapeake Bay[557] are likely to increase in size and intensity as warming increases unless efforts to control runoff of agricultural fertilizers are redoubled. Greater spring runoff into East Coast estuaries and the Gulf of Mexico would flush more nitrogen into coastal waters stimulating harmful blooms of algae and the excess production of microscopic plants that settle near the seafloor and deplete oxygen supplies as they decompose. In addition, all else being equal, greater runoff reduces salinity, which when coupled with warmer surface water increases the difference in density between surface and bottom waters, thus preventing the replacement of oxygen in the deeper waters. As dissolved oxygen levels decline below a certain level, living things cannot survive. They leave the area if they can, and die if they cannot.

Coastal waters are very likely to continue to warm by as much 4 to 8°F in this century, both in summer and winter.[234] This will result in a northward shift in the geographic distribution of marine life along the coasts; this is already being observed.[70,347] The shift occurs because some species cannot tolerate the higher temperatures and others are out-competed by species from farther south moving in.[270] Warming also opens the door to invasion by species that humans are intentionally or unintentionally transporting around the world, for example in the ballast water carried by ships. Species that were previously unable to establish populations because of cold winters are likely to find the warmer conditions more welcoming and gain a foothold,[567] particularly as native species are under stress from climate change and other human activities. Non-native clams and small crustaceans have already had major effects on the San Francisco Bay ecosystem and the health of its fishery resources.[559]

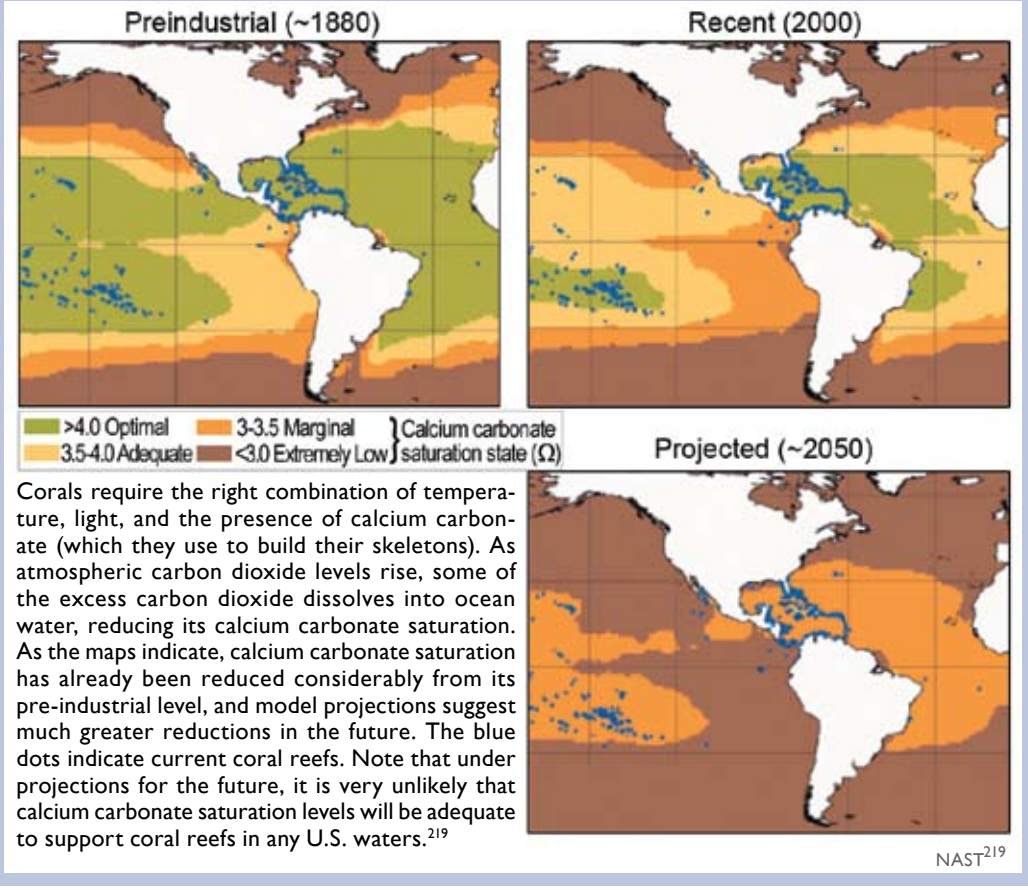
Higher water temperatures and ocean acidification due to increasing atmospheric carbon dioxide will present major additional stresses to coral reefs, resulting in significant die-offs and limited recovery.

In addition to carbon dioxide's heat-trapping effect, the increase in its concentration in the atmosphere is gradually acidifying the ocean. About one-third of the carbon dioxide emitted by human activities has been absorbed by the ocean, resulting in a decrease in the ocean's pH. Since the beginning of the industrial era, ocean pH has declined demonstrably and is projected to decline much more by 2100 if current emissions trends continue. Further declines in pH are very likely to continue to affect the ability of living things to create and maintain shells or skeletons of calcium carbonate. This is because at a lower pH less of the dissolved carbon is available as carbonate ions (see *Global Climate Change*).[70,259]

Ocean acidification will affect living things including important plankton species in the open ocean, mollusks and other shellfish, and corals.[22,23,70,259] The effects on reef-building corals are likely to be particularly severe during this century. Coral calcification rates are likely to decline by more than 30 percent under a doubling of atmospheric carbon dioxide concentrations, with erosion outpacing reef formation at even lower concentrations.[22] In addition, the reduction in pH also affects photosynthesis, growth, and reproduction. The upwelling of deeper ocean water, deficient in carbonate, and thus potentially detrimental to the food chains supporting juvenile salmon has recently been observed along the U.S. West Coast.[259]

Acidification imposes yet another stress on reef-building corals, which are also subject to bleaching – the expulsion of the microscopic algae that live inside the corals

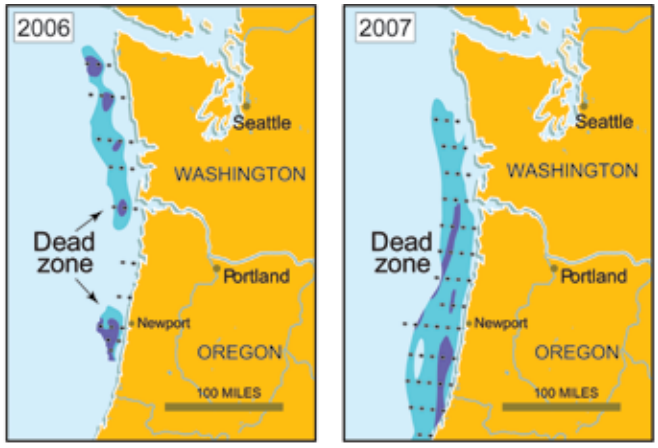
Calcium Carbonate Saturation in Ocean Surface Waters



Corals require the right combination of temperature, light, and the presence of calcium carbonate (which they use to build their skeletons). As atmospheric carbon dioxide levels rise, some of the excess carbon dioxide dissolves into ocean water, reducing its calcium carbonate saturation. As the maps indicate, calcium carbonate saturation has already been reduced considerably from its pre-industrial level, and model projections suggest much greater reductions in the future. The blue dots indicate current coral reefs. Note that under projections for the future, it is very unlikely that calcium carbonate saturation levels will be adequate to support coral reefs in any U.S. waters.[219]

NAST[219]

Pacific Coast "Dead Zone"
2006 to 2007



PISCO; NOAA-NWFSC; OSU/COAS[562]

Climate change affects coastal currents that moderate ocean temperatures and the productivity of ecosystems. As such, it is believed to be a factor in the low-oxygen "dead zone" that has appeared along the coast of Washington and Oregon in recent years.[561] In the maps above, blue indicates low-oxygen areas and purple shows areas that are the most severely oxygen depleted.

and are essential to their survival – as a result of heat stress[70] (see *Ecosystems* sector and *Islands* region). As a result of these and other stresses, the corals that form the reefs in the Florida Keys, Puerto Rico, Hawaii, and the Pacific Islands are projected to be lost if carbon dioxide concentrations continue to rise at their current rate.[560]

Changing ocean currents will affect coastal ecosystems.

Because it affects the distribution of heat in the atmosphere and the oceans, climate change will affect winds and currents that move along the nation's coasts, such as the California Current that bathes the West Coast from British Columbia to Baja California.[70] In this area, wind-driven upwelling of deeper ocean water along the coast is vital to moderation of temperatures and the high productivity of Pacific Coast ecosystems. Coastal currents are subject to periodic variations caused by the El Niño-Southern Oscillation and the Pacific Decadal Oscillation, which have substantial effects on the success of salmon and other fishery resources. Climate change is expected to affect such coastal currents, and possibly the larger scale natural oscillations as well, though these effects are not yet well understood. The recent emergence of oxygen-depletion events on the continental shelf off Oregon and Washington (a dead zone not directly caused by agricultural runoff and waste discharges such as those in the Gulf of Mexico or Chesapeake Bay) is one example.[561]

Adaptation: Coping with Sea-Level Rise

Adaptation to sea-level rise is already taking place in three main categories: (1) protecting the coastline by building hard structures such as levees and seawalls (although hard structures can, in some cases, actually increase risks and worsen beach erosion and wetland retreat), (2) accommodating rising water by elevating or redesigning structures, enhancing wetlands, or adding sand from elsewhere to beaches (the latter is not a permanent solution, and can encourage development in vulnerable locations), and (3) planned retreat from the coastline as sea level rises.[269]

Several states have laws or regulations that require setbacks for construction based on the planned life of the development and observed erosion rates.[371] North Carolina, Rhode Island, and South Carolina are using such a moving baseline to guide planning. Maine's Coastal Sand Dune Rules prohibit buildings of a certain size that are unlikely to remain stable with a sea-level rise of 2 feet. The Massachusetts Coastal Hazards Commission is preparing a 20-year infrastructure and protection plan to improve hazards management and the Maryland Commission on Climate Change has recently made comprehensive recommendations to reduce the state's vulnerability to sea-level rise and coastal storms by addressing building codes, public infrastructure, zoning, and emergency preparedness. Governments and private interests are beginning to take sea-level rise into account in planning levees and bridges, and in the siting and design of facilities such as sewage treatment plants (see Adaptation box in *Northeast* region).

An Agenda for Climate Impacts Science

Both mitigation and adaptation decisions are becoming increasingly necessary. Advancing our knowledge in the many aspects of science that affect the climate system has already contributed greatly to decision making on climate change issues. Further advances in climate science including better understanding and projections regarding rainfall, storm tracks, storm intensity, heat waves, and sea-level rise will improve decision making capabilities.

The focus below, however, is on advancing our knowledge specifically on climate change impacts and those aspects of climate change responsible for these impacts in order to continue to guide decision making.

Recommendation 1: Expand our understanding of climate change impacts.

There is a clear need to increase understanding of how ecosystems, social and economic systems, human health, and infrastructure will be affected by climate change in the context of other stresses. New understanding will come from a mix of activities including sustained and systematic observations, field and laboratory experiments, model development, and integrated impact assessments. These will incorporate shared learning among researchers, practitioners (such as engineers and water managers), and local stakeholders.

Ecosystems

Ecosystem changes, in response to changes in climate and other environmental conditions, have already been documented. These include changes in the chemistry of the atmosphere and precipitation, vegetation patterns, growing season length, plant productivity, animal species distributions, and the frequency and severity of pest outbreaks and fires. In the marine environment, changes include the health of corals and other living things due to temperature stress and ocean acidification. These observations not only document climate-change impacts, but also provide critical input to understanding how and why these changes occur, and how changes in ecosystems in turn affect climate. In this way, records of observed changes can improve projections of future impacts related to various climate change scenarios.

In addition to observations, large-scale, whole-ecosystem experiments are essential for improving projections of impacts. Ecosystem-level experiments that vary multiple factors, such as temperature, moisture, ground-level ozone, and atmospheric carbon dioxide, would provide process-level understanding of the ways ecosystems could respond to climate change in the context of other environmental stresses. Such experiments are particularly important for ecosystems with the greatest potential to experience massive change due to the crossing of thresholds or tipping points.

Insights regarding ecosystem responses to climate change gained from both observations and experiments are the essential building blocks of ecosystem simulation models. These models, when rigorously developed and tested, provide powerful tools for exploring the ecosystem consequences of alternative future climates. The incorporation of ecosystem models into an integrated assessment framework that includes socioeconomic, atmospheric and ocean chemistry, and atmosphere-ocean general circulation models should be a major goal of impacts research. This knowledge can provide a base for research studies into ways to manage critical ecosystems in an environment that is continually changing.

Economic systems, human health, and the built environment

As natural systems experience variations due to a changing climate, social and economic systems will

be affected. Food production, water resources, forests, parks, and other managed systems provide life support for society. Their sustainability will depend on how well they can adapt to a future climate that is different from historical experience.

At the same time, climate change is exposing human health and the built environment to increasing risks. Among the likely impacts are an expansion of the ranges of insects and other animals that carry diseases and a greater incidence of health-threatening air pollution events compounded by unusually hot weather associated with climate change. In coastal areas, sea-level rise and storm surge threaten infrastructure including homes, roads, ports, and oil and gas drilling and distribution facilities. In other parts of the country, floods, droughts, and other weather and climate extremes pose increasing threats.

Careful observations along with climate and Earth system models run with a range of emissions scenarios can help society evaluate these risks and plan actions to minimize them. Work in this area would include assessments of the performance of delivery systems, such as those for regional water and electricity supply, so that climate change impacts and costs can be evaluated in terms of changes in risk to system performance. It will be particularly important to understand when the effects on these systems are extremely large and/or rapid, similar to tipping points and thresholds in ecosystems.

In addition, the climate change experienced outside the United States will have implications for our nation. A better understanding of these international linkages, including those related to trade, security, and large-scale movements of people in response to climate change, is desirable.

Recommendation 2:
Refine ability to project climate change, including extreme events, at local scales.

One of the main messages to emerge from the past decade of synthesis and assessments is that while climate change is a global issue, it has a great deal of regional variability. There is an indisputable need to improve understanding of climate system effects at these smaller scales, because these are often the scales of decision making in society. Understanding impacts at local scales will also help to target finite resources for adaptation measures. Although much progress has been made in understanding important aspects of this variability, uncertainties remain. Further work is needed on how to quantify cumulative uncertainties across spatial scales and the uncertainties associated with complex, intertwined natural and social systems.

Because region-specific climate changes will occur in the context of other environmental and social changes that are also region-specific, it is important to continue to refine our understanding of regional details, especially those related to precipitation and soil moisture. This would be aided by further testing of models against observations using established metrics designed to evaluate and improve the realism of regional model simulations.

Continued development of improved, higher resolution global climate models, increased computational capacity, extensive climate model experiments, and improved downscaling methods will increase the value of geographically specific climate projections for decision makers in government, business, and the general population.

Extreme weather and climate events are a key component of regional climate. Additional attention needs to be focused on improved observations (made on the relevant time and space scales to capture high-impact extreme events) and associated research and analysis of the potential for future changes in extremes. Impacts analyses indicate that extreme weather and climate events often play a major role in determining climate-change consequences.

Recommendation 3:
Expand capacity to provide decision makers and the public with relevant information on climate change and its impacts.

The United States has tremendous potential to create more comprehensive measurement, archive, and data-access systems and to convey needed information that could provide great benefit to society. There are several aspects to fulfilling this goal: defining what is most relevant, gathering the needed information, expanding the capacity to deliver information, and improving the tools for decision makers to use this information to the

best advantage. All of these aspects should involve an interactive and iterative process of continual learning between those who provide information and those who use it. Through such a process, monitoring systems, distribution networks, and tools for using information can all be refined to meet user needs.

For example, tools used by researchers that could also be useful to decision makers include those that analyze and display the probability of occurrence of a range of outcomes to help in assessing risks.

Improved climate monitoring can be efficiently achieved by following the Climate Monitoring Principles recommended by the National Academy of Sciences and the Climate Change Science Strategic Plan in addition to integrating current efforts of governments at all levels. Such a strategy complements a long-term commitment to the measurement of the set of essential climate variables identified by both the Climate Change Science Program and the Global Climate Observing System. Attention must be placed on the variety of time and space scales critical for decision making.

Improved impacts monitoring would include information on the physical and economic effects of extreme events (such as floods and droughts), available, for example, from emergency preparedness and resource management authorities. It would also include regular archiving of information about impacts.

Improved access to data and information archives could substantially enhance society's ability to respond to climate change. While many data related to climate impacts are already freely and readily available to a broad range of users, other data, such as damage costs, are not, and efforts should be made to make them available. Easily accessible information should include a set of agreed-upon baseline indicators and measures of environmental conditions that can be used to track the effects of changes in climate. Services that provide reliable, well-documented, and easily used climate information, and make this information available to support users, are important.

Recommendation 4:
Improve understanding of thresholds likely to lead to abrupt changes in climate or ecosystems.

Paleoclimatic data show that climate can and has changed quite abruptly when certain thresholds are crossed. Similarly, there is evidence that ecological and human systems can undergo abrupt change when tipping points are reached.

Within the climate system there are a number of key risks to society for which understanding is still quite limited. Additional research is needed in some key areas, for example, identifying thresholds that lead to rapid changes in ice sheet dynamics. Sea-level rise is a major concern and improved understanding of the sensitivity of the major ice sheets to sustained warming requires improved observing capability, analysis, and modeling of the ice sheets and their interactions with nearby oceans. Estimates of sea-level rise in previous assessments, such as the recent Intergovernmental Panel on Climate Change 2007 report, did not fully quantify the magnitude and rate of future sea-level rise due to inadequate scientific understanding of potential instabilities of the Greenland and Antarctic ice sheets.

Tipping points in biological systems include the temperature thresholds above which insects survive winter, and can complete two life cycles instead of one in a single growing season, contributing to infestations that kill large numbers of trees. The devastation caused by bark beetles in Canada, and increasingly in the U.S. West, provides an example of how crossing such a threshold can set off massive destruction in an ecosystem with far-reaching consequences.

Similarly, there is increasing concern about the acidification of the world's oceans due to rising atmospheric carbon dioxide levels. There are ocean acidity thresholds beyond which corals and other living things, including some that form the base of important marine food chains, will no longer be able to form the shells and other body structures they need to survive. Improving understanding of such thresholds is an important goal for future research.

Recommendation 5:
Improve understanding of the most effective ways to reduce the rate and magnitude of climate change, as well as unintended consequences of such activities.

This report underscores the importance of reducing the concentrations of heat-trapping gases in the atmosphere. Impacts of climate change during this century and beyond are projected to be far larger and more rapid in scenarios in which greenhouse gas concentrations continue to grow rapidly compared to scenarios in which concentrations grow more slowly. Additional research will help identify the desired mix of mitigation options necessary to control the rate and magnitude of climate change.

In addition to their intended reduction of atmospheric concentrations of greenhouse gases, mitigation options also have the potential for unintended consequences, which should also be examined in future research. For example, the production, transportation, and use of biofuels could lead to increases in water and fertilizer use as well as in some air pollutants. It could also create competition among land uses for food production, biofuels production, and natural ecosystems that provide many benefits to society. Improved understanding of such unintended consequences, and identification of those options that carry the largest negative impacts, can help decision makers make more informed choices regarding the possible trade-offs inherent in various mitigation strategies.

Recommendation 6:
Enhance understanding of how society can adapt to climate change.

There is currently limited knowledge about the ability of communities, regions, and sectors to adapt to future climate change. It is important to improve understanding of how to enhance society's capacity to adapt to a changing climate in the context of other environmental stresses. Interdisciplinary research on adaptation that takes into account the interconnectedness of the Earth system and the complex nature of the social, political, and economic environment in which adaptation decisions must be made would be central to this effort.

The potential exists to provide insights into the possible effectiveness and limits of adaptation options that might be considered in the future. To realize this potential, new research would be helpful to document past responses to climate variability and other environmental changes, analyze the underlying reasons for them, and explain how individual and institutional decisions were made. However, human-induced climate change is projected to be larger and more rapid than any experienced by modern society so there are limits to what can be learned from the past.

A major difficulty in the analysis of adaptation strategies in this report has been the lack of information about the potential costs of adaptation measures, their effectiveness under various scenarios of climate change, the time horizons required for their implementation, and unintended consequences. These types of information should be systematically gathered and shared with decision makers as they consider a range of adaptation options. It is also clear that there is a substantial gap between the available information about climate change and the development of new guidelines for infrastructure such as housing, transportation, water systems, commercial buildings, and energy systems. There are also social and institutional obstacles to appropriate action, even in the face of adequate knowledge. These obstacles need to be better understood so that they can be reduced or eliminated.

Finally, it is important to carry out regular assessments of adaptation measures that address combined scenarios of future climate change, population growth, and economic development paths. This is an important opportunity for shared learning in which researchers, practitioners, and stakeholders collaborate using observations, models, and dialogue to explore adaptation as part of long-term, sustainable development planning.

Concluding Thoughts

Responding to changing conditions

Human-induced climate change is happening now, and impacts are already apparent. Greater impacts are projected, particularly if heat-trapping gas emissions continue unabated. Previous assessments have established these facts, and this report confirms, solidifies, and extends these conclusions for the United States. It reports the latest understanding of how climate change is already affecting important sectors and regions. In particular, it reports that some climate change impacts appear to be increasing faster than previous assessments had suggested. This report represents a significant update to previous work, as it draws from the U.S. Climate Change Science Program's Synthesis and Assessment Products and other recent studies that examine how climate change and its effects are projected to continue to increase over this century and beyond.

Climate choices

Choices about emissions now and in the coming years will have far-reaching consequences for climate change impacts. A consistent finding of this assessment is that the rate and magnitude of future climate change and resulting impacts depend critically on the level of global atmospheric heat-trapping gas concentrations as well as the types and concentrations of atmospheric particles (aerosols). Lower emissions of heat-trapping gases will delay the appearance of climate change impacts and lessen their magnitude. Unless the rate of emissions is substantially reduced, impacts are expected to become increasingly severe for more people and places.

Similarly, there are choices to be made about adaptation strategies that can help to reduce or avoid some of the undesirable impacts of climate change. There is much to learn about the effectiveness of the various types of adaptation responses and how they will interact with each other and with mitigation actions.

Responses to the climate change challenge will almost certainly evolve over time as society learns by doing. Determining and refining societal responses will be an iterative process involving scientists, policymakers, and public and private decision makers at all levels. Implementing these response strategies will require careful planning and continual feedback on the impacts of mitigation and adaptation policies for government, industry, and society.

The value of assessments

Science has revolutionized our ability to observe and model the Earth's climate and living systems, to understand how they are changing, and to project future changes in ways that were not possible in prior generations. These advances have enabled the assessment of climate change, impacts, vulnerabilities, and response strategies. Assessments serve a very important function in providing the scientific underpinnings of informed policy. They can identify advances in the underlying science, provide critical analysis of issues, and highlight key findings and key unknowns that can guide decision making. Regular assessments also serve as progress reports to evaluate and improve policy making and other types of decision making related to climate change.

Impacts and adaptation research includes complex human dimensions, such as economics, management, governance, behavior, and equity. Comprehensive assessments provide an opportunity to evaluate the social implications of climate change within the context of larger questions of how communities and the nation as a whole create sustainable and environmentally sound development paths.

A vision for future U.S. assessments

Over the past decade, U.S. federal agencies have undertaken two coordinated, national-scale efforts to evaluate the impacts of global climate change on this country. Each effort produced a report to the nation – *Climate Change Impacts on the United States*, published in 2000, and this report, *Global Climate Change Impacts in the United States*, published in 2009. A unique feature of the first report was that in addition to reporting the current state of the science, it created a national discourse on climate change that involved hundreds of scientists and thousands of stakeholders including farmers, ranchers, resource managers, city planners, business people, and local and regional government officials. A notable feature of the second report is the incorporation of information from the 21 topic-specific Synthesis and Assessment Products, many motivated by stakeholder interactions.

A vision for future climate change assessments includes both sustained, extensive stakeholder involvement, and targeted, scientifically rigorous reports that address concerns in a timely fashion. The value of stakeholder involvement includes helping scientists understand what information society wants and needs. In addition, the problem-solving abilities of stakeholders will be essential to designing, initiating, and evaluating mitigation and adaptation strategies and their interactions. The best decisions about these strategies will come when there is widespread understanding of the complex issue of climate change – the science and its many implications for our nation.

Federal Advisory Committee Authors

David M. Anderson is the Director for the World Data Center for Paleoclimatology, Chief of the Paleoclimatology Branch of NOAA's National Climatic Data Center, and an Associate Professor at the University of Colorado.

Donald F. Boesch is President of the University of Maryland Center for Environmental Science. His area of expertise is biological oceanography.

Virginia R. Burkett is the Chief Scientist for Global Change Research at the U.S. Geological Survey. Her areas of expertise are coastal ecology, wetland management, and forestry.

Lynne M. Carter is the Director of the Adaptation Network, a non-profit organization, and a project of the Earth Island Institute. Through assessment and action, she works to build resilience in communities and ecosystems in the face of a changing climate.

Stewart J. Cohen is senior researcher with the Adaptation and Impacts Research Division of Environment Canada, and an Adjunct Professor with the Department of Forest Resources Management of the University of British Columbia.

Nancy B. Grimm is a Professor of Life Sciences at Arizona State University. She studies how human-environment interactions and climate variability influence biogeochemical processes in both riverine and urban ecosystems.

Jerry L. Hatfield is the Laboratory Director of the USDA-ARS National Soil Tilth Laboratory in Ames, Iowa. His expertise is in the quantifications of spatial and temporal interactions across the soil-plant-atmosphere continuum.

Katharine Hayhoe is a Research Associate Professor in the Department of Geosciences at Texas Tech University and Principal Scientist and CEO of ATMOS Research & Consulting. Her research examines the potential impacts of human activities on the global environment.

Anthony C. Janetos is the Director of the Joint Global Change Research Institute, a joint venture between the Pacific Northwest National Laboratory and the University of Maryland. His area of expertise is biology.

Thomas R. Karl, (Co-Chair), is the Director of NOAA's National Climatic Data Center. His areas of expertise include monitoring for climate change and changes in extreme climate and weather events. He is also president of the American Meteorological Society.

Jack A. Kaye currently serves as Associate Director for Research of the Earth Science Division within NASA's Science Mission Directorate. He is responsible for NASA's research and data analysis programs in Earth System Science.

Jay H. Lawrimore is Chief of the Climate Analysis Branch at NOAA's National Climatic Data Center. He has led a team of scientists that monitors the Earth's climate on an operational basis.

James J. McCarthy is Alexander Agassiz Professor of Biological Oceanography at Harvard University. His areas of expertise are biology and oceanography. He is also President of the American Association for the Advancement of Science.

A. David McGuire is a Professor of Ecology in the U.S. Geological Survey's Alaska Cooperative Fish and Wildlife Research Unit located at the University of Alaska Fairbanks. His areas of expertise are ecosystem ecology and terrestrial feedbacks to the climate system.

Jerry M. Melillo, (Co-Chair), is the Director of The Ecosystems Center at the Marine Biological Laboratory in Woods Hole. He specializes in understanding the impacts of human activities on the biogeochemistry of ecological systems.

Edward L. Miles is the Virginia and Prentice Bloedel Professor of Marine Studies and Public Affairs at the University of Washington. His fields of specialization are international science and technology policy, marine policy and ocean management, and the impacts of climate variability and change.

Evan Mills is currently a Staff Scientist at the U.S. Department of Energy's Lawrence Berkeley National Laboratory. His areas of expertise are energy systems and risk management in the context of climate change.

Jonathan T. Overpeck is a climate system scientist at the University of Arizona, where he is also the Director of the Institute of the Environment, as well as a Professor of Geosciences and a Professor of Atmospheric Sciences.

Federal Advisory Committee Authors

Jonathan A. Patz is a Professor & Director of Global Environmental Health at the University of Wisconsin in Madison. He has earned medical board certification in both Occupational/Environmental Medicine and Family Medicine.

Thomas C. Peterson, (Co-Chair), is a physical scientist at NOAA's National Climatic Data Center in Asheville, North Carolina. His areas of expertise include data fidelity, international data exchange and global climate analysis using both *in situ* and satellite data.

Roger S. Pulwarty is a physical scientist and the Director of the National Integrated Drought Information System Program at NOAA in Boulder, Colorado. His interests are in climate risk assessment and adaptation.

Benjamin D. Santer is an atmospheric scientist at Lawrence Livermore National Laboratory. His research focuses on climate model evaluation, the use of statistical methods in climate science, and identification of "fingerprints" in observed climate records.

Michael J. Savonis has 25 years of experience in transportation policy, with extensive expertise in air quality and emerging environmental issues. He currently serves as a Senior Policy Advisor at the Federal Highway Administration.

H. Gerry Schwartz, Jr. is an internationally known expert in environmental and civil engineering. He is past-president of both the Water Environment Federation and the American Society of Civil Engineers, a member of the National Academy of Engineering, and a private consultant.

Eileen L. Shea serves as Director of the NOAA Integrated Data and Environmental Applications Center and Chief of the Climate Monitoring and Services Division, National Climatic Data Center, NOAA/NESDIS. Her educational experience focused on marine science, environmental law, and resource management.

John M.R. Stone is an Adjunct Research Professor in the Department of Geography and Environmental Studies at Carleton University. He has spent the last 20 years managing climate research in Canada and helping to influence the dialogue between science and policy.

Bradley H. Udall is the Director of the University of Colorado Western Water Assessment. He was formerly a consulting engineer at Hydrosphere Resource Consultants. His expertise includes water and policy issues of the American West and especially the Colorado River. He is an affiliate of NOAA's Earth System Research Laboratory.

John E. Walsh is a President's Professor of Global Change at the University of Alaska, Fairbanks and Professor Emeritus of Atmospheric Sciences at the University of Illinois. His research interests include the climate of the Arctic, extreme weather events as they relate to climate, and climate-cryosphere interactions.

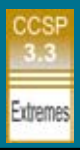
Michael F. Wehner is a member of the Scientific Computing Group at the Lawrence Berkeley National Laboratory in Berkeley, California. He has been active in both the design of global climate models and in the analysis of their output.

Thomas J. Wilbanks is a Corporate Research Fellow at the Oak Ridge National Laboratory and leads the Laboratory's Global Change and Developing Country Programs. He conducts research on such issues as sustainable development and responses to concerns about climate change.

Donald J. Wuebbles is the Harry E. Preble Professor of Atmospheric Sciences at the University of Illinois. His research emphasizes the study of chemical and physical processes of the atmosphere towards improved understanding of the Earth's climate and atmospheric composition.

PRIMARY SOURCES OF INFORMATION

CCSP Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.	
CCSP 1.1 Temperature Trends	*Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*
	Thomas R. Karl, NOAA; Susan J. Hassol, STG Inc.; Christopher D. Miller, NOAA; William L. Murray, STG Inc.
CCSP 1.2 Past Climate	*Past Climate Variability and Change in the Arctic and at High Latitudes*
	Richard B. Alley, Pennsylvania State Univ.; Julie Brigham-Grette, Univ. of Massachusetts; Gifford H. Miller, Univ. of Colorado; Leonid Polyak, Ohio State Univ.; James W.C. White, Univ.of Colorado; Joan J. Fitzpatrick, USGS
CCSP 1.3 Reanalysis	*Re-Analysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change*
	Randall M. Dole, Martin P. Hoerling, Siegfried Schubert, NOAA
CCSP Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.	
CCSP 2.1 GHG Emissions	Part A: *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* Part B: *Global-Change Scenarios: Their Development and Use*
	Leon E. Clarke, James A. Edmonds, Hugh M. Pitcher, Pacific Northwest National Lab.; Henry D. Jacoby, MIT; John M. Reilly, MIT; Richard G. Richels, Electric Power Research Institute; Edward A. Parson, Univ. of Michigan; Virginia R. Burkett, USGS; Karen Fisher-Vanden, Dartmouth College; David W. Keith, Univ. of Calgary; Linda O. Mearns, NCAR; Cynthia E. Rosenzweig, NASA; Mort D. Webster, MIT; John C. Houghton DOE/Office of Biological and Environmental Research
CCSP 2.2 Carbon Cycle	*The First State of the Carbon Cycle Report (SOCCR) North American Carbon Budget and Implications for the Global Carbon Cycle*
	Anthony W. King, ORNL; Lisa Dilling, Univ. of Colorado/NCAR; Gregory P. Zimmerman,ORNL; David Fairman, Consensus Building Institute Inc.; Richard A. Houghton, Woods Hole Research Center; Gregg Marland, ORNL; Adam Z. Rose, Pennsylvania State Univ. and Univ. Southern California; Thomas J. Wilbanks, ORNL
CCSP 2.3 Aerosol Impacts	*Atmospheric Aerosol Properties and Climate Impacts*
	Mian Chin, NASA; Ralph A. Kahn, NASA; Stephen E. Schwartz, DOE/BNL; Lorraine A. Remer, NASA/GSFC; Hogbin Yu, NASA/GSFC/UMBC; David Rind, NASA/GISS; Graham Feingold, NOAA/ESRL; Patricia K. Quinn, NOAA/PMEL; David G. Streets, DOE/ANL; Philip DeCola, NASA HQ; Rangasayi Halthore, NASA HQ/NRL
CCSP 2.4 Ozone Trends	*Trends in Emissions of Ozone-Depleting Substances, Ozone Layer Recovery, & Implications for Ultraviolet Radiation Exposure*
	A.R. Ravishankara, NOAA; Michael J. Kurylo, NASA; Christine Ennis, NOAA/ESRL

CCSP Goal 3: *Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.*	
	Climate Models: An Assessment of Strengths and Limitations
	David C. Bader and Curt Covey, Lawrence Livermore National Lab.; William J. Gutowski Jr., Iowa State Univ.; Isaac M. Held, NOAA/GFDL; Kenneth E. Kunkel, Illinois State Water Survey; Ronald L. Miller, NASA/GISS; Robin T. Tokmakian, Naval Postgraduate School; Minghua H. Zhang, State Univ. of New York Stony Brook; Anjuli S. Bamzai, U.S. DOE
	Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols
	Hiram Levy II, NOAA/GFDL; Drew Shindell, NASA/GISS; Alice Gilliland, NOAA /ARL; M. Daniel Schwarzkopf, NOAA/GFDL; Larry W. Horowitz, NOAA/GFDL; Anne M. Waple, STG Inc.
	*Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands*
	Thomas R. Karl, NOAA; Gerald A. Meehl, NCAR; Christopher D. Miller, NOAA; Susan J. Hassol, STG Inc.; Anne M. Waple, STG Inc.; William L. Murray, STG Inc.
	Abrupt Climate Change
	John P. McGeehin, USGS; John A. Barron, USGS; David M. Anderson, NOAA; David J. Verardo, NSF; Peter U. Clark, Oregon State Univ.; Andrew J. Weaver, Univ. of Victoria; Konrad Steffen, Univ. of Colorado; Edward R. Cook, Columbia Univ.; Thomas L. Delworth, NOAA; Edward Brook, Oregon State Univ.
CCSP Goal 4: *Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.*	
	Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region
	James G. Titus, U.S. EPA; K. Eric Anderson, USGS; Donald R. Cahoon, USGS; Dean B. Gesch, USGS; Stephen K. Gill, NOAA; Benjamin T. Gutierrez, USGS; E. Robert Thieler, USGS; S. Jeffress Williams, USGS
	Thresholds of Climate Change in Ecosystems
	Daniel B. Fagre, USGS; Colleen W. Charles, USGS
	The Effects of Climate Change on Agriculture, Land Resources, Water Resources and Biodiversity in the United States
	Peter Backlund, NCAR; Anthony Janetos, PNNL/Univ. of Maryland; David Schimel, National Ecological Observatory Network; Margaret Walsh, USDA
	Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources
	Susan Herrod Julius, U.S. EPA; Jordan M. West, U.S. EPA; Jill S. Baron, USGS and Colorado State Univ.; Linda A. Joyce, USDA Forest Service; Brad Griffith, USGS; Peter Kareiva, The Nature Conservancy; Brian D. Keller, NOAA; Margaret Palmer, Univ. of Maryland; Charles Peterson, Univ. of North Carolina; J. Michael Scott, USGS and Univ. of Idaho
	Effects of Climate Change on Energy Production and Use in the United States
	Thomas J. Wilbanks, ORNL; Vatsal Bhatt, Brookhaven National Lab.; Daniel E. Bilello, National Renewable Energy Lab.; Stanley R. Bull, National Renewable Energy Lab.; James Ekmann, National Energy Technology Lab.; William C. Horak, Brookhaven National Lab.; Y. Joe Huang, Mark D. Levine, Lawrence Berkeley National Lab.; Michael J. Sale, ORNL; David K. Schmalzer, Argonne National Lab.; Michael J. Scott, Pacific Northwest National Lab.

CCSP 4.6 Health	*Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*
	Janet L. Gamble, U.S. EPA; Kristie L. Ebi, ESS LLC.; Anne E. Grambsch, U.S. EPA; Frances G. Sussman, Environmental Economics Consulting; Thomas J. Wilbanks, ORNL
CCSP 4.7 Transportation	*Impacts of Climate Variability and Change on Transportation Systems and Infrastructure -- Gulf Coast Study*
	Michael J. Savonis, Federal Highway Administration; Virginia R. Burkett, USGS; Joanne R. Potter, Cambridge Systematics
CCSP Goal 5: *Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.*	
CCSP 5.1 Data Uses & Limitations	*Uses and Limitations of Observations, Data, Forecasts, and Other Projections in Decision Support for Selected Sectors and Regions*
	John Haynes, NASA; Fred Vukovich, SAIC; Molly K. Macauley, RFF; Daewon W. Byun, Univ. of Houston; David Renne, NREL; Gregory Glass, Johns Hopkins School of Public Health; Holly Hartmann, Univ. of Arizona
CCSP 5.2 Uncertainty	*Best Practice Approaches for Characterizing, Communicating and Incorporating Scientific Uncertainty in Climate Decision Making*
	M. Granger Morgan, Dept. of Engineering and Public Policy, Carnegie Mellon Univ.; Hadi Dowlatabadi, Inst. for Resources, Environment and Sustainability, Univ. of British Columbia; Max Henrion, Lumina Decision Systems; David Keith, Dept. of Chemical and Petroleum Engineering and Dept. of Economics, Univ. of Calgary; Robert Lempert, The RAND Corp.; Sandra McBride, Duke Univ.; Mitchell Small, Dept. of Engineering and Public Policy, Carnegie Mellon Univ.; Thomas Wilbanks, Environmental Science Division, ORNL
CCSP 5.3 Decision Support	*Decision Support Experiments and Evaluations using Seasonal-to-Interannual Forecasts and Observational Data: A Focus on Water Resources*
	Nancy Beller-Simms, NOAA; Helen Ingram, Univ. of Arizona; David Feldman, Univ. of California; Nathan Mantua, Climate Impacts Group, Univ. of Washington; Katharine L. Jacobs, Arizona Water Institute; Anne M. Waple, STG Inc.
Other Assessments Referenced	
IPCC WG-1	Working Group I - *Climate Change 2007: The Physical Science Basis*
	Susan Solomon, Dahe Qin, Martin Manning, Zhenlin Chen, Melinda Marquis, Kristen B. Averyt, Melina M.B. Tignor, Henry LeRoy Miller, Jr.
IPCC WG-2	Working Group II - *Climate Change 2007: Impacts, Adaptation and Vulnerability*
	Martin L. Parry, Osvalda F. Canziani, Jean P. Palutikof, Paul J. van der Linden, Clair E. Hanson
IPCC WG-3	Working Group III - *Climate Change 2007: Mitigation of Climate Change*
	Bert Metz, Ogunlade R. Davidson, Peter R. Bosch, Rutu Dave, Leo A. Meyer
IPCC Emissions Scenarios	*Special Report on Emissions Scenarios*
	Nebojsa Nakicenovic, Robert Swart

	Climate Change and Water
	Bryson Bates, Zbigniew W. Kundzewicz, Shaohong Wu, Jean P. Palutikof
	Potential Impacts of Climate Change on U.S. Transportation
	Henry G. Schwartz, Jr., Alan C. Clark, G. Edward Dickey, George C. Eads, Robert E. Gallamore, Genevieve Giuliano, William J. Gutowski, Jr., Randell H. Iwasaki, Klaus H. Jacob, Thomas R. Karl, Robert J. Lempert, Luisa M. Paiewonsky, S. George H. Philander, Christopher R. Zeppie
	Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change
	Jerry M. Melillo, Anthony C. Janetos, Thomas R. Karl, Eric J. Barron, Virginia Rose Burkett, Thomas F. Cecich, Robert W. Corell, Katharine L. Jacobs, Linda A. Joyce, Barbara Miller, M. Granger Morgan, Edward A. Parson, Richard G. Richels, David S. Schimel
	Impacts of a Warming Arctic, Arctic Climate Impact Assessment
	Robert W. Corell, Susan J. Hassol, Pål Prestrud, Patricia A. Anderson, Snorri Baldursson, Elizabeth Bush, Terry V. Callaghan, Paul Grabhorn, Gordon McBean, Michael MacCracken, Lars-Otto Reiersen, Jan Idar Solbakken, Gunter Weller

ACRONYMS AND ABBREVIATIONS

ARS: Agricultural Research Service
CCSP: Climate Change Science Program
CIESIN: Center for International Earth Science Information Network
CIRES: Cooperative Institute for Research in Environmental Sciences
CMIP: Coupled Model Intercomparison Project
DOE: Department of Energy
EIA: Energy Information Administration
IARC: International Arctic Research Center
IPCC: Intergovernmental Panel on Climate Change
NASA: National Aeronautics and Space Administration
NASS: National Agricultural Statistics Service
NAST: National Assessment Synthesis Team
NCDC: National Climatic Data Center
NESDIS: National Environmental Satellite, Data, and Information Service
NOAA: National Oceanic and Atmospheric Administration
NRCS: Natural Resources Conservation Service
NSIDC: National Snow and Ice Data Center
NWS: National Weather Service
NWFSC: Northwest Fisheries Science Center
PISCO: Partnership for Interdisciplinary Studies of Coastal Oceans
PLJV: Playa Lakes Joint Venture
SAP: Synthesis and Assessment Product
SRH: Southern Regional Headquarters
USACE: United States Army Corps of Engineers
USBR: States Bureau of Reclamation
USDA: United States Department of Agriculture
U.S. EPA: United States Environmental Protection Agency
USFS: United States Forest Service
USGS: United States Geological Survey

REFERENCES

[1] CCSP, 2009: *Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decisionmaking*. [Morgan, G., H. Dowlatabadi, M. Henrion, D. Keith, R. Lempert, S. McBrid, M. Small, and T. Wilbanks (eds.)]. Synthesis and Assessment Product 5.2. National Oceanic and Atmospheric Administration, Washington DC.

[2] Historical data: Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, and T.F. Stocker, 2008: High-resolution carbon dioxide concentration record 650,000-800,000 years before present. *Nature*, **453(7193)**, 379-382.

1959-2008 data: Tans, P., 2008: *Trends in Atmospheric Carbon Dioxide: Mauna Loa*. NOAA Earth System Research Laboratory (ESRL). [Web site] <http://www.esrl.noaa.gov/gmd/ccgg/trends/> Data available at <ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt>

2100 projected data: International Institute for Applied System Analysis (IIASA) GGI Scenario Database, 2008. <http://www.iiasa.ac.at/Research/GGI/DB/>

[3] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz, and R. Van Dorland, 2007: Changes in atmospheric constituents and in radiative forcing. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 129-234.

[4] Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy, and X. Zhang, 2007: Couplings between changes in the climate system and biogeochemistry. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 499-587.

[5] Ko, M., J.S. Daniel, J.R. Herman, P.A. Newman, and V. Ramaswamy, 2008: The future and recovery. In: *Trends in Emissions of Ozone-Depleting Substances, Ozone Layer Recovery, and Implications for Ultraviolet Radiation Exposure*. [Ravishankara, A.R., M.J. Kurylo, and C.A. Ennis (eds.)]. Synthesis and Assessment Product 2.4. NOAA's National Climatic Data Center, Asheville, NC, pp. 133-154.

[6] Ravishankara, A.R., M.J. Kurylo, and A.-M. Schmoltner, 2008: Introduction. In: *Trends in Emissions of Ozone-Depleting Substances, Ozone Layer Recovery, and Implications for Ultraviolet Radiation Exposure*. [Ravishankara, A.R., M.J. Kurylo, and C.A. Ennis (eds.)]. Synthesis and Assessment Product 2.4. NOAA's National Climatic Data Center, Asheville, NC, pp. 23-28.

[7] Blasing, T.J., 2008: *Recent Greenhouse Gas Concentrations*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory. <http://cdiac.ornl.gov/pns/current_ghg.html>

[8] Fahey, D.W. (lead author), 2007: *Twenty Questions and Answers about the Ozone Layer: 2006 Update*. World Meteorological Organization, Geneva, Switzerland, 50 pp. <http://www.esrl.noaa.gov/csd/assessments/2006/twentyquestions.html>

[9] Thompson, D.W.J. and S. Solomon, 2002: Interpretation of recent Southern Hemisphere climate change. *Science*, **296(5569)**, 895-899.

[10] Kahn, R.A., H. Yu, S.E. Schwartz, M. Chin, G. Feingold, L.A. Remer, D. Rind, R. Halthore, and P. DeCola, 2009: Introduction. In: *Atmospheric Aerosol Properties and Climate Impacts*. [Chin, M., R.A. Kahn, and S.E. Schwartz (eds.)]. Synthesis and Assessment Product 2.3. National Aeronautics and Space Administration, Washington, DC, pp. 9-20.

[11] Solomon, S., G.-K. Plattner, R. Knutti, and P. Friedlingstein, 2009: Irreversible climate change because of carbon dioxide emissions. *Proceedings of the National Academy of Sciences*, **106(6)**, 1704-1709.

[12] Archer, D., 2005: Fate of fossil fuel CO_2 in geologic time. *Journal of Geophysical Research*, **110**, C09S05, doi:10.1029/2004JC002625.

[13] Shindell, D.T., H. Levy II, A. Gilliland, M.D. Schwarzkopf, and L.W. Horowitz, 2008: Climate change from short-lived emissions due to human activities. In: *Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols*. [Levy II, H., D.T. Shindell, A. Gilliland, M.D. Schwarzkopf, and L.W. Horowitz, (eds.)]. Synthesis and Assessment Product 3.2. U.S. Climate Change Science Program, Washington, DC, pp. 27-60.

[14] Santer, B.D., J.E. Penner, and P.W. Thorne, 2006: How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes? In: *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. Synthesis and Assessment Product 1.1 U.S. Climate Change Science Program, Washington, DC, pp. 89-118.

[15] Hansen, J., M. Sato, R. Ruedy, L. Nazarenko, A. Lacis, G.A. Schmidt, G. Russell, I. Aleinov, M. Bauer, S. Bauer, N. Bell, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Del Genio, G. Faluveg E. Fleming, A. Friend, T. Hall, C. Jackman, M. Kelley, N. Kiang, D. Koch, J. Lean, J. Lerner, K. Lo, S. Menon, R. Miller, P. Minnis, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, D. Shindell, P. Stone, S. Sun, N. Tausnev, D. Thresher, B. Wielicki, T. Wong, M. Yao, and S. Zhang 2005: Efficacy of climate forcings. *Journal of Geophysical Research*, **110**, D18104, doi:10.1029/2005JD005776.

[16] National Research Council, 2005: *Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties*. National Academies Press, Washington DC, 207 pp.

[17] Hansen, J., M. Sato, R. Ruedy, A. Lacis, and V. Oinas, 2000: Global warming in the twenty-first century: an alternative scenario. *Proceedings of the National Academy of Sciences*, **97(18)**, 9875-9880.

[18] Field, C.B., J. Sarmiento, and B. Hales, 2007: The carbon cycle of North America in a global context. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* [King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J.

Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. NOAA's National Climatic Data Center, Asheville, NC, pp. 21-28.

[19] Tarnocai, C., C.-L. Ping, and J. Kimble, 2007: Carbon cycles in the permafrost region of North America. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* [King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. NOAA's National Climatic Data Center, Asheville, NC, pp. 127-138.

[20] Jansen, E., J. Overpeck, K.R. Briffa, J.-C. Duplessy, F. Joos, V. Masson-Delmotte, D. Olago, B. Otto-Bliesner, W.R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba and D. Zhang, 2007: Palaeoclimate. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 433-497.

[21] Canadell, J.G., C. Le Quéré, M.R. Raupach, C.B. Field, E.T. Buitenhuis, P. Ciais, T.J. Conway, N.P. Gillett, R.A. Houghton, and G. Marland, 2007: Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences*, **104(47)**, 18866-18870.

[22] Royal Society, 2005: *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide*. Policy Document 12/05. Royal Society, London, 60 pp.

[23] Orr, J.C., V.J. Fabry, O. Aumont, L. Bopp, S.C. Doney, R.A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R.M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R.G. Najjar, G.-K. Plattner, K.B. Rodgers, C.L. Sabine, J.L. Sarmiento, R. Schlitzer, R.D. Slater, I.J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool, 2005: Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature*, **437(7059)**, 681-686.

[24] Allen, M.R., 2003: Liability for climate change. *Nature*, **421(6926)**, 891-892.

[25] Clarke, L., J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, and R. Richels, 2007: *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*. Sub-report 2.1A of Synthesis and Assessment Product 2.1. U.S. Department of Energy, Office of Biological & Environmental Research, Washington, DC, 154 pp.

[26] The spatial average of annual-average surface air temperatures around the globe is commonly referred to as the global average surface air temperature.

[27] Meier, M.F., M.B. Dyurgerov, U.K. Rick, S. O'Neel, W.T. Pfeffer, R.S. Anderson, S.P. Anderson, and A.F. Glazovsky, 2007: Glaciers dominate eustatic sea-level rise in the 21st century. *Science*, **317(5841)**, 1064-1067.

[28] Trenberth**,** K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden, and P. Zhai, 2007: Observations: surface and atmospheric climate change. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 235-335.

[29] Steffen, K., P.U. Clark, J.G. Cogley, D. Holland, S. Marshall, E. Rignot, and R. Thomas, 2008: Rapid changes in glaciers and ice sheets and their impacts on sea level. In: *Abrupt Climate Change*. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 60-142.

[30] Lanzante, J.R., T.C. Peterson, F.J. Wentz, and K.Y. Vinnikov, 2006: What do observations indicate about the change of temperatures in the atmosphere and at the surface since the advent of measuring temperatures vertically? In: *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. Synthesis and Assessment Product 1.1 U.S. Climate Change Science Program, Washington, DC, pp. 47-70.

[31] Santer, B.D., P.W. Thorne, L. Haimberger, K.E. Taylor, T.M.L. Wigley, J.R. Lanzante, S. Solomon, M. Free, P.J. Gleckler, P.D. Jones, T.R. Karl, S.A. Klein, C. Mears, D. Nychka, G.A. Schmidt, S.C. Sherwood, and F.J. Wentz, 2008: Consistency of modelled and observed temperature trends in the tropical troposphere. *International Journal of Climatology*, **28(13)**, 1703-1722.

[32] Uncertainties in the data are an order of magnitude smaller than the trend according to Karl, T.R., J.R. Christy, R.A. Clarke, G.V. Gruza, J. Jouzel, M.E. Mann, J. Oerlemans, M.J. Salinger, and S.-W. Wang, 2001: Observed climate variability and change. In: *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 99-181.

Temperature data:

Smith, T.M. and R.W. Reynolds, 2004: Improved extended reconstruction of SST (1854–1997). *Journal of Climate*, **17(12)**, 2466-2477.

Jones, P.D., M. New, D.E. Parker, S. Martin, and I.G. Rigor, 1999: Surface air temperature and its changes over the past 150 years. *Reviews of Geophysics*, **37(2)**, 173-199.

Carbon dioxide data:

Data from 1974 to present: Tans, P., 2008: *Trends in Atmospheric Carbon Dioxide: Mauna Loa*. NOAA Earth System Research Laboratory (ESRL). [Web site] <http://www.esrl.noaa.gov/gmd/ccgg/trends/> Data available at <ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt>

1958-1974 data are from the Scripps Institution of Oceanography (Keeling) Mauna Loa Observatory record. <http://scrippsco2.ucsd.edu/>

Pre-1958 values are annual points taken from a smooth fit to the Law Dome data: Etheridge, D.M., L.P. Steele, R.L. Langenfelds, R.J. Francey, J.-M. Barnola, and V.I. Morgan, 1996: Natural and anthropogenic changes in atmospheric CO_2 over the last 1000 years from air in Antarctic ice and firn. *Journal of Geophysical Research*, **101(D2)**, 4115-4128.

[33] Easterling, D. and M. Wehner, 2009: Is the climate warming or cooling? *Geophysical Research Letters*, **36**, L08706, doi:10.1029/2009GL037810.

[34] Barnett, T.P., D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, and M.D. Dettinger, 2008: Human-induced changes in the hydrology of the western United States. *Science*, **319(5866)**, 1080-1083.

[35] Willett, K.M., N.P. Gillett, P.D. Jones, and P.W. Thorne, 2007: Attribution of observed surface humidity changes to human influence. *Nature*, **449(7163)**, 710-712.

[36] Santer, B.D., C. Mears, F.J. Wentz, K.E. Taylor, P.J. Gleckler, T.M.L. Wigley, T.P. Barnett, J.S. Boyle, W. Brüggemann, N.P. Gillett, S.A. Klein, G.A. Meehl, T. Nozawa, D.W. Pierce, P.A. Stott, W.M. Washington, and M.F. Wehner, 2007: Identification of human-induced changes in atmospheric moisture content. *Proceedings of the National Academy of Sciences*, **104(39)**, 15248-15253.

[37] Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan, 2007: Observations: oceanic climate change and sea level. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 385-432.

[38] Barnett, T.P., D.W. Pierce, K.M. AchutaRao, P.J. Gleckler, B.D. Santer, J.M. Gregory, and W.M. Washington, 2005: Penetration of human-induced warming into the world's oceans. *Science*, **309(5732)**, 284-287.

[39] Pierce, D.W., T.P. Barnett, K.M. AchutaRao, P.J. Gleckler, J.M. Gregory, and W.M. Washington, 2006: Anthropogenic warming of the oceans: observations and model results. *Journal of Climate*, **19(10)**, 1873-1900.

[40] Lemke, P., J. Ren, R.B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P. Mote, R.H. Thomas, and T. Zhang, 2007: Observations: changes in snow, ice and frozen ground. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 337-383.

[41] Luthcke, S.B., H.J. Zwally, W. Abdalati, D.D. Rowlands, R.D. Ray, R.S. Nerem, F.G. Lemoine, J.J. McCarthy, and D.S. Chinn, 2006: Recent Greenland ice mass loss by drainage system from satellite gravity observations. *Science*, **314(5803)**, 1286-1289.

[42] Pfeffer, W.T., J.T. Harper, and S. O'Neel, 2008: Kinematic constraints on glacier contributions to 21st-century sea-level rise. *Science*, **321(5894)**, 1340-1343.

[43] Williams, S.J., B.T. Gutierrez, J.G. Titus, S.K. Gill, D.R. Cahoon, E.R. Thieler, K.E. Anderson, D. FitzGerald, V. Burkett, and J. Samenow, 2009: Sea-level rise and its effects on the coast. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 11-24.

[44] IPCC (Intergovernmental Panel on Climate Change), 1996: Summary for policy makers. In: *Climate Change 1995: The Science of Climate Change*. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., L.G. Meiro Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 1-7.

[45] IPCC (Intergovernmental Panel on Climate Change), 2007: Summary for policymakers. In: *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 1-18.

[46] Wigley, T.M.L., V. Ramaswamy, J.R. Christy, J.R. Lanzante, C.A. Mears, B.D. Santer, and C.K. Folland, 2006: Executive summary. In: *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. Synthesis and Assessment Product 1.1 U.S. Climate Change Science Program, Washington, DC, pp. 1-15.

[47] National Research Council, 2006: *Surface Temperature Reconstructions for the Last 2,000 Years*. National Academies Press, Washington DC, 196 pp.

[48] Mann, M.E., Z. Zhang, M.K. Hughes, R.S. Bradley, S.K. Miller, S. Rutherford, and F. Ni, 2008: Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. *Proceedings of the National Academy of Sciences*, **105(36)**, 13252-13257.

[49] Hegerl, G.C., F.W. Zwiers, P. Braconnot, N.P. Gillett, Y. Luo, J.A. Marengo Orsini, N. Nicholls, J.E. Penner, and P.A. Stott, 2007: Understanding and attributing climate change. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 663-745.

[50] LeTreut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson, and M. Prather, 2007: Historical overview of climate changes science. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 93-127.

[51] Santer, B.D., T.M.L. Wigley, T.P. Barnett, and E. Anyamba, 1996: Detection of climate change, and attribution of causes. In: *Climate Change 1995: The Science of Climate Change*. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., L.G. Meiro Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 407-443.

[52] Mitchell, J.F.B., D.J. Karoly, G.C. Hegerl, F.W. Zwiers, M.R. Allen, and J. Marengo, 2001: Detection of climate change and attribution of causes. In: *Climate Change 2001: The Scientific Basis.* Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 695-738.

[53] Santer, B.D., M.F. Wehner, T.M.L. Wigley, R. Sausen, G.A. Meehl, K.E. Taylor, C. Ammann, J. Arblaster, W.M. Washington, J.S. Boyle, and W. Brüggemann, 2003: Contributions of anthropogenic and natural forcing to recent tropopause height changes. *Science*, **301(5632)**, 479-483.

[54] Zhang, X., F.W. Zwiers, G.C. Hegerl, F.H. Lambert, N.P. Gillett, S. Solomon, P.A. Stott and T. Nozawa, 2007: Detection of human influence on twentieth-century precipitation trends. *Nature*, **448(7152)**, 461-465.

[55] Burke, E.J., S.J. Brown, and N. Christidis, 2006: Modeling the recent evolution of global drought and projections for the twenty-first century with the Hadley Centre climate model. *Journal of Hydrometeorology*, **7(5)**, 1113-1125.

[56] Gillett, N.P., F.W. Zwiers, A.J. Weaver, and P.A. Stott, 2003: Detection of human influence on sea level pressure. *Nature*, **422(6929)**, 292-294.

[57] Gedney, N., P.M. Cox, R.A. Betts, O. Boucher, C. Huntingford, and P.A. Stott, 2006: Detection of a direct carbon dioxide effect in continental river runoff records. *Nature*, **439(7078)**, 835-838.

[58] Dole, R. and M. Hoerling, 2008: Introduction. In: *Reanalysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change.* [Dole, R., M. Hoerling, and S. Schubert (eds.)]. Synthesis and Assessment Prod-

uct 1.3. NOAA's National Climatic Data Center, Asheville, NC, pp. 5-10.

[59] The temperature data for the globe is the standard NOAA/NCDC temperature product.
The solar data are a composite of 3 different data sets:
Fröhlich, C. and J. Lean, 2004: Solar radiative output and its variability: evidence and mechanisms. *Astronomy and Astrophysics Review*, **12(4)**, 273-320.
Willson, R.C. and A.V. Mordvinov, 2003: Secular total solar irradiance trend during solar cycles 21023. *Geophysical Research Letters*, **30(5)**, 1199, doi:10.1029/2002GL016038.
Dewitte, S., D. Crommelynck, S. Mekaoui, and A. Jouko, 2004: Measurement and uncertainty of the long-term total solar irradiance trend. *Solar Physics*, **224(1-2)**, 209-216.

[60] Lean, J.L. and D.H. Rind, 2008: How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006. *Geophysical Research Letters*, **35**, L18701, doi:10.1029/2008GL034864.

[61] Min, S.-K., X. Zhang, F.W. Zwiers, and T. Agnew, 2008: Human influence on Arctic sea ice detectable from early 1990s onwards. *Geophysical Research Letters*, **35**, L21701, doi:10.1029/2008GL035725.

[62] Gillett, N.P., D.A. Stone, P.A. Stott, T. Nozawa, A.Y. Karpechko, G.C. Hegerl, M.F. Wehner, and P.D. Jones, 2008: Attribution of polar warming to human influence. *Nature Geoscience*, **1(11)**, 750-754.

[63] Ramaswamy, V., J.W. Hurrell, G.A. Meehl, A. Phillips, B.D. Santer, M.D. Schwarzkopf, D.J. Seidel, S.C. Sherwood, and P.W. Thorne, 2006: Why do temperatures vary vertically (from the surface to the stratosphere) and what do we understand about why they might vary and change over time? In: *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. Synthesis and Assessment Product 1.1. U.S. Climate Change Science Program, Washington, DC, pp. 15-28.

[64] Stott, P.A., 2003: Attribution of regional-scale temperature changes to anthropogenic and natural causes. *Geophysical Research Letters*, **30(14)**, 1724, doi:10.1029/2003GL017324.

[65] Zwiers, F.W. and X. Zhang, 2003: Towards regional-scale climate change detection. *Journal of Climate*, **16(5)**, 793-797.

[66] Santer, B.D., T.M.L. Wigley, P.J. Glecker, C. Bonfils, M.F. Wehner, K. AchutaRao, T.P. Barnett, J.S. Boyle, W. Brüggemann, M. Fiorino, N.P. Gillett, J.E. Hansen, P.D. Jones, S.A. Klein, G.A. Meehl, S.C.B. Raper, R.W. Reynolds, K.E. Taylor, and W.M. Washington, 2006: Forced and unforced ocean temperature changes in Atlantic and Pacific tropical cyclogenesis regions. *Proceedings of the National Academy of Sciences*, **103(38)**, 13905-13910.

[67] Gillett, N.P., P.A. Stott, and B.D. Santer, 2008: Attribution of cyclogenesis region sea surface temperature change to anthropogenic influence. *Geophysical Research Letters*, **35**, L09707, doi:10.1029/2008GL033670.

[68] Gutowski, W.J., G.C. Hegerl, G.J. Holland, T.R. Knutson, L.O. Mearns, R.J. Stouffer, P.J. Webster, M.F. Wehner, and F.W. Zwiers, 2008: Causes of observed changes in extremes and projections of future changes. In: *Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 81-116.

[69] Root, T.L., D.P. MacMynowski, M.D. Mastrandrea, and S.H. Schneider, 2005: Human-modified temperatures induce species changes: joint attribution. *Proceedings of the National Academy of Sciences*, **102(21)**, 7465-7469.

[70] Janetos, A., L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw, 2008: Biodiversity. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 151-181.

[71] CCSP, 2006: *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. Synthesis and Assessment Product 1.1. U.S. Climate Change Science Program, Washington, DC, 164 pp.

[72] Smith, T.M., R.W. Reynolds, T.C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land–ocean surface temperature analysis (1880–2006). *Journal of Climate*, **21(10)**, 2283-2296.

[73] Haimberger, L., C. Tavolato, and S. Sperka, 2008: Toward elimination of the warm bias in historic radiosonde temperature records – some new results from a comprehensive intercomparison of upper air data. *Journal of Climate*, **21(18)**, 4587-4606.

[74] Sherwood, S.C., C.L. Meyer, R.J. Allen, and H.A. Titchner, 2008: Robust tropospheric warming revealed by iteratively homogenized radiosonde data. *Journal of Climate*, **21(20)**, 5336-5352.

[75] Titchner, H.A., P.W. Thorne, M.P. McCarthy, S.F.B. Tett, L. Haimberger, and D.E. Parker, 2008: Critically reassessing tropospheric temperature trends from radiosondes using realistic validation experiments. *Journal of Climate*, **22(3)**, 465-485.

[76] Delworth, T.L., P.U. Clark, M. Holland, W.E. Johns, T. Kuhlbrodt, J. Lynch-Stieglitz, C. Morrill, R. Seager, A.J. Weaver, and R. Zhang, 2008: The potential for abrupt change in the Atlantic Meridional Overturning Circulation. In: *Abrupt Climate Change*. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 258-359.

[77] Wentz, F.J., L. Ricciardulli, K. Hilburn, and C. Mears, 2007: How much more rain will global warming bring? *Science*, **317(5835)**, 233-235.

[78] Stott, P.A., D.A. Stone, and M.R. Allen, 2004: Human contribution to the European heatwave of 2003. *Nature*, **432(7017)**, 610-614.

[79] CCSP, 2008: Introduction. In: *Climate Models: An Assessment of Strengths and Limitations* [Bader, D.C., C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian, and M.H. Zhang (authors)]. Synthesis and Assessment Product 3.1 U.S. Department of Energy, Office of Biological and Environmental Research, Washington, DC, pp. 7-12.

[80] Randall, D.A., R.A. Wood, S. Bony, R. Coman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi, and K.E. Taylor, 2007: Climate models and their evaluation. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 589-662.

[81] Nakićenović, N. and R. Swart (eds.), 2000: *Special Report on Emissions Scenarios*. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, 599 pp. <http://www.ipcc.ch/ipccreports/sres/emission/index.htm>

[82] Raupach, M.R., G. Marland, P. Ciais, C. Le Quéré, J.G. Canadell, G. Klepper, and C.B. Field, 2007: Global and regional drivers of accelerating CO_2 emissions. *Proceedings of the National Academy of Sciences*, **104(24)**, 10288-10293.

[83] O'Neill, B.C. and M. Oppenheimer, 2004: Climate change impacts are sensitive to the concentration stabilization path. *Proceedings of the National Academy of Sciences*, **101(47)**, 16411-16416.

[84] Schneider, S.H. and M.D. Mastrandrea, 2005: Probabilistic assessment of ''dangerous'' climate change and emissions pathways. *Proceedings of the National Academy of Sciences*, **102(44)**, 15728-15735.

[85] Lenton, T.M., H. Held, E. Kriegler, J.W. Hall, W. Lucht, S. Rahmstorf, and H.J. Schellnhuber, 2008: Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences*, **105(6)**, 1786-1793.

[86] Hansen, J., M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R. Miller, L. Nazarenko, K. Lo, G.A. Schmidt, G. Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N.Y. Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, N. Unger, M. Yao, and S. Zhang, 2007: Dangerous human-made interference with climate: a GISS modelE study. *Atmospheric Chemistry and Physics*, **7(9)**, 2287-2312.

[87] Ramanathan, V. and Y. Feng, 2008: On avoiding dangerous anthropogenic interference with the climate system: formidable challenges ahead. *Proceedings of the National Academy of Sciences*, **105(38)**, 14245-14250.

[88] Meinshausen, M., 2006: What does a 2°C target mean for greenhouse gas concentrations? - A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates. In: *Avoiding Dangerous Climate Change* [Schellnhuber, J.S., W. Cramer, N. Nakićenović, T.M.L. Wigley, and G. Yohe (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 265-280.

[89] Meinshausen, M., B. Hare, T.M.L. Wigley, D. van Vuuren, M.G.J. den Elzen, and R. Swart, 2006: Multi-gas emission pathways to meet climate targets. *Climatic Change*, **75(1)**, 151-194.

[90] Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao, 2007: Global climate projections. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 747-845.

[91] Refer to the description of the emissions scenarios in the *Global Climate Change* section on pages 22-25. "Lower emissions scenario" refers to IPCC SRES B1, "higher emissions scenario" refers to A2 and "even higher emissions scenario" refers to A1FI.

[92] IPCC Emissions Scenarios (Even Higher, Higher Emission Scenario, Lower Emission Scenario): Nakićenović, N. and R. Swart (eds.), 2000: Appendix VII: Data tables. In: *Special Report on Emissions Scenarios*. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York. <http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/> Emission trajectories are spline fits as per Raupach, M.R., G. Marland, P. Ciais, C. Le Quéré, J.G. Canadell, G. Klepper, and C.B. Field, 2007: Global and regional drivers of accelerating CO_2 emissions. *Proceedings of the National Academy of Sciences*, **104(24)**, 10288-10293.

Stabilization scenario (450 ppm): CCSP 2.1a Scenario Information 070707 data file. From: Clarke, L., J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, and R. Richels, 2007: *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*. Sub-report 2.1A of Synthesis and Assessment Product 2.1. U.S. Department of Energy, Office of Biological & Environmental Research, Washington, DC. The emissions and concentrations shown were from MINICAM 1 and 2. See CCSP 2.1A Executive summary for more information. Spread sheet available at <http://www.climatescience.gov/Library/sap/sap2-1/finalreport/default.htm>

Observations of CO_2 emissions (Fossil Fuel CO_2 Emissions graphic) are updates to: Marland, G., B. Andres, T. Boden, 2008: *Global CO_2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2005.* Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN. <http://cdiac.ornl.gov/ftp/ndp030/global.1751_2005.ems>

Observations of CO_2 concentrations (Atmospheric CO_2 Concentrations graphic): Tans, P., 2008: *Trends in Atmospheric Carbon Dioxide: Mauna Loa*. NOAA Earth System Research Laboratory (ESRL). [Web site] <http://www.esrl.noaa.gov/gmd/ccgg/trends/> Data available at <ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt>

[93] CMIP3-A: This analysis uses 15 models simulations from the WCRP CMIP3 that were available at resolutions finer than 4 degrees (CCSM3.0, CSIRO, UKMO-HadCM3, IPSL, ECHAM5/MPI, CGCM3.1(T47), GFDL2.0, UKMO-HadGEM1, MIROC3.2(medres), MRI-CGCM2.3.2a, CNRM, GFDL2.1, INM-CM3, ECHO-G, PCM). See Wehner, M., 2005: Changes in daily precipitation and surface air temperature extremes in the IPCC AR4 models. *US CLIVAR Variations*, **3(3)**, 5-9.

Hatching indicates at least two out of three models agree on the sign of the projected change in precipitation.

We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset, <http://www-pcmdi.llnl.gov/projects/cmip/index.php>. Support of this dataset is provided by the Office of Science, U.S. Department of Energy. For an overview and documentation of the CMIP3 modelling activity, see Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor, 2007: The WCRP CMIP3 multi-model dataset: a new era in climate change research. *Bulletin of the American Meteorological Society*, **88(9)**, 1383-1394.

[94] Hare, B. and M. Meinshausen, 2006: How much warming are we committed to and how much can be avoided? *Climatic Change*, **75(1)**, 111-149.

[95] den Elzen, M.G.J. and M. Meinshausen, 2006: Multi-gas emission pathways for meeting the EU 2°C climate target. In: *Avoiding Dangerous Climate Change* [Schellnhuber, J.S., W. Cramer, N. Nakićenović, T.M.L. Wigley and G. Yohe (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 299-310.

[96] Seidel, D.J., Q. Fu, W.J. Randel, and T.J. Reichler, 2008: Widening of the tropical belt in a changing climate. *Nature Geoscience*, **1(1)**, 21-24.

[97] Cook, E.R., P.J. Bartlein, N. Diffenbaugh, R. Seager, B.N. Shuman, R.S. Webb, J.W. Williams, and C. Woodhouse, 2008: Hydrological variability and change. In: *Abrupt Climate Change*. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 143-257.

[98] Emanuel, K., 2005: Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, **436(7051)**, 686-688.

[99] Vecchi, G.A., K.L. Swanson, and B.J. Soden, 2008: Whither hurricane activity? *Science*, **322(5902)**, 687-689.

[100] Emanuel, K., R. Sundararajan, and J. Williams, 2008: Hurricanes and global warming: Results from downscaling IPCC AR4 simulations. *Bulletin of the American Meteorological Society*, **89(3)**, 347-367.

[101] Vecchi, G.A. and B.J. Soden, 2007: Effect of remote sea surface temperature change on tropical cyclone potential intensity. *Nature*, **450(7172)**, 1077-1070.

[102] Alley, R.B., P.U. Clark, P. Huybrechts, and I. Joughin, 2005: Ice-sheet and sea-level changes ice-sheet and sea-level changes. *Science*, **310(5747)**, 456-460.

[103] Rahmstorf, S., 2007: A semi-empirical approach to projecting future sea-level rise. *Science*, **315(5810)**, 368-370.

[104] Mitrovica, J.X., N. Gomez, and P.U. Clark, 2009: The sea-level fingerprint of West Antarctic collapse. *Science*, **323(5915)**, 753.

[105] Clark, P.U., A.J. Weaver, E. Brook, E.R. Cook, T.L. Delworth, and K. Steffen, 2008: Introduction: Abrupt changes in the Earth's climate system. In: *Abrupt Climate Change*. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 19-59.

[106] Brook, E., D. Archer, E. Dlugokencky, S. Frolking, and D. Lawrence, 2008: Potential for abrupt changes in atmospheric methane. In: *Abrupt Climate Change*. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 360-452.

[107] Temperatures for the contiguous U.S. are based on data from the U.S. Historical Climatology Network Version 2 (Menne *et al*. 2008). Temperatures for Alaska, Hawaii, and Puerto Rico are based on data from the Cooperative Observers Network adjusted to remove non-climatic influences such as changes in instruments and observer practices and changes in the station environment (Menne and Williams, 2008).

U.S. time series on page 27 is calculated with data for the contiguous US, Alaska, and Hawaii. US map on page 28 lower left includes observed temperature change in Puerto Rico. Winter temperature trend map in the agriculture section, page 76, is for the contiguous US only.

References for this endnote:

Menne, M.J., C.N. Williams, and R.S. Vose, 2009: The United States Historical Climatology Network Monthly Temperature Data - Version 2. *Bulletin of the American Meteorological Society*, Early online release, 25 February 2009, doi:10.1175/2008BAMS2613.1

Menne, M.J. and C.N. Williams Jr., 2008: Homogenization of temperature series via pairwise comparisons. *Journal of Climate*, **22(7)**, 1700-1717.

[108] Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, 2007: Regional climate projections. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 847-940.

[109] CMIP3-C: Analysis for the contiguous U.S. was based on methods described in: Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville, 2004: Emission pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, **101(34)**, 12422-12427; and Hayhoe, K., C. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A.M. Stoner, and D. Wuebbles, 2008: Regional climate change projections for the Northeast USA. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 425-436. This analysis uses 16 models simulations from the WCRP CMIP3. Where models had multiple runs, only the first run available from each model was used. See <http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html> for more information.

The Alaskan projections are based on 14 models that best captured the present climate of Alaska; see Walsh, J.E., W.L. Chaman, V. Romanovsky, J.H. Christensen, and M. Stendel, 2008: Global climate model performance over Alaska and Greenland. *Journal of Climate*, **21(23)**, 6156-6174.

Caribbean and Pacific islands analyses use 15 models simulations from the WCRP CMIP3 that were available at resolutions finer than 4 degrees (CCSM3.0, CSIRO, UKMO-HadCM3, IPSL, ECHAM5/MPI, CGCM3.1(T47), GFDL2.0, UKMO-HadGEM1, MIROC3.2(medres), MRI-CGCM2.3.2a, CNRM, GFDL2.1, INM-CM3, ECHO-G, PCM). See Wehner, M., 2005: Changes in daily precipitation and surface air temperature extremes in the IPCC AR4 models. *US CLIVAR Variations*, **3(3)**, 5-9.

We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset, <http://www-pcmdi.llnl.gov/projects/cmip/index.php>. Support of this dataset is provided by the Office of Science, U.S. Department of Energy. For an overview and documentation of the CMIP3 modelling activity, see Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor, 2007: The WCRP CMIP3 multi-model dataset: a new era in climate change research. *Bulletin of the American Meteorological Society*, **88(9)**, 1383-1394.

[110] Detailed local-scale projections about temperature and precipitation changes displayed in this report were generated using well-documented "statistical downscaling" techniques [Wood *et al*., 2002] for the contiguous U.S. and Alaska. These techniques use statistical relationships between surface observations and climate simulations of the past to develop modifications for the global model results. These modifications are then applied to the climate projections for the future scenarios. The approach is also used to drive daily simulations by a well-established hydrological modeling framework for the contiguous U.S. [Liang *et al*., 1994]. This method, which modifies global climate model simulations to better account for landscape variations and other features affecting climate at the regional to local scale, has been previously applied to generate high-resolution regional climate projections for the Northeast, Midwest, Northwest, and Southwest [Wood *et al*., 2004; Hayhoe *et al*., 2004; Hayhoe *et al*., 2008; Cayan *et al*., 2008; Cherkauer *et al*., 2009]. Comparison of these methods with dynamically downscaled projections generated using regional climate model simulations provide strong justification for the use of such techniques [Wood *et al*., 2004; Hayhoe *et al*., 2008].

References for this endnote:

Cayan, D., E. Maurer, M. Dettinger, M. Tyree, and K. Hayhoe, 2008: Climate change scenarios for the California region. *Climatic Change*, **87(Supplement 1)**, S21-S42.

Cherkauer, K. and T. Sinha, 2009: Hydrologic impacts of projected future climate change in the Lake Michigan region. *Journal of Great Lakes Research*, in press.

Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville, 2004: Emission pathways, climate change, and impacts on Cali-

fornia. *Proceedings of the National Academy of Sciences*, **101(34)**, 12422-12427.

Hayhoe, K., C. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A.M. Stoner, and D. Wuebbles, 2008: Regional climate change projections for the Northeast USA. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 425-436.

Liang, X., D. Lettenmaier, E. Wood, and S. Burges, 1994: A simple hydrologically-based model of land surface water and energy fluxes for general circulation models. *Journal of Geophysical Research*, **99(D7)**, 14415-14428.

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen, 2002: A long-term hydrologically-based data set of land surface fluxes and states for the conterminous United States. *Journal of Climate*, **15(22)**, 3237-3251.

Wood, A.W., L.R. Leung, V. Sridhar, and D.P. Lettenmaier, 2004: Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs. *Climatic Change*, **62(1-3)**, 189-216.

Wood, A.W., E.P. Maurer, A. Kumar, and D.P. Lettenmaier, 2002: Long range experimental hydrologic forecasting for the eastern U.S. *Journal of Geophysical Research*, **107(D20)**, 4429, doi:10.1029/2001JD000659.

[111] NOAA's National Climatic Data Center, 2008: *The USHCN Version 2 Serial Monthly Dataset*. [Web site] <http://www.ncdc.noaa.gov/oa/climate/research/ushcn/>

[112] Kunkel, K.E., P.D. Bromirski, H.E. Brooks, T. Cavazos, A.V. Douglas, D.R. Easterling, K.A. Emanuel, P.Ya. Groisman, G.J. Holland, T.R. Knutson, J.P. Kossin, P.D. Komar, D.H. Levinson, and R.L. Smith, 2008: Observed changes in weather and climate extremes. In: *Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 35-80.

[113] Groisman, P.Ya., R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, and J.H. Lawrimore, 2004: Contemporary changes of the hydrological cycle over the contiguous United States, trends derived from *in situ* observations. *Journal of Hydrometeorology*, **5(1)**, 64-85. The climate regions are different than those used in this article but the methodology is identical.

[114] Karl, T.R., G.A. Meehl, T.C. Peterson, K.E. Kunkel, W.J. Gutowski Jr., and D.R. Easterling, 2008: Executive summary. In: *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 1-9.

[115] Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H.-P. Huang, N. Harnik, A. Leetmaa, N.-C. Lau, C. Li, J. Velez, and N. Naik, 2007: Model projections of an imminent transition to a more arid climate in southwestern North America. *Science*, **316(5828)**, 1181-1184.

[116] USGS, 2005: *Changes in Streamflow Timing in the Western United States in Recent Decades*. USGS fact sheet 2005-3018. U.S. Geological Survey, National Streamflow Information Program, La Jolla, CA, 4 pp. <http://pubs.usgs.gov/fs/2005/3018/>

[117] CMIP3-B: Analysis for the contiguous U.S. was based on methods described in: Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville, 2004: Emission pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, **101(34)**, 12422-12427; and Hayhoe, K., C. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A.M. Stoner, and D. Wuebbles, 2008: Regional climate change projections for the Northeast USA. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 425-436. This analysis uses 16 models simulations from the WCRP CMIP3. Where models had multiple runs, only the first run available from each model was used. See <http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html> for more information.

We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset, <http://www-pcmdi.llnl.gov/projects/cmip/index.php>. Support of this dataset is provided by the Office of Science, U.S. Department of Energy. For an overview and documentation of the CMIP3 modelling activity, see Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor, 2007: The WCRP CMIP3 multi-model dataset: a new era in climate change research. *Bulletin of the American Meteorological Society*, **88(9)**, 1383-1394.

[118] Swanson, K.L., 2008: Nonlocality of Atlantic tropical cyclone intensities. *Geochemistry, Geophysics, Geosystems*, **9**, Q04V01, doi:10.1029/2007GC001844.

[119] Knutson, T.R., J.J. Sirutis, S.T. Garner, G.A. Vecchi, and I. Held, 2008: Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions. *Nature Geoscience*, **1(6)**, 359-364.

[120] Emanuel, K., 2007: Environmental factors affecting tropical cyclone power dissipation. *Journal of Climate*, **20(22)**, 5497-5509.

[121] Number of strongest hurricanes, number of landfalling strongest hurricanes, and number of landfalling hurricanes are based on data obtained from NOAA's Oceanographic and Meteorological Laboratory: <http://www.aoml.noaa.gov/hrd/hurdat/ushurrlist18512005-gt.txt> with updates. The total number of named storms are adjusted to account for missing tropical storms and hurricanes in the pre-satellite era using the method of Vecchi and Knutson (2008). Basin and landfalling totals are displayed in 5-year increments (pentads) from 1881 through 2010. The final 5-year period was standardized to a comparable 5-year period assuming the level of activity from 2006 to 2008 persists through 2010.

Vecchi, G.A. and T.R. Knutson, 2008: On estimates of historical North Atlantic tropical cyclone activity. *Journal of Climate*, **21(14)**, 3580-3600.

[122] Elsner, J.B., J.P. Kossin, and T.H. Jagger, 2008: The increasing intensity of the strongest tropical cyclones. *Nature*, **455(7209)**, 92-95.

[123] Bell, G.D. and M. Chelliah, 2006: Leading tropical modes associated with interannual and multidecadal fluctuations in North Atlantic hurricane activity. *Journal of Climate*, **19(4)**, 590-612.

[124] Levinson, D.H. and J. Lawrimore (eds.), 2008: State of the climate in 2007. *Bulletin of the American Meteorological Society*, **89(7, Supplement)**, S1-S179.

[125] Kossin, J.P., K.R. Knapp, D.J. Vimont, R.J. Murnane, and B.A. Harper, 2007: A globally consistent reanalysis of hurricane variability and trends. *Geophysical Research Letters*, **34**, L04815, doi:10.1029/2006GL028836.

[126] Rahmstorf, S., A. Cazenave, J.A. Church, J.E. Hansen, R.F. Keeling, D.E. Parker, and R.C.J. Somerville, 2007: Recent climate observations compared to projections. *Science*, **316(5825)**, 709.

[127] Zervas, C., 2001: *Sea Level Variations of the United States 1985-1999*. NOAA technical report NOS CO-OPS 36. National Oceanic and Atmospheric Administration, Silver Spring, MD, 66 pp.

<http://tidesandcurrents.noaa.gov/publications/techrpt36doc.pdf> Trends were calculated for locations that had at least 10 months of data per year and at least 41 years of data during the 51-year period.

[128] Sea-level rise numbers are calculated based on an extrapolation of NOAA tide gauge stations with records exceeding 50 years, as reported in Zervas, C., 2001: *Sea Level Variations of the United States 1985-1999*. NOAA technical report NOS CO-OPS 36. National Oceanic and Atmospheric Administration, Silver Spring, MD, 66 pp. <http://tidesandcurrents.noaa.gov/publications/techrpt36doc.pdf>

[129] Kunkel, K.E., N.E. Westcott, and D.A.R. Knistovich, 2002: Assessment of potential effects of climate changes on heavy lake-effect snowstorms near Lake Erie. *Journal of Great Lakes Research*, **28(4)**, 521-536.

[130] Burnett, A.W., M.E. Kirby, H.T. Mullins, and W.P. Patterson, 2003: Increasing Great Lake-effect snowfall during the twentieth century: a regional response to global warming? *Journal of Climate*, **16(21)**, 3535-3542.

[131] Trapp, R.J., N.S. Diffenbaugh, H.E. Brooks, M.E. Baldwin, E.D. Robinson, and J.S. Pal, 2007: Changes in severe thunderstorm environment frequency during the 21st century caused by anthropogenically enhanced global radiative forcing. *Proceedings of the National Academy of Sciences*, **104(50)**, 19719-19723.

[132] ACIA, 2005: *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, and New York, 1042 pp. <http://www.acia.uaf.edu/pages/scientific.html>

[133] Stroeve, J., M.M. Holland, W. Meier, T. Scambos, and M. Serreze, 2007: Arctic sea ice decline: faster than forecast. *Geophysical Research Letters*, **34**, L09501, doi:10.1029/2007GL029703.

[134] L'Heureux, M.L., A. Kumar, G.D. Bell, M.S. Halpert, and R.W. Higgins, 2008: Role of the Pacific-North American (PNA) pattern in the 2007 Arctic sea ice decline. *Geophysical Research Letters*, **35**, L20701, doi:10.1029/2008GL035205.

[135] Johannessen, O.M., 2008: Decreasing Arctic sea ice mirrors increasing CO_2 on decadal time scale. *Atmospheric and Oceanic Science Letters*, **1(1)**, 51-56.

[136] National Snow and Ice Data Center, 2008: *Arctic Sea Ice Down to Second-Lowest Extent; Likely Record-Low Volume*. Press release October 2, 2008. <http://nsidc.org/news/press/20081002_seaice_pressrelease.html>

[137] Polyak, L., J. Andrews, J. Brigham-Grette, D. Darby, A. Dyke, S. Funder, M. Holland, A. Jennings, J. Savelle, M. Serreze, and E. Wolff, 2009: History of sea ice in the Arctic. In: *Past Climate Variability and Change in the Arctic and at High Latitude*. Synthesis and Assessment Product 1.2. U.S. Geological Survey, Reston, VA, pp. 358-420.

[138] Images from *Sea Ice Yearly Minimum 1979-2007.* [Web site] NASA/Goddard Space Flight Center Scientific Visualization Studio. Thanks to Rob Gerston (GSFC) for providing the data. <http://svs.gsfc.nasa.gov/goto?3464>

[139] Fetterer, F., K. Knowles, W. Meier, and M. Savoie, 2002: updated 2008: *Sea Ice Index*. [Web site] National Snow and Ice Data Center, Boulder, CO. <http://nsidc.org/data/seaice_index/>

[140] Pacala, S., R. Birdsey, S. Bridgham, R.T. Conant, K. Davis, B. Hales, R. Houghton, J.C. Jenkins, M. Johnston, G. Marland, and K. Paustian, 2007: The North American carbon budget past and present. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* [King, A.W., L. Dilling, G.P. Zimmerman, D.F. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, pp. 29-36.

[141] Marland, G., R.J. Andres, T.J. Blasing, T.A. Boden, C.T. Broniak, J.S. Gregg, L.M. Losey, and K. Treanton, 2007: Energy, industry, and waste management activities: an introduction to CO_2 emissions from fossil fuels. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* [King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, pp. 57-64.

[142] Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof (eds.), 2008: *Climate Change and Water*. Technical paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, Switzerland, 210 pp.

[143] Feng, S. and Q. Hu, 2007: Changes in winter snowfall/precipitation ratio in the contiguous United States. *Journal of Geophysical Research*, **112**, D15109, doi:10.1029/2007JD008397.

[144] Guttman, N.B. and R.G. Quayle, 1996: A historical perspective of U.S. climate divisions. *Bulletin of the American Meteorological Society*, **77(2)**, 293-303. Operational practices described in this paper continue.

[145] Groisman, P.Ya., R.W. Knight, D.R. Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev, 2005: Trends in intense precipitation in the climate record. *Journal of Climate*, **18(9)**, 1326-1350.

[146] Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen, and I.A. Shiklomanov, 2007: Freshwater resources and their management. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 173-210.

[147] Groisman, P.Ya. and R.W. Knight, 2008: Prolonged dry episodes over the conterminous United States: new tendencies emerging during the last 40 years. *Journal of Climate*, **21(9)**, 1850-1862.

[148] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl, 2006: Going to the extremes: an intercomparison of model-simulated historical and future changes in extreme events. *Climatic Change*, **79(3-4)**, 185-211.

[149] Lettenmaier, D., D. Major, L. Poff, and S. Running, 2008: Water resources. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 121-150.

[150] Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe, 2007: Past and future changes in climate and hydrological indicators in the U.S. Northeast. *Climate Dynamics*, **28(4)**, 381-407.

[151] Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer, 2008: Stationarity is dead: Whither water management? *Science*, **319(5863)**, 573-574.

[152] Christensen, N.S., A.W. Wood, N. Voisin, D.P. Lettenmaier, and R.N. Palmer, 2004: The effects of climate change on the hydrology

and water resources of the Colorado River basin. *Climatic Change*, **62(1-3)**, 337-363.

[153] Mote, P., A. Hamlet, and E. Salathé, 2008: Has spring snowpack declined in the Washington Cascades? *Hydrology and Earth System Sciences*, **12(1)**, 193-206.

[154] Knowles, N., M.D. Dettinger, and D.R. Cayan, 2006: Trends in snowfall versus rainfall in the western United States. *Journal of Climate*, **19(18)**, 4545-4559.

[155] Huntington T.G., G.A. Hodgkins, B.D. Keim, and R.W. Dudley, 2004: Changes in the proportion of precipitation occurring as snow in New England (1949 to 2000). *Journal of Climate*, **17(13)**, 2626-2636.

[156] Burakowski, E.A., C.P. Wake, B. Braswell, and D.P. Brown, 2008: Trends in wintertime climate in the northeastern United States: 1965–2005. *Journal of Geophysical Research*, **113**, D20114, doi:10.1029/2008JD009870/

[157] Stewart, I.T., D.R. Cayan, and M.D. Dettinger, 2004: Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario. *Climatic Change*, **62(1-3)**, 217-232.

[158] Stewart, I.T., D.R. Cayan, and M.D. Dettinger, 2005: Changes toward earlier streamflow timing across western North America. *Journal of Climate*, **18(8)**, 1136-1155.

[159] Rauscher, S.A., J.S. Pal, N.S. Diffenbaugh, and M.M. Benedetti, 2008: Future changes in snowmelt-driven runoff timing over the western United States. *Geophysical Research Letters*, **35**, L16703, doi:10.1029/2008GL034424.

[160] Pierce, D.W., T.P. Barnett, H.G. Hidalgo, T. Das, C. Bonfils, B.D. Santer, G. Bala, M.D. Dettinger, D.R. Cayan, A. Mirin, A.W. Wood, and T. Nozawa, 2008: Attribution of declining western U.S. snowpack to human effects. *Journal of Climate*, **21(23)**, 6425-6444.

[161] Bonfils, C., B.D. Santer, D.W. Pierce, H.G. Hidalgo, G. Bala, T. Das, T.P. Barnett, D.R. Cayan, C. Doutriaux, A.W. Wood, A. Mirin, and T. Nozawa, 2008: Detection and attribution of temperature changes in the mountainous western United States. *Journal of Climate*, **21(23)**, 6404-6424.

[162] U.S. Environmental Protection Agency, 2008: *National Water Program Strategy: Response to Climate Change*. U.S. Environmental Protection Agency, Washington, DC, 97 pp. <http://www.epa.gov/water/climatechange/>

[163] Ebi, K.L., J. Balbus, P.L. Kinney, E. Lipp, D. Mills, M.S. O'Neill, and M. Wilson, 2008: Effects of global change on human health. In: *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* [Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, and T.J. Wilbanks (authors)]. Synthesis and Assessment Product 4.6. U.S. Environmental Protection Agency, Washington, DC, pp. 39-87.

[164] Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott, 2007: North America. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 617-652.

[165] Winter, J., J.W. Harvey, O.L. Franke, and W.M. Alley, 1998: *Ground Water and Surface Water: A Single Resource*. USGS circular 1139. U.S. Geological Survey, Denver, CO, 79 pp. <http://pubs.usgs.gov/circ/circ1139/>

[166] Austin, J.A. and S.M. Colman, 2007: Lake Superior summer water temperatures are increasing more rapidly than regional air temperatures: a positive ice-albedo feedback. *Geophysical Research Letters*, **34**, L06604, doi:10.1029/2006GL029021.

[167] U.S. General Accounting Office, 2003: *Freshwater Supply: States' Views of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*. GAO-03-514. General Accounting Office, Washington, DC, 110 pp. <http://www.gao.gov/new.items/d03514.pdf>

[168] U.S. Environmental Protection Agency, 2002: *The Clean Water and Drinking Water Infrastructure Gap Analysis*. EPA-816-R-02-020. U.S. Environmental Protection Agency, Washington, DC, 50 pp. <http://www.epa.gov/safewater/gapreport.pdf>

[169] National Research Council, 2004: *Confronting the Nation's Water Problems: The Role of Research*. National Academies Press, Washington, DC, 310 pp.

[170] Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos, and R.T. Perez, 2007: Perspectives on climate change and sustainability. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 811-841.

[171] U.S. Bureau of Reclamation, 2005: *Water 2025: Preventing Crises and Conflict in the West*. U.S. Bureau of Reclamation, Washington, DC, 32 pp. Updated from USBR <http://www.usbr.gov/uc/crsp/GetSiteInfo>

[172] Wilbanks, T.J., P. Romero Lankao, M. Bao, F. Berkhout, S. Cairncross, J.-P. Ceron, M. Kapshe, R. Muir-Wood, and R. Zapata-Marti, 2007: Industry, settlement and society. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 357-390.

[173] Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 717-743.

[174] Hartmann, H.C., 2008: Decision support for water resources management. In: *Uses and Limitations of Observations, Data, Forecasts and Other Projections in Decision Support for Selected Sectors and Regions*. Synthesis and Assessment Product 5.1. U.S. Climate Change Science Program, Washington, DC, pp. 45-55.

[175] Ruhl, J.B., 2005: Water wars, eastern style: divvying up the Apalachicola-Chattahoochee-Flint River Basin. *Journal of Contemporary Water Research & Education*, **131**, 47-54.

[176] Leitman, S., 2008: Lessons learned from transboundary management efforts in the Apalachicola-Chattahoochee-Flint Basin, USA. In: *Transboundary Water Resources: A Foundation for Regional Stability in Central Asia* [Moerlins, J.E., M.K. Khankhasayev, S.F. Leitman, and E.J. Makhmudov (eds.)]. Springer, Dordrecht and London, pp. 195-208.

[177] Gobalet, K., P. Schulz, T. Wake, and N. Siefkin, 2004: Archaeological perspectives on Native American fisheries of California, with emphasis on steelhead and salmon. *Transactions of the American Fisheries Society*, **133(4)**, 801-833.

[178] Hammersmark, C., W. Fleenor, and S. Schladow, 2005: Simulation of flood impact and habitat extent for a tidal freshwater marsh restoration. *Ecological Engineering*, **25(2)**, 137-152.

[179] Kondolf, G., P. Angermeier, K. Cummins, T. Dunne, M. Healey, W. Kimmerer, P. Moyle, D. Murphy, D. Patten, S. Railsback, D. Reed, R. Spies, and R. Twiss, 2008: Projecting cumulative benefits of multiple river restoration projects: An example from the Sacramento-San Joaquin River system in California. *Environmental Management*, **42(6)**, 933-945.

[180] McKee, L., N. Ganju, and D. Schoellhamer, 2006: Estimates of suspended sediment entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California. *Journal of Hydrology*, **323(1-4)**, 335-352.

[181] Trenham, P., H. Shaffer, and P. Moyle, 1998: Biochemical identification and assessment of population subdivision in morphologically similar native and invading smelt species (*Hypomesus*) in the Sacramento San Joaquin estuary, California. *Transactions of the American Fisheries Society*, **127(3)**, 417-424.

[182] Vengosh, A., J. Gill, M. Davisson, and G. Hudson, 2002: A multiisotope (B, Sr, O, H, and C) and age dating (^{3}H-^{3}He and ^{14}C) study of groundwater from Salinas Valley, California: hydrochemistry, dynamics, and contamination processes. *Water Resources Research*, **38(1)**, 1008, doi:10.1029/2001WR000517.

[183] Haggerty, G.M., D. Tave, R. Schmidt-Petersen, and J. Stomp, 2008: Raising endangered fish in New Mexico. *Southwest Hydrology*, **7(4)**, 20-21.

[184] National Research Council, 2004: *Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery*. National Academies Press, Washington, DC, 398 pp.

[185] National Research Council, 2008: *Hydrology, Ecology, and Fishes of the Klamath River Basin*. National Academies Press, Washington, DC, 272 pp.

[186] National Research Council, 2007: *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability*. National Academies Press, Washington, DC, 218 pp.

[187] U.S. Bureau of Reclamation, 2007: *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead: Final Environmental Impact Statement*. [U.S. Bureau of Reclamation, Boulder City, NV], 4 volumes. <http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html>

[188] University of Arizona, Undated: *Native American Water Rights in Arizona*. [Web site] <http://www.library.arizona.edu/about/libraries/govdocs/waterdoc.html>

[189] Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, and D.W. Stahle, 2004: Long-term aridity changes in the western United States. *Science*, **306(5698)**, 1015-1018.

[190] Ingram, H., D. Feldman, N. Mantua, K.L. Jacobs, D. Fort, N. Beller-Simms, and A.M. Waple, 2008: The changing context. In: *Decision-Support Experiments and Evaluations Using Seasonal-to-Interannual Forecasts and Observational Data: A Focus on Water Resources* [Beller-Simms, N., H. Ingram, D. Feldman, N. Mantua, K.L. Jacobs, and A.M. Waple (eds.)]. Synthesis and Assessment Product 5.3. NOAA's National Climatic Data Center, Asheville, NC, pp. 7-28.

[191] Bull, S.R., D.E. Bilello, J. Ekmann, M.J. Sale, and D.K. Schmalzer, 2007: Effects of climate change on energy production and distribution in the United States. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. 45-80.

[192] Hyman, R.C., J.R. Potter, M.J. Savonis, V.R. Burkett, and J.E. Tump, 2008: Why study climate change impacts on transportation? In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. 1-1 to 1F-2 [48 pp.]

[193] Hatfield, J., K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, and D. Wolfe, 2008: Agriculture. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 21-74.

[194] Feldman, D.L., K.L. Jacobs, G. Garfin, A. Georgakakos, B. Morehouse, P. Restrepo, R. Webb, B. Yarnal, D. Basketfield, H.C. Hartmann, J. Kochendorfer, C. Rosenzweig, M. Sale, B. Udall, and C. Woodhouse, 2008: Making decision-support information useful, useable, and responsive to decision-maker needs In: *Decision-Support Experiments and Evaluations Using Seasonal-to-Interannual Forecasts and Observational Data: A Focus on Water Resources* [Beller-Simms, N., H. Ingram, D. Feldman, N. Mantua, K.L. Jacobs, and A.M. Waple (eds.)]. Synthesis and Assessment Product 5.3. NOAA's National Climatic Data Center, Asheville, NC, pp. 101-140.

[195] McCabe, G.J. and D.M. Wolock, 2007: Warming may create substantial water supply shortages in the Colorado River basin. *Geophysical Research Letters*, **34**, L22708, doi:10.1029/2007GL031764.

[196] Brekke, L., B. Harding, T. Piechota, B. Udall, C. Woodhouse, and D. Yates (eds.), 2007: Appendix U: Climate Technical Work Group Report: Review of science and methods for incorporating climate change information into Bureau of Reclamation's Colorado River Basin planning studies. In: *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead: Final Environmental Impact Statement*. U.S. Bureau of Reclamation, Boulder City, NV, 110 pp. <http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html>

[197] U.S. Department of Energy, 2006: *Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water*. Sandia National Laboratories, Albuquerque, NM, 80 pp. <http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf>

[198] California Energy Commission, 2005: *California's Water -- Energy Relationship*. CEC-700-2005-011-SF. California Energy Commission, [Sacramento], 174 pp. <http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF>

[199] California Energy Commission, 2006: *Refining Estimates of Water-related Energy Use in California*. CEC-500-2006-118. California Energy Commission, [Sacramento]. <http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF>

[200] U.S. Energy Information Administration, 2008: *Energy in Brief: What are Greenhouse Gases and How Much are Emitted by the United States?* [Web site] Energy Information Administration, Washington, DC. <http://tonto.eia.doe.gov/energy_in_brief/greenhouse_gas.cfm>

[201] Wilbanks, T.J., *et al*., 2007: Executive summary. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer,

and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. x-xii.

[202] From *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, U.S. EPA. Allocations from "Electricity & Heat" and "Industry" to end uses are WRI estimates based on energy use data from the International Energy Agency (IEA, 2005). All data is for 2003. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996).

[203] U.S. Energy Information Administration, 2008: *Annual Energy Review 2007.* U.S. Department of Energy, Washington, DC, 400 pp. <http://www.eia.doe.gov/emeu/aer/pdf/aer.pdf>

[204] Bhatt, V., J. Eckmann, W.C. Horak, and T.J. Wilbanks, 2007: Possible indirect effects on energy production and distribution in the United States. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. 81-97.

[205] Scott, M.J. and Y.J. Huang, 2007: Effects of climate change on energy use in the United States. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. 8-44.

[206] U.S. Department of Energy, 2008: *Buildings Energy Data Book*. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, [Washington, DC]. <http://buildingsdatabook.eere.energy.gov/>

[207] U.S. Census Bureau, 2002: *Population of States and Counties of the United States: 1790-2000.* U.S. Census Bureau, Washington, DC, 226 pp. <http://www.census.gov/population/www/censusdata/hiscendata.html> See <http://www.census.gov/popest/counties/> for 2008 estimates.

[208] Feldman, D.L., K.L. Jacobs, G. Garfin, A. Georgakakos, B. Morehouse, R. Webb, B. Yarnal, J. Kochendorfer, C. Rosenzweig, M. Sale, B. Udall, and C. Woodhouse, 2008: Decision-support experiments within the water resource management sector. In: *Decision-Support Experiments and Evaluations Using Seasonal-to-Interannual Forecasts and Observational Data: A Focus on Water Resources* [Beller-Simms, N., H. Ingram, D. Feldman, N. Mantua, K.L. Jacobs, and A.M. Waple (eds.)]. Synthesis and Assessment Product 5.3. NOAA's National Climatic Data Center, Asheville, NC, pp. 65-100.

[209] Hightower, M. and S.A. Pierce, 2008: The energy challenge. *Nature*, **452(7185)**, 285-286.

[210] Wilbanks, T.J., *et al*., 2007: Conclusions and research priorities. In: *Effects of Climate Change on Energy Production and Use in the United States* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program, Washington, DC, pp. 98-108.

[211] Maulbetsch, J.S. and M.N. DiFilippo, 2006: *Cost and Value of Water Use at Combined Cycle Power Plants*. CEC-500-2006-034. California Energy Commission, PIER Energy-Related Environmental Research. <http://www.energy.ca.gov/2006publications/CEC-500-2006-034/CEC-500-2006-034.PDF>

[212] U.S. Energy Information Administration, 2002: *National Trends in Coal Transportation*. [Web site] Energy Information Administration, Washington, DC. <http://www.eia.doe.gov/cneaf/coal/ctrdb/natltrends.html>

[213] NOAA's National Climatic Data Center, 2008: *Climate of 2008: Midwestern U.S. Flood Overview*. [Web site] <http://www.ncdc.noaa.gov/oa/climate/research/2008/flood08.html>

[214] CBO Testimony, 2005: *Macroeconomic and Budgetary Effects of Hurricanes Katrina and Rita.* Statement of Douglas Holtz-Easkin, Director, before the Committee on the Budget, U.S. House of Representatives. Congressional Budget Office, Washington, DC, 21 pp. <http://www.cbo.gov/doc.cfm?index=6684>

[215] Potter, J.R., V.R. Burkett, and M.J. Savonis, 2008: Executive summary. In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. ES-1 to ES-10.

[216] U.S. Energy Information Administration, U.S. Department of Energy [data]; assembled by Evan Mills, Lawrence Berkeley National Laboratory. Data available at <http://www.eia.doe.gov/cneaf/electricity/page/disturb_events.html>

[217] Kafalenos, R.S., K.J. Leonard, D.M. Beagan, V.R. Burkett, B.D. Keim, A. Meyers, D.T. Hunt, R.C. Hyman, M.K. Maynard, B. Fritsche, R.H. Henk, E.J. Seymour, L.E. Olson, J.R. Potter, and M.J. Savonis, 2008: What are the implications of climate change and variability for Gulf coast transportation? In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. 4-1 to 4F-27 [104 pp.]

[218] U.S. Energy Information Administration, 2008: *Monthly Energy Review*. U.S. Department of Energy, Energy Information Administration, Washington, DC. <http://www.eia.doe.gov/emeu/mer/contents.html>

[219] National Assessment Synthesis Team (NAST), 2001: *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*. Cambridge University Press, Cambridge, UK, and New York, 612 pp. <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/>

[220] ACIA, 2004: *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, and New York, 139 pp. <http://www.acia.uaf.edu>

[221] U.S. Environmental Protection Agency, 2008: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*. USEPA 430-R-08-005. U.S. Environmental Protection Agency, Washington, DC, 473 pp. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

[222] National Research Council, 2008: *Potential Impacts of Climate Change on U.S. Transportation.* Transportation Research Board special report 290. Transportation Research Board, Washington, DC, 280 pp. <http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf>

[223] Schimel, D., A. Janetos, P. Backlund, J. Hatfield, M.G. Ryan, S.R. Archer, and D. Lettenmaier, 2008: Synthesis. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 183-193.

[224] Burkett, V.R., R.C. Hyman, R. Hagelman, S.B. Hartley, M. Sheppard, T.W. Doyle, D.M. Beagan, A. Meyers, D.T. Hunt, M.K. Maynard, R.H. Henk, E.J. Seymour, L.E. Olson, J.R. Potter, and

N.N. Srinivasan, 2008: Why study the Gulf Coast? In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Synthesis and Assessment Product 4.7. U.S. Department of Transportation, Washington, DC, pp. 2-1 to 2F-26. [66 pp.]

[225] Peterson, T.C., M. McGuirk, T.G. Houston, A.H. Horvitz, and M.F. Wehner, 2008: *Climate Variability and Change with Implications for Transportation*. National Research Council, Washington, DC, 90 pp. <http://onlinepubs.trb.org/onlinepubs/sr/sr290Many.pdf>

[226] Hay, J.E., R. Warrick, C. Cheatham, T. Manarangi-Trott, J. Konno, and P. Hartley, 2005: *Climate Proofing: A Risk-based Approach to Adaptation*. Asian Development Bank, Manila, The Philippines, 191 pp. <http://www.adb.org/Documents/Reports/Climate-Proofing/default.asp>

[227] OSHA, 2008: Heat stress. In: *OSHA Technical Manual, Section III: Chapter 4*. Occupational Safety & Health Administration, Wash ington, DC. <http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html>

[228] Landsea, C.W., 1993: A climatology of intense (or major) Atlantic hurricanes. *Monthly Weather Review*, **121(6)**, 1710-1713.

[229] NOAA's National Climatic Data Center, 2008: *Billion Dollar U.S. Weather Disasters* [Web site] <http://www.ncdc.noaa.gov/oa/reports/billionz.html>

[230] Larsen, P.H., S. Goldsmith, O. Smith, M.L. Wilson, K. Strzepek, P. Chinowsky, and B. Saylor, 2008: Estimating future costs for Alaska public infrastructure at risk from climate change. *Global Environmental Change*, **18(3)**, 442-457.

[231] U.S. Environmental Protection Agency, 2008: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*. USEPA 430-R-08-005. U.S. Environmental Protection Agency, Washington, DC, 473 pp. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

[232] National Agricultural Statistics Service, 2002: *2002 Census of Agriculture*. USDA National Agricultural Statistics Service, Washington, DC. <http://www.agcensus.usda.gov/Publications/2002/index.asp>

[233] Wolfe, W., L. Ziska, C. Petzoldt, A. Seaman, L. Chase, and K. Hayhoe, 2007: Projected change in climate thresholds in the northeastern U.S.: implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 555-575.

[234] Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles, 2007: *Confronting Climate Change in the U.S. Northeast: Science, Impacts and Solutions*. Synthesis report of the Northeast Climate Impacts Assessment. Union of Concerned Scientists, Cambridge, MA, 146 pp.

[235] Gu, L., P.J. Hanson, W.M. Post, D.P. Kaiser, B. Yang, R. Nemani, S.G. Pallardy, and T. Meyers, 2008: The 2007 eastern U.S. spring freeze: increased cold damage in a warming world? *BioScience*, **58(3)**, 253-262.

[236] Inouye, D.W., 2008: Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers. *Ecology*, **89(2)**, 353-362.

[237] Either hydrogen dioxide or oxygenated hydrocarbons.

[238] Peet, M.M. and D.W. Wolf, 2000: Crop ecosystem responses to climate change: vegetable crops. In: *Climate Change and Global Crop Productivity* [Reddy, K.R. and H.F. Hodges (eds.)]. CABI Publishing, New York, and Wallingford, UK, 472 pp.

[239] Bridges, D.C. (ed.), 1992: *Crop Losses Due to Weeds in the United States*. Weed Science Society of America, Champaign, IL, 403 pp.

[240] Joyce, L.A., G.M. Blate, J.S. Littell, S.G. McNulty, C.I. Millar, S.C. Moser, R.P. Neilson, K. O'Halloran, and D.L. Peterson, 2008: National forests. In: *Preliminary Review of Adaptation Options for Climate-sensitive Ecosystems and Resources.* [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (authors)]. Synthesis and Assessment Product 4.4. U.S. Environmental Protection Agency, Washington, DC, pp. 3-1 to 3-127.

[241] Kiely, T., D. Donaldson, and A. Grube, 2004: *Pesticides Industry Sales and Usage: 2000 and 2001 Market Estimates*. U.S. Environmental Protection Agency, Washington, DC, 33 pp. <http://www.epa.gov/oppbead1/pestsales/>

[242] Natural Resources Conservation Service, 1997: *1997 Five-Year Natural Resources Inventory.* USDA Natural Resources Conservation Service, Washington, DC. <http://www.nrcs.usda.gov/technical/NRI/1997/index.html>

[243] Ryan, M.G., S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, and W. Schlesinger, 2008: Land resources. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 75-120.

[244] Parmesan, C., 1996: Climate and species range. *Nature*, **382(6594)**, 765-766.

[245] Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, M. Nolan, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J.M. Welker, K.S. Winker, and K. Yoshikawa, 2005: Evidence and implications of recent climate change in northern Alaska and other Arctic regions. *Climatic Change*, **72(3)**, 251-298.

[246] Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet, and G. Sem, 2007: Small islands. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 687-716.

[247] Millennium Ecosystem Assessment, 2005: *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute, Washington, DC, 86 pp. <http://www.millenniumassessment.org>

[248] Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, and A.A. Velichko, 2007: Ecosystems, their properties, goods, and services. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 211-272.

[249] National Interagency Fire Center, [2008]: *Total Wildland Fires and Acres (1960-2007).* National Interagency Coordination Center, Boise, ID. Data at <http://www.nifc.gov/fire_info/fire_stats.htm>

[250] CCSP, 2009: Case studies. In: *Thresholds of Climate Change in Ecosystems* [Fagre, D.B., C.W. Charles, C.D. Allen, C. Birkeland, F.S. Chapin III, P.M. Groffman, G.R. Guntenspergen, A.K. Knapp,

A.D. McGuire, P.J. Mulholland, D.P.C. Peters, D.D. Roby, and G. Sugihara] Synthesis and Assessment Product 4.2. U.S. Geological Survey, Reston, VA, pp. 32-73.

[251] Pounds, J.A., M.R. Bustamante, L.A. Coloma, J.A. Consuegra, M.P. L. Fogden, P.N. Foster, E. La Marca, K.L. Masters, A. Merino-Viteri, R. Puschendorf, S.R. Ron, G.A. Sánchez-Azofeifa, C.J. Still, and B.E. Young, 2006: Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature*, **439(7073)**, 161-167.

[252] Peterson, T.C., D.M. Anderson, S.J. Cohen, M. Cortez-Vázquez, R.J. Murnane, C. Parmesan, D. Phillips, R.S. Pulwarty, and J.M.R. Stone, 2008: Why weather and climate extremes matter. In: *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 11-34.

[253] Backlund, P., D. Schimel, A. Janetos, J. Hatfield, M.G. Ryan, S.R. Archer, and D. Lettenmaier, 2008: Introduction. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 11-20.

[254] Burkett, V.R., D.A. Wilcox, R. Stottlemeyer, W. Barrow, D. Fagre, J. Baron, J. Price, J.L. Nielsen, C.D. Allen, D.L. Peterson, G. Ruggerone, and T. Doyle, 2005: Nonlinear dynamics in ecosystem response to climatic change: case studies and policy implications. *Ecological Complexity*, **2(4)**, 357-394.

[255] Anderson, K.E., D.R. Cahoon, S.K. Gill, B.T. Gutierrez, E.R. Thieler, J.G. Titus, and S.J. Williams, 2009: Executive summary. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 1-8.

[256] Park, R.A., M.S. Trehan, P.W. Mausel, and R.C. Howe, 1989: *The Effects of Sea Level Rise on U.S. Coastal Wetlands*. U.S. Environmental Protection Agency, Washington, DC, 55 pp.

[257] Gutierrez, B.T., S.J. Williams, and E.R Thieler, 2009: Ocean coasts. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 43-56.

[258] *Monaco Declaration*, 2009: Developed at the *Second International Symposium on the Ocean in a High-CO_2 World*, Monaco, 6-9 October 2008. <http://ioc3.unesco.org/oanet/Symposium2008/MonacoDeclaration.pdf>

[259] Feely, R.A., C.L. Sabine, J.M. Hernandez-Ayon, D. Ianson, and B. Hales, 2008: Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science*, **320(5882)**, 1490-1492.

[260] Beckage, B., B. Osborne, D.G. Gavin, C. Pucko, T. Siccama, and T. Perkins, 2008: A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *Proceedings of the National Academy of Sciences*, **105(11),** 4197-4202.

[261] Beever, E.A., P.F. Brussard, and J. Berger, 2003: Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. *Journal of Mammology*, **84(1)**, 37-54.

[262] Krajick, K., 2004: All downhill from here? *Science*, **303(5664)**, 1600-1602.

[263] Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki, 2007: Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences*, **104(16)**, 6720-6725.

[264] Williams, J.E., A.L. Haak, N.G. Gillespie, H.M. Neville, and W.T. Colyer, 2007: *Healing Troubled Waters: Preparing Trout and Salmon Habitat for a Changing Climate*. Trout Unlimited, Arlington, VA, 12 pp. <http://www.tu.org/climatechange>

[265] Daily, G.C., T. Soderqvist, S. Aniyar, K. Arrow, P. Dasgupta, P.R. Ehrlich, C. Folke, A. Jansson, B.O. Jansson, N. Kautsky, S. Levin, J. Lubchenco, K.G. Maler, D. Simpson, D. Starrett, D. Tilman, and B. Walker, 2000: Ecology - The value of nature and the nature of value. *Science*, **289(5478)**, 395-396.

[266] Hamilton, J.M. and R.S.J. Tol, 2004: The impact of climate change on tourism and recreation. In: *Human-Induced Climate Change - An Interdisciplinary Assessment* [Schlesinger, M., H.S. Kheshgi, J. Smith, F.C. de la Chesnaye, J.M. Reilly, T. Wilson, and C. Kolstad (eds.)]. Cambridge University Press, Cambridge (UK), pp. 147-155.

[267] Cordell, H.K., B. McDonald, R.J. Teasley, J.C. Bergstrom, J. Martin, J. Bason, and V.R. Leeworthy, 1999: Outdoor recreation participation trends. In: *Outdoor Recreation in American Life: A National Assessment of Demand and Supply Trends* [Cordell, H.K. and S.M. McKinney (eds.)]. Sagamore Publishing, Champaign, IL, pp. 219-321.

[268] Wall, G., 1998: Implications of global climate change for tourism and recreation in wetland areas. *Climatic Change*, **40(2)**, 371-389.

[269] Titus, J.G. and M. Craghan, 2009: Shore protection and retreat. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 87-104.

[270] Peterson, C.H., R.T. Barber, K.L. Cottingham, H.K. Lotze, C.A. Simenstad, R.R. Christian, M.F. Piehler, and J. Wilson, 2008: National estuaries. In: *Preliminary Review of Adaptation Options for Climate-sensitive Ecosystems and Resources*. [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (authors)]. Synthesis and Assessment Product 4.4. U.S. Environmental Protection Agency, Washington, DC, pp. 7-1 to 7-108.

[271] Titus, J.G. and J.E. Neumann, 2009: Implications for decisions. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 141-156.

[272] Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich, and A. Woodward, 2007: Human health. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 391-431.

[273] Borden, K.A. and S.L. Cutter, 2008: Spatial patterns of natural hazards mortality in the United States. *International Journal of Health Geographics*, **7:64**, doi:10.1186/1476-072X-7-64.

[274] Gamble, J.L., K.L. Ebi, A. Grambsch, F.G. Sussman, T.J. Wilbanks, C.E. Reid, K. Hayhoe, J.V. Thomas, and C.P. Weaver, 2008: Introduction. In: *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* [Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, and T.J. Wilbanks (authors)]. Synthesis and Assessment Product 4.6. U.S. Environmental Protection Agency, Washington, DC, pp. 13-37.

[275] Brikowski, T.H., Y. Lotan, and M.S. Pearle, 2008: Climate-related increase in the prevalence of urolithiasis in the United States. *Proceedings of the National Academy of Sciences*, **105(28)**, 9841-9846.

[276] Semenza, J.C., 1999: Acute renal failure during heat waves. *American Journal of Preventive Medicine*, **17(1)**, 97.

[277] Luber, G.E. and L.M Conklin, 2006: Heat-related deaths: United States, 1999–2003. *Morbidity and Mortality Weekly Report*, **55(29)**, 796-798.

[278] Zanobetti, A. and J. Schwartz, 2008: Temperature and mortality in nine US cities. *Epidemiology*, **19(4)**, 563-570.

[279] Davis, R.E., P.C. Knappenberger, P.J. Michaels, and W.M. Novicoff, 2003: Changing heat-related mortality in the United States. *Environmental Health Perspectives*, **111(14)**, 1712-1718.

[280] U.S. Energy Information Administration, 2005: Table HC10.6: Air conditioning characteristics by U.S. census region, 2005. In: *2005 Residential Energy Consumption Survey*. Data available at <http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html>

[281] U.S. Energy Information Administration, 2005: Table 2: Type of air-conditioning equipment by census region and survey year. In: *2005 Residential Energy Consumption Survey*. Data available at <http://www.eia.doe.gov/emeu/consumptionbriefs/recs/actrends/recs_ac_trends_table2.html>

[282] Sheridan, S.C., A.J. Kalkstein, and L.S. Kalkstein, 2008: Trends in heat-related mortality in the United States, 1975–2004. *Natural Hazards*, **50(1)**, 145-160.

[283] Hayhoe, K., K. Cherkauer, N. Schlegal, J. VanDorn, S. Vavrus, and D. Wuebbles, 2009: Regional climate change projections for Chicago and the Great Lakes. *Journal of Great Lakes Research*, in press.

[284] Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville, 2004: Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, **101(34)**, 12422-12427.

[285] Vavrus, S. and J. van Dorn, 2008: Projected future temrperature and precipitation extremes in Chicago. *Journal of Great Lakes Research*, in press.

[286] Lemmen, D.S. and F.J. Warren (eds.), 2004: *Climate Change Impacts and Adaptation: A Canadian Perspective*. Climate Change Impacts and Adaptation Program, Natural Resources Canada, Ottawa, ON, 174 pp. <http://adaptation.nrcan.gc.ca/perspective/pdf/report_e.pdf>

[287] Ebi, K.L., J. Smith, I. Burton, and J. Scheraga, 2006: Some lessons learned from public health on the process of adaptation. *Mitigation and Adaptation Strategies for Global Change*, **11(3)**, 607-620.

[288] Ebi, K.L., T.J. Teisberg, L.S. Kalkstein, L. Robinson, and R.F. Weiher, 2004: Heat watch/warning systems save lives: estimated costs and benefits for Philadelphia 1995-98. *Bulletin of the American Meteorological Society*, **85(8)**, 1067-1073.

[289] Medina-Ramon, M. and J. Schwartz, 2007: Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 U.S. cities. *Occupational and Environmental Medicine*, **64(12)**, 827-833.

[290] U.S. Environmental Protection Agency, 2008: *National Air Quality: Status and Trends through 2007*. U.S. EPA Air Quality Assessment Division, Research Triangle Park, NC, 48 pp. <http://www.epa.gov/airtrends/2008/index.html>

[291] Tao, Z., A. Williams, H.-C. Huang, M. Caughey, and X.-Z. Liang, 2007: Sensitivity of U.S. surface ozone to future emissions and climate changes. *Geophysical Research Letters*, **34**, L08811, doi:10.1029/2007GL029455.

[292] California Air Resources Board, 2007: *Recent Research Findings: Health Effects of Particulate Matter and Ozone Air Pollution*. [Online fact sheet] California Air Resources Board, [Sacramento], 7 pp. <http://www.arb.ca.gov/research/health/fs/pm_ozone-fs.pdf>

[293] California Climate Action Team, 2006: *Climate Action Team Report to Governor Schwarzenegger and the Legislature*. California Environmental Protection Agency, Sacramento, 107 pp. <http://www.climatechange.ca.gov/climate_action_team/reports/index.html>

[294] Westerling A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, 2006: Warming and earlier spring increase western U.S. forest wildfire activity. *Science*, **313(5789),** 940-943.

[295] Rhode Island Public Transit Authority, Undated: *Air Quality Alert Days Program*. [Web site] <http://www.ripta.com/content259.html>

[296] Friedman, M.S., K.E. Powell, L. Hutwagner, L.M. Graham, and W.G. Teague, 2001: Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma. *Journal of the American Medical Association*, **285(7)**, 897-905.

[297] Wuebbles, D.J., H. Lei, and J.-T. Lin, 2007: Intercontinental transport of aerosols and photochemical oxidants from Asia and its consequences. *Environmental Pollution*, **150**, 65-84.

[298] Bell, M.L., R. Goldberg, C. Hogrefe, P. Kinney, K. Knowlton, B. Lynn, J. Rosenthal, C. Rosenzweig, and J.A. Patz, 2007: Climate change, ambient ozone, and health in 50 U.S. cities. *Climatic Change*, **82(1-2),** 61-76.

[299] U.S. Environmental Protection Agency, 2008: *National Pollutant Discharge Elimination System (NPDES) Combined Sewer Overflows Demographics.* [Web site] <http://cfpub.epa.gov/npdes/cso/demo.cfm?program_id=5>

[300] Tibbetts, J., 2005: Combined sewer systems: down, dirty, and out of date. *Environmental Health Perspectives*, **113(7)**, A464-A467.

[301] U.S. Environmental Protection Agency, 2008: *Clean Watersheds Needs Survey 2004: Report to Congress*. U.S. Environmental Protection Agency, Washington, DC. <http://www.epa.gov/cwns/2004rtc/cwns2004rtc.pdf>

[302] Patz, J.A., S.J. Vavrus, C.K. Uejio, and S.L. McClellan, 2008: Climate change and waterborne disease risk in the Great Lakes region of the U.S. *American Journal of Preventive Medicine*, **35(5)**, 451-458.

[303] Centers for Disease Control and Prevention, 2009: *West Nile Virus: Statistics, Surveillance, and Control*. [Web site] <http://www.cdc.gov/ncidod/dvbid/westnile/surv&control.htm>

[304] Kilpatrick, A.M., M.A. Meola, R.M. Moudy, and L.D. Kramer, 2008: Temperature, viral genetics, and the transmission of West Nile virus by *Culex pipiens* mosquitoes. *PLoS Pathogens*, **4(6)**, e1000092. doi:10.1371/journal.ppat.1000092

[305] Sussman, F.G., M.L. Cropper, H. Galbraith, D. Godschalk, J. Loomis, G. Luber, M. McGeehin, J.E. Neumann, W.D. Shaw, A. Vedlitz, and S. Zahran, 2008: Effects of global change on human welfare. In: *Analyses of the Effects of Global Change on Human*

Health and Welfare and Human Systems [Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, and T.J. Wilbanks (authors)]. Synthesis and Assessment Product 4.6. U.S. Environmental Protection Agency, Washington, DC, pp. 111-168.

[306] Smith, J.B. and D. Tirpak (eds.), 1989: *The Potential Effects of Global Climate Change on the United States* U.S. Environmental Protection Agency, Washington, DC, 413 pp.

[307] Ziska, L.H. and F.A. Caulfield, 2000: Rising CO_2 and pollen production of common ragweed (*Ambrosia artemisiifolia L.*), a known allergy-inducing species: implications for public health. *Australian Journal of Plant Physiology*, **27(10)**, 893-898.

[308] Mohan J.E., L.H. Ziska, W.H. Schlesinger, R.B. Thomas, R.C. Sicher, K. George, and J.S. Clark, 2006: Biomass and toxicity responses of poison ivy (*Toxicodendron radicans*) to elevated atmospheric CO_2. *Proceedings of the National Academy of Sciences*, **103(24)**, 9086-9089.

[309] Hunt, R., D.W. Hand, M.A. Hannah, and A.M. Neal, 1991: Response to CO_2 enrichment in 27 herbaceous species. *Functional Ecology*, **5(3)**, 410-421.

[310] Ziska, L.H., 2003: Evaluation of the growth response of six invasive species to past, present and future atmospheric carbon dioxide. *Journal of Experimental Botany*, **54(381)**, 395-404.

[311] CDC, 2007: *2007 National Diabetes Fact Sheet*. Centers for Disease Control and Prevention, Atlanta, GA, 14 pp. <http://www.cdc.gov/diabetes/pubs/factsheet07.htm>

[312] Patz, J.A., H.K. Gibbs, J.A. Foley, J.V. Rogers, and K.R. Smith, 2007: Climate change and global health: quantifying a growing ethical crisis. *EcoHealth*, **4(4)**, 397-405.

[313] Wilbanks, T.J., P. Kirshen, D. Quattrochi, P. Romero-Lankao, C. Rosenzweig, M. Ruth, W. Solecki, J. Tarr, P. Larsen, and B. Stone, 2008: Effects of global change on human settlements. In: *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* [Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, and T.J. Wilbanks (authors)]. Synthesis and Assessment Product 4.6. U.S. Environmental Protection Agency, Washington, DC, pp. 89-109.

[314] U.S. Census Bureau, 2005*: Domestic Net Migration in the United States: 2000 to 2004: Population Estimates and Projections.* <http://www.census.gov/prod/2006pubs/p25-1135.pdf>

[315] U.S. General Accounting Office, 2003: *Alaska Native Villages: Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance.* GAO-04-142. U.S. General Accounting Office, Washington, DC, 82 pp. <http://purl.access.gpo.gov/GPO/LPS42077>

[316] Gamble, J.L., K.L. Ebi, F.G. Sussman, T.J. Wilbanks, C. Reid, J.V. Thomas, and C.P. Weaver, 2008: Common themes and research recommendations. In: *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems* [Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, and T.J. Wilbanks (authors)]. Synthesis and Assessment Product 4.6. U.S. Environmental Protection Agency, Washington, DC, pp. 169-176.

[317] United States Conference of Mayors, 2005: *U.S. Conference of Mayors Climate Protection Agreement,* as endorsed by the 73rd Annual U.S. Conference of Mayors meeting, Chicago, 2005. <http://usmayors.org/climateprotection/agreement.htm>

[318] Semenza, J.C., J.E. McCullough, W.D. Flanders, M.A. McGeehin, and J.R. Lumpkin, 1999: Excess hospital admissions during the July 1995 heat wave in Chicago. *American Journal of Preventive Medicine*, **16(4)**, 269-277.

[319] Borden, K.A., M.C. Schmidtlein, C.T. Emrich, W.W. Piegorsch, and S.L. Cutter, 2007: Vulnerability of U.S. cities to environmental hazards. *Journal of Homeland Security and Emergency Management*, **4(2)**, article 5. <http://www.bepress.com/jhsem/vol4/iss2/5>

[320] van Kamp, I., K. Leidelmeijer, G. Marsman, and A. de Hollander, 2003: Urban environmental quality and human well-being: towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning*, **65(1-2)**, 5-18.

[321] Grimmond, S., 2007: Urbanization and global environmental change: local effects of urban warming. *Geographical Journal*, **173(1)**, 83-88.

[322] Anderson, C.A., 2001: Heat and violence. *Current Directions in Psychological Science*, **10(1)**, 33-38.

[323] Anderson, C.A., B.J. Bushman, and R.W. Groom, 1997: Hot years and serious and deadly assault: empirical test of the heat hypothesis. *Journal of Personality and Social Psychology*, **73(6)**, 1213-1223.

[324] Milly, P.C.D., R.T. Wetherald, K.A. Dunne, and T.L. Delworth, 2002: Increasing risk of great floods in a changing climate. *Nature*, **415(6871)**, 514-517.

[325] Miller, N.L., K. Hayhoe, J. Jin, and M. Auffhammer, 2008: Climate, extreme heat, and electricity demand in California. *Journal of Applied Meteorology and Climatology*, **47(6)**, 1834-1844.

[326] Wang, J.X.L. and J.K. Angell, 1999: *Air Stagnation Climatology for the United States (1948-1998).* NOAA/Air Resources Laboratory atlas no.1. NOAA Air Resources Laboratory, Silver Spring, MD, 74 pp.

[327] Riebsame, W.E., S.A. Changnon Jr., and T.R. Karl, 1991: *Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987–89 Drought*. Westview Press, Boulder, CO, 174 pp.

[328] NOAA's National Climatic Data Center, 2009: *NCDC Climate Monitoring: U.S. Records* [Web site] <http://www.ncdc.noaa.gov/oa/climate/research/records/>

[329] NOAA's National Climatic Data Center, 2009: *U.S. Percent Area Wet or Dry.* [Web site] <http://www.ncdc.noaa.gov/img/climate/research/2008/ann/Reg110_wet-dry_bar01001208-mod_pg.gif>

[330] Leung L.R. and W.I. Gustafson Jr., 2005: Potential regional climate change and implications to U.S. air quality. *Geophysical Research Letters*, **32**, L16711, doi:10.1029/2005GL022911.

[331] Several U.S. Department of Energy reports document the increase in electricity demand to provide air-conditioning in hotter summers in many regions of the country: Chapter 2: Carbon dioxide emissions. In: *Emissions of Greenhouse Gases in the United States 2002*. Report released 2004. <http://www.eia.doe.gov/oiaf/1605/archive/gg03rpt/index.html>; *South Atlantic Household Electricity Report*. Release date: 2006. <http://www.eia.doe.gov/emeu/reps/enduse/er01_so-atl.html>; *South Central Appliance Report 2001*. Updated 2005. <http://www.eia.doe.gov/emeu/reps/appli/w_s_c.html>

[332] CCSP, 2007: *Effects of Climate Change on Energy Production and Use in the United States.* [Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott (eds.)]. Synthesis and Assessment Product 4.5. U.S. Department of Energy, Office of Biological & Environmental Research, Washington, DC, 160 pp. See chapters 2 and 3.

[333] Daily data were used for both air stagnation and heat waves:

1. Heat waves:

• The GHCN-Daily dataset from NCDC was used <http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/>

• Data from 979 U.S. stations having long periods of record and high quality.

• At each station, a day was considered hot if the maximum temperature for that day was at or above the 90% of daily maximum temperatures at that station.

2. Air stagnation:

• For each day in summer and at each air-stagnation grid point, it was determined if that location had stagnant air:

◦ The stagnation index was formulated by Wang, J.X.L. and J.K. Angell, 1999: *Air Stagnation Climatology for the United States (1948-1998)*. NOAA/Air Resources Laboratory atlas no.1 NOAA Air Resources Laboratory, Silver Spring, MD, 74 pp. <http://www.arl.noaa.gov/documents/reports/atlas.pdf>

◦ Operational implementation of this index is described at <http://www.ncdc.noaa.gov/oa/climate/research/stagnation/index.php>

Note: Although Wang and Angell used a criteria of four day stagnation periods, single stagnation days were used for this analysis.

3. For each location in the air stagnation grid, the nearest station (of the aforementioned 979 U.S. stations) was used to determine the coincidence of summer days having stagnant air and excessive heat as a percentage of the number of days having excessive heat.

[334] Solecki, W.D. and C. Rosenzweig, 2006: Climate change and the city: observations from metropolitan New York. In: *Cities and Environmental Change* [Bai, X. (ed.)]. Yale University Press, New York.

[335] Rosenzweig, C. and W. Solecki (eds.), 2001: *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change – Metro East Coast*. Columbia Earth Institute, New York. <http://metroeast_climate.ciesin.columbia.edu/>

[336] Kirshen, P., M. Ruth, W. Anderson, T.R. Lakshmanan, S. Chapra, W. Chudyk, L. Edgers, D. Gute, M. Sanayei, and R. Vogel, 2004: *Climate's Long-term Impacts on Metro Boston (CLIMB) Final Report*. Civil and Environmental Engineering Department, Tufts University, 165 pp. <http://www.clf.org/uploadedFiles/CLIMB_Final_Report.pdf>

[337] Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, X. Bai, and J.M. Briggs, 2008: Global change and the ecology of cities. *Science*, **319(5864)**, 756-760.

[338] Kuo, F.E. and W.C. Sullivan, 2001: Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior*, **33(3)**, 343-367.

[339] Julius, S.H., J.M. West, G. Blate, J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M. Palmer, C. Peterson, and J.M. Scott, 2008: Executive summary. In: *Preliminary Review of Adaptation Options for Climate-sensitive Ecosystems and Resources* [Julius, S.H. and J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (authors)]. Synthesis and Assessment Product 4.4. U.S. Environmental Protection Agency, Washington, DC, pp. 1-1 to 1-6.

[340] Baker, L.A., A.J. Brazel, N. Selover, C. Martin, N. McIntyre, F.R. Steiner, A. Nelson, and L. Musacchio, 2002: Urbanization and warming of Phoenix (Arizona, USA): impacts, feedbacks, and mitigation. *Urban Ecosystems*, **6(3)**, 183-203.

[341] LoVecchio, F., J.S. Stapczynski, J. Hill, A.F. Haffer, J.A. Skindlov, D. Engelthaler, C. Mrela, G.E. Luber, M. Straetemans, and Z. Duprey, 2005: Heat-related mortality – Arizona, 1993-2002, and United States, 1979-2002. *Morbidity and Mortality Weekly Report*, **54(25)**, 628-630.

[342] Scott, D., J. Dawson, and B. Jones, 2008: Climate change vulnerability of the US Northeast winter recreation–tourism sector. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 577-596.

[343] Bin, O., C. Dumas, B. Poulter, and J. Whitehead, 2007: *Measuring the Impacts of Climate Change on North Carolina Coastal Resources*. National Commission on Energy Policy, Washington, DC, 91 pp. <http://econ.appstate.edu/climate/>

[344] Mills, E., 2005: Insurance in a climate of change. *Science*, **309(5737)**, 1040-1044.

[345] Adapted from U.S. Government Accountability Office, 2007: *Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades are Potentially Significant*. U.S. Government Accountability Office, Washington, DC, 68 pp. <http://purl.access.gpo.gov/GPO/LPS89701> Data shown are not adjusted for inflation.

[346] Pielke Jr., R.A., J. Gratz, C.W. Landsea, D. Collins, M. Saunders, and R. Musulin, 2008: Normalized hurricane damages in the United States: 1900-2005. *Natural Hazards Review*, **9(1)**, 29-42.

[347] Rosenzweig, C., G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, and P. Tryjanowski, 2007: Assessment of observed changes and responses in natural and managed systems. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 79-131.

[348] Pielke Jr., R.A., 2005: Attribution of disaster losses. *Science*, **310(5754)**, 1615; and Mills, E., 2005: Response. *Science*, **310(5754)**, 1616.

[349] Mills, E., 2009: A global review of insurance industry responses to climate change. *The Geneva Papers on Risk and Insurance–Issues and Practice*, in press.

[350] Meehl, G.A. and C. Tebaldi, 2004: More intense, more frequent, and longer lasting heat waves in the 21st century. *Science*, **305(5686)**, 994-997.

[351] Mills, E., 2006: Synergisms between climate change mitigation and adaptation: an insurance perspective. *Mitigation and Adaptation Strategies for Global Change*, **12(5)**, 809-842.

[352] U.S. Government Accountability Office, 2007 [data]; assembled by Evan Mills, Lawrence Berkeley National Laboratory.

[353] Reeve, N. and R. Toumi, 1999: Lightning activity as an indicator of climate change. *Quarterly Journal of the Royal Meteorological Society*, **125(555)**, 893-903.

[354] Price, C. and D. Rind, 1994: Possible implications of global climate change on global lightning distributions and frequencies. *Journal of Geophysical Research*, **99(D5)**, 10823-10831.

[355] Ross, C., E. Mills, and S. Hecht, 2007: Limiting liability in the greenhouse: insurance risk-management in the context of global climate change. *Stanford Environmental Law Journal and Stanford Journal of International Law*, *Symposium on Climate Change Risk*, **26A/43A**, 251-334.

[356] Nutter, F.W., 1996: Insurance and the natural sciences: partners in the public interest. *Research Review: Journal of the Society of Insurance Research*, **Fall**, 15-19.

[357] Federal Emergency Management Agency, 2008: *Emergency Management Institute*. [Web site] <http://training.fema.gov/EMIWeb/CRS/>

[358] Bernstein, L., J. Roy, K.C. Delhotal, J. Harnisch, R. Matsuhashi, L. Price, K. Tanaka, E. Worrell, F. Yamba, and Z. Fengqi, 2007: Industry. In: *Climate Change 2007: Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Metz, B., O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyer (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 447-496.

[359] Hayhoe, K., C.P. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A. Hertel, and D. Wuebbles, 2008: Regional climate change projections for the northeast U.S. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 425-436.

[360] New York City Department of Health and Mental Hygiene, 2006: Deaths associated with heat waves in 2006. In: *NYC Vital Signs:*

Investigation Report, Special Report. Department of Health and Mental Hygiene, New York, 4 pp. <http://www.nyc.gov/html/doh/downloads/pdf/survey/survey-2006heatdeaths.pdf>

[361] Kunkel, K.E., H.-C. Huang, X.-Z. Liang, J.-T. Lin, D. Wuebbles, Z. Tao, A. Williams, M. Caughey, J. Zhu, and K. Hayhoe, 2008: Sensitivity of future ozone concentrations in the northeast U.S. to regional climate change. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 597-606.

[362] Hauagge, R. and J.N. Cummins, 1991: Phenotypic variation of length of bud dormancy in apple cultivars and related malus species. *Journal of the American Society for Horticultural Science*, **116(1)**, 100-106.

[363] DeMoranville, C., 2007: Personal communication from May 29, 2008. Experts at the University of Massachusetts Cranberry Station estimate cranberry chilling requirements to be around 1,200-1,400 hours, but they advise growers to seek 1,500 hours to avoid crop failure. There are 4-5 commonly grown cultivars but no low-chill varieties. Dr. Carolyn DeMoranville is the director of the UMass Cranberry Station, a research and extension center of UMass-Amherst.

[364] Iverson, L., A. Prasad, and S. Matthews, 2008: Potential changes in suitable habitat for 134 tree species in the northeastern United States. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 487-516.

[365] U.S. Department of Agriculture (USDA) National Agriculture Statistics Service (NASS), 2002: *Statistics by State*. [Web site] <http://www.nass.usda.gov/Statistics_by_State/>

[366] St. Pierre, N.R., B. Cobanov, and G. Schnitkey, 2003: Economic losses from heat stress by U.S. livestock industries. *Journal of Dairy Science*, **86(E Sup)**, E52- E77.

[367] Gornitz, V., S. Couch, and E.K. Hartig, 2001: Impacts of sea level rise in the New York City metropolitan area. *Global and Planetary Change*, **32(1)**, 61-88.

[368] AIR Worldwide Corporation, 2008: *The Coastline at Risk: 2008 Update to the Estimated Insured Value of U.S. Coastal Properties*. AIR Worldwide Corporation, Boston, MA, 3 pp. <http://www.air-worldwide.com/download.aspx?c=388&id=15836>

[369] Kirshen, P., C. Watson, E. Douglas, A. Gontz, J. Lee, and Y. Tian, 2008: Coastal flooding in the northeastern United States due to climate change. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 437-451.

[370] Bowman, M., D. Hill, F. Buonaiuto, B. Colle, R. Flood, R. Wilson, R. Hunter, and J. Wang, 2008: Threats and responses associated with rapid climate change in metropolitan New York. In: *Sudden and Disruptive Climate Change: Exploring the Real Risks and How We Can Avoid Them*. [MacCracken, M.C., F. Moore, and J.C. Topping Jr. (eds.)]. Earthscan, London and Sterling, VA, pp. 119-142.

[371] Titus, J.G., 2009: Ongoing adaptation. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 157-162.

[372] International Snowmobile Manufacturers Association, 2006: *International Snowmobile Industry Facts and Figures*. [Web site] <http://www.snowmobile.org/pr_snowfacts.asp>

[373] Northeast Climate Impact Assessment (NECIA), 2006: *Climate Change in the U.S. Northeast: A Report of the Northeast Climate Impacts Assessment*. Union of Concerned Scientists, Cambridge, MA, 35 pp.

[374] Atlantic States Marine Fisheries Commission, 2005: *American Lobster*. [Web site] <http://www.asmfc.org/americanLobster.htm>

[375] Fogarty, M.J., 1995: Populations, fisheries, and management. In: *The Biology of the American Lobster* Homarus americanus. [Factor, J.R. (ed.)]. Academic Press, San Diego, CA, pp. 111-137.

[376] Glenn, R.P. and T.L. Pugh, 2006: Epizootic shell disease in American lobster (*Homarus americanus*) in Massachusetts coastal waters: interactions of temperature, maturity, and intermolt duration. *Journal of Crustacean Biology*, **26(4)**, 639-645.

[377] Fogarty, M., L. Incze, K. Hayhoe, D. Mountain, and J. Manning, 2008: Potential climate change impacts on Atlantic cod (*Gadus morhua*) off the northeastern United States. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 453-466.

[378] Dutil, J.-D. and K. Brander, 2003: Comparing productivity of North Atlantic cod (*Gadus morhua*) stocks and limits to growth production. *Fisheries Oceanography*, **12(4-5)**, 502-512.

[379] Drinkwater, K.F., 2005: The response of Atlantic cod (G*adus morhua*) to future climate change. *ICES Journal of Marine Science*, **62(7)**, 1327-1337.

[380] Karl, T.R. and R.W. Knight, 1998: Secular trends of precipitation amount, frequency, and intensity in the United States. *Bulletin of the American Metrological Society*, **79(2)**, 231-241.

[381] Keim, B.D., 1997: Preliminary analysis of the temporal patterns of heavy rainfall across the southeastern United States. *Professional Geographer*, **49(1)**, 94-104.

[382] Observed changes in precipitation for the Southeast were calculated from the US Historical Climatology Network Version 2. See Menne, M.J., C.N. Williams, and R.S. Vose, 2009: The United States Historical Climatology Network Monthly Temperature Data - Version 2. *Bulletin of the American Meteorological Society*, Early online release, 25 February 2009, doi:10.1175/2008BAMS2613.1

[383] Temperature:

Menne, M.J., C.N. Williams, and R.S. Vose, 2009: The United States Historical Climatology Network Monthly Temperature Data - Version 2. *Bulletin of the American Meteorological Society*, Early online release, 25 February 2009, doi:10.1175/2008BAMS2613.1

Precipitation:

NOAA's National Climatic Data Center, 2008: *The USHCN Version 2 Serial Monthly Dataset*. [Web site] <http://www.ncdc.noaa.gov/oa/climate/research/ushcn/>

[384] Hoyos, C.D., P.A. Agudelo, P.J. Webster, and J.A. Curry, 2006: Deconvolution of the factors contributing to the increase in global hurricane intensity. *Science*, **312(577)**, 94-97.

[385] Mann, M.E. and K.A. Emanuel, 2006: Atlantic hurricane trends linked to climate change. *EOS Transactions of the American Geophysical Union*, **87(24)**, 233, 244.

[386] Trenberth, K.E. and D.J. Shea, 2006: Atlantic hurricanes and natural variability in 2005. *Geophysical Research Letters*, **33**, L12704, doi:10.1029/2006GL026894.

[387] Webster, P.J., G.J. Holland, J.A. Curry, and H.-R. Chang, 2005: Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science*, **309(5742)**, 1844-1846.

[388] Komar, P.D. and J.C. Allan, 2007: Higher waves along U.S. East Coast linked to hurricanes. *EOS Transactions of the American Geophysical Union*, **88(30)**, 301.

[389] Change calculated from daily minimum temperatures from NCDC's Global Historical Climatology Network - Daily data set. <http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/>

[390] Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden, and C.D. Woodroffe, 2007: Coastal systems and low-lying areas. In: *Climate Change 2007: Impacts, Adaptations and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 316-356.

[391] Boyles, S., 2008: *Heat Stress and Beef Cattle*. Ohio State University Extension Service. <http://beef.osu.edu/library/heat.html>

[392] Convention on Biological Diversity, 2006: *Guidance for Promoting Synergy Among Activities Addressing Biological Diversity, Desertification, Land Degradation and Climate Change*. CBD technical series 25. Secretariat of the Convention on Biological Diversity, Montreal, Canada, 43 pp. <http://www.biodiv.org/doc/publications/cbd-ts-25.pdf>

[393] Burkett, V., 2008: The northern Gulf of Mexico coast: human development patterns, declining ecosystems, and escalating vulnerability to storms and sea level rise. In: *Sudden and Disruptive Climate Change: Exploring the Real Risks and How We Can Avoid Them*. [MacCracken, M.C., F. Moore, and J.C. Topping (eds.)]. Earthscan Publications, London [UK], and Sterling, VA, pp. 101-118.

[394] Twilley, R.R., E. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E. Siemann, R.G. Welzel, and R.J. Zimmerman, 2001: *Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage*. Union of Concerned Scientists, Cambridge, MA, and Ecological Society of America, Washington, DC, 82 pp.

[395] USGS, photos and images:
Photos on the left:
Tihansky, A.B., 2005: Before-and-after aerial photographs show coastal impacts of Hurricane Katrina. *Sound Waves*, September. <http://soundwaves.usgs.gov/2005/09/fieldwork2.html>
Images on the right:
Adapted from Fauver, L., 2007: Predicting flooding and coastal hazards: USGS hydrologists and geologists team up at the National Hurricane Conference to highlight data collection. *Sounds Waves*, June. <http://soundwaves.usgs.gov/2007/06/meetings.html>

[396] Barras, J.A., 2006: *Land Area Change in Coastal Louisiana After the 2005 Hurricanes: A Series of Three Maps*. U.S. Geological Survey open-file report 2006-1274. <http://pubs.usgs.gov/of/2006/1274>

[397] Main Development Region of the Atlantic Ocean is defined in: Bell, G.D., E. Blake, C.W. Landsea, S.B. Goldenberg, R. Pasch, and T. Kimberlain, 2008: Tropical cyclones: Atlantic basin. In: Chapter 4: The Tropics, of *State of the Climate in 2007* [Levinson, D.H. and J.H. Lawrimore (eds.)]. *Bulletin of the American Meteorological Society*, **89(Supplement)**, S68-S71.

[398] Williams, K.L., K.C. Ewel, R.P. Stumpf, F.E. Putz, and T.W. Workman, 1999: Sea-level rise and coastal forest retreat on the west coast of Florida. *Ecology*, **80(6)**, 2045-2063.

[399] McNulty, S.G., J.M. Vose, and W.T. Swank, 1996: Potential climate change affects on loblolly pine productivity and hydrology across the southern United States. *Ambio*, **25(7)**, 449-453.

[400] Zimmerman, R.J., T.J. Minello, and L.P. Rozas, 2002: Salt marsh linkages to productivity of penaeid shrimps and blue crabs in the northern Gulf of Mexico. In: *Concepts and Controversies in Tidal Marsh Ecology* [Weinstein, M.P. and D.A. Kreeger (eds.)]. Kluwer, Dordrecht and Boston, pp. 293-314.

[401] U.S. Army Corps of Engineers, 2009: *Risk Reduction Plan: Levees/Floodwalls/Armoring*. [Web site] U.S. Army Corps of Engineers New Orleans District. <http://www.mvn.usace.army.mil/hps2/hps_levees_flood_armor.asp>

[402] Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, and D.R. Zak, 2003: *Confronting Climate Change in the Great Lakes Region: Impacts on Our Communities and Ecosystems*. Union of Concerned Scientists, Cambridge, MA, and Ecological Society of America, Washington, DC, 92 pp. <http://www.ucsusa.org/greatlakes/>

[403] Hayhoe, K., D. Wuebbles, and the Climate Science Team, 2008: *Climate Change and Chicago: Projections and Potential Impacts*. City of Chicago, [175 pp.] <http://www.chicagoclimateaction.org/>

[404] Wuebbles, D.J. and K. Hayhoe, 2004: Climate change projections for the United States Midwest. *Mitigation and Adaptation Strategies for Global Change*, **9(4)**, 335-363.

[405] Ebi, K.L. and G.A. Meehl, 2007: The heat is on: climate change and heat waves in the Midwest. In: *Regional Impacts of Climate Change: Four Case Studies in the United States*. Pew Center on Global Climate Change, Arlington, VA, pp. 8-21. <http://www.pewclimate.org/regional_impacts>

[406] Kalkstein, L.S., J.S. Green, D.M. Mills, A.D. Perrin, J.P. Samenow, and J.-C. Cohen, 2008: Analog European heat waves for U.S. cities to analyze impacts on heat-related mortality. *Bulletin of the American Meteorological Society*, **89(1)**, 75-85.

[407] Hayhoe, K., S. Sheridan, J.S. Greene and L. Kalkstein, 2009: Climate change, heat waves, and mortality projections for Chicago. *Journal of Great Lakes Research*, in press.

[408] Lin, J.-T., K.O. Patten, X.-Z. Liang, and D.J. Wuebbles, 2008: Climate change effects on ozone air quality in the United States and China with constant precursor emissions. *Journal of Applied Meteorology and Climatology*, **47(7)**, 1888-1909.

[409] Holloway, T., S.N. Spak, D. Barker, M. Bretl, K. Hayhoe, J. Van Dorn, and D. Wuebbles, 2008: Change in ozone air pollution over Chicago associated with global climate change. *Journal of Geophysical Research*, **113**, D22306, doi:10.1029/2007JD009775.

[410] Hedegaard, G.B., J. Brandt, J.H. Christensen, L.M. Frohn, C. Geels, K.M. Hansen, and M. Stendel, 2008: Impacts of climate change on air pollution levels in the Northern Hemisphere with special focus on Europe and the Arctic. *Atmospheric Chemistry and Physics*, **8(12)**, 3337-3367.

[411] Several different city of Chicago analyses have substantiated the finding of up to 77 degree difference – for example, see City of Chicago, Department of Environment, Undated: *City Hall Rooftop Garden*. [Web site] <http://egov.cityofchicago.org/city/webportal/portalDeptCategoryAction.do?deptCategoryOID=-536889314&contentType=COC_EDITORIAL&topChannelName=Dept&entityName=Environment&deptMainCategoryOID=-536887205>

[412] Angel, J. and K. Kunkel, 2009: The response of Great Lakes water levels to future climate scenarios with an emphasis of Lake Michigan. *Journal of Great Lakes Research*, in press.

[413] Annin, P., 2006: *The Great Lakes Water Wars*. Island Press, Washington, DC, 303 pp.

[414] Assel, R.A., 2003: *An Electronic Atlas of Great Lakes Ice Cover, Winters: 1973-2002*. NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 2 CD-ROM set or DVD. <http://www.glerl.noaa.gov/data/ice/atlas>

[415] Changnon, S.A. (ed.), 1996: *The Great Flood of 1993: Causes, Impacts and Responses*. Westview Press, Boulder, CO, 321 pp.

[416] Changnon, S.A. and K.E. Kunkel, 2006: *Severe Storms in the Midwest*. Illinois State Water Survey, Champaign, IL, 74 pp. <http://www.sws.uiuc.edu/pubdoc/IEM/ISWSIEM2006-06.pdf>

[417] Kunkel, K.E., K. Andsager, G. Conner, W.L. Decker, H.J. Hilaker Jr., P.N. Knox, F.V. Nurnberger, J.C. Rogers, K. Scheeringa, W.M. Wendland, J. Zandlo, and J.R. Angel, 1998: An expanded digital daily database for climatic resources applications in the midwestern United States. *Bulletin of the American Meteorological Society*, **79(7)**, 1357-1366.

[418] Agricultural Research Service, 1990: *USDA Plant Hardiness Zone Map*. Agricultural Research Service, Washington, DC, 1 map.
Arbor Day Foundation, 2006: *Hardiness Zones*. [Web site] The Arbor Day Foundation, Nebraska City, NE. <http://www.arborday.org/media/zones.cfm>

[419] Woodhouse, C.A. and J.T. Overpeck, 1998: 2000 years of drought variability in the central United States. *Bulletin of the American Meteorological Society*, **79(12)**, 2693-2714.

[420] DeGaetano, A.T. and R.J. Allen, 2002: Trends in twentieth-century temperature extremes across the United States. *Journal of Climate*, **15(22)**, 3188-3205.

[421] Garbrecht, J., M. Van Liew, and G.O. Brown, 2004: Trends in precipitation, streamflow, and evapotranspiration in the Great Plains of the United States. *Journal of Hydrologic Engineering*, **9(5)**, 360-367.

[422] McGuire, V., 2007: *Water-level Changes in the High Plains Aquifer, Predevelopment to 2005 and 2003 to 2005*. U.S. Geological Survey scientific investigations report 2006–5324. U.S. Geological Survey, Reston, VA, 7 pp. <http://pubs.usgs.gov/sir/2006/5324/>

[423] Dennehy, K. 2000: *High Plains Regional Ground-Water Study*. U.S. Geological Survey fact sheet FS-091-00, 6 pp. <http://pubs.er.usgs.gov/usgspubs/fs/fs09100>

[424] Gurdak, J.J., R.T. Hanson, P.B. McMahon, B.W. Bruce, J.E. McCray, G.D. Thyne, and R.C. Reedy, 2007: Climate variability controls on unsaturated water and chemical movement, High Plains aquifer, USA. *Vadose Zone Journal*, **6(3)**, 533-547.

[425] Green, T.R., M. Taniguchi, and H. Kooi, 2007: Potential impacts of climate change and human activity on subsurface water resources. *Vadose Zone Journal*, **6(3)**, 531-532.

[426] Data from the PRISM Group, Oregon State University <http://www.prismclimate.org>; Map created by National Climatic Data Center, March 2009.

[427] Mahmood, R., S.A. Foster, T. Keeling, K.G. Hubbard, C. Carlson, and R. Leeper, 2006: Impacts of irrigation on 20th century temperature in the northern Great Plains. *Global and Planetary Change*, **54(1-2)**, 1-18.

[428] Moore, N. and S. Rojstaczer, 2002: Irrigation's influence on precipitation: Texas High Plains, USA. *Geophysical Research Letters*, **29(16)**, 1755, doi:10.1029/2002GL014940.

[429] Schubert, S.D., M.J. Suarez, P.J. Pegion, R.D. Koster, and J.T. Bacmeister, 2004: On the cause of the 1930s Dust Bowl. *Science*, **303(5665)**, 1855-1859.

[430] Motha, R.P. and W. Baier, 2005: Impacts of present and future climate change and climate variability on agriculture in the temperate regions: North America. *Climatic Change*, **70(1-2)**, 137-164.

[431] Izaurralde, R.C., N.J. Rosenberg, R.A. Brown, and A.M. Thomson, 2003: Integrated assessment of Hadley Center (HadCM2) climate-change impacts on agricultural productivity and irrigation water supply in the conterminous United States: Part II. Regional agricultural production in 2030 and 2095. *Agricultural and Forest Meteorology*, **117(1-2)**, 97-122.

[432] Ziska, L. and K. George, 2004: Rising carbon dioxide and invasive, noxious plants: potential threats and consequences. *World Resource Review*, **16**, 427-447.

[433] Parton, W., M. Gutmann, and D. Ojima, 2007: Long-term trends in population, farm income, and crop production in the Great Plains. *Bioscience*, **57(9)**, 737-747.

[434] Reilly, J., F. Tubiello, B. McCarl, D. Abler, R. Darwin, K. Fuglie, S. Hollinger, C. Izaurralde, S. Jagtap, J. Jones, L. Mearns, D. Ojima, E. Paul, K. Paustian, S. Riha, N. Rosenberg, and C. Rosenzweig, 2003: U.S. agriculture and climate change: new results. *Climatic Change*, **57(1-2)**, 43-69.

[435] Allen, V.G., C.P. Brown, R. Kellison, E. Segarra, T. Wheeler, P.A. Dotray, J.C. Conkwright, C.J. Green, and V. Acosta-Martinez, 2005: Integrating cotton and beef production to reduce water withdrawal from the Ogallala aquifer in the southern high plains. *Agronomy Journal*, **97(2)**, 556-567.

[436] Hanson, J.D., M.A. Liebig, S.D. Merrill, D.L. Tanaka, J.M. Krupinsky, and D.E. Stott, 2007: Dynamic cropping systems: increasing adaptability amid an uncertain future. *Agronomy Journal*, **99(4)**, 939-943.

[437] Cameron, G.N. and D. Scheel, 2001: Getting warmer: effect of global climate change on distribution of rodents in Texas. *Journal of Mammalogy*, **82(3)**, 652-680.

[438] Levia, D.F. and E.E. Frost, 2004: Assessment of climatic suitability for the expansion of *Solenopsis invicta* Buren in Oklahoma using three general circulation models. *Theoretical and Applied Climatology*, **79(1-2)**, 23-30.

[439] Peterson, A.T., 2003: Projected climate change effects on Rocky Mountain and Great Plains birds: generalities of biodiversity consequences. *Global Change Biology*, **9(5)**, 647-655.

[440] Niemuth, N.D. and J.W. Solberg, 2003: Response of waterbirds to number of wetlands in the prairie pothole region of North Dakota, USA. *Waterbirds*, **26(2)**, 233-238.

[441] Conway, W.C., L.M. Smith, and J.D. Ray, 2005: Shorebird breeding biology in wetlands of the Playa Lakes, Texas, USA. *Waterbirds*, **28(2)**, 129-138.

[442] Scanlon, B., R. Reedy, and J. Tachovsky, 2007: Semiarid unsaturated zone chloride profiles: archives of past land use change impacts on water resources in the southern High Plains, United States. *Water Resources Research*, **43**, W06423, doi:10.1029/2006WR005769.

[443] Haukos, D.A. and L.M. Smith, 2003: Past and future impacts of wetland regulations on playa ecology in the southern Great Plains. *Wetlands*, **23(3)**, 577-589.

[444] Matthews, J., 2008: *Anthropogenic Climate Change in the Playa Lakes Joint Venture Region: Understanding Impacts, Discerning Trends, and Developing Responses*. Playa Lakes Joint Venture, Lafayette, CO, 40 pp. <http://www.pljv.org/cms/climate-change>

[445] Playa Lakes Joint Venture, Undated: *Playas and the Ogallala Aquifer – What's the Connection?* Playa Lakes Joint Venture, Lafayette, CO, 2 pp. <http://www.pljv.org/assets/Media/Recharge.pdf>

[446] U.S. Census Bureau, 2007: *Census Bureau Announces Most Populous Cities*. Press release June 28, 2007. <http://www.census.gov/Press-Release/www/releases/archives/population/010315.html>

[447] Ebi, K.L., D.M. Mills, J.B. Smith, and A. Grambsch, 2006: Climate change and human health impacts in the United States: an update on the results of the US national assessment. *Environmental Health Perspectives*, **114(9)**, 1318-1324.

[448] Nielsen, D.C., P.W. Unger, and P.R. Miller, 2005: Efficient water use in dryland cropping systems in the Great Plains. *Agronomy Journal*, **97(2)**, 364-372.

[449] NOAA's National Climatic Data Center, 2008: Southwest region Palmer Hydrological Drought index (PHDI). In: *Climate of 2008 – October: Southwest Region Moisture Status*. [Web site] NOAA National Climatic Data Center, Asheville, NC. <http://www.ncdc.noaa.gov/img/climate/research/prelim/drought/Reg107Dv00_palm06_pg.gif>

[450] Guhathakurta, S. and P. Gober, 2007: The impact of the Phoenix urban heat island on residential water use. *Journal of the American Planning Association*, **73(3)**, 317-329.

[451] Gleick, P.H., 1988: Regional hydrologic consequences of increases in atmospheric CO_2 and other trace gases. *Climatic Change*, **10(2)**, 137-160.

[452] Woodhouse, C.A., S.T. Gray, and D.M. Meko, 2006: Updated streamflow reconstructions for the upper Colorado River basin. *Water Resources Research*, **42,** W05415, doi:10.1029/2005WR004455.

[453] Meko, D.M., C.A. Woodhouse, C.A. Basisan, T. Knight, J.J. Lukas, M.K. Hughes, and M.W. Salzer, 2007: Medieval drought in the upper Colorado River basin. *Geophysical Research Letters*, **34**, L10705, doi:10.1029/2007GL029988.

[454] Stine, S., 1994: Extreme and persistent drought in California and Patagonia during mediaeval time. *Nature*, **369(6481)**, 546-549.

[455] Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Hastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer, 2005: Regional vegetation die-off in response to global-change drought. *Proceedings of the National Academy of Sciences*, **102(42)**, 15144-15148.

[456] Archer, C.L. and K. Caldiera, 2008: Historical trends in the jet streams. *Geophysical Research Letters*, **35**, L08803, doi:10.1029/2008GL033614.

[457] McAfee, S.A. and J.L. Russell, 2008: Northern annular mode impact on spring climate in the western United States. *Geophysical Research Letters*, **35**, L17701, doi:10.1029/2008GL034828.

[458] Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, 2006: Warming and earlier spring increase western U.S. forest wildfire activity. *Science*, **313(5789)**, 940-943.

[459] Lenihan, J.M., D. Bachelet, R.P. Neilson, and R. Drapek, 2008: Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. *Climatic Change*, **87(Supplement 1)**, S215-S230.

[460] Westerling, A.L. and B.P. Bryant, 2008: Climate change and wildfire in California. *Climatic Change*, **87(Supplement 1)**, S231-S249.

[461] Fried, J.S., J.K. Gilless, W.J. Riley, T.J. Moody, C.S. de Blas, K. Hayhoe, M. Moritz, S. Stephens and M. Torn, 2008: Predicting the effect of climate change on wildfire behavior and initial attack success. *Climatic Change*, **87(Supplement 1)**, S251-S264.

[462] Moritz, M.A. and S.L. Stephens, 2008: Fire and sustainability: considerations for California's altered future climate. *Climatic Change*, **87(Supplement 1)**, S265-S271.

[463] Rehfeldt, G.E., N.L. Crookston, M.V. Warwell, and J.S. Evans, 2006: Empirical analyses of plant-climate relationships for the western United States. *International Journal of Plant Sciences*, **167(6)**, 1123-1150.

[464] Weiss, J. and J.T. Overpeck, 2005: Is the Sonoran Desert losing its cool? *Global Change Biology*, **11(12)**, 2065-2077.

[465] Dole, K.P., M.E. Loik, and L.C. Sloan, 2003: The relative importance of climate change and the physiological effects CO_2 on freezing tolerance for the future distribution of *Yucca brevifolia*. *Global and Planetary Change*, **36(1-2),** 137-146.

[466] Loarie, S.R., B.E. Carter, K. Hayhoe, S. McMahon, R. Moe, C.A. Knight, and D.D. Ackerley, 2008: Climate change and the future of California's endemic flora. *PLoS ONE*, **3(6)**, e2502, doi:10.1371/journal.pone.0002502.

[467] Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. daFonseca, and J. Kent, 2000: Biodiversity hotspots for conservation priorities. *Nature*, **403(6772)**, 853-858.

[468] Mittermeier R.A., P. Robles Gil, M. Hoffman, J. Pilgrim, T. Brooks, C. Goettsch Mittermeier, J. Lamoreux, and G.A.B. da Fonseca, 2005: *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Conservation International, Washington DC, 392 pp.

[469] Farjon, A. and C.N. Page (eds.), 1999: *Conifers: Status Survey and Conservation Action Plan*. IUCN/SSC Conifer Special Group. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, and Cambridge, UK, 121 pp.

[470] Nixon, K.C., 1993: The genus *Quercus* in Mexico. In: *Biological Diversity of Mexico: Origins and Distribution* [Ramamoorthy, T.P., R. Bye, A. Lot, and J. Fa (eds.)]. Oxford University Press, New York, 812 pp.

[471] Brower, L.P., G. Castilleja, A. Peralta, J. López-García, L. Bojórquez-Tapia, S. Díaz, D. Melgarejo, and M. Missrie, 2002: Quantitative changes in forest quality in a principal overwintering area of the monarch butterfly in Mexico, 1971–1999. *Conservation Biology*, **16(2)**, 346-359.

[472] Goodrich, G. and A. Ellis, 2008: Climatic controls and hydrologic impacts of a recent extreme seasonal precipitation reversal in Arizona. *Journal of Applied Meteorology and Climatology*, **47(2)**, 498-508.

[473] Allan, R.P. and B.J. Soden, 2008: Atmospheric warming and the amplifications of precipitation extremes. *Science*, **321(5895)**, 1481-1484.

[474] Bales, R.C., N.P. Molotch, T.H. Painter, M.D. Dettinger, R. Rice, and J. Dozier, 2006: Mountain hydrology of the western United States. *Water Resources Research*, **42**, W08432, doi:10.1029/2005WR004387.

[475] Delta Risk Management Strategy, 2008: Section 2: Sacramento/San Joaquin Delta and Suisun Marsh. In: *Phase I Report: Risk Analysis*. California Department of Water Resources, [13 pp.] <http://www.drms.water.ca.gov>

[476] Delta Risk Management Strategy, 2008: Summary report. In: *Phase I Report: Risk Analsysis*. California Department of Water Resources, [42 pp.]. <http://www.drms.water.ca.gov>

[477] Zimmerman, G., C. O'Brady, and B. Hurlbutt, 2006: Climate change: modeling a warmer Rockies and assessing the implications. In: *The 2006 State of the Rockies Report Card*. Colorado College, Colorado Springs, pp. 89-102. <http://www.coloradocollege.edu/stateoftherockies/06ReportCard.html>

[478] Lazar, B. and M. Williams, 2008: Climate change in western ski areas: potential changes in the timing of wet avalanches and snow quality for the Aspen ski areas in the years 2030 and 2100. *Cold Regions Science and Technology*, **51(2-3)**, 219-228.

[479] Kleeman, M.J., 2008: A preliminary assessment of the sensitivity of air quality in California to global change. *Climatic Change*, **87(Supplement 1)**, S273-S292.

[480] Vicuna, S., R. Leonardson, M.W. Hanemann, L.L. Dale, and J.A. Dracup, 2008: Climate change impacts on high elevation hydropower generation in California's Sierra Nevada: a case study in the upper American River. *Climatic Change*, **87(Supplement 1)**, S123-S137.

[481] Medellín-Azuara, J., J.J. Harou, M.A. Olivares, K. Madani, J.R. Lund, R.E. Howitt, S.K. Tanaka, M.W. Jenkins, and T. Zhu, 2008: Adaptability and adaptations of California's water supply system to dry climate warming. *Climatic Change*, **87(Supplement 1)**, S75-S90.

[482] Baldocchi, D. and S. Wong, 2008: Accumulated winter chill is decreasing in the fruit growing regions of California. *Climatic Change*, **87(Supplement 1)**, S153-S166.

[483] Lobell, D., C. Field, K. Nicholas Cahill, and C. Bonfils, 2006: Impacts of future climate change on California perennial crop yields: model projections with climate and crop uncertainties. *Agricultural and Forest Meteorology*, **141(2-4)**, 208-218.

[484] Purkey, D.R., B. Joyce, S. Vicuna, M.W. Hanemann, L.L. Dale, D. Yates, and J.A. Dracup, 2008: Robust analysis of future climate change impacts on water for agriculture and other sectors: a case study in the Sacramento Valley. *Climatic Change*, **87(Supplement 1)**, S109-S122.

[485] Mote, P.W., 2003: Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. *Northwest Science*, **77(4)**, 271-282.

[486] Mote, P., E. Salathé, V. Dulière, and E. Jump, 2008: *Scenarios of Future Climate for the Pacific Northwest*. Climate Impacts Group, University of Washington, Seattle, 12 pp. <http://cses.washington.edu/db/pubs/abstract628.shtml>

[487] Hamlet, A.F., P.W. Mote, M. Clark, and D.P. Lettenmaier, 2005: Effects of temperature and precipitation variability on snowpack trends in the western United States. *Journal of Climate*, **18(21)**, 4545-4561.

[488] Mote, P.W., 2006: Climate-driven variability and trends in mountain snowpack in western North America. *Journal of Climate*, **19(23)**, 6209-6220.

[489] Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier, 2004: Mitigating the effects of climate change on the water resources of the Columbia River basin. *Climatic Change*, **62(1-3)**, 233-256.

[490] Figure provided by the Climate Impacts Group, University of Washington, Seattle. <http://cses.washington.edu/cig/>

[491] Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier, 2005: Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society*, **86(1)**, 39-49.

[492] Hamlet, A.F. and D.P. Lettenmaier, 2007: Effects of 20th century warming and climate variability on flood risk in the western U.S. *Water Resources Research*, **43**, W06427, doi:10.1029/2006WR005099.

[493] Bonneville Power Administration, 2001: *The Columbia River System Inside Story*. Internal report DOE/BP-3372. Bonneville Power Administration, Portland OR, 2nd edition, 78 pp. <http://www.bpa.gov/corporate/Power_of_Learning/docs/columbia_river_inside_story.pdf>

[494] Casola, J.H., J.E. Kay, A.K. Snover, R.A. Norheim, L.C. Whitely Binder, and Climate Impacts Group, 2005: *Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture*. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, 43 pp. <http://cses.washington.edu/db/pdf/kc05whitepaper459.pdf>

[495] Ministry of the Environment, British Columbia, Canada, 2007: *Environmental Trends 2007: The Mountain Pine Beetle in British Columbia*. <http://www.env.gov.bc.ca/soe/et07/pinebeetle.html>

[496] Francis, R.C. and N.J. Mantua, 2003: Climatic influences on salmon populations in the northeast Pacific. In: *Assessing Extinction Risk for West Coast Salmon* [MacCall, A.D. and T.C. Wainwright (eds.)]. NOAA technical memo NMFS-NWFSC-56. National Marine Fisheries Service, [Washington, DC], pp. 37-67. <http://www.nwfsc.noaa.gov/assets/25/3946_06162004_130044_tm56.pdf>

[497] Salathé, E.P., 2005: Downscaling simulations of future global climate with application to hydrologic modelling. *International Journal of Climatology*, **25(4)**, 419-436.

[498] Mote, P.W., A. Petersen, S. Reeder, H. Shipman, and L. Whitely Binder, 2008: *Sea Level Rise Scenarios for Washington State*. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, and Washington Department of Ecology, Lacey, 11 pp. <http://www.cses.washington.edu/db/pdf/moteetalslr579.pdf>

[499] Petersen, A.W., 2007: *Anticipating Sea Level Rise Response in Puget Sound*. M.M.A. thesis, School of Marine Affairs. University of Washington, Seattle, 73 pp.

[500] Snover, A.K., L. Whitely Binder, J. Lopez, E. Willmott, J. Kay, D. Howell, and J. Simmonds, 2007: *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. The Climate Impacts Group, University of Washington, and King County, Washington, in association with and published by ICLEI – Local Governments for Sustainability, Oakland, CA, 172 pp.

[501] Fitzpatrick, J., R.B. Alley, J. Brigham-Grette, G.H. Miller, L. Polyak, and M. Serreze, 2008: Preface: Why and how to use this synthesis and assessment report. In: *Past Climate Variability and Change in the Arctic and at High Latitude*. Synthesis and Assessment Product 1.2. U.S. Geological Survey, Reston, VA, pp. 8-21.

[502] Data provided by Dr. Glenn Juday, School of Natural Resources and Agricultural Science, Agricultural and Forestry Experiment Station, University of Alaska, Fairbanks.

[503] Euskirchen, E.S., A.D. McGuire, D.W. Kicklighter, Q. Zhuang, J.S. Clein, R.J. Dargaville, D.G. Dye, J.S. Kimball, K.C. McDonald, V.E. Melillo, V.E. Romanovsky, and N.V. Smith, 2006: Importance of recent shifts in soil thermal dynamics on growing season length, productivity, and carbon sequestration in terrestrial high-latitude ecosystems. *Global Change Biology*, **12(4)**, 731-750.

[504] Euskirchen, E.S., A.D. McGuire, and F.S. Chapin III, 2007: Energy feedbacks of northern high-latitude ecosystems to the climate system due to reduced snow cover during 20th century warming. *Global Change Biology*, **13(11)**, 2425-2438.

[505] Barber, V.A., G.P. Juday, and B.P. Finney, 2000: Reduced growth of Alaskan white spruce in the twentieth century from temperature-induced drought stress. *Nature*, **405 (6787)**, 668-673.

[506] Juday, G.P., V. Barber, P. Duffy, H. Linderholm, T.S. Rupp, S. Sparrow, E. Vaganov, and J. Yarie, 2005: Forests, land management, and agriculture. In: *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, and New York, pp. 781-862. <http://www.acia.uaf.edu/pages/scientific.html>

[507] Balshi, M.S., A.D. McGuire, P. Duffy, M. Flannigan, J. Walsh, and J.M. Melillo, 2008: Assessing the response of area burned to changing climate in western boreal North America using a Multivariate Adaptive Regression Splines (MARS) approach. *Global Change Biology*, **15(3)**, 578-600.

[508] Berman, M., G.P. Juday, and R. Burnside, 1999: Climate change and Alaska's forests: people, problems, and policies. In: *Assessing the Consequences of Climate Change in Alaska and the Bering Sea Region*. Proceedings of a workshop at the University of Alaska Fairbanks, 29-30 October 1998. Center for Global Change and Arctic System Research, University of Alaska, pp. 21-42.

[509] Fleming, R.A. and W.J.A. Volney, 1995: Effects of climate change on insect defoliator population processes in Canada's boreal forest: some plausible scenarios. *Water, Soil, and Air Pollution*, **82(1-2)**, 445-454.

[510] Kasischke, E.S. and M.R. Turetsky, 2006: Recent changes in the fire regime across the North American boreal region - spatial and temporal patterns of burning across Canada and Alaska. *Geophysical Research Letters*, **33**, L09703, doi:10.1029/2006GL025677.

[511] Chapin, F.S., III, S.F. Trainor, O. Huntington, A.L. Lovecraft, E. Zavaleta, D.C. Natcher, A.D. McGuire, J.L. Nelson, L. Ray, M. Calef, N. Fresco, H. Huntington, T.S. Rupp, L. DeWilde, and R.A. Naylor, 2008: Increasing wildfire in Alaska's boreal forest: pathways to potential solutions of a wicked problem. *BioScience*, **58(6)**, 531-540.

[512] Berner, J. and C. Furgal, 2005: Human health. In: *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, and New York, pp. 863-906. <http://www.acia.uaf.edu/pages/scientific.html>

[513] Klein, E., E.E. Berg, and R. Dial, 2005: Wetland drying and succession across the Kenai Peninsula Lowlands, south-central Alaska. *Canadian Journal of Forest Research*, **35(8)**, 1931-1941.

[514] Riordan, B., D. Verbyla, and A.D. McGuire, 2006: Shrinking ponds in subarctic Alaska based on 1950–2002 remotely sensed images. *Journal of Geophysical Research*, **111**, G04002, doi:10.1029/2005JG000150.

[515] Osterkamp, T., 2007: Characteristics of the recent warming of permafrost in Alaska. *Journal of Geophysical Research*, **112**, F02S02, doi:10.1029/2006JF000578.

[516] Instanes, A., O. Anisimov, L. Brigham, D. Goering, L.N. Khrustalev, B. Ladanyi, and J.O. Larsen, 2005: Infrastructure: buildings, support systems, and industrial facilities. In: *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, UK, and New York, pp. 907-944. <http://www.acia.uaf.edu/pages/scientific.html>

[517] Brown, J. and V.E. Romanovsky, 2008: Report from the International Permafrost Association: State of permafrost in the first decade of the 21st century. *Permafrost and Periglacial Processes*, **19(2)**, 255-260.

[518] Busey, R.C., L.D. Hinzman, J.J. Cassano, and E. Cassano, 2008: Permafrost distributions on the Seward Peninsula: past, present, and future. In: *Proceedings of the Ninth International Conference on Permafrost*, University of Alaska Fairbanks, June 29-July 3, 2008 [Kane, D.L. and K.M. Hinkel (eds.)]. Institute of Northern Engineering, University of Alaska, Fairbanks, pp. 215-220.

[519] Shumaker, V.O., 1979: *The Alaska Pipeline*. Julian Messner, New York, 64 pp.

[520] Bengtsson, L., K.I. Hodges, and E. Roeckner, 2006: Storm tracks and climate change. *Journal of Climate*, **19(15)**, 3518-3543.

[521] U.S. Army Corps of Engineers, 2008: *Newtok Evacuation Center, Mertarvik, Nelson Island, Alaska*. Revised environmental assessment. U.S. Army Corps of Engineers, Alaska District, [Elmendorf AFB, 64 pp.]

[522] Jones, B.M., C.D. Arp, M.T. Jorgenson, K.M. Hinkel, J.A. Schmutz, and P.L. Flint, 2009: Increase in the rate and uniformity of coastline erosion in Arctic Alaska. *Geophysical Research Letters*, **36**, L03503, doi:10.1029/2008GL036205.

[523] Yin, J.H., 2005: A consistent poleward shift of the storm tracks in simulations of 21st century climate. *Geophysical Research Letters*, **32**, L18701, doi:10.1029/2005GL023684.

[524] Salathé, E.P., Jr., 2006: Influences of a shift in North Pacific storm tracks on western North American precipitation under global warming. *Geophysical Research Letters*, **33**, L19820, doi:10.1029/2006GL026882.

[525] Data provided by Dr. David Atkinson, International Arctic Research Center, University of Alaska, Fairbanks.

[526] Feely, R.A., C.L. Sabine, K. Lee, W. Berelson, J. Kleypas, V.J. Fabry and F.J. Millero, 2004: Impact of anthropogenic CO_2 on $CaCO_3$ system in the oceans. *Science*, **305(5682)**, 362-366.

[527] Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L. McNutt, 2006: A major ecosystem shift in the northern Bering Sea. *Science*, **311(5766)**, 1461-1464.

[528] Ray, G.C., J. McCormick-Ray, P. Berg, and H.E. Epstein, 2006: Pacific walrus: benthic bioturbator of Beringia. *Journal of Experimental Marine Biology and Ecology*, **330(1)**, 403-419.

[529] Mueter, F.J. and M.A. Litzow, 2007: Sea ice retreat alters the biogeography of the Bering Sea continental shelf. *Ecological Applications*, **18(2)**, 309-320.

[530] Shea, E.L., G. Dolcemascolo, C.L. Anderson, A. Barnston, C.P. Guard, M.P. Hamnett, S.T. Kubota, N. Lewis, J. Loschnigg, and G. Meehl, 2001: *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change: Pacific Islands.* East-West Center, Honolulu, HI, 102 pp. <http://www2.eastwestcenter.org/climate/assessment/>

[531] Guidry, M.W. and F.T. Mackenzie, 2006: *Climate Change, Water Resources, and Sustainability in the Pacific Basin: Emphasis on O'ahu, Hawai'I and Majuro Atoll, Republic of the Marshall Islands*. University of Hawaii Sea Grant Program, Honolulu, 100 pp. <http://nsgl.gso.uri.edu/hawau/hawaut06001.pdf>

[532] CEO, 2004: *Caribbean Environmental Outlook*. [Heileman, S., L.J. Walling, C. Douglas, M. Mason, and M. Chevannes-Creary (eds.)]. United Nations Environmental Programme, Kingston, Jamaica, 114 pp. <http://www.unep.org/geo/pdfs/caribbean_eo.pdf>

[533] Church, J.A., N.J. White, and J.R. Hunter, 2006: Sea-level rise at tropical Pacific and Indian Ocean islands. *Global and Planetary Change*, **53(3)**, 155-168.

[534] Burns, W.C.G., 2002: Pacific island developing country water resources and climate change. In: *The World's Water* [Gleick, P. (ed.)]. Island Press, Washington, DC, 3rd edition, pp. 113-132.

[535] Baker, J.D., C.L. Littnan, and D.W. Johnston, 2006: Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the northwestern Hawaiian Islands. *Endangered Species Research*, **2**, 21-30.

[536] Firing, Y. and M.A. Merrifield, 2004: Extreme sea level events at Hawaii: influence of mesoscale eddies. *Geophysical Research Letters*, **31**, L24306, doi:10.1029/2004GL021539.

[537] Scott, D., M. Overmars, T. Falkland, and C. Carpenter, 2003: *Pacific Dialogue on Water and Climate, Synthesis Report.* South Pacific Applied Geoscience Commission, Fiji Islands, 28 pp. <http://www.oas.org/CDWC/Documents/SIDS%20Paper/Pacific%20Report%20-%20Final.pdf>

[538] Hay, J., N. Mimura, J. Campbell, S. Fifita, K. Koshy, R.F. McLean, T. Nakalevu, P. Nunn, and N. deWet, 2003: *Climate Variability and Change and Sea Level Rise in the Pacific Islands Regions: A Resource Book for Policy and Decision Makers, Educators and Other Stakeholders*. South Pacific Regional Environmental Programme (SPREP), Apia, Samoa, 94 pp. <http://www.sprep.org/publication/pub_detail.asp?id=181>

[539] Gillespie, R.G., E.M. Claridge, and G.K. Roderick, 2008: Biodiversity dynamics in isolated island communities: interaction between natural and human-mediated processes. *Molecular Ecology*, **17(1)**, 45-57.

[540] Becken, S. and J.E. Hay, 2007: *Tourism and Climate Change: Risks and Opportunities*. Channel View Publications, Clevedon, UK, and Buffalo, NY, 329 pp.

[541] State of Hawaii, Division of Business, Economic Development, and Tourism, 2008: *Facts and Figures: State of Hawaii.* [Web site] <http://hawaii.gov/dbedt/info/economic/library/facts/state>

[542] Cesar, H.S.F. and F.H. van Beukering, 2004: Economic valuation of the coral reefs of Hawaii. *Pacific Science*, **58(2)**, 231-242.

[543] Hoegh-Guldberg, O., P.J. Mumby, A.J. Hooten, R.S. Steneck, P. Greenfield, E. Gomez, C.D. Harvell, P.F. Sale, A.J. Edwards, K. Caldeira, N. Knowlton, C.M. Eakin, R. Iglesias-Prieto, N. Muthiga, R.H. Bradbury, A. Dubi, and M.E. Hatziolos, 2007: Coral reefs under rapid climate change and ocean acidification. *Science*, **318(5857)**, 1737-1742.

[544] Donner, S.D., W.J. Skirving, C.M. Little, M. Oppenheimer, and O. Hoegh-Guldberg, 2005: Global assessment of coral bleaching and required rates of adaptation under climate change. *Global Change Biology*, **11(12)**, 2251-2265.

[545] Paulay, G., L. Kirkendale, G. Lambert, and C. Meyer, 2002: Anthropogenic biotic interchange in a coral reef ecosystem: a case study from Guam. *Pacific Science*, **56(4)**, 403-422.

[546] Hotta, M., 2000: The sustainable contribution of fisheries to food security in the Asia and Pacific region: regional synthesis. In: *Sustainable Contribution of Fisheries to Food Security.* Food and Agriculture Organization of the United Nations, Bangkok, Thailand, pp. 1-28. <http://www.fao.org/DOCREP/003/X6956E/x6956e02.htm>

[547] Graham, N.A.J., S.K. Wilson, S. Jennings, N.V.C. Polunin, J.P. Bijoux, and J. Robinson, 2006: Dynamic fragility of oceanic coral reef ecosystems. *Proceedings of the National Academy of Sciences*, **103(22)**, 8425-8429.

[548] Lehodey, O., M. Bertignac, J. Hampton, A. Lewis, and J. Picaut, 1997: El Niño Southern Oscillation and tuna in the western Pacific. *Nature*, **389(6652)**, 715-718.

[549] Crowell, M., S. Edelman, K. Coulton, and S. McAfee, 2007: How many people live in coastal areas? *Journal of Coastal Research*, **23(5)**, iii-vi.

[550] Gill, S.K., R. Wright, J.G. Titus, R. Kafalenos, and K. Wright, 2009: Population, land use, and infrastructure. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and

S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 105-116.

[551] U.S. Commission on Ocean Policy, 2004: *An Ocean Blueprint for the 21st Century*. U.S. Commission on Ocean Policy, Washington, DC. <http://www.oceancommission.gov/documents/full_color_rpt/welcome.html>

[552] Day, J.W., Jr., D.F. Boesch, E.J. Clairain, G.P. Kemp, S.B. Laska, W.J. Mitsch, K. Orth, H. Mashriqui, D.J. Reed, L. Shabman, C.A. Simenstad, B.J. Streever, R.R. Twilley, C.C. Watson, J.T. Wells, and D.F. Whigham, 2007: Restoration of the Mississippi Delta: essons from hurricanes Katrina and Rita. *Science*, **315(5819)**, 1679-1684.

[553] Boesch, D.F. (ed.), 2008: *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland*. University of Maryland Center for Environmental Science, Cambridge, MA, 85 pp. <http://www.umces.edu/climateimpacts/>

[554] Cazenave, A., K. Dominh, S. Guinehut, E. Berthier, W. Llovel, G. Ramillien, M. Ablain, and G. Larnicol, 2009: Sea level budget over 2003–2008: a reevaluation from GRACE space gravimetry, satellite altimetry and Argo. *Global and Planetary Change*, **65(1-2)**, 83-88.

[555] Vaughan, D.G. and R. Arthern, 2007: Why is it hard to predict the future of ice sheets? *Science*, **315(5818)**, 1503-1504.

[556] Justić, D., N.N. Rabalais, and R.E. Turner, 2003: Simulated responses of the Gulf of Mexico hypoxia to variations in climate and anthropogenic nutrient loading. *Journal of Marine Systems*, **42(2-3)**, 115-126.

[557] Boesch, D.F., V.J. Coles, D.G. Kimmel, and W.D. Miller, 2007: Coastal dead zones and global climate change: ramifications of climate change for Chesapeake Bay hypoxia. In: *Regional Impacts of Climate Change: Four Case Studies in the United States*. Pew Center for Global Climate Change, Arlington, VA, pp. 57-70. <http://www.pewclimate.org/regional_impacts>

[558] Wicks, C., D. Jasinski, and B. Longstaff, 2007: *Breath of Life: Dissolved Oxygen in Chesapeake Bay*. EcoCheck, Oxford, MD, 4 pp. <http://www.eco-check.org/pdfs/do_letter.pdf>

[559] Kimmerer, W.J., E. Garside, and J.J. Orsi, 1994: Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. *Marine Ecology Progress Series*, **113**, 81-93.

[560] Carpenter, K.E., M. Abrar, G. Aeby, R.B. Aronson, S. Banks, A. Bruckner, A. Chiriboga, J. Cortés, J.C. Delbeek, L. DeVantier, G.J. Edgar, A.J. Edwards, D. Fenner, H.M. Guzmán, B.W. Hoeksema, G. Hodgson, O. Johan, W.Y. Licuanan, S.R. Livingstone, E.R. Lovell, J.A. Moore, D.O. Obura, D. Ochavillo, B.A. Polidoro, W.F. Precht, M.C. Quibilan, C. Reboton, Z.T. Richards, A.D. Rogers, J. Sanciangco, A. Sheppard, C. Sheppard, J. Smith, S. Stuart, E. Turak, J.E.N. Veron, C. Wallace, E. Weil, and E. Wood, 2008: One-third of reef-building corals face elevated extinction risk from climate change and local impacts. *Science*, **321(5888)**, 560-563.

[561] Chan, F., J.A. Barth, J. Lubchenco, A. Kirincich, H. Weeks, W.T. Peterson, and B.A. Menge, 2008: Emergence of anoxia in the California current large marine ecosystem. *Science*, **319(5865)**, 920.

[562] Data for hypoxia distribution maps made available by Dr. Bill Peterson, (NOAA), the Bonneville Power Administration, Drs. Francis Chan and Jane Lubchenco, (PISCO, Partnership for Interdisciplinary Studies of Coastal Oceans), Drs. Jack Barth and Steve Pierce (Oregon State University/College of Oceanic and Atmospheric Sciences) and NOAA Northwest Fisheries Science Center.

[563] Crozier, L.G., A.P. Hendry, P.W. Lawson, T.P. Quinn, N.J. Mantua, J. Battin, R.G. Shaw, and R.B. Huey, 2008: Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications*, **1(2)**, 252-270.

[564] Hondzo, M. and H.G. Stefan, 1991: Three case studies of lake temperature and stratification response to warmer climate. *Water Resoures Research*, **27(8)**, 1837-1846.

[565] Morel, F.M.M., A.M.L. Kraepiel, and M. Amyot, 1998: The chemical cycle and bioaccumulation of mercury. *Annual Review of Ecology and Systematics*, **29**, 543-566.

[566] Williamson, C.E., J.E. Saros, and D.W. Schindler, 2009: Sentinels of change. *Science*, **323(5916)**, 887-888.

[567] Stachowicz, J.J., J.R. Terwin, R.B. Whitlatch, and R.W. Osman, 2002: Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. *Proceedings of the National Academy of Sciences*, **99(24)**, 15497-15500.

[568] Keleher, C.J. and F.J. Rahel, 1996: Thermal limits to salmonid distributions in the Rocky Mountain region and potential habitat loss due to global warming: A Geographic Information System (GIS) approach. *Transactions of the American Fisheries Society*, **125(1)**, 1-13.

[569] McCullough, D., S. Spalding, D. Sturdevant, and M. Hicks, 2001: *Issue Paper 5: Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids.* EPA-910-D-01-005, prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. [EPA Pacific Northwest Regional Office (Region 10), Seattle, WA], 114 pp.

PHOTO AND FIGURE CREDITS

Cover: Blue marble, USA, NASA WorldWind
Inside Cover: USA map, NOAA/NCDC; Water glass, ©iStockphotos.com/luchschen; Tractor trailer ©iStockphotos.com/Clayton Hansen; Hospital scene, ©iStockphotos.com/Jeffrey Smith; San Francisco, Grant Goodge,STG Inc.
Table of Contents: Planet Earth, NASA; Water glass,©iStockphotos.com/luchschen; Tractor trailer©iStockphotos.com/Clayton Hansen; Hospital scene, ©iStockphotos.com/Jeffrey Smith; San Francisco, Grant Goodge,STG Inc.
Throughout the report, Adaptation title texture, ©iStockphotos.com/Bill Noll
Page 6, 13: Planet Earth, NASA
Page 38: Lake Effect snow, Dave Kelly, NOAA National Severe Storms Laboratory
Page 41: Water glass,©iStockphotos.com/luchschen; Skagit River, Philip Mote PhD, Climate Impacts Group, Univ. of Washington
Page 47: Turbidity in New York City's Ashokan, Thurlough Smyth, Climate Change Planning,New York City Department of Environmental Protection, Bureau of Environmental Planning & Assessment
Page 48: Flood water road damage, Grant Goodge, STG Inc.
Page 51: Two Lake Powell photos, John C. Dohrenwend
Page 52: Water and energy corner schematic, Electric Power Research Institute, Palo Alto, CA and Tetra Tech Inc., Lafayette, CA
Page 59: St. Lucie power plant, CCSP SAP 4.5
Page 55: Map, Rocky Bilotta, Earth Resources Technology
Page 60: Hydro-electric dam, Philip Mote PhD, Climate Impacts Group, Univ. of Washington; Ship, NOAA
Page 61: Tractor trailer©iStockphotos.com/claylib; Houses against bridge, Associated Press/Jeff Roberson
Page 65: Kosrae Island photo, John E. Hay
Page 66: Flooded railway Plainfield, IA, Don Becker, USGS
Page 68: Broken bridge, Joe Furr
Page 75: CO_2 plant photos, Lewis Ziska, USDA ARS
Page 80: Edith's checkerspot butterfly, Camille Parmesan, University of Texas at Austin
Page 83: Rob Wu, CCSP SAP 4.3
Page 85: Polar bear, Mike Dunn, North Carolina Museum of Natural Sciences
Page 86: Pika, ©iStockphotos.com/Global Exposure; Climate change graphic depicting the changing forests, Boston Globe/Landov
Page 89: Hospital scene, ©iStockphotos.com/Jeffrey Smith
Page 91: Urban heat island, ©Crown Copyright and Licensing, Canada
Page 92: New York and Atlanta smog, Paul Grabhorn
Page 93: Los Angeles smog, ©iStockphotos.com/Stein Photo
Page 95: Mosquito, upper corner, ©iStockphotos.com/Julie Le de Leseleuc; Virus cycle illustration, Deborah Misch, STG Inc.
Page 97: Poison ivy plant and girl scratching, Sara Veasey, NOAA/NCDC
Page 98: EMS officer and woman, Sara Veasey, NOAA/NCDC
Page 99: San Franciso, Grant Goodge, STG Inc., Midwest flood, Associated Press/Jeff Roberson
Page 101: Person in floodwater, Associated Press/Dave Martin; Aerial flood, USGS
Page 109: New York City, Applied Science Associates, Inc.; Boston Deer Island sewage plant, Massachusetts Water Resources Authority
Page 113: Dry Lake Lanier, Kent Frantz, NOAA National Weather Service Southern Regional Headquarters
Page 114: Barrier islands , USGS
Page 115: Fish plant, Barataria Terrebonne; Flooded area, Dr. Kerry St. Pé of the Barataria-Terrebonne National Estuary program
Page 116: Flood levee, U.S. Army Corps of Engineers
Page 118: Chicago map, City of Chicago; Thermal image, Chicago Police Department and the Cook County Sheriff's Department
Page 120: Flooded highway, Missouri Highway & Transportation Department/USGS; Flood of 1993, NOAA
Page 125: Dust bowl, NOAA
Page 126: Mallard duck, ©iStockphotos.com/Andy Gehrig
Page 127: Playa lakes, Katharine Hayhoe, Texas Tech University
Page 128: Seedlings, USDA/NRCS
Page 132: Map, Rocky Bilotta, Earth Resources Technology
Page 142: Alaska pipeline, SSgt. Joshua Strang, U.S. Air Force
Page 143: Leaning trees, NOAA
Page 147: El Niño billboard, NOAA National Weather Service Pacific Region Headquarters
Page 148: Micronesia, Eric L. Gilman
Page 150: Ghost swamp, USGS, National Wetlands Research Center
Page 152: Sea wall, Jack Pellette, National Weather Service

Contact Information

Global Change Research Information Office
c/o U.S. Global Change Research Program Office
1717 Pennsylvania Avenue, NW
Suite 250
Washington, DC 20006
202-223-6262 (voice)
202-223-3065 (fax)

To obtain a copy of this document, place an order at the Global Change Research Information Office (GCRIO) web site:
http://www.gcrio.org/orders

U.S. Global Change Research Program and the Subcommittee on Global Change Research

Jack Kaye, Vice Chair,
National Aeronautics and Space Administration,
Acting Director, U.S. Global Change Research Program

Allen Dearry
Department of Health and Human Services

Anna Palmisano
Department of Energy

Mary Glackin
National Oceanic and Atmospheric Administration

Charles Vincent
Department of Defense

William Hohenstein
Department of Agriculture

Linda Lawson
Department of Transportation

Thomas Armstrong
U.S. Geological Survey

Tim Killeen
National Science Foundation

Patrick Neale
Smithsonian Institution

William Breed
U.S. Agency for International Development

Joel Scheraga
Environmental Protection Agency

Jonathan Pershing
Department of State

EXECUTIVE OFFICE AND OTHER LIAISONS

Robert Marlay
Climate Change Technology Program

Katharine Gebbie
National Institute of Standards & Technology

Jason Bordoff
Council on Environmental Quality

Philip DeCola
Office of Science and Technology Policy

Stuart Levenbach
Office of Management and Budget

Margaret McCalla
Office of the Federal Coordinator for Meteorology

Howard Frumkin
Center for Disease Control

This book summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is an authoritative scientific report written in plain language, with the goal of better informing public and private decision making at all levels.

U.S. Global Change Research Program

http://www.globalchange.gov

CAMBRIDGE
UNIVERSITY PRESS
www.cambridge.org

ISBN 978-0-521-14407-0

NATIONAL RAILROAD PASSENGER CORPORATION
187 S. Holgate Street Seattle, WA 98107
tel (206)-903-5539, fax (206)-382-4166

Public Resource Center
Department of Planning and Development
City of Seattle
PO Box 34019
Seattle, WA 98124-4019

29 November 2012

RE: Seattle Arena Proposal – Project 3014195
1700 1St Avenue South
Comments on the Scope of the EIS

Also transmitted via email to: prc@seattle.gov

Amtrak requests that the scope of the Seattle Arena EIS include the following:

- Current and anticipated increases in rail traffic volume in the vicinity of the proposed site (including passenger and freight frequencies, as well as, associated non-revenue train movement crossing S. Holgate Street that bisects Amtrak's Seattle Facility). Please note that the initial traffic study submitted by the applicant, while addressing road freight mobility, did not address rail traffic mobility in the area.

- Impacts to Amtrak Facility - employee/vehicle movement through our facility (bisected by S. Holgate Street) and subsequent impact to facility operations including, but not limited to, Amtrak vendor access, equipment servicing and maintenance, and on-time service delivery to State-supported *Amtrak Cascades* trains, Sound Transit Sounder commuter trains, and Amtrak's two national long distance trains: the *Coast Starlight* (Seattle, WA to Los Angeles, CA) and the *Empire Builder* (Seattle, WA to Chicago, IL)

- Impacts to passenger access to King Street Station

- Impacts to pedestrian and vehicle safety at rail crossings, especially at S. Holgate Street since current and future event attendees will be crossing, at grade, through an active rail yard facility with 12 sets of tracks (should suggested mitigation not be considered).

- Impacts and mitigation measures during construction

NATIONAL RAILROAD PASSENGER CORPORATION
187 S. Holgate Street Seattle, WA 98107
tel (206)-903-5539, fax (206)-382-4166

Rail Traffic Analysis

The traffic impact analysis for the proposal should account for anticipated growth in rail traffic, including passenger, freight, and yard operations. The Washington State Department of Transportation (WSDOT) Rail Plan calls for increased passenger service through 2023.

Amtrak Cascades passenger service will increase between Seattle's King Street Station and Union Station in Portland. In 2017, *Amtrak Cascades* will add 2 daily roundtrips, increasing from 4 to 6 daily round trips (12 trains).

Amtrak will maintain its once daily roundtrip (2 trains) of the *Coast Starlight* between Seattle, WA and Los Angeles, CA. Daily intercity passenger rail service south of Seattle increases from the current 5 roundtrips to 7 roundtrips in 2017 (14 daily trains).

WSDOT's 2008 *Amtrak Cascades Mid-Range Plan* identifies further service improvements by 2023. This includes an Increase from 6 to 13 roundtrips between Seattle and Portland, Oregon and Increase from 2 to 4 roundtrips between Seattle and Vancouver, British Columbia—34 daily *Amtrak Cascades* trains, 2 *Coast Starlight* trains, and 2 *Empire Builder* trains (38 daily trains passing through the vicinity of the proposed arena.

Sound Transit Sounder presently provides 9 daily roundtrips (18 trains) of weekday commuter service south of Seattle to and from King Street Station. Sounder service south of Seattle increases to 13 roundtrips (26 trains) by 2017.

Union Pacific and Burlington Northern Santa Fe, both private railroads, transport rail freight south of King Street Station. Future rail volumes are projected to increase.

Impact to Amtrak Facility Operations

In 2012, Amtrak completed a $37 million investment in phases 1 and 2 of our administrative and maintenance facility in Seattle to address the growing mobility needs of the State of Washington Rail Plan, Sound Transit Sounder Commuter service, and Amtrak's national long-distance operations. Design for phases 3 & 4 are currently underway, and will result in an additional $50 million dollar investment by Amtrak to meet agency and partner's long range plans.

South Holgate Street bisects the Seattle Amtrak Facility. Pedestrian and vehicle traffic from the area and current stadium events create safety, security, and operational concerns at the rail crossing. Additional events, as a result of the proposed arena directly adjacent to S. Holgate Street and the Amtrak Facility, will result in increased traffic (both vehicular and pedestrian) and increased risk to safety, security, and operations.

NATIONAL RAILROAD PASSENGER CORPORATION
187 S. Holgate Street Seattle, WA 98107
tel (206)-903-5539, fax (206)-382-4166

The EIS should consider the impacts to Amtrak operations on State-supported, commuter, and long-distance train service that operate from our facility. This includes current and future impacts of pedestrians and vehicles fouling tracks during events-due to congestion and violating train warning devices, impacts to employee, crew, and vendor movement within the Amtrak facility, and to Kings Street Station that support passenger rail service, and impact to overall Amtrak service delivery

Passenger access to King Street Station

King Street Station is the 15th busiest Amtrak station in the nation. 672, 351 Amtrak passengers used King Street Station in FY12, more when you include Sound Transit commuters.

Access to King Street station is constrained by a single road access and current congestion due construction of a mixed use facility and hotel just south off the station. Temporary construction congestion will be replaced by increased traffic as a result of future use of the facilities. Additionally, current stadium event traffic and event traffic control procedures impacts passenger access to King Street Station and station operations. The EIS should address the additional impacts of the proposed arena's event traffic on pedestrian and vehicular access to, and operation of, King Street Station

Safety

Safety is one of the highest priorities for Amtrak and our railroad partners. The proposed arena plan calls for parking to be accommodated by commercial parking lots off the site-mostly located to the east and south of the proposed location. As a result, driving to parking lots, and walking back to the arena will require using at-grade railroad crossings, with S. Holgate most likely receiving most of the traffic since it is the closest to the proposed facility.

Pedestrians and vehicles that ignore crossing gates and warning signals when trains are approaching are always of concern. Currently, some pedestrians and event attendees ignore warning devices, cross the tracks and even climb over stationary trains when at S. Holgate Street. Additionally, vehicles going to, and leaving events via S. Holgate foul tracks as a result of congestion and are often caught between crossing gates as trains approach S. Holgate Street.

The EIS should address the impacts of increased pedestrian and vehicle traffic on safety at S. Holgate and S. Lander Streets. In addition to safety improvements at existing at-grade crossings, the EIS should evaluate the mitigation outlined below in Potential Mitigation section

NATIONAL RAILROAD PASSENGER CORPORATION
187 S. Holgate Street Seattle, WA 98107
tel (206)-903-5539, fax (206)-382-4166

Construction Impact Analysis

Scope of EIS should include temporary construction impacts to traffic, specifically to Amtrak facility operations and maintenance at S. Holgate Street and passenger operations at King Street Station, as well as air quality and noise impacts to the proposed site area.

Potential Mitigation Measures

Permanent closure of S. Holgate Street and the grade separation of rail crossings at S. Lander Street as included in the City of Seattle's 2012-2017 Capital Improvement Plan (CIP) and the Metropolitan Transportation Plan, *Transportation 2040.*

The State of Washington Department of transportation has conducted two traffic studies that examine the closure of S. Holgate Street (S. Holgate Street Railway Crossing Closure Traffic Study Seattle, Washington" Traffic Impact Analysis, December 2003 and January 2005) and the grade separation of the rail crossing at S. Lander Street. Both studies concluded that the closure of S. Holgate would not negatively impact the traffic flow in the area and improve safety. Additionally, closure of S. Holgate Street and the inclusion of the grade separation at S. Lander would eliminate all rail traffic vehicle delays on surface streets and eliminate pedestrian safety concerns

Inclusion of a grade separated pedestrian crossing over S. Holgate would restore/facilitate east-west pedestrian movement to/from the proposed area site.

Thank you for your consideration of this request.

Port of Seattle

P.O. Box 1209
Seattle, WA 98111-1209
Tel: (206) 787-3000

www.portseattle.org

November 30, 2012

John Shaw, Senior Transportation Planner
City of Seattle
Dept. of Planning and Development
700 5th Ave, Suite 2000
P.O. Box 34019
Seattle, WA 98124-4019

Re: ***Scoping for the EIS for Proposed Seattle Arena, DPD project number 3014195***

Dear Mr. Shaw:

Thank you for the opportunity to provide input into the scoping process for the EIS for the Seattle Arena. Port of Seattle seaport properties comprise the heart of the region's maritime and industrial center. The Port has invested more than $1 billion to develop modern shipping terminals within the Duwamish MIC to support international trade and export Washington goods. As part of our Century Agenda strategic plan, we intend to increase marine cargo volume to 3.5 million TEUs (twenty-foot equivalent units) and significantly increase the value of export cargo creating thousands of new jobs throughout the region. The Port also anticipates the need to extend hours of operation of our cargo loading / transfer activities in the area to 24/7 levels..

One of the sites under consideration is amongst critical freight corridors to the Port. This EIS process serves as a key step in understanding the risks of jeopardizing the Port and the potential cost to the family wage jobs and tax revenues supported by the seaport. Therefore the Port of Seattle is looking forward to a thorough analysis of the impacts and siting of this facility as well as mitigation of the impacts.

Alternatives To The Proposed SoDo Location

WAC 197-11-928 provides as follows:

> When the proposal involves both private and public activities, it shall be characterized as either a private or a public project for the purposes of lead agency designation, depending upon whether the primary sponsor or initiator of the project is an agency or from the private sector. Any project in which agency and private interests are too intertwined to make this characterization shall be considered a public project...

The SEPA provisions concerning the analysis of alternatives to "public projects" are more demanding than the requirements for the consideration of alternatives to private projects. Government agencies proposing public projects have a duty to consider off-site alternatives to the proposal. WAC 197-11-440(5)(d); *Weyerhaeuser*, 124 Wn.2d at 505. In addition, SEPA requires proposals for "public projects" to be described in terms of objectives rather than solutions. WAC 197-11-060(3)(a)(iii).

Here, there are several reasons the City should consider more than one off-site alternative to the SoDo location for the proposed arena independently of the proponent's preference for the SoDo site. This has already been accepted for one alternative at Seattle Center. However, if the goal of the analysis is to determine lower environmental impacts and reduce public costs, evaluation of additional site(s), outside of Seattle, will be necessary. The proposed arena is clearly a "public" project that is supported and financed with public resources by the taxpayers of the City of Seattle and King County. Second, because the arena is intended to draw spectators from across the Puget Sound region, the EIS should consider alternative sites located outside the City of Seattle. For these reasons, the City should expand the consideration of alternatives to the proposal to review more than the proposed SoDo location and the Seattle Center alternative. See *Weyerhaeuser, supra.*, (consideration of alternatives for proposed public landfill was inadequate under SEPA.)

Direct, Indirect, and Cumulative Environmental Impacts

Among the probable significant adverse environmental impacts that the City should consider are the cumulative impacts of adding this proposed basketball arena to the tightly confined Sodo neighborhood that is already home to football and baseball arenas. WAC 197-11-792(c)(iii)(cumulative impacts are part of the scope of impacts to be considered in an EIS) and WAC 197-11-060(4)(e)(content of environmental review). "Cumulative impacts" are typically considered to be the "past, present and reasonably foreseeable impacts..." of a proposal. See 40 CFR § 1508.7 As explained below, the City should consider the cumulative traffic impacts of adding this high impact facility to a neighborhood that contains the Port's critical freight corridors for movement of cargo from ships to trucks and rail.

Traffic Analysis

The analysis should cover the transportation-related issues associated with the proposed arena and any ancillary development, including impacts on auto, truck, bus, light and heavy passenger rail, freight rail, pedestrian and bicycle modes.

For the permanent configuration, including both the new arena and any ancillary development that is planned, there are several different scenarios that must be evaluated:

A. "Built" worst-case event scenarios, for both weekday and weekend day/evenings, both with and without the impacts of any permanent roadway changes resulting from the project:

- Arena only –with existing land uses
- Cumulative event analysis (combined with traffic generated by nearby traffic generators with similar traffic patterns/event timing.)

For the SoDo location, and as appropriate, any alternative location that would experience similar peaking characteristics, this analysis should include the impacts of:

- One or both existing facilities having an event/s allowed with current dual event restrictions
- Removal of dual event restrictions

The evaluation of these scenarios should include sensitivity analyses of the impacts of traffic management and police control plans (temporary closures of surrounding roadways on event days). This should cover both the existing scenario, where each individual event venue generates its own individual traffic control plan, and as well as a potential area-wide traffic control plan for multiple events. For the SoDo location, it should cover the proposed guidance for arena patrons to approach the area from the south, rather than the I-5/I-90 interchange. It should also contain sensitivity analyses of the projected transit mode splits and the ability of the transportation system components to handle volumes. Also of importance are the impacts of patrons arriving early for activities related to proposed ancillary development.

B. The project should determine specific roadway and intersections segments to be analyzed for each proposed location, and be similar in scope to the analysis carried out for Century Link Field. At a minimum, in order to determine the project's impacts to Port access needs, for the SoDo location, the EIS should analyze the following intersections:

-- 1st Ave S/S Atlantic St	-- 1st Ave S/S Royal Brougham Wy
-- 1st Ave S/S Mass. St	-- 1st Ave S/S Holgate St
-- 1st Ave S/S Lander St	-- 1st Ave S/S Spokane St
-- 4th Ave S/SR-519 Ramps	-- 4th Ave S/I-90 Off-ramp
--4th Ave S/S Holgate Street	--S Atlantic St/SR-99 East Frontage Rd
--S Atlantic St/Colorado Ave/Little "h" cluster	

The analysis methodology, analysis periods, and assumptions should be developed in consultation with affected agencies, including the Washington State Department of Transportation and Sound Transit, and for locations in the City of Seattle, the Port of Seattle and AMTRAK prior to initiating the analysis.

C. All traffic analyses should cover a scenario that assumes night, and weekend gate hours for Port of Seattle terminals and rail intermodal yards.

D. For the SoDo location, the EIS should evaluate the effect of the street vacations, not only during event times, but also during a non-event day's morning, midday, and afternoon peak hours. The effect on arterial operations along both 1st Avenue S (from S Lander Street to S King Street) and SR 519 (from I-90 to East Marginal Way) should be evaluated.

E. In addition to the local roadway network, the analysis should include the operational impacts on the regional transportation system (I-5, I-90, SR-99).

F. The new arena is expected to be completed and in operation before some of the major transit improvements in the region will be in operation. What is the ability of the transit system and services to accommodate arena-related ridership? What are the conflicts with peak period ridership for other purposes—e.g., patrons attempting to reach the arena during the pm rush hour? How does the ability of the transit system change over the years, and what are the strategies for managing periods where gaps will exist?

G. The analysis should evaluate the impacts of additional and concurrent events on congestion, travel time, and travel time reliability on both general freight mobility, and, in the case of the SoDo location, on the Port's primary access routes, including freeway, intermodal, and transload center connectors such as Hanford St at the entrance to the Main SIG intermodal yard and Spokane St between I-5 and T-5 and T-18.

H. For the SoDo location, the Port of Seattle is also concerned about the potential for conflict between arena patrons and rail movements. What is the impact of train blockages on the ability of the arena to load/unload both patrons on foot and those using the proposed garage? How will the resulting congestion impact the area, in particular the Port's primary access routes, including freeway, intermodal and transload center connectors? How will the additional arena event-related vehicular and pedestrian crossings of area railroad tracks be accommodated and what are the potential impacts to their safety and to rail operations? What would the impacts on emergency responders be in case of an incident? The following table further details the Port's concerns to be addressed, and the performance measure the EIS should use to evaluate impacts:

Transportation Analysis Needs for New Arena EIS—Focus on SODO location

Concern	Performance measures to evaluate
A. Effect on regional highways (I-5 and I-90)	• Net change in peak period and early afternoon travel time related to single event and concurrent event day. • Net change in annual vehicle hours of delay for base and banner year conditions. • Variability in delay created by event traffic (a measure of system reliability)
B. Effect on primary access routes to Port terminals	• Level of service analysis for key intersections in SoDo for the commuter peak hour, pre-event arrival peak, and post-event egress peak. The following intersections should be included in any analysis: -- 1st Ave S/S Atlantic St -- 1st Ave S/S Royal Brougham Wy -- 1st Ave S/S Mass. St -- 1st Ave S/S Holgate St -- 1st Ave S/S Lander St -- 1st Ave S/S Spokane St -- 4th Ave S/SR-519 Ramps -- 4th Ave S/I-90 Off-ramp --4th Ave S/S Holgate Street --S Atlantic St/SR-99 East Frontage Rd --S Atlantic St/Colorado Ave/Little "h" cluster • Effect that rerouting event traffic to the Spokane Street Viaduct would have on access to Terminals 5 and 18 as well as to the SIG Yard. • Net change in delay related to single-event and concurrent-event day. • Net change in annual vehicle hours of delay for base and banner year conditions. • Variability in delay created by event traffic (a measure of system reliability)
C. Effect of street vacations	• Peak period and early afternoon level of service analysis for key intersections listed above to determine Net change in delay without and with the street vacations. • Net change in annual vehicle hours of delay for base and banner year conditions. • Variability in delay created by street vacation(s) and event traffic (a measure of system reliability)
D. Safety of RR Crossings	• Net change in pedestrians and vehicles crossing tracks at S Holgate Street. • Frequency and duration of train blockages at the at-grade crossings • Historic rail-vehicle and rail-pedestrian collisions in SoDo (all crossings) • Safety analysis of RR crossing • Pedestrian storage needs when waiting for a train • Effect of additional queues, delays or safety issues on the potential to close S Holgate Street during events or permanently

Parking Analysis

Even with an aggressive traffic management plan encouraging the use of transit, the proposed arena will likely generate significant numbers of personal vehicles looking for parking. The EIS should evaluate the availability of adequate parking, both existing and new, within the walking shed of the site: Are there sufficient spaces? Are they available

when patrons are arriving, both immediately before an event, or early, to take advantage of ancillary development like restaurants and pubs? What are the likely conflicts with daytime and evening use of the available spaces and existing trip generators in the area? For the SoDo location, that should include both a dual event under the current restrictions, and a scenario where those restrictions are removed. What is the impact of the limitations of the parking supply, and its pattern of dispersion, on both passenger and freight traffic, other businesses, and neighborhoods in the study area? What are the differences between weekday, weekday evening, and weekend events? The effort should include a sensitivity analysis that evaluates impacts if likely parking guidance systems and other means of parking management do not achieve the projected goals.

Air Quality

The EIS must analyze issues of air quality given the large trip generation potential of a facility of this size. The air quality analysis must account for the inevitable traffic congestion caused by adding such facility to an already constrained street network. A great deal of the fan base can be expected to live outside of the City of Seattle. Therefore air quality should be analyzed within the framework of the City's goal of being carbon neutral.

Construction

Depending on the timing and location of construction of the proposed new arena, the traffic impacts of construction could be significant. The EIS should include an evaluation of the impacts of construction on both roadway, and, where relevant, rail traffic. This should take into consideration other projects that may impact the capacity and functionality of the impacted transportation infrastructure during the construction timeframe.

Land and Shoreline Use

It should be noted that page three of the Determination of Significant and Scoping Notice incorrectly categorizes the proposed use as "indoor sports and recreation." The correct use is Spectator Sports Facility per SMC 23.84A.010. The distinction is important since the Indoor Sports and Recreation use is characterized by the players whereas the Spectator Sports Facility use is characterized by the fans.

Use Compatibilities
The EIS must analyze issues of incompatible uses created by the proposed arena, particularly for the SoDo site. We are concerned about use compatibility issues emanating from the arena itself as well as from the accompanying commercial uses that would cater to the fans (restaurants, taverns, retail, etc.). Statements by the applicant about planned accompanying uses suggest that they should be considered as part of the arena proposal. Moreover the City will have a stake in the level of utilization of the arena and may try to cultivate related commercial uses as a means of boosting arena utilization.

The proposal harkens back to past planning debates about residential uses adjacent to Port terminals. Experience in Seattle and in other cities show that residential uses are inherently incompatible with intensive marine cargo operations and other industrial uses. As a result, attempts to provide mitigation for use conflicts might ultimately fail and the City's economy would suffer as a result. Even with advance notice of existing conditions, over time new residents will begin to file nuisance complaints, attempt to delay future permits and potentially file law suits once they actually experience living in close proximity to an industrial use. A very similar incompatibility exists between industrial uses and pedestrian-oriented commercial uses. The arena-related commercial uses would be oriented towards an animated street life. For example, the restaurants could be expected to have sidewalk seating. An issue of compatibility with nearby industrial uses is created any time a new use involves patrons who object to the sights and sounds of industry.

Scarcity of Industrial Land and Shorelines

Seattle's working waterfront is a scarce resource. Past generations invested tremendously in the Duwamish manufacturing and industrial district by filling tide flats and straightening the course of the Duwamish River. To this day the district represents prime industrial land by offering access to a deep water port, the interstate highways, and railheads. Presently-adopted City policies underscore the need to preserve industrial designations in this area. (See the Land Use and Container Port elements of the Seattle Comprehensive Plan.) Similar designations for this area exist in King County and Puget Sound Regional Council plans and also fit into the state's planning framework under the Growth Management Act. The EIS must analyze the impacts of the arena consuming industrially-zoned land. This point is timely given that citywide vacancy rates for commercial properties have been higher than for industrial properties for some time now.

Related to the issue of the scarcity of industrial land we note that materials from the applicant have represented the proposed arena facility extending slightly outside two important land use boundaries. The May 31st presentation to the Seattle City Council showed the facility extending outside (to the east) of the Stadium Transition Area Overlay District and also outside of the IC zone into the IG2 zone. (The presentation can be found here:
http://clerk.seattle.gov/~public/meetingrecords/2012/gpnf20120531_1a.pdf) The Spectator Sports Facility use is not permitted in IG2 within the Duwamish MIC. Beyond the regulatory aspect, this is such a conflict with adopted city policies about protecting industrial land that the EIS process must answer how this encroachment will be mitigated.

Speculation Patterns

The EIS must analyze the likely displacement of industrial businesses caused by property speculation. The speculation pattern is well-known: new markets for non-industrial developments lead to increased property valuations which, in turn, lead to increased rents that established industrial businesses can no longer afford. This pattern stems from two different conditions: 1) the existing code allows for a certain amount of non-industrial developments as prescribed by the size-of-use limits for the various I-zones (IC in

particular) and 2) property owners make predictions that their land will experience additional up zoning in the future. There is compelling evidence that the applicant's actions have already caused speculation -- the price they recently paid for land at the SoDo site is reportedly three times the price-per-square-foot that three of the parcels sold for only 18 months earlier.

Utilities

The EIS must analyze whether the arena project would overburden utility infrastructure. City Light is already trying to reduce loads based on substation capacity, particularly in the downtown area. Introducing the arena to an area that has historically been warehouses exacerbates the problem. Similar issues may exist for the sanitary sewer system and should be studied in the EIS.

Thank you for the opportunity to provide input into the EIS scoping process. We are looking forward to working with your staff throughout the EIS process, in particular with regard to the expected transportation and land use compatibility impacts of the proposed project. Please do not hesitate to call Geri Poor at (206) 787 3778 or Joseph Gellings at (206) 787 3368 if you have any questions.

Sincerely,

Stephanie Jones Stebbins
Director, Seaport Division Environmental and Planning

cc: Bob Chandler, Marshall Foster, Tom Hauger ***City of Seattle***
Linda Styrk, Patricia Akiyama, Kurt Beckett, Joseph Gellings, Traci Goodwin, Eric Hanson, Mike Merritt, Geri Poor, Christine Wolf, ***Port of Seattle***

Encl: Report: Impact of a SoDo Arena on Port of Seattle Operations, Heffron Transportation Inc., August 7, 2012
Report: Economic Issues of a Proposed Arena, BST Associates, August 6, 2012
Report: SoDo Arena Proposal, Seattle Duwamish Manufacturing and Industrial Center, Land Use and Planning Issue, Steinbrueck Urban Strategies, LLC, August 7, 2012

Final Report on Pacific Herring (*Clupea pallasi*) Test Development and Validation

with an Appendix on Herring Embryo Temperature Tolerance Comparisons between West Coast Stocks

DEPARTMENT OF ECOLOGY
State of Washington

Revised September 2012

Publication No. 11-10-086

Publication and Contact Information

This report is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/summarypages/1110086.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, BERA0008.

The Activity Tracker Code for this study is 10-123.

Updated from November 2011 to include another lab.

For more information contact:

Publications Coordinator
Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Phone: 360-407-6600

Washington State Department of Ecology - www.ecy.wa.gov/

o	Headquarters, Olympia	360-407-6000
o	Northwest Regional Office, Bellevue	425-649-7000
o	Southwest Regional Office, Olympia	360-407-6300
o	Central Regional Office, Yakima	509-575-2490
o	Eastern Regional Office, Spokane	509-329-3400

Cover photos by Paul Dinnel at the Shannon Point Marine Center
Left: Normal larvae at hatch
Right: Abnormal larvae at hatch

Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

If you need this document in a format for the visually impaired, call the Water Quality Program at (360) 407-6600. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Final Report on Pacific Herring (*Clupea pallasi*) Test Development and Validation

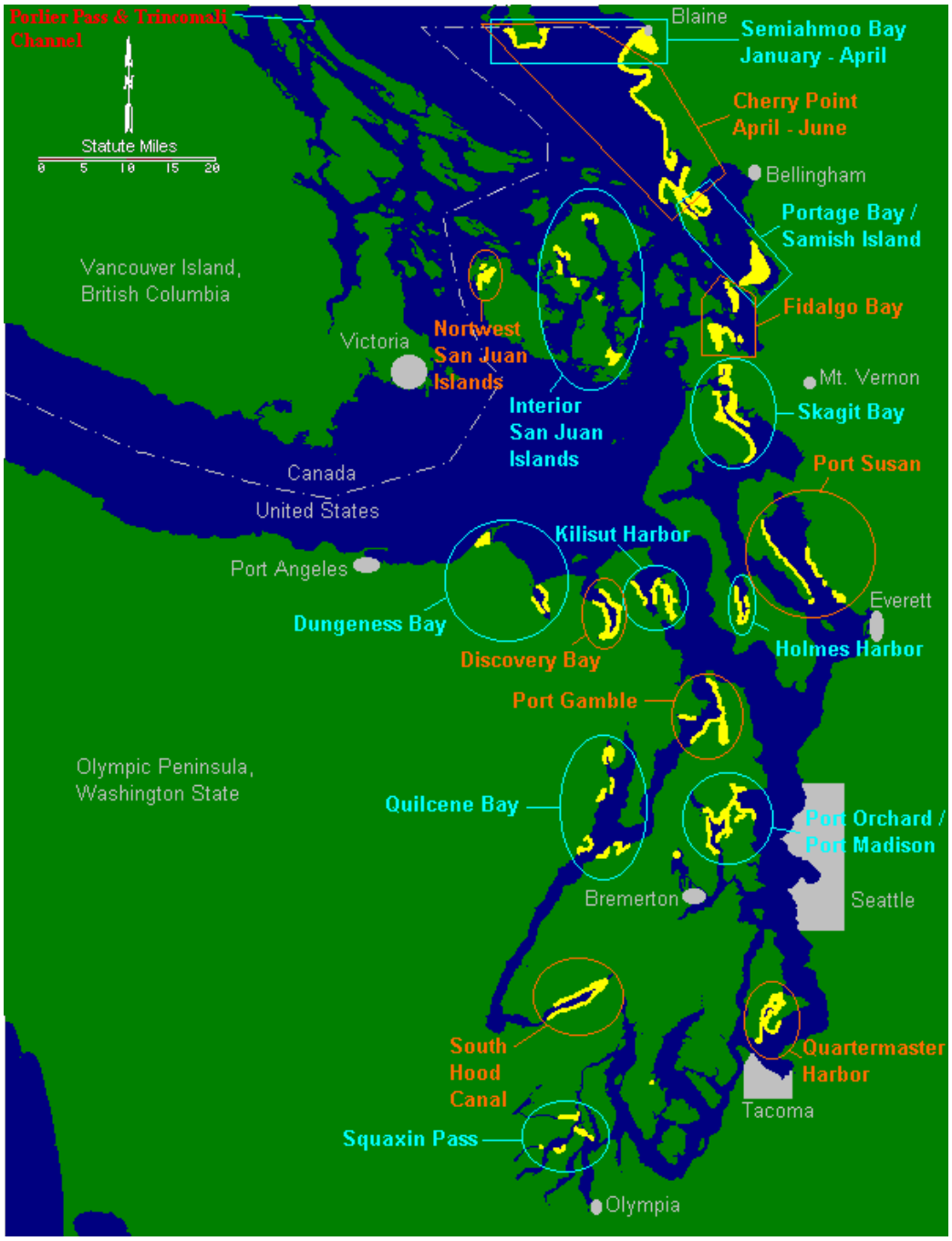
---

with an Appendix on Herring Embryo Temperature Tolerance Comparisons between West Coast Stocks

by

Randall Marshall

Water Quality Program
Washington State Department of Ecology
Olympia, Washington 98504-7600



Documented Herring Spawning Grounds in Washington State
Washington Department of Fish and Wildlife

Table of Contents

Table of Contents ..... **iii**
List of Tables iv
List of Figures iv
Introduction **1**
Background **1**
Analysis of Validation Data **2**
Results **3**
Ninety-six-hour acute survival tests 3
Larval 7-day survival and growth test 5
Embryo survival and development test 9
Overall Results **11**
Conclusions **13**
References **17**
Appendix A. Glossary **19**
Appendix B. Concentration-Response Relationships for Embryo and Larval Tests **23**
Appendix C. Embryo Temperature Tolerance Comparisons of West Coast Stocks **45**
Background 45
Results 47
Conclusions 53

List of Tables

Table 1. 96-hour Acute test reference toxicant results 4
Table 2. 96-hour acute test effluent monitoring history 5
Table 3 Nautilus, Fife 7-day Survival & Growth Test Results with Three Reference Toxicants 7
Table 4 Shannon Point, Nautilus, Burnaby, and New Fields 7-day Survival & Growth Test Results with Copper 8
Table 5. Nautilus, Fife embryo survival & development test reference toxicant results..... 9
Table 6. Shannon Point embryo survival & development test reference toxicant results 10
Table 7. Nautilus, Burnaby Embryo Survival & Development Test Copper Results 11
Table 8. Abnormality rates for herring outplants at Cherry Point in the 1990s 15
Table 9. Comparison of Cherry Point herring embryo temperature tolerance to other stocks. 49
Table 10. Comparison of San Francisco Bay to Lynn Canal herring embryoemperature tolerance..... 51

List of Figures

Figure 1 - Herring Larvae following a 12-day Exposure to Copper..... 6
Figure 2. Live Hatch Rate Responses to Five Temperatures..... 46
Figure 3. Normal Survival Rate Responses to Five Temperatures..... 46
Figure 4. Live Hatch Rate Responses at Two Highest Test Temperatures..... 47
Figure 5. Normal Survival Rate Responses at Two Highest Test Temperatures..... 47
Figure 6. Comparison of Live Hatch Median Effect Levels for San Francisco Bay and Lynn Canal 51
Figure 7. Comparison of Normal Survival Median Effect Levels for San Francisco Bay and Lynn Canal 51

Introduction

Because of the serious and ongoing decline in the population of the state's once largest herring stock, the Department of Ecology and Western Washington University have been developing and validating herring toxicity tests since the 2000 spawning season. The effort has cost close to $870,000 so far. The Department of Ecology provided 45% of these funds, industry provided 40%, and the remaining 15% of the funding came from grants. The herring test development effort has produced methods for a 96-hour acute survival test, an embryo survival & development test, and a larval 7-day survival & growth test. A description of the method development and final detailed protocols was recently published in the peer-reviewed journal, **Archives of Environmental Contamination and Toxicology**. (Dinnel et al, 2011)

Paul Dinnel is the lead researcher for the project and works at the Shannon Point Marine Center in Anacortes, WA. Nautilus Environmental in Fife, WA also contributed to method development and successfully completed the validation exercise for all three herring tests and all three reference toxicants. Nautilus Environmental in Burnaby, BC has successfully completed herring chronic method validations using copper chloride. The King County Environmental Lab participated in some of the method development trials, but never completed the validation exercise. New Fields in Port Gamble, WA recently reported copper chloride results for the herring 7-day survival and growth test. This report has been updated from the original November 2011 publication in order to incorporate the New Fields results.

The eight documents listed in the references with Dr. Paul Dinnel as the primary author describe the process of herring test development. Many combinations of test duration, test chamber type and size, feeding routines, salinities, test temperatures, etc. were tried over the years in order to find the optimal test conditions for the three herring tests. The final herring test protocols are described in Dinnel et al, 2011. Lists of the herring test conditions are also included in the Department of Ecology's ***Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria***. (Marshall, 2008)

Background

The Cherry Point herring stock has been a great concern to Washington State in recent years. It once had a spawning biomass equal to that of all of the other herring stocks in the state combined. According to Washington Department of Fish and Wildlife (WDFW) annual spawning surveys (Stick et al, 2009), the Cherry Point stock size declined from nearly 15,000 tons of spawning biomass in 1973 to just above 800 tons in 2000. Stock size rose gradually until 2007 when it began declining again and dropped below 800 tons in 2010.

Recruitment is the number of first time spawners and is a direct measure of the success of reproduction two years earlier. Recruitment from 1974 to 1995 averaged 2121 tons. 1994 had a record recruitment of 4076 tons. However, recruitment dropped steeply in 1996 and only averaged 755 tons from 1996 to 2001. Recruitment in 2004 was only 22 tons. Herring deposit eggs nearshore where human activities can be a significant factor in environmental quality.

Even though the available evidence points to other causes such as malnutrition and disease as being key factors in the Cherry Point herring decline, permit writers included herring toxicity testing requirements in industry National Pollutant Discharge Elimination System (NPDES) permits in the Cherry Point area in order to rule out effluent toxicity as the cause of the decline in recruitment. Requirements to test with herring have also been put into municipal wastewater plant permits near Cherry Point and into permits for industry discharges in other locations with vulnerable herring stocks.

Topsmelt (*Atherinops affinis*) is EPA's standard fish species for larval survival & growth testing on the West Coast. A limited amount of testing with anonymous oil refinery and aluminum smelter effluent samples showed the 7-day larval herring survival & growth test to be more sensitive than topsmelt in 3 out of 4 tests. (Dinnel et al, 2008)

The herring embryo test was more sensitive than the echinoderm (sea urchin, *Strongylocentrotus purpuratus*, or sand dollar, *Dendraster excentricus*) embryo test in 1 out of 4 industry effluent tests, but the echinoderm test results were more sensitive in 2 out of 4 tests. (Dinnel et al, 2008) Earlier comparison testing established that herring embryos were more sensitive to creosote leachate than echinoderm embryos. (Dinnel et al, 2006)

Industries have been routinely monitoring effluent discharges since 2007 using the 96-hour herring acute survival test. Some of these samples were also tested with 96-hour fathead minnow or topsmelt acute tests. See Table 2 for all of the acute test results. The 96-hour acute survival test with herring was more sensitive than topsmelt in 2 out of 13 tests on industry effluent samples in the agency CETIS database, but the topsmelt acute test was more sensitive twice as often. The fathead minnow 96-hour acute survival test was more sensitive than herring in 2 out of seven tests on industry effluent while herring were more sensitive in none of those 7 tests.

Dr. Dinnel is currently working on a manuscript for a more detailed article on herring versus EPA test comparisons to be published in a peer-reviewed journal.

Analysis of Validation Data

We agreed with industry at the beginning of this project that a herring test would be considered to be validated for regulatory use when a commercial lab demonstrated the ability using three reference toxicants to get no more than a 60% coefficient of variation (CV) in point estimates at the 25% effect level and sufficient power to differentiate a minimum significant difference of less than or equal to 40 percent between control and treatment groups at a statistical power of 80 percent (alpha = 5 percent, beta = 20 percent). The most convenient measure of statistical power for this purpose is the percent minimum significant difference (PMSD) calculated by CETIS (Tidepool Scientific, 2010) for every control comparison. We also specified that a meaningful concentration-response relationship was a validation criterion and that point estimates at the 50% effect level would be considered, especially when data would not support calculation of the 25%

effect level. The three reference toxicants chosen for the validation exercise were copper chloride ($CuCl_2$), potassium chloride (KCl), and sodium dodecyl sulfate (SDS).

The control comparisons and point estimates in this report were produced according to recommendations in EPA toxicity test manuals and analyzed using CETIS v1.8.0.4. The conditions for running linear regression to derive point estimates were not met by several test datasets and missing point estimates would be a problem because of the relatively low number of test results available for analysis. In addition, linear regression and its alternative in the EPA manuals, Spearman-Kärber, can produce point estimates that are quite different from the same dataset and should not be combined into the same assessment of variability. For these reasons, Spearman-Kärber was used to calculate all median effect (LC50 or EC50) results for quantal data sets. Linear regression produced all 25% effect (LC25 and EC25) point estimates for quantal datasets. Linear interpolation provided both 25% and 50% (IC25 and IC50) point estimates for nonquantal data.

Results

Ninety-six-hour acute survival tests

The 96-hour acute survival test results from Nautilus Environmental in Fife are shown in Table 1 (reference toxicants) and Table 2 (industry effluents). These results show:

- The coefficients of variation for the LC25s and LC50s from the three reference toxicants were all below 60%. The highest CV was 41% for the copper chloride LC25s.
- The average PMSD for the reference toxicant data was 17.8%. Only 1 of the 16 reference toxicant acute test PMSDs (52.9%) was over 40%.
- In the acute results from testing with industry effluents, the mean PMSD for fathead minnows was 10.7%, for herring was 12.8%, and for topsmelt was 20.4%. One herring PMSD (40.1%) was over 40%, but topsmelt also had a PMSD of 40.0% in one of the thirteen tests conducted with this standard EPA species.

Table 1. 96-hour Acute test reference toxicant results

Test Code	Start Date	Reference Toxicant	Control Comparisons			Point Estimates	
			NOEC	LOEC	PMSD	LC25	LC50
NEFacute01	3□18□2005	Copper chloride	600	□ 600	4.3□	NC	NC
NEFacute02	3□22□2005	Copper chloride	1000	2000	52.9□	1086.6	1447.3
NEFacute03	3□28□2005	Copper chloride	1000	2000	19.2□	1337.2	1893.5
NEFacute04	4□5□2005	Copper chloride	500	1000	23.3□	533.6	749.2
NEFacute05	5□18□2005	Copper chloride	1000	2000	13.6□	1335.6	1802.5
NEFacute06	5□19□2005	Copper chloride	1000	2000	9.9□	1952.7	2256.0
			Coefficient of Variation			**0.41**	**0.35**

Test Code	Start Date	Reference Toxicant	Control Comparisons			Point Estimates	
			NOEC	LOEC	PMSD	LC25	LC50
NEFacute07	3□18□2005	Potassium chloride	250	500	9.1□	525.9	637.3
NEFacute08	4□5□2005	Potassium chloride	250	500	8.9□	600.2	677.6
NEFacute09	5□18□2005	Potassium chloride	500	1000	4.5□	NC	707.1
NEFacute10	5□19□2005	Potassium chloride	500	1000	7.5□	NC	671.3
NEFacute11	6□3□2005	Potassium chloride	400	800	23.3□	796.0	857.4
			Coefficient of Variation			**0.22**	**0.12**

Test Code	Start Date	Reference Toxicant	Control Comparisons			Point Estimates	
			NOEC	LOEC	PMSD	LC25	LC50
NEFacute12	3□20□2005	Sodium dodecyl sulfate	5	10	20.5□	NC	9.1
NEFacute13	4□5□2005	Sodium dodecyl sulfate	5	10	37.0□	NC	7.1
NEFacute14	5□18□2005	Sodium dodecyl sulfate	2.5	5	31.5□	NC	4.4
NEFacute15	5□18□2005	Sodium dodecyl sulfate	2.5	5	8.9□	4.9	5.5
NEFacute16	6□3□2005	Sodium dodecyl sulfate	5	10	10.7□	5.6	6.9
			Coefficient of Variation			**0.09**	**0.27**

Table 2. 96-hour acute test effluent monitoring history

Industry Facility	Sample Collection	Test Organism	Biological Endpoint	Control Comparisons NOEC	LOEC	PMSD	LC50
Aluminum Smelter	2/26/2007	Pacific herring	96-hour survival	100	> 100	2.5%	
Oil Refinery 1	1/17/2007	Pacific herring	96-hour survival	100	> 100	12.0%	
	2/19/2007	Pacific herring	96-hour survival	100	> 100	2.5%	
	3/4/2009	Pacific herring	96-hour survival	100	> 100	9.9%	
	3/26/2009	Pacific herring	96-hour survival	25	50	8.5%	74.9
	4/6/2010	Pacific herring	96-hour survival	100	> 100	25.1%	
	1/31/2011	Pacific herring	96-hour survival	25	50	12.6%	62.9
	2/24/2011	Pacific herring	96-hour survival	100	> 100	11.0%	
Oil Refinery 2	2/20/2007	Pacific herring	96-hour survival	100	> 100	7.6%	
		topsmelt	96-hour survival	100	> 100	11.3%	
	3/28/2007	Pacific herring	96-hour survival	100	> 100	13.8%	
		topsmelt	96-hour survival	100	> 100	19.9%	
	3/6/2009	Pacific herring	96-hour survival	100	> 100	7.4%	
	3/30/2009	Pacific herring	96-hour survival	100	> 100	15.6%	
	4/7/2010	Pacific herring	96-hour survival	100	> 100	18.9%	
	2/24/2011	Pacific herring	96-hour survival	100	> 100	8.0%	
Oil Refinery 3	1/30/2007	fathead minnow	96-hour survival	50	100	12.3%	76.9
		Pacific herring	96-hour survival	100	> 100	6.7%	
		topsmelt	96-hour survival	3.6	100	17.8%	> 100
	6/11/2007	fathead minnow	96-hour survival	50	100	20.2%	66.9
		Pacific herring	96-hour survival	50	100	13.3%	69.7
		topsmelt	96-hour survival	50	100	22.7%	70.7
	5/21/2008	fathead minnow	96-hour survival	100	> 100	10.1%	
		Pacific herring	96-hour survival	100	> 100	40.1%	
		topsmelt	96-hour survival	100	> 100	22.6%	
	2/27/2009	fathead minnow	96-hour survival	100	> 100	5.9%	
		Pacific herring	96-hour survival	100	> 100	6.7%	
		topsmelt	96-hour survival	100	> 100	5.0%	
	3/26/2009	Pacific herring	96-hour survival	50	100	11.6%	81.3
	4/6/2010	fathead minnow	96-hour survival	50	100	15.0%	> 100
		Pacific herring	96-hour survival	50	100	18.8%	> 100
		topsmelt	96-hour survival	12.5	25	27.0%	45.6
	2/1/2011	fathead minnow	96-hour survival	100	> 100	7.1%	
		Pacific herring	96-hour survival	100	> 100	12.5%	
		topsmelt	96-hour survival	100	> 100	25.3%	
	2/24/2011	fathead minnow	96-hour survival	50	100	6.2%	> 100
		Pacific herring	96-hour survival	50	100	17.3%	99.6
		topsmelt	96-hour survival	50	100	26.1%	63.0
Oil Refinery 4	1/30/2007	Pacific herring	96-hour survival	100	> 100	6.5%	
		topsmelt	96-hour survival	100	> 100	14.5%	
	5/21/2008	Pacific herring	96-hour survival	25	100	21.0%	48.7
		topsmelt	96-hour survival	50	100	40.0%	64.5
	2/27/2009	Pacific herring	96-hour survival	100	> 100	10.6%	
		topsmelt	96-hour survival	100	> 100	11.3%	
	4/7/2010	Pacific herring	96-hour survival	100	> 100	14.2%	
		topsmelt	96-hour survival	50	100	22.2%	> 100
	2/2/2011	Pacific herring	96-hour survival	100	> 100	12.1%	

Larval 7-day survival and growth test

The herring 7-day survival & growth test results from the Nautilus Environmental lab in Fife using all three reference toxicants are shown in Table 3. These results show:

- All of the CVs for the Nautilus, Fife 7-day survival & growth tests were under 60%. The 25% effect and 50% effect point estimate CVs for all three reference toxicants and all three endpoints (survival, biomass, and weight) were under 60%.

- Replicate 4 of 100 ug/L was excluded from the 4/5/2010 copper chloride test because of being an outlier. If the result from this test chamber had been included, the CV for the biomass IC25 would have been 70%. The CV for the biomass IC50 was 15%, even with the outlier included.
- The outlier was included in the weight calculations. With replicate 4 of 100 ug/L included, the standard deviation for 7-day survival at this concentration was 0.22 and Ecology Publication WQ-R-95-80 requires a switch to the weight endpoint when survival standard deviations exceed 0.20.
- The LOEC remained the same whether replicate 4 of 100 was included or not. Because control comparisons are used for effluent monitoring, the LOEC is a more pertinent consideration.
- All of the PMSDs for each reference toxicant and endpoint were less than 40%.

The herring 7-day survival & growth test results with copper chloride from the Shannon Point Marine Center, Nautilus, Burnaby, and New Fields are shown in Table 4. These results show:

- The Shannon Point Marine Center produced a CV for the LC25 that was 68% and a CV for the biomass IC25 that was 92%. The CV for the weight IC25 was 48%. The CV for the LC50 was 48% and the CV for the biomass IC50 was 39%.
- The Nautilus, Burnaby lab produced CVs that were all under 30% for the 25% effect and 50% effect point estimates from all three endpoints in the 7-day survival & growth tests.
- New Fields produced CVs under 60% for 7-day survival and for weight. The CV for the biomass IC25 was 77%, but the CV for the biomass IC50 was 37%. Three of the four biomass NOEC - LOEC pairs were identical including those from the test with the biomass IC25 causing the CV exceedance.
- All of the PMSDs from the Shannon Point Marine Center, Nautilus, Burnaby, and New Fields 7-day survival & growth tests were under 40%.

Figure 1 - Herring Larvae following a 12-day Exposure to Copper

The copper exposure concentrations ranged from 0 µg/liter for the herring at the top of the photo to 750 µg/liter for those at the bottom. Note the progressively smaller larval sizes and underutilized yolk sacs as the copper concentrations get higher.

Table 3 Nautilus, Fife 7-day Survival □ Growth Test Results with Three Reference Toxicants

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFlarv01	4/5/2010	Copper chloride	7-day Survival	359.7	434.1	200	400	20.5%
			Biomass	189.9	469.5	200	400	30.3%
			Weight	617.6	> 800	400	800	30.2%
NEFlarv02	4/12/2010	Copper chloride	7-day Survival	399.3	552.8	200	400	23.5%
			Biomass	245.8	490.8	200	400	30.4%
			Weight	604.7	> 800	400	800	19.2%
NEFlarv03	5/17/2010	Copper chloride	7-day Survival	572.8	717.6	400	800	35.1%
			Biomass	448.4	630.2	400	800	35.9%
			Weight	694.6	> 800	400	800	20.0%
NEFlarv04	3/2/2011	Copper chloride	7-day Survival	NC	537.1	400	800	17.3%
			Biomass	131.4	467.0	100	200	18.3%
			Weight	294.9	780.0	200	400	18.7%
Coefficients of Variation			**7-day Survival**	**0.26**	**0.21**			
			Biomass	**0.54**	**0.15**			
			Weight	**0.32**				

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFlarv05	4/6/2010	Potassium chloride	7-day Survival	567.8	617.8	250	500	11.6%
			Biomass	233.9	565.4	125	250	20.4%
			Weight	429.8	> 1000	250	500	22.3%
NEFlarv06	4/13/2010	Potassium chloride	7-day Survival	504.9	579.3	500	1000	24.8%
			Biomass	320.9	547.9	250	500	31.5%
			Weight	495.8	> 500	250	500	20.5%
NEFlarv07	5/18/2010	Potassium chloride	7-day Survival	488.3	531.1	250	500	15.6%
			Biomass	254.5	482.4	250	500	21.8%
			Weight	> 500	> 500	250	500	14.5%
NEFlarv08	5/18/2010	Potassium chloride	7-day Survival	560.8	594.6	500	1000	15.3%
			Biomass	206.4	420.3	125	250	16.4%
			Weight	246.0	590.7	125	250	14.0%
Coefficients of Variation			**7-day Survival**	**0.07**	**0.06**			
			Biomass	**0.19**	**0.13**			
			Weight	**0.33**				

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFlarv09	4/14/2010	Sodium dodecyl sulfate	7-day Survival	1.43	1.75	1.25	2.5	13.8%
			Biomass	1.46	1.76	1.25	2.5	26.8%
			Weight	> 1.25	> 1.25	1.25	> 1.25	19.1%
NEFlarv10	5/19/2010	Sodium dodecyl sulfate	7-day Survival	NC	0.87	0.625	1.25	19.0%
			Biomass	0.35	0.71	< 0.625	0.625	32.4%
			Weight	0.38	> 0.625	< 0.625	0.625	27.7%
NEFlarv11	5/19/2010	Sodium dodecyl sulfate	7-day Survival	NC	0.88	0.625	1.25	18.4%
			Biomass	0.76	0.91	0.625	1.25	29.2%
			Weight	> 0.625	> 0.625	0.625	> 0.625	26.7%
NEFlarv12	5/20/2010	Sodium dodecyl sulfate	7-day Survival	NC	0.88	0.625	1.25	8.2%
			Biomass	0.63	0.81	0.3125	0.625	21.7%
			Weight	0.53	> 0.625	0.3125	0.625	19.0%
Coefficients of Variation			**7-day Survival**		**0.40**			
			Biomass	**0.59**	**0.46**			
			Weight	**0.24**				

Table 4. Shannon Point, Nautilus, Burnaby, and New Fields 7-day Survival Growth Test Results with Copper

Shannon Point Marine Center

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
SPMClarv01	3 8 2010	Copper chloride	7-day Survival	NC	743.2	540	900	16.0
			Biomass	563.8	683.9	540	900	17.1
			Weight	691.9	900	540	900	19.2
SPMClarv02	4 6 2010	Copper chloride	7-day Survival	194.6	445.5	117	117	11.8
			Biomass	52.9	261.5	117	117	23.2
			Weight	174.7	540	117	194	23.8
SPMClarv03	4 14 2010	Copper chloride	7-day Survival	170.5	283.2	117	194	11.3
			Biomass	76.4	394.4	324	540	25.0
			Weight	429.0	540	324	540	25.8
SPMClarv04	2 9 2011	Copper chloride	7-day Survival	536.2	NC	324	540	10.1
			Biomass	371.9	540.0	324	540	17.2
			Weight	471.2	540	324	540	18.7
Coefficients of Variation			**7-day Survival**	**0.68**	**0.48**			
			Biomass	**0.92**	**0.39**			
			Weight	**0.48**				

Nautilus Environmental, Burnaby

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEBlarv01	4 13 2010	Copper chloride	7-day Survival	294.1	427.1	324	540	14.1%
			Biomass	367.9	433.1	324	540	28.1%
			Weight	> 540	> 540	540	> 540	31.2%
NEBlarv02	4 13 2010	Copper chloride	7-day Survival	390.6	445.3	324	540	15.8%
			Biomass	333.1	418.2	324	540	21.7%
			Weight	407.4	> 540	324	540	17.2%
NEBlarv03	4 14 2010	Copper chloride	7-day Survival	269.5	352.3	194	324	19.0%
			Biomass	202.9	290.1	194	324	22.0%
			Weight	277.3	470.8	194	324	25.5%
NEBlarv04	4 14 2010	Copper chloride	7-day Survival	323.8	399.7	194	324	27.8%
			Biomass	252.9	390.6	324	540	37.1%
			Weight	486.5	> 540	540	> 540	30.7%
Coefficients of Variation			**7-day Survival**	**0.16**	**0.10**			
			Biomass	**0.26**	**0.17**			
			Weight	**0.27**				

New Fields

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NFlarv01	4 12 2010	Copper chloride	7-day Survival	138.2	277.0	324	540	18.9%
			Biomass	17.1	142.5	194	324	27.3%
			Weight	135.4	> 540	194	324	26.3%
NFlarv02	2 11 2011	Copper chloride	7-day Survival	359.5	489.3	200	400	23.5%
			Biomass	113.0	381.2	200	400	30.4%
			Weight	567.1	> 900	400	800	19.2%
NFlarv03	2 11 2011	Copper chloride	7-day Survival	299.8	449.6	194	324	14.9%
			Biomass	113.4	338.4	194	324	24.2%
			Weight	246.9	> 900	324	540	28.9%
NFlarv04	2 15 2011	Copper chloride	7-day Survival	407.6	537.9	324	540	20.3%
			Biomass	244.5	390.5	194	324	24.1%
			Weight	293.1	617.5	194	324	17.5%
Coefficients of Variation			**7-day Survival**	**0.39**	**0.26**			
			Biomass	**0.77**	**0.37**			
			Weight	**0.59**				

Embryo survival and development test

The herring embryo survival & development test results with all three reference toxicants from the Nautilus Environmental lab in Fife are shown in Table 5. These results show:

- All of the CVs for the Nautilus, Fife embryo survival & development tests were under 40% and easily met the goal of being less than 60%.
- 12 of the 13 PMSDs for live hatch were under 40%. The one PMSD for live hatch which exceeded 40% was 54.5%. 11 of the 13 PMSDs for normal survival were under 40%. The two PMSDs for normal survival which exceeded 40% were 41.3% and 61.2%.

Table 5. Nautilus, Fife embryo survival □ development test reference toxicant results

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFemb01	3□4□2005	Copper chloride	Live Hatchout	264.0	315.6	200	400	29.0□
			Normal Survival	250.0	295.5	200	400	29.9□
NEFemb02	3□18□2005	Copper chloride	Live Hatchout	276.0	381.4	150	300	20.5□
			Normal Survival	234.8	310.6	150	300	20.6□
NEFemb03	5□4□2005	Copper chloride	Live Hatchout	138.2	225.7	100	200	20.9□
			Normal Survival	111.4	187.2	50	100	19.0□
NEFemb04	5□13□2005	Copper chloride	Live Hatchout	371.5	383.7	200	400	15.6□
			Normal Survival	246.9	324.4	200	400	17.2□
		Coefficients of Variation	**Live Hatchout**	**0.36**	**0.23**			
			Normal Survival	**0.32**	**0.22**			

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFemb05	3□4□2005	Potassium chloride	Live Hatchout	NC	648.1	500	1000	13.9□
			Normal Survival	NC	633.7	500	1000	14.4□
NEFemb06	3□18□2005	Potassium chloride	Live Hatchout	586.1	581.8	500	1000	36.9□
			Normal Survival	548.6	536.5	500	1000	41.3□
NEFemb07	5□4□2005	Potassium chloride	Live Hatchout	525.3	636.1	500	1000	35.4□
			Normal Survival	503.6	595.0	500	1000	34.9□
NEFemb08	5□13□2005	Potassium chloride	Live Hatchout	590.8	670.0	500	1000	14.0□
			Normal Survival	537.1	655.6	500	1000	14.8□
		Coefficients of Variation	**Live Hatchout**	**0.06**	**0.06**			
			Normal Survival	**0.04**	**0.09**			

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEFemb09	3□4□2005	Sodium dodecyl sulfate	Live Hatchout	□5	□5	5	□5	14.8□
			Normal Survival	□5	□5	5	□5	17.0□
NEFemb10	3□18□2005	Sodium dodecyl sulfate	Live Hatchout	6.1	7.1	5	10	25.2□
			Normal Survival	6.0	7.0	5	10	26.8□
NEFemb11	5□4□2005	Sodium dodecyl sulfate	Live Hatchout	2.6	2.8	2.5	5	19.9□
			Normal Survival	2.6	2.8	2.5	5	18.7□
NEFemb12	5□13□2005	Sodium dodecyl sulfate	Live Hatchout	5.2	5.4	5	10	21.4□
			Normal Survival	5.2	5.4	5	10	26.7□
NEFemb13	5□27□2005	Sodium dodecyl sulfate	Live Hatchout	5.1	6.0	5	10	54.5□
			Normal Survival	NC	6.4	5	10	61.2□
		Coefficients of Variation	**Live Hatchout**	**0.31**	**0.34**			
			Normal Survival	**0.38**	**0.34**			

The herring embryo survival & development test results with all three reference toxicants from the Shannon Point Marine Center are shown in Table 6. These results show:

- All of the CVs for the 25% effect and 50% effect point estimates from the Shannon Point Marine Center embryo survival & development tests were less than or equal to 40% and easily met the goal of being less than 60%.
- All of the 12 PMSDs for live hatch were under 40%. 11 of the 12 PMSDs for normal survival were under 40%. The one PMSD for normal survival which exceeded 40% was 47.6%.

Table 6. Shannon Point embryo survival □ development test reference toxicant results

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
SPMCemb01	3□14□2002	Copper chloride	Live Hatchout	□ 1000	□ 1000	1000	□ 1000	10.7□
			Normal Survival	377.2	516.0	316	422	15.6□
SPMCemb02	2□6□2003	Copper chloride	Live Hatchout	693.2	917.6	700	□ 700	32.6□
			Normal Survival	288.5	338.7	221	295	23.1□
SPMCemb03	3□24□2003	Copper chloride	Live Hatchout	351.1	696.4	□ 190	190	6.3□
			Normal Survival	179.7	249.9	□ 190	190	5.7□
SPMCemb04	3□25□2003	Copper chloride	Live Hatchout	529.3	629.7	450	600	10.3□
			Normal Survival	162.2	227.5	□ 190	190	9.6□
		Coefficients of Variation	**Live Hatchout**	**0.33**	**0.20**			
			Normal Survival	**0.40**	**0.39**			

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
SPMCemb05	1□29□2002	Potassium chloride	Live Hatchout	□ 1200	□ 1200	1200	□ 1200	14.5□
			Normal Survival	444.7	474.2	380	506	47.6□
SPMCemb06	3□24□2003	Potassium chloride	Live Hatchout	699.8	715.3	600	800	6.5□
			Normal Survival	592.3	617.9	450	600	9.9□
SPMCemb07	3□24□2003	Potassium chloride	Live Hatchout	685.5	719.9	600	800	6.0□
			Normal Survival	494.0	531.7	450	600	7.0□
SPMCemb08	3□25□2003	Potassium chloride	Live Hatchout	674.1	721.2	450	600	8.1□
			Normal Survival	511.5	551.0	450	600	12.6□
		Coefficients of Variation	**Live Hatchout**	**0.19**	**0.004**			
			Normal Survival	**0.12**	**0.11**			

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
SPMCemb09	3□13□2002	Sodium dodecyl sulfate	Live Hatchout	2.0	2.2	1.41	1.88	10.3□
			Normal Survival	1.9	1.9	0.79	1.05	14.3□
SPMCemb10	1□25□2003	Sodium dodecyl sulfate	Live Hatchout	1.9	2.1	1.8	2.4	15.6□
			Normal Survival	1.6	1.8	1.01	1.35	16.9□
SPMCemb11	2□5□2003	Sodium dodecyl sulfate	Live Hatchout		2.3	1.8	2.4	20.3□
			Normal Survival		2.1	1.8	2.4	26.4□
SPMCemb12	3□25□2003	Sodium dodecyl sulfate	Live Hatchout	1.0	1.2	0.76	1.01	9.1□
			Normal Survival	0.9	1.0	0.76	1.01	6.3□
		Coefficients of Variation	**Live Hatchout**	**0.34**	**0.26**			
			Normal Survival	**0.36**	**0.29**			

The herring embryo survival & development test results with copper chloride from the Nautilus Environmental lab in Burnaby are shown in Table 7. These results show:

- One of the CVs for the Nautilus, Burnaby embryo survival & development tests was over 60%. The CV for the live hatch EC25 was 72%. The CVs for the normal survival EC25 and the live hatch and normal survival EC50s were 35% or less.
- All of the PMSDs for live hatch were under 40%. 4 of the 5 PMSDs for normal survival were under 40%. The one PMSD for normal survival which exceeded 40% was 41.0%.

Table 7. Nautilus, Burnaby Embryo Survival □ Development Test Copper Results

Test Code	Start Date	Reference Toxicant	Biological Endpoint	Point Estimates EC25	Point Estimates EC50	Control Comparisons NOEC	Control Comparisons LOEC	Control Comparisons PMSD
NEBemb01	3□19□2010	Copper chloride	Live Hatchout	91.7	340.3	100	200	29.2□
			Normal Survival	178.6	195.7	100	200	41.0□
NEBemb02	4□15□2010	Copper chloride	Live Hatchout	137.9	265.7	200	400	15.4□
			Normal Survival	117.4	193.1	50	100	19.5□
NEBemb03	4□15□2010	Copper chloride	Live Hatchout	113.7	247.9	50	100	28.5□
			Normal Survival	98.6	157.8	100	200	34.4□
NEBemb04	3□17□2011	Copper chloride	Live Hatchout	340.2	498.9	200	400	29.2□
			Normal Survival	244.5	285.1	200	400	26.6□
NEBemb05	3□18□2011	Copper chloride	Live Hatchout	70.0	233.5	□ 50	50	25.0□
			Normal Survival	183.1	241.9	100	200	26.5□
		Coefficients of Variation	**Live Hatchout**	**0.72**	**0.35**			
			Normal Survival	**0.35**	**0.23**			

Overall Results

- The Shannon Point Marine Center, Nautilus, Fife, Nautilus, Burnaby, and New Fields labs together conducted 16 copper chloride reference toxicant tests using the larval herring 7-day survival & growth test method. The CVs from the LC25s and LC50s were 37% and 28% respectively. The CVs from the biomass IC25s and IC50s were 66% and 32% respectively. The CVs from the weight IC25s and IC50s were 43% and 25% respectively.
- The Shannon Point Marine Center, Nautilus, Fife, and Nautilus, Burnaby labs together conducted 13 copper chloride reference toxicant tests using the herring embryo survival & development test. The CV from live hatch EC25s from all three labs was 68%. The CV from live hatch EC50s was 51%. The CVs from normal survival EC25s and EC50s were 38% and 34% respectively.
- The mean PMSDs from all labs for all test materials were below 30%. The mean PMSD for 96-hour survival was 14.5%. The mean PMSDs from the 7-day survival & growth test were 17.8% for 7-day survival, 25.5% for biomass, and 22.3% for weight. The mean PMSDs from the embryo survival & development test were 20.0% for live hatch and 22.9% for normal survival.
- Appendix B contains the concentration-response graphs for all herring test results in our CETIS database. The concentration-response relationships generally look good and resemble the responses of standard toxicity test species in the CETIS database. These graphs are organized by test type and test code in the same way as Tables 1 – 7. The test

materials include reference toxicants, effluents, creosote leachate, and ambient water samples from the Cherry Point Reach.

Conclusions

The ten year effort to develop and validate herring toxicity tests was successful. We now have three herring toxicity tests that are well-established locally and have already had some limited regulatory use for monitoring effluents and assessing ballast water biocide toxicity. However, the use of the herring toxicity tests for monitoring effluents is constrained by the availability of test organisms during spawning season. Due to this constraint, the herring tests should only be used for screening effluents for toxicity to herring, and the full regulatory application should be reserved for the standard toxicity tests which are readily available all year. Herring are a key regional species and screening for risks is important. Testing of environmental samples is another very important need for the herring toxicity tests. More details supporting the conclusions that the herring tests are both ready and needed are in the lists below.

1. The herring tests are ready for use:

    - The herring tests have already established a track record of use for reference toxicant testing, effluent monitoring, testing environmental samples, evaluating ballast water biocides, examining creosote toxicity, assessing dinoflagellate toxicity, and comparing the embryo temperature tolerance of different West Coast herring stocks (See Appendix C.).
    - The three herring tests demonstrated the ability to detect differences in response of 40% or greater as statistically significant. The overall PMSD averages for each test were lower than 30%. Occasional PMSDs were above 40%, but our CETIS database shows that to also be the case for the standard EPA tests. All of the labs individually demonstrated the ability to achieve PMSDs below 40% in most of their herring test results.
    - Only the 25% effect level point estimates produced an occasional CV over 60%. CVs from the 50% effect level point estimates always met the less than 60% criterion. This fact shows that much of the variability contributing to higher CVs comes from the point estimate calculation at the 25% effect level and not from test organism performance.
    - The only interlaboratory CV which failed for any of the endpoints from the three herring tests was the CV for the live hatch EC25s. The live hatch EC50s and the EC25s for all of the other larval and embryo endpoints provided interlaboratory CVs below 60%.
    - The Nautilus Environmental lab in Fife successfully validated all three herring tests using all three reference toxicants. The Shannon Point Marine Center successfully validated the herring embryo survival & development test using all three reference toxicants.
    - The herring tests can pass the validation criteria using all three reference toxicants. However, the use of only one reference toxicant is standard quality control for the established toxicity tests. Copper chloride is a popular reference toxicant. Potassium chloride and sodium dodecyl sulfate produced none of the CVs over 60%. Lab evaluations based upon copper chloride results are adequate without potassium chloride and sodium dodecyl sulfate results. It is also more economical to use one reference toxicant.
    - The Nautilus Environmental lab in Burnaby successfully validated the larval 7-day survival & growth test and the embryo survival & development test using copper

chloride. The CVs for the survival & growth test were especially good (all less than 30%). The CVs for the embryo survival & development test were all less than 40% except for the live hatch EC25 which had a CV of 72%.

- The New Fields lab in Port Gamble successfully validated the larval 7-day survival and growth test using copper chloride. The CV for the biomass IC25 exceeded 60% but this was due to one test result and the CV for the biomass IC50 was well under 60%. In addition, the NOEC – LOEC pairs were identical for three of the four tests and the remaining NOEC – LOEC pair was not much different. The NOEC and LOEC are a better representation of regulatory decisions in this state than the IC25.
- The Nautilus Environmental lab in Burnaby and the New Fields lab in Port Gamble can fill the gap from the closure of the Nautilus Environmental lab in Fife.
- The interlaboratory evaluation showed a problem with the consistency of live hatch as measured by the 25% effect level point estimate. In addition, the Nautilus Environmental lab in Burnaby had a CV over 60% for the live hatch EC25. Live hatch results should be excluded from sensitive regulatory decisions until copper chloride reference toxicant testing has met the validation criterion of a CV less than or equal to 60%. In addition to quality control plotting, the results of the last four routine copper chloride reference toxicant tests should have a CV for the live hatch EC25 that is less than 60% or only the normal survival results will be considered.

2. The herring tests are needed:

    - WDFW has reported locations within the spawning grounds of the Quartermaster Harbor, Port Gamble, and Port Orchard/Madison herring stocks where eggs usually die soon after deposition. The chemicals causing these mortalities remain unknown.
    - Dr. Richard Kocan and Dr. Paul Hershberger assessed Cherry Point spawning zone conditions by exposing herring embryos at 12 stations along the shoreline. The percentages of abnormal larvae from these outplants were averaged for the 4 years (1990, 1991, 1992, and 1998) of study. See Table 8. The average percent abnormal ranged from 54.3% at the worst station to 25.4% at the best station. Stations that are adjacent along the shoreline tend to also be adjacent in the table when ranked by percent abnormal. The probability that this pattern occurred due to chance alone is nearly 5000:1. The northern six stations had significantly ($\alpha = 0.05$) better development than the southern six stations. Even though the whole shoreline was once used, herring spawned during these years only near the northernmost stations. Testing to determine cause and effect has not yet been done.

Table 8. Abnormality rates for herring outplants at Cherry Point in the 1990s

location	stations numbered north to south	average % abnormal
s. of Al smelter pier	7	54.3
ravine	8	43.0
s. of oil refinery pier	10	40.8
n. of oil refinery pier	9	40.2
gravel pier	5	38.7
Neptune Beach	11	38.7
Sandy Point	12	35.1
n. of Al smelter pier	6	34.6
Viewpoint	2	30.8
n. of oil refinery pier	3	30.7
s. of oil refinery pier	4	27.8
Point Whitehorn	1	25.4
lab controls		29.4

- Herring early lifestages are sensitive to polycyclic aromatic hydrocarbons and to creosote. The herring tests would be good for assessing whether cleanup of these or other materials is adequate.
- Herring tests would be good for investigating the effects of harmful algal blooms, rising water temperatures, and increasing ocean acidification on fish early lifestages.

This page purposely left blank

References

Dinnel, P.A., D.P. Middaugh, N.T. Schwarck, H.M. Farren, R.K. Haley, R.A. Hoover, J. Elphick, K. Tobiason, R.R. Marshall. 2011. Methods for Conducting Bioassays Using Embryos and Larvae of Pacific Herring, *Clupea pallasi*. Arch Environ Contam Toxicol 60:290–308.

Dinnel, P.A., R. Hoover, L. Lechuga, K. Tobiason, J. Elphick. 2008. Development of Larval Pacific Herring, *Clupea pallasi*, Bioassay Protocols: Refinement, Validation, Refinery Effluent and Cherry Point Ambient Water Testing During 2007. Final Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 58 pp.

Dinnel, P.A. 2008. Pacific herring, *Clupea pallasi*, embryo and larval bioassay protocols. Summary Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 18 pp.

Dinnel, P.A., C. Montanez, K. Bergmann, J. Elphick. 2007. Refinement of the larval Pacific herring, *Clupea pallasi*, survival and growth bioassay protocol. Final Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 63 pp.

Dinnel, P.A., L. Paisano, A. Shi, J. Elphick, K. Bergmann, J. Alaimo. 2006. Development of embryo and larval Pacific herring, *Clupea pallasi*, Bioassay protocols: phase V. Final Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 89 pp + appendix.

Dinnel, P.A., H.M. Farren, L. Marko, S.A. Morales. 2005. Development of embryo and larval Pacific herring, *Clupea pallasi*, bioassay protocols: phase IV. Final Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 82 pp.

Dinnel, P.A., R.K. Haley, B. Keopaseut. 2003. Development of embryo and larval Pacific herring, *Clupea pallasi*, bioassay protocols: phase III. Final Report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 83 pp.

Dinnel, P.A., N.T. Schwarck, A. Balderas, M. Cotter, D.P. Middaugh. 2002. Development of embryo and larval Pacific herring, *Clupea pallasi*, bioassay protocols: phase II. Final report for Washington Department of Ecology by Shannon Point Marine Center, Western Washington University, Anacortes, WA, 56 pp + appendices.

Hershberger, P.K., R.M. Kocan. 1999. Final Report – 1999, Survival potential of Cherry Point herring: larval abnormalities and weight at hatch following in situ incubation of developing embryos. Washington Department of Natural Resources #FY00-092.

Hershberger, P.K. and R.M. Kocan 2001. Final Report – 2000, Washington DNR herring study 2000: health of Puget Sound stocks. Washington Department of Natural Resources #FY00-183.

Marshall, R. 2008. Laboratory guidance and whole effluent toxicity test review criteria. Washington Department of Ecology Publ. No. WQ-R-95-80, December 2008 Revision, WDOE Water Quality Program, Olympia, WA, 78 pp

Stick, K. and A. Linquist. 2009. 2008 Washington State Herring Stock Status Report. Washington Department of Fish and Wildlife Stock Status Report No. FPA 05-09, November 2009.

Tidepool Scientific. 2010. CETIS (Comprehensive Environmental Toxicity Information System) v.1.8.0.4. Tidepool Scientific Software, McKinleyville, CA

This page is purposely left blank

Appendix A. Glossary

biomass – The mass of the surviving organisms at the end of the test divided by the number of organisms at the beginning of the test. The biomass endpoint is contrasted with the weight endpoint which is the mass of surviving organisms at the end of the test divided by the number of organisms at the end of the test. The biomass endpoint accounts for biomass loss due to death.

CETIS (Comprehensive Environmental Toxicity Information System) – A database application produced by Tidepool Scientific Software (http://www.tidepool-scientific.com/) which includes the ability to perform a wide range of statistical analyses relevant for data from toxicity testing.

coefficient of variation (CV) – The standard deviation divided by the mean. The CV is used in this report as a measure of the variability of reference toxicant test results. Reference toxicant test results should ideally be nearly equal because the tests are run under identical controlled conditions. Higher CVs represent a higher "plus or minus factor" for the point estimates from the test results.

concentration-response relationship – Toxicity tests are conducted using a series of increasing concentrations of the toxicant with the expectation that adverse effects will increase as the toxicant concentration increases. Toxicity tests also include a nontoxic control to ensure that test organism performance meets minimum expectations and to use in statistical comparisons with the toxicant concentrations. The accuracy of some statistical analyses, such as linear interpolation, are dependent on adverse effects increasing incrementally as the toxicant concentration increases. Examination of the concentration-response relationship is also important in understanding test results such as the NOEC and LOEC. See Appendix B for examples of concentration-responses from this project.

EC25 and EC50 – "EC" stands for effect concentration. The EC25 is the toxicant concentration estimated to cause an adverse effect in 25% of the test organisms. The EC50 is the toxicant concentration estimated to cause an adverse effect in 50% of the test organisms. The "EC" is the generic designation for a point estimate and can be used for the other point estimates (IC25, IC50, LC25, and LC50) as well.

effect level – The degree of adverse effect in the test organisms relative to the control. For example, the LC25 represents 25% mortality or 75% survival. A biomass IC25 represents a 25% reduction in biomass relative to the control.

embryo – The earliest fish lifestage beginning with the first cell division after fertilization and continuing until hatch. The embryo is sometimes called the egg, but an egg also includes yolk and other egg structures such as the chorion which are not a part of the embryo.

larva – The lifestage beginning after the complete utilization of the yolk and the commencement of feeding until the larvae metamorphosis into juveniles. Herring larvae are poor swimmers and generally drift like plankton. Herring juveniles can swim against currents and go where they want to go.

IC25 and IC50 – "IC" stands for inhibition concentration. The IC25 is the toxicant concentration which inhibits biomass or weight by 25% relative to the control. The IC50

is the toxicant concentration which inhibits biomass or weight by 50% relative to the control.

LC25 and LC50 – "LC" stands for lethal concentration. The LC25 is the toxicant concentration estimated to cause 25% mortality. The LC50 is the toxicant concentration estimated to cause 50% mortality. The LC25 and LC50 are the same as the EC25 and EC50 applied specifically to lethality.

linear interpolation - An analysis whereby a curve is fit to nonquantal concentration-response data so that point estimates at specific effect levels can be made. Although linear interpolation can be performed on quantal data, it is usually reserved for nonquantal weight and reproduction data. In order to be accurate, linear interpolation depends on adverse effects increasing incrementally as the toxicant concentration increases. Incremental increases in adverse effects do not always happen especially when the lower toxicant concentrations are below the toxic threshold and either chance or toxicant stimulation (hormesis) increase test organism survival, growth, or reproduction relative to the control.

linear regression – An analysis whereby an equation is fit to quantal concentration-response data using a model so that point estimates at specific effect levels can be made. The specific linear regression analysis used in the context of this project fits data to the probit model. If the data do not fit the model or if the concentration-response is too sharp (one or fewer partial responses), then linear regression will not run. Linear regression is the preferred analysis for estimating 25% effect levels from quantal data.

live hatch - The number of live herring after hatch divided by the number of eggs (embryos) at the beginning of the test.

LOEC (lowest observed effects concentration) – The LOEC is the lowest concentration in a toxicity test which shows a statistically significant difference from the control.

mean – The mean is the arithmetic average and is often just called the average. For the purposes of this report, the mean is calculated by adding all of the measurements and dividing by the number of measurements.

median effect level – The median effect level is the toxicant or sample concentration associated with a 50% effect on test organisms. Because the median effect level is determined from the midpoint (median) of a concentration-response curve, it is the best single representative for the overall test result. The median effect level has the highest precision of all effect levels and the narrowest confidence interval. For these reasons, the median effect level is usually preferred in comparative toxicology.

NOEC (no observed effects level) – The NOEC is the highest concentration in a toxicity test which does not show a statistically significant difference from the control. The NOEC is by definition the next concentration below the LOEC in the concentration series.

normal survival – The number of normal herring after hatch divided by the number of eggs (embryos) at the beginning of the test.

Pacific herring (*Clupea pallasi*) – Pacific herring are a key forage fish species in the region. They are an important link in the food chain process for converting zooplankton biomass into the biomass of larger fish such as salmon. From Stick et al, 2009:

Forage fishes in general, and herring specifically, are vital components of the marine ecosystem and are a valuable indicator of the overall health of the marine environment. Many species of sea birds, marine mammals, and finfish, including lingcod (*Ophiodon elongatus*), chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, depend on herring as an important prey item.

PMSD (percent minimum significant difference) – Given the number of replicates used in a test and the variability in test organism response across those replicates, the PMSD is an estimate of the minimum difference needed between a test concentration and a control in order for that difference to be considered significantly different when subjected to a statistical comparison.

point estimation – Using toxicity test data to estimate a toxicant concentration that would cause a specified effect level. See **EC25 and EC50**, **IC25 and IC50**, **LC25 and LC50**, **linear interpolation**, **linear regression**, and **Spearman-Kärber**.

prolarva – Another common term for this lifestage is yolk-sac larva. These are larva which are still relying on the yolk sac for nourishment just after hatch and are relatively inactive. The 96-hour acute survival test is run using herring prolarva. The lower activity and interaction with the environment can make prolarvae less sensitive to some toxicants.

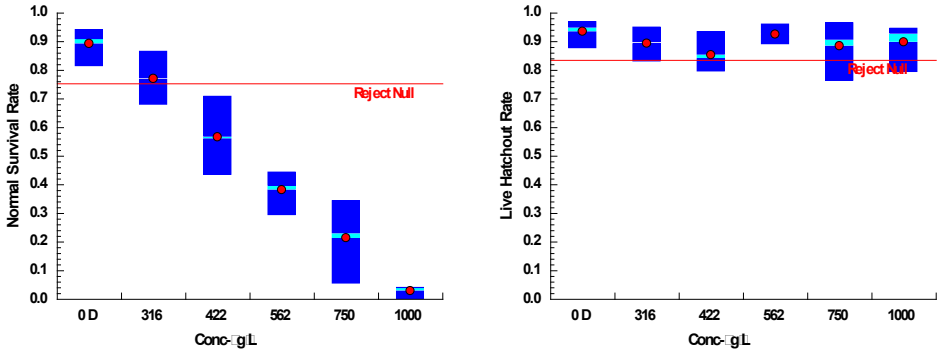
quantal and nonquantal data – Quantal results are derived by counting the number of organisms at the end of a test to get a number such as the number alive or the number normal which is then divided by the total number of organisms at the beginning of the test. A quantal result can therefore only occur as a number between 0 and 1 inclusive. Nonquantal results come from measuring a property of the test organisms such as weight or biomass and can be any number within the realm of possibility for the property being measured. Because quantal numbers are bounded by 0 and 1 and nonquantal numbers are not, different analyses are sometimes required. For example, linear regression and Spearman-Kärber only work with quantal data.

Spearman-Kärber – A nonparametric procedure for estimating the median effect level (LC50 or EC50) point estimate from quantal data. Because it is a nonparametric procedure, Spearman-Kärber will work with most toxicity test data showing a sufficiently large concentration-response. However, Spearman-Kärber only provides the 50% effect level.

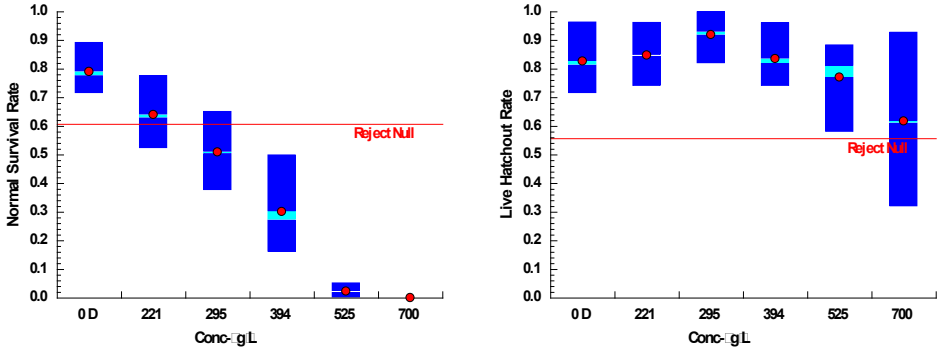
This page is purposely left blank

Appendix B. Concentration-Response Relationships for Embryo and Larval Tests

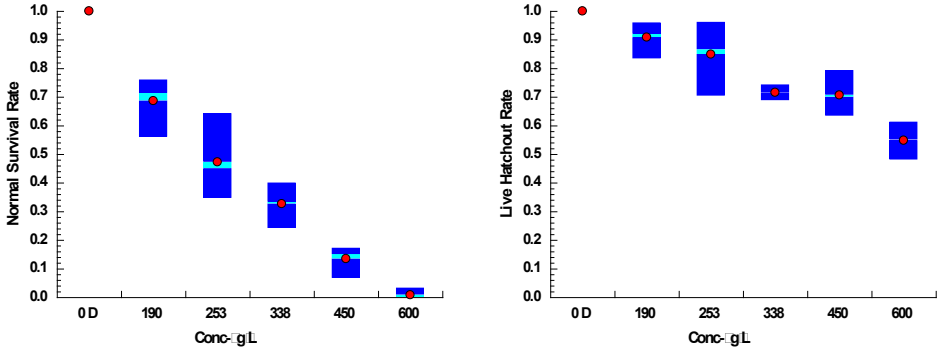
SPMCemb01 – 3/14/2002 – **$CuCl_2$**



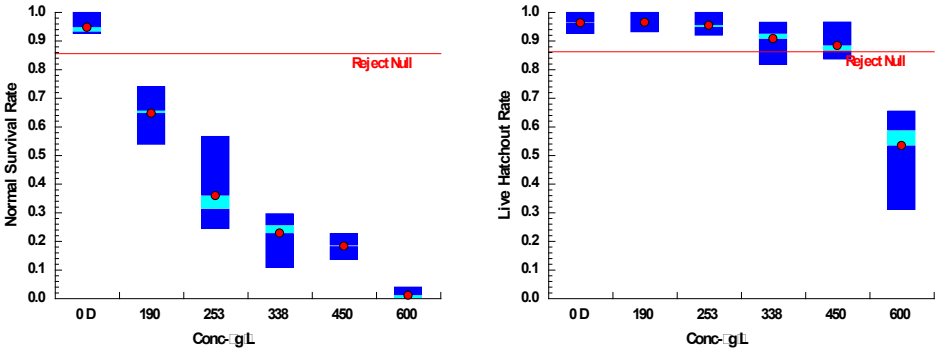
SPMCemb02 – 2/6/2003 – **$CuCl_2$**



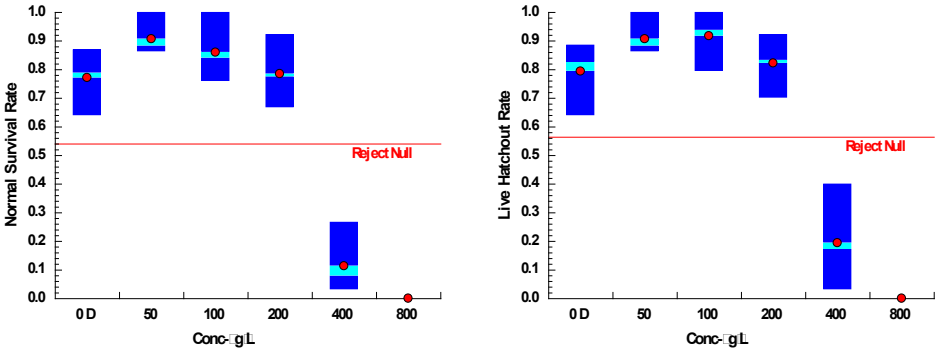
SPMCemb03 – 3/24/2003 – **$CuCl_2$**



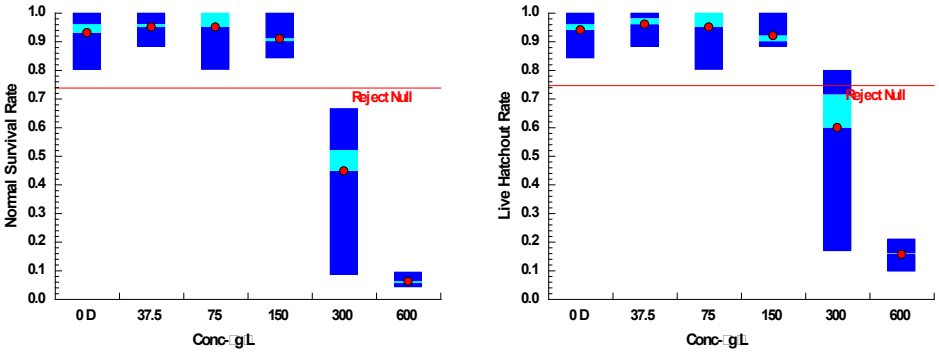
SPMCemb04 – 3/25/2003 – **$CuCl_2$**



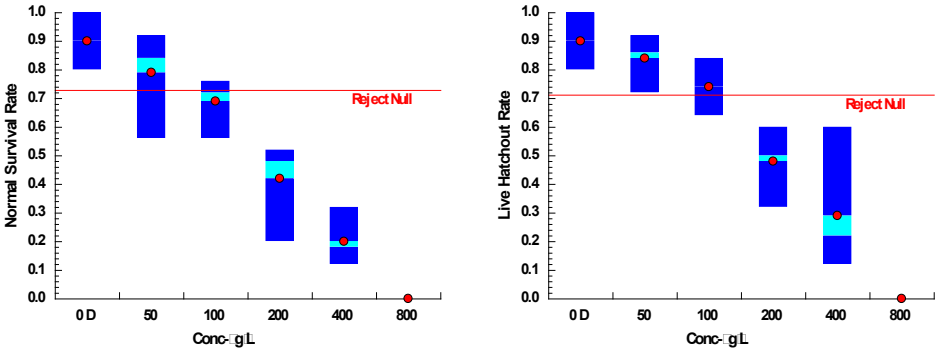
NEFemb01 – 3/4/2005 - **$CuCl_2$**



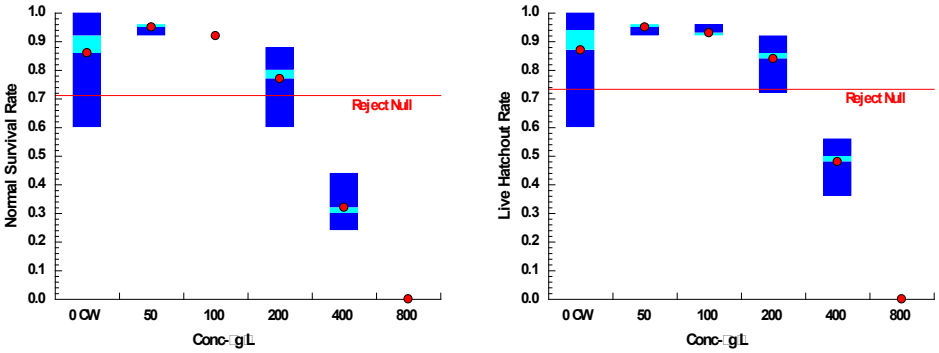
NEFemb02 – 3/18/2005 - **$CuCl_2$**



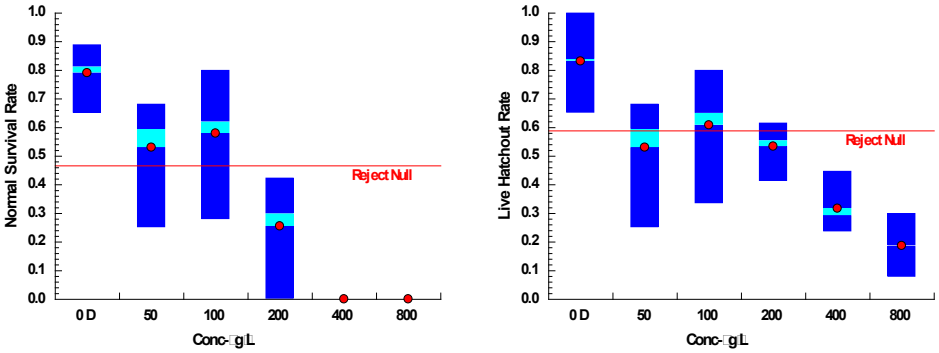
NEFemb03 – 5/4/2005 - **$CuCl_2$**



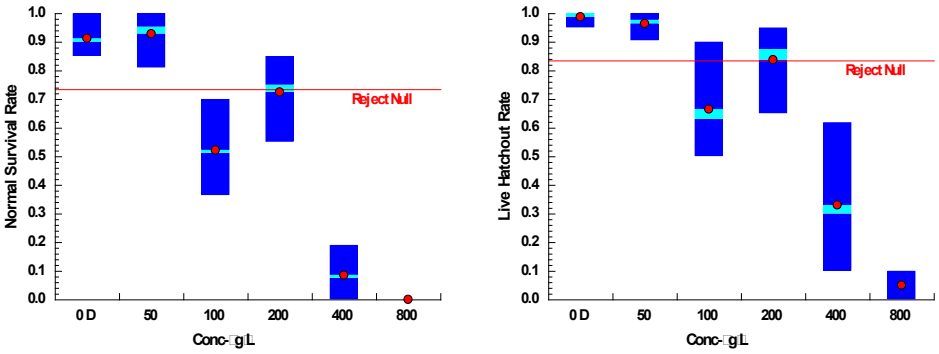
NEFemb04 – 5/13/2005 - **$CuCl_2$**



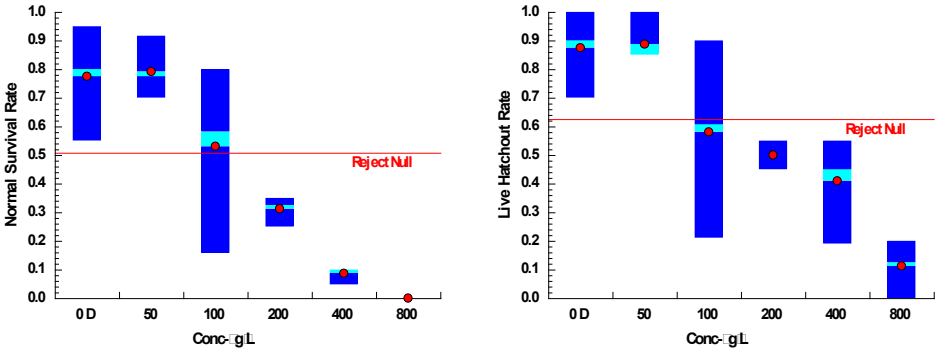
NEBemb01 – 3/19/2010 - **$CuCl_2$**



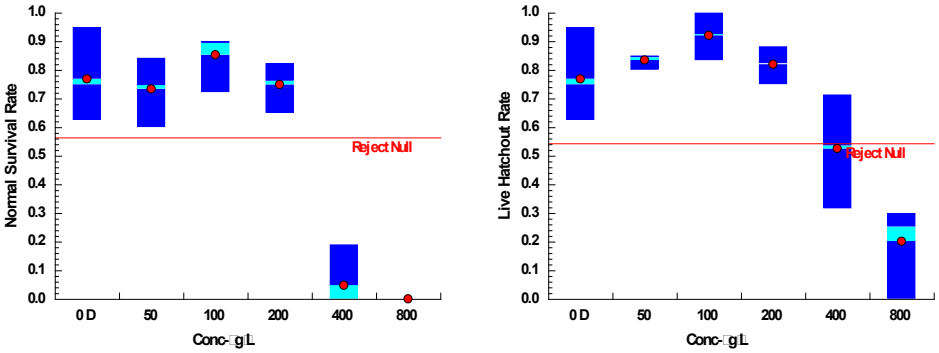
NEBemb02 – 4/15/2010 - **$CuCl_2$**



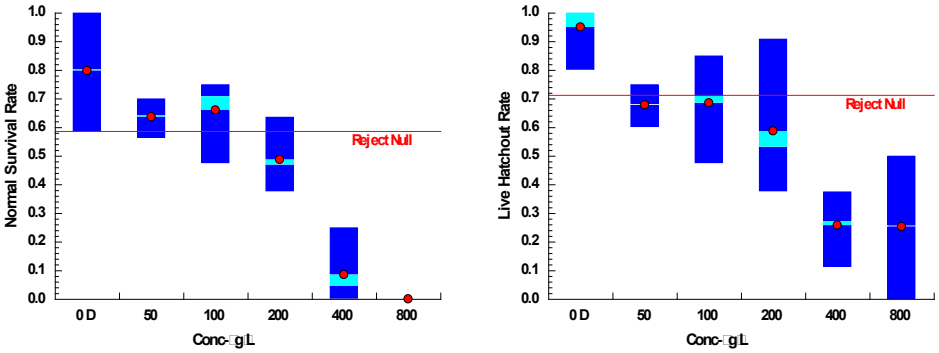
NEBemb03 – 4/15/2010 - **$CuCl_2$**



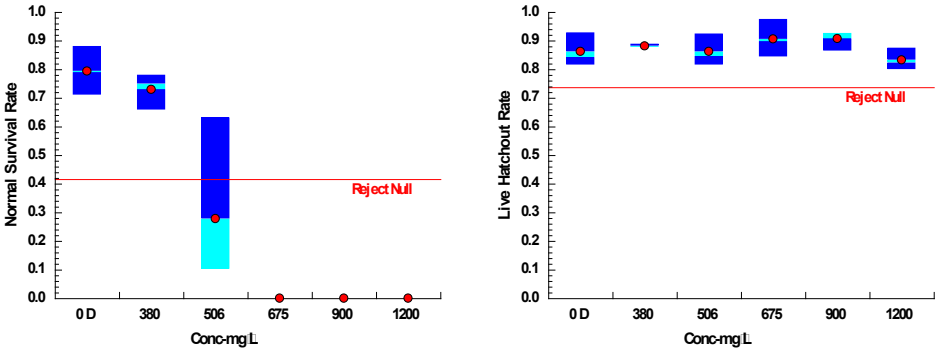
NEBemb04 – 3/17/2011 - **$CuCl_2$**



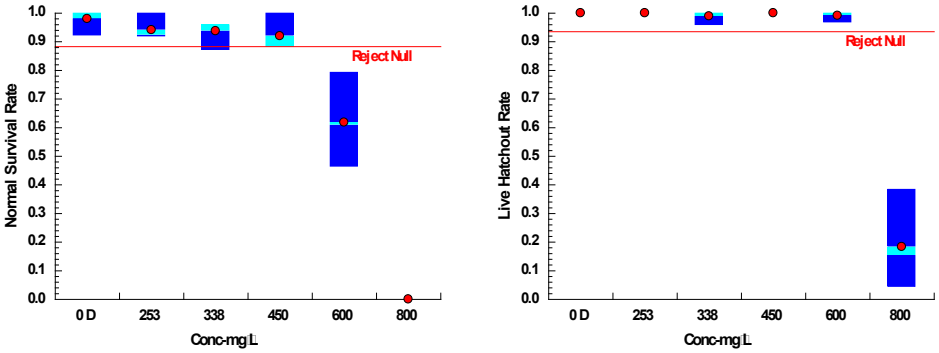
NEBemb05 – 3/18/2011 - **$CuCl_2$**



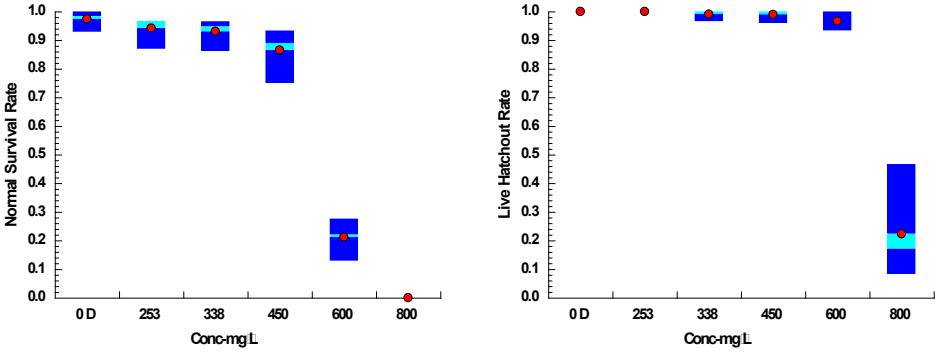
SPMCemb05 – 1/29/2002 – **KCl**



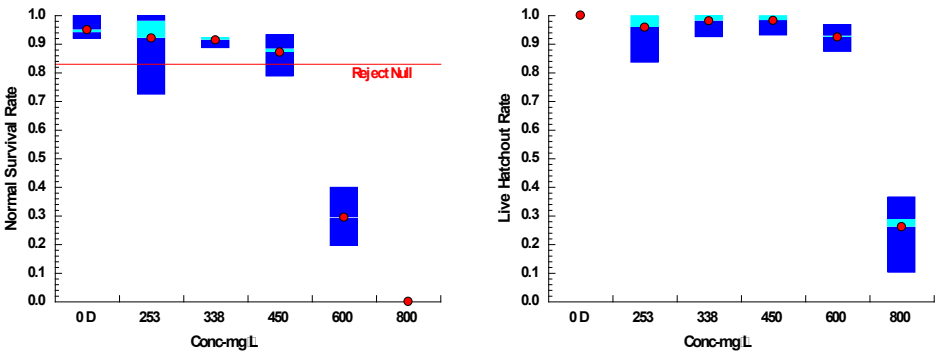
SPMCemb06 – 3/24/2003 – **KCl**



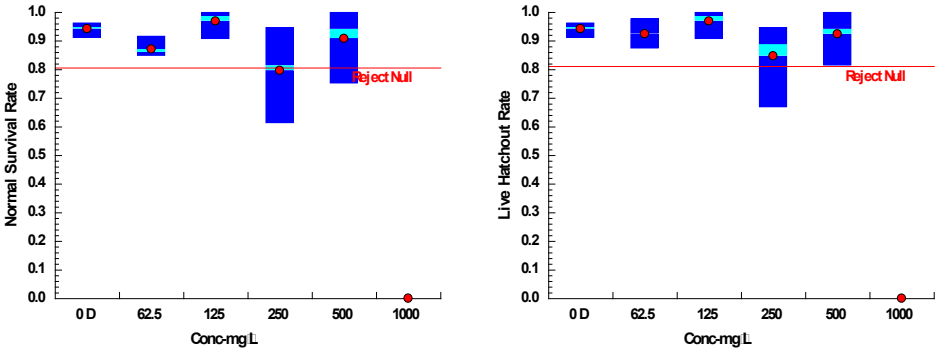
SPMCemb07 – 3/24/2003 – **KCl**



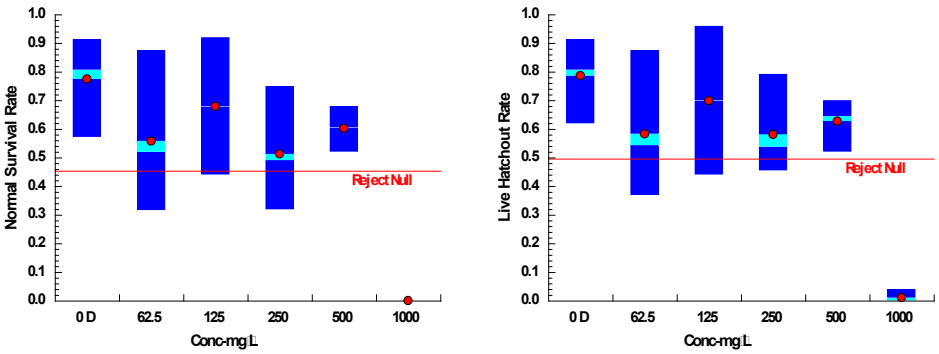
SPMCemb08 – 3/25/2003 – **KCl**



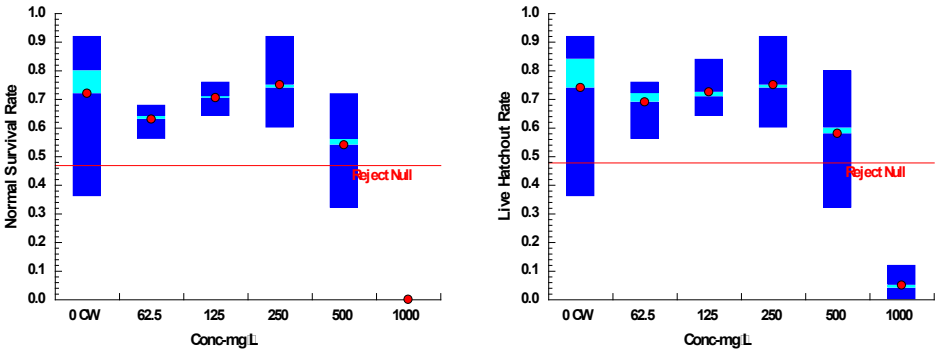
NEFemb05 – 3/4/2005 – **KCl**



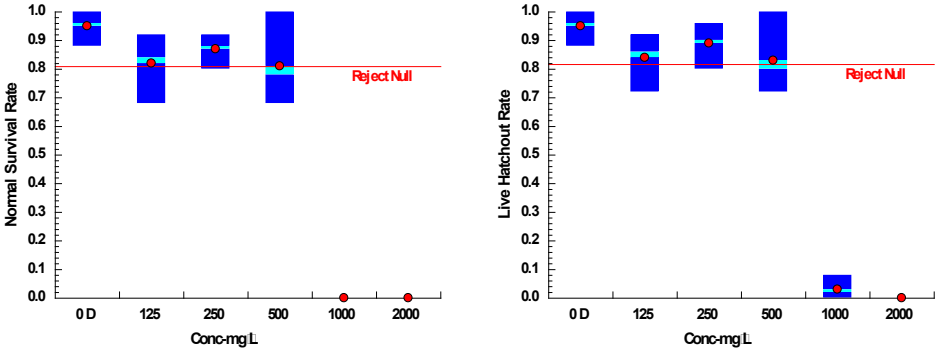
NEFemb06 – 3/18/2005 – **KCl**



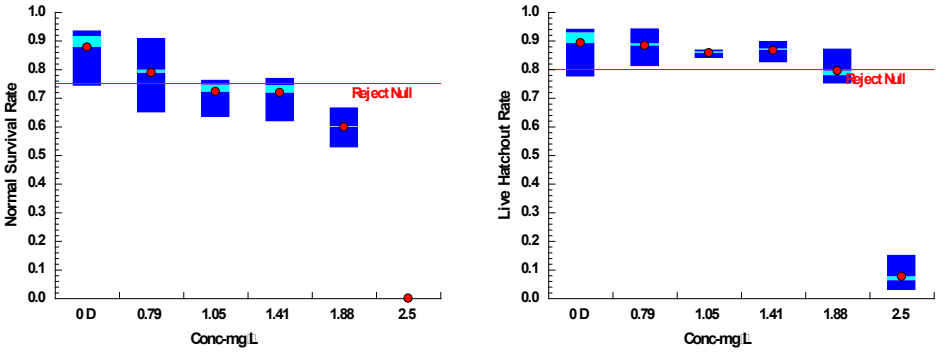
NEFemb07 – 5/4/2005 – **KCl**



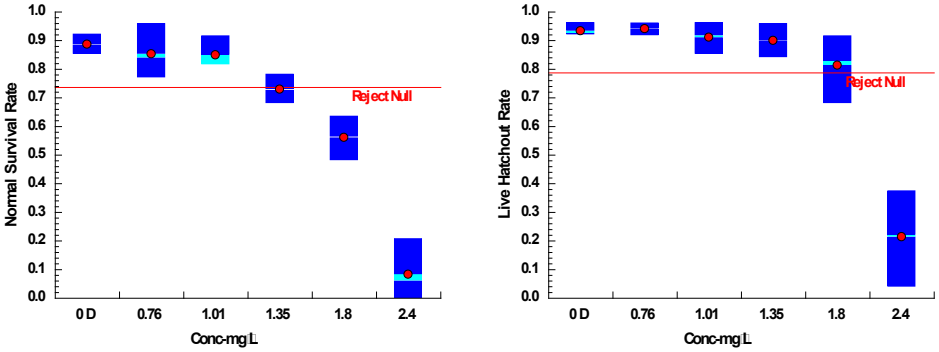
NEFemb08 – 5/13/2005 – **KCl**



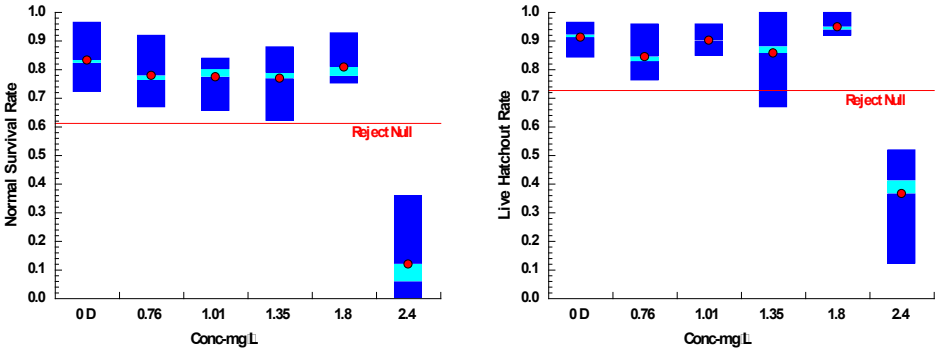
SPMCemb09 – 3/13/2002 – **SDS**



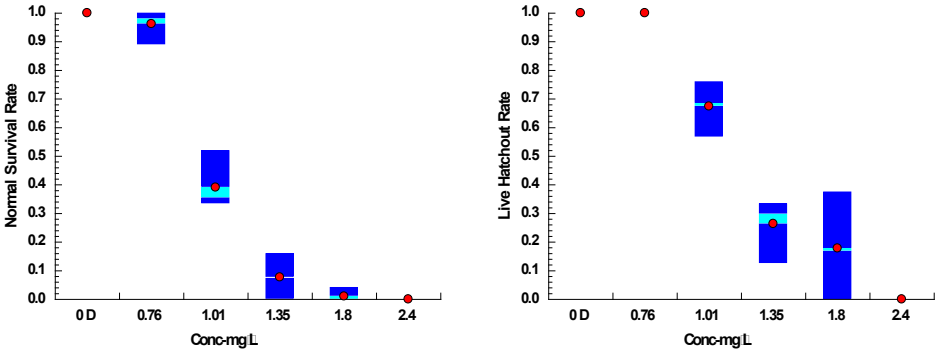
SPMCemb10 – 1/25/2003 – **SDS**



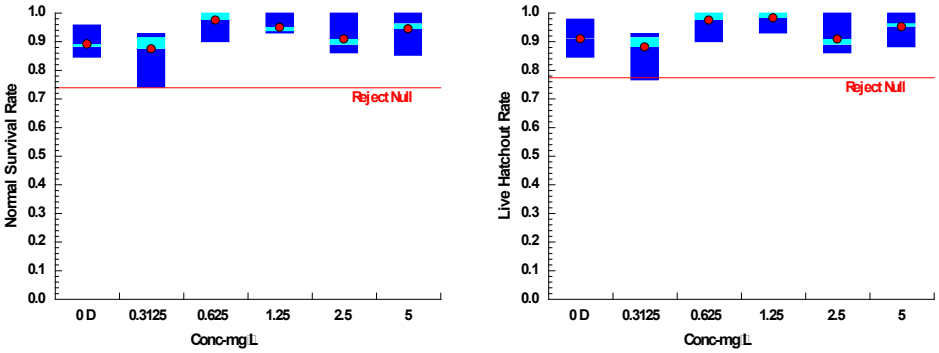
SPMCemb11 – 2/5/2003 – **SDS**



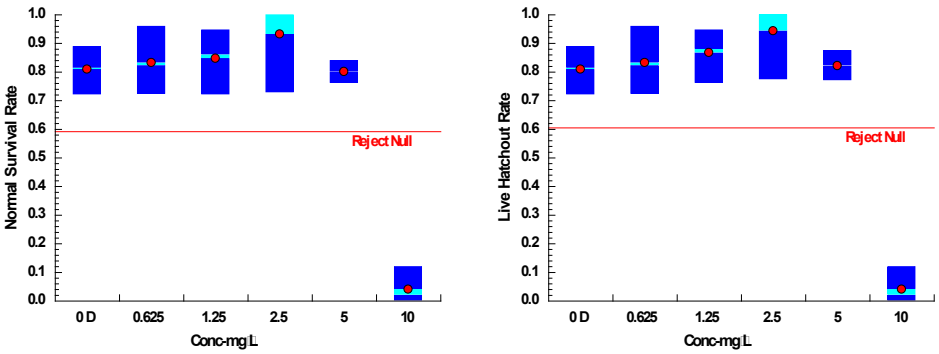
SPMCemb12 – 3/25/2003 – **SDS**



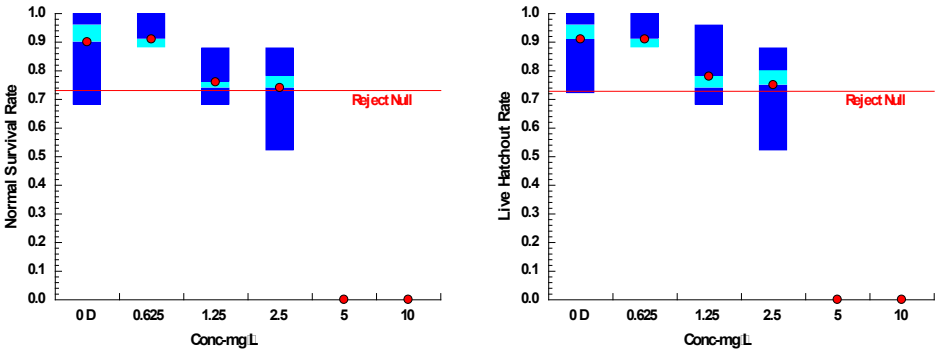
NEFemb09 – 3/4/2005 – **SDS**



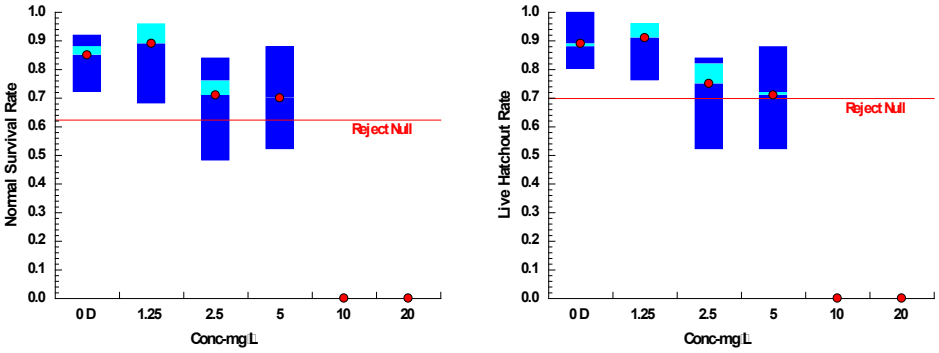
NEFemb10 – 3/18/2005 – **SDS**



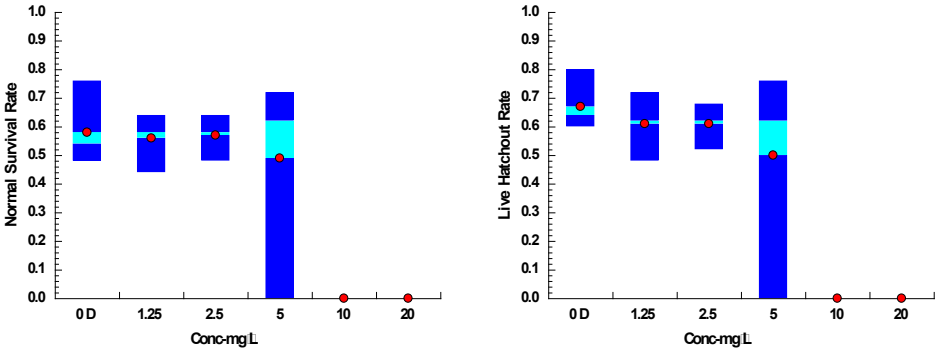
NEFemb11 – 5/4/2005 – **SDS**



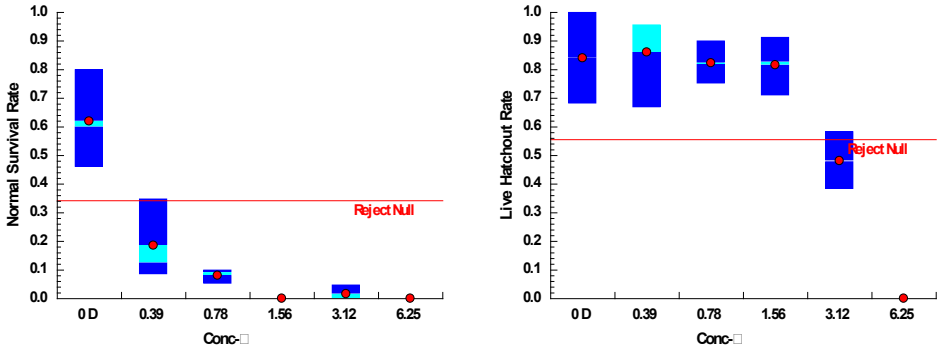
NEFemb12 – 5/13/2005 – **SDS**



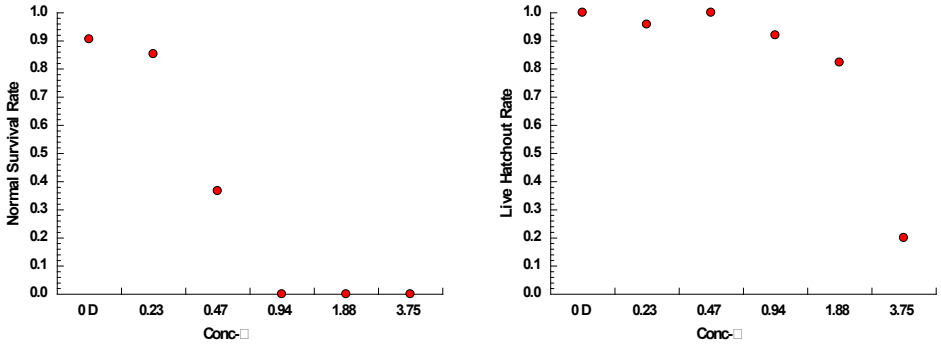
NEFemb13 – 5/27/2005 – **SDS**



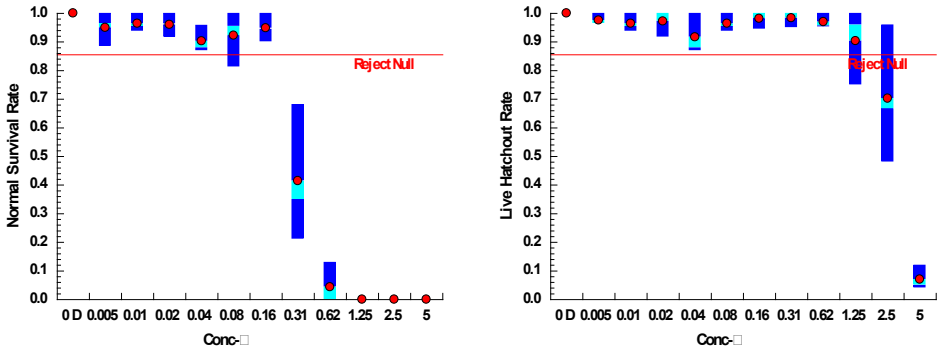
SPMCemb13 – 1/20/2005 - – % **creosote** saturated seawater



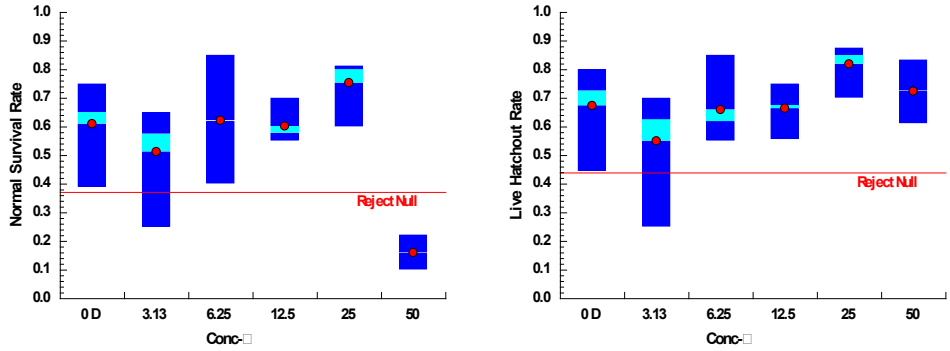
SPMCemb14 – 1/29/2005 - % **creosote** saturated seawater (insufficient replication required Fisher's Exact Test)



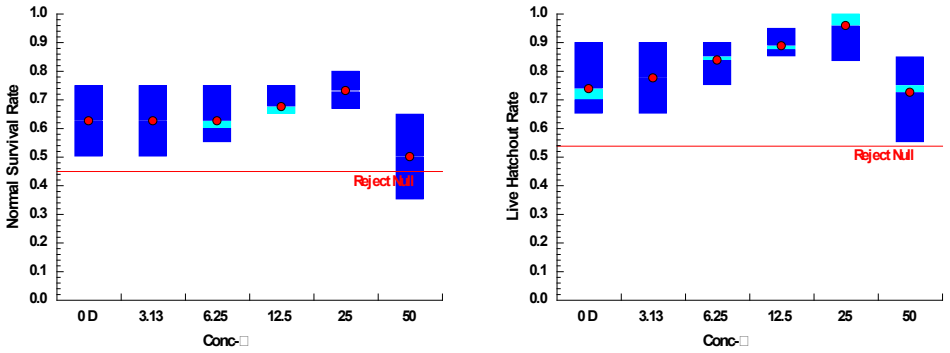
SPMCemb15 – 3/5/2005 – % **creosote** saturated seawater



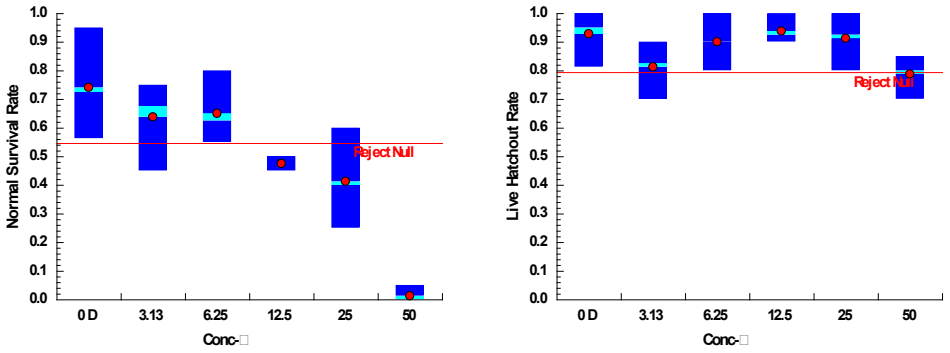
NEFemb14 – 5/17/2007 – **Oil Refinery 1 Effluent**



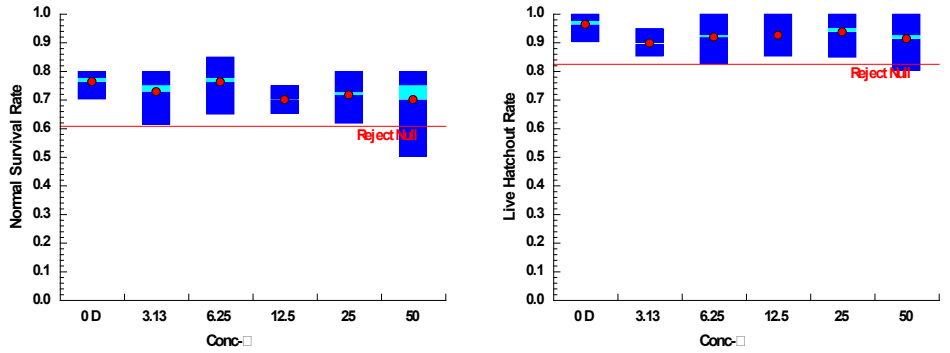
NEFemb15 – 5/16/2007 – **Oil Refinery 2 Effluent**



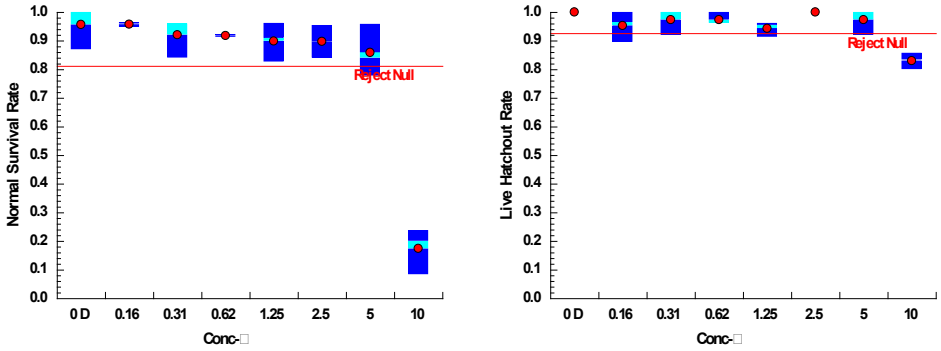
NEFemb16 – 5/16/2007 – **Oil Refinery 4 Effluent**



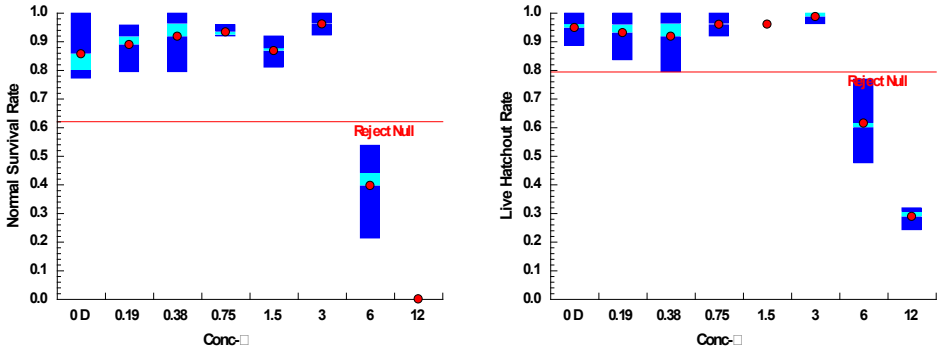
NEFemb17 – 5/16/2007 – **Aluminum Smelter Effluent**



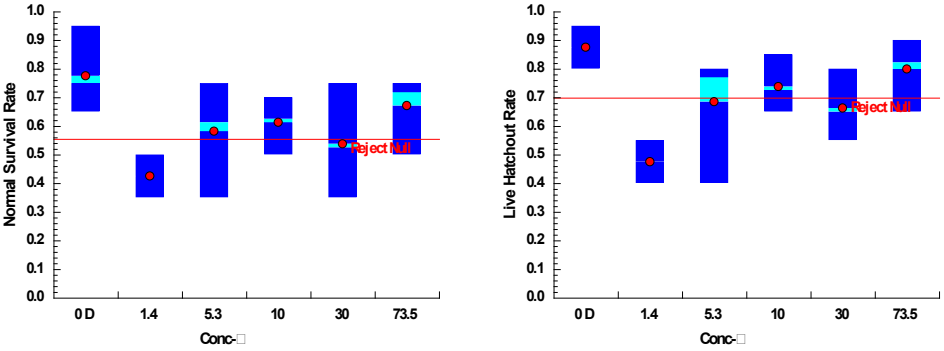
SPMCemb16 – 3/21/2005 – **POTW effluent** spiked with $CuCl_2$, KCl, and SDS



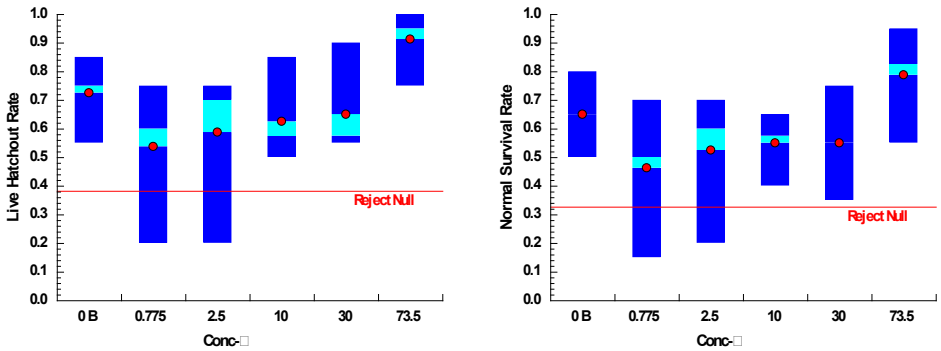
SPMCemb17 – 5/5/2005 – **POTW effluent** spiked with $CuCl_2$, KCl, and SDS



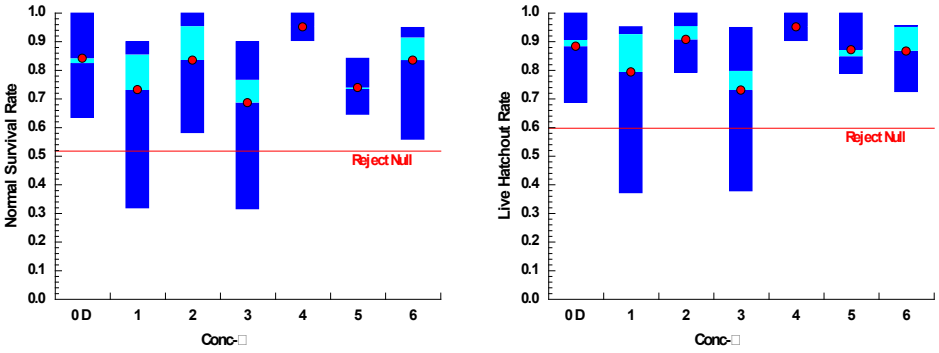
NEFemb18 – 5/4/2011 – **POTW effluent** (unmodified sample from a WWTP)



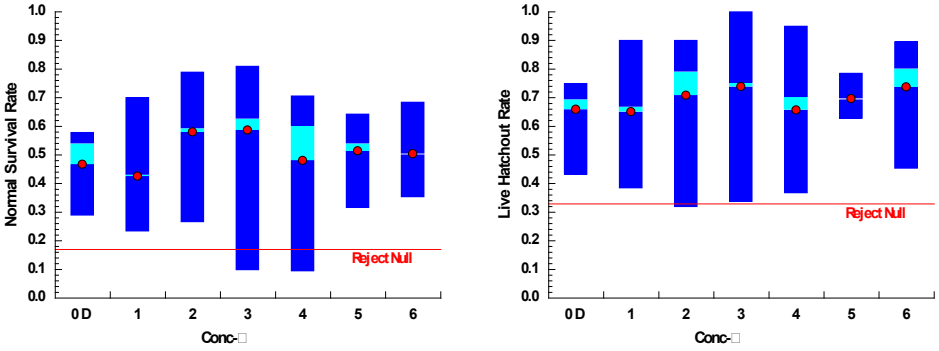
NEFemb19 – 5/4/2011 – **POTW effluent** (unmodified sample from another WWTP)



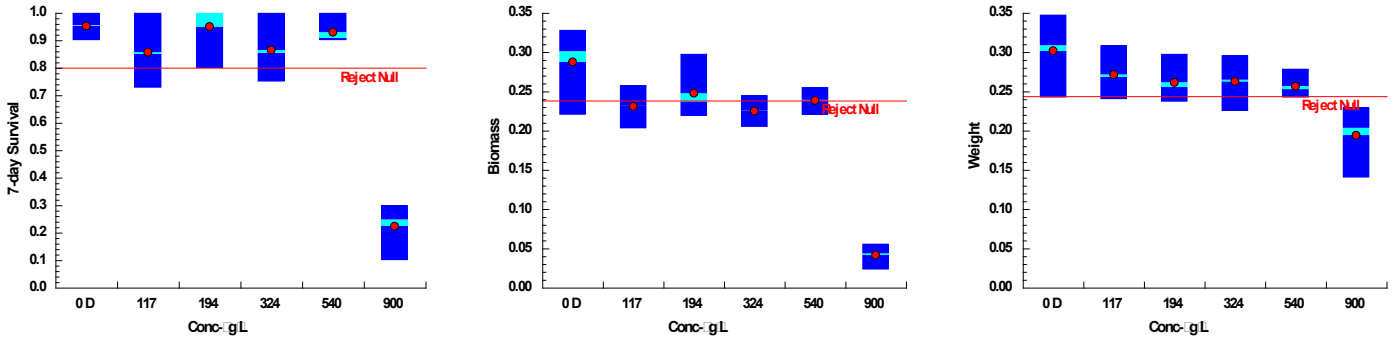
SPMCemb18 – 5/15/2007 – **Cherry Point Reach** samples from 3 stations (odd # shallow; following even # deep)



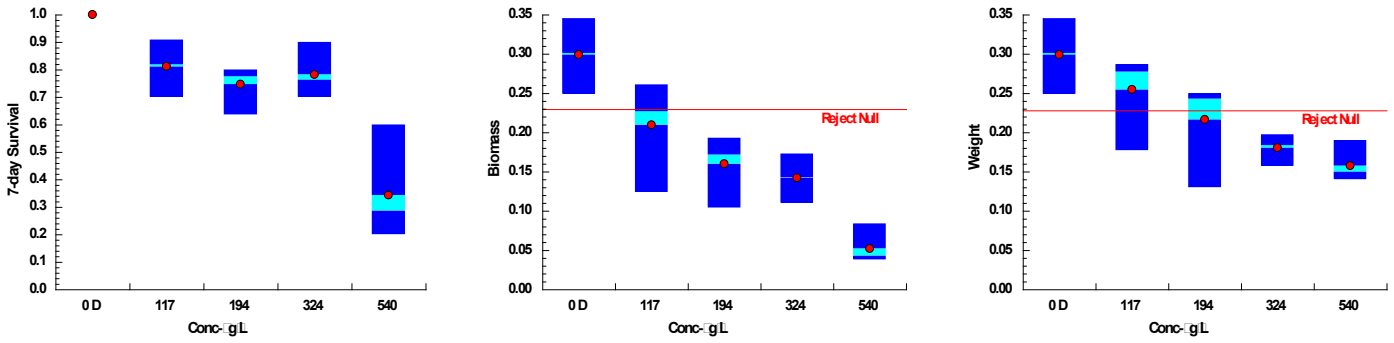
SPMCemb19 – 5/30/2007 – **Cherry Point Reach** samples from 3 stations (odd # shallow; following even # deep)



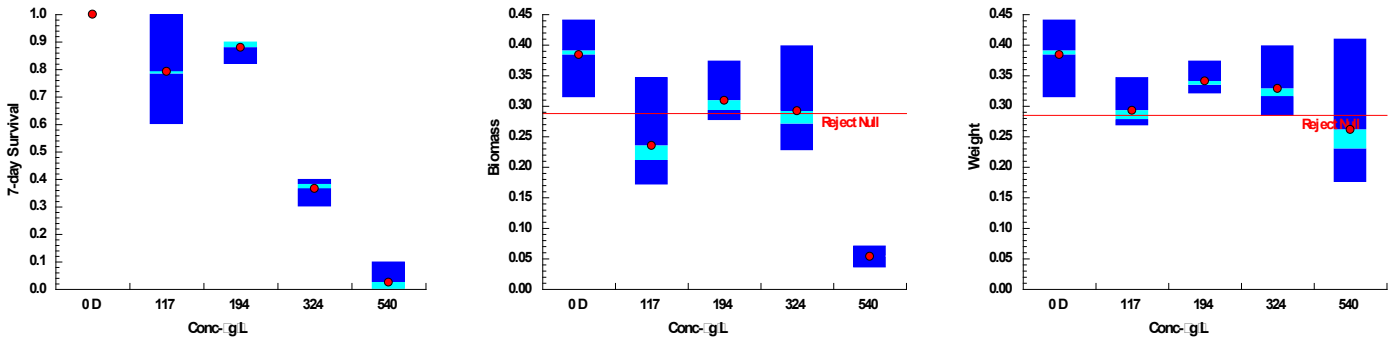
SPMClarv01 – 3/8/2010 – **$CuCl_2$**



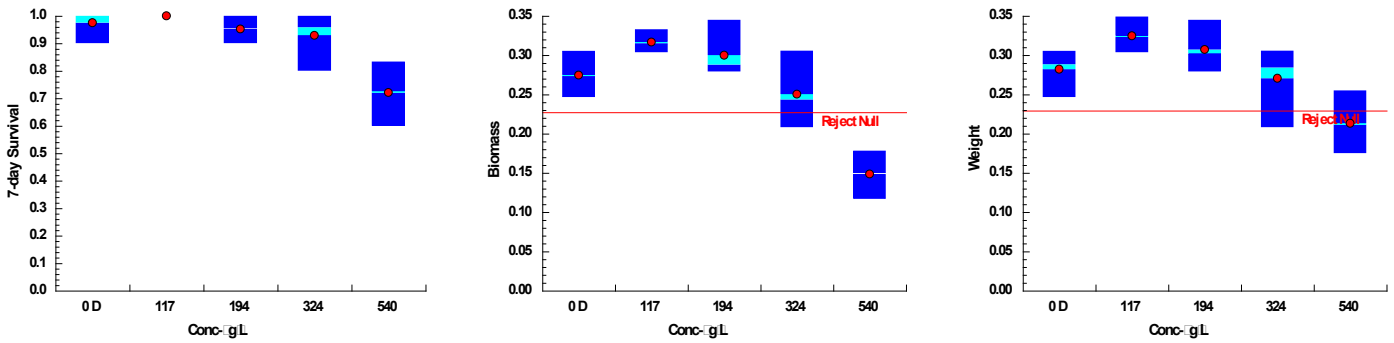
SPMClarv02 – 4/6/2010 – **$CuCl_2$**



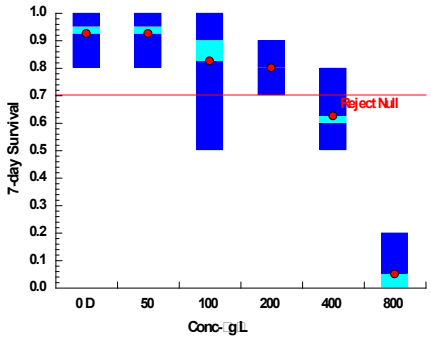
SPMClarv03 – 4/14/2010 – **$CuCl_2$**

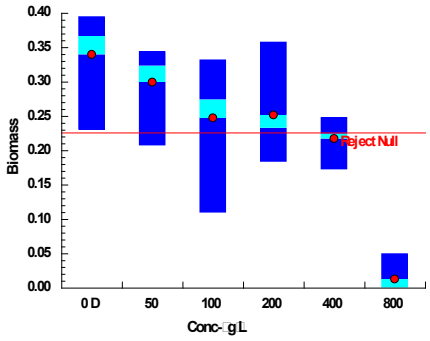


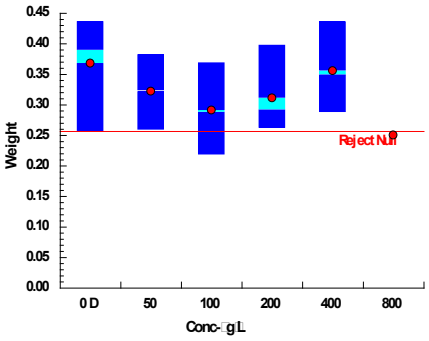
SPMClarv04 – 2/9/2011 – **$CuCl_2$**



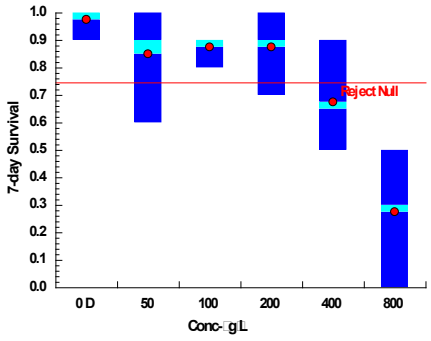
NEFlarv01 – 4/5/2010 – **$CuCl_2$**

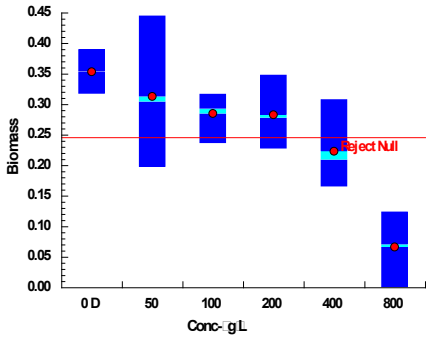


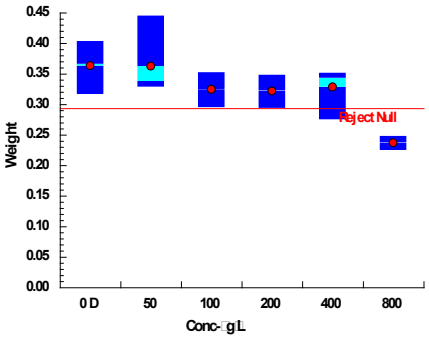




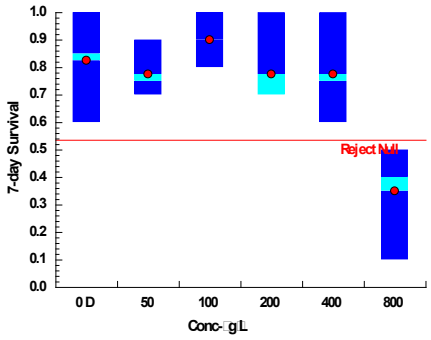
NEFlarv02 – 4/12/2010 – **$CuCl_2$**

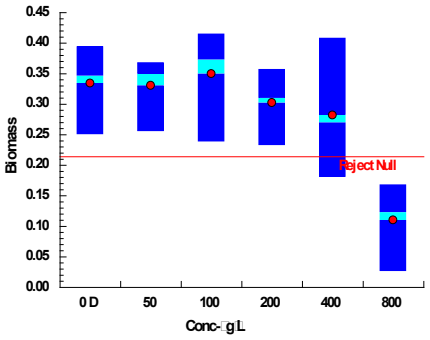


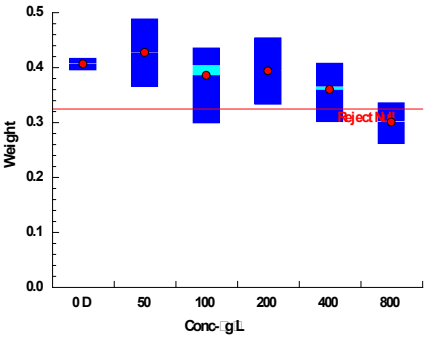




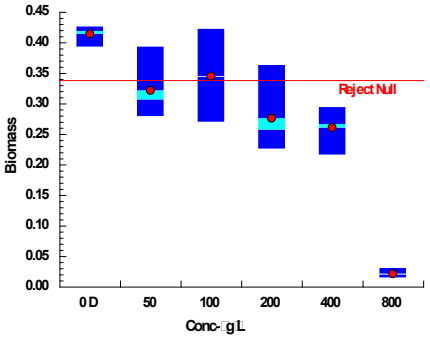
NEFlarv03 – 5/17/2010 – **$CuCl_2$**

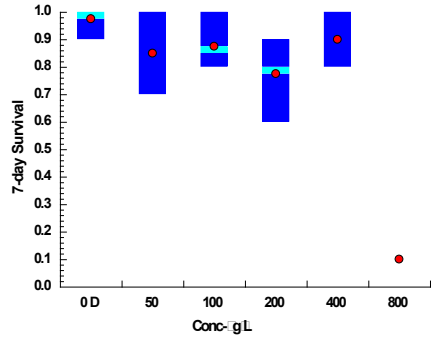


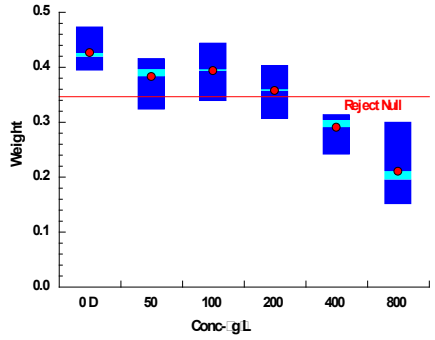




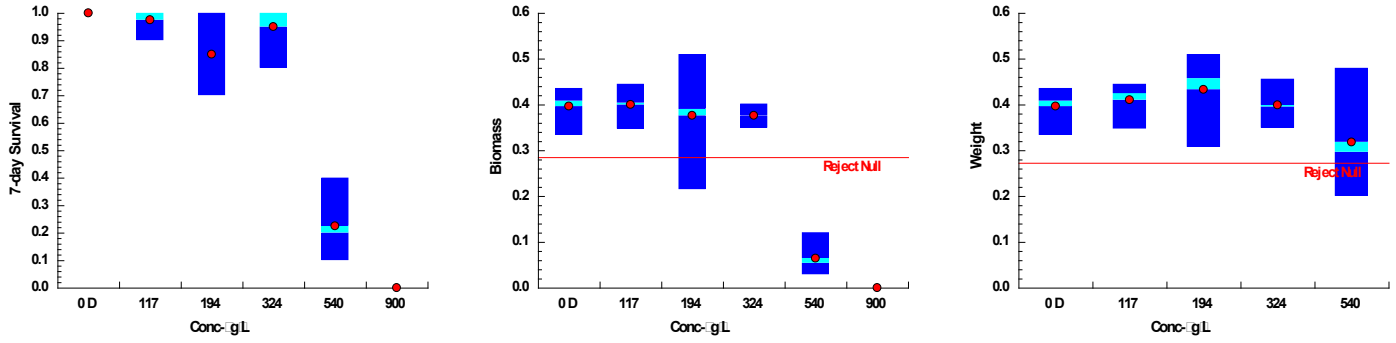
NEFlarv04 – 3/2/2011 – **$CuCl_2$**



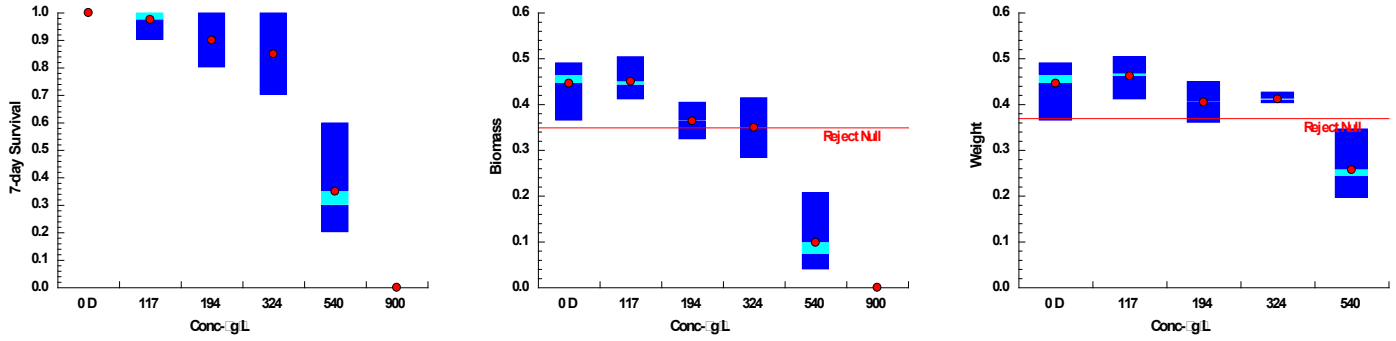




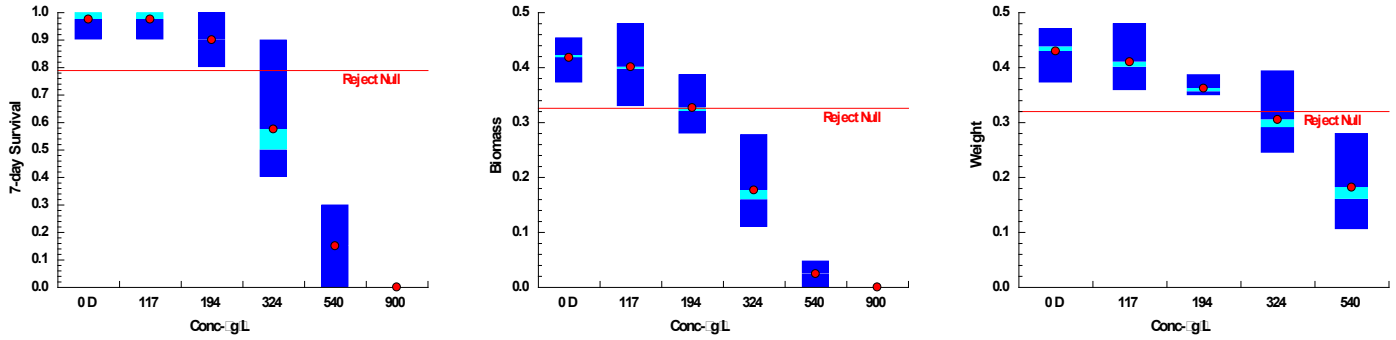
NEBlarv01 – 4/13/2010 – **$CuCl_2$**



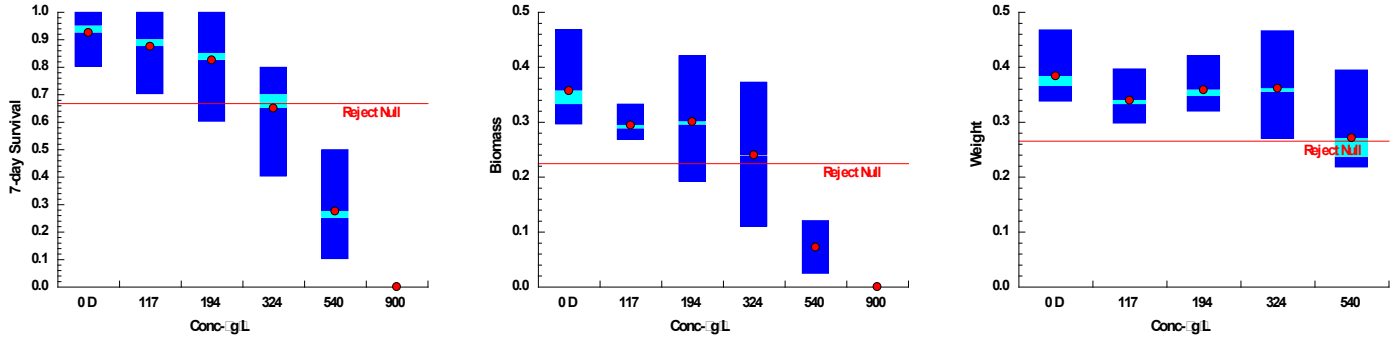
NEBlarv02 – 4/13/2010 – **$CuCl_2$**



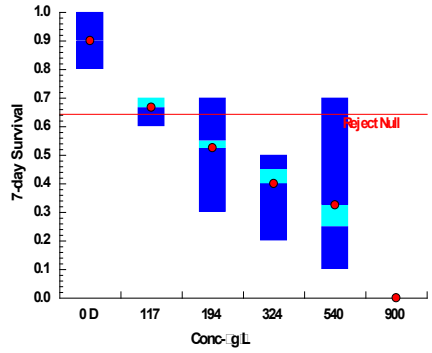
NEBlarv03 – 4/14/2010 – **$CuCl_2$**

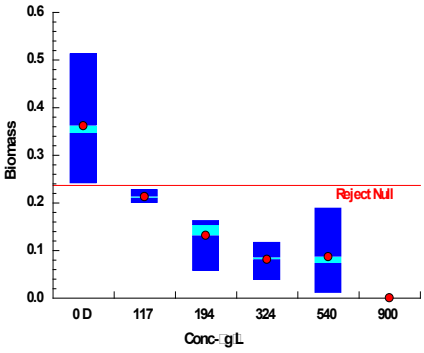


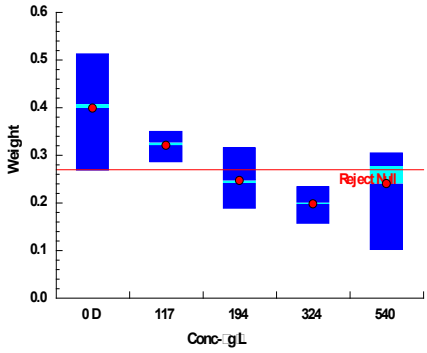
NEBlarv04 – 4/14/2010 – **$CuCl_2$**



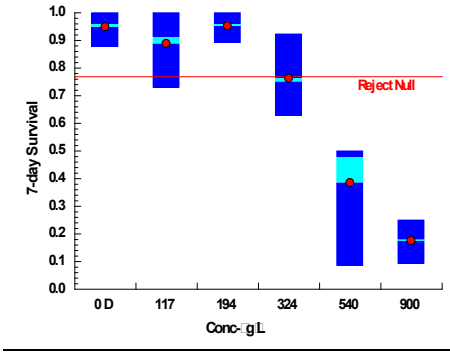
NFlarv01 – 4/12/2010 – **$CuCl_2$**

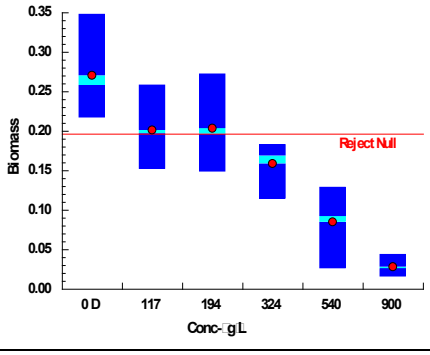


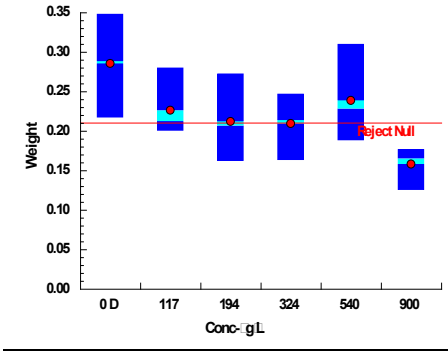




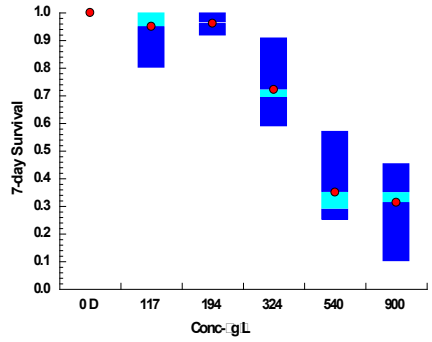
NFlarv02 – 2/11/2011 – **$CuCl_2$**

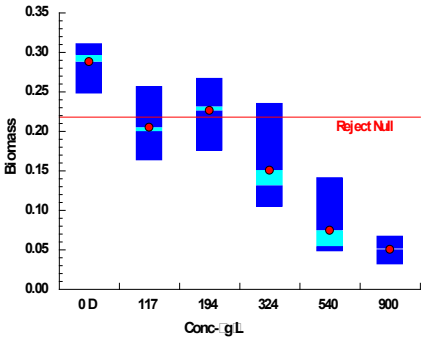


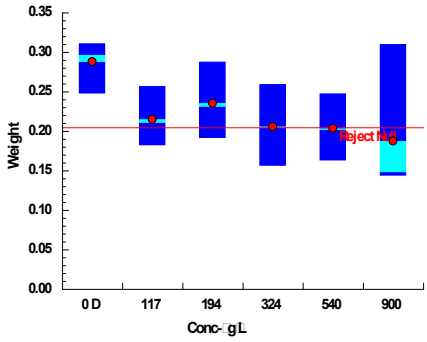




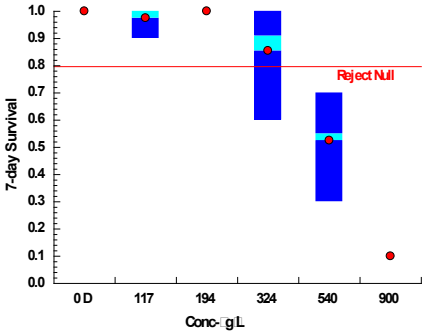
NFlarv03 – 2/11/2011 – **$CuCl_2$**

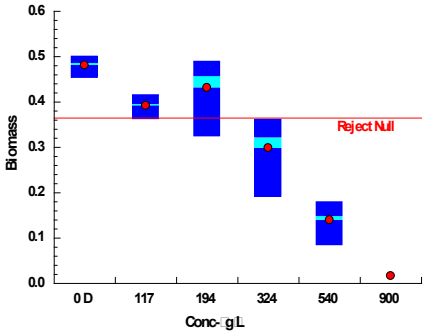


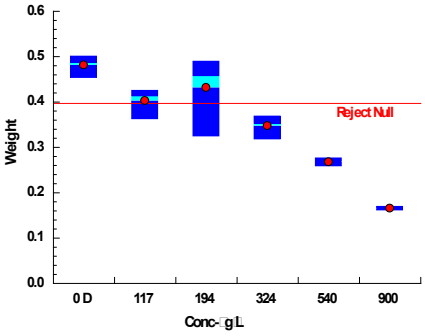




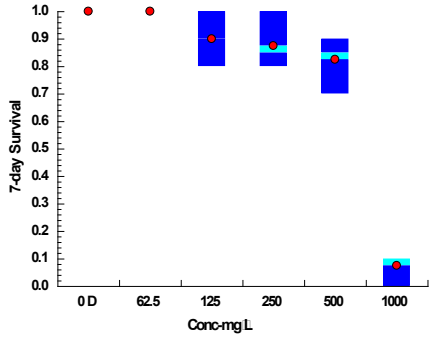
NFlarv04 – 2/15/2011 – **$CuCl_2$**

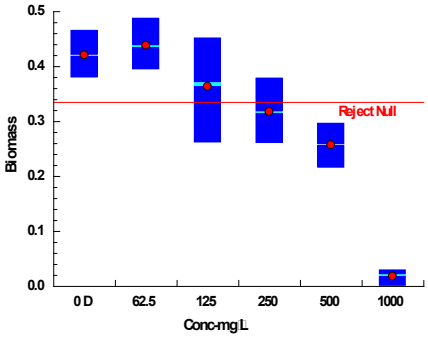


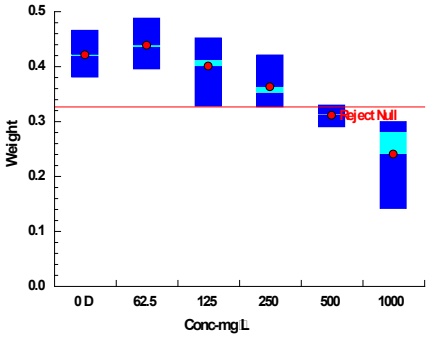




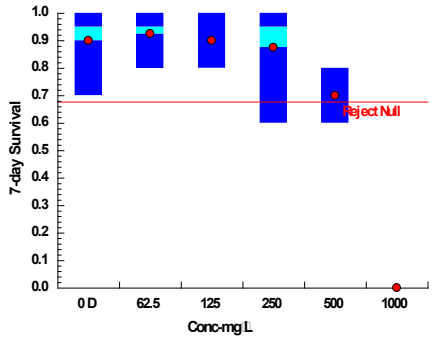
NEFlarv05 – 4/6/2010 – **KCl**

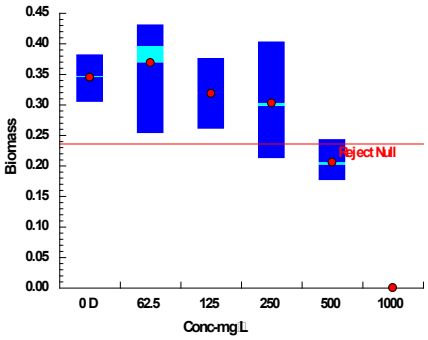


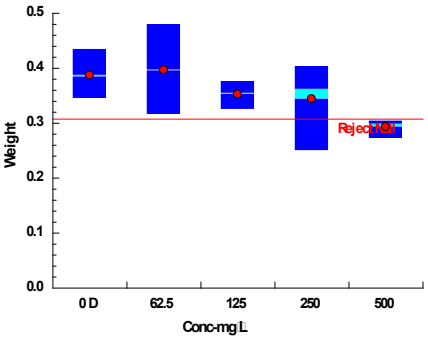




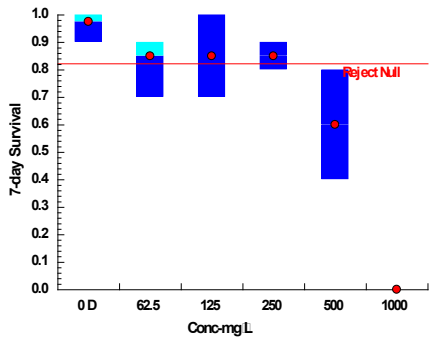
NEFlarv06 – 4/13/2010 – **KCl**

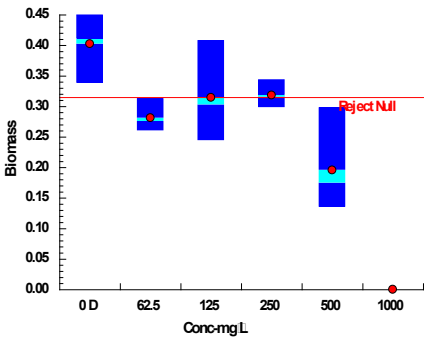


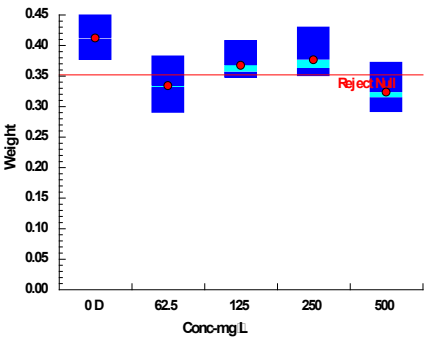




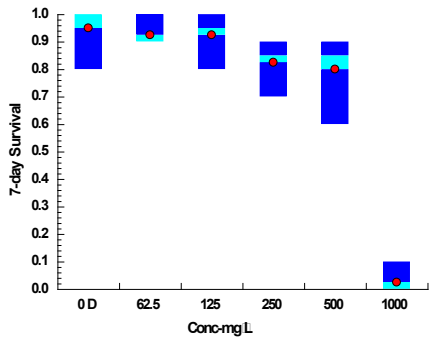
NEFlarv07 – 5/18/2010 – **KCl**

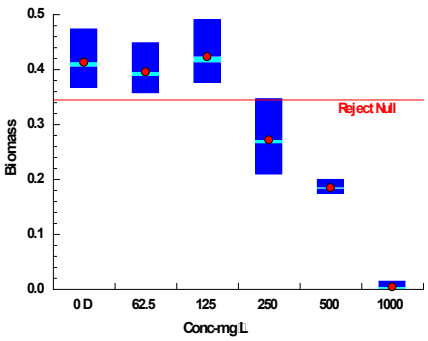


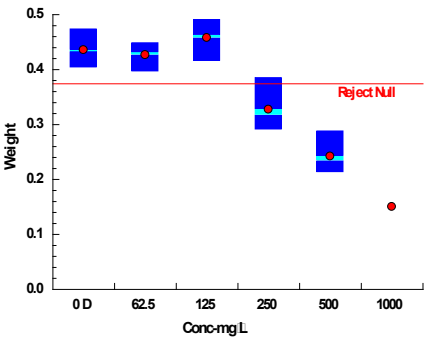




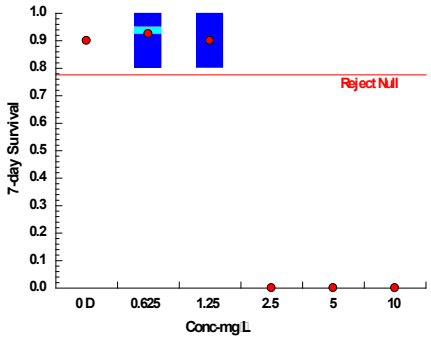
NEFlarv08 – 5/18/2010 – **KCl**

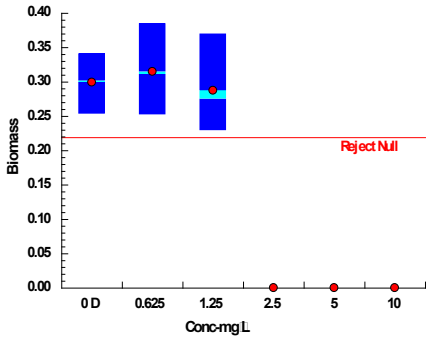


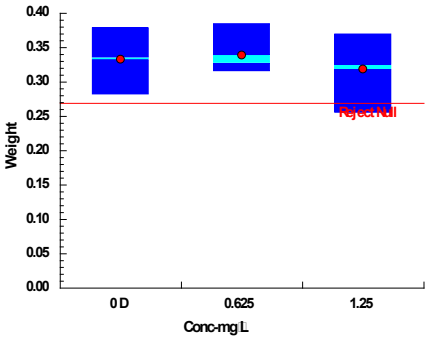




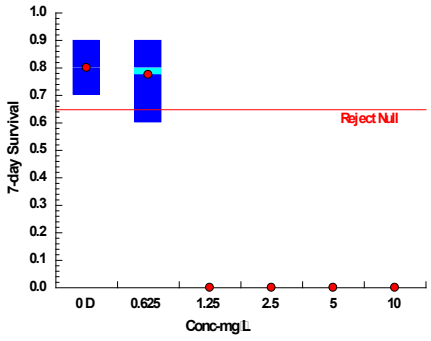
NEFlarv09 – 4/14/2010 – **SDS**

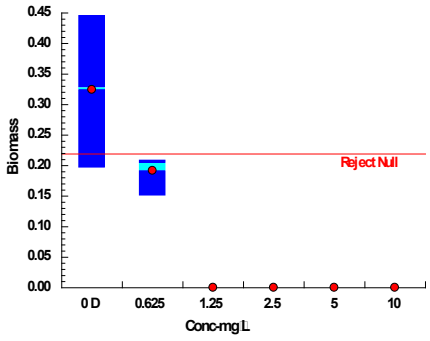


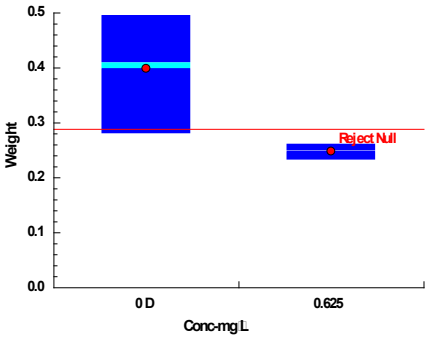




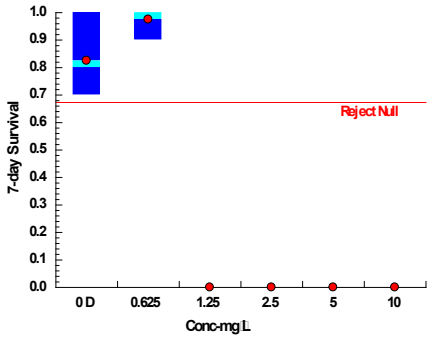
NEFlarv10 – 5/19/2010 – **SDS**

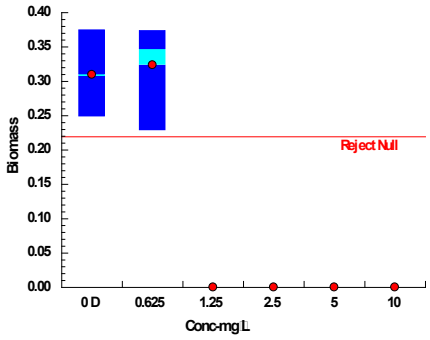


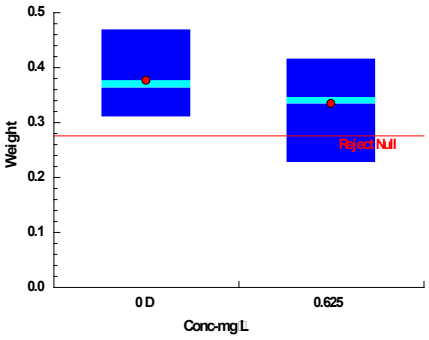




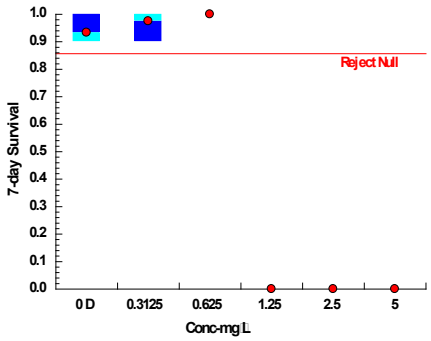
NEFlarv11 – 5/19/2010 – **SDS**

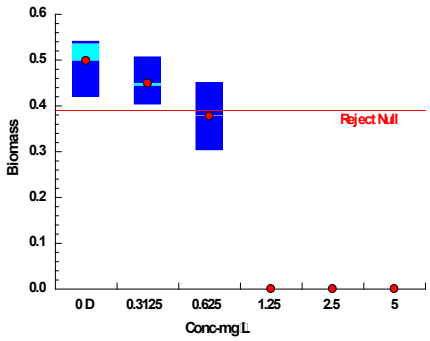


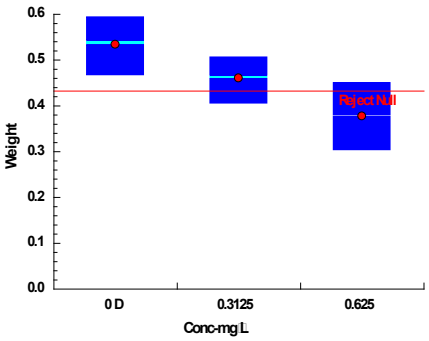




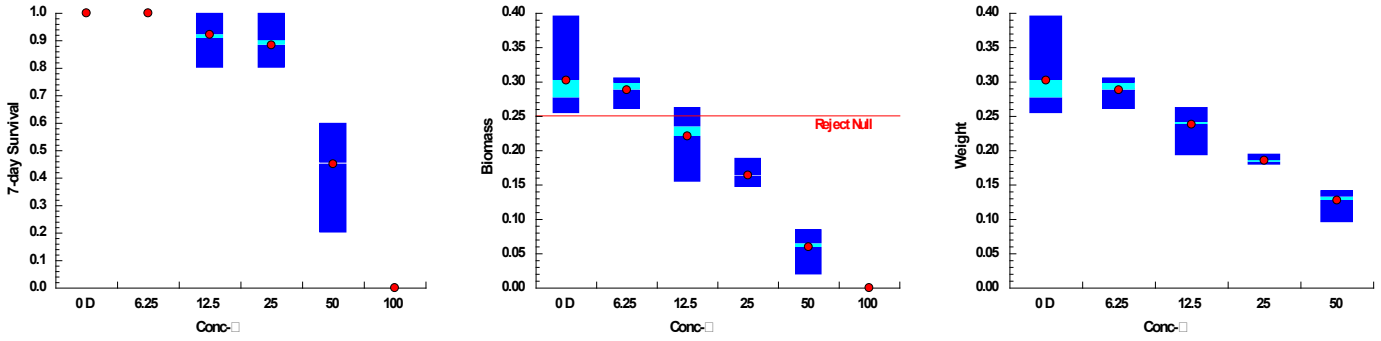
NEFlarv12 – 5/20/2010 – **SDS**



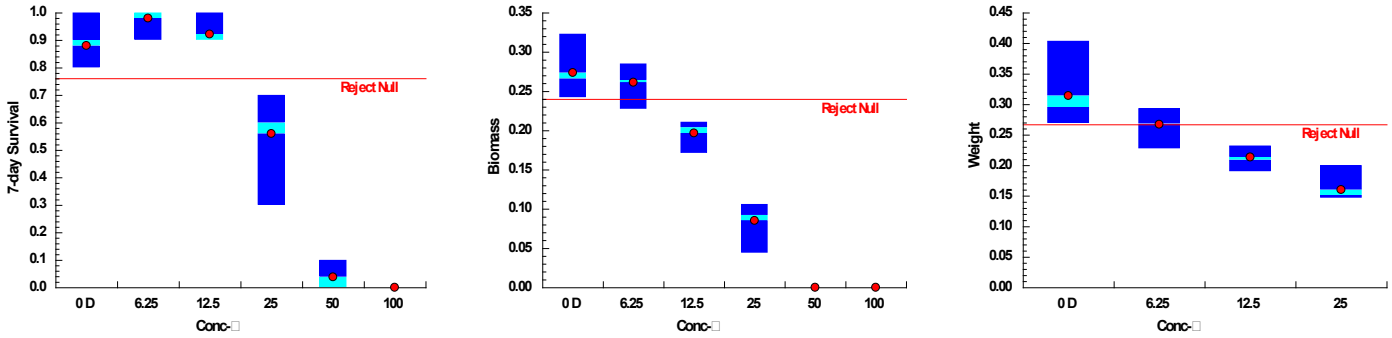




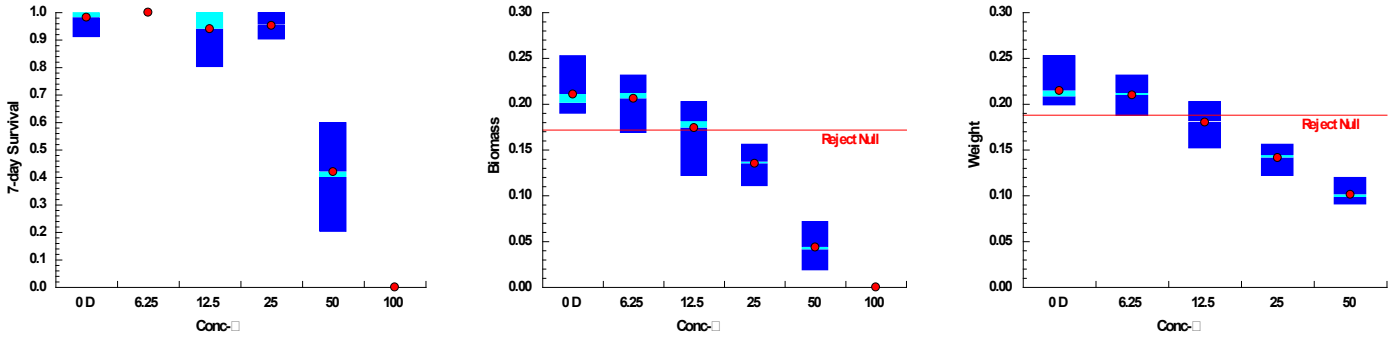
SPMClarv05 – 4/5/2007 – **Oil Refinery 1 Effluent**



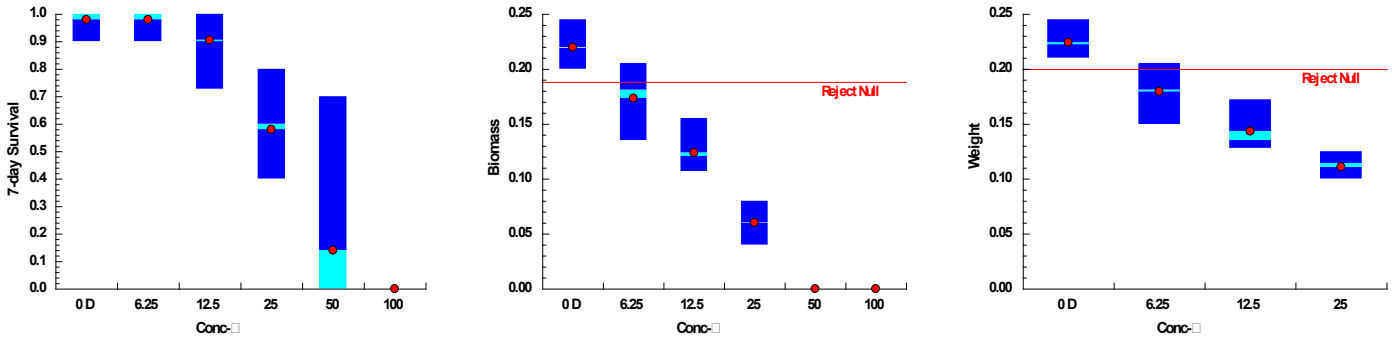
SPMClarv06 – 4/16/2007 – **Oil Refinery 2 Effluent**



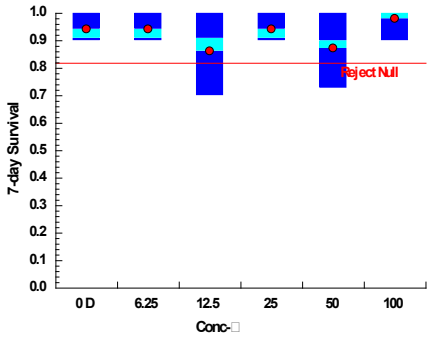
SPMClarv07 – 6/1/2007 – **Oil Refinery 3 Effluent**

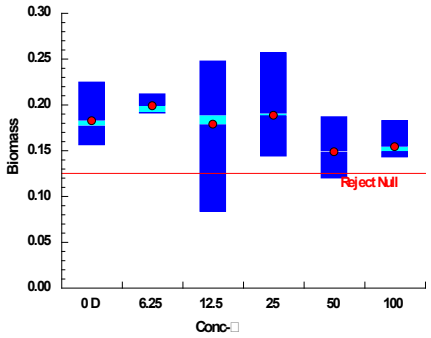


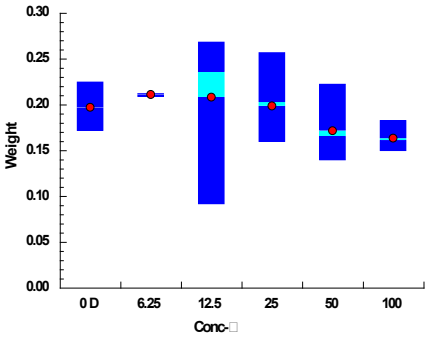
SPMClarv08 – 6/15/2007 – **Oil Refinery 4 Effluent**



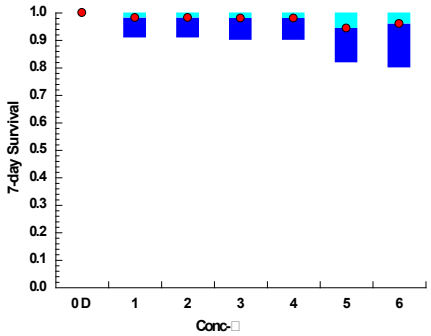
SPMClarv09 – 5/16/2007 – **Aluminum Smelter Effluent**

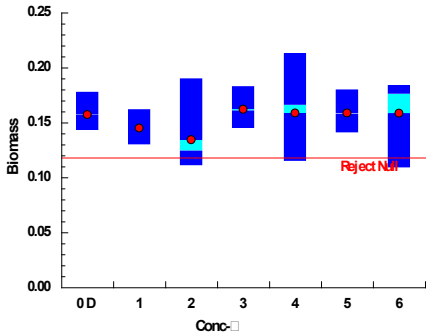


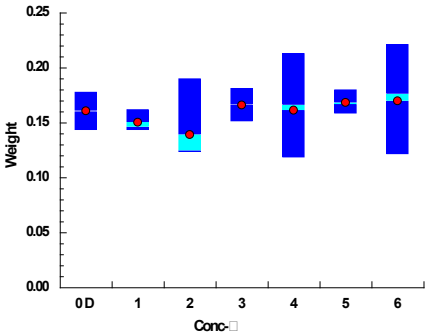




SPMClarv10 – 5/15/2007 – **Cherry Point Reach** samples from 3 stations (odd # shallow; following even # deep)







Appendix C. Embryo Temperature Tolerance Comparisons of West Coast Stocks

Background

Herring deposit eggs in shallow water and sometimes even in the intertidal zone. Herring embryos can be exposed to heat through water, air, or sunlight. The degree of heat exposure will vary between herring stocks depending on the latitude and time of year for spawning. The Cherry Point herring spawn in late spring raising concern about the role warm temperatures might play in the decline in recruitment. However, the Cherry Point herring may have acquired tolerance for the warm temperatures common during their spawning season. It made sense to test the hypothesis that Cherry Point herring are more tolerant of heat than other regional herring by comparing the temperature tolerance of embryos from the stocks we receive for toxicity testing purposes from spawning grounds from San Francisco to Alaska.

Given the variety of toxicity test species and protocols used routinely, commercial testing labs must be able to test on any given day at multiple test temperatures. Since this was the case with the labs participating in herring toxicity test validation, we had a convenient opportunity to expose test chambers containing newly fertilized herring embryos to a series of temperatures and determine a temperature-response relationship. If enough of these temperature-response relationships could be generated to perform statistics, then statistical analysis could reveal whether embryos from different herring stocks have varying tolerance for warm temperatures related to spawning location or timing.

The temperature tolerance test method followed the same protocol (Dinnel et al, 2011) as for the herring embryo survival & development test except that replicates of four test chambers were held in separate incubators at 10°, 12°, 15°, 18°, and 20° C. The labs successfully completed all tests except:

- One of the Puget Sound tests had only 11% live hatch and 0% normal survival at 12° C and this is obvious in Figure 1 and Figure 2. The lab reported that the test chambers from this test were subjected to constant vibration from an aeration pump in the 12° C incubator.
- One Puget Sound test was conducted without 18° C so n= 1 for the mean at that temperature.
- For similar reasons, the Strait of Georgia data has n = 2 for the means at 15° and 18° C.

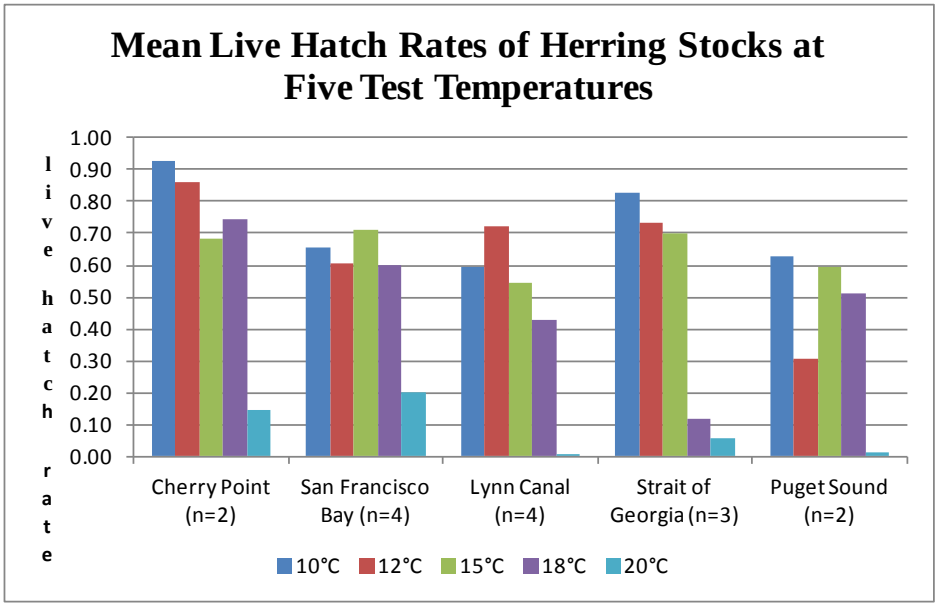


Figure 2. Live Hatch Rate Responses to Five Temperatures

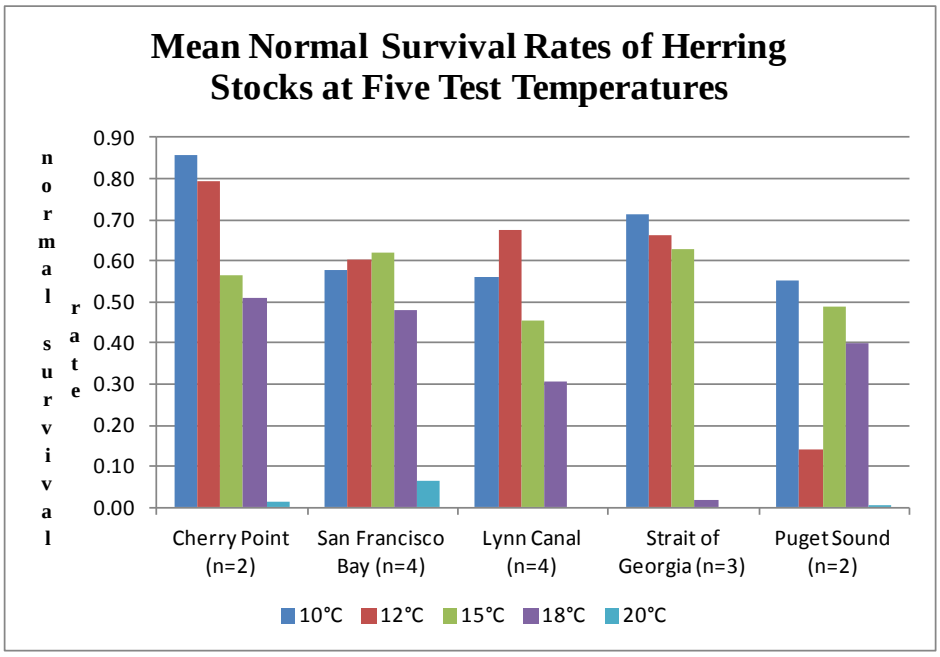


Figure 3. Normal Survival Rate Responses to Five Temperatures

Results

The threshold for embryo temperature response in Figure 2 and Figure 3 looks to be around 18° C for all stocks. Below 18° C other influences seem to be affecting response and produce no consistent trends between temperatures or stocks. However, most of the herring test results at 18° C show reduced live hatch and all show reduced normal survival. Comparisons of embryo responses at 18° and 20° C more clearly show differences in temperature tolerance between herring stocks. Figure 4 and Figure 5 illustrate the differences in response between the five herring populations at just these two temperatures.

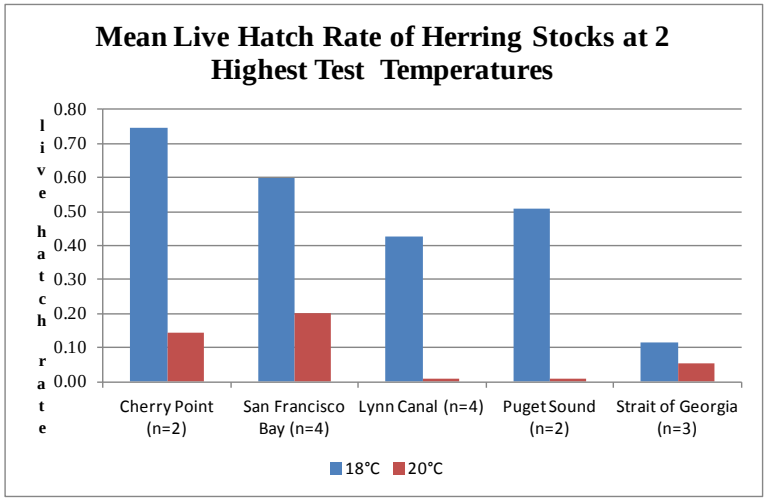


Figure 4. Live Hatch Rate Responses at Two Highest Test Temperatures

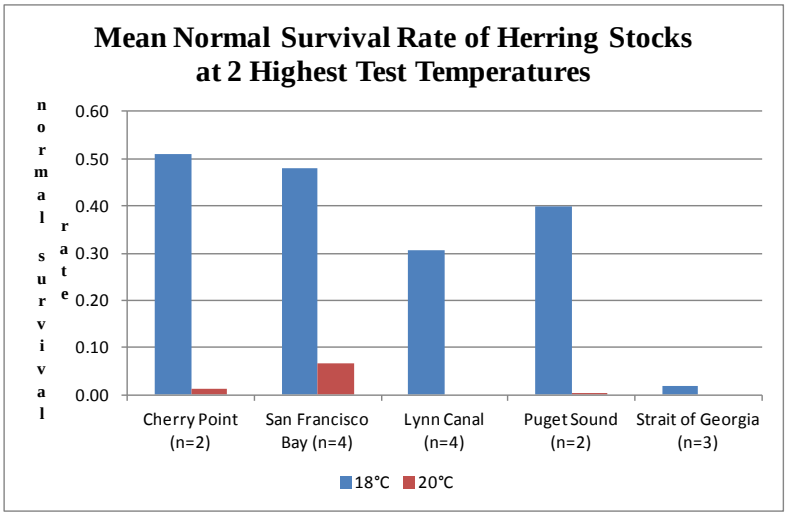


Figure 5. Normal Survival Rate Responses at Two Highest Test Temperatures

Table 9 shows the results of statistical comparisons of the temperature tolerance of Cherry Point herring embryos to those of the other four herring stocks. Because of the low number of temperature tolerance tests for Cherry Point, Strait of Georgia, and Puget Sound, statistical comparisons needed to be based upon the test organism responses in individual test chambers. There were four separate test chambers (replicates) run at each temperature in order to account for variability in test organism response. The number of data points available for analysis is the number of temperature tolerance tests times four. Table 9 shows the total number (N) of replicate responses used in each set of statistical comparisons.

SPSS 14.0 provided the statistical analyses for the temperture data. The Shapiro-Wilk test determined if datasets were normally distributed and the Levene test determined if the two datasets being compared had equal variances. The choice of mean comparison calculation was based upon $p < 0.01$ as the cutoff for rejecting the null hypothesis that the data were normally distributed or had equal variances. Because of the mix of results for the assumptions tests, Table 9 provides 2-tailed probability (p) values for the nonparametric Mann-Whitney U test and for both equal and unequal variance t-tests. Discussions below use $p < 0.05$ as the cutoff for rejecting the null hypothesis that temperature tolerance was not different.

The results in Table 9 show:

- **For live hatch at 18° C**, the Strait of Georgia ($p = 0.0000003$), Lynn Canal ($p= 0.006$), and Puget Sound ($p = 0.03$) herring were significantly different from Cherry Point. The Cherry Point and San Francisco Bay herring difference was not significant with $p = 0.18$.
- **For normal survival at 18° C**, the Strait of Georgia was significantly different ($p < 0.001$) from Cherry Point. The difference from Lynn Canal was not quite significant with $p = 0.09$. The differences between the Cherry Point and San Francisco Bay herring ($p = 0.77$) and Puget Sound herring ($p = 0.45$) were not significant.
- **For live hatch at 20° C**, Cherry Point herring were significantly different from Lynn Canal ($p < 0.001$) and Puget Sound ($p = 0.003$). The difference with the Strait of Georgia herring was not quite significant with $p = 0.07$. The difference between the Cherry Point and San Francisco Bay herring was not significant with $p = 0.47$.
- **For normal survival at 20° C**, the Cherry Point herring were significantly different from Lynn Canal ($p = 0.04$). The Cherry Point herring were not quite significantly different from San Francisco Bay ($p = 0.08$) or Strait of Georgia ($p = 0.08$) herring. The difference between the Cherry Point and Puget Sound herring was not significant with $p = 0.44$.

Table 9. Comparison of Cherry Point herring embryo temperature tolerance to other stocks

Probability (2-tailed p) Values Involved in Comparisons of Cherry Point Herring Temperature Tolerance to other Stocks

Live Hatch at 18°Celsius	Cherry Point	Lynn Canal	Puget Sound	San Francisco Bay	Strait of Georgia
N	8	16	4	16	8
mean	0.746	0.428	0.510	0.598	0.116
Shapiro-Wilk test for normality	0.958	0.114	0.519	0.236	0.033
Levene test for equal variance		0.047	0.316	0.020	0.550
Mann-Whitney U		0.017	0.027	0.244	0.001
equal variance t-test		0.006	0.029	0.177	0.0000003
unequal variance t-test		0.001	0.077	0.096	0.001
Live Hatch at 20°Celsius	Cherry Point	Lynn Canal	Puget Sound	San Francisco Bay	Strait of Georgia
N	8	16	8	16	12
mean	0.144	0.009	0.010	0.203	0.055
Shapiro-Wilk test for normality	0.107	0.000	0.000	0.017	0.003
Levene test for equal variance		0.000	0.000	0.023	0.019
Mann-Whitney U		0.000	0.003	0.733	0.072
equal variance t-test		0.0002	0.008	0.465	0.053
unequal variance t-test		0.016	0.016	0.387	0.090
Normal Survival at 18°Celsius	Cherry Point	Lynn Canal	Puget Sound	San Francisco Bay	Strait of Georgia
N	8	16	4	16	8
mean	0.511	0.306	0.400	0.480	0.018
Shapiro-Wilk test for normality	0.063	0.025	0.734	0.447	0.000
Levene test for equal variance		0.923	0.022	0.400	0.000
Mann-Whitney U		0.084	0.392	0.668	0.000
equal variance t-test		0.090	0.450	0.771	0.0009
unequal variance t-test		0.097	0.339	0.782	0.001
Normal Survival at 20°Celsius	Cherry Point	Lynn Canal	Puget Sound	San Francisco Bay	Strait of Georgia
N	8	16	8	16	12
mean	0.013	0.000	0.005	0.066	0.000
Shapiro-Wilk test for normality	0.000	NC	0.000	0.004	NC
Levene test for equal variance		0.000	0.093	0.014	0.000
Mann-Whitney U		0.041	0.440	0.082	0.075
equal variance t-test		0.038	0.447	0.083	0.074
unequal variance t-test		0.170	0.450	0.024	0.170

Some of the p values from comparison of the means from Cherry Point and San Francisco Bay herring are quite large. The comparison of normal survival at 18° C provided p = 0.77. To refine the impression that a large p value represents similarity between these stocks, a one-sample t-test was done of Cherry Point normal survival data versus the mean normal survival rate (0.48) at 18° C for San Francisco Bay. The comparison yielded p = 0.75 allowing acceptance of the null hypothesis that Cherry Point normal survival at 18° C equals 0.480 (the mean normal survival rate for San Francisco Bay). The null hypothesis that the Cherry Point herring response equaled the mean for another stock was also accepted for comparisons to San Francisco Bay live hatch at 20° C (p = 0.21) and Puget Sound normal survival at 18° C (p = 0.28).

San Francisco Bay and Lynn Canal both have four temperature tolerance test results and provide a good opportunity for statistical comparisons of point estimates derived from the responses at all temperatures for each test. Test organism responses at a series of temperatures are the same mathematically as test organism responses at a series of chemical concentrations. Median effect levels such as the LC50 are the standard metric in toxicology for comparing the toxicity of different chemicals or the sensitivity of different species. CETIS was used to calculate median effect level point estimates using herring embryo responses at all five test temperatures. Spearman-Kärber provided point estimates for the median live hatch effect level and linear regression (probit model) provided point estimates for the median effect level for normal survival. These point estimates allowed additional statistical comparisons of the difference in response between stocks using data from all of the test temperatures.

Because they are the southernmost and northernmost herring stocks in the study, the data from the San Francisco Bay and Lynn Canal herring stocks also provide an opportunity to test the hypothesis that herring embryos from southern stocks have greater tolerance for warm temperatures. Table 10 presents 1-tailed probability (p) values to test this hypothesis. Table 10 also contains comparison results for replicate responses at 18° and 20° C similar to Table 9 of comparisons of Cherry Point to the other stocks.

The Shapiro-Wilk test determined if datasets were normally distributed and the Levene test determined if the two datasets being compared had equal variances. The choice of mean comparison calculation was based upon $p < 0.01$ as the cutoff for rejecting the null hypothesis that the data were normally distributed or had equal variances. Because of the mix of results for these assumptions tests, Table 10 provides 1-tailed probability (p) values for the nonparametric Mann-Whitney U test and for both the equal and unequal variance t-tests. The discussion below uses $p < 0.05$ as the cutoff for rejecting the null hypothesis that temperature tolerance was not different between San Francisco Bay and Lynn Canal.

Table 10 uses the "EL50" for median effect levels for herring temperature responses because the "ET50" is standard toxicological nomenclature for responses related to time. The results in Table 10 show:

- Comparisons of live hatch ($p = 0.048$) and normal survival ($p = 0.03$) show San Francisco Bay herring to be significantly more tolerant of embryo exposure to 18° C than Lynn Canal herring.
- Comparisons of live hatch ($p = 0.0005$) and normal survival ($p = 0.0005$) show San Francisco Bay herring to be significantly more tolerant of embryo exposure to 20° C than Lynn Canal.
- The median effect temperature for live hatch from San Francisco Bay herring was significantly higher ($p = 0.014$) than the median effect temperature for Lynn Canal. The difference between median effect temperatures for normal survival was almost significant with $p = 0.0505$.

Table 10. Comparison of San Francisco Bay to Lynn Canal herring embryo temperature tolerance

Probability (p) Values Involved in Comparisons of San Francisco Bay Herring Temperature Tolerance to Lynn Canal

Assumptions tests are 2-tailed and comparison of means tests are 1-tailed.	Live Hatch			Normal Survival		
	EL50	18□C	20□C	EL50	18□C	20□C
N	4	16	16	4	16	16
San Francisco Bay mean	19.5° C	0.598	0.203	18.6□C	0.480	0.066
Lynn Canal mean	17.2° C	0.428	0.009	16.8□C	0.306	0.000
Shapiro-Wilk test - San Francisco Bay	0.360	0.236	0.017	0.060	0.447	0.004
Shapiro-Wilk test - Lynn Canal	0.107	0.114	0.000	0.171	0.025	NC
Levene test for equal variance	0.007	0.783	0.000	0.000	0.388	0.000
Mann-Whitney U	0.0105	0.068	0.0005	0.0105	0.027	0.0005
equal variance t-test	0.0085	0.048	0.0005	0.032	0.0305	0.0015
unequal variance t-test	0.014	0.048	0.001	0.0505	0.0305	0.0025

Figure 6 (live hatch) and Figure 7 (normal survival) illustrate the comparisons of median effect temperature estimates.

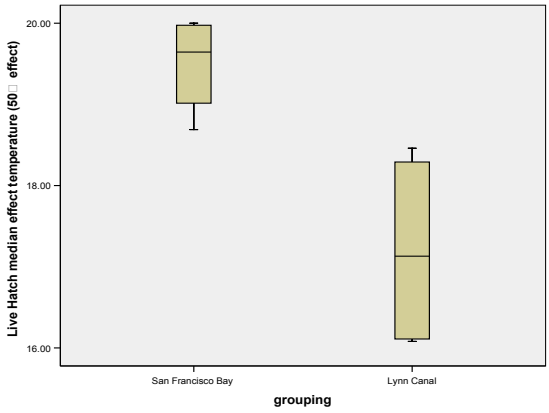


Figure 6. Comparison of Live Hatch Median Effect Levels for San Francisco Bay and Lynn Canal

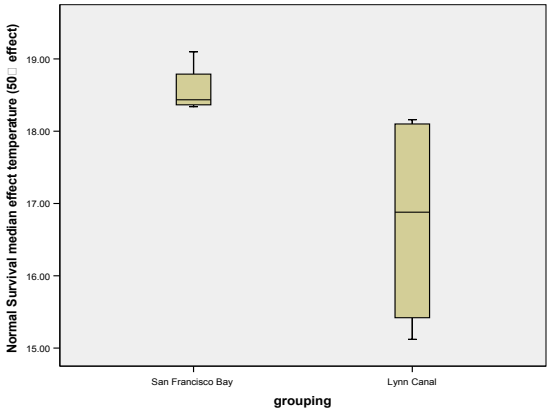


Figure 7. Comparison of Normal Survival Median Effect Levels for San Francisco Bay and Lynn Canal

This page purposely left blank

Conclusions

The comparison of San Francisco Bay herring temperature tolerance to Lynn Canal demonstrates the utility of the approach when at least four test results are available. As hypothesized, the San Francisco Bay herring embryos were significantly more tolerant of higher water temperature than Lynn Canal based upon comparisons of live hatch and normal survival measurements at two temperatures. Comparisons of the median effect levels for live hatch showed a significant difference that accounted for responses at all five test temperatures. The difference in normal survival median effect level was close to significant.

Statistical comparisons showed Cherry Point herring to have significant differences from Lynn Canal and Strait of Georgia herring in embryo live hatch and normal survival response at 18° and 20° C. Cherry Point herring were significantly different from Puget Sound for live hatch, but demonstrated some similarity for normal survival. The San Francisco Bay and Cherry Point herring embryo results did not demonstrate statistically significant differences in any of the comparisons. Statistics found the hypotheses acceptable that Cherry Point response for normal survival at 18° C and live hatch at 20 C equaled the mean responses for San Francisco Bay. This relationship is as predicted given the late spring spawning of the Cherry Point herring and distance south for the San Francisco Bay spawning grounds.

More temperature tolerance testing is needed. All of the stocks involved in this study should be brought up to a minimum of four tests a piece. In addition, it is important to determine whether the differences seen in temperature tolerance are due to genetics or to environmental conditioning. The information may prove to be a key consideration for resource management in a changing climate.

00

June | 12

The Great Giveaway:
An analysis of the United States' long-term trend of selling federally-owned coal for less than fair market value.

By Tom Sanzillo

Author's Note & Data Limitations

This report examines the coal leasing fair market value appraisal program of the United States Department of Interior Bureau of Land Management (BLM). The BLM's practice of withholding information related to its fair market appraisal process has hindered the preparation of this report. In its policy handbook, the BLM states that such information is available to the public and the agency is committed to external review of its appraisal process. However, this study provides evidence that the opposite is true. Contrary to its stated protocols, the agency actively denies public information requests. Furthermore, there has been no robust programmatic or public external review of the coal leasing program for almost 30 years.

Despite this limitation, the author believes that commentary on this topic is possible based upon the information that is currently available on the public record. The author is aware of the risks to sound methodology, measurement of coal price and reserve valuations that come because BLM has not made the data publicly available. ***In this instance the data are available and are being withheld.*** The methods and conclusions contained in this report, particularly the quantitative calculations of revenue losses, would be significantly improved with access to the actual fair market appraisals and supporting documentation.

About the Author

Tom Sanzillo is the president of TR Rose Associates, a financial policy and consulting business in New York and the director of finance for the Institute for Energy Economics and Financial Analysis. For the past four years, he has helped his clients pursue strategies to increase fuel diversity in the United States system of electricity generation. He has written several studies on coal plants, rate impacts, credit analyses, and the public and private financial structures for coal. In addition, Tom has testified as an expert witness, taught several training sessions, and conducted media interviews. Prior to his work with TR Rose Associates and the Institute for Energy Economics and Financial Analysis, Tom spent 17 years with both the City and the State of New York in various senior financial management positions. He was formerly the State of New York's First Deputy Comptroller, a position responsible for the management and oversight of the state pension system and its investments, contracts, and audits. As first deputy comptroller, Tom was also responsible for oversight and audit activities of local government finance.

Table of Contents

Executive Summary **4**

Part I: Introduction **10**
- **Historical Background** **12**
  - Early Management 12
  - The 1920 Mineral Leasing Act 12
  - New Federal Coal Leasing Programs 13
  - The 1982 Powder River Basin Lease Sale 14
- **Implications & Investigations** **15**
  - General Accounting Office Analysis 15
- **The Linowes Commission** **16**
  - Office of the Inspector General 17
  - BLM's Response 17
- **Changes to the Program** **18**
  - Land Use Planning 18
  - Regional Sale Activity Planning 18
  - Lease Sale Activity 18
  - Exceptions for Leases Outside Production Regions 19
  - Disclosure and Oversight Issues 19

Part II: A History of Lax Oversight: 1983 to the Present **20**
- **Decertification of Coal Production Zones in 1990** **20**
- **Current Oversight** **21**
  - Office of the Inspector General 21
  - Congress 22
  - Government Accountability Office 22
  - Withholding Information 23
- **The Current Fair Market Valuation Process** **24**
  - Determining Fair Market Value 25
  - Collecting Revenue 26
- **Loss in Revenue** **27**
  - Technical Basis and Rationale for Calculation 27

Part III: Changing Market Dynamics **32**
- **Ignoring Larger Market Forces** **32**
  - Exports 33
  - Cost of Production Pressures 34
  - Loss of Central Appalachian Coal 36
  - Declining Price of Natural Gas 36
- **Recent Coal Leasing: Still Below Fair Market Value** **36**

Part IV: Implications for the Future **37**
- **Findings** **37**
- **Recommendations** **41**
- **Conclusion** **43**

Appendix A: Discussion of Model **44**

Appendix B: Recent Coal Lease Case Studies 47

Appendix C: GAO Archived Coal Lease Research 52

EXECUTIVE SUMMARY

Rapidly changing market forces are driving a profound transformation of the Powder River Basin (PRB), which contains the United States' largest remaining coal reserve. Historically less significant than the country's other coal producing regions, the PRB has increased in national—and even global—significance in the last 40 years. Located in southeastern Montana and northeastern Wyoming, the PRB currently produces 44 percent of the nation's coal. The Department of Interior (DOI), through its agency the Bureau of Land Management (BLM), is responsible for the sale of PRB coal. Given that the United States owns almost all the coal in the region, the U.S. government holds an effective monopoly of western coal. As a result, government policies—or more precisely those of the DOI—are extremely influential and shape annual coal production levels and the market price of coal.

The BLM has a legal obligation to the American public to secure a fair market value for coal on public land. Historically the agency has sold PRB coal for below fair market value and continues to fail the public to this day. As a result of policy choices and an inherently subjective and flawed fair market value appraisal process—the problems of which are exacerbated by the agency's failure to consider changing market dynamics—the U.S. Treasury has lost approximately $28.9 billion in revenue throughout the last 30 years. Despite past political scandals and promises of programmatic reform, neither the DOI nor the BLM coal leasing activities have been audited or the subject of any major publicly available, external review regarding the sale of PRB coal for almost thirty years. As applied by the federal government in the case of federal coal leasing, the term "fair market value" rings hollow.

The 1982 Powder River Basin Lease Sales

BLM leases coal tracts to private producers in a tightly controlled and mostly secretive process. After the BLM and the coal industry select parcels to mine, the agency establishes a fair market price for the coal tract that is held strictly confidential. The parcels are offered at a competitive auction, and the highest bidder that exceeds the confidential price is then awarded the mining lease. Most coal tracts sell for hundreds of millions of dollars and typically generate at least 20 years of revenue for federal and state governments, which splits the revenue 50/50. If the BLM fails to set the price at fair market value—or, in other words, if it sets the price too low—both federal and state governments lose revenue.

The government has historically lost revenue as a result of the flawed fair market value process. The issue of lost revenue in the federal coal leasing program was most clearly brought into the public consciousness in the mid-1980s. Following a period of intense program review and redesign, the agency lifted a 10 year federal moratorium on coal sales and placed 1.6 billion tons of PRB coal for sale in 1982. Surrounded by criticisms of leaked information, botched policies, and abrupt program changes, the sale quickly devolved into scandal. A Congressional committee, the General Accounting Office (GAO), and the congressionally chartered Linowes Commission reviewed the sales and determined that the agency had effectively ignored its own appraisals and sold the coal at below fair market value.

According to GAO, DOI's internal checks, which were designed to ensure the receipt of fair market value, all failed. The one external check on the system, the failsafe on which the program relied—competition among coal producers—also failed. As the studies showed, there was a severely limited number of bidders on each of the 11 tracts offered for sale in 1982. In the end, the federal government lost $100 million in revenue. The agency originally denied that it sold coal tracts below fair market value. Over time, however, DOI has taken credit for this action, claiming it wanted to provide domestic utilities with low-priced coal.

Lack of Oversight

Although the DOI implemented reforms in the wake of the scandal—particularly those designed to increase external review and enhance the transparency of the bidding process—neither Congress nor any independent entity has conducted an evaluation of the program in nearly 30 years. This lack of reporting is in sharp contrast to the years prior to the scandal when the GAO and other public interest research created a healthy body of literature for decision makers and the public. Moreover, there has been no follow up to any of the audits or studies conducted after the controversial 1982 sales. The last on-point review that covered the major issues related to fair market value was a 1983 GAO audit.

Making matters worse, the DOI disbanded a resource available to help the BLM manage this process. In 1990 the agency decertified the PRB as a coal production region. The designation would have required BLM to plan and monitor coal production in the region according to a systematic, rational management process. The DOI justified its decision to decertify the region by claiming there was no interest in coal mining in the PRB at the time. Immediately after announcing the decertification, however, the BLM was flooded with applications for new coal leases. Although the BLM continues to deny that the PRB is a coal production region, the country's largest remaining coal reserve produces 47 percent of the coal used to generate electricity.

Recently, Congressman Edward Markey, the ranking Democrat of the House Committee on Natural Resources, requested a GAO review of the federal coal leasing program. Concerned about rising levels of exports, the flawed fair market valuation process, and the fact that the program hasn't been evaluated in 30 years, Markey made the request in order to provide Congress with the most up to date and relevant information and analysis on the topic. The BLM, which has built a wall of resistance to oversight, was hostile to the request.

Loss of Revenue

The U.S. Treasury lost $100 million as a result of the 1982 lease sales. As this report demonstrates, an analysis of all of the lease sales and royalty payments since that time shows that the U. S. Treasury lost out on an additional $28.9 billion, adjusted to 2011 dollars. (To determine this figure, the author applied the adjustment used by the GAO in 1983 audit to calculate the actual fair market value for each lease sale since 1982. After determining the difference between the BLM's fair market value and the accurate value, the author then calculated the sum of all bonus payments and royalties.) As this analysis demonstrates, reduced competition and an appraisal process skewed toward low coal prices result in this revenue loss.

The current lease program allows coal producers to set the terms for the mining, distribution and pricing of coal. Theoretically, the bid process should stimulate competition among coal producers and this competition should then drive up prices to a market level. Competition is meant to both augment the valuation and serve as an independent check on BLM's coal appraisals. But without

competition, the appraisal process is inherently flawed. Since 1991, the BLM has issued 26 coal leases; of these, only four have had more than one bidder. (And these leases had only two bidders each.) It is well known among industry officials, that the BLM's common practice is to allow lease applicants to designate coal tracts in a manner that inhibits competition. Thus, competition between coal producers in the PRB is virtually nonexistent.

The U.S. Treasury also loses revenue because the fair market value appraisal process itself is largely skewed in favor of lower coal prices. More than simply selling coal inappropriately, the 1982 sales essentially flooded the market with low cost coal, and that has had ramifications to this day for U.S. coal markets. The response by the stock market and coal analysts to recent lease awards reveals that the BLM is still selling coal below market value. The sale price of a lease awarded in 2011 to Cloud Peak Energy, a PRB coal producer, was so much lower than expected that the stock market—instantly recognizing the bargain—revalued the company and raised Cloud Peak's stock price that same day. When two additional auctions were held six weeks later, despite flaws in those processes, coal of lower quality than that in the Cloud Peak sale was sold for the highest price in the history of the program. BLM's recent acceptance of Peabody Energy's bid on the South Porcupine lease led one industry review of the proceeding to declare "looks like a bargain" when compared with other recent sales.

Ignoring Larger Market Forces

The skewed appraisal process is revealed most clearly by the limited explanation given by the BLM in its Records of Decision (RODs), the agency's formal justification for a lease transaction. These justifications fail to address the fundamental market challenges facing the BLM and the nation regarding the current and future use, as well as the price of coal. Today, market dynamics—such as the depletion of Central Appalachian coal reserves and low natural gas prices, which are edging out coal—are placing upward pressure on long-term PRB coal prices. In addition, the BLM fails to consider recent studies that call into question current coal reserves estimates. A recent report by the US Geological Survey raises questions about the long-term accessibility of affordable coal in the PRB. However, the BLM does not recognize any of these significant market forces in its RODs.

Perhaps the most alarming aspect of the BLM's flawed appraisal process in the current market is the Bureau's silence on the topic of coal exports. Although producers will continue to mine coal for U.S. domestic electricity generation, the most significant revenue generators (and the source of future share value) for these companies are export sales. Today every coal producer in the PRB region has announced expanded export scenarios. To improve their bottom line—particularly given the uncertainty of U.S. coal markets—coal producers are investing in port activity across the United States to increase export potential and improve revenues and profits. One recent study places the export potential of U.S. coal producers at 500 million tons per year, half of the nation's typical annual production. As more U.S. coal is exported, it is likely that upward pressure on coal prices will also raise the price of electricity generated by coal. When it conducts its leasing activity, BLM is neither accounting for these trends nor facilitating discussion regarding the implications of selling one of the nation's last remaining coal reserves to foreign markets.

Recommendations

The Powder River Basin is undergoing a rapid and profound transformation, one likely to come at a significant cost to both U.S. taxpayers and ratepayers. The concerns associated with the BLM's federal coal leasing program—lack of oversight and accountability, loss of revenue, failure to

consider changing market dynamics—warrant robust oversight. To address these issues, the author calls for the following, immediate actions:

1. **The Department of the Interior should implement an immediate moratorium on the sale of federal coal leases in the Powder River Basin.**

   The current lease program is purportedly designed to provide coal supplies for U.S. electricity generation at a fair market value. The DOI's real rationale for the sale of below market value PRB coal was to provide *cheap* coal for *cheap* electricity. Although the demand driver for expanded coal production was once domestic electricity generation, this is no longer the case. While the region will continue to provide coal to meet domestic energy needs, over the long-term, as PRB coal becomes more expensive, the primary revenue driver for coal producers will be export sales. Today, the demand for new PRB lease applications and coal reserves is driven by coal producers responding to international supply and demand price signals in global markets, not to meet the need of the nation for electricity. This is modern day coal producer speculation, a practice that has been a concern of both Congress and presidents going back to Theodore Roosevelt. An immediate moratorium is necessary because the actions of these coal producers have clear implications for the U.S. economy and its environment, as well as the electricity grid and political system. In the history of the coal lease program, policy makers have implemented moratoriums when far fewer challenges faced the program.

2. **The Department of Interior should re-instate the PRB as a Coal Production Region.**

   The BLM's Records of Decision (ROD) reflect the fact that the BLM is only paying attention to low-level microeconomic issues when selling coal. This fundamental failure reflects the inadequacy of an agency with neither a publicly accountable, regularized system of monitoring and analyzing coal markets nor the information necessary to grapple with the globalization of PRB coal. There are no publicly available documents or studies that reflect the multiplicity of issues that face the agency in this time of dramatic change. The claim, for example, in the RODs that use of coal for domestic electricity protects national security when coal producers will actually export increasing amounts of coal to Asia borders on the Kafkaesque. Redesignating the PRB and other areas as coal production regions will assist the BLM address these broader economic issues.

3. **Congress must conduct a fundamental review of the federal coal leasing program, beginning with an evaluation of the use of U.S. coal assets.**

   Eighty percent of the coal in the PRB belongs to the U.S. government, granting the federal government an effective monopoly on western coal. The effective monopoly has ramifications for coal production throughout the country. Given that this resource is a public asset, coupled with the fact that there are significant economic, environmental, and foreign policy dimensions to this issue, a thorough review of the program is warranted. The failure of Congress to publicly address the coal leasing issue, despite rising production and revenue growth is a significant lapse that is only now being recognized. Critical to the debate are the following questions: What, for the foreseeable future, will be the primary use of PRB coal? Who will be its primary beneficiaries? What are the future prospects for coal use in America?

In addition to these primary recommendations, the author also suggests the following:

The General Accounting Office should conduct an audit, or series of audits, of the Bureau of Land Management's federal coal leasing program. From the early 1970's through 1983 the GAO produced over 20 policy driven audits of the coal lease program. The BLM's federal coal leasing program has not been the subject of an independent review in nearly 30 years. Although the GAO reviewed the program in 1983, it has never conducted an audit of the program since issuing its original report (a 1994 audit of a specific lease problem provided some additional insights but was not an on-point audit of the full program). Recently, as a result of changing market conditions, Representative Edward Markey requested an audit of the program in order to provide Congress with up-to-date analysis and information. The BLM responded in a hostile manner. The fair market value lease program—which is shrouded in secrecy on the grounds of protecting the federal government and third party interests—warrants investigation.

The Department of Interior's Office of the Inspector General should conduct oversight activities regarding the Bureau of Land Management's interactions with coal producers. During the 1982 scandal, a federal investigation discovered that DOI staff leaked confidential pricing information to coal industry representatives. In the wake of the scandal, both the Linowes Commission and the GAO Office acknowledged the need for more oversight of the BLM's dealings with the industry to avoid potential conflicts of interest.

An independent entity should evaluate the Bureau of Land Management's coal leasing program, with specific attention paid to fair market valuation. Throughout the past 30 years, there has been a lack of public oversight of the federal coal leasing program. The lack of oversight, accountability, and transparency continues today. The BLM policy requires public inspection and external review to ensure program integrity, particularly those aspects of the process that are protected by the BLM's confidentiality claims. However, the external review process has not occurred. Given the scandal that ensued after the 1982 lease sales—and the promise of reform that never materialized—it is readily apparent that a new entity, independent of the current oversight bodies, must be created in order to provide adequate oversight. This organization, which could be patterned on the Independent Private Sector Inspector General, could provide an external review of the program and ensure public inspection. The entity, which should remain in existence for at least 10 years, should regularly report to the president, Congress, and the public.

Conclusion

The BLM's process for valuing and selling federal coal in the Powder River Basin in essence created a de facto energy policy for the nation. The significant volume of coal that flooded the market after the 1982 sales, coupled with thirty years of anti-competitive program practices, drove the price of coal down for more than two decades, making coal artificially cheap. As this report shows, a continued failure to correct the BLM's flawed process and lax oversight exposes both federal and state governments to a significant loss of revenue.

In today's rapidly changing environment, the business consensus that produced BLM's practice of selling coal below its fair market value is unraveling. Coal producers, now faced with a changing market, a host of potential regulatory conditions, and far more lucrative opportunities in the export arena, will be raising the price of PRB coal, and the nation's coal in general, to support their own

needs. The long-term price outlook for PRB coal is upward and volatile. The long-term supply outlook for PRB coal is aggressive and global, not domestic.

The BLM is poorly prepared to handle these issues. The coal industry, which has a track record of limited transparency, has enjoyed a long history as a protected political class. Unfortunately, BLM has adopted this same culture of insularity. Given future mining projections—12 billion tons by 2035—it is time for Congress to reevaluate the program. The last public discussion regarding the agency's mission and program was nearly 30 years ago. The stakes are much higher now.

PART I: INTRODUCTION

The Powder River Basin is the largest coal-producing region in the country and contains one of the most significant coal deposits in the world. The size of the nation's federal coal holdings—approximately one-third of the country's total reserves—has effectively granted the U.S government monopoly control of the coal industry in the West. Today, those holdings have ramifications for the supply and price of coal throughout the United States. The debate regarding how the government should manage these coal resources—and particularly how they should be valued—has challenged numerous American presidents, policy makers, and public land managers since the 1800s. Today, the Bureau of Land Management (BLM) of the Department of the Interior (DOI) is charged with managing these public lands for the benefit of future generations, while simultaneously ensuring that the nation's coal is sold at fair market value.

According to federal law, the BLM cannot accept less than fair market value for the sale of a federal coal lease.[1] Fair market value is defined as the amount of cash, or terms reasonably equivalent to cash, for which a willing knowledgeable seller can sell property to a knowledgeable purchaser who is willing, but not obligated, to buy. Prior to a sale the BLM prepares an estimate of the fair market value of the coal lease in accordance with standard appraisal methods. This fair market appraisal, or the estimated value of the coal, essentially acts as the BLM's benchmark price—a guidepost against which bids are measured to ensure the agency complies with federal law. As agency officials, land managers, and elected officials have discovered, this appraisal process is complex, inherently flawed, and ultimately based on subjective judgments.

Congress and policy makers have struggled to design a robust program and accurately appraise these coal-rich, public lands at fair market value. Since the turn of the 20th century, three separate leasing moratoriums have been adopted. Given the significance of the fair market value assessment—and its role as a policy tool that enables the U.S. government to act as a price leader and set the price direction of PRB coal—these moratoriums provided policy makers with timely and important opportunities to evaluate the program. Despite substantial review and attempts at reform, the U.S. government has historically failed in its fiduciary responsibilities, more often than not selling its coal at below market value.

Since the controversial 1982 lease sale of 1.6 billion tons of PRB coal, and the adoption of reforms in the immediate wake of the scandal no government entity has conducted public oversight of the program. In fact, actions by the BLM—most notably the 1990 decision to decertify the PRB as a coal production region—have only exacerbated the problem. As a result of decertification, the agency quietly streamlined the lease sale process and turned over additional control to industry. Since 1982, production in the region has soared. A review of the record reveals that the U.S. Treasury has lost roughly $28.9 billion in revenue. As a result of today's rapidly changing global coal markets—particularly the draw of lucrative export opportunities—coal producers expect to mine an addition 12 billion tons by 2035. Given the historical record, it's likely that the U.S. taxpayer will continue to lose.

About the Report

The federal coal leasing program's historic, fundamental problems are exacerbated in today's marketplace. The inherently flawed fair market value appraisal process, coupled with decertification and the region's increasing rates of production, encouraged this analysis of BLM's program. The purpose of this study is threefold: (1) to use publicly available evidence to assess whether BLM has historically met the fair market value standard for the lease sale of federal coal; (2) to shine a light on the government's lack of oversight and accountability; and (3) to assess how the nation's coal supply, its markets, and the government are responding to the current challenge.

Organized in four parts, this analysis:

- Describes the historical context and examines the controversial PRB lease of 1982 as a case study (Part I);

- Examines the policy of decertification, the BLM's current methodology of fair market valuation, and estimates the loss of revenue to the U.S. Treasury from the flawed process (Part II);

- Examines the changing nature of coal markets and coal producers in the region to demonstrate that the BLM is failing to take important major market dynamics into consideration (Part III); and finally

- Presents both immediate and more long-term policy changes to address the problem (Part IV).

Based solely on information that is available in the public record, this analysis is intended to spark a much needed and long-overdue conversation about the BLM's federal coal leasing program.

Historical Background

A historical look at the federal coal leasing program reveals a program fraught with controversy. Since the early 1900s, policy makers have struggled to design a robust and fair process to value and sell the nation's coal resources, while promoting environmental stewardship and protecting the social and economic concerns of local communities. These issues, coupled with concerns about speculation and the control of the industry by a few large interests, have dominated the debate since the program's inception. All of these issues were brought most clearly into the public consciousness in the 1980s, with the controversial sale of 1.6 billion tons of Powder River Basin coal.

Since the 1970s, when the DOI addressed these concerns it ultimately imposed three separate moratoriums in order to adopt new reforms. Contrary to current industry opinion, these necessary and timely moratoriums provided both policy makers and agency officials with an opportunity to review and reform the program. Given modern-day concerns related to the program, a review of the historical record is relevant for policy makers today. Although DOI continues to grapple with the same policy issues it faced 30 years ago, today's rapidly changing and increasingly complex markets make the task much more difficult.

Early Management

During the late 19th century, Congress passed a series of laws to address the management of federal coal resources. Reflecting the growing concern that federal lands with significant amounts of coal were much more valuable than lands without, the 1864 Pacific Railroad Act allowed lands with coal to be sold at a higher price. This law eventually gave way to the 1873 Coal Lands Act, which established a minimum price for lands with coal relative to the distance from a railroad, as most of the coal during this period was used by railroads to power steam locomotives. Often these laws proved problematic, as the lines between lands with coal and those without were not easily defined. As a result, these land laws were often ignored and the government typically did not receive the full value for lands with coal. [2]

The abuses of the Coal Lands Act eventually came to light under the Theodore Roosevelt Administration. Concerns regarding the management of this public asset led Roosevelt to withdraw 66 million acres of federal coal lands from the program to prevent their sale to the private sector, enacting the first moratorium. The influence of the conservationist movement, whose principles Roosevelt championed, was readily apparent at this time. Roosevelt argued, "The nation should retain its full title to its fuel resources, and its right to supervise their development in the interest of the public as a whole."[3] Although Roosevelt proposed a federal coal leasing system during his administration, a stalemate ultimately ensued and the Coal Lands Act governed federal coal sales until 1920.

The 1920 Mineral Leasing Act

The enactment of the Mineral Leasing Act (MLA) in 1920 broke the policy stalemate and created a leasing system for federal coal, oil and gas.[4] The Act prevented the government from mining coal outright and provided for the federal government to contract with private coal producers for the extraction and sale of coal from federal lands. In essence, the MLA gave the DOI the authority to control almost every aspect of the development of federal coal. Control of this process—along with the fact that the government owned almost all of the coal in the PRB—effectively gave the federal

government monopoly control of the emerging coal industry in the West.[5] By 1920, the basic financial relationship between the government and coal producers was established.

Beginning in the 1960s, interest in western federal coal increased sharply until a significant amount of coal was under lease by the decade's end. Despite the large amount of acreage leased, very little coal was actually mined as companies often held leases for speculative reasons.[6] In addition to these concerns, the program's critics also charged that far too much coal was leased during this period for much lower prices than the government should have received.[7] By 1971, DOI had become concerned about a variety of factors relating to the federal coal leasing program, including the importance of federal coal in the West, the large amounts under lease, and the fact that top DOI officials had paid little attention to the program during the period of rapid expansion in the 1960s. As concerns regarding the program's management reached a critical point, the DOI informally suspended coal leasing, implementing the nation's second leasing moratorium in May 1971.[8] Two years later, then-Interior Secretary Rogers Morton announced that BLM[9] would undertake the responsibility of developing a new federal coal-leasing program.[10]

New Federal Coal Leasing Programs

During this period, a major social transformation was occurring across the country with the birth of the modern-day environmental movement and the emergence of a "no growth" movement concerned with increasing development pressures.[11] According to these critics, federal coal production threatened the West—which contained the country's few remaining pristine and sparsely populated areas. Against this backdrop, the coal industry projected a strong demand for western coal to meet the growing need for electricity and argued for large-scale coal mining.

The problems faced by the lease program were eventually outlined in a report to Congress in 1975.[12] The study documented a list of program and policy concerns, many of which remain relevant today. The most critical issues addressed included:

- the definition, enforcement, and practical application of provisions related to coal producer speculation (i.e., gaining and holding lease rights without plans for or actual mining taking place);
- the domination of coal mining by a few large owners;
- the inability of the federal government to receive fair value from the coal lease sales (given that at the time, competition was limited and royalty rates had not been adjusted to keep pace with economic changes.);
- the failure of the DOI to take its role of environmental protection seriously;
- the inadequate attention paid to social and economic impacts of new mining activity on host states and local communities; and
- the lack of an independent source of information, regarding aspects of coal production, for Congress. (an especially urgent issue, given plans for intensified mining in the Powder River Basin.)

To address these issues, Congress passed the Federal Coal Leasing Amendments Act (FCLAA) in 1976. FCLAA required a fair return to the public for federal coal resources and imposed diligent development requirements - meaning that the development or production of a coal tract must occur within a certain period after the lease sale. This requirement was created to address concerns driven by the history of coal producer speculation and market manipulation. Specifically, the legislation: established a 12.5 percent royalty payment rate;[13] increased a state's share of bonus,

royalty and rent revenues from 37.5 to 50 percent; and directed the government to ensure the maximum economic recovery of its leased coal.[14] The act also required diligent development within ten years and emphasized competitive bidding and a fair market value process. [15]

That same year, Congress also enacted the Federal Land Policy and Management Act (FLPMA), which specifically assigned BLM oversight in the management of federal coal resources. The act also required that BLM provide an opportunity for public participation and conduct adequate land use planning, and also reinforced the Bureau's obligations under the National Environmental Policy Act (NEPA) of 1969.[16] In 1979, DOI made further changes to the leasing program and created the Federal Coal Management Program (FCMP), which introduced the concept of 12 federal coal production regions and established two types of advisory boards, the Federal-State Advisory Board and the Regional Coal Teams (RCT). The new management program was first implemented in the Powder River Basin with the regional lease sale held in 1982.

The 1982 Powder River Basin Lease Sale

As Congress, public land managers, and policy experts debated the leasing program's controversial details, the 1971 moratorium remained in effect. Although it was intended to last only a few years, the moratorium lasted for more than a decade, before it was lifted in January 1981 as one of the last official acts of the Carter administration.[17] In April 1982, DOI offered several tracts totaling 1.6 billion tons of coal— one-twelfth of the country's total reserves at the time—for sale in Montana and Wyoming.[18] Surrounded by criticism of leaked information and botched policies, the decision to lease the tracts under new program rules proved controversial and the handling of the lease transaction devolved into a scandal.[19]

In the months prior to the sale, the Minerals Management Service (MMS), an agency within the DOI responsible for determining the value of the tracts had conducted a fair market appraisal of the leases. The agency then sent these values to BLM offices in Montana and Wyoming for review.[20] In the following weeks, several significant problems emerged. At some point before the April sale, DOI staff leaked pricing information from the appraisals to coal industry representatives. Although DOI was made aware of the leak, the agency did not issue a report.

At a meeting in Washington a few weeks later, agency officials made an abrupt and seemingly arbitrary policy decision to change the bid process. The agency reduced the amount it was willing to accept at auction for the coal tract to a level below the fair market value established in the internal appraisal.[21] Concerned that the appraisal prices were too high and that the leases might be priced out of the market, agency officials reduced the value of the tracts by roughly 50 percent.[22] By reducing the bid prices, the DOI guaranteed the agency would receive less revenue as a result of the sale.

During the sale, which proceeded despite these issues, bids came in at or slightly above the reduced levels. DOI then awarded these leases based on the new values, and PRB coal was mined based on these terms and conditions. In essence, the BLM rewrote the rules of the new program and effectively ignored the appraisals, thus setting a pattern for future coal pricing. The reduced bid had the effect of setting what the coal producers perceived as the market price that the government would accept for the coal at a level far below that of the fair market value in the agency appraisal.

Implications & Investigations

The decision to proceed with the sale of the new coal tracts quickly proved controversial. Concerns arose that the leases were sold for less than fair market value. The minimally acceptable bid price effectively granted a "gift" to the coal producers and a loss of revenue for the U. S. Treasury. Rumors circulated regarding the leak by the DOI officials of critical price information leaked to coal industry representatives and regarding the DOI's decision to lower the bid prices. Expert opinion, which was already conflicted on the need for the sale, only intensified after the integrity of the process was called into question. These issues—which were exacerbated by the sheer size of the sale—directly sparked a series of investigative reports.

Following the controversial 1982 sale, members of Congress called for an investigation into the leasing program. In April 1983, the House Appropriations Committee concluded that the DOI sold federal PRB leases for $60 million less than fair market value.[23] In May 1983, the U.S. General Accounting Office (GAO)[24] concluded that the leases were sold for $100 million less than fair market value. And ultimately, a congressional commission, which was led by David Linowes and charged with taking a broader look at leasing policy,[25] concurred with earlier reports and suggested significant reforms and presented policy recommendations to correct the abuses.[26] (Later that year Congress imposed its third moratorium, pending the completion of the work of the Linowes Commission.[27]) The Office of the Inspector General also conducted an investigation into the ethical lapses of agency personnel. The GAO and the Linowes Commission reports, which stand out as authoritative studies, remain relevant today.

General Accounting Office Analysis

At the request of Representative Edward Markey and Senator Max Baucus, the GAO evaluated the controversial issues surrounding the 1982 sales of the PRB coal leases. Specifically, the GAO was asked to: (1) examine allegations of unauthorized disclosure of data by DOI employees; (2) examine why the DOI abruptly changed policies regarding the bidding system; and (3) to determine whether or not the public received fair market value for its coal.[28]

The GAO determined DOI's actions were inappropriate.[29] The audit also found significant flaws in the fair market value appraisals. Based on its own revised estimates of the fair market value of the 1982 leases, the GAO concluded that the coal tracts BLM sold for $67 million should have sold for $167 million.[30] The GAO also noted that many of the coal tracts only had one bidder, meaning there was a lack of competition among companies. More competition could have driven up the price of the coal and offset the distortions created by the BLM's artificially low coal prices. More competition would have generated more revenue for the government. Because BLM sold U.S. coal for *249 percent below fair market value*, the U.S. Treasury lost $100 million on the transaction.

Given the concerns regarding the DOI's valuation of tracts, as well as the policies and procedures regarding bidding, the GAO found that the Secretary of the Interior "may wish to reconsider Departmental determinations and cancel leases for which fair market value was not received."[31] In its final report to Congress, the GAO recommended that the Secretary of the Interior postpone regional coal sales until DOI strengthened its procedures for determining the fair market value of federal coal.[32] Ultimately, the DOI disagreed and proceeded with the sale.

The 1983 GAO audit represents the most recent, independent review of the fundamental issues of the BLM's coal leasing program – the management of the fair market value process and the revenue

received from coal lease sales. Recognized as a seminal study, the review is known for its in-depth treatment of several topics that are relevant today, including the:

- scope and definition of fair market value;
- responsibility of the Secretary;
- inherent flaws in the appraisal process;
- incentives for coal industry gaming of the system by limiting competition through design of coal tracts;
- questionable interaction of coal industry representatives with DOI and BLM officials;
- extent to which small changes in appraisal formulas have large ramifications for coal bidding and coal markets;
- significant discrepancies between BLM appraisals and actual benchmark prices used to award leases.
- significant discrepancies between BLM price benchmarks and GAO's independent assessment of BLM's fair market value of the coal.[33]

The Linowes Commission

The Linowes Commission on Fair Market Value Policy for Federal Coal Leasing (Linowes Commission) was chartered to study the leasing program and issue recommendations regarding the question, *How can the federal government lease its coal lands to realize fair market value, while also achieving numerous other goals that are often in apparent conflict?* [34] Its mandate was to look at the leasing program more broadly. In formulating the report, the Linowes Commission built on the investigative work of the GAO and gave consideration to testimony, statements, and comments of diverse organizations and individuals.[35] The commission issued a report in February 1984 that contained 36 recommendations for reform covering topics such as federal coal leasing levels, appraisal methods and general organization and management. This report focuses on the commission's review of the 1982 lease sale and its review of appraisal methods.

Assisted by the investigative work conducted previously by oversight entities, the Linowes Commission concluded that the lower bid prices published by the DOI for the 1982 bids acted as the effective "market price" for the coal.[36] In February 1984, the Commission transmitted its findings and recommendations to Congress. Recognizing that uncertainty is inherent in the appraisal process, it recommended that the DOI develop methods and procedures that are "unassailable not only in fact but also in public perception." Emphasizing that a lack of formal guidance precluded external review of appraisal procedures, the Commission also suggested the agency develop guidelines to promote uniform field office appraisals.

The Linowes Commission also viewed competition at the time of sale as a failsafe check against flaws in the appraisal process.[37] Presumably, parties to a competitive sale for a coal tract would arrive at a judgment of market value through their opposing bids, independent of the appraisal

process. If the appraisal produces a bid price that is too low, robust competition among coal producers should result in a higher price, thereby protecting the federal government interest. (This was an assumption of the program at its inception and remains so today.[38]) The inability to establish regular, active competition leaves the BLM reliant on the accuracy of the appraisal as a proxy measure for market activity.[39]

The problems created by the DOI's flawed internal process during the 1982 coal tract sale, including the bid manipulation, could have been mitigated by robust competition at the time of sale. However, the sale of each coal tract drew only limited interest from producers. The lack of competition among coal producers eliminated the last and only, independent, external check on the internal BLM fair market value process. The Linowes Commission and GAO reviews effectively showed the internal checks and balances meant to ensure a fair market value appraisal—committee review, agency counsel review, senior management participation, and post appraisal review—all failed in this case.

Office of the Inspector General

The Inspector General (IG) is responsible for independently and objectively identifying risks and vulnerabilities that directly impact the DOI's ability to accomplish its mission. During the coal leasing scandals of the 1980s, the Inspector General was also asked to investigate the DOI's decision to reduce coal price values by 50 percent for the purposes of the bid price. After a thorough review, the IG discovered that agency personnel: 1) leaked portions of the fair market appraisal data to industry officials prior to the bid solicitation; 2) accepted gifts from those same industry officials; 3) were in a position to influence the outcome of the fair market appraisal and final bid selection; and 4) used their authority to reduce the minimum acceptable bid offered by the agency. Although the IG forwarded his findings to the Department of Justice (DOJ), no action was taken as the DOJ remanded the matter back to the DOI for potential ethics actions.[40]

BLM's Response

The findings of the GAO report, the Linowes Commission, and the Inspector General all point to serious problems regarding a lack of oversight, accountability, and transparency within the agency. As PRB production rates soared, increasing amounts of federal and state revenue was at stake. In response to these reviews, DOI defended its actions, denying it had acted improperly by leasing coal at below fair market value.[41] In fact, the agency stated that the GAO's technical adjustments were incorrect. The BLM asserted that the GAO did not correctly interpret the drop in coal markets between 1980 and 1982. The BLM also stated that had it asked for higher amounts, no producers would have bid on the leases. In the end, the agency rejected GAO's recommendations to cancel the bids.

In an interesting side note, when the agency was again audited (on an unrelated issue), it mentioned the 1982 sales, but this time citing national policy concerns to justify its 1982 actions. BLM asserted it was trying to keep the price of PRB coal low in order to provide low cost electricity to consumers.[42] It went so far as to cite the subsequent decline in coal prices after 1982, claiming that an increase in the supply of low-cost PRB coal ultimately had a positive impact on the country.[43]

Changes to the Program

The Linowes Commission and the GAO reports resulted in some changes to the program in 1985, but the programs basic structure largely remains the same. The basic structure for the federal coal program established under FCLAA was set out in regulations promulgated in 1979 and 1982. Under these rules, coal leasing is supposed to be carried out in three phases: 1) land use planning; 2) regional sale activity planning; and 3) lease sale activities.[44] The post-1982 reforms promoted orderly and predictable leasing for state and local government, as well as industry. It also attempted to promote competition, assure fair market value and require due diligence for coal valuations.[45]

Land Use Planning

Land use planning is intended to ensure that coal leasing passes through four screening phases. The first screen requires the agency to determine the development potential of the area. This analysis includes estimates of the quality and amount of economically recoverable coal reserves. Next, the agency considers whether lands may be unsuitable for mining. Lands deemed unsuitable are dropped from consideration for leasing. Multiple use trade-offs are then assessed to determine whether other important uses may be incompatible with mining. Potential conflicts may lead to further removing areas from consideration for leasing. Finally, the agency consults with surface owners to obtain the necessary consent for mining as required by the Surface Mining Control and Reclamation Act.

Regional Sale Activity Planning

Once planning is completed and a final land use plan (Resource Management Plan) is adopted, regional coal lease activity planning begins. The process is guided by the Regional Coal Team (RCT), a federal-state advisory group chartered under the provisions of the Federal Advisory Committee Act. The RCT reviews the land use plan and a long-range market analysis in an attempt to determine whether to proceed with leasing. If the RCT decides to move forward with leasing, a panel of science advisors and an internal BLM review council are appointed to assist the RCT in tract delineation, site-specific analysis, and environmental impact statement (EIS) preparation. A call for expressions of interest in leasing is also published in the Federal Register. Responses may be used by the RCT in delineating potential coal tracts. The RCT then recommends a regional leasing level to the Secretary of the Interior and identifies, ranks, analyzes, and selects tracts for study in the regional coal lease sale EIS. A regional lease sale decision is then published in the Federal Register.

Lease Sale Activity

Finally, the lease sale is scheduled. Public comment is solicited on fair market value and appropriate mining methods to achieve the maximum economic recovery of the coal resource. A regional evaluation team then prepares its own estimate of the value of each lease tract. Following a three-day period of public notice, the lease sale is offered by means of sealed bids. A post-sale analysis of the bids is then made recommending acceptance of the highest bid for each tract. Only high bids that meet or exceed fair market value may be accepted.

Exceptions for Leases Outside Production Regions

There are no exceptions to the phase one land use planning, and phase three lease sale activity requirements. Regional sale activity planning (phase two), however need not be carried out in two situations. First, emergency leasing is allowed within designated federal coal production regions. Such leases are issued following an application and are used when coal is needed to maintain production levels in the near term. Second, regional sale activity planning is not required for leases "outside production regions". The authority of BLM to lease outside coal zones was established in 1982. The "lease by application" process, now the almost exclusive leasing method used by BLM, was originally intended to be an exception to normal practice.[46] The term "coal production region" is not defined, but the federal government informally took the view that an area is not a coal production region unless substantial interest in new leasing exists.[47] Nonetheless, the Powder River RCT has decided that the Powder River Basin, one of the largest coal production regions in the world, is not a coal production region. There are currently no designated coal production regions in the country.

What this means as a practical matter is that rather than having the BLM take the initiative on coal leasing by first deciding whether there is sufficient demand for coal, and then designing tracts to maximize competition, the BLM defers to industry, allowing it to decide whether it wants more coal. Not surprisingly, the industry has designed tracts in ways that allow individual applicants to avoid competition and to demand leasing based on considerations of company share value and strategic positioning in the market. The process that emerged from the program history, scandal and various investigations also created the modern day operational protocols for the fair market value part of the lease process.

Disclosure and Oversight Issues

The Linowes Commission and the GAO made recommendations regarding how the BLM and the DOI should address ongoing disclosure and oversight issues. The program's stance on balancing conflicts between the U.S. government's legitimate confidentiality concerns and routine program oversight is expressed in the BLMs operating handbook. In essence, the program protected government and industry confidentiality during the bid process, but committed to a system of post-sale external review. The post-sale external reviews presumably completes the process as it ensures: 1) the soundness of the fair market value appraisal; and 2) that BLM officials follow policies and protocols before, during and after the sale to ensure fair market value is received. The handbook, an element of the program reforms, was written in the wake of the 1982 scandal.

In the end, the most lasting impact of the 1982 lease scandal, Linowes Commission, activity by Congress and subsequent debate was not a commitment to fair market standards. Those standards of fair return were always part of the government's program and simply reaffirmed. Rather, it was the recommendation to create the agency's handbook titled *Economic Valuations of Coal Properties*. This document provides instruction to agency officials on how to conduct fair market valuations. It also provides objective guidelines that external reviewers can use to ensure that program reforms have been carried out, and to demonstrate that the BLM is responding regularly to the inherent challenges of the valuation process. While the assessment of the Linowes Commission is still mentioned by the agency, the handbook purportedly governs the coal lease programs' operational determinations regarding individual coal tracts.[48]

PART II: A HISTORY OF LAX OVERSIGHT: 1983 TO THE PRESENT

Given the documented concerns about the federal coal leasing program, it's logical to assume that the BLM would work diligently to increase the program's transparency. One might also expect a robust program of evaluation to ensure that the fair market standard is complied with. However, the lack of any meaningful oversight of the program in the last 30 years demonstrates that there is no publicly available, independent evidence that the BLM leases coal according to fair market value standards. This section examines several critical areas of program monitoring and oversight.

Decertification of Coal Production Regions in 1990

In 1979, DOI created the Federal Coal Management Program (FCMP), which first introduced the concept of the 12 federal coal production regions, or regions of the country where mining occurs. The program also established two types of advisory committees, including the Federal-State Advisory Board and the Regional Coal Teams (RCTs). The program required the BLM staff to engage in a deliberate and coordinated series of actions designed to identify coal tracts and set production levels. (See the discussion in the *Changes to the Program* section) BLM was also required to consider stakeholder input, drawing from a broad cross-section of data, prior to placing a tract up for bid.[49] For the most part these regulations were never implemented[50] and by 1990, BLM's regional coal teams had successfully lobbied to disband, or decertify, all 12 coal production regions.

The process of decertification essentially stopped regional lease sales, but allowed the lease by application (LBA) process to continue. The LBA process, which is invoked by an application *outside of a coal-production region*, requires an applicant to submit a proposal for review by the RCTs. If the proposal is approved, the BLM then begins an environmental impact assessment for the tract.[51] By eliminating the PRB's status as a coal production region, decertification ultimately streamlined the leasing process, reduced competition, and allowed the applicant (typically a private coal company) to design lease boundaries.[52] In short, the decertification of the Powder River Basin gave coal companies nearly complete control of coal mining in the region.

Although the BLM claimed that the regions were decertified because there was limited interest in mining at the time, in fact the opposite was true. As the GAO noted in its 1994 audit of a specific complaint on a lease, "Within four months of the Powder River Basin region decertification, industry filed four applications for about 800 million tons of recoverable coal to maintain existing mines in the region."[53] In the months and years following decertification, interest in coal leasing skyrocketed. In 1983, the PRB coal region produced 151 million tons of coal; by 1993, production had jumped to 275 million tons annually; and by 2010, the PRB region was producing 470 million tons of coal. Since 1990, the BLM reports that 21 tracts, totaling nearly 6 billion tons, have been offered for sale under the LBA process in Wyoming.[54]

Understanding the significant impact of decertification, and its adverse impact on public lands, local communities, and other environmental issues, several organizations have worked to reinstitute the designation. As a result of increasing leasing and mining activity since decertification, WildEarth

Guardians petitioned the BLM to reinstate the PRB as a coal production region in 2009. After BLM denied the petition, WildEarth Guardians, the Sierra Club, and Defenders of the Wildlife challenged the agency, arguing that both current and anticipated levels of coal production and leasing activity met the test of an active coal region. The organizations also asserted that the agency's current leasing process, which was implemented as a direct result of decertification, "prevents the BLM from fully analyzing and addressing the environmental impacts—in particular, the global warming impacts—of coal leasing."[55] The suit called for the recertification of the PRB and requested more intensive environmental analysis regarding the issue of climate change. The BLM and the coal industry aggressively contested this suit, which a federal court in Wyoming recently dismissed without reaching the merits.

The BLM's rejection of the coal production regions—despite the industry's continuing applications for additional reserves — has several policy implications that remain relevant today. First, the BLM's actions reaffirm its commitment to coal producers over and above its commitment to the sound management of a public resource. With only minimal supervision, producers are allowed to determine the need, scope, location and pace of mining. The practical workings of the program contradict the intention of Congress to promote the sound management of these public lands. Second, the BLM has effectively rejected an ongoing monitoring and information resource that could improve both its FMV appraisals and its stewardship of the coal resources under its jurisdiction. Third, the BLM eliminated a potentially useful internal check of the FMV process. The coal production region designation process discussed above would provide an important feedback loop within the agency for the FMV process and the information and market trend information that provide the inputs for the appraisals.

Given the historic tensions between the agency, the public, and the coal industry, decertification moves the BLM in the wrong direction and ultimately reduces the transparency of an agency whose actions are already suspect.

Current Oversight

The BLM's federal coal leasing program generates significant revenue for the U.S. Since 2000, total annual revenues from the coal leasing program, including all bonus payments, rents and royalties, (See section below *Collecting Revenue)* increased from $377 million to more than $1 billion.[56] Although the financial and economic importance of the program warrants robust oversight, very little evaluation has occurred. In the last two decades, the decertification of the PRB has only exacerbated the problem. Intensifying the problem is BLM's refusal to provide the public with documentation regarding how it determines fair market value for the purposes of awarding leases. Despite these critical factors—revenue generation, PRB production increases and the lack of information—the GAO, the Office of the Inspector General, and even Congress—which has not commissioned any studies of the coal lease program since the mid-1980s—have failed in their oversight obligations.

Office of the Inspector General

Although the IG has performed a number of important audits regarding the management of abandoned mines[57] and land boundaries,[58] the office has not published any significant reviews of the coal leasing program or related functions of coal leasing since at least 2000.

CONGRESS

Congress has not issued a policy study related to the fair market value aspect of the coal lease program since the 1980s. As part of its annual budget justification to Congress, the BLM provides reports regarding certain performance indicators related to the coal leasing program. These reports, which have been reduced to annual budget justifications, contain misleading and incomplete information regarding coal markets and program operations. For example, the budget justifications inform Congress that program activity (coal leasing) will be limited in the upcoming years due to a weak market. Yet during the same fiscal year when activity was supposed to be limited, the Secretary of the Interior announced a major expansion including 2.4 billion tons of new reserves under lease by coal producers involving over 20,000 acres.[59] In short, these justifications are perfunctory at best.

GOVERNMENT ACCOUNTABILITY OFFICE

Between 1972 and 1994 the GAO issued 22 reports, audits, and testimonies on several aspects of the DOI's coal leasing program (See *Appendix C*).[60] Those reports covered fair market value appraisals and needs assessments for leasing and implementation. GAO also examined royalty assessment and collection policies, coal pricing, the decertification of regions and several other issues of interest to Congress and the general public. In 1979, GAO conducted a thorough analysis of the program and provided decision-makers with a forward-looking view of the program. After it published its seminal audit in the wake of the 1982 scandal, GAO neither conducted a follow-up audit nor review of BLM compliance with the new standards outlined in the handbook.[61] Failing in its obligation to provide the public and decision-makers with timely information, the GAO has been silent regarding the efficacy of the federal coal leasing program since 1994.

A review of its current documents, including its five-year, strategic plan, makes evident that the GAO does not plan to return to the issue, and its silence is likely to continue. This is particularly striking given for the following reasons:

1. **The BLM recognizes the importance of external review.** In its handbook, the BLM recognizes that external review, which is normally conducted as an independent; third party appraisal is an integral part of the fair market value appraisal process. The process is based on subjective judgments and takes into account inherently challenging market changes.[62] The external review is a necessary post-audit check on a secret bidding process (as determined by Congress and the agency) that is supported by the appraisal process. More than a mere technicality, the review is essential and affirms the integrity of each and every lease transaction and the integrity of the organizational culture in which the processes were implemented. The last evaluation of BLM indicated flawed appraisal assumptions, conflicted staff, and questionable manipulation of the pre- and post-bid process. In the absence of any meaningful review in the last 30 years, the DOI is subject to the critique that it has never completed a lease transaction according to its own protocols.

2. **The Powder River Basin has increased in national importance as a fuel source for the U.S. electrical grid since 1982.** The region currently provides 47 percent of the coal used for electricity in the United States. (For additional detail on these significant market changes related to coal, see Part III. These geological, economic, regional and global factors are potential game-changers for the PRB.) In the past—when the PRB played almost no role in electricity generation for the nation—any *one* of these factors would have prompted an

outpouring of congressional and think tank resources and public discourse. Yet today given the national importance of the PRB, coupled with the fact that *all* of these forces are affecting market dynamics, it is worrisome that these changes have not prompted a national discussion. Although the GAO explicitly states that it is concerned with commodity price volatility in energy markets, general problems related to economic efficiency, and auditing more traditional areas of waste fraud and abuse, this is not evident in the case of the coal lease program.[63]

3. **The PRB is a coal production region.** Despite the BLM's consistent legal position that the PRB is not a coal production region, as defined in law and regulation, the agency continues to lease ever-increasing amounts of coal reserves primarily using the inappropriate lease by application (LBA) process. The BLM's agreement with western coal producers to place new coal reserves under lease has increased from a steady stream in 1991 to a cascade in 2011. As the next section of this report demonstrates, the agency continues to lease coal below fair market value. Absent any independent review, the red-flag warnings—originally raised in 1982—continue to exist.

Recently, Representative Edward Markey (D-Massachusetts), the ranking member of the House Natural Resources Committee, formally requested a GAO report examining federal coal leasing practices.[64] Concerned with the expansion of coal exports, the need for an up-to-date review of fair market value appraisal processes, and the length of time that had elapsed since the last review, Markey asked the GAO to specifically address the implications of rising coal exports on declining domestic demand. The BLM's response to Congressman Markey's request was negative. According to the *Platts Coal Trader*, the leading industry trade paper, the agency found the request "odd."[65] It remains unclear whether the GAO will undertake this report.

Withholding Information

The reforms instituted after the 1982 scandal attempted to balance the legitimate confidentiality needs of the government with the public's right to know how its assets are managed. Changes to the program implemented throughout the 1980s stipulated that the agency would not publish bid prices, but would keep the information confidential. Ultimately, this required that the agency and its staff—in private—arrive at market valuations fairly. At the time, a process of post-transaction audit or review of these lease awards was deemed necessary to ensure constant accountability.

According to the BLM's handbook, one way of obtaining openness and post-transaction accountability is to publicly release the documents that the BLM uses to set the fair market valuation. The BLM policy specifically states that after "bid acceptance and/or rejection decisions have been reached by the authorized officer, the fair market value appraisals and estimates can be released to the public upon request on those tracts where the high bid has been accepted."[66] As the author discovered, meaningful data are not made available to the public regarding the fair market leasing aspects of the BLM's coal leasing program. Although the policy manual creates the perception that this information is publicly available, in practice the BLM denies requests for information.

In order to evaluate both past and current leasing activity, a number of environmental organizations—some which are active litigants on matters involving the agency—have made formal

requests to BLM, requesting the specific pre- and post-sale appraisal reports identified above. In the last year, environmental organizations working in the region filed two separate Freedom of Information Act (FOIA) requests. The first FOIA, filed by the Powder River Basin Resource Council, requested information pertaining to recently granted (2011) West Antelope II North and South leases. The second FOIA, filed by WildEarth Guardians, requested information regarding 10 existing leases awarded under various program scenarios by the BLM since 1991.)

The BLM responded. It did not release the core documents that explained how it arrived at its fair market value determination. According to the BLM this non-disclosure: protects the trade secrets of third parties, who would be harmed if the information was released; protects agency staff, who should be afforded the comfort of expressing opinions during the deliberative process; and protects the government both from those who would litigate against it and from the release of information that would allow gaming of the system.[67] The failure of the BLM to publically release this information to the groups requesting it ultimately demonstrates that the purpose of the handbook—and the ethic of disclosure it once embraced—is no longer the operational policy of BLM.

The 1982 scandal brought about pronounced reforms. However, once the spotlight of the scandal dimmed, the promised oversight—external review and public inspection—never occurred. The purpose of this study is not only to determine whether the fair market value standard is being met, but also to assess how the nation's coal supply, its markets, and government are responding to current challenges. The remaining sections of this report address the implications of selling federal coal below fair market values.

The Current Fair Market Valuation Process

According to federal law, the BLM cannot accept less than fair market value for the sale of a federal coal lease.[68] The BLM has interpreted and operationalized its statutory mandate to receive fair market value for coal mined under leases that it issues to private coal producers.[69] Prior to a lease sale, the BLM prepares an estimate of the fair market value of the coal lease. The estimate, which is prepared in accordance with standard appraisal methods, is strictly confidential.

The term fair market value is defined as the amount of cash, or terms reasonably equivalent to cash, for which a willing, knowledgeable seller can sell property to a knowledgeable purchaser who is willing, but not obligated, to buy. Specifically, fair market value is determined by reference and exposure to a competitive market to which the property must be exposed for a reasonable time. The market value is only that value transferable from owner to owner. [70] To determine the value, the BLM produces a formal valuation for a tract that has been identified by a coal producer in an application. The fair market appraisal, which is supposed to provide the agency with a reasonable estimate of the value of the coal, acts as the BLM's benchmark price. It is a guidepost against which bids are measured to document the agency's compliance with federal law.[71] (For a more detailed look at how the BLM calculates fair market value, see the sidebar, *Determining Fair Market Value*.)

As a practical matter, under the current lease by application procedures, coal producers initiate the leasing process by identifying minable coal tracts. BLM employees responding to an application then gather data, prepare valuation documents, and arrange dates for bidding. A coal producer is then able to offer a bid, via submitting an application, on a specific tract. Theoretically, the applicant competes with other coal producers who may have an interest in developing the same tract. The

BLM then accepts the highest bid submitted at a competitive lease sale that meets or exceeds its estimate of fair market value.[72] The data is then stored and used as documentation for future coal tract sales. This process is codified in BLM's handbook, entitled *Economic Valuations of Coal Properties*, which was created in the mid-1980s.

Determining Fair Market Value

Many of the components of the current program design flow from the detailed analysis made by the Linowes Commission. Recognizing that appraisals are only as good as the quality of the data used in their preparation, and that judgments on valuations are subjective, the Commission asserted that strict program guidelines must be implemented to ensure standards of integrity and instill public confidence in the process. According to the BLM's handbook,[73] the FMV of a coal tract, that has been proposed for development by a coal producer, can be derived either by using a comparable sales approach or by employing an income approach.[74]

Comparable Sales Approach

The comparable sales approach, which is the method that the BLM prefers, allows the value of recent sales to be accepted as the new market value for a similarly situated coal tract. This approach is grounded in real world, market-based transactions. If a prior buyer and seller agree to a price on a similar property within a reasonably similar timeframe, the presumption is that the government's acceptance of that price is reasonable as a measure of fair market value. Although coal tracts may vary to some degree, they must retain sufficient degrees of similarity in order to permit the BLM to use the comparable sales approach.

The BLM's method allows for adjustments based on a variety of factors, including but not limited to location, stripping ratios, coal quality, and seam thickness. Regulatory rules and coal price changes, which are larger market drivers, may cause adjustments to comparable properties. A discount factor, which is calculated based upon the BLM personnel's judgments, is then applied to these adjustments. The result is a presentation of the price of coal on a discounted, per ton value basis.

The discounted per ton value is a snap-shot of the future price of coal over the projected 20 year life of the mine expressed in today's dollars. The per-ton calculation is then multiplied by the total tonnage derived from the mining plan, and each property is assigned a comparable sales value. The comparable sales are then weighed and reconciled, and BLM decides upon a single value for the proposed site as the accepted FMV. The FMV derived under the comparable sale approach is expressed as both a per-ton value and a total value for the lease. (**Reference sidebar)**

Income Approach

The income approach to determining FMV applies BLM's general methodology and creates a financial model for the specific tract under consideration. The agency has ultimately deemed this approach less desirable, as it requires more judgment and heightens the risk of speculation and bias in the actual appraisal outcome.[75] In this method, the estimated annual revenues are subtracted from the estimated annual expenses. A discount rate, which approximates rates of return, is factored in and adjustments are made for inflation, taxes and uncertainty scenarios. The amount is divided by the total tonnage from the mine plan. The net amount, expressed on a per ton basis, represents the net amount available for the purposes of the lease. In effect, this amount can be viewed as a rent payment. (**Reference sidebar)**

SIDEBAR

FMV Property # 1 = Original Sales Price/Per Ton +/- (NPV Adjustments)
FMV Property # 2 = Original Sales Price/Per Ton +/- (NPV Adjustments)
FMV Property # 3 = Original Sales Price/Per Ton +/- (NPV Adjustments)
FMV BLM Coal Tract = Weighted Adjusted Average (Comparable Sale # 1, 2,3)

Source: TR Rose & Associates

FMV= (NPV estimated revenues-NPV estimated expenses)/total tonnage

Source: TR Rose & Associates

SIDEBAR END

COLLECTING REVENUE

As the owner of the coal asset, the U.S. government collects a bonus or lease payment, a 12.5 percent royalty payment on revenues from actual tonnage, and a $3 per acres rent payment.[76] The bonus and royalty sources of revenue are explained below.

Bonus Payment

Under the current program, the market value, which is derived from either the comparable sales or income based methods, is not disclosed to prospective bidders. After the BLM establishes a sale date, the applicant – and any other interested parties (assuming there are any) -- are then asked to submit bids, which they believe meet or exceed BLM's fair market value estimate. The winning bidder must then make arrangements to pay for the lease. The lease payments are usually paid to the federal government in increments. The proceeds from this sale are split evenly between the federal government and the state in which the coal is mined.

The appraisal process outlined in the BLM handbook attempts to capture market changes, either by monitoring adjustments to comparable sales or through the dynamics of accurate data collection and forecasting in the income approach.[77] In theory, if markets are strong, revenue generated by the sale of the coal will significantly exceed mining costs. Therefore, a stronger market and higher coal price should be captured in a higher fair market value calculation and ultimately a higher bonus payment. If BLM's process is robust, the FMV should capture a rising price environment.

Similarly, conditions intrinsic to the tract that might increase or decrease the costs of production adjust its value in the FMV appraisal process. The combination and weighing of the factors ultimately sets the final valuation. The bonus payment is established as a function of the FMV. If the FMV appraisal sets it too low, the government foregoes revenue, effectively bolstering coal producer profitability.

Royalty Payments

The government collects a per ton royalty payment on the revenues generated by the sale of the amount of coal mined. This payment enables the government to capture additional revenue as production occurs and to share price risk as markets fluctuate. In short, coal producers are provided with an incentive to find higher prices. Coal companies must balance competing corporate financial objectives—increasing operating margins and improving market share—which often conflict. As a result, these companies must make short and long-term trade-offs. (For a more detailed discussion of this is issue as applied to the model used for this study, see *Appendix A*.)

Role of Price of Coal in Fair Market Valuations

To support the revenue assumptions expressed by the coal producer, the BLM's handbook states that a market study of coal prices must accompany any appraisal. However, the handbook fails to provide staff with specific standards and practices regarding how the market assessment should be conducted. It also fails to include guidance regarding the type and quality of data used to form the basis of the coal price analysis.[78] The handbook does provide at least broad discretion regarding the type and quality of information that agency officials use to help inform the judgments they make that are related to the values supplied in the discounted cash flow analysis. It also sets forth standards for staff who conduct fair market appraisals. Data and method must be given due consideration. In the end, the fair market value judgment is just that, a judgment.

The coal price assumptions used in any appraisal have a significant impact on the ultimate value assigned to the specific coal tract.[79] If the coal price used is too low, the U.S. government gives away the coal for below market value, and the U.S. government loses revenue. There is a loss of revenue to the U.S. government like that identified by Congress, the GAO and the Linowes Commission in the 1982 coal tract transactions. Market distortions introduced, can also be introduced like those acknowledged by BLM in the 1994 GAO audit. If the coal price assumption is too high, coal producers must decide whether to bid on the coal tract or to wait.

Loss in Revenue

In the wake of the 1982 scandal, the government reformed its federal coal leasing program. The lease program now relies upon a system of confidential appraisals and public bidding to establish its purported compliance with the fair market standard. Although the appraisal process—which is governed by federal statute, regulation, and the internal BLM handbook—outlines vigorous standards, there is no publicly available evidence that the BLM has followed these standards. There is evidence that the coal is leased at levels below the fair market value. The net result? A loss of revenue in the range of **$27.6 to $28.9 billion** for the federal government and its partner states since 1983.

TECHNICAL BASIS AND RATIONALE FOR CALCULATION

The agency's rejection of Freedom of Information Act (FOIA) requests creates methodological challenges for a quantitative analysis of the loss in revenue from the BLM's practices. As a result, this report's statements and conclusions are based on the information available in the public record and augmented by information provided by such entities as the Energy Information Agency (EIA). The basic assumption used in this study is that BLM has and continues to repeat the same undervaluing of coal that was demonstrated by the GAO in its 1983 audit. There is simply no evidence to the contrary on the public record.

Why apply the adjustment used by the GAO in its 1983 audit? The GAO represents the only publicly available, relevant independent check on the FMV program in the last 30 years. The GAO found that BLM awarded leases of 1.6 billion tons of coal for $67 million in 1982 that were actually worth $167 million. This amounts to a 249 percent discrepancy between the BLM's sale price of these leases and the fair market value derived by the GAO in its investigative analysis of these leases.[80] Following the 1983 audit, BLM acknowledged that the subsequent decline in coal prices from 1983 to 1994 had a desirable impact on regional economies. In addition, the coal industry frequently points out how low cost coal from the PRB is dramatically more cost effective than all other fuels. Coal from the PRB has a competitive economic advantage.

The Wyoming Mining Association (WMA) has published an estimate that the nation enjoys a total annual savings of $285 billion from reliance on PRB coal versus the next lowest cost energy source, natural gas. As a method of estimating the overall value of PRB coal, the WMA calculation assumes electricity prices would rise by $118 billion annually if natural gas were substituted for PRB coal. The WMA model uses the alternative market measure of power prices established by natural gas to gauge the current value of PRB coal.[81] While the WMA conducted the study prior to the decline in natural gas prices, the significant competitive advantage of PRB coal with other fuel sources has been the critical reason why it has gained such a large percentage of market share in the last 30 years. Even in the current environment when natural gas prices are low, and every other coal-burning region in the country is stressed by competition from natural gas, PRB's low price keeps it relatively competitive.

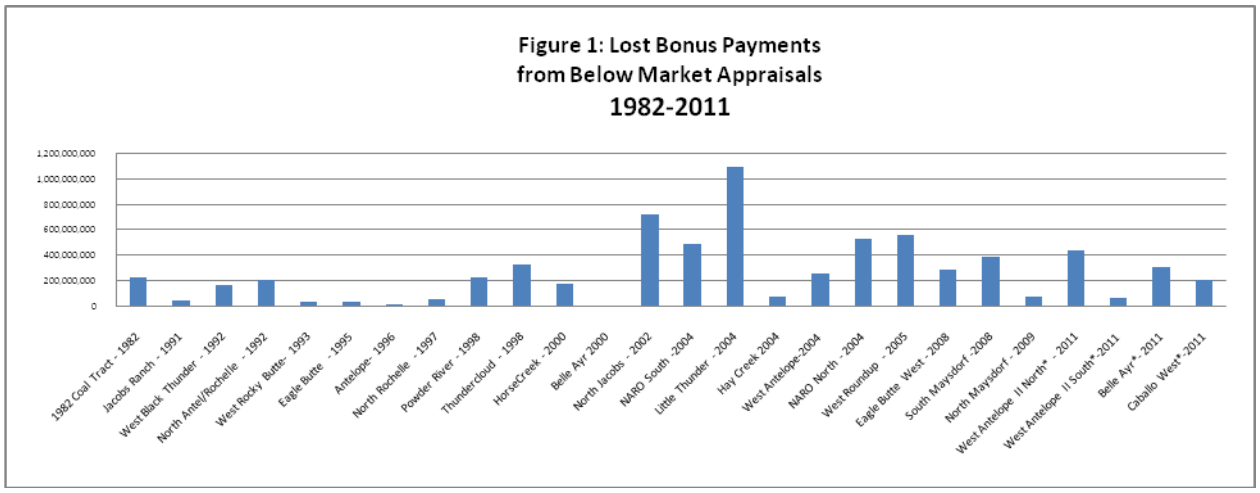
PRB coal is also more competitive vis-à-vis other types of coal in the United States. Peabody Energy, the nation's largest coal producer, has projected the market headroom value of PRB coal at $29 to $36 per ton from 2011-2014.[82] Unlike the WMA analysis and the comparison with natural gas, the Peabody presentation is comparing the "parity price" of PRB coal against alternative coals produced in other regions. Peabody's presentation to investors seeks to quantify "unlocked" value that the company sees in its PRB coal reserves. The company projects far greater value in the PRB mines than is currently recognized by traditional, corporate asset valuation models or presumably the fair market value modeling used by BLM. This positions the company to attract investors, if not buyers. The alternative fair market value for PRB coal arrived at by the model used in this paper for 2010 is $33 per ton, very similar to that of Peabody. Whether one considers the undervaluing of the coal in 1982, the coal industry view of substantial competitive advantages of PRB coal versus other fuels; Peabody Energy's pitch to investors that the coal has strong upside potential; the persistent lack of competition in bidding or the recent mishandling of lease valuations in 2011 (see below), PRB coal is undervalued by BLM, and has been for decades.

To calculate the loss in revenue to the government since 1982, the adjustment made by the GAO has been applied to all approved lease sales since that year. The calculations below represent the amount that DOI would have collected had it applied at least the same FMV methods applied by the GAO, adjusted to 2011 dollars. *(For a more in-depth look at the assumptions behind the model, see Appendix A.)*

Bonus Payment Loss

To estimate the approximate loss in bonus payment revenue, the author reviewed available data for BLM leases awarded between 1982 and 2011. The lease sales price was then adjusted upward based on the percentage difference (between actual payments received and adjusted fair market value from the 1982 sale) that the GAO established in its 1983 audit. The new fair market value was then subtracted from the actual cash payment made for each lease since 1982. The difference

constitutes the amount of bonus payment lost by the BLM's failure to charge a fair market value. The loss in bonus payment revenue for each sale, which is illustrated by *Figure 1*, has been adjusted to 2011 dollars. Cumulatively, the loss of actual cash from bonus payments between 1982 and 2011 totals $7.1 billion.



Source: TR Rose & Associates

Royalty Value Losses

As with the calculation for the loss in bonus payment revenue, the same loss percentage that the GAO established in its 1983 audit is used to establish a new market price for subbituminous coal for every year since 1982.[83] This market value price, which serves as a market proxy, is multiplied by the total annual production of subbituminous coal to establish the fair market value for annual production. This value is then subtracted from the actual production and price values in the EIA database to find the difference between the actual value of the sale price and the total value of the coal had it been sold at a fair market price. This total dollar figure is then multiplied by 12.5 percent, the rate at which royalty payments are assessed according to the lease agreements between the BLM and coal producers.

As *Figure 2* demonstrates, for the period between 1983 and 2009, the total foregone value in royalty payments alone, adjusted to 2011 dollars, is in the range of $20.5 to $21.8 billion.[84] This range represents an estimation of the foregone value in royalty payments since 1982, adjusted to 2011 dollars.

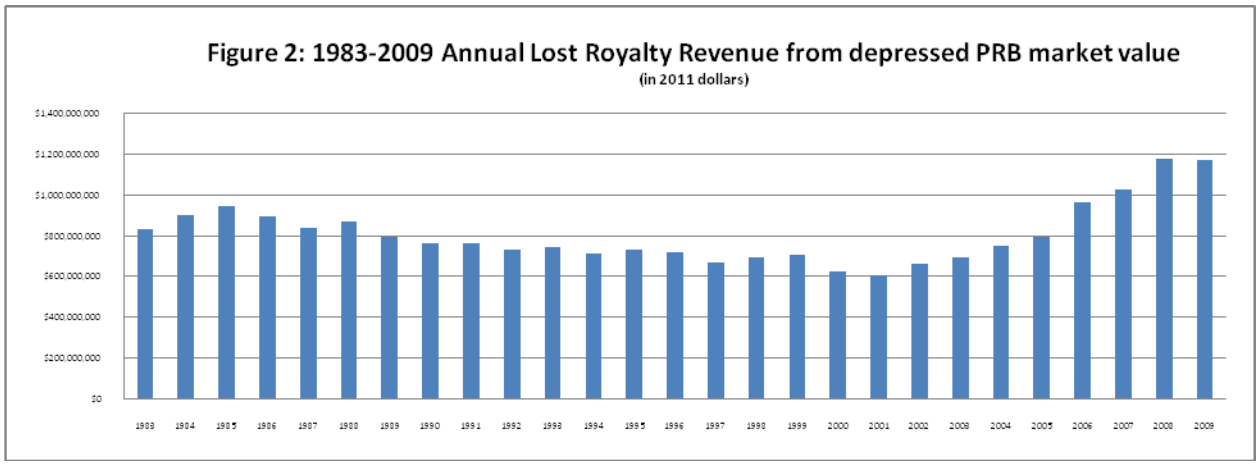
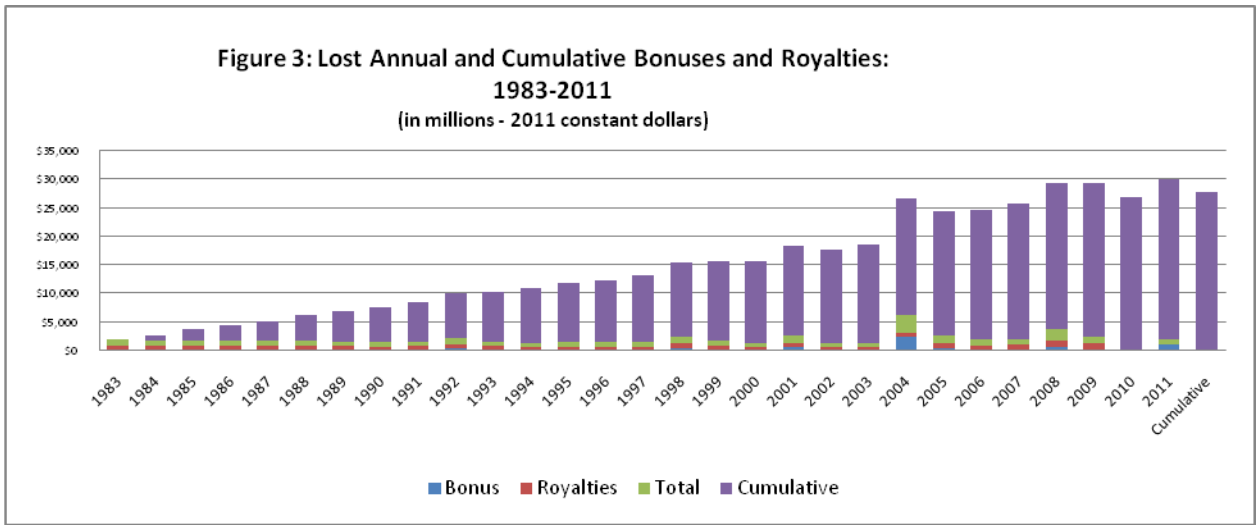


Figure 2. Source: TR Rose & Associates

In summary, the author finds:

- The loss of actual cash from bonus payments of **$7.1 billion** represents the estimated amount DOI would have collected had it applied at least the same FMV methods to all approved leases since 1982 that the GAO used that year in its original fair market value calculations. The GAO audit represents the only publicly available, relevant independent check on the FMV program in the last 30 years;

- The estimated royalty losses equal an approximation of the revenue that would have been collected if coal producers had charged a "market price" for PRB coal since 1982. The range of values from $**20.5 billion to $21.8 billion** represents 12.5 percent (the royalty tax) of the difference between the aggregate of all revenues from all coal sales from 1983 through 2009 set at a "market price" minus the aggregate of all revenues from all sales for the same period that are actually reported in EIA's database,



Source: TR Rose & Associates

Taken together, the author estimates that federal and state governments lost between **$27.6 and $28.9 billion**[85] **i**n cash and value from the below market valuations—and subsequent market imbalances—created by BLM's administration of the fair market value portion of the coal lease program. The losses can be categorized into two areas: *$7.1 billion in lost bonus payments* and between *$20.5 and $21.8 billion in lost royalties*, the cash equivalent of lost revenues from coal producers.

PART III: CHANGING MARKET DYNAMICS

Ignoring Larger Market Forces

Today**, the** BLM actively grants both new leases and extensions on existing leases on PRB coal tracts. Between now and 2035, EIA projects 12 billion tons of coal will be mined. In March 2011, Interior Secretary Ken Salazar announced a series of coal lease sales and Records of Decisions (RODs) on pending lease applications. When finalized, these transactions will lease 2.36 billion tons of coal reserves.

Against this increase in PRB leasing activity, a major transformation in coal markets is occurring. The four most significant demand pressures causing this shift are: increasing international demand for the export of PRB coal; cost of production pressures; the loss of Central Appalachian reserves; and declining natural gas prices. These factors drive coal producer investment strategy and current coal market analyses.

As the following section illustrates, BLM is failing to consider these critical larger market forces in its appraisal process, despite the acknowledgement of their importance by the four main coal producers in the region—Peabody Energy, Arch Coal, Cloud Peak, and Alpha Natural Resources (See Table A). Although each company has a distinct corporate strategy and roles in the industry, their holdings in the PRB follow very similar story lines. Each company has low to modest margins with heightened concerns for cost of production pressures; has projects in the works to derive revenue from PRB export sales; and has increased their coal reserves in the PRB in the last year. The previous section detailed the loss of revenue to date for coal leases. Looking forward, the U.S. stands to lose even more revenue if the BLM continues to ignore larger market forces.

PUT THIS IN A SIDEBAR

Table A: Selected Financial Data of Powder River Basin Producers
(all dollar values in billions except stock prices)[86]

Financial Metric	Peabody Energy	Arch Coal	Alpha Natural Resources	Cloud Peak Energy
Total Market Capitalization	9.07	2.65	3.87	1.08
2011 Annual Revenue	7.97	2.85	6.9	1.55
2011 EBITDA	2.13	1.04	1.26	.35
52 Week Price Range of Stock	$29.78-$73.95	$11.25-$36.99	$15.49-$61.66	$15.91-$24.34

Source: TR Rose & Associates

Peabody Energy, Arch Coal and Alpha Natural Resources are the three largest coal producers in the nation. Cloud Peak Energy is the only company that mines coal exclusively in the Powder River Basin (Cloud Peak is often referred to as a "pure play" because its production is exclusive to the PRB). Peabody represents the largest coal producer in the United States with a market capitalization of $9.0 billion (Peabody owns mines outside the United States). This is large for the coal industry, but relatively small compared to other energy industry leaders (e.g. Exxon Mobil's market capitalization is $357 billion). The four producers generate just over $14 billion in revenue from all mines in their collective portfolios. Each of the companies is producing relatively strong returns. Alpha Natural Resources is particularly challenged, given its recent acquisition of Massey Energy, a Central Appalachian mining concern with historically high cost mining issues. Arch Coal is also challenged given its high exposure to thermal coal and recent acquisitions. Stock prices have been volatile and declining over the past year, reflecting broad, global uncertainty, a soft domestic market and company-specific challenges.

SIDEBAR END

EXPORTS

The coal producers of the PRB have embraced a market view of expansion during worldwide uncertainty and uneven economic growth. In the broadest sense, global opportunities are expanding while U.S. coal domestic markets are shrinking and unstable. Changes in production and concerns about environmental risk have altered the future use of coal in the United States. Coal industry analysts project a worldwide growth in demand of 4 billion tons of coal from 2008-2035, with demand heavily concentrated in China, India and the Pacific Rim.[87] One analyst, discussing the risks and opportunities, succinctly summarizes the industry's view on exports: "There is an industry consensus that it is now more profitable to export increasing levels of coal. The export strategy is the industry's method for managing their interests."[88]

Coal Producer Export Activity

As a result, coal producers with holdings in the PRB are seeking to increase their investments in the region, despite a general drop in U.S. demand for coal-fired power plants.[89] Although export sales from the PRB are currently quite small,[90] a growing international market has created incentives for coal producers to adopt aggressive export scenarios.[91] Coal producers are increasing exports from the PRB,[92] announcing new deals,[93] exploring new markets,[94] and investing in new rail and shipping capacity.[95] Those scenarios support the proposition that selling PRB coal in international markets will provide higher per-ton revenue yields. Currently, each of the four major coal producers have export strategies related to their coal portfolios in the PRB:

- **Peabody Energy** is the world's largest private sector coal producer. One-third of its total reserves are in the Powder River Basin, and the region is one part of Peabody's strategic global network of coal reserves and trading relations. The company has announced deals with Asian partners for export of PRB coal and briefed Wall Street coal analysts on enhanced revenue benefits and share value of PRB exports. In addition, Peabody has consistently advised investors of its activities in the PRB export area and announced its participation in the proposed Bellingham/Cherry Point terminal expansion in Washington state to export PRB coal;

- **Arch Coal** is the second largest producer of PRB coal. In 2011, Arch Coal opened its first overseas office in Singapore.[96] Throughout 2010 and 2011, the company stepped up export activity and provided revenue projections on future deals,[97] informed investors of its export activities, announced rail transport and nationwide terminal investments[98] and secured new mine reserves for export purposes in the region;[99]

- **Alpha Natural Resources'** recent merger with Massey Energy consolidated the company's position as a leader in the nation's coal industry. Its export efforts are currently focused largely on its metallurgical and thermal eastern coal reserves. Alpha controls more terminal space in the Gulf and East coast than any other coal producer. Although the company is supportive of West Coast terminal efforts, it has not publically taken a financial position regarding any of the port proposals to date.[100]

- **Cloud Peak Energy** is the only pure play PRB producer of the major corporations in the region. During 2011 the company announced an agreement for terminal expansion[101] and continued to support other similar projects.[102] Cloud Peak's annual revenue and share value already benefit from PRB exports. In 2011 the company exported 4.7 million tons or 4.8 percent of its production. These exports accounted for 18.5 percent—or $287 million— of the company's $1.55 billion total revenue; and[103]

Ultimately, these factors all contribute to a long-term rising price environment for Powder River Basin coal, as markets shift and coal production undergoes a major transformation. The continued pressure by coal producers for more federal coal leases, even in the face of historically low current prices, strongly attests to the industry's bullishness in the long-term health of the region. Despite this rising price environment, there is uncertainty and increasing volatility. Although they will continue to supply the shrinking—but still significant, demand for domestic electricity generation—coal producers are mitigating this uncertainty with a greater reliance on exports.

For the nation as a whole, and very specifically for the Powder River Basin, the move to exports reflects efforts by coal producers and financial interests to globalize production, distribution, and pricing of PRB coal. The result: volatile and upward pressure on long-term prices for the traditional consumer of domestic coal, the U.S. electricity industry and the American public.

Cost of Production Pressures

The BLM also fails to consider recent government studies that raise questions about the rising cost of production of the region's coal reserves. Reserves are relevant to market forces in the sense that the factors described in this paper place additional pressure on PRB production. A 2008 study by the United States Geological Survey (USGS) raised concerns about the diminished size of the PRB's economically recoverable coal reserves.[104] The USGS surveyed the mines and coal beds in the Gillette Field—which is responsible for 37 percent of the nation's coal supply—and calculated the available coal resources, the amount of recoverable coal, and then the coal reserves.[105] (Coal reserves, a subset of coal resources, can be defined as the portion of recoverable coal that can be mined, processed, and marketed at a profit at the time of the economic evaluation.) The report concludes that the Gillette reserves have significantly less recoverable coal at affordable prices than

previously thought. Given the sheer size of the field, the USGS report has significant repercussions for the coal industry.

In June 2009, the *Wall Street Journal* surveyed the opinion of industry leaders and the EIA regarding the USGS findings. The EIA's response conceded the fundamental accuracy of the report findings, "The Energy Information Administration, part of the Department of Energy, says it is reassessing its coal tally in light of the new USGS data. It intends to create a new coal baseline from which it will begin its annual subtraction as soon as [it] can."[106] Fundamentally, the EIA's decision to create a new baseline recognized the need to more carefully monitor this valuable resource. In light of evidence that the current accounting method is unreliable, the administration's challenge is even more urgent. A representative from Peabody Energy also affirmed the accuracy of the USGS' findings, stating that the entity, "made a leap forward with this study." The industry spokesperson added that the company has reached similar conclusions to the USGS.

The issues raised by the USGS report, and the EIA's acknowledgement of the problem, are fundamental. Yet there are no references to the USGS study in any formal BLM documents related to coal lease transactions. By effectively ignoring the USGS red-flag warning, BLM reaffirms that the judgment of coal producers based on the mine plans submitted in applications will be the underlying basis for its coal lease awards. BLM has failed to disclose a coherent public management opinion on the USGS study as it relates to agency's decisions on: assessing potential impacts on future coal quality, mine location, price, cost of production or any of the other critical factors the study raised. Instead of taking into account critical larger market forces, the BLM tends to use outdated information and poor market analysis that do not reflect conditions in current or future coal markets.

By ignoring basic market realities, the BLM adopts assumptions that maintain a skewed view of potential scenarios and likely outcomes. The USGS study, as well as the EIA's response, also supports the thesis that coal prices in the PRB will rise. The BLM's consistent disregard of market factors understates the demand pressures on the PRB market. These understatements enable the BLM to repeat its historic practice of low valuations. *Table B* shows that coal producers with holdings in the PRB are seeking to increase their investments in the region. In 2011, Peabody, Alpha and Cloud Peak all successfully secured new leases under the BLM lease program. Recently, Arch Coal secured additional tonnage under state-leased coal reserves in Montana.

Table B: Coal Reserves of Powder River Basin Producers

Company	Total Reserve Tons (in billions)[107]	Powder River Basin Tons (in billions)	2011 Pending Applications [108]
Peabody Energy[109]	9.2	3.1	3
Arch Coal[110]	5.5	3.26	3
Alpha Natural Resources[111]	5.0	.65[112]	1
Cloud Peak Energy[113]	1.4	1.4	1

Source: TR Rose & Associates

Loss of Central Appalachian Coal

Recoverable reserves in Central Appalachia are almost depleted. The fundamental reason for the depletion is geological, as the area has been the most intensively mined region in the United States for decades. Although the remaining reserves still possess high energy and low sulfur content, they are in areas more difficult to mine.[114] The complexity and increasing cost of mining Central Appalachian coal has led producers to adopt controversial mining techniques, such as mountaintop removal coal mining. With the adoption of more complex and destructive mining techniques comes increased oversight and regulation. These factors have led to dramatic increases in the costs of coal production.[115] The rising costs of production have made coal less competitive as a source of fuel[116] as most of the major utilities have indicated that they no longer consider Central Appalachian coal an economically viable fuel for their coal-fired plants.[117] As less coal is available from Central Appalachia, more pressure will be placed on the nation's other coal producing regions—including the Powder River Basin—to fill the void.

Declining Price of Natural Gas

Throughout the last two years natural gas prices have declined precipitously and most analysts agree that these prices will stay low for the foreseeable future. The decline in prices has sufficient depth and duration to shift utility spending away from coal and toward natural gas and renewables. The decline of natural gas prices is a significant economic factor that contributes to the retirement of existing coal plants.[118] Low natural gas prices have also led to low power prices and have effectively diminished the ability of Central and Northern Appalachian coal to compete in current power markets. As natural gas prices remain low, regional markets and individual plant performance also indicates the potential for Illinois Basin coal to lose market share. Powder River Basin coal, because of its relatively low price, shows less chance for displacement by natural gas.[119] As domestic coal markets begin to settle out from these changes, the Powder River Basin and Illinois Basin can both expect greater demand pressures from domestic electric generation.

Recent Coal Leasing: Still Below Fair Market Value

The evidence demonstrates that the BLM is ignoring the major forces driving change and their resulting impact on price. In Records of Decisions from 2011 sales, the BLM fails to consider the loss of Central Appalachian coal, increasing levels of coal exports, decline in natural gas prices or the specific impact of these factors on the supply, demand, and price of PRB coal.[120] As demonstrated by high bids from coal producers on the BLM leases in the PRB, as well as these producers' aggressive and increasing interest in the BLM lease activity, the long term prices of coal from the PRB will continue to increase. This is occurring despite currently low domestic coal prices and the prospect of generally diminished use of coal for electric generation in the United States. Long-term price increases specific to the PRB are being driven by the rise in production costs, domestic demand and exports. Coal producer activity anticipates a period of long-term price increases and profitability.

Regional production trends have created intensified mining pressures on PRB coal producers and placed upward pressure on long-term PRB prices. At the time of this writing, PRB short-term coal prices as with all domestic coal are low. Coal producers and BLM are nevertheless pressing forward with their applications for new PRB reserves.[121] Moreover, it is against this backdrop that recent lease issuances by the BLM continue to demonstrate the agency's pattern of providing coal to producers at below fair market value.

The sale of the West Antelope North II tract to Cloud Peak—best demonstrates how BLM is still failing to receive fair market value for federal coal leases in the PRB. In this case the BLM failed to consider changing market dynamics, including most critically the increasing level of exports. Since no detailed, formal independent review is permitted by the BLM, the clear indication used in this study is the market itself. In May 2011, the agency agreed to a lease bid from Cloud Peak Energy. The so-called fair market value level accepted by the BLM was low, *Platts Coal Trader*, commented on the view held in the coal industry that the price was low. Cloud Peak's stock price rose precipitously on the day of the sale reflecting market reaction that the company had received a favorable deal. One stock analyst for UBS raised the company stock rating based on the lease award. Six weeks later BLM received record high bids on two coal tracts that contained lower quality coal than that in the Cloud Peak tract. The message is clear: *four separate, independent market sources familiar with the deals offered information that raise red flag warnings that BLM's fair market value on the Cloud Peak lease was defective.* (For additional detail on these case studies see *Appendix B*).

In another more recent sale BLM awarded a lease to Peabody Energy for the control of the South Porcupine reserve. BLM accepted the company bid of $1.11 per ton. SNL Energy's *Coal Report* stated the following:

> Peabody's South Porcupine bid also looks like a bargain compared to the August 2011 auction in which Alpha Natural Resources, Inc. unit paid $1.10 per ton for the West Caballo reserve, which contains coal of significantly lesser quality than the South Porcupine."[122]

PART IV: IMPLICATIONS FOR THE FUTURE

Findings

An analysis of the BLM's federal coal leasing program presents five critical points of consideration for policy makers, investors, public interest groups, land managers, elected officials, taxpayers and ratepayers.

1. **The U.S. government's possession of a large coal asset in the PRB constitutes a monopoly of supply;**

2. **The government acts as a price leader—an entity with the ability to significantly shape the price direction of western coal;**

3. **Oversight of the federal coal program has been non-existent;**

4. **BLM's appraisal process is inherently flawed, anti-competitive and is failing to take into consideration larger market forces; and**

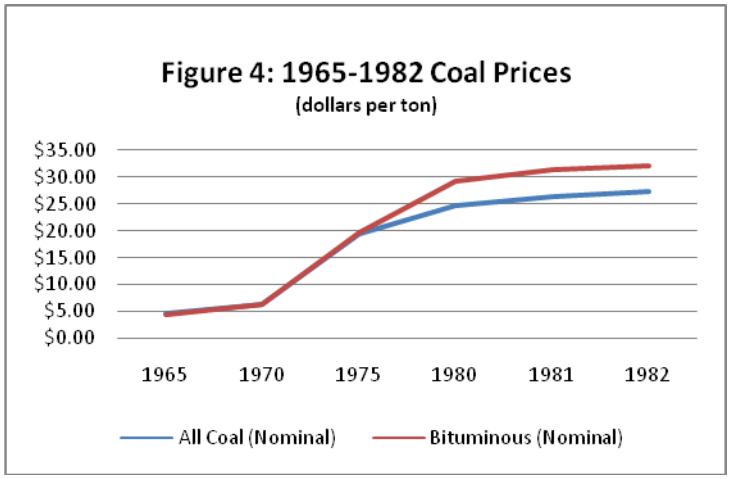
5. **BLM's failure to correct its flawed appraisal process has resulted in the loss of approximately $28 billion in foregone revenue to federal and state governments;**

6. **The BLM's process for selling federal coal has created a de facto national energy policy.**

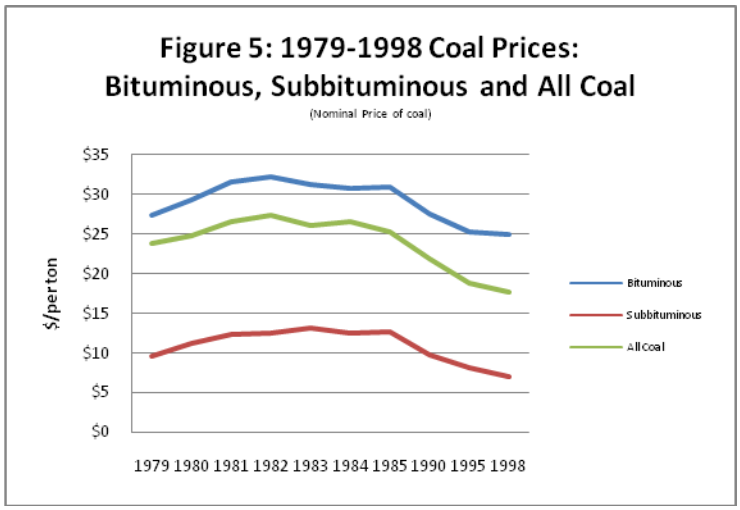
Each of these findings has significant implications for current policies.

First, the U.S. government's possession of a large coal asset in the PRB constitutes a monopoly of supply. The existence of a monopoly means that action taken by the owner will lead and shape—if not dominate—the markets where it holds sway. At the time of the 1982 sale, the federal government owned 80 percent of the federal coal in the Powder River Basin. The remaining 20 percent—which consisted of state and privately owned coal—could only be developed jointly with the federal government as a result of intermingled ownership patterns.[123] In addition, the laws governing federal coal leasing policy (originally adopted in 1920 and then amended in the 1970s) ultimately gave the DOI control of almost every aspect of production. As one leading scholar of federal coal policy writes, "There is not much of a distinction between western coal development and federal coal development. As one goes, so will go the other."[124]

Second, the government acts as a price leader of western coal. As a result of its vast ownership of resources, the government *is* the price leader for western coal, meaning that the government's actions and policies shape the market price for PRB coal. [125] The timing of the 1982 sales (and the significant volume of coal leases) flooded the market with cheap coal and drove prices down for more than two decades. *Figure 4* and *Figure 5* best illustrate these market distortions. *Figure 4*, which shows the price of coal between 1965 and 1982, demonstrates the historic upward trend in the price of coal prior to the 1982 transaction. However, *Figure 5*, which charts the price of coal from 1982 to 1998, demonstrates that a significant shift occurred in 1982, after which nation-wide coal prices declined.



Source: TR Rose & Associates



Source: TR Rose & Associates

Rather than serving as a policy that *reflected* the market, the so-called fair market value standard used by the BLM was more of a policy tool that *led* the market. The inherent power of the DOI over the marketplace was crystallized in a 1979 DOI report: "The government is the price leader for western coal properties due to its vast ownership of unleased, low cost coal. All lease prices will tend to go to the level the Department chooses."[126] BLM's statements in response to the GAO in 1994 that the decline in coal prices occurred (after a decade-long steep rise) because of an increase in the supply of low cost coal, reflects the flooding effect of the 1982 decision on price and market perception.[127] It also represents DOI's comprehension of its role in U.S. coal markets.

Third, oversight is non-existent. In the last 30 years, neither Congress nor any independent entity has conducted an audit, study, or independent review of the program. In addition, there has been no follow-up to any of the evaluations conducted in the wake of the 1982 scandal. The last review of the leasing program was the 1983 GAO audit.

Fourth, BLM's process is flawed and fails to take into account larger market forces. The BLM's process is shrouded in secrecy, as no evidence suggests that federal coal leases sold since 1982 were for fair market value. In addition, the agency fails to take into account larger market dynamics, such as the decline in Central Appalachian coal, the rising level of exports and natural gas prices. These market forces are driving up long-term coal prices in the PRB. However, the agency is not recognizing these factors in any of the Records of Decision related to current lease sales.[128]

Fifth, BLM's process of selling leases for less than fair market value has resulted in a loss of $28.9 billion to federal and state governments. By applying the adjustments to fair market value used by the GAO in 1983, adjusted for 2011 dollars, the author has found that cumulatively more than $7.1 billion in bonus payments and between $20.5 and $21.8 billion in royalty payments has been foregone in federal and state revenue since 1982.

And finally, the sales had a profound impact on the nation's energy policy. The availability of cheap coal from the PRB has not only provided the industry with a price advantage that has allowed much deeper market penetration throughout the years—from 5 percent in 1982 to nearly 48 percent today—but it has also had significant implications for the nation's energy policy. For the past 30

years the U.S. government has effectively selected coal as the primary energy source to power the nation's electric grid. In addition to its market penetration, analysts have concluded that coal's dominance has effectively prevented the development of public-private partnership policies and programs to improve energy diversity in the United States.[129] Others have observed that U.S. energy policy, while offering significant support to the coal industry for decades, has in fact failed to produce sufficient innovation in the field of coal burning technology. As GE's Chief Executive Officer Jeffrey Immelt reflected, coal boilers are a backward looking energy technology. [130]

Recommendations

Between now and 2035, the EIA estimates another 12 billion tons of coal will be produced in the PRB. Coal producer's estimates of production from the region are even higher. In addition, no known oversight activities are planned for the program. Given the findings of this study, three specific top-level recommendations emerge from this report.

In the short-term, it's imperative that:

1. **The Department of the Interior should implement an immediate moratorium on the sale of federal coal leases in the Powder River Basin.**

   The current lease program is purportedly designed to provide coal supplies for U.S. electricity generation at a fair market value. The DOI's real rationale for the sale of below market value PRB coal was to provide *cheap* coal for *cheap* electricity. Although the demand driver for expanded coal production was once domestic electricity generation, this is no longer the case. While the region will continue to provide coal to meet domestic energy needs, over the long-term, as PRB coal becomes more expensive, the primary revenue driver for coal producers will be export sales. Today, the demand for new PRB lease applications and coal reserves is driven by coal producers responding to international supply and demand price signals in global markets, not to meet the needs of the nation for electricity. This is modern day coal producer speculation, a practice that has been a concern of both Congress and presidents going back to Theodore Roosevelt. An immediate moratorium is necessary because the actions of these coal producers have clear implications for the U.S. economy and its environment, as well as the electricity grid and political system. In the history of the coal lease program, policy makers have implemented moratoriums when far fewer challenges faced the program.

2. **The Department of Interior should re-instate the PRB as a Coal Production Region**

   BLM's Records of Decision (RODs) reflect the fact that the BLM is only paying attention to low-level microeconomic issues when selling coal. This fundamental failure reflects the inadequacy of an agency with neither a publicly accountable, regularized system of monitoring and analyzing coal markets nor the information necessary to grapple with the globalization of PRB coal. There are no publicly available documents or studies that reflect the multiplicity of issues that face the agency in this time of dramatic change. The claim, for example, in the RODs that use of coal for domestic electricity protects national security when coal producers will actually export increasing amounts of coal to Asia borders on the Kafkaesque. Redesignating the PRB and other areas as coal production regions will assist the BLM address these broader economic issues.

3. **Congress must conduct a fundamental review of the federal coal leasing program, beginning with an evaluation of the use of U.S. coal assets.**

> Eighty percent of the coal in the PRB belongs to the U.S. government, granting the federal government an effective monopoly on western coal. The effective monopoly has ramifications for coal production throughout the country. Given that this resource is a public asset, coupled with the fact that there are significant economic, environmental, and foreign policy dimensions to this issue, a thorough review of the program is warranted. The failure of Congress to publicly address the coal leasing issue, despite rising production and revenue growth is a significant lapse that is only now recognized. Critical to the debate are the following questions: What, for the foreseeable future, will be the primary use of PRB coal? Who will be its primary beneficiaries? What are the future prospects for coal use in America?

In addition to these primary recommendations, the author also suggests:

The General Accounting Office should conduct an audit of the Bureau of Land Management's federal coal leasing program.

From the early 1970's through 1983 the GAO produced over 20 policy driven audits of the coal lease program. The BLM's federal coal leasing program has not been the subject of an independent review in nearly 30 years. Although the GAO reviewed the program in 1983, it has never conducted an audit of the program since issuing its original report (a 1994 audit of a specific lease problem provided some additional insights but was not an audit of the full program). Recently, as a result of changing market conditions, Representative Edward Markey requested an audit of the program in order to provide Congress with up-to-date analysis and information. The BLM responded in a hostile manner. The fair market value lease program—which is shrouded in secrecy on the grounds of protecting the federal government and third party interests—warrants investigation.

The Office of Inspector General should conduct oversight activities regarding the Bureau of Land Management's interaction with coal producers.

During the 1982 scandal, a federal investigation discovered that DOI staff leaked confidential pricing information to coal industry representatives. In the wake of the scandal, both the Linowes Commission and the GAO Office of Inspector General acknowledged the need for more oversight of BLM's dealings with the industry, recognizing potential conflicts of interest.

An independent entity evaluate the Bureau of Land Management's coal leasing program, with specific attention paid to fair market valuation.

Throughout the past 30 years, there has been a lack of public oversight of the federal coal leasing program. The lack of oversight, accountability, and transparency continues today. BLM policy requires public inspection and external review to ensure program integrity, particularly those aspects of the process that are protected by BLM's confidentiality claims. However, the external review process has not occurred. Given the scandal that ensued after the 1982 lease sales—and the promise of reform that never materialized—it is readily apparent that a new entity, independent of the current oversight bodies, must be created in order to provide adequate oversight. This

organization, which could be patterned on the Independent Private Sector Inspector General, could provide an external review of the program and ensure public inspection. The entity, which should remain in existence for at least 10 years, should regularly report to the president, Congress, and the public.

Conclusion

The Department of the Interior's Bureau of Land Management (BLM) presides over a large publicly owned coal asset. BLM's mission is to manage the asset so that the government receives a market price for the sale of the nation's coal. As this report demonstrates, there is no evidence that the BLM receives a market price for the coal. There is, however, evidence that the government has foregone billions of dollars in revenue.

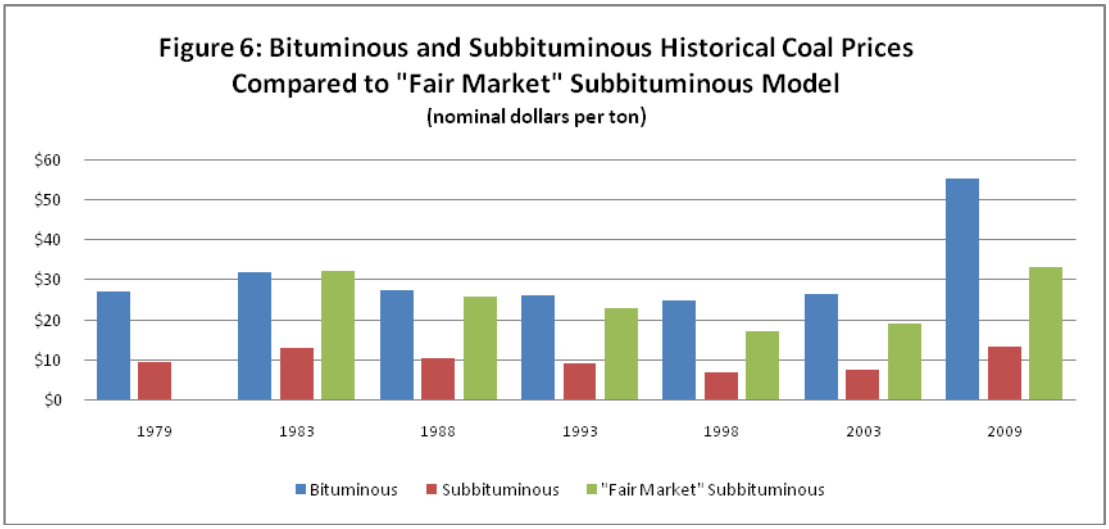
The fundamental reason provided by the agency for its failure to adhere to the market standard—although the agency alternately agrees and denies the facts of the matter—is the need for the government to provide low cost coal. This paper demonstrates that the BLM has kept coal prices artificially low by selling it to coal producers at below market value. In today's rapidly changing environment, the business consensus that produced BLM's practice of selling coal below its fair market value is unraveling. Coal producers, now faced with a changing market, a host of potential regulatory conditions, and far more lucrative opportunities in the export arena, will be raising the price of PRB coal, and the nation's coal in general, to support their own needs. The long-term price outlook for PRB coal is upward and volatile.

The BLM is poorly prepared to handle these issues. The coal industry, which has a track record of limited transparency, has enjoyed a long history as a protected political class. Unfortunately, BLM has adopted this same culture of insularity. The last public discussion on its mission and program was almost 30 years ago. The stakes are much higher now.

APPENDIX A: DISCUSSION OF MODEL

Discussion of Calculation and Implications of Model

The model prepared for this study keeps PRB prices that coal producers would charge to utilities effectively competitive. It achieves this even though PRB prices would rise beyond the historically depressed price levels in the PRB. This model assumes that the price of PRB coal could have been considerably higher over the last 30 years and that it still would have gained market share. In 1983 PRB coal prices were considered high. The EIA and another analysts' forward-looking view at the time projected continued, upward price pressure on coal prices.[131] BLM's original appraisals, in a number of cases, estimated higher coal prices as did the GAO's own final conclusions about lost revenue. The model used in this study shows that adjusted PRB coal prices would have remained competitive with CAPP, ILB and NAPP coal. Coal prices from these other regions have been consistently higher at the mine mouth due to coal quality and the advantage of location. The model assumes, as does BLM in its statements to the GAO regarding the depressive effect of low cost PRB coal on national coal prices, *that BLM is a price leader.* Therefore, setting a higher price for PRB coal would have allowed for greater market headroom for eastern coal as well.



Source: TR Rose & Associates

The model presupposes increases in PRB coal as if BLM's process actually reflected the market rather than directed it. It is logical to argue that the high prices presumed in the model would have been a disincentive to production. Therefore, the amount of coal production would never have increased as rapidly as it did, and so, no royalty revenue was actually lost. Fundamentally, however, this point is irrelevant to the discussion. The U.S. government has sold 9 billion tons of coal since 1982, and the public record shows that the first 1.6 billion tons were sold at an inappropriate price. However, the economic implication of the model needs some discussion. The primary point: the model assumes that ***rising PRB coal prices would not have foreclosed a rise in the use of PRB coal.***

First, the variance in price identified by the industry (and this study) between PRB coal and the general coal market is wide. So is the variance between the cost of electricity produced by PRB coal and electricity produced with other fuels.[132] This wide gap, identified by WMA and Peabody analysts as well, suggests that PRB coal would be competitive and profitable if deployed at higher prices.[133] The U.S. government from the 1970's to the present has promoted coal as a priority.[134]

Second, the coal story has an economic logic that is specific to the coal industry and its interaction with the investment and regulatory needs of the utility sector. Economic theory does not easily explain coal markets. A period of rising coal prices, within limits, could be sustainable in some regions because capital outlays for new and retrofitted coal plants are long term. Markets can change. The price of competitive energy sources might increase more rapidly than coal, public regulatory bodies might be committed to coal and/or transmission logistics might require ongoing operation of coal plants despite disadvantageous pricing. Historically, flat pricing, even declining prices, for coal did not act as a disincentive to coal production.

On the contrary, low prices and modest margins for coal producers served as a tool of market penetration for coal and coal mine expansion. Investor-owned utilities, their regulators and public power agencies engage in a constant process of investment selection for upgrade, expansion and future consideration of energy options. These options are influenced by the price of transportation, fuel, construction costs, financial markets, the regulatory landscape and a host of local, state and national (and increasingly global) issues. The use of very low priced coal to achieve market penetration over the past 30 years was one way to accomplish a dominant position for coal.[135]

The likely outcome of higher PRB prices would have been higher coal prices generally, but not necessarily a curtailment of coal's market share increases. As the 1980s became the 1990s and then 2000s, coal's competitive advantage stayed strong against nuclear, gas and other competitors.[136] The headroom in coal pricing in the PRB created substantial market leeway for coal to continue to gain market share.

It might be argued that PRB coal prices would not rise to the level estimated by this study. Even if the fair market lease prices were systematically increased it would not necessarily have an impact on the market price of coal. BLM refuted this position when it declared to the GAO that its 1982 decision flooded the markets with coal and pushed prices down for the better part of a decade. BLM believes, and this author concurs, a policy choice backed by years of implementation practice consistent with that decision sent the price of coal plummeting. Other policy decisions can be designed to send prices in the opposite direction if desired by a monopoly owner.

In addition, the GAO study showed that significantly higher market coal prices were to be expected in the early 1980's and beyond. BLM's prices in some instances exceeded the coal prices levels used in this study. For example, BLM's original appraisal prices for two tracts were 26 and 39 cents per ton.[137] GAO even estimated one coal tract price at 60 cents per ton.[138]

Furthermore, BLM's claims that coal producers would not bid for higher priced coal, especially in a slowing 1982 market is belied by the fact that one coal producer doubled its bid for the same coal tract between April and October 1982.[139] On another tract BLM originally set the price of coal at less than one tenth of one cent per ton (0.029 cents per ton). Then, due to an oversight it listed ***and sold*** the coal for 2.5 cents per ton. A coal producer paid a price 85 times higher than the amount

that BLM estimated was fair market value.[140] At bottom, the price indicator—coal sold for below fair market value—has an impact over time. GAO makes clear that the use of non-competitive prices as the basis for future FMV determinations is inappropriate.[141] Yet, from the limited information available on the public record this is the practice BLM has followed for decades.

GAO found that when coal tracts are designed to serve one coal company and thereby eliminate competition, the value of the tract increases and so should the revenue to the United States Treasury. The FMV, under conditions of no competition, should not then be calculated as if a market exists, but instead be established based on the value of the tract to the individual company receiving the advantage of this anti-competitive practice. [142]

These facts and this analysis indicate a far more fluid and upward potential for PRB coal prices. The 1982 coal sales decision was the continuation of a long-standing practice of leasing coal for below fair market value. Higher prices over time would not have severely restricted the market penetration of PRB coal. The same interplay of federal monopoly policies, state regulatory decisions and coal industry political power is still at work today. These forces act as a brake on the loss of coals market share.[143] The political and market power of the coal industry has been relatively diminished compared to prior periods in history.[144] The industry nevertheless is still able to persuade state regulators and political decision makers, particularly those in the public power realm,[145] to stay with coal and mobilize against greater fuel diversity in the nation's system of electricity generation.[146] This is true even when coal is not competitive and is causing actual financial harm to those who are held captive to prior decisions.[147]

The explanation for the loss of revenue and value to the United States government is embedded in its policy choice to supply low-cost electricity to the nation. At minimum, that decision had a substantial price tag for the U.S. Treasury. The fact that the United States government holds monopoly control over a natural asset that has value only upon extraction creates a contentious basis for assessing a true fiscal cost. More research, transparency and debate would advance the discussion of how BLM actually managed the nation's coal asset for the last 30 years. However, the discussion makes clear that any successful energy strategy related to power generation embarked upon by the private sector will require considerable, long-term levels of public support of both a financial and policy nature.

Coal was always abundant, but the evidence suggests it was never cheap.

APPENDIX B: RECENT COAL LEASE CASE STUDIES

Cloud Peak's Purchase of West Antelope II North

On May 11, 2011 the BLM announced that Antelope Coal, LLC. (an affiliate of Cloud Peak Energy) was the successful bidder on the West Antelope North II coal tract in Wyoming.[148] The tract contained 350.3 million tons of coal (8967 Btu) and the 85 cents per ton bid placed the total value of the lease at $297.7 million. This sale was significant for a variety of reasons, but most notably: (1) Cloud Peak was the sole bidder; and (2) the sale enabled the company to add $293 million to its value—approximately 30 percent of total company assets.[149]

The day the sale was announced, Platts' *Coal Trader* noted that in prior sales where no competition took place, and where bid prices were low, the BLM rejected the bid and required a producer to come back with another, higher bid:[150]

> Coal producers in Wyoming's Powder River Basin stand to benefit from Cloud Peak's purchase of the West Antelope North last week, which industry observers say came at a relatively low price that acknowledges both the higher price of mining and perhaps, a more cloudy future for domestic coal markets.[151]

The same article supports the "low price" perception given how the market reacted to Cloud Peak's stock price. "News of the lower-than-expected bid prompted UBS to raise its stock price target for Cloud Peak from $26 to $31 per share." Cloud Peak's stock price rose by 4.8% on higher than average volume trading at the time of the sale announcement.[152]

Platts Coal Trader's coverage of the bid and stakeholder commentary on the BLM decision also provides important details, noting that analysts and industry officials keyed in on the stripping ratio as a critical issue that might have pushed the tract price down. All other things being equal under the BLM's fair market protocol, rising production costs would decrease the value of the coal tract. "Mining costs are affected by strip ratios; that's probably one of the biggest determinants in mining costs," stated a BLM official, speaking on condition of anonymity because the agency does not comment on lease sales.

The article also pointed out that the lack of transparency at the BLM made it impossible for outsiders to understand how decisions are made. How rising coal cost of production might be weighed against, say rising coal prices is not a matter of regular discussion and disclosure. How the BLM's fair market appraisal might navigate the conflicting market pressures of high inventories, low natural gas prices and rising exports is discussed in the Platts' *Coal Trader* article as well. As an industry commentator states: "The salvation is going to be exports off the West Coast."

Ultimately, the BLM accepted Cloud Peak's bid because it met the fair market value standard. Although the actual fair market value is confidential, *Platts Coal Trader's* analysis raises some questions about how agency officials calculated the actual value. The sale raises three critical issues:

- First, the BLM appears to have valued the stripping ratio as the driving factor in the FMV calculation. Cloud Peak read the same geological data, and, knowledgeable about the FMV appraisal system, developed its bid accordingly. Understanding the coal market, the likelihood of competition for the tract (none) and the real price achievable on the market, Cloud Peak strategically placed its bid. The UBS and the stock market boost present a clear picture: the BLM undervalued the coal asset by giving more weight to losses on the stripping ratio downside against the stronger rising price upside. Cloud Peak understood the FMV lease appraisal system and exploited it to its advantage.

- Second, the BLM's view about the trajectory of coal prices is defective. Long-term PRB coal prices are rising. The BLM has ignored this reality. As noted in several places throughout this analysis, the agency is aware of the value of the leases it awards. It is also aware of the implications for the market and for the coal producers. Cloud Peak's bid may have met BLM's fair market value standard, but as has been historically the case with the BLM, the BLM's determination of fair market value is far below the price Cloud Peak will get on the broader market for the coal.

- Third, the discussion about exports is also missing from BLM's decision. However, it is very much part of the market analysis of the transaction, as the quote from the industry spokesperson demonstrated. There is no mention of exports in the agency ROD for the lease. The ROD is the only formal, publicly available document that provides a rationale for the lease. At present, Cloud Peak only exports from its Spring Creek mine in Montana, but higher Btu value coal is an important part of its current export strategy.[153] The West Antelope tract would seem to have a high potential for export.

The Sale of the Belle Ayr North Coal Tract

On July 13, 2011 Peabody Energy announced it was the winner of the bid for Belle Ayr North coal tract. Its bid of 95 cents per ton for the 1,671-acre parcel added 220 million tons of 8500 Btu coal to its 2.9 billion PRB reserve.[154] Peabody's bid exceeded that of Alpha Natural Resources, the applicant for the site. Alpha's bid was for 78.2 cents per ton.

Peabody's bid was the second highest bid on record for a coal tract exceeding the per ton price of coal in the Cloud Peak transaction. It was particularly surprising given that the coal quality for this tract, 8500 Btu, is lower than the quality on the Cloud Peak tract (8967 Btu). The sale was also controversial since it is unprecedented for an applicant for a site (Alpha) to lose out at an auction. Alpha's interest in increasing its holdings in the Belle Ayr tracts built upon its other Belle Ayr holdings. However, the Belle Ayr tract Alpha identified is contiguous with Peabody's Caballo mine holdings. Although the auction process is supposed to be competitive, the coal tract selection process has failed to produce robust competition in the past.[155]

Peabody's CEO Greg Boyce offered some insights into the company's views on its motivation surrounding the sale, which involved a competitive bid unusual for federal lease auctions. "The PRB has been the cornerstone of our production platform for a number of years, and we've been active in PRB lease sales over a long period of time." He then added:

> So as we look at how you continue to sustain the level of production when you're producing 140 [million] to 150 million tons a year of PRB coal, you have to continue

> to replace that reserve base. So, it shouldn't be any surprise that for any lease sale out there, we're going to actively look at those reserves, look at their proximity to our operations, how they could be integrated into our operations in order to not only provide longevity but also the potential to expand as the economy here in this country recovers and exports become a much bigger component of PRB in the longer term.[156]

The Sale of the Caballo West Tract

On August 17, 2011, the BLM accepted Alpha Natural Resources bid for the Caballo West tract.[157] The original applicant for the tract was Peabody Energy. Alpha's bid of $1.10 per ton or $143.4 million for the 1,024acre, 8500 Btu coal tract represents the highest price paid for a tract in the history of the program.[158] Peabody Energy's second place bid of 98 cents per ton was also historically high.

The Caballo West auction took place shortly after Peabody Energy outbid Alpha, the original applicant, on the Belle Ayr site. Competition for these tracts is extremely rare. According to the *Platts Coal Trader*, "Of the 14 coal tract auctions completed by the Bureau of Land Management since 2000, only this auction and the last one in July, both between Alpha and Peabody, have been lost by the company that applied for the initial lease by application, or LBA."[159]

Alpha's and Peabody Energy's willingness to pay high prices for mid-quality PRB coal suggests a long-term demand for PRB coal. SNL Energy's *Coal Report* viewed the implications of the auction:

> The salient factor for other PRB coal producers out of all this is that the two recent bidding wars will likely drive up the price for the future federal leasing for Wyoming PRB coal, because BLM takes into account prior bid amounts when setting its secret fair market value estimates for future coal tracts. BLM does not reveal how it sets its fair market value estimates, so it is not clear how it will factor into these two recent winning bids for mid-Btu coal when it sets value for future reserves sales of high-Btu coal of mines further to the South of Caballo and Belle Ayr, and low-Btu mines farther to the north.[160]

The Sale of the South Hilight Tract

In December 2011 the BLM awarded Arch Coal a federal coal lease for the South Hilight tract in the southern PRB. The tract sold for $1.35 per ton for the 222 million tons of 9000 Btu coal. Arch Coal was the sole bidder on the tract. The $1.35 per ton bid for high quality BTU coal reflected Arch's view that the region would produce sufficient demand at rising prices.

According to Steve Leer, Chairman and CEO of Arch Coal:

> "Because of their very high quality, the South Hilight reserves are exceptionally well positioned to serve both the growing export market and expanding domestic demand for ultra-low sulfur coals."[161]

The Record of Decision in the case, signed on March 1, 2011 makes no reference to the use of the coal in export markets. It concentrates on coal burning for U.S. domestic electric and compliance with pollution control laws in the United States.[162]

The Sale of the South Porcupine Tract

In May, 2012 the BLM award the coal reserve at the South Porcupine coal tract to Peabody Energy for a $1.11 per ton bid for 8905 Btu coal. The $1.11 per ton bid was for coal of a higher quality than the earlier bid by Alpha Natural Resources for the Caballo West tract in August of 2011. Alpha's bid of $1.10 ton was for 8500 Btu coal.

SNL Energy's *Coal Report*[163] commented:

> In December 2011, Arch Coal Inc. paid a record $1.35 per ton for the South Hilight coal tract, which contains coal with a slightly higher heating content than South Porcupine but also a slightly higher sulfur content.
>
> Peabody's South Porcupine bid also looks like a bargain compared to an August 2011 auction in which an Alpha Natural Resources Inc. unit paid $1.10 per ton for the West Caballo reserve, which contains coal of significantly lesser quality than South Porcupine.

Peabody Energy was the sole bidder on the project.

These five coal lease sales illustrate the following points:

1. The bid prices reflect a long-term rising price outlook for PRB coal on the part of Peabody Energy, Alpha Natural Resources and Arch Coal. The market's response to the Cloud Peak sale reflects the same. The outlook is predicated on intensified domestic demand and rising exports.

   The need for each company to build reserve capacity in low, medium and high Btu PRB coal is essential to its current share value, revenue earning potential and stock value. Locking in new reserve positions is vital for each company's domestic and international market expansion;

2. The BLM's approach to these sales taken cumulatively, send a red flag warning that the agency is unprepared for the market changes taking place. The Cloud Peak price was far below any measure of fair market value, if the concept is to be reasonably understood. The most recent South Porcupine lease sale lead SNL Energy's *Coal Report* to comment: "looks like a bargain;" and

3. Commentary at the time of the Cloud Peak sale was that the FMV was adjusted downward by the BLM because of the rising cost of production on the tract. The market, more alert to the rising price environment than BLM, immediately raised the company's stock value. Three months later bids of 97 cents per ton and $1.10 per ton met the fair market value for lower quality coal. How the prices rose for lower quality coal between 14 percent and 29 percent in a matter of weeks reflects poorly on the FMV method and process.

Furthermore, although the Alpha and Peabody bids reflect historically high prices for PRB coal, the August 2010 Peabody investor presentation shows market headroom pricing of $36.00 per ton.

Peabody's and Arch's views on the possible premiums achieved through export sales suggest growing and persistent excess cash profits for coal producers from rising international activity. These market measures support much higher valuations[164] than those attained by the limited competition achieved in the Caballo and Belle Ayr sales.[165]

Cloud Peak's bid drove the company stock valuation considerably higher because of its coal producing position (because it is a PRB pure play producer, as no other financial activity was providing cross currents to effect its value at the time) and because it was perceived as a sweetheart deal. On price alone, the Cloud Peak sale should have generated a higher per ton value and a higher bonus payment for the United States Treasury. Instead, the federal Treasury lost funds.

The BLM's Record of Decision in each case directly or indirectly materially misrepresents what market the coal will be sold in, where it will be consumed, where its impacts will be experienced, and what impact its production will have domestically and internationally on supply and price and the status of alternative energy supplies. The full purpose for which this coal is being mined is not reflected in the ROD.[166]

Finally, each of the five successful bidders is active in export markets. Current and future share value and corporate strategic decision-making are tied to greater integration of production with global markets. The coal producers do not have as their exclusive intent—if it is their intent any longer at all[167]—to provide coal to U.S. domestic utilities at affordable prices.

APPENDIX C: GAO ARCHIVED COAL LEASE RESEARCH

	Date	Title of Report	Critical Issues Covered in Report
1.	3/9/1972	Improvements Needed in Administration of Federal Coal-Leasing Program	Recommended stronger enforcement of environmental and reclamation requirements, flexibility in ability to adjust royalty lease terms more often, disallowing deferment of coal development on granted leases.
2.	4/28/1975	Further Action Needed on Recommendations for Improving the Administration of Federal Coal-Leasing Program	Reiterated recommendations from 1972 report on the improvements needed in Federal coal-leasing program.
3.	10/15/1975	Federal Coal Leasing Program Administered by the Department of Interior	Provided data and analysis on coal reserves, regional production and largest mining companies.
4.	3/26/1976	Issues Related to the Development of Federal Coal Resources	DOI has decided to base its leasing policy on the number and value of bids received instead of on advance planning, timing, or estimates of the quantity of coal to be produced. DOI's current leasing program is superior to its previous system, but mapping, drilling, and land management planning weaknesses can jeopardize the success of the entire operation.
5.	4/1/1976	Role of Federal Coal Resources in Meeting National Energy Goals Needs To Be Determined and the Leasing Process Improved	Important quotes: "DOI has decided to lift the moratorium without having reasonable goals of how much coal to lease or when to lease. Recommended stronger enforcement of environmental and reclamation requirements, flexibility in ability to adjust royalty lease terms more often, disallowing deferment of coal development on granted leases." "In the past, DOI gave little attention to adequately valuing coal lands and leased coal."
6.	7/20/1976	Department of Interior's Approval Process for Coal Mining Plan	The audit reviewed policy and procedures used by DOI to approve mine plans. It then applied these standards and protocols to approval of several coal and mining plans.
7.	10/25/1977	United States Coal Development and the Federal Coal Leasing Amendments Act of 1975 - Statement of Monte Canfield, Jr. Director, Energy and Minerals Division Before the Subcommittee on Energy Production and Supply	The success of a federal leasing program revolves around three key points: resource and reserve data, maximizing economic recovery, and coordinating the planning for future leasing and production between the Department of Energy (DOE) and Interior.
8.	12/30/1977	Status of Competition In the Coal Industry	Report explored the companies in the industry.
9.	6/25/1979	Issues Facing the Future of Federal Coal Leasing	GAO report examined questions on new leasing program: how to balance fair market leasing goals with environmental, socioeconomic and economic goals in a less regulated environment.
10.	6/25/1979	Statement of John Sprague, Associate Director, Energy and Minerals Division, before the Subcommittee on Mines and Mining	Testimony. Statement expresses concern regarding Interior's decision to restart competitive leasing before performing analysis of current leases, suggests analyzing ability to meet coal production goals for 1985-1990.
11.	9/20/1979	Statement of John Sprague, Associate Director, Energy and Minerals Division, before the Subcommittee on Mines and Mining	Testimony: Follow up to earlier testimony of 6/25/1979, concerned Interior not taking into account uncertainties when calculating amount of coal production goals.

12.	8/22/1980	A Shortfall in Leasing Coal From Federal Lands: What Effect on National Energy Goals?	Addressed serious problems regarding leasing insufficient amounts of coal, not selecting the best coal areas for lease, and not having needed coal data are indicated in the Department of the Interior's lease sale in the Green River-Hams Fork region of Colorado and Wyoming.
13.	12/12/1980	Mapping Problems May Undermine Plans for New Federal Coal Leasing	GAO reviewed problems associated with the Department of the Interior's coal mapping program as it would affect the future leasing of coal from Federal lands, found that maps that are often inaccurate, unreliable, and inappropriate either to define broad planning boundaries or to support the kinds of economic, energy, and environmental trade-off decisions.
14.	8/6/1981	How Interior Should Handle Congressionally Authorized Federal Coal Lease Exchanges	GAO called into questions Interior's lease exchange for Utah company, didn't meet Congressional requirements for non-competitive lease, and didn't prepare proper equal value determination.
15.	8/20/1981	Simplifying the Federal Coal Management Program	GAO reviewed Interior's regulation governing its coal lease program and commented on ways to streamline provisions related to maximum economic recovery, diligent development, logical mining units and environmental review requests.
16.	4/28/1982	Cooperative Leasing Offers Increased Competition, Revenues, and Production From Federal Coal Leases in Western Checkerboard Lands	GAO evaluated the Department of the Interior's ongoing experiment with cooperative leasing agreements, before meaningful comparisons can be made against other leasing alternatives. More experience with the concept is needed.
17.	8/10/1982	Need for Guidance and Controls on Royalty Rate Reductions for Federal Coal Leases	GAO discussed problems encountered by the Department of the Interior in its procedures for granting or denying requests for royalty rate reductions on federal coal leases, found Interior was not sufficiently used its existing accounting and auditing expertise to review reduction applications.
18.	3/7/1983	Coal Exchange Management Continues To Need Attention	GAO examined several aspects of the proposed exchange of coal land ownership in Montana between the Bureau of Land Management (BLM) and a mineral company.
19.	5/11/1983	Analysis of the Powder River Basin Federal Coal Lease Sale: Economic Valuation and Legislative Changes Needed	Review of 1982 sale of 11 coal tracts. GAO review found BLM leased tracts for $100 million less than fair market value.
20.	5/23/1983	Analysis of the Powder River Basin Federal Coal Lease Sale	Testimony: Specifically discusses competitive leases for land adjacent to mining operations already in place, adoption of entry level bidding (lower minimum acceptable bids) that lowered final bid value. GAO evaluation showed that most of the Powder River coal leases sold for less than fair market value.
21.	9/6/1983	Fair Market Value Policy of Federal Coal Leasing	Testimony: Further discussion regarding Powder River/fair market value, discussed recommended valuation improvements. Recommended quantitative tests for FMV regardless of bidding and greater reliance on arm's length and prior sales.
22.	1/27/1984	Evaluation of Department of the Interior Comments on GAO's Report on the Powder River Basin Coal Sale	GAO presented its evaluation of the Department of the Interior's comments on a GAO report, which analyzed the Powder River Basin federal coal lease sale. GAO emphasized that there is a need to develop the best possible procedures to ensure receipt of fair market value without improper

			influence by Interior.
23.	6/11/1984	Deficiencies in the Department of the Interior OIG Investigation of the Powder River Basin Coal Lease Sale	GAO reviewed the conduct of a Department of the Interior, Office of the Inspector General (OIG) investigation into the Powder River Basin coal lease sale. GAO found that the three reports were incomplete and unreliable.
24.	8/2/1984	Legislative Changes Are Needed To Authorize Emergency Federal Coal Leasing	GAO recommended changes to Interior's emergency lease procedures, FMV determination flawed because did not assume higher value to emergency applicant.
25.	2/17/1987	Mineral Resources: Interior Has Improved Its Administration of Coal Exchanges	GAO evaluated the Department of the Interior's procedures for administering the trade or exchange of federal coal lands, GAO recommended administering lease exchanges in a way that ensured competition would still exist.
26.	8/25/1987	Mineral Revenues: Coal Lease Readjustment Problems Remedied but Not All Revenue Is Collected	GAO examined BLM's actions regarding readjusting coal leases and collecting royalties, found BLM did not readjust on time, did not collect $187 million, MMS did not collect royalties because of inadequate financial management.
27.	9/30/87	Mineral Resources: Interior's Actions on Three Coal Leases	GAO reviewed BLM's proposal to suspend a portion of a firm's coal leases for non-performance on diligence standards.
28.	8/4/1992	Mineral Resources: Proposed Revision to Coal Regulations	GAO report critical of BLM proposed rule to allow leaseholders to only produce .3 percent of recoverable coal reserves and still maintain lease. BLM did not explain reasons, did not present evidence this was necessary, and would allow leases to be held without production.
29.	9/16/1994	Mineral Resources: Federal Coal-Leasing Program Needs Strengthening	Congress passed legislation to discourage the speculative holding of federal coal leases and to encourage the development of leased coal. Yet GAO found that the Bureau of Land Management (BLM) has taken actions that do not further these goals.

END NOTES

[1] 30 USC Section 201 (a) (1)
[2] Nelson, Robert, *The Making of Federal Coal Policy,* Duke University Press: Durham, N.C., 1983, p. 14 (hereinafter cited as Nelson).
[3] Nelson, p. 20.
[4] United States Commission on Fair Market Value Policy for Federal Coal Leasing, *Report of the Commission: fair market value policy for federal coal leasing,* (Commission on Fair Market Value Policy for Federal Coal Leasing, 1984,) p. 1 (hereinafter cited as Linowes).
[5] Nelson, p. 6. The terms included: Rent payments of $1 per acre from the sixth year onward; Royalties of at least 5 cents per ton; Leases could be renegotiated every twenty years A requirement for diligent development and continued mine operation, or annual advance payments.
[6] Nelson, p. 25.
[7] Linowes, p. 491.
[8] Nelson, p.28.
[9] Although legally formed in 1946, BLM had no unified legislative mandate until Congress enacted the Federal Land Policy and Management Act of 1976 (FLPMA).
[10] Nelson, p. 45.
[11] Nelson, p. 30.

[12] House of Representatives, *Federal Coal Leasing Amendments of 1975 report (to accompany HR 6721), House of Representatives, 94-681.*
[13] See: Linowes p. 200. Prior to the 1971 moratorium, royalty payments ranged from 15 to 20 cents per ton.
[14] Nelson, p. 105.
[15] For a discussion of the specific political and policy dilemmas facing Interior at the time and how the final bill and regulations addressed those issues see: James Rasband, James Salzman and Mark Squillace, *Coal Leasing,* Natural Resources Law and Policy, Second Edition, Foundation Press, 2009. 1160-1165.
[16] http://www.blm.gov/wy/st/en/programs/energy/Coal_Resources/PRB_Coal/history.print.html. "History of the coal program", accessed February 12, 2012.
[17] Linowes, p. 2.
[18] Linowes, p. 375.
[19] The debate leading up to the new leasing program centered on coal producers who had leases but were not actively mining the reserves. Holding reserves for speculative purposes was a problem for a number of reasons, but it was also an indication that no new leases were required. The Linowes Commission review concluded that the 1982 coal tract sales were not needed for the purposes of maintaining the supply of coal to the nation's markets, see Linowes, p.133.
[20] Linowes, p. 375.
[21] Linowes, p. 376.
[22] Linowes, p. 376.
[23] *A Report to the Committee on Appropriations, U.S. House of Representatives, on the Coal Leasing Program of the U.S. Department of the Interior*, prepared by the Surveys and Investigations Staff, House Appropriations Committee (Washington, D.C., April, 1983).
[24] United States General Accounting Office, *Analysis of the Powder River Basin Federal Coal Lease Sale: Economic Valuation Improvements and Legislative Changes Needed,* GAO/RCED-83-119, May 11, 1983, (hereinafter referred to as: GAO/RCED-83-119). See also: GAO, *Evaluation of Department of Interior Comments on GAO's Report on the Powder River Basin Coal Sale,* B-201410, January 23, 1984. (hereinafter cited as GAO-Comments).
[25] Linowes, p. 491.
[26] Three other related investigations by the Department of Interior's Office of Inspector General evaluated the behavior of agency personnel resulting in a referral to the Department of Justice. The subsequent Department of Justice investigation report did not recommend criminal indictment but did cite potential violations of government ethics rules. These reports did not opine on the question of the fair market value.
[27] Office of Technology Assessment, United States Congress, *Environmental Protection in the Federal Coal Leasing Program,* Washington, D.C: U.S. Congress, Office of Technology Assessment, OTA-237, May 1984, p. 4.
[28] The charges to the GAO as described in GAO/RCED-83-119, p 1.
[29] GAO/RCED-83-119, p. iii-iv.
[30] GAO/RCED-83-119: Appendix 4 – Table: Calculation of GAO's Revised Estimate of Value for Powder River Basin Leases Offered for Sale on April 28, 1982, p. 87.
[31] Ibid, p. viii.
[32] Ibid, p.viii.
[33] The discussion in GAO/RCED-83-119 and GAO-Comments shed light on the type and level of price adjustments contemplated by the BLM at the time and the market response to those assumptions. Taken together these reports demonstrate the almost arbitrary nature of the pre-auction process within BLM. The GAO's view that a tract designed for one bidder is not competition, nor are the results of the bid usable for fair market value determinations is important. The agency used below FMV methods before 1982, used it for the 1982 sale and then depended on the same coal prices and methods for the next thirty years (see p. 52, GAO/RCED-83-119). For example, on one coal tract BLM originally set the price at 0.29 cents per ton. Due to policy choices and administrative error the tract was actually bid out for 2.50 cents per ton. Coal producer's bid 2.50 cent ton for the parcel – 85 times the level of BLM's appraisal. On another tract the agency rejected an April 1982 bid for $11 million. In October the same company bid $22 million on the same tract. Another tract received an appraisal price of 26.8 cents per ton. The BLM reduced the price to 8 cents per ton. The FMV adjustment was 326% from the appraised level. Some of the giveaways are greater than others. Coal producers were not dissuaded from bidding because of high prices. The BLM's pricing was arbitrary and capable of estimating significant market price fluctuations up and down. Market price, per se, because of there being only one bidder was truly in the eyes of the beholder. The GAO argued when it was clear the parcel was only for one company that a completely different market price analysis and price negotiation was necessary (see discussion on pages 59-60 of RCED-83-119).
[34] Linowes, p.1.
[35] The period of the 1970s was a period of robust policy debate on the program and policy issues surrounding the coal leasing program. This was, at a time when very little coal was actually being mined compared to 2012 production levels. Report to the Federal Trade Commission on Federal Energy Land Policy, *Efficiency, Revenue and Competition, (*Washington DC, Senate Committee On Interior and Insular Affairs, 94th Congress, 2d., Session, 1976; Council on Economic Priorities*, Leased and Loss: A Study of Public and Indian Coal Leasing in the West,* New York CEP, 1974; Katherine Fletcher, Ed. *A Scientific and Policy Review of the Draft Environmental Impact Statement for the Proposed Federal Coal Leasing Program of the Bureau of Land Management, Department of Interior,* The Institute of Ecology, Environmental Impact Assessment Project,1974; Congress of the United States , Office of Technology Assessment, *Management of Fuel and Non Fuel Minerals in Federal Lands: Current Status and Issues,* Washington, D.C.: OTA, Apr., 1979; General Accounting Office, *Role of Federal Coal Resources in Meeting National Energy Goals Needs to be Determined and the Leasing Process Improved,* Washington, D.C.: GAO, 1976; Leasing Policy Development Office, U.S. Department of Energy, *Federal Coal Leasing and 1985 and 1990 Regional Coal Production Forecasts,* Washington, S.C., DOE, June 1978; William Watson and Richard Bernkopf, *Economic Analysis of Maximum Economic Recovery of Federal Coal,* Washington, D.C.: Program Analysis Office, U.S. Geological Survey, Department of Interior, May 29, 1979, United States General Accounting Office, *Issues Facing the future of federal coal leasing,* report to Congress, EMD79-47, June 25,1979.
[36] Linowes, p. 388-389.

[37] See discussion of competition and the specific dynamics of the eleven coal tracts: GAO/RCED-83-119.49-56.
[38] According to BLM's website, of the 25 leases posted since 1991 to the present only four have had two bidders, all others have had only one bid. The four lease sales with two bidders were Thundercloud (1998), West Roundup (2005), Caballo West (2011) and Belle Ayr (2011). For example, the Organization for Economic Cooperation and Development (OECD) publishes a guide to bid-rigging in public procurements. Its principal red-flag warning of a defective procurement scheme is a "small number of bidders – the possibility of bid rigging is higher if there are few bidders." OECD, *Detecting Bid Rigging in Public Procurements,* http//www.oecd.org/dataoecd/36/38/42594486.pdf, p.7.
[39] See discussion on the Alpha Natural Resources and Peabody bidding in *Appendix B*. Even limited competition is unlikely to be an adequate check on BLM's fair market value process in the current environment.
[40] The Inspector General's investigations of the leaks that occurred during the bid process were subjected to criticism by the Linowes Commission and were the subject of a highly critical United States General Accounting Office study. United States General Accounting Office, *Deficiencies in the Department of Interior OIG Investigation of the Powder River Basin Coal Lease Sale,* GAO/RCED, 84-167, June 11, 1987.
[41] GAO-Comments.
[42] GAO, *Mineral Resources: Federal Coal Lease Program Needs Strengthening,* GAO RCED-94-10, September 1994 (hereinafter referred to as: GAO/RCED-94-10), p. 53.
[43] In response to GAO/RCED-94-10 Interior officials wrote a 12-page line-by-line response. They did not object to GAO's assertions that it was the 1982 flooding of the market with low cost coal that created a downward pricing spiral. In fact the DOI response was an overall robust defense of low priced coal and its benefits to the US economy. See Appendix VII of the audit page 87. In a very real sense the agency had changed its position over a ten year period from one of a more technical defense of the appraisal process to one where it was declaring that the decision was sound policy and had a desirable impact on the U.S. economy.
[44] See: Rasband, Salzman and Squillace, *Op Cit.* Like many of the issues addressed in this paper each of the areas discussed in this section could benefit from far greater elaboration. As noted throughout this report there is very limited discussion of the contemporary status on these issues. Little has been published of a public policy or academic nature in the last thirty years. By necessity, many complex issues are treated in a shortened version and the reader is encouraged to pursue the studies listed in these endnotes.
[45] United States Department of Interior, Bureau of Land Management, *Economic Evaluation of Coal Properties,* Release 3-285, April 7, 1994, p. I-4, (BLM-Handbook). Prior to the 1970s the Department did not conduct much diligence on coal valuations. The scandal heightened the issue for the Department at the time.
[46] See: Title 43, Subtitle D, Chapter 11 Subchapter C, Part 3425.1-5, which grants BLM the authority to contract outside coal zones. This provision of law, along with the emergency lease provisions (Part 3425.1-4), establish the two contracting exceptions to the norm. Part 3425.0-2 makes clear these contracting methods are for narrowly tailored circumstances.
[47] James Rasband, James Salzman and Mark Squillace, *Coal Leasing,* Natural Resources Law and Policy, Second Edition, Foundation Press, 2009. 1160-1165.
[48] In response to Congressman Markey's request for an audit of BLM's coal leasing program the agency used as its defense against the audit that it is governed by the handbook. See: Henry Clay Webster, *Federal coal leasing review sought by BLM,* Platts' *Coal Trader*, April 26, 2012.
[49] GAO/RCED-83-119, p. 18. This is the same handbook that calls for external review and promises to release appraisal documents to the public after leases are issued.
[50] Nelson, p. 235. Nelson's discussion throughout his study, published in 1983, highlights a strong tendency within DOI to oppose any form of governmental planning in the coal production process.
[51] http://www.blm.gov/wy/st/en/programs/energy/Coal_Resources/PRB_Coal/history.print.html
[52] These design boundaries are routinely drawn (gamed) by coal producers and accepted by BLM to prevent competition. One coal consultant explains it this way: "As a practical matter, most companies will attempt to define LBA tracts that, because of location or geometry, are of interest only to the nominating company. This minimizes competitive bidding on the tract, and may result in a lower cost lease." JT Boyd Company, Mining and Global Consultants, *Powder River Basin Coal Resource and Cost Study,* Report 3155.001, September 2011. In the Matter of Application of Public Service Company of Colorado for Approval of Its 2011 Electric Resource Plan, Docket: 11A-869, Attachment: LWG 1-3.A1.
[53] RCED/GAO 94-10, p. 20.
[54] These leases include approximately 19,172 acres and 5.793 billion tons of mineable coal. Eighteen of these leases were issued to the following producing mines for the purpose of extending operations at those mines: Jacobs (2), Black Thunder (3), North Antelope Rochelle (4), Eagle Butte (2), Antelope (3), Buckskin (1), Cordero/Rojo (2), and the former North Rochelle (10). The remaining two leases, the West Rocky Butte and the West Roundup, were issued to companies intending to open new mines. The West Rocky Butte lease was issued to Northwestern Resources Company in 1992. That company planned to start a new mine to recover the coal included in the Rocky Butte and West Rocky Butte leases but the new mine was never developed. The Rocky Butte and West Rocky Butte leases are now held by Caballo Coal Company, a subsidiary of PEC, and are included in the Caballo Mine. The West Roundup lease was issued to West Roundup Resources, Inc., a subsidiary of PEC, and has been incorporated into the recently permitted School Creek Mine. Source: US Department of Interior Bureau of Land Management Record of Decision, West Coal Creek Lease Application, WY 172585, Campbell, Wyoming, June 11, 2011, p. 3-4
[55] WIldEarth Guardians v. Sierra Club and Defenders of Wildlife v. Salazar, Secretary of Department of Interior, United States District Court for the District of Colombia, Civ. No.1:11-CV-00670-CKK.
[56] United States Department of the Treasury, *Receipts to Treasury,* May 20, 2009.
[57] Office of the Inspector General, *Abandoned Mines in the Department of Interior,* C-IN-MOA-0004-2007, July 1, 2008.
[58] Office of Inspector General, *Management of Land Boundaries,* C-IN-MOA-0001-2009
[59] For example, BLM's 2012 Budget Justification states: "No significant change is projected for the coal leasing program through 2013. A process is being developed in Wyoming to approve multiple leases at the same time but this effort is being offset by lower market demands and mergers." The same budget presentation projects a decline of acres under management during 2010-2012 periods. Bureau of Land Management, *Budget Justification and Performance Information Fiscal Year 2011,* Coal Management Performance Overview, Section IV, p.135-

[60] For a listing of those reports found on the General Accounting Office website see: Appendix: C: *GAO Archived Coal Lease Research.*
[61] GAO/RCED-83-119.
[62] GAO continues to audit DOI and BLM activity regularly. For example, GAO has released audits on the need for BLM to improve its oversight of gas and oil leases. GAO, *Past Work Offers Insights to Consider in Restructuring Interior's Oversight,* GAO-0-888T, July 22, 2010 as well as point out major management challenges on revenue collections on these leases. GAO, Department of Interior: Major Management Challenges, GAO-11-424T, March 1, 2011. GAO has also audited DOI's overall appraisal operations including BLM's land appraisal operations that do not include coal appraisals. GAO, *Actions Needed to Improve Compliance with Appraisal Standards, Increase Efficiency and Broader Oversight,* GAO-06-1050, September 29, 2006.
[63]GAO, *GAO*: *Serving the Congress and the Nation: 2010-2015,* August 16, 2010, www.gao.gov.htext.910559.html
[64] Letter from: Representative Edward Markey, House Committee on Natural Resources to Gene Dodaro, Comptroller General, U.S. Government Accountability Office, April 24, 2012.
[65] Henry Clay Webster, *Federal Coal leasing review at BLM,* Platts' *Coal Trader*, April 25, 2012.
[66] BLM-Handbook, p. V-5.
[67] Letter from Donald Shapiro, State Director, Bureau of Land Management, Wyoming State Office to Shannon Anderson, Powder River Basin Council, April 12, 2011. See also: Donald Simpson, State Director, Bureau of Land Management, Wyoming State Office to Jeremy Nichols, WildEarth Guardians, August 2011 in relation to the ten lease requests.
[68] 30 USC Section 201 (a) (1)
[69] BLM-Handbook, p. I-2:3 – A discussion of DOI's various operational interpretations of FMV as applied to the 1982 coal tracts and the underlying policy issues can be found in GAO-RCED 83-119 and DOI's subsequent response (GAO-B-208410). The agency has not publicly provided such a detailed review of its policy considerations for FMV and how they relate to the changing nature of coal markets since.
[70] Ibid, p. 1-3.
[71] Ibid.
[72] http://www.blm.gov/wy/st/en/programs/energy/Coal_Resources/coalfaqs/critical_concepts.html
[73] BLM-Handbook. The following is a summary of several sections of detailed methodological guidance provided to agency staff in the handbook. This discussion is for illustration purposes and does not intend to be exhaustive in capturing the complexity of the coal tract appraisal process.
[74] Typically, BLM is entering into 20 year lease agreements.
[75] BLM-Handbook, p. III-14.
[76] http:www.blm.gov/wo/ct/en/prog/energy/con/md_non-energy.html
[77] BLM-Handbook, p.II-3. The Data Requirements section of the Handbook stresses a meticulous concern for documentation consistent with the standards set out by the Commission and set forth in the introduction.
[78] BLM-Handbook, *Determining Revenues*, p. III-16.
[79] GAO, *Issues Facing the Future of Coal Leasing,* EMD-TRI-47, June 25, 1978.

[81] A significant determinant in price setting in a monopoly situation is the terms and conditions imposed on the transaction by the monopoly owner. By effectively deploying the asset to coal producers on the current terms and conditions, the monopoly owner, the United States government, has for its own reasons also deployed considerable value that might otherwise be captured through a rigorous application of a fair market value methodology. There are alternative ways of presenting the value of PRB coal. The WMA study and Peabody's investor presentation are others. More analytical work needs to be done. The lack of a robust literature is part of the problem outlined in this paper and encountered in its preparation.
[82] Christina A. Morrow, Vice President Investor Relations, *Jefferies 6th Annual Global Industrial A&D Conference,* August 10, 2010, Slide 23.
[83] Actual coal price assumptions used in the 1982 DOI appraisals are not fully disclosed in the GAO audit or the Linowes Commission report. The importance of the coal price assumption used in a fair market valuation cannot be overstated. It is a critical policy issue addressed in a 1979 GAO audit: United States General Accounting Office, *Issues Facing the Future of Coal Leasing,* EMD-79-47, June 25, 1979. Each appraisal has an embedded coal outlook in its calculation. .
[84] When applying the 249% adjustment to the price of coal in the 1983-1988 period the impact on PRB coal prices is somewhat high (in excess of $30.00 per ton). Two of the coal tracts in the 1982 sale were estimated with coal prices in excess of $25.00 per ton. The lower coal price scenario used in this paper is higher than BLM's 1982 lowest price estimate and lower than its highest price estimate. See: GAO/RCED, 83-119, p. 22. Had there been no strong price signals sent by BLM and markets continued apace all coal prices in the country were expected to rise. See: Charles Komanoff, Power Plant Costs Escalation: Nuclear and Coal Capital lost, Regulation and Economics, New York: Van Nostrand-Rheiinhold Company, 1981, p. 257 (hereinafter referred to as Komanoff). Prices were expected to rise in the post-1982 period, though not as precipitously as the 1970's, a period dominated by international oil price shocks. "Coal is expected to meet increased energy demand and to replace other traditional sources of energy that are increasing in price more rapidly than coal throughout the projection period." United States Energy Information Administration, *1983 Annual Energy Outlook with Projections through 1995,* May, 1984, p. 109. The lower range scenario in the model used in this paper reduces the 1983-1988 coal prices from the 249 percent upward adjustment by 30 percent. For a full discussion of the economic and energy contexts see Chapters 4, 5 and 6 of EIA's 1983 Energy Outlook.
[85] All of the estimated losses from BLM's fair market leasing activity are calculated in 2011 constant dollars.
[86] All values from company profiles Financial Statistics, Yahoo Finance, March 18, 2012.
[87] Greg Boyce, CEO Peabody Energy, *Energy for the World One BTU at a time,* Barclay's CEO Energy/Power Conference, September 8, 2011. p. 8.
[88] Energy Publishing, Inc. *Coal and Energy Price Report,* Volume 12, No. 88, May 10, 2010.
[89] Among the factors influencing market behavior environmental regulation, low natural gas prices, utilities switching coal suppliers, coal plant retirements, diminished public support and the reaction of state public service commission regulators.

[90] The Energy Information Administration, *U.S. Domestic and Foreign Coal Distribution by State of Origin, 2010* shows that Montana and Wyoming exported 6.6 million of 479 million tons produced in 2010, or 1.3%.
[91] One estimate places the export goal of the coal industry at 100 million tons per year from the PRB. See: Richard K. Morse and Lars Schernikau, *Asia's changing landscape,* World Coal, Volume 20, Number 10, October 2011, p.20. A recent study by Wood Mackenzie, reported on by SNL Energy's *Coal Report Coal Daily*, but not publicly available, places overall US export potential at 500 million tons by 2030, suggesting even higher levels of export from the PRB. See: Dan Lowrey, *Woodmac sees half of U.S. Coal production exported by 2030,* SNL Energy's *Coal Report*, March 17, 2012.
[92] Cloud Peak Energy, *2010 Form 10K*, March 2, 2011, p.108. (Cloud-Peak, 2010 10K)
[93] Arch Coal, Inc., *Arch Coal announces agreement with Canada's Ridley Terminal for Pacific Coast Exports,* January18, 2011.
[94] Rick Navarre, President and Chief Commercial Officer, *Expanding Markets and Productivity Growth Opportunities,* 2010 Analyst and Investor Forums, June 17, 2010, Slide 42. Hereafter: (Peabody-Navarre) specifically addresses Peabody's view of potential for PRB sales in the Asia Pacific markets: South Korea, Japan, Hong Kong, China and India (an estimated market of between 140 and 260 million tons per year). Slides 20, 30, 37 provides information on nature of many of the larger individual markets.
[95] Deck Slone, Arch Coal, *Raymond James 3rd Annual Coal Investors Conference,* November 11, 2010, Slide 12.
[96] Arch Coal, *Arch Coal Establishes Asia-Pacific Subsidiary,* May 9, 2011
[97] Peter Gartrell, *Arch CEO sees $20 range for PRB coal to Asia,* Platts' *Coal Trader*, January 31, 2011.
[98] Arch Coal, *Arch Coal Acquires Equity Interest in West Coast Terminal,* January 12, 2011 and *Arch Coal Announces Agreement with Canada's Ridley Terminal for Pacific Coast Exports,* January 18, 2011.
[99] Arch Coal, *Arch Coal Secures State-Controlled Otter Creek Coal Reserves in Montana, March 18, 2010.*
[100] Barry Cassell, *Alpha looks to Gulf Coast for coal export opportunities,* SNL Energy's *Coal Report*, June 21, 2011.
[101] Cloud Peak Energy, *Cloud Peak Agrees to Terms for Terminal Capacity (Westshore Terminal Canada),* June 14, 2011.
[102] Cloud Peak Energy, *Second Quarter Investor Presentation,* Slides 14 and 15, August 2011.
[103] Cloud Peak Energy, 2011 Form 10K.
[104] United States Geological Society, *Assessment of Coal Geology, Resources and Reserves in the Gillette Coalfield, Powder River Basin, Wyoming,* Open-File Report: 2008-1202. http://pubs.usgs,gov/of/2008/1202. (USGS-Gillette)
[105] From an audit perspective this sample is statistically significant because it comprises such a sizable portion of the nation's coal supply. The sample size is also highly relevant since the area surveyed will be the leading source of the nation's coal supply for at least the next two decades.
[106] Rebecca Smith, U.S. *Foresees A Thinner Cushion of Coal, Wall Street Journal*, June 8, 2009.
[107] All reserve information in this chart are cumulative totals of the assigned and unassigned tonnage provided by the PRB coal producers in their 10K's, or in the case of the newly merged Alpha and Massey company in the investor presentation announcing the merger.
[108] US Department of Interior Bureau of Land Management Record of Decision, West Coal Creek Lease Application, WY 172585, Campbell, Wyoming, June 11, 2011.
[109] Peabody Energy, *2010 Form 10 K,* Assigned and Unassigned Reserves, February 28, 2011.29-30.
[110] Arch Coal, *2010 Form 10K,* Assigned and Unassigned Reserves, March 1, 2011, p. 41.
[111] Alpha Natural Resources, *Creating an Industry Leader: Alpha Natural Resources/Massey Energy*, January 31, 2011, Page 5.
[112] Alpha Natural Resources, *2010 Form 10K,* February 25, 2010, p. 48.
[113] Cloud Peak Energy, *2010 Form 10K,* p.10
[114] United States Geological Survey, *Production and Depletion of Appalachian and Illinois Basin Coal Reserves,* The National Coal Resource Assessment Overview, U.S. Geological Survey Professional Paper, 1625-FFor a discussion of the history of mining in the area and depletion see: "USGS-CAPP/ILB"
[115] Rick Navarre, President and Chief Commercial Officer, *Expanding Markets and Productivity Growth Opportunities,* 2010 Analyst and Investor Forums, June 17, 2010, Slide 40. Hereafter: (Peabody-Navarre).
[116] Energy Information Agency, *Annual Energy Outlook 2011 with Projections through 2035,* April 2011, p. 86.
[117] See: Coal and Energy Price Report, *Market Commentary,* March 19 and 30, 2010 for coverage of Santee Cooper's coal deal for ILB coal and indications from Progress Energy, Duke and Southern Company's declining interest in CAPP coal. See: *American Electric Power: American Electric Power Seeks Bids for Coal,* Trading Markets.com, March 23, 2010. For a more data driven discussion of the trend, see: Michael Niven and Jesse Gilbert, *Subbituminous coal deliveries eclipse bituminous deliveries in March,* SNL Energy's *Coal Report*, July 20, 2011.
[118] Susan Tierney, *Why Coal Plants Retire: Power Market Fundamentals of 2012,* Analysis Group, Inc., February 16, 2012.
[119] One model designed by SNL Energy's *Coal Report* monitors the coal-to-gas switching potential and updates it. See: Jesse Gilbert and Steve Piper, *Prospects for Coal to Natural Gas Switching in the Second Half of 2011,* SNL Energy's *Coal Report*, 2011. A recent update: Jesse Gilbert, *Coal-to-gas switching: It's all in the price,* SNL Energy's *Coal Report*, March 7, 2012.
[120] Michael Niven and Jesse Gilbert, *Subbituminous coal deliveries eclipse bituminous deliveries in March,* SNL Energy's *Coal Report*, July 20, 2011.
[121] BLM recently reoffered the South Porcupine coal tract after an initial offering failed to produce a bid that met the fair market value. Dan Lowrey, *BLM schedules May lease sale for South Porcupine coal tract in Wyoming,* SNL Energy's *Coal Report*, April 14, 2012
[122] Dan Lowrey, *Update: Peabody secures huge coal tract for North Antelope min in PRB,* May 18, 2012.
[123] Nelson, p 5
[124] Nelson, p 6.
[125] Department of Interior, Federal Coal Management Program, *Final Report and Recommendation for the Secretary on Fair Market Value and Minimum Acceptable Value Bids for Federal Coal Leasing,* December 1979, pp. 1-2.
[126] Ibid.
[127] GAO/RCED-94-10, p.87.

[128] It is noteworthy that BLM finally rejected a bid of a major coal producer, Peabody, at the South Porcupine site. This was after the May 2011 stories on Cloud Peak and subsequent market response showed the sweetheart nature of the deal, after higher bids for cheaper coal from other companies in subsequent bids and after litigants in the decertification case challenged BLM's longstanding practice of giving away coal for below fair market value (see: WIldEarth Guardians v. . Salazar, Secretary of Department of Interior, United States District Court for the District of Colombia, Civ. No.1:11-CV-00670-CKK.

[129] Daniel Yergin, *The Quest,* New York: Penguin Books, p. 400.

[130] See Thomas Friedman, *Hot, Flat and Crowded,* New York: Farrar, Strauss and Grioux, 2008.

[131] The 1983 EIA Outlook projected increasing PRB coal prices and increased PRB production during the 1983 to 1995 period, p. 109.

[132] For yet another way to understand this point see: Bernstein Commodities and Power, *No Light for Dark Spreads: How the Ruinous Economics of Coal-Fired Power Plants Affect the Markets for Coal and Gas,* February 18, 2011. The study demonstrates that CAPP pricing in a time of declining natural gas prices and lower power prices is uncompetitive. The findings of the paper on PRB coal, for the most part, continue to document the PRB coal price advantage.

[133] A 1981 study of comparative costs of coal and nuclear energy generation contained a forty-year forward-looking coal price forecast. The estimate, driven in large part by the 1974-1979 periods, projected a 2.3% annual increase in the price of coal in real terms. The author of the study viewed the 1970's price hikes as anomalous, but provided a rising price future for coal prices that was conservative. The study also demonstrates how even with this rising price scenario (and during a period of rising construction costs) coal still proved to be the most affordable alternative. This is essentially the same market viewed by BLM appraisers in the 1982 sale and the GAO auditors in the subsequent audit. Komanoff, p.257.

[134] Daniel Yergin, *The Quest,* New York: Penguin Books, p. 400.

[135] Synapse Energy Economics, *Phasing Out Federal Subsidies for Coal,* April 13, 2010.

[136] One usually unnoticed area of coal market subsidy and support is the United States Department of Agriculture Rural Utility Service. For seventy years, until February 2008, the agency supplied low interest capital subsidies to the nation's network of rural cooperatives. In February 2008 the USDA initiated a moratorium on future loans for new construction of coal fired power plants. USDA was and is a major support for coal plant development in the nation. This support for coal plants (and nuclear) included several billion dollars in federal loan losses for bad nuclear and coal deals during the 1990's. See: GAO/RCED, *Rural Development: Financial Conditions of the Rural Utilities Service's Loan Portfolio,* April 1997 and additional GAO Testimony (GAO/RCED-97-198, July 1997) and (GAO/T-AIMD-98-123, March 30, 1998).

[137] GAO-RCED-83-119, p. 39.

[138] GAO-RCED-83-119, p. 61.

[139] GAO-Comments, p.7.

[140] The GAO describes the original process in GAO-RCED-83-119, p. 60 and adds this case for emphasis in GAO-Comments, p. 7.

[141] See GAO-RCED-83-119, p. 52.

[142] GAO-RCED, 83-119, p.70.

[143] Moody's has recently projected that coal's share of electric generation will settle out at about 30%. In this authors view this is occurring at a time when the market price of power would suggest even greater losses. See: Dan Testa, *Moody's: In US energy mix, displacement of coal by gas is permanent,* SNL Energy's Coal Report, June 7, 2012.

[144] Michael Niven, *Survey: Utility sector confidence in future of coal is plummeting,* SNL Energy's Coal Report, June 4, 2012.

[145] Abby Gruen, *Public power sector facing rocky transition to gas-fired generation*, SNL Energy Coal Daily Report, June 8, 2012.

[146] Kathleen Hart, *Duke CEO warns against 'all gas, all the time' for electric generation*, SNL Energy's *Coal Report*, April 11, 2012; Michael Niven, *Study: Retrofitted coal plants in tough position against cheap gas,* SNL Energy's *Coal Report*, April 12, 2012; Frank Maisano, *Solyndra mess undermines green jobs message,* SNL Energy's *Coal Report Blogs*, September 21, 2011.

[147] The largest new coal plant in the country Prairie State is nearing completion. Although it originally promised to provide low cost power to communities in five states in the Midwest it is unlikely the plant will ever produce power below the price of market power. See: Dan Gearino, *Cities on hook for power plants costs,* Columbus Dispatch, June 9, 2012. Moody's recent coverage of the public power sector highlighted this concern of those entities with new coal plants, including Prairie State. See: Abby Gruen, *Public power sector facing rocky transition to gas-fired generation*, SNL Energy Coal Daily Report, June 8, 2012.

[148] BLM, *Antelope Coal Submits its Successful Bid at Lease Sale*, May 11, 2011. Barry Cassell, *Cloud Peak wins federal PRB coal reserve with bid of 85 cents/ton,* May 12, 2011 and Peter Gartrell, *Cloud Peak Energy's $297 million bid for PRB coal tract,* Platts' *Coal Trader*, May 12, 2011. The company was awarded the South Antelope tract at the June 15th auction: Barry Cassell, *Cloud Peak Energy wins 2nd Antelope Coal tract,* June 16, 2011. See also: Barry Cassell, *BLM Schedules Cloud Peak Lease Sale: Will Peabody also bid,* SNL Energy's *Coal Report*, March 1, 2012.

[149] Cloud Peak, *Investor Presentation,* August 2011, p. 37.

[150] Peter Gartrell, *BLM Approves Cloud Peak Energy's $297 Million Bid for PRB Coal Tract,* Platts' *Coal Trader*, May 12, 2011.

[151] Peter Gartrell, *Cloud Peak tract price may reflect higher mining costs, weak market,* Platts' *Coal Trader*, May 16, 2011.

[152] Amy Poszywak, *Thursday's Energy Stocks: Cloud Peak up after winning coal tract bid,* SNL Energy's *Coal Report*, May 12, 2011.

[153] Cloud Peak Energy, *Investor Presentation,* Second Quarter 2011, Spring Creek Export Quality Advantage, August 2011, p. 12.

[154] Peabody Energy, *Peabody Energy named winning bidder for 220 million tons of Powder River Basin Coal Resources,* July 13, 2011. Barry Cassell, *Peabody Elbows Alpha Natural Resources aside to grab PRB reserves,* SNL Energy's *Coal Report*, July 14, 2011.

[155] See Barry Cassell, *Following failed coal bid, what is in store for Alpha Belle Ayr mine?,* SNL Energy's *Coal Report*, July 14, 2011 and *Peabody looks at more PRB production for School Creek, Caballo*, SNL Energy's *Coal Report*, July 19, 2011.

[156] Barry Cassell, *Peabody looks at more PRB production from School Creek, Caballo,* SNL Energy's *Coal Report*, *July 19, 2011*

[157] Bureau of Land Management, *BLM Caballo West Coal Lease Sale Winning Bid Over $143 Million,* August 13, 2011.

[158] Barry Cassell, *BLM accepts Alpha's record bid for PRB coal reserve tract,* SNL Energy's *Coal Report*, August 18, 2011 and Henry Clay Webster, *Alpha Natural Records win LBA sought by Peabody,* Platts' *Coal Trader*, August 18, 2011.

[159] Webster, Platts' *Coal Trader*, *Record Setting Bid.*

[160] Cassell, SNL Energy's *Coal Report*, *BLM Accepts Alpha Bid.*

[161] Dan Lowrey, *Update: Arch wins South Hilight Coal tract in PRB with $300M bid,* SNL Energy's *Coal Report*, December 15, 2011

[162] Bureau of Land Management, *Record of Decision Environmental Statement for the South Hilight Field Coal Lease Application,* WYW 174596.

[163] Dan Lowrey, *Update: Peabody secures huge coal tract for North Antelope mine in PRB,* Platts' *Coal Trader*, May 18, 2012.

[164] The model used for this study supports a value for the Cloud Peak leases at North and South Antelope leases of $866 million; for Peabody, Belle Ayr of $525 million; and for Alpha Natural Resources Caballo at $356 million. This is a difference of $1 billion with the actual amount granted by BLM. BLM's failure to disclose details of the sales requires market proxies to be established to make these estimates. We use the 1982 market variance established by the GAO.

[165] One long-time coal scholar Professor Mark Squillace, University of Colorado makes a similar observation about the limited validity of the competitive price received from the Caballo sale given the fact of two bidders. BLM staff, however, saw the two bidders as clear evidence of an effective program and a competitive market. Peter Gartrell, *Peabody Energy outbids Alpha to win PRB coal tract with $210.6 million bid,* Platts' *Coal Trader* Coal Trader, July 14, 2011. Two bidders for a coal tract in a robust, emerging global market should not satisfy a competitive standard. (See: OECD-Bid Rigging).

[166] For a more detailed review of the flaws in the Records of Decision by this author see: Declaration of Tom Sanzillo, WildEarth Guardians, Defenders of Wildlife and Sierra Club v. Ken Salazar, U.S. Department of Interior and Robert V. Abbey, Director, U.S. Bureau of Land Management and State of Wyoming and Natural Mining Association and Wyoming Mining Association, Civ. No. 1.11-cv-00670-CKK, paragraphs 66-74.

[167] Henry Clay Webster, *Arch Coal Shifts to export strategy in new document,* Platts' *Energy Outlook* Coal Outlook, May 28, 2012.

Bounding the role of black carbon in the climate system: A scientific assessment

by

T. C. Bond[1], S. J. Doherty[2], D. W. Fahey[3], P. M. Forster[4], T. Berntsen[5], B. J. DeAngelo[6], M. G. Flanner[7], S. Ghan[8], B. Kärcher[9], D. Koch[10], S. Kinne[11], Y. Kondo[12], P. K. Quinn[13], M. C. Sarofim[6], M. G. Schultz[14], M. Schulz[15], C. Venkataraman[16], H. Zhang[17], S. Zhang[18], N. Bellouin[19], S. K. Guttikunda[20], P. K. Hopke[21], M. Z. Jacobson[22], J. W. Kaiser[23], Z. Klimont[24], U. Lohmann[25], J. P. Schwarz[3], D. Shindell[26], T. Storelvmo[27], S. G. Warren[28], C. S. Zender[29]

[1]University of Illinois at Urbana-Champaign, Urbana, Illinois, USA.
[2]Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, Washington, USA.
[3]NOAA Earth System Research Laboratory, Boulder, Colorado, USA and Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA
[4]University of Leeds, Leeds, UK.
[5]Center for International Climate and Environmental Research-Oslo and Department of Geosciences, University of Oslo, Oslo, Norway.
[6]US Environmental Protection Agency, Washington, DC, USA.
[7]University of Michigan, Ann Arbor, Michigan, USA.
[8]Pacific Northwest National Laboratory, Richland, Washington, USA.
[9]Deutsches Zentrum für Luft- und Raumfahrt Oberpfaffenhofen, Wessling, Germany.
[10]US Department of Energy, Washington, DC, USA.
[11]Max Planck Institute, Hamburg, Germany.
[12]University of Tokyo, Tokyo, Japan.
[13]NOAA Pacific Marine Environment Laboratory, Seattle, Washington, USA.
[14]Forschungszentrum Jülich GmbH, Jülich, Germany.
[15]Norwegian Meteorological Institute, Oslo, Norway.
[16]Indian Institute of Technology, Bombay, India.
[17]China Meteorological Administration, Beijing, China.
[18]Peking University, Beijing, China.
[19]Met Office Hadley Centre, Exeter, UK.
[20]Division of Atmospheric Sciences, Desert Research Institute, Reno, Nevada, USA
[21]Clarkson University, Potsdam, New York, USA.
[22]Stanford University, Stanford, California, USA.
[23] European Centre for Medium-range Weather Forecasts, Reading, UK, King's College London, London, UK, and Max Planck Institute for Chemistry, Mainz, Germany.
[24]International Institute for Applied System Analysis, Laxenburg, Austria.
[25]Eidgenössische Technische Hochschule Zürich, Zurich, Switzerland.
[26]NASA Goddard Institute for Space Studies, New York, New York, USA.
[27]Yale University, New Haven, Connecticut, USA.
[28]University of Washington, Seattle, Washington, USA.
[29]University of California, Irvine, California, USA.

Accepted Article

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/jgrd.50171

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Abstract

Black carbon aerosol plays a unique and important role in Earth's climate system. Black carbon is a type of carbonaceous material with a unique combination of physical properties. This assessment provides an evaluation of black-carbon climate forcing that is comprehensive in its inclusion of all known and relevant processes and that is quantitative in providing best estimates and uncertainties of the main forcing terms: direct solar absorption, influence on liquid, mixed-phase, and ice clouds, and deposition on snow and ice. These effects are calculated with climate models, but when possible, they are evaluated with both microphysical measurements and field observations. Predominant sources are combustion related; namely, fossil fuels for transportation, solid fuels for industrial and residential uses, and open burning of biomass. Total global emissions of black carbon using bottom-up inventory methods are 7500 Gg yr^{-1} in the year 2000 with an uncertainty range of 2000 to 29000. However, global atmospheric absorption attributable to black carbon is too low in many models, and should be increased by a factor of almost three. After this scaling, the best estimate for the industrial-era (1750 to 2005) direct radiative forcing of atmospheric black carbon is +0.71 W m^{-2} with 90% uncertainty bounds of (+0.08, +1.27) W m^{-2}. Total direct forcing by all black carbon sources, without subtracting the pre-industrial background, is estimated as +0.88 (+0.17, +1.48) W m^{-2}. Direct radiative forcing alone does not capture important rapid adjustment mechanisms. A framework is described and used for quantifying climate forcings, including rapid adjustments. The best estimate of industrial-era climate forcing of black carbon through all forcing mechanisms, including clouds and cryosphere forcing, is +1.1 W m^{-2} with 90% uncertainty bounds of +0.17 to +2.1 W m^{-2}. Thus, there is a very high probability that black carbon emissions, independent of co-emitted species, have a positive forcing and warm the climate. We estimate that black carbon, with a total climate forcing of +1.1 W m^{-2}, is the second most important human emission in terms of its climate-forcing in the present-day atmosphere; only carbon dioxide is estimated to have a greater forcing. Sources that emit black carbon also emit other short-lived species that may either cool or warm climate. Climate forcings from co-emitted species are estimated and used in the framework described herein. When the principal effects of co-emissions, including cooling agents such as sulfur dioxide, are included in net forcing, energy-related sources (fossil-fuel and biofuel) have an industrial-era climate forcing of +0.22 (-0.50 to +1.08) W m^{-2} during the first year after emission. For a few of these sources, such as diesel engines and possibly residential biofuels, warming is strong enough that eliminating all emissions from these sources would reduce net climate forcing (*i.e.,* produce cooling). When open burning emissions, which emit high levels of organic matter, are included in the total, the best estimate of net industrial-era climate forcing by all black-carbon-rich sources becomes slightly negative (-0.06 W m^{-2} with 90% uncertainty bounds of -1.45 to +1.29 W m^{-2}). The uncertainties in net climate forcing from black-carbon-rich sources are substantial, largely due to lack of knowledge about cloud interactions with both black carbon and co-emitted organic carbon. In prioritizing potential black-carbon mitigation actions, non-science factors, such as technical feasibility, costs, policy design, and implementation feasibility play important roles. The major sources of black carbon are presently in different stages with regard to the feasibility for near-term mitigation. This assessment, by evaluating the large number and complexity of the associated physical and radiative processes in black-carbon climate forcing, sets a baseline from which to improve future climate forcing estimates.

Table of Contents

0. Executive Summary

0.1. Background and motivation

0.2. Major findings

1. Introduction

1.1. What is black carbon?

© 2013 American Geophysical Union. All Rights Reserved.

1.2. How does black carbon affect the Earth's radiative budget?

1.3. How can we quantify the climate effect of black carbon?

1.4. Guiding principles

2. Measurements and microphysical properties of black carbon

2.1. Section summary

2.2. Definitions

2.3. Black carbon formation and evolution

2.4. Measurement of BC mass

2.5. Optical properties of black carbon

2.6. Measurement of absorption coefficients

2.7. Microphysical properties affecting MAC and ω_0

2.8. Measured and modeled MAC and ω_0

2.9. CCN activity of black carbon

3. Emission magnitudes and source categories

3.1. Section summary

3.2. Introduction

3.3. Bottom-up inventory procedures

3.4. Total BC emissions and major source categories

3.5. Regional emissions

3.6. Comparison among energy-related emission estimates

3.7. Major sources of uncertainty in emissions

3.8 Trends in BC emissions

3.9. Receptor modeling to evaluate source contributions

4. Constraints on black-carbon atmospheric abundance

4.1. Section summary

4.2. Introduction

4.3. Atmospheric absorption and extinction by absorbing species

4.4. Observations of atmospheric black carbon concentrations

4.5. Comparison between modeled and observed BC concentrations and AAOD

4.6. Vertical distribution of BC

4.7 Causes of model biases

4.8. Summary of limitations in inferring black carbon atmospheric abundance

5. Black-carbon direct radiative forcing

5.1. Section summary

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

5.2. Introduction

5.3. Emission, lifetime, and burden

5.4. Mass absorption cross section

5.5. Scaling modeled BC AAOD to observations

5.6. Forcing efficiency

5.7. All-source and industrial-era BC DRF

5.8. Previous observationally scaled radiative forcing estimates

5.9 Implications of increased BC AAOD

5.10. Summary of uncertainties in BC DRF

6. Black carbon interactions with clouds

6.1. Section Summary

6.2. Introduction

6.3. Black-carbon semi-direct effects on cloud cover

6.4. BC indirect effects on liquid clouds

6.5. BC indirect effects on mixed-phase and ice clouds

6.6. Comprehensive modeling of BC cloud effects

6.7. Summary of uncertainties in estimating indirect effects

7. Cryosphere changes: Black carbon in snow and ice

7.1. Section summary

7.2. Introduction

7.3. Modeled forcing

7.4. Measurements of BC in snow and comparison with models

7.5. Sources of BC to Arctic and Himalayan snow

7.6. Estimate of forcing by BC in the cryosphere

8. Climate response to black carbon forcings

8.1. Section summary

8.2. Introduction to climate forcing, feedback and response

8.3. Surface temperature response to atmospheric black carbon

8.4. Precipitation changes due to black-carbon direct and semi-direct effects

8.5. Climate response to the snow albedo effect

8.6. Detection and attribution of climate change due to black carbon

8.7. Conclusions

9. Synthesis of black-carbon climate effects

9.1 Section summary

9.2. Introduction

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

9.3. Global climate forcing definition

9.4. BC global climate forcing components and uncertainties

9.5. Uncertainties in BC global climate forcings

9.6. Total forcing estimates and comparison with previous work

10. Net climate forcing by black-carbon-rich source categories

10.1 Section summary

10.2. Introduction

10.3. Approach to estimating forcing from BC-rich source categories

10.4. Climate forcing per emission for co-emitted aerosols and precursors

10.5. Net climate forcing by BC-rich source categories

10.6. Climate forcing by selected sources

10.7. Comparison with forcing on longer time scales

10.8. Cautions regarding net forcing estimates

11. Emission metrics for black carbon

11.1 Section summary

11.2. Introduction

11.3. The GWP and GTP metrics

11.4. Calculations of metric values for BC

11.5. Uncertainties

11.6. Shortcomings of global metrics

11.7. Choice of time horizon

11.8. Towards metrics for the net effect of mitigation options

12. Mitigation considerations for BC-rich Sources

12.1. Section summary

12.2. Mitigation framework for comprehensive evaluation

12.3. Costs and benefits of mitigation

12.4. Technical and programmatic feasibility for individual BC-rich source categories

12.5. International perspective on BC reductions in aggregate

12.6. Policy delivery mechanisms

12.7. Synthesis of considerations for identifying important mitigation options

Acknowledgements

Appendix A. Author contributions

Appendix B. Using sky-photometer aerosol absorption optical depth retrievals to constrain black carbon models

B.1. Background and methods

B.2. Uncertainties

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Appendix C. Data supporting co-emitted species forcings in Section 10

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

0. Executive Summary

0.1. Background and motivation

Black carbon is emitted in a variety of combustion processes and is found throughout the Earth system. Black carbon has a unique and important role in the Earth's climate system because it absorbs solar radiation, influences cloud processes, and alters the melting of snow and ice cover. A large fraction of atmospheric black carbon concentrations is due to anthropogenic activities. Concentrations respond quickly to reductions in emissions because black carbon is rapidly removed from the atmosphere by deposition. Thus, black carbon emission reductions represent a potential mitigation strategy that could reduce global climate forcing from anthropogenic activities in the short term and slow the associated rate of climate change.

Previous studies have shown large differences between estimates of the effect of black carbon on climate. To date, reasons behind these differences have not been extensively examined or understood. This assessment provides a comprehensive and quantitative evaluation of black carbon's role in the climate system and explores the effectiveness of a range of options for mitigating black carbon emissions. As such, this assessment includes the principal aspects of climate forcing that arise from black carbon emissions. It also evaluates the net climate forcing of combustion sources that emit large quantities of black carbon by including the effects of co-emitted species such as organic matter and sulfate aerosol precursors. The health effects of exposure to black carbon particles in ambient air are not evaluated in this assessment.

0.2. Major Findings

0.2.1. Black carbon properties

1. Black carbon is a distinct type of carbonaceous material that is formed primarily in flames, is directly emitted to the atmosphere, and has a unique combination of physical properties. It strongly absorbs visible light; is refractory with a vaporization temperature near 4000 K; exists as an aggregate of small spheres; and is insoluble in water and common organic solvents. In measurement and modeling studies, the use of the term 'black carbon' frequently has not been limited to material with these properties, causing a lack of comparability among results.

2. Many methods used to measure black carbon can be biased by the presence of other chemical components. Measured mass concentrations can differ between methods by up to 80% with the largest differences corresponding to aerosol with low black carbon mass fractions.

3. The atmospheric lifetime of black carbon, its impact on clouds and its optical properties depend on interactions with other aerosol components. Black carbon is co-emitted with a variety of other aerosols and aerosol precursor gases. Soon after emission, black carbon becomes mixed with other aerosol components in the atmosphere. This mixing increases light absorption by black carbon, increases its ability to form liquid-cloud droplets, alters its capacity to form ice nuclei, and, thereby, influences its atmospheric removal rate.

0.2.2. Black carbon emissions and abundance

1. Sources whose emissions are rich in black carbon ('BC-rich') can be grouped into a small number of categories, broadly described as diesel engines, industry, residential solid fuel and open burning. The largest global sources are open burning of forests and savannas. Dominant emitters of black carbon from other types of combustion depend on the location. Residential solid fuels (*i.e.,* coal and biomass) contribute 60 to 80% of Asian and African emissions, while on-road and off-road diesel engines contribute about 70% of emissions in Europe, North America and Latin America. Residential coal is a significant source in China, the former USSR and a few Eastern European countries. These categories represent about 90% of black-carbon mass emissions.

Other miscellaneous black-carbon-rich sources, including emissions from aviation, shipping, and flaring, account for another 9%, with the remaining 1% attributable to sources with very low black carbon emissions.

2. *Total global emissions of black carbon using bottom-up inventory methods are 7500 Gg yr^{-1} in the year 2000 with an uncertainty range of 2000 to 29000.* Emissions of 4800 (1200 to 15000) Gg yr^{-1} black carbon are from energy-related combustion, which includes all but open burning, and the remainder is from open burning of forests, grasslands, and agricultural residues.

3. *An estimate of background black carbon abundances in a pre-industrial year is used to evaluate climate effects.* In this assessment, we use the term 'industrial era' to denote differences in the atmospheric state between present day and the year 1750. We use a pre-industrial value of 1400 Gg of black carbon per year from biofuel and open biomass burning, although some fraction was anthropogenic at that time.

4. *Current emission estimates agree on the major sources and emitting regions, but significant uncertainties remain.* Information gaps include the amounts of biofuel or biomass combusted, and the type of technology or burning, especially in developing countries. Emission estimates from open biomass burning lack data on fuel consumed, and black-carbon emission factors from this source may be too low.

5. *Black carbon undergoes regional and intercontinental transport during its short atmospheric lifetime.* Atmospheric removal occurs within a few days to weeks via precipitation and contact with surfaces. As a result, black carbon is found in remote regions of the atmosphere at concentrations much lower than in source regions.

6. *Comparison with remote sensing observations indicates that global atmospheric absorption attributable to black carbon is too low in many global aerosol models.* Scaling atmospheric black carbon absorption to match observations increases the modeled globally averaged, industrial-era black carbon absorption by a factor of 2.9. Some of the model underestimate can be attributed to the models lacking treatment of enhanced absorption caused by mixing of black carbon with other constituents. The remainder is attributed to underestimates of the amount of black carbon in the atmosphere. Burden underestimates by factors of 1.75 to 4 are found in Africa, South Asia, Southeast Asia, Latin America, and the Pacific region. In contrast, modeled burdens in North America, Europe, and Central Asia are approximately correct. The required increase in modeled BC burdens is compatible with in-situ observations in Asia and space-based remote sensing of biomass burning aerosol emissions.

7. *If all differences in modeled black carbon abundances were attributed to emissions, total emissions would be 17000 Gg yr^{-1} compared to the bottom-up inventory estimates of 7500 Gg yr^{-1}.* The industrial-era value of about *14000 Gg yr^{-1}*, obtained by subtraction of estimated pre-industrial emissions, is used as the best estimate of emissions to determine final forcing values in this assessment. However, some of the difference could be attributed to poorly modeled removal instead of emissions. Both energy-related burning and open biomass burning are implicated in underestimates of emission rates, depending on the region.

0.2.3. Synthesis of black-carbon climate forcing terms

1. *Radiative forcing used alone to estimate black-carbon climate effects fails to capture important rapid adjustment mechanisms.* Black-carbon-induced heating and cloud microphysical effects cause rapid adjustments within the climate system, particularly in clouds and snow. These rapid adjustments cause radiative imbalances that can be represented as adjusted or effective forcings, accounting for the near-term global response to black carbon more completely. The effective forcing accounts for the larger response of surface temperature to a radiative forcing by black carbon in snow and ice compared to other forcing mechanisms. These factors are included in the climate forcing values reported in this assessment.

2. The best estimate of industrial-era climate forcing of black carbon through all forcing mechanisms is +1.1 W m^{-2} with 90% uncertainty bounds of +0.17 to +2.1 W m^{-2}. This estimate includes cloud forcing terms with very low scientific understanding that contribute additional positive forcing and a large uncertainty. This total climate forcing of black carbon is greater than the direct forcing given in the fourth Intergovernmental Panel on Climate Change (IPCC) report. There is a very high probability that black

Accepted Article

carbon emissions, independent of co-emitted species, have a positive forcing and warm the climate. This black carbon climate forcing is based on the change in atmospheric abundance over the industrial era (1750 to 2005). The black-carbon climate-forcing terms that make up this estimate are listed in Table 0.1. For comparison, the radiative forcings including indirect effects from emissions of the two most significant long-lived greenhouse gases, carbon dioxide (CO_2) and methane (CH_4), in 2005 were +1.56 and +0.86 W m^{-2}, respectively.

3. The fossil-fuel direct effect of black carbon of +0.27 W m^{-2} is higher than the value provided by the IPCC in 2007. This increase is caused by higher absorption per mass and atmospheric burdens than used in models for IPCC. The black-carbon-in-snow forcing estimate in this assessment is comparable, although more sophisticated. Our total climate forcing estimate of +1.1 W m^{-2} includes biofuel and open-biomass sources of black carbon, as well as cloud effects that the IPCC report did not explicitly isolate for black carbon.

0.2.4. Black-carbon direct radiative forcing

1. Direct radiative forcing of black carbon is caused by absorption and scattering of sunlight. Absorption heats the atmosphere where black carbon is present and reduces sunlight that reaches the surface and that is reflected back to space. Direct radiative forcing is the most commonly cited climate forcing associated with black carbon.

2. The best estimate for the industrial-era (1750 to 2005) direct radiative forcing of black carbon in the atmosphere is +0.71 W m^{-2} with 90% uncertainty bounds of +0.08 to +1.27 W m^{-2}. Previous direct forcing estimates ranged from +0.2 to +0.9 W m^{-2} and the median value was much lower. The range presented here is altered because we adjust global aerosol models with observational estimates of black carbon absorption optical depth as done in some previous studies.

3. Direct radiative forcing from all present-day sources of black carbon (including pre-industrial background sources) is estimated to be +0.88 W m^{-2} with 90% uncertainty bounds of +0.17 to +1.48 W m^{-2}. This value is 24% larger than industrial-era forcing because of appreciable pre-industrial emissions from open burning and biofuel use.

4. Estimates of direct radiative forcing are obtained from models of black carbon abundance and location. The ability to estimate radiative forcing accurately depends on the fidelity of these models. Modeling of and observational constraints on the black-carbon vertical distribution are particularly poor.

0.2.5. Black-carbon cloud effects

1. Black carbon influences the properties of ice clouds and liquid clouds through diverse and complex processes. These processes include: changing the number of liquid cloud droplets, enhancing precipitation in mixed-phase clouds, and changing ice particle number and cloud extent. The resulting radiative changes in the atmosphere are considered climate *indirect effects* of black carbon. In addition, in the *semi-direct effect*, light absorption by black carbon alters the atmospheric temperature structure within, below, or above clouds and consequently alters cloud distributions. Liquid-cloud and semi-direct effects may have either negative or positive climate forcings. The best estimates of the cloud-albedo effect and the semi-direct effect are negative. Absorption by black carbon within cloud droplets and mixed-phase cloud changes cause positive climate forcing (warming). At present, even the sign of black-carbon ice-cloud forcing is unknown.

2 The best estimate of the industrial-era climate forcing from black carbon cloud effects is positive with substantial uncertainty (+0.23 W m^{-2} with a -0.47 to +1.0 W m^{-2} 90% uncertainty range). This positive estimate has large contributions from cloud effects with a very low scientific understanding and large uncertainties. The cloud effects, summarized in Table 0.1, are the largest source of uncertainty in quantifying black carbon's role in the climate system. Very few climate model studies have isolated the influence of black carbon in these indirect effects.

0.2.6. Black-carbon snow and ice effects

Accepted Article

1. Black carbon deposition on snow and ice causes positive climate forcing. Even aerosol sources with negative globally averaged climate forcing, such as biomass combustion, can produce positive climate forcing in the Arctic because of their effects on snow and ice.

2. The best estimate of climate forcing from black carbon deposition on snow and sea ice in the industrial era is +0.13 W m^{-2} with 90% uncertainty bounds of +0.04 to +0.33 W m^{-2}. The all-source present-day climate forcing including preindustrial emissions is somewhat higher at +0.16 W m^{-2}. These climate forcings result from a combination of radiative forcing, rapid adjustments, and the stronger snow-albedo feedback caused by black-carbon-on-snow forcing. This enhanced climate feedback is included in the +0.13 W m^{-2} forcing estimate.

3. Species other than black carbon are a large fraction of the absorbing aerosol mass that reduces reflectivity of snow and ice cover. These species include dust and absorbing organic carbon; the latter is co-emitted with black carbon or may come from local soils.

4. The role of black carbon in the melting of glaciers is still highly uncertain. Few measurements of glacial black-carbon content exist, and studies of the impact on glacial snow melt have not sufficiently accounted for natural impurities such as soil dust and algae or for the difficulty in modeling regions of mountainous terrain.

0.2.7. Impacts of black-carbon climate forcing

1. The black-carbon climate forcings from the direct effect and snowpack changes cause the troposphere and the top of the cryosphere to warm, inducing further climate response in the form of cloud, circulation, surface temperature and precipitation changes. In climate model studies, black-carbon direct effects cause equilibrium global warming that is concentrated in the Northern Hemisphere. The warming response to black-carbon-in-snow forcing is greatest during local spring and over mid-to-high northern latitudes. In terms of equilibrium global-mean surface temperature change the BC total climate forcing estimate over the industrial era would correspond to a warming between 0.1 and 2.0 K. Note that not all this warming has been realized in the present day, as the climate takes more than a century to reach equilibrium and many co-emitted species have a cooling effect, countering the global-mean warming of BC.

2. Regional circulation and precipitation changes may occur in response to black-carbon climate forcings. These changes include a northward shift in the Inter-Tropical Convergence Zone and changes in Asian monsoon systems where concentrations of absorbing aerosols are large. Black-carbon cloud indirect effects are also expected to induce a climate response. However, global models do not simulate robust responses to these complex and uncertain climate-forcing mechanisms.

0.2.8. Net climate forcing by black-carbon-rich source categories

1. Other species co-emitted with black carbon influence the sign and magnitude of net climate forcing by black-carbon-rich source categories. The net climate forcing of a source sector is a useful metric when considering mitigation options. Principal co-emitted species that can change the sign of short-lived forcing are organic matter and sulfur species. The direct radiative forcing is positive for almost all black-carbon-rich source categories, even when negative direct forcings by sulfate and organic matter are considered. Liquid-cloud forcing by co-emitted aerosol species can introduce large negative forcing. Therefore, high confidence in net positive total climate forcing is possible only for black-carbon source categories with low co-emitted species, such as diesel engines.

2. The best estimate of the total industrial-era climate forcing by short-lived effects from all black-carbon-rich sources is near zero with large uncertainty bounds. Short-lived effects are defined as those lasting less than one year, including those from aerosols and short-lived gases. This total is +0.22 (-0.50 to +1.08) W m^{-2} for fossil-fuel and biofuel-burning emissions, and -0.06 W m^{-2} with 90% uncertainty bounds of -1.45 to +1.29 W m^{-2} when open burning emissions are included.

Accepted Article

3. *The climate forcings from specific sources within black-carbon source categories are variable depending upon the composition of emissions.* Some subsets of a category may have net positive climate forcing even if the whole category does not. Selecting such individual source types from each category can yield a group of measures that, if implemented, would reduce climate forcing. However, the positive forcing reduction would be much less than the total climate forcing of +1.1 W m^{-2} attributable to all industrial-era black-carbon emissions in 2005.

4. *Short-lived forcing effects from black-carbon-rich sources are substantial compared with the effects of long-lived greenhouse gases from the same sources, even when the forcing is integrated over 100 years.* Climate forcing from changes in short-lived species in each source category amounts to 5 to 75% of the combined longer-lived forcing by methane, effects on the methane system, and CO_2, when the effects are integrated over 100 years.

0.2.9 Major factors in forcing uncertainty

1. *Observational constraints on global, annual average black carbon direct radiative forcing are limited by a lack of specificity in attributing atmospheric absorption to black carbon, dust or organic aerosol.* These constraints are required to correct demonstrated biases in the distributions of atmospheric black carbon in climate models.

2. *Altitude and removal rates of black carbon are strong controlling factors.* They determine black-carbon absorption forcing efficiency, microphysical effects on clouds, and the sign of semi-direct effects. Models do not accurately represent black-carbon vertical distributions. Removal rates, particularly wet removal, affect most facets of black carbon forcing, including its lifetime, horizontal and vertical extent, and deposition to the cryosphere.

3. *Black-carbon emission rates from both energy-related combustion and biomass burning currently appear underestimated*. Underestimates occur largely in Asia and Africa. Uncertainties in biomass burning emissions also affect pre-industrial black-carbon emission rates and net forcing.

4. *Black carbon effects on clouds are a large source of uncertainty*. Models of liquid-cloud and semi-direct effects disagree on signs and magnitudes of forcing. However, potentially large forcing terms and uncertainties come from black carbon effects on mixed-phase clouds, cloud-absorption and ice clouds, which have been estimated in a very small number of studies.

5. *Estimates of forcing rely on accurate models of the Earth system.* Black-carbon cloud interactions rely on fidelity in representation of clouds without black carbon present, and likewise, reductions in snow and sea ice albedo by black carbon depend on accurate representation of coverage of snow and sea ice. Uncertainties due to model biases of these distributions have not been assessed.

0.2.10. Climate metrics for black carbon emissions

1. *The 100-year global-warming-potential (GWP) value for black carbon is 900 (120 to 1800 range) with all forcing mechanisms included.* The large range derives from the uncertainties in the climate forcings for black carbon effects. The GWP and other climate metric values vary by about ±30% between emitting regions. Black-carbon metric values decrease with increasing time horizon due to the short lifetime of black carbon emissions compared to CO_2. Black carbon and CO_2 emission amounts with equivalent 100-year GWPs have different impacts on climate, temperature, rainfall, and the timing of these impacts. These and other differences raise questions about the appropriateness of using a single metric to compare black carbon and greenhouse gases.

0.2.11. Perspective on mitigation options for black carbon emissions

1. *Prioritization of black-carbon mitigation options is informed by both scientific and non-scientific factors.* Scientific issues include the magnitude of black carbon emissions by sector and region, and net climate forcing including co-emissions and impacts on the cryosphere. Non-science factors, such as technical feasibility, costs, policy design, and implementation feasibility also play roles. The major sources of black carbon are presently in different stages with regard to technical and programmatic feasibility for near-term mitigation.

Accepted Article

2. *Mitigation of diesel-engine sources appears to offer the most confidence in reducing near-term climate forcing.* Mitigating emissions from residential solid fuels also may yield a reduction in net positive forcing. The net effect of other sources, such as small industrial coal boilers and ships, depends on the sulfur content, and net climate benefits are possible by mitigating some individual source types.

0.2.12. Policy implications

1. *Our best estimate of black carbon forcing ranks it as the second most important individual climate-warming agent after carbon dioxide, with a total climate forcing of +1.1 W m^{-2} (+0.17 to +2.1 W m^{-2} range).* This forcing estimate includes direct effects, cloud effects, and snow and ice effects. The best estimate of forcing is greater than the best estimate of indirect plus direct forcing of methane. The large uncertainty derives principally from the indirect climate-forcing effects associated with the interactions of black carbon with cloud processes. Climate forcing from cloud drop inclusions, mixed phase cloud effects, and ice cloud effects together add considerable positive forcing and uncertainty. The relative importance of black carbon climate forcing will increase following reductions in the emissions of other short-lived species or decrease if atmospheric burdens of long-lived greenhouse gases continue to grow.

2. *Black carbon forcing concentrates climate warming in the mid-high latitude Northern Hemisphere.* As such, black carbon could induce changes in the precipitation patterns from the Asian Monsoon. It is also likely to be one of the causes of Arctic warming in the early 20th century.

3. *The species co-emitted with black carbon also have significant climate forcing.* Black carbon emissions are primarily attributable to a few major source categories. For a subset of these categories, including diesel engines and possibly residential solid-fuel, the net impact of emission reductions can be a lessening of positive climate forcing (cooling). However, the impact of *all* emissions from black-carbon-rich sources is slightly negative (-0.06 W m^{-2}) with a large uncertainty range (-1.45 to +1.29 W m^{-2}). Therefore, uniform elimination of all emissions from black-carbon-rich sources could lead to no change in climate warming, and sources and mitigation measures chosen to reduce positive climate forcing should be carefully identified. The uncertainty in the response to mitigation is larger when more aerosol species are co-emitted.

4. *All aerosol that is emitted or formed in the lower atmosphere adversely affects public health.* Mitigation of many of these sources would increase positive climate forcing (warming). In contrast, reduction of aerosol concentrations by mitigating black-carbon-rich source categories would be accompanied by very small or slightly negative changes in climate forcing. These estimates of climate forcing changes from source mitigation are associated with large uncertainties.

5. *Forcings by greenhouse-gases alone do not convey the full climate impact of actions that alter emission sources.* Black-carbon-rich source sectors emit short-lived species, primarily black carbon, other aerosols and their precursors, and long-lived greenhouse gases (*e.g.*, CO_2 and CH_4). The total climate forcing from the short-lived components is a substantial fraction of the total (up to 75%) even when both short-lived and long-lived forcings are integrated over 100 years after emission.

Accepted Article

Accepted Article

1. Introduction

[1] In the year 2000, a pair of papers [*Jacobson*, 2000; *Hansen et al.*, 2000] pointed out that black carbon— small, very dark particles resulting from combustion—might presently warm the atmosphere about one-third as much as CO_2. Because black carbon absorbs much more light than it reflects, it warms the atmosphere through its interaction with sunlight. This warming effect contrasts with the cooling effect of other particles that are primarily scattering and, thus, reduce the amount of energy kept in the Earth system. Radiative forcing (RF) by atmospheric BC stops within weeks after emissions cease because its atmospheric lifetime is short unlike the long timescale associated with the removal of CO_2 from the atmosphere. Thus, sustained reductions in emissions of BC and other short-lived climate warming agents, especially methane and tropospheric ozone (O_3), could quickly decrease positive climate forcing and hence climate warming. While such targeted reductions will not avoid climate change, their value in a portfolio to manage the trajectory of climate forcing is acknowledged in the scientific community [*e.g.*, *Molina et al.*, 2009; *Ramanathan and Xu,* 2010].

[2] Discussions of black carbon's role in climate rest on a long history. Urban pollution had been a concern for hundreds of years [*Brimblecombe*, 1977] and blackness was used as an indicator of pollution since the early 1900s [*Uekoetter*, 2005]. Black carbon was first isolated in urban pollution, as *Rosen et al.* [1978] and *Groblicki et al.* [1981] found that graphitic, refractory particles were responsible for light absorption. Shortly after *McCormick and Ludwig* [1967] suggested that aerosols could influence climate, *Charlson and Pilat* [1969] pointed out that aerosol absorption causes warming rather than cooling. The magnitude of climate effects was first estimated hypothetically to examine post-nuclear war situations [*Turco et al.*, 1983], and later using realistic distributions from routine human emissions [*Penner et al.,* 1993; *Haywood and Shine*, 1995]. It was known that particles traveled long distances from source regions [*Rodhe et al.*, 1972], reaching as far as the Arctic [*Heintzenberg*, 1980]. International experiments organized to examine aerosol in continental outflow were initiated in the late 1990s [*Raes et al*., 2000]. They confirmed that absorbing aerosol was prevalent in some regions and an important component of the atmospheric radiation balance [*Satheesh and Ramanathan,* 2000]. This coincident confirmation of atmospheric importance and proposal of policies for mitigation triggered further debate.

[3] In the decade since the initial proposals, the speed of Arctic climate change and glacial melt has increased the demand for mitigation options which can slow near-term warming, such as reductions in the emissions of short-lived warming agents. The impact of air quality regulations that reduce sulfate particles is also being recognized. Most particles, including sulfates, cool the climate system, masking some of the warming from longer-lived greenhouse gases (GHGs) and BC. Thus, regulating these particles to protect human health may have the unintended consequence of increasing warming rapidly. BC also plays a direct role in surface melting of snow and ice and, hence, may have an important role in Arctic warming [*Quinn et al.,* 2008]; if so, targeted reductions could have disproportionate benefits for these sensitive regions.

[4] Particulate matter was originally regulated to improve human health. Evidence supporting the link between particles and adverse respiratory and cardiovascular health continues to mount [*Pope et al.,* 2009]. High human exposures to particulate matter in urban settings are linked to sources that emit black carbon [*Grahame and Schlesinger,* 2007; *Naeher et al.*, 2007; *Janssen et al.*, 2011] and to intense exposures in indoor air [*Smith et al.,* 2010]. Thus, reducing particulate matter is desirable to improve human welfare, regardless of whether those reductions reduce climate warming.

[5] For the past few years, the opportunity to reduce black carbon has received pervasive policy attention at high levels. The G8 declaration, in addition to promising GHG reductions, committed to "…taking rapid action to address other significant climate forcing agents, such as black carbon." [9 July 2009, L'Aquila, Italy]. The Arctic Council, recognizing that "…reductions of emissions have the potential to slow the rate of Arctic snow, sea ice and sheet ice melting in the near-term…," established a task

force in 2009 to offer mitigation recommendations [29 April 2009, Tromsø, Norway] and "encouraged" the eight member states to implement certain black-carbon reduction measures [12 May 2011, Nuuk, Greenland]. The United States has complemented this international interest with passage of a bill [H.R. 2996] requiring a study of the sources, climate and health impacts, and mitigation options for black carbon both domestically and internationally. A proposed revision to the Gothenburg Protocol [*UNECE*, 1999] states that parties "should, in implementing measures to achieve their national targets for particulate matter, give priority, to the extent they consider appropriate, to emission reductions measures which also significantly reduce black carbon." [*UNECE*, 2011]. In February 2012 the Climate and Clean Air Coalition was formed with the aim of reducing climate warming and air pollutants through action on short-lived pollutants – in particular, BC, methane and hydrofluorocarbons (http://www.unep.org/ccac).

[6] The prospect of achieving quick climate benefits by reducing BC emissions is tantalizing, but the scientific basis for evaluating the results of policy choices has not yet been fully established. This assessment is intended to provide a comprehensive and quantitative scientific framework for such an evaluation. In the remainder of this section, we briefly define black carbon, present our terms of reference for the assessment, and describe its structure.

1.1. What is black carbon?

[7] Black carbon is a distinct type of carbonaceous material, formed only in flames during combustion of carbon-based fuels. It is distinguishable from other forms of carbon and carbon compounds contained in atmospheric aerosol because it has a unique combination of the following physical properties:

1. It *strongly absorbs visible light* with a mass absorption cross section of at least 5 m^2g^{-1} at a wavelength of 550 nm.
2. It is *refractory;* that is, it retains its basic form at very high temperatures, with a vaporization temperature near 4000K.
3. It is *insoluble* in water, in organic solvents including methanol and acetone, and in other components of atmospheric aerosol, and
4. It exists as an *aggregate* of small carbon spherules.

[8] The strong absorption of visible light at all visible wavelengths by black carbon is the distinguishing characteristic that has raised interest in studies of atmospheric radiative transfer. No other substance with such strong light absorption per unit mass is present in the atmosphere in significant quantities. BC has very low chemical reactivity in the atmosphere; its primary removal process is wet or dry deposition to the surface. BC is generally found in atmospheric aerosol particles containing a number of other materials, many of which are co-emitted with BC from a variety of sources.

[9] In this assessment, the term 'black carbon' and the abbreviation 'BC' is used to denote ambient aerosol material with the above characteristics. Note that this definition of black carbon has not been used rigorously or consistently throughout most previous literature describing absorbing aerosol and its role in the atmosphere. Section 2 gives further discussion of terminology.

1.2. How does black carbon affect the Earth's radiative budget?

[10] Figure 1.1 illustrates the multi-faceted interaction of BC with the Earth system. A variety of combustion sources, both natural and anthropogenic, emit BC directly to the atmosphere. The largest global sources are open burning of forests and savannas, solid fuels burned for cooking and heating, and on-road and off-road diesel engines. Industrial activities are also significant sources, while aviation and shipping emissions represent minor contributions to emitted mass at the global scale. The difficulty in quantifying emissions from such diverse sources contributes to the uncertainty in evaluating BC's climate role. Once emitted, BC aerosol undergoes regional and intercontinental transport and is removed from the atmosphere through wet (*i.e.,* in precipitation) and dry deposition to the Earth's surface, resulting in an average atmospheric lifetime of about a week.

[11] Radiative forcing over the industrial era (1750 –present) has typically been used (*e.g.*, by the IPCC [*Forster et al.,* 2007]) to quantify and compare first-order climate effects from different climate change mechanisms. Many of BC's effects on clouds and

Accepted Article

within the cryosphere are not easily assessed within this framework. These effects result in rapid adjustments involving the troposphere and land surface that lead to a perturbed energy balance that can also be quantified in units of radiative forcing. We employ the term 'climate forcing' to encompass both traditional radiative forcing and the rapid adjustment effects on clouds and snow (Table 1.1); this is discussed further in Section 1.3.2.

[12] The best quantified climate impact of BC is its atmospheric *direct radiative forcing* — the consequent changes in the radiative balance of the Earth due to an increase in absorption of sunlight within the atmosphere. When BC is located above a reflective surface, such as clouds or snow, it also absorbs solar radiation reflected from that surface. Heating within the atmosphere and a reduction in sunlight reaching the surface can alter the hydrological cycle through changes in latent heating, and also by changing convection and large-scale circulation patterns.

[13] A particularly complex role of BC and other aerosols in climate is associated with changes in the formation and radiative properties of liquid-water and ice clouds. BC particles may increase the reflectivity and lifetime of warm (liquid) clouds, causing net cooling, or they may reduce cloudiness, resulting in warming. Aerosol particles can change cloud droplet number and cloud cover in ice clouds, or in mixed-phase clouds made up of both ice and liquid water. Changes in droplet number may also alter cloud emissivity, affecting longwave radiation.

[14] BC also produces warming when it is deposited on ice or snow because BC decreases the reflectivity of these surfaces, causing more solar radiation to be absorbed. The direct absorption of sunlight produces warming which affects snow and ice packs themselves, leading to additional climate changes, and ultimately to earlier onset of melt and amplified radiative forcing.

[15] An important consideration in evaluating the climate role of BC emissions is the role of co-emitted aerosols, aerosol precursors and other gases. Many of these co-emitted species arise in the same combustion sources that produce BC. The greatest emissions by mass include sulfur-containing particles or precursors; organic aerosols that are directly emitted; organic compounds that are precursors to aerosols and ozone; nitrogen oxides that play roles in ozone formation and methane destruction and are precursors to nitrated aerosols; and long-lived GHGs. Sources also emit smaller quantities of ionic species such as potassium and chloride. With the exception of 'brown' organic carbon, non-BC particles absorb little or no light, so they often cool rather than warm climate. They also play a role in many, but not all, of the same cloud processes as BC.

[16] In contrast to BC, most other aerosols and precursors are chemically reactive in the atmosphere. Because of transport and chemical and microphysical transformation after emission, the atmospheric aerosol becomes a complex array of atmospheric particles, some of which contain BC. Pure BC aerosol rarely exists in the atmosphere and, because it is just one component of this mixed aerosol, it cannot be studied in isolation. Compared with pure BC, mixed-composition particles differ in their lifetimes, interaction with solar radiation, and interactions with clouds. The components of these mixed particles may come from the same or different sources than BC.

[17] The overall contribution of natural and anthropogenic sources of BC to climate forcing requires aggregating the multiple aspects of BC's interaction with the climate system, as well as the climate impacts of constituents that are co-emitted with BC. Each contribution may lead to positive climate forcing (generally leading to a warming) or negative climate forcing (generally cooling). As discussed in the body of this assessment, BC impacts include both warming and cooling terms. While globally averaged climate forcing is a useful concept, BC concentration and deposition are spatially heterogeneous. This means that climate forcing by aerosols and climate response to aerosols is likely distributed differently than the forcings and responses of well-mixed GHGs.

1.3. Assessment terms of reference

[18] We use the term 'scientific assessment' to denote an effort directed at answering a particular question by evaluating the current body of scientific knowledge. This assessment addresses the question, 'What is the contribution of black carbon to climate

Accepted Article

forcing?' The terms of reference of this assessment include its scope and approach. The primary scope is a comprehensive evaluation of annually averaged, BC global climate forcing including all known forcing terms, BC properties affecting that forcing, and climate responses to BC forcing. Climate forcing of BC is evaluated for the industrial era (*i.e.,*1750 to 2000). A secondary evaluation addresses the potential interest of BC sources for mitigation. Therefore, we discuss the analyses and tools required for a preliminary evaluation of major BC sources: climate change metrics, net forcing for combined BC and co-emitted species, and factors relating to feasibility.

[19] Our approach relies on synthesizing results of global models from the published literature to provide central estimates and uncertainties for BC forcing. This analysis was guided by the principles of being comprehensive and quantitative, described in more detail as follows:

1. Comprehensiveness with regard to physical effect. As discussed in the foregoing section, BC affects multiple facets of the Earth system, all of which respond to changes in emissions. In evaluating the total climate forcing of BC emissions, we included all known and relevant processes. The main forcing terms are direct solar absorption, influence on liquid, mixed-phase, and ice clouds, and reduction of surface snow and ice albedo.

2. Comprehensiveness with regard to existing studies. Multiple studies have provided estimates of BC climate forcing caused by different mechanisms. These studies often rely on dissimilar input values and assumptions so that the resulting estimates are therefore not comparable. In order to include all possible studies, we sometimes harmonized dissimilar estimates by applying simplified adjustments.

3. Comprehensiveness with regard to source contribution. Atmospheric science has historically focused on individual pollutants rather than the net impacts of sources. However, each pollutant comes from many sources, and each source produces multiple pollutants. Mitigation of BC sources will reduce warming due to BC, but it will also alter emissions of cooling particles or their precursors; short-lived warming gases, such as ozone precursors; and long-lived GHGs. Multi-pollutant analyses of climate impacts have been demonstrated in other work, and we continue that practice here for key sources that account for most of the BC emissions. We include forcing for other pollutants emitted by BC sources by scaling published model results. Although such scaling may yield imprecise estimates of impact, we assert that ignoring species or effects could result in misconceptions about the true impact of mitigation options.

4. Quantification and diagnosis. For each aspect of BC climate forcing, we provide an estimate of the central value and of the uncertainty range representing the 90% confidence limits. When understanding of physical processes is sufficiently mature that the factors governing forcing are known, observations and other comparisons can assist in weighting modeled forcing estimates. Model sensitivity studies based on this physical understanding allow estimates of uncertainty. When the level of scientific understanding is low, an understanding of the dominant factors is not well established. In this situation the application of observations to evaluate global models is not well developed, and only model diversity was used to estimate the uncertainty. When possible, we identified the causes of variation and key knowledge gaps that lead to persistent uncertainties. In this pursuit, we highlighted critical details of individual studies that may not be apparent to a casual reader. This synthesis and critical evaluation is one of the major value-added contributions of this assessment. The terms of reference require that new calculations be conducted if and only if required to harmonize diverse lines of evidence, including differences between simulations and observations.

[20] The target audience for this assessment includes scientists involved in climate, aerosol, and cloud research and non-specialists and policymakers interested in the role of BC in the climate system. The document structure reflects this audience diversity by including an Executive Summary (Section 0), individual section summaries, and introductory material that is required to support understanding of principles.

Accepted Article

1.3.1. Assessment structure

[21] The remaining eleven sections of this document reflect the scope of this assessment. They include seven providing in-depth analysis of the science surrounding BC alone (Sections 2 - 8), a climate forcing synthesis (Section 9), additional necessary context for discussions of the net climate forcing from BC-rich sources (Section 10), a climate metrics analysis (Section 11), and mitigation considerations for BC-rich sources (Section 12). They are described in more detail as follows:

2. Measurements and microphysical properties of black carbon. The assessment begins with a review of BC-specific properties, including the techniques used to measure BC. The interactions of BC with the climate system depend upon its microphysical properties, optical properties, and mixing with other aerosol components. These govern all impacts shown in Figure 1.1.

3. Emission magnitudes and source categories. The origins and emission rates of BC are basic components of understanding its total impact. This section identifies major sources of BC, and those containing high fractions of BC (*i.e.,* 'BC-rich sources'). It also identifies other climate-active aerosols or aerosol precursors emitted from these sources. Finally, data from ambient measurements are reviewed to evaluate emission estimates and the contributions of particular source types.

4. Constraints on black-carbon atmospheric abundance. The burden of BC in the atmosphere and its geographic distribution are basic quantities that directly affect all climate forcing estimates. Observations that constrain the magnitude and location of modeled atmospheric burdens are discussed here.

5. Black-carbon direct radiative forcing. The direct interaction between BC and sunlight unquestionably results in a net positive radiative forcing of climate. This section discusses the basic components that affect direct radiative forcing and the best estimates for each of these components, and it explores the reasons for differences in published radiative forcing values.

6. Black carbon interactions with clouds. BC influences clouds by changing droplet formation and microphysical properties and by altering the thermal structure of the atmosphere. BC is not uniformly distributed with altitude in the lower atmosphere. It directly warms the atmosphere where it is located and alters atmospheric dynamics, the meteorological conditions affecting cloud formation, and the quantity of clouds. In addition, BC, as well as other particles, influences the size and number of water droplets and ice crystals in water and ice clouds through microphysical interactions. All of these changes produce climate forcing by altering cloud properties. This section evaluates the magnitude of changes in water clouds, mixed-phase clouds and ice clouds. The section emphasizes changes caused by BC alone, instead of the more common examination of cloud changes by all particles.

7. Cryosphere changes: Black carbon in snow and ice. This section evaluates BC that is removed from the atmosphere both in precipitation and through dry deposition and, thereby, is incorporated into surface snow and ice, reducing reflectivity. This initial radiative forcing is amplified by a series of rapid adjustments. This section evaluates modeled cryosphere forcing estimates, including discussion of the microphysical factors that affect radiative transfer in snow and ice packs, and model choices that affect the amplification of that forcing through rapid adjustments. The section also compares the sources and magnitudes of modeled cryospheric BC concentrations with observations and uses this comparison to scale model estimates of forcing for a best estimate.

8. Climate response to black carbon forcings. Forcing is a common measure of radiative impact, but of ultimate concern is the climate response to BC, especially if it differs from that of other forcing agents. This section discusses the adjustments in the climate system that affect the efficacy of the forcing by BC in the atmosphere and cryosphere. It also reviews the sparse knowledge about how regional and global climate respond to changes in top-of-atmosphere (ToA) forcing and atmospheric heating.

9. Synthesis of black-carbon climate effects. In this section, best estimates of climate forcing from direct atmospheric light absorption, microphysical cloud changes, the rapid adjustment to direct atmospheric absorption, and the darkening of surface snow and ice by BC are combined with estimates of the forcing efficacy to estimate the total climate forcing of BC in the

Accepted Article

industrial era (1750 to 2000). Total present-day (*i.e.,* 'all-source') forcing is also given for direct radiative forcing and snow and ice forcings.

10. Net climate forcing by BC-rich source categories. While the preceding sections examine the total climate forcing for BC emissions alone, many other species are co-emitted from BC sources, even when they are BC-rich. This section examines the total climate forcing of BC-rich sources by quantifying the forcing per emission of all species from a given source.

11. Emission metrics for black carbon. One method of evaluating mitigation of BC versus mitigation of other climate-active species like greenhouse gases is to compare forcing per emitted mass of different compounds in a common framework. This comparison involves scientific issues as well as value judgments. This section summarizes metrics commonly used in climate policy discussions, and provides metrics for BC based on the forcing values summarized in Section 9 for direct use in the policy community.

12. Mitigation considerations for BC-rich sources. The preceding sections estimate the contributions to climate forcing of BC emissions alone and of the net effect from BC and co-emitted species from BC-rich sources. Future decisions regarding mitigation of climate forcing will include other considerations, including cost and availability of alternatives, additional benefits, and feasibility of implementation. This section discusses these elements for the major BC-rich sources, including regional differences among emission types and potential reduction policies. In addition, this section describes an evaluation framework that extends beyond purely scientific considerations, consistent with our goal of a comprehensive discussion. However, a thorough evaluation of the factors required for a complete mitigation analysis is beyond the scope of this assessment.

1.3.2. Use of radiative forcing concepts

[22] In synthesizing results for BC climate forcing from the published literature, inconsistencies are regularly encountered in the use of radiative forcing concepts, conventions, and terminology. Our definitions for these terms as used in this assessment are listed in Table 1.1 along with descriptions of their derivation from climate models. Most discussions about climate change refer to measures that are variously called 'radiative forcing' or 'climate forcing.' Our use of the term 'radiative forcing' follows the IPCC definition given by Forster *et al.* [2007] that keeps tropospheric and surface temperatures fixed. Many aerosol effects (*e.g.,* rapid adjustments in aerosol, cloud or snow distributions in response to the initial radiative forcing) can also be measured as changes in fluxes at the tropopause, making them amenable to comparison with radiative forcings. The sum of the radiative forcing and forcing due to these rapid adjustments yields the adjusted forcing. For the atmosphere and most of the land surface such rapid adjustments occur within a few days of applying the forcing. For the cryosphere, there is more of a continuum of adjustment processes and timescales, and rapid adjustments are usually considered to occur on seasonal timescales or less. For comparability to other forcing agents such as long-lived GHGs, these forcings can be scaled by their efficacy to yield the 'effective forcing.' We give the sum of radiative forcing and all other forcing-like terms the name 'climate forcing,' and this usage is similar to that in the IPCC assessments [*IPCC,* 2007].

[23] Radiative forcing employed in IPCC reports assumes that anthropogenic impact is well represented by the difference between present day and the year 1750, the beginning of the industrial era. This may not be true for BC, where there is evidence of considerable anthropogenic biofuel and open burning before 1750. For the purposes of this assessment, the global climate forcings of BC and co-emitted species are evaluated from the beginning of the industrial era (1750). This definition gives forcing that can be compared with the temperature change since that time, without requiring attribution to a particular cause. Rather than assuming that this value represents the present-day contribution of humans to climate forcing, we refer to the difference between year-2000 forcing and year-1750 forcing as 'industrial-era forcing.' For direct and cryosphere forcing, we also estimate forcing from all sources, even those that might have been ongoing before 1750. This is referred to as the 'all-source' forcing.

Accepted Article

1.3.3. Contrast with previous assessments

[24] Motivation to undertake this assessment derived, in part, from the scope of previous and concurrent assessments, namely the IPCC Fourth Assessment Report [AR4, *IPCC*, 2007] and the UNEP/WMO Integrated Assessment of Black Carbon and Tropospheric Ozone [*UNEP/WMO*, 2011a,b], respectively. A comprehensive and quantitative evaluation of BC sources and associated climate forcing terms was beyond the scope of IPCC AR4 (see Section 9.6 for more details). The primary focus in AR4 was the direct radiative forcing of fossil fuel sources of BC, and that forcing was estimated by weighting all studies equally without examining variation. Other terms beyond direct forcing were not evaluated; without these, even the sign of the total forcing cannot be estimated. The focus of the UNEP/WMO assessment was identification of mitigation strategies for short-lived climate forcing agents that would significantly reduce short-term anthropogenic climate forcing through examination with two climate models. Evaluation of model results in the context of observations, the microphysical properties of BC, and findings from other models were beyond the scope of the UNEP/WMO effort.

2. Measurements and microphysical properties of black carbon

2.1. Section summary

[1]

1. The term 'black carbon' has not been used rigorously or consistently in measurement studies or in modeling studies that use measurements. For future work, we recommend that the term 'refractory black carbon', or rBC, be adopted for the distinctive material defined herein as black carbon.

2. Either during or soon after emission, BC becomes internally mixed with other aerosol components such that it and other chemical species exist together within the same particle. This mixing can alter the optical properties of BC and influence its atmospheric lifetime and ability to form cloud droplets and ice crystals. Hence, the climate impacts of BC must be evaluated in the context of changes in its physico-chemical properties due to interactions with other aerosol components.

3. Freshly emitted BC particles are small in diameter and hydrophobic and, therefore, make very poor cloud condensation nuclei. Aging of BC after emission and associated accumulation of soluble mass increases the size and hygroscopicity of the internally mixed BC and enhances its cloud condensation nuclei (CCN) activity.

4. The mass absorption cross section of BC (MAC_{BC}) is a fundamental input to models of radiative transfer. Measured values for freshly generated BC fall within a relatively narrow range of 7.5 ± 1.2 m^2g^{-1} at 550 nm. MAC_{BC} increases by approximately 50% as BC becomes internally mixed with other aerosol chemical components.

5. Filter-based measurements of both absorption coefficient and BC mass concentrations can be biased by the presence of other chemical components in internally or externally mixed aerosol. Measured mass concentrations can differ between methods by up to 80% with the largest differences corresponding to aerosol with lower BC to organic carbon (OC) ratios. These measurement uncertainties may confound our understanding of trends, spatial and temporal variability, and impacts on climate.

2.2. Definitions

2.2.1. Black carbon

[2] Black carbon (BC) is distinct from other forms of carbon and carbon compounds contained in atmospheric aerosol. As stated in Section 1.1, it has a unique combination of properties. These properties are: strong visible light absorption of at least 5 m^2g^{-1} at 550 nm [*Bond and Bergstrom*, 2006], refractory with vaporization temperature near 4000 K [*Schwarz et al.*, 2006], aggregate morphology [*Medalia and Heckman*, 1969], and insolubility in water and common organic solvents [*Fung*, 1990]. Its absorption is consistent with a wavelength-independent refractive index across the visible spectrum [*Marley et al.*, 2001]. The combination of

Accepted Article

these properties distinguishes BC from other light absorbing material, such as some organic carbon compounds. The individual spherules are formed in flames, and the aggregate nature is caused by rapid coagulation [*Haynes and Wagner*, 1981], differentiating black carbon from planar graphite.

[3] In this assessment, the term 'black carbon' and the notation 'BC' is used to denote ambient aerosol material that has the above characteristics. The term 'black carbon' given here has not been used rigorously or consistently throughout all previous modeling and measurement literature, and as we discuss later in this section, most measurement techniques do not respond only to this substance. Measurements and nomenclature that uniquely identify this substance would assist in more rigorous evaluation.

2.2.2. Organic matter and other carbon aerosols

[4] 'Organic aerosol' (OA) is a broad term indicating carbon-containing compounds that contain hydrogen and, usually, oxygen. All sources that emit BC also emit primary organic aerosol (POA), as well as gases that may become secondary organic aerosol (SOA) in the atmosphere. In atmospheric chemistry, the combination of BC and OA is often called 'carbonaceous aerosol.' As used in this assessment, this term excludes primary organic particles directly emitted from plants [*Heald and Spracklen*, 2009] and organisms such as fungi and bacteria, which tend to be much larger in size than BC. It also excludes biogenic SOA, which may have small sizes but are emitted from natural, non-combustion sources [*Guenther et al.*, 2006]. This usage is consistent with previous IPCC reports [*Forster et al.*, 2007]. *Gelencser* [2005] further describes the chemical nature of OA. Mineral dust also contains carbon as carbonate, which is also not included in the carbon aerosol considered in this assessment.

[5] The term 'organic carbon' (OC) refers to the carbon mass within OA, excluding the associated oxygen and hydrogen content. Although OA is the quantity most relevant to climate, measurements and emission inventories have usually reported values of OC because it was more commonly measured. The ratio between OA and OC mass (OA:OC ratio) depends on the amount of oxygen incorporated in the organic molecules. It varies from about 1.1 to 2.2 [*Russell*, 2003], depending on the combustion source, with lower values of OA:OC from coal or diesel and higher values from biomass combustion. A default value for POA:OC of 1.3 or 1.4 is often assumed in global modeling [*Penner et al.*, 1998; *Dentener et al.*, 2006].

2.2.3. Other particulate light absorbers

[6] Two other types of atmospheric particles absorb visible light: dust and 'brown carbon.' Most of the dust in the atmosphere originates from deserts [*e.g.*, *Chin et al.,* 2009], and smaller amounts come from construction, on-road and off-road traffic, and agriculture. Dust particles are more weakly absorbing per mass than BC: about 0.009 m^2g^{-1} at 550nm for Asian dust [*Clarke et al.,* 2004]. They can be distinguished from BC particles because they are typically large (*i.e.,* greater than 2 μm in diameter), crystalline, and composed of crustal elements. They also have relatively more absorption at shorter wavelengths compared with long visible wavelengths. Although dust is more weakly absorbing than BC, globally averaged total absorption by dust is significant due to its relatively high mass abundance [*Sokolik and Toon*, 1996].

[7] Brown carbon, a subset of OA, is a complex mixture of organic compounds lacking a formal analytical definition. Its light absorption is weak, with MAC less than 1 m^2g^{-1} at 550 nm, and has a strong wavelength dependence [*Kirchstetter et al.*, 2004; *Chakrabarty et al.*, 2010]. This strong wavelength dependence can be used to distinguish its absorption from that of BC [*Wonaschütz et al.*, 2009]. Unlike BC, brown carbon is soluble in some organic compounds and responds to analytical techniques that use solubility to isolate humic-like substances [*Andreae and Gelencser*, 2006; *Graber and Rudich*, 2006]. Brown carbon particles and BC are similar in size.

2.3. Black carbon formation and evolution

[8] BC is produced during the combustion of carbon-based fuels when oxygen is insufficient for complete combustion. Even if adequate oxygen is supplied overall, fuel-rich, oxygen-poor zones can occur when the reactants are not well mixed. A complex

Accepted Article

series of reactions involving polycyclic aromatic hydrocarbon molecules forms precursors of BC. These precursors coagulate to sizes large enough to serve as particle nuclei and grow through reactions on the surface. Electron microscopy images show that these spherules are unique among atmospheric particles, with wrinkled graphite layers forming a shell around a hollow or disordered interior [*Heidenreich et al.*, 1968]. They have diameters on the order of tens of nanometers [*e.g., Martins et al.,* 1998a; *Posfai et al.,* 1999; *Li et al.,* 2003] and high carbon-to-hydrogen ratios. Soon after formation, the graphitic spherules coagulate to form aggregates or fractal chain-like structures consisting of hundreds or thousands of spherules [*e.g., Medalia and Heckman*, 1969; *Li et al.,* 2003] (Figure 2.1). If the combustion exhaust is kept hot, and if sufficient oxygen is well mixed with the flame products, these carbon particles may be eliminated by oxidation reactions before they leave the combustion chamber [*e.g., Lee et al.,* 1962]. Otherwise, they are emitted.

[9] The morphology of emitted chain-like aggregates changes rapidly after emission. Water vapor and other gas-phase species condense upon the aggregates, which collapse into more densely packed clusters [*Huang et al.*, 1994; *Ramachandran and Reist*, 1995; *Weingartner et al.*, 1997; *Martins et al.,* 1998b]. Other particulate and gas phase species present in the surrounding atmosphere also coagulate with the combustion aerosol. Electron microscopy images and measurements of optical properties indicate that freshly emitted particles often exist as an external mixture in which organic and inorganic light-scattering components and strongly light-absorbing components (BC) reside in different particles [*Posfai et al.,* 2003; *Li et al.,* 2003; *Mallet et al.*, 2004]. After emission, condensation and coagulation cause individual chemical components to become internally mixed (*i.e.,* different aerosol components existing together within a single particle). Such particles are no longer pure BC, but contain sulfate and organic material [*Lee et al.,* 2002; *Shiraiwa et al.,* 2007]. We refer to these internally mixed particles as 'BC-containing' particles. Mixing has been observed to occur within a few hours after emission at some locations [*Moteki et al.*, 2007; *Moffet and Prather*, 2009], but there are insufficient measurements to estimate the extent of internal mixing throughout the atmosphere. Global aerosol models that simulate microphysical processes predict that most BC is mixed with other substances within 1 to 5 days [*Jacobson*, 2001a] and this prevalent internal mixing is found at all altitudes [*Aquila et al.*, 2011].

[10] The top portion of Figure 2.2 summarizes particle properties that are used as input into global and radiative transfer models and that can be constrained by measurements. Each characteristic may affect the representation of atmospheric processes and resulting modeled concentrations, as shown in the lower portion of Figure 2.2. Pure BC and BC-containing particles are separated in Figure 2.2 because their microphysical, optical, hygroscopic and cloud-nucleating properties differ [*Abel et al.,* 2003; *Slowik et al.,* 2004]. For example, as BC ages, it becomes coated or internally mixed with non-BC components and the resulting BC-containing particles become more hydrophilic, which can lead to a reduced lifetime and atmospheric loading [*Stier et al.,* 2006a]. Internal mixing with other compounds can enhance absorption of solar radiation according to microphysical models [*Fuller et al.,* 1999; *Jacobson*, 2001a*; Lack and Cappa*, 2010] and measurements, primarily laboratory-based [*Schnaiter et al.,* 2005; *Slowik et al.,* 2007]. As a result, the additional material in BC-containing particles must be taken into account when modeling both radiative transfer and atmospheric lifetime [*Stier et al.,* 2006b].

[11] In the remainder of this section, we discuss the physical properties that affect estimates of climate forcing, measurements of these properties and representation of these properties in global models. We begin with a discussion of BC mass concentration in Section 2.4. Important optical properties of BC, including absorption, are discussed in Section 2.5, followed by a review of absorption measurements in Section 2.6. Section 2.7 reviews microphysical properties affecting the mass absorption cross-section and single-scattering albedo while Section 2.8 discusses measurements and modeling of these two parameters. Finally, Section 2.9 discusses properties of BC and BC-containing particles that are relevant to nucleating liquid cloud droplets. The discussion of microphysical properties, which also affect the interaction of BC-containing particles with ice clouds, appears in Section 6.5.

2.4. Measurement of BC mass

Accepted Article

[12] Ambient air samples of particles that contain BC always contain other constituents as well. The mass fraction of BC in atmospheric aerosol is typically less than 10%. Thus, BC mass concentration (in g m^{-3}) cannot be measured directly by collecting aerosol in an air sample and weighing it. Instead, BC mass must be determined indirectly, usually through optical methods, thermal heating combined with optical methods, or laser-induced incandescence (Table 2.1). BC is associated with high sp^2-bonded carbon content [*Hopkins et al.*, 2007] and with Raman spectroscopic responses similar to graphite [*Rosen et al.*, 1979; *Dippel et al.*, 1999], but these analyses do not respond uniquely to all materials identified as BC.

[13] The measurement of BC mass concentrations by some methods can be biased when BC is sampled with other aerosol components. This mixing can take place either within ambient aerosol particles before sampling, or in the sample itself if BC and other particles are collected and measured simultaneously. Biases occur either because the mixing increases absorption or extinction (see Section 2.6), because BC is incorrectly classified as another material, or because another material is incorrectly classified as BC (*i.e.,* lack of specificity). Most techniques measure similar BC mass concentrations when they are applied to pure BC or when other aerosol components are removed by applying heat [*Knox et al.,* 2009; *Kondo et al.*, 2009] or by solvent rinsing [*Subramanian et al.*, 2006]. For that reason, measurements of untreated samples are usually in closer agreement for diesel exhaust, which contains little non-BC material, than they are for aged (*i.e.,* internally mixed) aerosol [*Schmid et al.*, 2001; *Chow et al.,* 2004; *Hitzenberger et al.*, 2006] or biomass burning aerosol (BB), which has a high content of organic matter and other inorganic substances that could cause interferences [*Novakov and Corrigan*, 1995; *Reid et al.,* 1998]. The major uncertainty in some measurements of BC mass is associated with isolating BC from the other constituents with which it is internally or externally mixed. A summary of measurement techniques for BC mass is listed in Table 2.1 along with common terminology and any directions and causes of bias. In addition, more explicit names for the measured quantities are suggested; some of these follow *Andreae and Gelencser* [2006]. Details of the measurement of BC mass concentrations are given below.

[14] The most common separation between BC and OC is accomplished by volatilizing and combusting material collected on a filter and by detecting the CO_2 produced as a function of temperature. The discrimination between these two classes of aerosol is based on the idea that BC is non-volatile or refractory, whereas OC is volatile. This thermal method does not detect BC directly, and the amount of refractory material detected depends on the details of the method. The analytical result is therefore an operational definition and is traditionally called elemental carbon (EC).

[15] In thermal methods based on volatility, the sample filter is first heated in inert gas to volatilize OC and then heated again with oxygen to combust the EC; cooling sometimes occurs before the second heating [*e.g., Chow et al.,* 1993; *Birch and Cary,* 1996; *Watson et al.*, 2005]. This technique measures all OC, not just combustion-derived primary aerosol. Inaccuracies in this method result from interpreting OC as EC, or vice versa, when properties of the sample cause EC to be released too early or OC to be held too long. One complication is 'charring' of OC (*i.e.,* conversion of OC to EC) at high temperatures, which reduces its volatility. Variations of thermal methods include different temperature ramping programs, and correcting for the charring of OC during pyrolysis by monitoring the optical reflectance of the sample filter [*Huntzicker et al.,* 1982] or light transmission [*Turpin et al.,* 1990]. Comparisons among protocols with differing temperature and optical corrections show that derived EC concentrations can differ by over an order of magnitude [*Schmid et al.,* 2001], and that large differences can be caused by the lack of correction for charring, which leads to considerable overestimates of EC. There are also significant differences between methods that correct for charring using optical reflectance or light transmission [*Chow et al.,* 2001; *Chow et al.,* 2004]. The two corrections yield comparable EC concentrations if the filter contains a shallow surface deposit of EC. If EC and OC are distributed throughout the filter, the two corrections yield different EC values, and the variability also depends on the temperature protocol used. Hence, the difference between the two methods depends, in part, on the OC/EC ratio in the sample. As a result, the correction schemes yield similar results for diesel exhaust, which is dominated by EC, but can differ widely for complex atmospheric mixtures. Optimization

Accepted Article

of temperature programs seeks to minimize charring and release EC and OC during the expected period of the analysis [*Conny et al.*, 2003; *Cavalli et al.*, 2010]. The accuracy of thermal measurements can also be increased by extracting OC with organic solvents before analysis, since BC is insoluble [*Fung*, 1990; *Subramanian et al.*, 2006].

[16] Detection of refractory BC (rBC) mass by laser-induced incandescence (*i.e.,* visible thermal radiation) has become increasingly widespread [*Schwarz et al.,* 2006, 2008a; *Moteki and Kondo*, 2010]. The Single Particle Soot Photometer (SP2) is able to provide continuous, real-time, size and coating information for individual particles containing rBC over a wide dynamic range of mass concentration. In the SP2, the rBC component of individual particles is heated to vaporization temperatures (*i.e.,* about 4000K) with an infrared intracavity laser, and incandescence proportional to rBC mass is detected. Essentially all rBC particles between 80 and 700 nm mass-equivalent diameter (MED) are measured, assuming void-free rBC has a density of 2 g cm^{-3}. The response of the SP2 to rBC mass and the lack of interference in measuring rBC mass when non-rBC aerosol components are present have been evaluated in the laboratory [*Schwarz et al.,* 2006; *Slowik et al.,* 2007; *Moteki and Kondo,* 2007]. The dominant uncertainty in the measured mass lies in calibrating its sensitivity to ambient rBC material. The range of this sensitivity is around 15% [*Moteki and Kondo*, 2010; *Laborde et al.*, 2012]. However, the limitations of the size range detected by the SP2 may introduce additional uncertainty, depending on the airmass. Typically, in remote regions the size range captured by the SP2 contains most of the rBC mass and about 50% of the rBC number [*Schwarz et al.,* 2008b; *Shiraiwa et al.,* 2008]. In urban environments a correction to total measured mass concentration of about 25% may be required. Pulsed laser-induced incandescence has also been used for environmental rBC measurements [*Chan et al.*, 2011].

2.5. Optical properties of black carbon

[17] Models of radiative transfer require the amount of particulate absorption and scattering in the atmosphere, known as the absorption and scattering coefficients (m^2 m^{-3} or simply m^{-1}). Atmospheric models convert modeled mass concentrations to these optical coefficients using intensive properties (*i.e.,* optical cross-section per mass in m^2g^{-1}) known as the mass absorption cross-section (MAC) and mass scattering cross-section (MSC). Estimates of these values are needed at all wavelengths, and the directional distribution of scattering (dimensionless) is also needed for radiative transfer models.

[18] From atmospheric measurements, MAC can be calculated in reverse: the light-absorption coefficient divided by mass concentration. Throughout this assessment, we often refer to MAC that is determined for BC alone (MAC_{BC}). MAC_{BC} is calculated by dividing the absorption coefficient attributable to BC by the BC mass concentration. The simple term MAC indicates the value determined by dividing by the total mass concentration of BC-containing particles, which is smaller than MAC_{BC}. All other properties are usually measured for BC-containing particles, not for pure BC. Optical properties depend on refractive index, density, size distribution, mixing state and particle shape. The propensity for water uptake affects the MSC and MAC of BC-containing particles, as well as their ability to form cloud droplets and their atmospheric lifetime due to removal by precipitation. For sub-saturated conditions (*i.e.,* relative humidity below 100%), this water uptake is characterized in terms of hygroscopicity or growth factor. When air is supersaturated, the climate-relevant quantity is the fraction of particles that act as CCN [*Hallett et al.*, 1989].

[19] The MAC was mentioned earlier as a distinguishing feature of BC. Values of MAC and MSC are fundamental inputs to radiative transfer models, required for all aerosols or aerosol components. These quantities are necessary to translate mass concentrations simulated by chemical transport models to their effects on radiative transfer. The wavelength-dependence of MAC must also be represented in models for the full solar spectrum. As its name implies, BC strongly absorbs light at all visible wavelengths. In contrast, other atmospheric aerosols that absorb light (OA, soil, and dust) are more yellow, brown or red, meaning they absorb more blue light than red light. The quantity generally used to characterize the spectral dependence of light absorption is the absorption Ångstrom exponent:

Accepted Article

$$Å_{abs} = -\log(MAC(\lambda_1)/MAC(\lambda_2)) / \log(\lambda_1/\lambda_2) \quad (2.1)$$

where $MAC(\lambda_1)$ and $MAC(\lambda_2)$ are the mass absorption cross sections at wavelengths λ_1 and λ_2, respectively. Two wavelengths spanning the visible range are commonly used, such as 450 and 650 nm. Alternatively, $Å_{abs}$ can be calculated from absorption coefficients at the two wavelengths. The value of $Å_{abs}$ for particles is usually greater than that of the bulk material. If the bulk material has no absorption wavelength dependence ($Å_{abs} = 0$), as does graphite [*Borghesi and Guizzetti*, 1991], then $Å_{abs} = 1$ for particles much smaller than the wavelength of light [*Rosen et al.*, 1979; *Moosmüller et al.*, 2011].

[20] Measurement studies have confirmed the value of $Å_{abs} = 1$ in regions where externally mixed BC dominates absorption [*Rosen et al.,* 1978; *Bergstrom et al.,* 2002, 2007; *Kirchstetter et al.,* 2004; *Clarke et al.,* 2007]. When BC becomes coated, $Å_{abs}$ can theoretically be as low as 0.8 or as high as 1.9 [*Lack and Cappa*, 2010]. In contrast, $Å_{abs}$ for OA has been observed to be between 3.5 to 7 [*e.g. Kirchstetter et al.,* 2004; *Sun et al.,* 2007; *Lewis et al.,* 2008; *Yang et al.,* 2009]. $Å_{abs}$ for dust is typically about 2 to 3, but can be higher for very red (iron-rich) dust [*e.g., Fialho et al.,* 2006; *Alfaro et al.,* 2004; *Bergstrom et al.,* 2007]. This difference in the wavelength-dependence of absorption of BC versus other absorbing aerosol has been used to approximate relative fractions of BC versus other light-absorbing constituents.

[21] The single-scattering albedo, $\square_0$, is scattering divided by extinction (*i.e.,* the sum of scattering and absorption), or

$$\omega_0 = MSC / (MSC + MAC) \quad (2.2)$$

Values of ω_0 near one indicate that the aerosol is mainly scattering. Values below about 0.8 indicate that the particles could have a net warming effect [*Haywood and Shine,* 1995]. The value that divides warming from cooling also depends on the albedo of the underlying surface or clouds and the fraction of light that is scattered upward by the particles [*Chyìlek and Wong*, 1995]. When the addition of aerosol causes a local increase in the planetary albedo, more shortwave radiative energy is reflected back to space, and aerosol exert a negative forcing. In contrast, when aerosols locally decrease the planetary albedo, the forcing is positive. MAC and ω_0 are the aerosol properties most relevant to the balance between negative and positive forcing, so we emphasize these two parameters in this section instead of MSC. Forcing is not very sensitive to ω_0 for strongly absorbing aerosol with values below 0.4.

2.6. Measurement of absorption coefficients

[22] Comprehensive reviews of absorption measurements have been provided by *Horvath* [1993] and by *Moosmüller et al.* [2009]. Here we summarize only the major challenges in these measurements. The most widely used technique to measure the absorption coefficient involves collecting aerosol on a filter and inferring atmospheric absorption from the resulting change in transmission of light through the filter [*Gundel et al.*, 1984], often at one mid-visible wavelength but sometimes at multiple wavelengths. Common instruments using this approach are the Particle Soot Absorption Photometer (PSAP) [*Bond et al.,* 1999; *Virkkula et al.,* 2005], which has been used to obtain a worldwide data base through the Global Atmospheric Watch program; the Hybrid Integrating Plate System (HIPS), which has been used to collect data by the Interagency Monitoring of Protected Visual Environments (IMPROVE) in U.S. National Parks [*Malm et al.,* 1994]; and the Aethalometer [*Hansen et al.,* 1982]. Other filter-based absorption instruments include the Integrating Plate [*Lin et al.,* 1973], and the Multi-Angle Absorption Photometer (MAAP) [*Petzold et al.,* 2005a]. These filter-based methods overestimate absorption if light transmission is also affected by particulate light scattering [*Horvath*, 1997*; Bond et al.,* 1999]. With the application of empirical corrections to overcome this artifact, accuracies of the PSAP, IP, HIPS, and Aethalometer range between 20 and 30% [*Bond et al.,* 1999; *Weingartner et al.,* 2003, *Virkkula et al.,* 2005], and accuracy of the MAAP is about 12% [*Petzold et al.*, 2005a]. However, these correction schemes are based on laboratory-generated aerosols that may limit their application and accuracy for the measurement of atmospheric aerosols. In addition, coating of BC with volatile compounds can greatly contribute to variation in filter-based measurements of light absorption [*Lack et al.*, 2008; *Cappa et al.,* 2008; *Kondo et al.,* 2009]. For example, PSAP absorption coefficients can be biased high (50 to

Accepted Article

80%) when the ratio of organic aerosol to BC is high (15 to 20). *Lack et al.* [2008] postulated that this high bias was due to the redistribution of liquid-like OC that affected either light scattering or absorption. This difficulty can be overcome by removing most of the mass of volatile aerosol components before the BC particles are collected on filters. This removal can be accomplished without significant charring of organic compounds with a heated sampling inlet. This technique is used for the Continuous Soot Monitoring System (COSMOS) instrument [*Kondo et al.,* 2011a]. Under those conditions, comparisons of ambient BC mass concentrations measured by light absorption (COSMOS), thermal-optical measurements, and laser-induced incandescence (*i.e.,* SP2) measurements have been found to agree within 10% [*Kondo et al.,* 2011a].

[23] Filter-based optical measurements of absorption are sometimes used to derive 'effective' BC mass concentrations by using an assumed MAC_{BC} to convert measured absorption to BC mass [*e.g., Sharma et al.,* 2002]. Given the artifacts and uncertainties associated with filter-based measurements and the choice of MAC_{BC}, the resulting BC mass concentrations also can be highly uncertain.

[24] Techniques that do not use filters are also available for the measurement of absorption by BC. In the photoacoustic spectrometer (PAS) [*Petzold and Niessner*, 1996; *Arnott et al.,* 1997; *Lack et al.,* 2006], particles are drawn into an acoustic cavity and irradiated by power-modulated laser light. The heat that is produced when the particles absorb laser light is transferred to the surrounding gas creating an increase in pressure. Sensitive microphones are used to detect the standing acoustic wave that results from the pressure change, and this signal is interpreted to infer the absorption coefficient. Gas phase absorbers can interfere with BC detection in PAS systems. The overall uncertainty of the PAS with respect to aerosol absorption has been reported at about 5% [*Lack et al.,* 2006].

[25] Absorption techniques, whether filter-based or non-filter based, are not specific for BC. Any light-absorbing aerosol other than BC that absorbs at the measurement wavelength is detected. The degree to which other light absorbing species interfere with the measurement of BC absorption depends on the relative abundance of light absorbing species and the size range and wavelength of the measurement. Measurement of the chemical composition of the aerosol and measurement of absorption at several wavelengths can help determine the interference from all atmospheric species. BC-containing aerosol generally fall into the submicron size range, so measurements of the submicron aerosol only can also reduce the interference of dust absorption.

2.7. Microphysical properties affecting MAC and ω_0

2.7.1. Optical models and required inputs

[26] Values of MAC and ω_0 can be predicted with several theories that describe how the particles interact with light. Particle density and refractive index of the bulk material are required to calculate MAC for all models. The assumed particle shape and size affect the model chosen. Common optical-modeling treatments that account for the fractal nature of fresh BC particles include the Rayleigh-Debye-Gans approximation [*Nelson*, 1989; *Dobbins and Megaridis*, 1991], superposition T-matrix theory [*Mishchenko et al.*, 2004], and discrete-dipole approximation [*Draine and Flatau*, 1994]. *Sorenson et al.* [2001] reviews many of the key optical relationships for aggregates. These models are useful for exploring how particle properties affect particle optics [*e.g., Liu and Mishchenko*, 2005].

[27] Global-model calculations of radiative transfer usually do not account for complex particle shapes. Instead, they use Mie theory, which can describe homogeneous or core-shell spherical particles. Although BC particles, especially freshly emitted ones, are not spherical, modeling radiative transfer accurately requires only that MAC, ω_0, and angular scattering are correct.

[28] BC nonsphericity creates difficulties in inferring other properties used in optical modeling from measurements. Air drag is different between spherical and non-spherical particles and affects inferences of particle size based on mobility [*Lall and Friedlander,* 2006]. The SP2 measurement detects BC mass and provides equivalent spherical diameters. Inferences of refractive

Accepted Article

index are often taken from optical measurements with the assumption of spherical particles, or from particles that are collected and compacted into a pellet. In either case, the material is not pure BC, but contains an unknown fraction of voids. Ideally, the refractive index, density and size used for modeling would be obtained for the pure material, but observed properties may be obtained for material with unknown and inconsistent void fractions. Despite these uncertainties, measurements of material properties and sizes are described below.

2.7.2. Density

[29] *Fuller et al.* [1999] compiled reported densities for several types of graphitic material and found values ranging from 0.625 to 2.25 g cm^{-3}. Based on the type of BC emitted from diesel combustion, they adopted the highest density, which was measured for paracrystalline graphite, as representative of strongly absorbing atmospheric BC. BC is not perfectly crystalline, so its microstructure, density, and refractive index differ from those of graphite. The density of pure graphite is 1.9 to 2.1 g cm^{-3} [*Hess and Herd*, 1993]. Densities for pressed pellets of BC with corrections for air volume fractions in the surface layer are slightly lower at 1.8 to 1.9 g cm^{-3} [*Medalia and Richards*, 1972; *Janzen*, 1980]. *Park et al.* [2004] reported a density of 1.8 g cm^{-3}, and *Kondo et al.* [2011a] found 1.718 ± 0.004 g cm^{-3} for fullerene soot. Some global models still use the density of 1 g cm^{-3} recommended by OPAC (Optical Properties of Aerosols and Clouds), which would result in an overestimate of absorption if all other factors are correct.

2.7.3. Refractive index

[30] The refractive index of a material is critical in determining the scattering and absorption of light, with the imaginary part of the refractive index having the greatest effect on absorption. Refractive index values are derived by assuming a theory for the interaction of BC with light (*i.e.,* reflectance or absorption) and adjusting optical parameters (including refractive index) until predictions match measurements. Three possible methods include: 1) fitting Fresnel's formula to reflectance and transmittance data measured for a compressed pellet; 2) fitting Mie theory to light-scattering data for individual spherical particles; and 3) fitting either Mie theory or an approximation formula to scattering and extinction data for particle ensembles. Method 1 has been used widely to estimate refractive indices of solid aerosols like combustion-generated BC [*Mullins and Williams,* 1987]. However, direct evidence of the optical flatness of pellet surfaces, which is necessary for application of Fresnel's formula, has never been shown for wavelengths shorter than the infrared region [*Janzen,* 1979]. Method 2, which is limited to spherical particles, uses measurements of resonance structures in Mie scattering to determine the refractive index [*Chýlek et al.,* 1983a] but its application to strongly absorbing particles is limited. In method 3, the refractive index and a size distribution function are inferred simultaneously from extinction or scattering data for an ensemble of particles. Solving this inversion problem requires a theory to connect microphysical and light-scattering properties; Mie theory has been used for spherical particles [*Lack et al.,* 2009] and the Rayleigh-Gans approximation for nonspherical particles [*Charalampoulos et al.,* 1989; *Van-Hulle et al.,* 2002]. For polydisperse or nonspherical particles, the inversion results may have large errors if the assumed size distributions or shapes differ from those of the actual particles. *Moteki et al.* [2010] developed a method to estimate refractive indices that accounted for non-spherical particles by measuring the relationship between the scattering cross-section and the particle volume.

[31] A variety of values for the refractive index of BC has been used in global climate models including the OPAC value of 1.74 - 0.44*i* [*Hess et al.,* 1998]. As reviewed by *Bond and Bergstrom* [2006], reported values of the refractive index of light absorbing carbon vary widely; the real part, *n,* appears to vary from that of water to that of diamond and the imaginary part, *k,* varies from that of negligibly absorbing material to that of graphite. *Bond and Bergstrom* [2006] hypothesize that strongly absorbing carbon with a single refractive index exists and that some of the variation in reported values results from void fractions in the material. Based on agreement between measured real and imaginary parts of the refractive index of light absorbing carbon, *Bond and Bergstrom* [2006] recommended a value of 1.95 – 0.79*i* at 550 nm. They caution, however, that this value may not represent void-free carbon. *Stier*

Accepted Article

et al. [2007] found that this value led to better agreement with observed atmospheric absorption, compared with the OPAC value. *Moteki et al.* [2010] found that the refractive index of ambient BC in the Tokyo urban area was about 2.26 – 1.26*i* at 1064 nm. The OPAC assumption for imaginary refractive index is not taken from combustion-generated particles, is lower than either of the latter two recommendations, and would lead to a MAC prediction about 30% lower if all other factors were equal.

[32] Radiative inversion methods can also infer values of refractive indices from remote-sensing measurements [*Dubovik and King,* 2000], but only for the entire mixed aerosol, which includes water and many other constituents other than BC. Currently, such data are available from about 500 globally distributed Aerosol Robotic Network (AERONET) surface sites [*Holben et al.,* 1998].

2.7.4. Particle Size

[33] Size distributions of the BC component in ambient aerosol are affected by the size of BC at emission and by subsequent coagulation. Condensation of non-BC material changes the overall aerosol size distribution, but the underlying size distribution of BC does not change except through coagulation. BC size can be diagnosed separately. The first measurements of ambient BC size distributions relied on impactors, which identify the size at which greatest mass appears [*Mallet et al.*, 2003; *Riddle et al.*, 2008]. SP2 measurements have provided BC number distributions in fresh urban plumes dominated by fossil-fuel (FF) combustion [*e.g., Kondo et al.,* 2011a; *Schwarz et al.,* 2008b], in aged plumes in Asian outflow [*Shiraiwa et al.,* 2008], and in the remote upper troposphere and lower stratosphere [*Schwarz et al.,* 2006; 2008b]. In the urban areas of Tokyo and Nagoya (Japan) and Seoul (Korea), the mass median diameter (MMD) and count median diameter (CMD) of fresh BC ranged from 120 to 160 nm and 50 to 80 nm, respectively. In plumes associated with wildfires, the MMD was measured to be about 200 nm and the CMD to be 120 nm [*Kondo et al.*, 2011b]. The distinct difference in the size between BC particles from fossil-fuel combustion and biomass burning seems to be a general feature (Figure 2.3). The CMD and MMD of BC observed in the Asian outflow were significantly higher than those in fresh urban plumes [*Shiraiwa et al.,* 2008], suggesting the growth of BC size by coagulation during transport after emissions. BC particles are largely found in the Aitken mode (*i.e.,* less than 100-nm diameter) and the accumulation mode because of their formation mechanism. Large concentrations of BC in the Aitken mode can result from high combustion temperatures and efficient fuel burn. For example, BC particles produced by aircraft jet engines have mean number diameters of about 30 nm [*Petzold et al.,* 2005b].

2.7.5. Configuration of BC-containing particles

[34] Internal mixing between BC and other compounds increases absorption of visible light, in part because the non-absorbing material can refract light toward the absorbing particle [*Ackerman and Toon*, 1981]. Because BC is insoluble, it is always distinctly separated from the other material in an internally mixed particle. It is often assumed that non-BC material surrounds the BC completely and approximately symmetrically, known as a 'core-shell' configuration. However, BC may also exist near the surface of the particle [*Sedlacek et al.*, 2012]. The presence, relative quantities, and location of non-absorbing material in BC-containing particles require a complex characterization commonly summarized in the single term 'mixing state.'

2.8 Measured and modelled MAC and ω_0

[35] As discussed above, optical models can either represent aggregates, or they can rely upon Mie theory with the assumption of spherical particles. Here, we review measured values of MAC_{BC} and ω_0, and discuss whether models can simulate these values.

2.8.1. MAC_{BC} derived from measurements

[36] Empirical values of MAC_{BC} have been obtained from measurements of light absorption by filter or photoacoustic methods, divided by measurements of EC mass from thermal evolution methods [*e.g., Martins et al.,* 1998a; *Moosmüller et al.,* 2001]. Measured values for freshly generated BC, where care has been taken to eliminate non-BC material, fall within a relatively narrow

Accepted Article

range of 7.5 ± 1.2 m^2g^{-1} [*Clarke et al.,* 2004; *Bond and Bergstrom,* 2006]. The MAC_{BC} may be reduced as the particles collapse into more compact forms with higher fractal dimensions [*Schnaiter et al.*, 2003; *Lewis et al.*, 2009]. Instrumental artifacts, as shown in Table 2.1, can hamper accurate inferences of MAC_{BC}.

[37] Laboratory measurements show that absorption increase is low for very thin coatings [*Slowik et al.,* 2007] and reaches a factor of 1.8 to 2 for thicker coatings [*Schnaiter et al.,* 2005; *Khalizov et al.* 2009; *Shiraiwa et al.,* 2010; *Cross et al*., 2010; *Bueno et al.*, 2011]. Filter-based and photoacoustic measurements report different degrees of enhancement in the measured absorption [*Slowik et al.,* 2007; *Knox et al.*, 2009].

[38] Values of MAC_{BC} enhancement are harder to confirm for atmospheric aerosol, and require measuring MAC_{BC} before and after removal of coatings. *Knox et al.* [2009] found enhancement by a factor of 1.2 to 1.6 near source regions. *Lack et al.* [2012] observed a factor of 1.4 enhancement for BC in biomass burning plumes. In contrast, similar measurements of absorption enhancement using a PAS in large urban centers revealed an average absorption enhancement of only 6%, although the MAC_{BC} of aged aerosol was 20 to 40% higher than that of freshly generated BC [*Cappa et al.,* 2012]. *Cappa et al.* hypothesize that the low values of enhancement are caused by BC inclusions at the edge of the sampled particles. Measurements made downwind (up to hundreds of kilometers) of BC source regions also give a wide range of enhancements. *Chan et al.* [2011] found MAC_{BC} values ranging from 10 to 50 m^2g^{-1}, showing a rough relationship with the ratio between non-BC and BC components. This study, which derived time-resolved MAC_{BC} from a photoacoustic spectrometer and laser-induced incandescence instrument system, appeared to contradict earlier work by the same group [*Chan et al.*, 2010] that found no apparent increase in MAC_{BC} using a PSAP to measure absorption and thermal-optical technique to measure EC. MAC_{BC} values inferred from filter-based techniques are more plentiful but may suffer from artifacts; *Cheng et al.* [2011] summarized MAC_{BC} from several studies ranging from 2 to 17 m^2g^{-1}, but used empirical correction factors to adjust some of the methods prior to calculating MAC_{BC}. A series of intensive experiments with identical sampling and analysis protocols gave MAC_{BC} values ranging from 6 to 20 m^2g^{-1} [*Quinn and Bates,* 2005].

[39] Most of the above measurements of MAC_{BC} after mixing with non-BC material were made under dry conditions or at relatively low humidity. However, water is also a component of mixed aerosols, both in clear air at high relative humidity and in clouds. Particles that have taken up water become even larger than mixed, dry atmospheric particles, but measurements at such elevated humidities are difficult. *Mikhailov et al.* [2006] measured a three-fold increase in absorption of BC at 100% relative humidity. *Brem et al.* [2012] also found an amplification factor of up to 2.7 for an absorbing organic material at 95% relative humidity.

2.8.2. Microphysical model ability to simulate MAC

2.8.2.1. MAC_{BC} of unmixed BC

[40] Particle size distribution has almost no influence on calculated MAC when particle diameter is below about 80 nm [*Bergstrom*, 1973]. The simplest theory that accounts for aggregate particles indicates that MAC depends only on the size of the component spherules. Therefore, modeled MAC_{BC} should not be very sensitive to particle size if either small, spherical particles are assumed, or if modeled aggregates are composed of spherules below 80 nm. However, measured MAC_{BC} values, at 7.5 ± 1.2 m^2g^{-1}, are about 30% higher than values calculated with either method, using best estimates of refractive indices and density. This comparison remains unchanged even with the higher refractive index values found by *Moteki et al.* [2010]. *Bond and Bergstrom* [2006] suggest that the 30% higher absorption of actual particles could be caused by interactions between neighboring BC spherules [*Iskander et al.,* 1991; *Fuller*, 1995]. *Liu and Mishchenko* [2005] calculated a 15 to 25% increase for many changes in aggregate parameters, compared with no interaction, but up to 20% decrease for spherule sizes larger than 30 nm. *Kahnert* [2010] showed that spherule interaction alone could not account for the discrepancy of 30%, and MAC modeled by *Adachi et al.* [2010] was similar for

Accepted Article

aggregates and spheres. The inability of microphysical models to reproduce measured MAC from best estimates of refractive index and density remains unresolved.

[41] Although MAC_{BC} is sensitive to the large differences in both refractive index and density used by different models, *Bond and Bergstrom* [2006] note some compensating errors. For models using OPAC refractive index and density, the low refractive imaginary index would underestimate MAC_{BC}, while the low assumed density (1 g cm^{-3}) would overestimate it. Therefore, the MAC_{BC} simulated with the OPAC refractive index and density is comparable to MAC using the values of refractive index and density recommended by *Bond and Bergstrom* [2006], although the model inputs are quite different. However, it may not be possible to simulate MAC and ω_0 of mixed particles using these erroneous values.

2.8.2.2. MAC of BC mixed with other substances

[42] Internal mixtures of BC and non-absorbing material, including water, are usually modeled either as a core-shell configuration, or as a homogeneous particle for which the effective refractive index is obtained using 'mixing rules.' Some frequently used mixing rules are volume mixing, in which refractive indices are proportional to substance volume; Bruggeman or Maxwell-Garnet effective medium approximations [*Heller*, 1965]; or the dynamic effective medium approximation [*Chýlek et al.*, 1996].

[43] Different representations of mixing often produce comparable estimates of absorption. For example, using the *Bond and Bergstrom* [2006] refractive index and density, *Adachi et al.* [2010] calculated MAC_{BC} for uncoated spheres as 6.4 m^2g^{-1}, with increases for volume mixing (13.6 m^2g^{-1}), core-shell (13.3 m^2g^{-1}), Maxwell-Garnet effective medium approximation (12.0 m^2g^{-1}), and realistic coated BC particles (9.9 m^2g^{-1}) at 550 nm wavelength. The assumption of a perfectly concentric core within a shell gives the highest absorption among core-shell particles [*Fuller*, 1995]. However, *Jacobson* [2006] showed that the dynamic effective medium approximation suggested for cloud droplets produced a much higher MAC_{BC} than a core-shell treatment. The absorption efficiency of BC may also be higher when it is coated by water, such as in cloud droplets (Section 6.3.3).

[44] The optics of mixed particles vary widely in space and time because they depend on the relative concentrations of BC and non-BC components, which may include water, liquid and solid components. A single value of MAC for an internally mixed aerosol is not appropriate due to the widely varying amounts of non-absorbing material surrounding BC cores. *Moffet and Prather* [2009] estimate that the increase above unmixed aerosol could be 80 to 200% for individual particles. This increase depends upon the relative sizes of the shell and the core, and the location of the core within the particle [*Fuller,* 1995]. *Bond et al.* [2006] suggest a smaller enhancement, concluding that MAC_{BC} is 80% higher for mixed than for unmixed spheres. However, because the absorption of aggregate BC appears to be 30% higher than that of spheres, the increase between uncoated, aggregate BC to coated, mixed spherical particles might be only 50%. The MAC_{BC} of 7.5 m^2g^{-1} for freshly emitted BC, plus an enhancement of 50%, agrees approximately with observed MAC_{BC} at dry conditions. A more precise evaluation of the agreement between models and observations is hampered by artifacts in the measurements.

2.8.3. Measured and modeled single-scattering albedo

[45] Single-scattering albedo of freshly generated BC has been measured as 0.10 to 0.28, as summarized by *Bond and Bergstrom* [2006]. *Khalizov et al.* [2009] and *Cross et al.* [2010] report similar values of ω_0 for fresh BC. Models of aggregate, pure-BC particles predict ω_0 of 0.1 to 0.3 [*Liu and Mishchenko*, 2005]. This value depends strongly on component spherule size but not on overall particle size [*Sorensen*, 2001]. Scattering and ω_0 for spherical BC depend greatly on the size distribution chosen. For example, ω_0 for particles of 50 and 250 nm diameter is 0.02 and 0.44, respectively, for a refractive index of $1.95 - 0.79i$. Forcing by BC scattering is small compared to that by BC absorption, so small variations in ω_0 produce only small changes in total forcing.

[46] As BC becomes mixed with other components, a large increase in scattering and, hence, in ω_0 occurs [*Khalizov et al.*, 2009; *Cross et al.*, 2010]. For mixed particles, values of ω_0 range from that of fresh particles to 0.9, depending upon the amount of added

Accepted Article

material. For these particles, forcing can be quite sensitive to ω_0. However, much of the added scattering and the tendency toward negative forcing are attributable to other chemical components, not to BC. Therefore, the forcing by BC alone should be estimated with the difference of two radiative-transfer scenarios, not just the change in ω_0.

2.8.4. Aerosol properties in global models

[47] In global simulations of radiative transfer, BC particles are assumed to be either externally or internally mixed with other aerosol components. For external mixing, the material properties of pure BC are used. If internal mixing is assumed, the non-BC material is either treated as a spherical shell around a BC core, or the refractive index and density of BC and non-BC material are averaged and a homogeneous particle is modeled. *Koch et al.* [2009a] summarize predicted MACBC and treatments of aging, removal, optical properties for many global models.

[48] All global models consider how aging affects removal rates of BC. Early models of atmospheric BC expressed the aging of BC by prescribing a timescale for converting hydrophobic BC to hydrophilic BC, typically about one day [*Koch et al.,* 2009a]. Many models have evolved to express aging explicitly in terms of coagulation with sulfate particles and condensation of sulfuric acid and secondary organic vapor on BC. Some models represent BC-containing aerosol with discrete size-resolved bins [*Jacobson*, 2001a]. Others, known as "multi-modal" models, represent different aerosol classes, such as unmixed BC and BC coagulated with other material [*Whitby and McMurry*, 1997]. Representations of removal rates vary from constant empirical values, to parameterization based on composition and particle number [*Abdul-Razzak and Ghan*, 2000], to explicit dependence on aerosol and cloud droplet size and composition [*Jacobson*, 2002].

[49] Although global models of BC consider mixing when determining removal rates, some do not incorporate enhanced MAC_{BC} due to mixing. Values of MAC_{BC} used in global models range from 2.3 to 18 m^2g^{-1} [*Koch et al.,* 2009a; Jacobson, 2012]. The diversity in MAC_{BC} arises either from whether the mixing state is assumed or calculated, whether it is determined at ambient RH or constant RH, and from other choices of aerosol properties. Many of the values are similar to or lower than the value for unmixed BC and are, therefore, lower than the average value of BC in the atmosphere.

2.9. CCN activity of black carbon

2.9.1. Measurements of CCN activity

[50] Particle size, hygroscopicity, and mixing state also affect the interaction of particles and clouds [*Pruppacher and Klett,* 1997; *McFiggans et al.*, 2006]. While BC-induced cloud changes are mainly discussed in Section 6, we review the processes of CCN activation here because they are closely related to the microphysical properties of BC-containing aerosol.

[51] Aerosol particles serve as nucleation sites for forming cloud droplets through a process known as *activation*. The ability of an aerosol particle to act as a cloud condensation nucleus depends on its size, composition, and mixing state, and the supersaturation with respect to water vapor within the cloud. The *critical supersaturation* for a given particle is the lowest supersaturation at which that particle activates and produces a cloud droplet. Any particle can activate in extremely supersaturated air. Particles that activate more easily (*i.e.,* that have a lower critical supersaturation) have a greater chance of affecting cloud droplet number concentration and cloud reflectivity, and they may also be more easily removed by wet deposition. Early studies found that soluble species were incorporated in cloud droplets more often than BC [*e.g., Hallberg et al.*, 1994], but could not confirm whether this was caused by differences in activation or in scavenging.

[52] If all other factors are equal, small particles require greater supersaturation to activate than do large particles. Less hygroscopic particles have larger critical supersaturations than more hygroscopic particles. Because freshly emitted BC particles are small in diameter and hydrophobic, they have very large critical supersaturations and make very poor CCN [*Dusek et al.*, 2006a]. Aging of BC after emission lowers the critical supersaturation of the BC-containing particle, as the addition of soluble

Accepted Article

mass increases both particle volume and hygroscopicity. Figure 2.4 shows the dependence of the critical supersaturation on particle diameter and BC mass fraction as simulated by a particle-resolved model [*Riemer et al.,* 2009]. For a given particle size, a higher BC mass fraction increases the critical supersaturation, although particle size has a stronger effect on CCN than does chemical composition [*Dusek et al.*, 2006b].

[53] 'Closure' studies compare measured CCN concentrations with values predicted from particle size and composition, assuming that only soluble components serve as CCN. Predicted CCN concentrations are usually greater than measured values, with large variability in the degree of agreement [*Medina et al.*, 2007]. This overprediction is worse with a mixture of hydrophobic and hygroscopic particles [*Wex et al.*, 2010]. Near source regions, externally mixed BC plays little role in CCN [*Rose et al.*, 2011] and closure is improved when externally mixed BC is assumed not to be CCN-active [*Lance et al.*, 2009]. However, closure studies to date have insufficient precision to confirm the contribution of coated BC to CCN. A comparison of heated and unheated particle size distributions can indicate the quantity of non-refractory material in atmospheric particles [*Sakurai et al.,* 2003; *Philippin et al.,* 2004; *Kuwata et al.,* 2007]. Figure 2.5 shows the relationship between the condensed mass per particle and the CCN activity of 100-nm BC particles observed in Tokyo [*Kuwata et al.,* 2009]. The number fraction of CCN-active BC particles increases with increasing condensed mass, indicating that 0.18×10^{-15} g of condensed coating material is required to activate these BC-containing particles at 0.9% supersaturation. In this case, the condensed compounds were primarily organic.

2.9.2. Global model treatment of CCN activity

[54] Treatment of BC in global climate models (GCMs) does not always reflect the theoretical dependence on size and soluble fraction. In some GCMs, the activation of BC to form cloud droplets is not considered at all. The simplest formulation, a *mass-based* parameterization, assumes that the number of cloud droplets activated is empirically related to the submicron aerosol mass. In turn, that mass is determined from the hydrophilic aerosol species sulfate, submicron sea salt, and hydrophilic carbonaceous aerosol, where carbonaceous aerosol is the sum of OA and BC [*Rotstayn et al.,* 2009]. This simple parameterization ignores differences in activation for particles of different sizes and composition. Many models have advanced to represent this behavior. Cloud droplet number concentration is sometimes empirically related to aerosol number concentration of certain sizes and to updraft velocities [*Lohmann et al.,* 2007]. Parameterizations of cloud droplet formation derived from Köhler theory have been developed by *Abdul-Razzak and Ghan* [2000] and *Nenes and Seinfeld* [2003]. In these schemes, dependence on size and hygroscopicity can be taken into account, including the competition between different types of particles. For example, large hygroscopic particles take up water, reduce supersaturation and, therefore, result in less activation of smaller or less hygroscopic particles such as those containing BC [*Ghan et al.,* 1998]. Models of greater complexity represent size-resolved incorporation of aerosols in cloud droplets and their removal [*Jacobson*, 2006]. Section 6 describes studies of BC effects on clouds using some of these advanced representations.

3. Emission magnitudes and source categories

3.1. Section summary

[1]

1. Global emission estimates use the 'bottom-up' method of multiplying emission factors by activity data. With this method, a bottom-up estimate of total global emissions in the year 2000 is about 7500 Gg BC yr^{-1}, with an uncertainty range of 2000 to 29000 Gg yr^{-1}. About 4800 Gg BC yr^{-1} is from energy-related burning, with the remainder of about 2800 Gg BC yr^{-1} from open biomass burning. Total primary organic aerosol (POA) emissions excluding biogenic matter are 47000 Gg POA yr^{-1} for the global total, with an uncertainty range of 18000 to 180000 Gg POA yr^{-1}. Energy-related burning and open burning produce 16000 and 31000 Gg POA yr^{-1}, respectively; the largest uncertainties are in open burning.

Accepted Article

2. Industrial-era emissions are the difference between present-day and the pre-industrial background year, 1750. These values are 6100 Gg BC yr^{-1} (4400 Gg BC yr^{-1} from energy-related burning and the remainder of about 1700 Gg BC yr^{-1} from open burning) and 33000 Gg POA yr^{-1} (14000 Gg POA yr^{-1} from energy-related sources and the rest from open burning).

3. Black-carbon emission sources are changing rapidly due to greater energy consumption, which increases emissions, and cleaner technology and fuels, which decreases them. Bottom-up inventories indicate that Asian emissions may have increased by 30% between 2000 and 2005.

4. Sources whose emissions are rich in BC can be grouped into a small number of categories, broadly described as diesel engines, industry, residential solid fuel and open burning. Dominant emitters of BC from energy-related combustion depend on the location. Asia and Africa are dominated by residential coal and biomass fuels (60-80%), while on-road and non-road diesel engines are leading emitters (about 70%) in Europe, North and Latin America. Residential coal contributes significantly in China, the former USSR and a few Eastern European countries.

5. Estimates of energy-related emissions agree broadly on the major contributing sectors and approximate magnitudes of BC emission. However, current inventories in many world regions lack information regarding the factors governing emissions. These include the type of technologies or burning, and the amounts of biofuel (BF) combusted. Major differences in estimates of energy-related emissions result from a few knowledge gaps. For energy-related emissions, these include sparse emission measurements of sources with the highest emissions. In industrialized countries, these may be a small fraction of the emitting sources. Only energy-use inventories in North America, Europe and urban East Asia provide a high level of detail. Measurements in developing countries are scarce for all source types.

6. Current emission factors from biomass burning, and thus emission estimates, might be biased low by a factor of at least two. Emission estimates from open burning are generally uncertain due to insufficient data on burned area and fuel consumed. Quantification of BC emissions from this source is also difficult because they strongly depend on the burning behavior and because of inherent problems with sampling and analyzing BC in smoke plumes from vegetation fires.

7. The majority (80%) of open fire emissions occurs in tropical latitudes, and interannual variability of BC emissions from forest or savanna fires can exceed one order of magnitude in some regions.

8. Because the net aerosol effect on climate depends on the ratio of absorbing to reflective particles such as OA and sulfate, we group emission sources into categories based on their combustion type and co-emissions. Major sources of BC, ranked in order of increasing POA:BC ratio, are diesel vehicles, residential burning of coal, small industrial kilns and boilers, burning of wood and other biomass for cooking and heating, and all open burning of biomass. A few of these sources also emit significant quantities of SO_2.

9. Receptor modeling studies of BC in urban areas that use chemical composition to identify dominant emission sources find source categories that are qualitatively similar to those in bottom-up inventories based on activity data.

3.2. Introduction

[2] Emission inventories, or global and regional tabulations of emission quantities, have a dual role. They are required inputs for atmospheric models that assess the environmental consequences of these emissions, and they also provide necessary information for the development of air quality and climate policies by indicating the largest or most easily manageable sources of emission. For BC and POA, inventories used in global models are typically 'bottom-up' tabulations constructed from estimates of activity (*e.g.,* mass of fuel burned or number of km driven) combined with emission factors (*e.g.,* grams BC emitted per mass of fuel burned or per km driven). To address major fractions of particulate air pollution, or climate forcing related to BC, identification of the sources that contribute to total emissions is needed. The identification of emitting sectors is important not only for mitigation policies, but also

Accepted Article

for historical reconstructions and future projections, as each sector has a different temporal evolution. The major BC emitters in each country or region depend on technological development and on practices common in each society.

[3] In this section, we first provide definitions of the terms, groupings of emission sources, and groupings of countries used throughout this assessment. Section 3.2 outlines general procedures for producing bottom-up inventories. We then present global totals, major source sectors, and regional contributions in Section 3.3. Section 3.4 discusses major sources of uncertainty in emission estimates, focusing on the sectors identified as most important. In Section 3.5, we discuss studies that have inferred the major sources of particulate matter based on the chemical composition of ambient aerosol, known as receptor modeling. These studies have been conducted primarily in urban areas. Finally, Section 3.6 gives an overview of inverse modeling results, where three-dimensional chemical and transport models are used to infer emission fluxes from the spatial and temporal characteristics of the observed concentration field.

[4] The forcing by species co-emitted with BC is important in determining the net radiative forcing by BC sources (see Section 10). In this section, we also discuss emissions of POA, the aerosol species most commonly emitted with BC. For BC sources, we also summarize co-emissions of SO_2, which is a precursor to sulfate. Dust and sea salt are other major aerosol components, but they are generally not co-emitted with BC and they usually have larger particle sizes than BC or its co-emissions. Aged aerosol, however, may contain all of these components. The discussion of uncertainties in this section emphasizes BC emissions.

3.2.1. Geographic aggregation

[5] In this assessment, we summarize emissions and concentrations based on ten groups of countries (called 'regions'), depicted in Figure 3.1. These groups were chosen based on proximity, development status, and basic meteorological similarity, although there is heterogeneity within each region. Countries in each region are listed in the Supplemental Information (Table S1).

3.2.2. Definitions and aggregation of emission sources

[6]

1. Activity. The term 'activity,' as it is commonly used in the emission community, indicates a quantitative measure of an event that leads to emission, such as the quantity of fuel burned, product manufactured, or kilometers driven.

2. Emission factor. The term 'emission factor' gives mass of BC emission per activity, as opposed to total emissions. Emission factors for BC vary by region and end-use, even for the same fuel.

3. Source categories. Because this assessment focuses on BC sources and their impacts, we isolate sources that contain large fractions of BC relative to other aerosol components or precursors. We group sources with some similarities into aggregates called 'source categories,' although there is some heterogeneity within these categories. For example, we lump both modern diesel engines with emission reduction technology and high-emitting, poorly maintained diesel engines into the category 'on-road diesel engines.' These categories are discussed further in Section 3.3.

4. BC-rich sources. This assessment examines sources that have non-negligible BC emissions and that, therefore, have a positive component of forcing. We differentiate between sources that are rich in BC with respect to co-emitted species, and those whose aerosol forcing is dominated by inorganic species. For our purposes in this assessment, a 'BC-rich' source is defined as having an estimated SO_2:BC emission ratio below 200:1.

5. Sectors. The term 'sectors,' as used throughout emission literature, refers to broad activity categories used for reporting by the International Energy Agency and the United Nations. These sectors are energy or transformation (which includes electricity generation), industrial activity, transportation, agriculture, and residential. The sector frequently termed 'residential combustion' may also contain commercial, agriculture, and miscellaneous activity. Energy-related combustion is conducted deliberately in pursuit of economic activity or to meet personal or industrial energy demands. Open biomass burning also produces large quantities of atmospheric pollutants, and this activity has also become known as a sector in atmospheric literature. Because

Accepted Article

sectors consist of many types of activity, they include both BC-rich sources and sources that emit little BC. For that reason, we present emissions from source categories rather than from sectors.

6. Aggregated emissions. We use some additional terms to describe aggregated emission categories. 'Energy-related' emissions include power plants, industrial activity, transportation, and residential fuel use. 'Open burning' includes combustion of forests and grasslands or savannah, regardless of the cause of the fire. We also include open burning of waste for disposal, including crop residue or urban waste, in the latter category. The term 'fossil fuel' indicates emissions from combustion of all fossil fuels, including diesel fuel and coal used in residential and industrial sectors. The term 'biofuel' denotes biomass burned intentionally to meet energy needs and includes solid, unprocessed biofuel such as wood and agricultural waste.

7. Industrial-era versus anthropogenic emissions. A distinction of importance to the IPCC, among others, is the identification of 'anthropogenic' emission sources. As discussed in Section 1.3.2, we follow IPCC practice and use a time-based definition of climate forcing that is more accurately described as 'industrial-era' forcing: the difference between the near-current year 2000 and the background year 1750. Industrial-era emissions are required to evaluate climate changes since 1750. 'All-source' emissions include the component that occurred both in 1750 and in the present day. Industrial-era emissions are more uncertain than all-source emissions because of the large uncertainties in activity during the background year, especially for open biomass burning. Anthropogenic emissions may not be the same as industrial-era emissions, as some emissions in 1750 may have been human-caused. Nominally, energy-related sources are all anthropogenic, as are sources associated with waste disposal. Vegetation fires are the only BC emission source that sometimes occurs without human activity.

3.3. Bottom-up inventory procedures

[7] Emissions from energy-related combustion and from open vegetative burning are derived from different types of input data and often created by separate communities. In this section, we summarize information needed to create inventory estimates to clarify the sources of uncertainties.

3.3.1. Energy-related emissions

[8] Emission estimates for activities related to energy use were first developed to evaluate air quality in urban areas, where both high concentrations and high population led to severe exposure to health risks. Urban regulations have historically targeted total particulate matter mass concentrations, not individual chemical species. For that reason, early source characterization focused on mass emissions, and many source measurements did not provide emission rates of individual components such as BC.

[9] Bottom-up inventory estimates from energy use are based on the following simple equation:

$$Emission = \sum_i A_i \, EF_i \, (1 - eff_i) \qquad (3.1)$$

In the equation above, A_i represents activity of a particular type (*e.g.,* fuel consumption or commodity production, conducted in a specific way); EF_i is an emission factor in grams per activity; and eff_i is the pollutant removal efficiency by a particular type of abatement. The subscript i represents different types of activity that result in emissions of the same pollutant. Both emission factors and removal efficiency depend on the type of activity and the pollutant. For global or regional emission inventories, activity is almost always given as mass of fuel burned.

[10] BC emission inventories from energy-related emissions are available for all countries. However, the level of detail used in each inventory varies greatly. Quantification of emissions and the identification of major contributing sources could be substantially refined by disaggregating the activity definitions used in Equation 3.1. For example, activity for a country might be

Accepted Article

given as total coal consumption in the residential sector, with a single emission factor used for all coal burning installations. This lumping ignores the fact that large boilers might have very different emission factors or better control devices than small coal stoves.

[11] Bottom-up inventories can be graded based on the level of refinement used in emission estimation. Table 3.1 proposes such criteria for grading energy-related emissions. Major uncertainties in current bottom-up inventories include insufficient knowledge of activity rates and emission characteristics. Emission factors are not as well understood for sources largely found in rural areas, such as off-road diesel engines. Furthermore, measurement resources have been concentrated in developed countries, so there are still relatively few measurements of key emission sources in developing countries. Section 3.7 gives further details on uncertainties, which vary by emission sector and by region.

3.3.2. Open burning emissions

[12] In contrast to energy use, open burning emissions are usually not included in national activity reports. There are thousands of open fires burning globally each day, and most of these are caused by humans, either purposefully or involuntarily. Open fires are ignited for many purposes, and their emissions differ by region and ecosystem type. In contrast to residential and industrial emission sources, which are predominantly located in the northern hemisphere mid latitudes, open fires occur largely in tropical regions, with 80% of emissions occurring there. National regulations about fire use and their enforcement vary among countries. Another important distinction between emissions from open fires and emissions from energy use is the very large inter-annual variability of the former. This is caused by variations in the accumulation of wooded or grass fuels, in fuel characteristics such as dryness, and in other factors influencing fire spread and fire severity. An extreme case in point is fires in Indonesia that are strongly influenced by the El Niño-Southern Oscillation in combination with the draining of peatlands. According to *Schultz et al*. [2008] BC emissions from Indonesian fires ranged between 40 and 1400 Gg yr^{-1} during the 1990s. *Mack et al*. [2011] report a single tundra fire whose fuel consumption was similar in magnitude to the annual net carbon sink for the entire Arctic tundra biome.

[13] The method for estimating emissions from large open fires is similar to Equation 3.1, but using different input data.

$$M_{emitted} = \sum_i BA_i \, FL_i \, CC_i \, EF_i \qquad (3.2)$$

Here, BA_i is the burned area (km^2), FL_i the available fuel load (kg dry matter per km^2), CC_i the combustion completeness (fraction) and EF_i the emission factor (g compound per kg dry matter). The first three parameters combine to produce activity, or total mass burned. The index *i* usually stands for one ecosystem type in each inventory grid cell. As fire activity has a pronounced seasonal cycle, *BA, FL,* and *CC* must also consider temporal variability of fires, although this is not yet state-of-the-art in global inventories for *FL* and *CC*. Similar to estimates of energy-related combustion, emissions for open burning can be accomplished at different levels of refinement, as summarized in Table 3.2.

[14] Burned area is either derived from aerial surveillance or retrieved from satellite instruments that measure surface temperature and reflectance [*Stocks et al.,* 2002; *Kasischke and French*, 1995]. Space-borne retrievals of burned area are generally based on the changes in surface reflectance as a result of the dark burn scar after a fire, but they occasionally make use of active fire detection as well [*Giglio et al*., 2009]. These retrievals can be confounded by apparent changes caused by the viewing geometry, cloud shadows, snow melt or temporary flooding, and other factors [*Roy et al.*, 2002; *Simon et al.,* 2004]. Some studies have also related fire radiative power from active burns to the amount of biomass combusted [*e.g., Wooster et al.,* 2005; *Kaiser et al.* 2009; *Kaiser et al.,* 2012] or to the amount of aerosol emitted [*e.g.*, *Ichoku and Kaufman*, 2005; *Sofiev et al.,* 2009].

Accepted Article

[15] Fuel loads and combustion completeness are normally extrapolated from smaller-scale field studies. Grassland fires often consume nearly 100% of the above-ground biomass [*e.g., Shea et al.,* 1996; *Keene et al.,* 2006]. In contrast, the combustion completeness in forests varies strongly depending on the fuel and burning conditions. If the fuel is sufficiently dry, the dead plant material and plant litter are often consumed almost completely. Larger branches and stems rarely burn entirely and living tree biomass is generally affected only in severe fires. The actual consumption of biomass in a given fire depends strongly on the ecosystem type and the fire size, severity and persistence. Fires can consume substantial amounts of soil material, which can dominate fire emissions, for example in peat areas of Indonesia or Siberia [*e.g., Goldammer and Seibert,* 1990; *Soja et al.,* 2004].

[16] Emission factors are obtained from laboratory experiments or field measurements in the smoke plumes of actual open burns. Different measurement methods for BC in each field study, systematic sampling biases, and the use of ecosystem mean emission factors to represent both flaming and smoldering combustion introduce uncertainties in the estimated emissions (see Section 3.7.2.3).

3.3.3. Waste burning emissions

[17] Combustion may be used to dispose of agricultural, household, or industrial waste. Well-controlled combustion systems, such as incinerators, emit little particle mass, and the discussion here focuses on uncontrolled burning. Activity data are among the most difficult to estimate, as they are not of economic interest and, therefore, not quantified by any organization. Large agricultural fires are detected with remote sensing, but the smaller fires are not and may be excluded from open burning emission estimates.

[18] Agricultural waste, such as cereal straws, woody stalks, and sugarcane leaves and tops, are generated during harvest periods. Some of this biomass finds use as animal fodder, thatching for rural homes, and fuel for residential cooking and agricultural and rural industry. A fraction of agricultural waste is burned in fields, often to clear them for a new sowing season, or sometimes as part of the harvesting process. The practice of agricultural waste burning has strong regional and crop-specific differences, and has large seasonal variations. Emissions from agricultural waste burning are typically calculated by multiplying crop production of a particular type, a fraction of residue per product, a fraction burned in the field, a fraction of dry matter, and the combustion completeness. Reported residue-to-product ratios [*Koopmans and Koppejan,* 1997] are larger for straw and stalks of crops like cereals (rice, wheat, millets) and legumes, but smaller for husks and hulls from rice and groundnut. Reported ranges of dry matter fraction are 0.71 to 0.85 and combustion efficiencies range from 0.68 to 0.89 [*Streets et al.*, 2003a]. However, the assumed fraction burned in field is subject to large uncertainties and is sometimes computed based on local practice and knowledge of competing uses of the agricultural waste [*Venkataraman et al.,* 2006].

[19] Emissions from garbage burning are estimated using per-capita waste generation rates, along with fraction burned and emission factors. Both waste generation rates and fraction burned are location-specific [*e.g.*, *Christian et al.,* 2010]. Waste generation is higher in industrialized countries and urban areas, but the fraction burned is higher in developing countries. Burning of industrial waste is quantified in industrialized countries, but it is highly controlled so that emissions are small. In contrast, informal disposal of industrial waste has not been quantified in developing countries and these emissions are not included in these estimates.

3.4. Total BC emissions and major source categories

[20] Table 3.3 summarizes the best estimates and their ranges for BC and POA emissions in the year 2000 as derived in this assessment from a variety of information sources described in this section. Figure 3.2 summarizes sources of global BC emissions from two global inventories, along with estimates of their uncertainty; it also shows emission ratios for co-emitted, cooling aerosol species or precursors. Figure 3.3 shows the same estimates tabulated by region. Estimates from SPEW (Speciated Pollutant Emissions Wizard [*Bond et al.*, 2004, 2007; *Lamarque et al.*, 2010]) and GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies [*Kupiainen and Klimont*, 2007; *Cofala et al.*, 2007; *Amann et al.,* 2011; *UNEP*, 2011]) are used as a reference for

Accepted Article

energy-related emissions throughout this assessment because they have the technological detail required to explore mitigation. SPEW estimates contain bottom-up uncertainties and are therefore used as the basis for Figure 3.2. GAINS estimates have the advantage of providing all co-emitted species, including gaseous emissions, and are used in the discussion of source category impacts in Section 10. Section 3.6 discusses differences between these inventories and compares other global and regional emission estimates.

[21] Figure 3.2 and Table 3.4 also give bottom-up estimates from open burning. Both RETRO (Reanalysis of the TROposphere over the last 40 years) [*Schultz et al.*, 2008]) and GFED (Global Fire Emissions Database [*van der Werf et al.*, 2006]) incorporate remote sensing information on fires to provide seasonal and interannual emission variation, and are frequently used by atmospheric models. Figure 3.4 shows the seasonal and interannual variability of open burning in five regions. However, because remote sensing poorly detects small agricultural fires, we rely on estimated activity data (SPEW and GAINS) for agricultural waste burning emissions. The figure and table also compare SPEW open-burning emissions, which are based on country information about total quantities burned.

[22] The left panel of Figure 3.2 presents total BC emissions for each source category, also indicating the regions of emission. This panel shows ranges calculated from uncertainties in both activity data and emission factors in SPEW, and a comparison with the same sectors in the GAINS database. Although totals for each category vary, there is general agreement that the three largest contributors are open burning, diesel engines, and residential solid fuels. A small number of industrial sources in developing countries also make a significant contribution.

[23] The two right panels of Figure 3.2 show emission ratios between POA and BC, and sulfur dioxide and BC. Higher ratios indicate that more aerosol species are co-emitted that could offset direct warming by BC. For BC in snow and sea ice, co-emission of non-absorbing aerosol (*e.g.,* sulfate) does not affect BC forcing, and co-emission of absorbing aerosol (*e.g.,* some POA) adds to the forcing. Not represented in the figure are gaseous species such as carbon monoxide and O_3 precursors, many of which contribute to warming (see Section 10).

[24] Table 3.5 provides numeric values for energy-related emission estimates in Figure 3.2, including additional disaggregation. For an estimate of energy-related BC emissions in the year 2000, we average the GAINS and SPEW totals without flaring, aircraft at cruise altitudes, and international shipping yielding 4430 Gg yr^{-1}. We then add those three sources for a total of 4770 Gg yr^{-1}. Relative uncertainties in BC emissions are taken from the SPEW bottom-up calculations, giving 90% uncertainty bounds of 1220 to 15000 Gg yr^{-1}. A similar estimate for POA gives a central estimate of 15900 Gg yr^{-1} with uncertainty bounds of (8800 to 23800) Gg yr^{-1}.

[25] Table 3.4 provides numeric values for biomass-burning emission estimates in Figure 3.2, including additional disaggregation. For an estimate of all-source, bottom-up emissions in 2000 from open burning, we average the RETRO and GFED climatological values for forests, grasslands and woodlands, yielding approximately 2450 Gg BC yr^{-1}. We add estimated activity-based data (average of SPEW and GAINS) for estimates of agricultural waste burning emissions (310 Gg BC yr^{-1}). The total is 2760 Gg BC yr^{-1}. A parallel estimate for POA gives 29200 Gg POA yr^{-1} from forests, grasses, and woodlands, and 1910 Gg POA yr^{-1} from agricultural waste burning. Bottom-up uncertainty estimates are discussed in Section 3.7.

[26] For energy-related emissions in the background year of 1750, we assume the values of 390 Gg BC yr^{-1} and 1560 Gg POA yr^{-1} given by *Dentener et al.* [2006]. These emissions are entirely from biofuel use. Industrial-era emissions are the difference, 4380 Gg BC yr^{-1} and 14300 Gg POA yr^{-1}. We also assume the *Dentener et al.* [2006] values for background open-burning emissions: 1230 Gg BC yr^{-1} and 12800 Gg POA yr^{-1}. Industrial-era emissions are the difference, 1740 Gg BC yr^{-1} and 18300 Gg POA yr^{-1}. With no constraints in the year 1750, the background values are crude assumptions, scaled by population and land-cover. Other

Accepted Article

work has estimated BC emissions in the middle to late 1800s [*Novakov et al.*, 2003; *Ito and Penner,* 2005; *Bond et al.*, 2007; *Junker and Liousse*, 2008], but none has provided estimates for earlier years.

[27] In the following sections, we briefly review contributions from individual source categories. Section 3.5 discusses some reasons for differences between the estimates presented in the figures, as well as other emission estimates.

3.4.1. Diesel engines

[28] On-road diesel engines include diesel cars and trucks, while off-road engines include engines used in agriculture, construction, and other heavy equipment. The diesel-engine category in this assessment specifically excludes shipping emissions, which are summarized separately. Diesel engines contributed about 20% of global BC emissions in 2000. These sources have the lowest co-emissions of aerosols or aerosol precursors of all the major BC sources. In order to enable use of the most advanced exhaust controls, sulfur must be removed from the diesel fuel during refining. Therefore, in regions with fewer controls, primary particulate matter emission factors are higher, but SO_2 emissions are also higher.

3.4.2. Industrial coal

[29] Industrial coal combustion is estimated to provide about 9% of global emissions, mainly in small boilers, process heat for brick and lime kilns, and coke production for the steel industry. Although coal combustors can be designed to produce little BC, coal can also be highly polluting when burned in simple combustors, which are still present in small industries, particularly in developing countries. Co-emitted SO_2 is estimated from coal sulfur content and exhaust control. The SO_2/BC ratio for industrial coal is much higher than for the other emission categories, where the fuel has little sulfur or more efficient flue-gas controls are in place. Emissions from coal-fired power plants, which emit much less BC because of their better combustion efficiency, are not included here.

3.4.3. Residential solid fuels

[30] Wood, agricultural waste, dung and coal are used for cooking or heating in homes, providing another 25% of BC emissions. Most of the emissions occur in single-family devices, which are often of simple design. When infrastructure and income do not allow access to low-emission residential energy sources such as electricity and natural gas, solid fuels are used extensively for cooking. Otherwise, they are used more often for heating. Coal and, less frequently, wood are also used for heating in multi-family building boilers. The designation ‘cooking’ in Figure 3.2 refers to regions where wood is primarily used for cooking, even if some heating occurs. Similarly, ‘heating’ includes all uses in regions where heating is dominant. This sector also includes emissions from both production and consumption of charcoal. The poor combustion and mixing in these simple devices results in relatively high POA:BC ratios, but SO_2 emissions are low except for coal.

3.4.4. Open burning

[31] Open burning of biomass in the location where it is grown is a very large contributor to global BC emissions, with bottom-up estimates predicting that it contributes about 40% of the total. Table 3.4 compares estimates of open-burning BC emissions for the periods 1997 to 2006 (GFED 3.1) and 1996-2000 (RETRO) with the climatological values from SPEW. Current global emissions estimated from open burning range between 2000 and 11000 Gg yr^{-1} for BC, and between 18000 and 77000 Gg yr^{-1} for OC in average years, as summarized by *Schultz et al.* [2008] and confirmed by subsequent work [*Lamarque et al.,* 2010; *van der Werf et al*., 2010]. Most studies fall into the range of 2000 to 6000 Gg yr^{-1} for BC and 20000 to 27000 Gg yr^{-1} for OC. The highest BC and OC emission estimates by *Chin et al.* [2002] resulted from the use of larger emission factors. A smaller contribution originates from open burning in agricultural fields, which is often done to clear residues after harvest. This source contributes about 300 Gg yr^{-1} BC and 1500 Gg yr^{-1} OC. In regions like south Asia, this source can contribute about 20% of carbonaceous aerosol emissions [*Venkataraman et al.*, 2006].

Accepted Article

[32] The average of 2760 Gg BC yr^{-1} in Table 3.4 (including emissions from agricultural waste burning) agrees well with the mean value of global BC estimates from the review of *Schultz et al.* [2008] after they adjusted the literature estimates to standard emission factors. However, modeling studies that constrain emissions using satellite observations indicate substantially larger biomass burning emissions of particulate matter. Section 4.5.1 discusses these studies further.

[33] Because fuel-air mixing is completely unmanaged in open burning, large quantities of organic matter can escape and average POA:BC ratios are highest of all sectors. This ratio can vary greatly depending on the burning conditions; *Andreae and Merlet* [2001] give an interquartile range of 4 to 14. If the burning is natural or accidental, vegetation may burn while it is still rooted and standing, thus allowing for some greater ventilation and oxygen supply. Deliberate burning may involve land clearing before collecting, piling and burning the material, which tends to favor oxygen-poor conditions.

3.4.5. Other emission sources

[34] BC emissions from the four major source types above are about 90% of the global total. Significant contributors of the remainder of BC emissions are listed in Table 3.5. Two of the largest groups are industrial and residential emissions that are not included in one of the preceding categories. In industry, biofuels are responsible for the higher BC emissions estimated by SPEW. Like coal-burning sources, these small sources are challenging to characterize. About half of the miscellaneous residential emissions come from middle distillate oil, and stationary diesel engines used for distributed power generation are estimated to produce about 85% of that. Charcoal, kerosene and liquefied petroleum gas make up the remainder of residential emissions.

[35] Although aviation emits BC at altitudes that otherwise have low aerosol concentrations, its contribution to BC mass is quite small. Likewise, shipping emits aerosol into regions that otherwise have low concentrations, but it ranks with minor sources of BC. These statements are supported by more refined emission estimates than those in Table 3.5. *Lee et al.* [2010] estimated 'soot' from aviation as 6 Gg yr^{-1} for 2004. *Eyring et al.* [2010] summarized shipping emission studies, giving a best estimate of 130 Gg yr^{-1} and a range of 5 to 280 Gg yr^{-1}.

[36] Other BC-rich sources include gasoline engines and flaring in the oil and gas industry. Gasoline engines have much lower particulate matter emission rates than diesel engines, so total emissions from gasoline are less than 10% of diesel BC emissions, although gasoline vehicles are more numerous. Flaring in the oil and gas industry is a poorly understood source both in terms of activity and emissions. Considering data from *Elvidge et al.* [2009], *Johnson et al.* [2011a] and *Johnson and Coderre* [2011], GAINS estimated BC emissions at nearly 4% of the anthropogenic global total with the majority originating in Russia, Nigeria and the Middle East.

[37] All BC-rich sources together constitute 99% of the global inventory. Low-BC sources include coal power plants for generating electricity. These are not considered a large source of BC because the high temperatures and well-managed combustion promote burnout of any BC that is formed. However, BC emission rates from power generation in developing countries are not well known (see Section 3.6.1).

3.5. Regional emissions

[38] The level of refinement in current inventories, limited by the availability of data, varies greatly among world regions (Table 3.6). Figure 3.3 presents emission estimates tabulated by region, rather than by source category. Substantial BC emissions occur in all regions, with the largest contributions in regions where open burning is high (Africa and Latin America). Dominant sources of BC emissions from energy-related combustion change with development from residential coal and biomass fuels (60-80%) in Asia and Africa, to on-road and non-road diesel transport (about 70%) in Europe, North and Latin America. Industrial uses of coal are also important in East Asia.

Accepted Article

[39] The largest open burning emissions occur in Africa, Latin America and Southeast Asia. Tropical savanna and forest burning contribute about 45% and 40% of global open fire emissions, respectively. Globally, burned area and fire emissions are mostly decoupled because most of the burned area occurs within savanna ecosystems with relatively low fuel loads and emissions per unit area, while forest lands have less burned area but higher and more variable fuel loads. As a consequence, interannual variability is higher in equatorial Asia than in Africa. Open burning at northern mid- to high-latitudes does not constitute a large fraction of global, annual BC emissions, but the timing and location of Eurasian open burning emissions in particular (*i.e.,* high-latitude spring in Figure 3.4) mean they have especially large contributions to BC cryosphere climate forcing, which has very high efficacy (Section 7). Figure 3.5 shows the distribution of the major source types by latitude. The Northern Hemisphere contains about 70% of the emissions (*i.e.,* 85% of energy-related emissions and 45% of open-burning emissions).

3.6. Comparison among energy-related emission estimates

[40] Thus far, emission estimates from GAINS and SPEW have provided a perspective on the major sources of global BC emissions. Other estimates of global and regional emissions are summarized in Table 3.7. These differ substantially, by up to factors of three for specific regions. We begin by reviewing global emission estimates. Differences in the totals can usually be ascribed to choices of emission factors or other characteristics within the major source categories, which we discuss individually. We then use this background to discuss differences among Asian emission estimates.

[41] *Penner et al.* [1993] developed one of the first global BC emission estimates based on applying constant global emission factors to broad sectors. *Cooke and Wilson* [1996] were the first to apply emission factors that depend on development level. An updated version of that inventory [*Cooke et al.* [1999], abbreviated as *Cooke99* for the following discussion] is commonly used in atmospheric modeling. *Liousse et al.* [1996] developed an early estimate of biofuel-burning emissions based on consumption estimates from the Food and Agriculture Organization. Bond *et al.* [2004] discussed the main sources of differences between SPEW and *Cooke99*. As discussed below, the largest differences are for power generation and diesel engines. A composite of national inventories reflecting growth between 2000 and 2006 was developed for the field campaign Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS). The global estimate totaled 5200 Gg yr^{-1} [www.cgrer.uiowa.edu/arctas/emission.html].

3.6.1. Differences in power generation emissions

[42] GAINS and SPEW agree on the magnitude of BC from power generation. However, *Cooke99* has much higher emissions from coal-fired power plants (an increase of 1600 Gg yr^{-1} BC and 2400 Gg yr^{-1} OC above both GAINS and SPEW). This difference resulted from assumptions of very high BC fractions in *Cooke99* while the other estimates relied on existing measurements. New measurements [*Zhang et al.*, 2008a] and subsequent harmonization of emission factors [*Lamarque et al*., 2010] support the use of lower emission factors and values nearer the SPEW and GAINS emissions for this sector. However, there remains a persistent but informal perception [*e.g., Gufran Beig*, personal communication] that BC fractions of particulate matter in developing countries, especially in power plants and industrial installations, could be higher than represented by existing measurements. Even if older, poorly operating power plants have high BC emission factors, there is no evidence that newly installed, modern power plants do. Thus, rapid growth in electricity generation is unlikely to cause sharp increases in BC emissions.

3.6.2. Differences in industrial coal emissions

[43] SPEW estimates of industrial coal emissions are about double those of GAINS. This difference is almost entirely due to assumptions in emission factors and BC fractions for the two major emitting categories, brick kilns and coke ovens. A few particulate matter (PM) measurements were available for brick kilns, but no measurements of total PM from uncaptured coking

Accepted Article

were available at the time of inventory development. Composition measurements for both sources were estimated based on expert judgment, as no composition measurements were available for either source.

3.6.3. Differences in diesel engine emissions

[44] GAINS and SPEW have similar emissions for year 2000 from on-road and off-road diesel engines, with SPEW being somewhat higher due to different assumptions about emission factors and the fraction of high-emitting vehicles. In previous versions of SPEW [*e.g., Bond et al.*, 2007], diesel emissions were higher than those given here due to different assumptions about the implementation of standards. The *Cooke99* inventory had much higher emissions from diesel engines, resulting from very large assumed emission factors in developing countries that were not based on measurements. Measurements have confirmed higher emission factors in locations with delayed emission standards [*Subramanian et al.,* 2009; *Assamoi and Liousse,* 2010], although no measurements are as high as the assumptions in the *Cooke99* inventory. However, an evaluation of trends in California [*Kirchstetter et al.*, 2008] indicates that emissions prior to regulation could have been higher by a factor of 10, greater than either the emission factors used in SPEW and GAINS, or in any reported measurements.

3.6.4. Differences in residential solid fuel sector

[45] Small-scale residential combustors constitute the largest difference between SPEW and GAINS. Estimates from SPEW are lower by 30% for biofuel used in cooking and all uses of coal, and higher by 35% for biofuel used in heating. The discrepancies in heating biofuel and coal emissions are largely due to activity data. For cooking stoves, activity in SPEW is lower by about 15%, and emission factor choices cause the remainder of the difference. GAINS uses the highest emission factor from fireplace measurements for cooking stoves (about 1.1 g BC [kg fuel]$^{-1}$), while SPEW uses an average of cooking stove measurements (about 0.8 g BC [kg fuel]$^{-1}$). Both are consistent with observed emission factors.

3.6.5. Asian emission inventories

[46] Detailed emission inventories have been developed for the Asian region and for individual countries within Asia. Here, we compare these inventories and identify some reasons for differences. Similar studies are not available in other world regions.

[47] Three emission inventories have been developed for Asia alone. Streets *et al.* [2003b] provided inventories to support modeling during the TRACE-P field campaign [*Jacob et al.,* 2003]. Emission factors in that inventory were an earlier version of those in SPEW [*Bond et al.*, 2004]. Two primary differences were the addition of small industries (brick kilns and coking) in SPEW, and adjustment of emission factors for residential fuel, where BC emission factors were reduced slightly and those for organic matter were greatly reduced. In addition, the TRACE-P inventory relies on some projected energy use because it was developed before year 2000 data became available. *Ohara et al.* [2007] developed an Asian emission inventory and also provided time trends for 1980-2003. They used a single emission factor for each sector drawn from *Streets et al.* [2003b], except for transportation where they developed a representation based on differing vehicle types. *Klimont et al.* [2009] drew on additional national data collected during the GAINS-Asia project to estimate emissions of BC and OC for the period 1990-2005 and projections to 2030. They developed technology specific factors, although they did not distinguish among some uses (*e.g.,* cooking versus heating), with the result that estimates were about 25% higher estimates than those of *Streets et al.* [2003b], *Ohara et al.* [2007], SPEW, and the current GAINS global model.

[48] For India, central values of BC emissions differ by a factor of about three. The lowest central value [*Reddy and Venkataraman,* 2002a,b; *Venkataraman et al.,* 2005] is from a difference (compared to SPEW) in the residential sector, where the India-only mean emission factor is about 16% lower than the global mean used by *Bond et al.* [2004]. Estimates by *Sahu et al.* [2008] are a factor of three larger, resulting from the use of the high power-plant and diesel emission factors from *Cooke et al.* [1999]. *Parashar et al.* [2005] estimated emissions a factor of two larger than those of *Reddy and Venkataraman*, largely caused by

Accepted Article

their new measurements of very high emission factors for biofuel (especially dung). Estimates from *Ohara et al.* [2007] and *Streets et al.* [2003b] are based on the same emission factors, so the large difference between them is surprising. Most of the 200-Gg yr^{-1} difference is attributable to biofuels in the residential sector (616 vs 420 Gg yr^{-1}, respectively). Activity data are frequently given in terms of total fuel calorific content rather than mass, and in these units the Ohara and Streets inventories are only 16% different. The difference, therefore, must be caused by differing assumptions in the conversion between fuel calorific content and mass. *Klimont et al.* [2009] used higher emission factors for cooking and national energy use statistics and estimated nearly 30% higher BC than current global GAINS implementation or SPEW, while OC was well within the range of GAINS and SPEW. *Lu et al.* [2011] obtained similar estimates to *Klimont et al.* [2009] and also estimated that BC emissions rose 35% between 2000 and 2010. The *Lu et al.* [2011] trends in Asian aerosol emissions compare favorably with remote-sensing data.

[49] For China, regional inventories are in broad agreement with global inventories on magnitudes and sources of BC emissions. *Cao et al.* [2006] developed an emission inventory based on Chinese data and some new emission factors. SPEW and the inventory of *Cao et al.* [2006] are quite similar. The *Streets et al.* [2003b] inventory lacks treatment of small industry. Zhang *et al.* [2009a] included small industry, particularly brick and cement kilns, following the approach of *Streets et al*. [2006], and estimated significantly higher total BC emissions from China. *Lu et al.* [2011] estimated generally higher growth in BC emissions between 2000 and 2010 (+46%) than previous studies. Organic matter emissions in *Cao et al.* [2006] are higher than those of the other studies due to the use of different emission factors. *Klimont et al.* [2009] estimates for BC are higher by about 15% than *Streets et al.* [2003b] and global inventories but lower than *Zhang et al.* [2009a]. While comparing total emissions for China yields in general fairly good agreement across the studies, there are significant sectoral shifts resulting primarily from uncertainties in coal versus briquette use in the residential sector and assumptions for the brick-making sector. For example, *Zhang et al.* [2009a] and GAINS use comparable assumptions for coal while *Klimont et al.* [2009] assumes more briquettes, leading to lower emissions from this sector in *Klimont et al.* On the other hand, for brick making both *Zhang et al.* and *Klimont et al.* rely on *Bond et al.* [2004] emission factors and estimate higher emissions than GAINS, which considers anecdotal evidence about the transition in this industry that leads to significantly lower emission factors.

3.7. Major sources of uncertainty in emissions

3.7.1. Energy-related combustion

[50] As discussed in Section 3.6, large differences between emission estimates are attributable to a few choices regarding emission factors made by inventory developers. Some of the diversity is not supported by measurements at emission sources, while other disagreements reflect true uncertainty in knowledge. A bottom-up estimate of uncertainty is about a factor of two using either a simple uncertainty combination for global emissions [*Bond et al.,* 2004] or a Monte Carlo approach for individual countries [*Lu et al.*, 2011].

3.7.1.1. Activity data

[51] For fossil-fuel combustion, activity estimates for many inventories in Table 3.7 have the same source (International Energy Agency (IEA), or United Nations fuel-consumption data), although many inventory developers adjust these data when inconsistencies are found or when finer allocation of activities is required (*e.g.*, road and off-road vehicles or vehicle type). For several larger countries, regional statistics are also available and using them allows for better spatial resolution; however, national and international statistics are not always consistent. Finally, some models chose to use data sets specifically developed for particular projects. For example, GAINS often uses national fuel-consumption estimates for most of the European countries, China, India and Pakistan. These may differ from IEA statistics, especially with regard to sectoral allocation. Total fuel consumption can be affected by the use of regional information on the calorific value of fuels.

Accepted Article

[52] Consumption of residential solid fuels, especially biofuel, is not well constrained. Biofuel consumption data are frequently drawn from disparate sources. For example, GAINS relies on IEA and national data, while SPEW uses the tabulation of *Fernandes et al.* [2007]. Fuel production and sales are not centralized in this sector, and many fuels are collected by the consumers or by small sellers. Activity data are therefore much more uncertain than for liquid or gaseous fuels or consumption in large installations. Estimates of fuel consumption are often based on per-capita consumption estimates multiplied by the number of people using solid fuels. Comparison of the residential biofuel consumption for the past years in India and China (*Streets and Aunan* [2005], *Venkataraman et al.* [2005], *Ohara et al.*, [2007], and GAINS) shows significant differences, typically ranging within about ±25%.

3.7.1.2. Emission factors

[53] Emission rates of both BC and organic carbon depend on the combustion process, including fuel composition, flame temperature, mixing between fuel and air during combustion and post-combustion treatment of the exhaust. Carbonaceous aerosols can be destroyed if the exhaust is kept hot and well mixed with air. Large, properly operating combustors, such as power plants and some modern installations using biofuel, tend to achieve this burnout, resulting in little emitted BC. Mixing between fuel and air before combustion also limits BC formation, so that gasoline engines emit much less BC than do diesel engines. Finally, BC may be removed through end-of-pipe controls that capture fine particles, as it is in particulate filters after diesel engines.

[54] The strong dependence of BC emissions on combustion processes means that the disaggregation of activity to represent combustion quality explicitly is an important component of inventories. The dependence also demands the development of emission factors under realistic operating conditions. Because most sources have several operating modes, it is important to obtain emission factors by measuring during a realistic sequence. This sequence of conditions may be called 'driving cycles' for vehicles, or 'burn cycles' for stoves, small boilers, or open combustion. Although design of existing cycles seeks to represent real-world operation, unrealistic choices of operating conditions may yield emission factors that are poorly representative. For example, very cold conditions or startup phases, which promote poor efficiency and high emissions, may be omitted from vehicle and stove emission testing, or tests may not include the poorest quality fuels.

[55] Uncertainties are particularly acute outside the United States and Europe. A few measurements are becoming available, but the limited number of studies has not dispelled concern that the highest emitters have been missed or significantly underrepresented.

1. Diesel engines. There is a good understanding of on-road emissions from normal vehicles in developed countries, although questions exist about how in-use vehicle emissions compare with those from tests in laboratories because of differences in driving conditions. Both averages and ranges of vehicle emissions in developing countries are not well quantified. Compared with on-road engines, there are many fewer measurements of off-road equipment, including engines used for agriculture and construction. A large uncertainty in determining total emissions is the contribution of poorly functioning vehicles with very high emissions, or 'super-emitters.' The fraction of such vehicles and their emission factors are not well known, and these assumptions result in major discrepancies between inventories, because a single super-emitter can produce many times more BC than a properly operating engine with an emission control system. Super-emitters are likely to be more widespread in developing countries, but data on the fraction of vehicles with such high emissions are extremely limited.

2. Industrial solid fuels. Emission estimates from the industrial sector are dominated by small, simple kilns in traditional production processes and old boilers. Activity data and emission factors for these sources are particularly difficult to obtain. Magnitudes and composition of emissions are the most uncertain of any of the major source categories due to lack of measurements.

3. Residential solid fuels. Although the residential sector is highly heterogeneous with regard to the types of fuels and devices used, a relatively small number of emission measurements have been made and many of these are from laboratory rather than in-use measurements. Limited data on emission magnitudes and composition are available to characterize this sector.

Accepted Article

3.7.1.3. Summary of uncertainties in energy-related emissions

[56] Major contributors to uncertainty in BC and OC emissions from energy use are: (1) measured particle emission factors obtained under laboratory conditions (*i.e.,* rather than in-use or in-field) for residential combustion, traditional industry, and vehicles with high emissions due to malfunction; (2) speciation of PM from high-emitting technologies into BC and OC; (3) quantification of individual emitters in sectors that contain even a small fraction of highly polluting devices; and (4) amounts of fuel burned in sectors where fuel and output are not formally monitored and tabulated. While most of the estimates tabulated here are given for the year 2000, rapid economic growth in countries with large BC emissions may have caused energy-related BC emissions to increase dramatically over the last decade. The year used for the inventory estimate is important when comparing atmospheric models with observations.

[57] In addition to the factors that affect total emission quantities, the location of emission may be poorly known for sources such as small industry and passenger or freight vehicles. These inaccuracies affect comparisons between measured and modeled concentrations.

3.7.2. Open biomass burning

3.7.2.1. Burned area

[58] Considerable uncertainties remain in the quantification of burned area. Current satellite retrievals cannot detect burn scars much smaller than one square kilometer, and the size of the burned area is sometimes wrongly determined. Active fires can be detected when they are larger than about 0.1 ha, but many fires cannot be observed during their flaming stage because of incomplete coverage of satellite orbits or clouds obscuring the scene. Given the current resolution of satellite instruments that are used for burned area retrievals (typically 0.25 to 1 km^2 at the sub-satellite point and 5 to 10 times larger at swath edges), only burn scars with a size of at least 12 to 40 ha can be detected from space. Field data and satellite retrievals of fire radiative power [*Wooster et al.,* 2005] show that the majority of fires are smaller, particularly in tropical regions [*cf. Schultz and Wooster,* 2008]. Uncertainties arising from the limited spatial resolution of current instruments could be as large as -30% to +40%, but in reality they are smaller due to compensating errors. Validation of individual fire scenes from the MODIS burned-area data set with high-resolution Landsat data indicates that burned areas are probably underestimated by about 10% on average [*M. Wooster, personal communication, 2009*].

3.7.2.2. Fuel load and combustion completeness

[59] Field studies, such as those in the savanna regions of South Africa [*Shea et al.,* 1996] or in boreal North America (summarized by *McKenzie et al*. [2007]), reveal that fuel loads can easily vary by a factor of three to twenty within a region of limited ecosystem diversity. This uncertainty is consistent with estimates of fuel load derived from analysis of satellite data [*Ito and Penner*, 2004]. Combustion completeness strongly depends on the weather conditions because bulk fuel, which constitutes a large fraction of fuel mass in wooded ecosystems, burns only when the fuel is sufficiently dry and when it is windy. Uncertainties in vegetation modeling for calculation of available fuel load and combustion completeness are highest in deforestation regions and in regions where peat fires occur [*van der Werf et al.,* 2006] (*e.g.*, Southeast Asia) where problems in modeling the combustion of organic soil layers containing peat leads to an uncertainty of about a factor of five. In some regions, like southern hemisphere Africa, models incorrectly predict seasonality, with peak emissions in bottom-up estimates occurring about 1–2 months earlier than the peak in satellite-detected AOD [*van der Werf,* 2006]. This is attributed to an increase in emissions as the fire season progresses, caused by a shift from grassland fires early in the dry season to woodland fires later in the dry season, associated with different fuel moistures and burning behaviors. Ecosystem modeling frameworks are moving toward capturing such temporal variations. Assuming that errors in fuel load estimates are uncorrelated across different regions, the global uncertainty in fuel load densities

Accepted Article

would be substantially lower than the variance encountered in individual field studies, but greater than the 50% model diversity reported by *Knorr et al.* [2012]. Our conservative estimate of the global uncertainty caused by fuel load densities and combustion completeness is a factor of two.

3.7.2.3. Emission factors

[60] As shown in Section 4.5, current models of the atmosphere underestimate absorption aerosol optical depth (AAOD) in Africa and Latin America, which are major biomass burning regions [*Koch et al.*, 2009a]. Some of the extra absorption in Africa could be caused by dust, but an explanation is needed for the underestimate in Latin America. The underestimate could be caused by low biases in burned area or fuel loads (see above), but inverse models [*Arellano et al.*, 2004; *Arellano et al.*, 2006; *Stavrakou and Müller,* 2006] indicate little bias in carbon monoxide (CO) emissions from biomass burning in these regions. The remaining suspects are fire emission factors, the relationship between emitted mass of BC and optical absorption in fire plumes, or incorrectly modeled aerosol lifetimes.

[61] Although biomass burning is a large component of global BC emissions, particulate and BC emission factors for this source are poorly constrained. As discussed in Section 2, measurements of BC depend on the analysis method. These method-dependent biases are more critical for biomass-burning emissions than for other sources, because these emissions pyrolyze and also contain materials that catalyze BC emission. The comprehensive literature review of *Andreae and Merlet* [2001] has become widely used, in particular for the compilation of global inventories [*e.g., van der Werf et al.*, 2006; *Schultz et al.,* 2008]. However, this review included only values based on thermal oxidation techniques and excluded optical absorption measurements. Even the highest BC emission factor in *Andreae and Merlet* [2001] is lower than values inferred from absorption measurements, which have been used in other studies [*Patterson and McMahon*, 1984; *Liousse et al*, 1996; *Chin et al.*, 2002; *Liley et al.,* 2003]. In part due to higher emission factors, *Liousse et al.* [2010] estimated African biomass burning emissions that were about 2.5 higher than GFED. *Martins et al.* [1998a] showed that thermal oxidation measurements underestimated BC mass, leading to unrealistically high MAC_{BC} values. Therefore, it is possible that the use of imperfect thermal methods yields BC emission factors that are too low.

[62] Comparisons between chemical and optical measurements would increase confidence in biomass-burning emission factors for BC. A review by *Watson et al.* [2005] showed differences of up to a factor of seven between different BC field measurements and discusses the various uncertainties related to both thermal and optical measurements. In contrast to *Martins et al.* [1998a], thermal measurements did not always yield lower BC mass estimates than absorption measurements.

[63] Representativeness of measured emission factors is another concern. Open fires have a high inherent variability. Some emission factors and characteristics are inferred from small, better-controlled fires in laboratory settings. The combustion intensity and the burning and airflow characteristics of these small fires may differ from those of fires in the real world [*Reid et al.,* 2005]. Oxygen-rich flaming combustion is generally associated with more BC and more heat release, while lower-temperature smoldering fires have higher overall particulate matter emission factors and CO emissions than flaming fires [*Lobert et al.*, 1991; *Ward et al.*, 1992; *Yokelson et al.,* 1997]. If a sample is dominated by emissions from one of these phases, then ratios of BC to total PM, or BC to CO, do not represent the overall emission profile.

[64] The relationship between emitted mass of BC and absorption of the fire plume can be biased because of aging processes. As smoke ages, organic material condenses, but no further BC is created. BC/PM ratios in aged plumes are lower than those in fresh plumes, and single-scattering albedos are higher (more scattering relative to absorption). Emission ratios are generally determined in fresh smoke plumes while models are evaluated with data from long-term regional averages, which are mostly of aged aerosol. If the relatively low BC ratios are then applied to fresh plumes, either BC emissions or absorption by BC could be underestimated.

[65] Data are presently insufficient to support firm conclusions about what updates should be made to BC emission rates from open burning of vegetation. However, thermal measurements may under predict absorption, and using regional-average optical

Accepted Article

properties as constraints could also under predict absorption at the time of emission. This body of evidence suggests that current emission factors from biomass burning might be biased low. Based on the data from *Andreae and Merlet* [2001] we estimate the lower uncertainty of BC emission factors to be a factor of 0.6 multiplied by the central value. Our estimate for the upper bound is a factor of 4.

3.7.2.4. Summary of uncertainties in open burning emissions

[66] The dominant uncertainty term for open burning emissions is the emission factor (error range: factor of 0.6 to 4). Fuel load and combustion completeness are uncertain by about a factor of two, while burned area is probably known within 10% on the global scale, although regional differences can be larger (*cf.,* Supplementary online material of *Schultz et al.* [2008]). Neglecting the independent error estimates from agricultural waste burning and assuming that errors are independent, error propagation yields an uncertainty range of a factor of 0.29 to 5. Based on the emission estimates in Section 3.4, bottom-up uncertainty ranges are 740 to 12800 Gg yr^{-1} for BC, and 8400 to 144000 Gg yr^{-1} for POA. These ranges are quite asymmetric.

3.8 Trends in BC emissions

[67] *Novakov et al.* [2003], *Ito and Penner* [2005], *Bond et al.* [2007], and *Junker and Liousse* [2008] all estimate large changes in BC emissions during the industrial era. All of these studies demonstrate that BC emissions are related to, but not directly proportional to fuel consumption. Typically, emission rates become greater as population and economic activity increase, and then decrease as cleaner technology is deployed. The resulting trend is an emission increase followed by a decrease, and is broadly consistent with measurement records downwind of industrializing countries [*McConnell et al.*, 2007].

[68] This discussion has focused primarily on the situation in the year 2000, but historical trends suggest how emissions may have changed since the year 2000 and how they will continue to change (see also Section 12.5). In regions where emission factors decrease faster than fuel consumption is growing, BC emissions and concentrations decline. *Murphy et al.* [2011] observed a 25% decrease across the United States between 1990 and 2004, and *Bahadur et al.* [2011] found a 50% decrease over a similar period in California, a state with more stringent standards. Ice-core measurements in Europe [*Legrand et al.*, 2007] also indicate a decrease in BC deposition since the 1970s. In contrast, when growth is rapid and clean technology has not yet been implemented, BC emissions and concentrations rise. *Lei et al.* [2011] suggests a 30% increase in Chinese BC emissions between 2000 and 2005. *Lu et al.* [2011] conclude that Asian BC emissions increased strongly since 2000, with emissions from the largest contributors, China and India, growing by about 40%. Increasing BC deposition is recorded in Himalayan ice cores [*Ming et al.*, 2008], although more measurements are needed given the high spatial variability in deposition in this region.

[69] Besides increases in fuel use and decreases in emission factors, other trends in fuel use affect net emissions. Cleaner fuels are chosen because of environmental regulations. Households switch to more convenient fuels as income rises, and those fuels tend to be cleaner. Fuels may be adopted for different uses (*e.g.,* energy production from agricultural waste).

[70] Historical records of charcoal deposits and anecdotal evidence suggest a decline of global emissions from open burning between the end of the 19th century and present-day, with strong regional differences [*Moulliot and Field*, 2005; *Power* et al., 2008; *Marlon et al*., 2008]. These changes have been attributed to the expansion of intensive grazing, agriculture and fire management [*Marlon et al*., 2008]. Fire records from North America suggest that fire severity, and hence carbon loss, increased during the last three decades [*Turetsky et al*., 2010]. This is consistent with climate model simulations indicating that fire activity will increase in the future because of increased temperatures and reduced rainfall [*Pechony and Shindell*, 2010; *Liu et al.*, 2010]. However, there have not yet been estimates of BC emissions from future increases in open burning.

3.9. Receptor modeling to evaluate source contributions

Accepted Article

[71] Most BC is emitted from sources that are either small and numerous, or large but episodic, so monitoring data for individual sources is not available to validate emission inventories. The quality of emission inventories and the contributions of dominant sources can be determined only by inferences drawn from atmospheric measurements. The use of measured atmospheric chemical composition to deduce the influence of emission source types is generally known as *receptor modeling*. Another type of study that uses the magnitude and spatial distribution of atmospheric constituents to infer emission source strengths is called *inverse modeling*. The latter type of study requires atmospheric measurement networks, which are discussed in Section 4.4. A discussion of inverse modeling results is given in Section 4.5. In this section, we summarize information from receptor studies that have used chemical composition to identify particular source categories.

[72] Receptor methods based on the chemical composition of particles include examining the ratios of target chemical compounds, such as isotope ratios measured in time-averaged aerosol samples [*Gustafsson et al.,* 2009] or in single particles [*Guazzotti et al.,* 2003]. Other approaches use an expanded suite of chemical species to elucidate additional sources, including elemental and ionic composition and organic and elemental carbon [*Watson et al.,* 1994] and additional organic molecular markers [*Schauer et al.,* 1996; *Zheng et al.,* 2002]. A limitation common to all receptor models is the inability to distinguish sources whose emissions have a very similar chemical composition.

[73] Among receptor models, the chemical mass balance model [*Friedlander*, 1973; *Watson et al.,* 1984; *Chow and Watson,* 2002, *Watson et al.,* 2002] and positive matrix factorization [*Paatero,* 1997; *Hopke et al.,* 2010] have seen wide application in air quality assessment. Receptor modeling may also exploit ensembles of atmospheric trajectories [*Ashbaugh et al.,* 1985]. The outcome is the identification of the pollution source types and estimates of the contribution of each source type to the observed concentrations. Elemental carbon (as measured by thermal techniques) is often used as a tracer of certain emission sources. As discussed in Section 2, this measurement may not be equivalent to light-absorbing carbon. However, it is referred to as BC in this section for congruency with other sections.

3.9.1. Receptor modeling in urban areas

[74] Table 3.8 summarizes source apportionment studies conducted to determine the sources of particulate matter pollution, usually in urban areas. The most detailed information exists in the United States, based on measurements from the U.S. Environmental Protection Agency's network of speciation samplers. Source contributions shown are specific to BC, in decreasing order of influence. For United States urban areas, it is possible to separate approximately six to ten major sources of BC, including diesel, gasoline, biomass, residual oil and local traffic. Several other sources also contribute to BC concentrations, depending on the location: steel mills, railroad emissions, and metal processing facilities.

[75] For Europe and other world regions, no separate apportionment of BC has been done. Instead, reviews [*e.g., Viana et al.,* 2008; *Johnson et al.,* 2011] were used to identify the largest contributors to the mass of particles smaller than 2.5 μm diameter ($PM_{2.5}$). Major sources of BC are also major sources of $PM_{2.5}$, but the converse is not always true; major sources of $PM_{2.5}$ may produce little BC if their emissions are primarily inorganic. Sources that are BC and OC emitters are shown in the table. Resuspended dust, secondary pollutants like sulfate and nitrate, or sea salt could also be contributors to $PM_{2.5}$ at some locations, but are not included in Table 3.8.

[76] Globally, BC from gasoline combustion is only about 10% that from diesel (Table 3.5), but in the urban atmosphere this source may constitute a significant fraction of particulate emissions. There are considerable problems in separating emissions from diesel and gasoline vehicles. For example, *Shah et al.* [2004] showed that slow-moving and stop-and-go diesel vehicles emit organic and elemental carbon in patterns that are very similar to those of gasoline powered vehicles. Thus, their mass contributions of diesel engines might be mis-allocated to gasoline engines. In a growing number of urban centers, especially in the developing countries like India and Bangladesh, *Guttikunda and Jawahar* [2012] showed that a significant fraction of BC emissions also

Accepted Article

originate from the brick kilns surrounding the city administrative boundaries, which consume a mix of coal, agricultural waste, and bunker fuel (in coastal cities).

[77] For European urban areas, the main sources of BC are vehicles, oil or solid-fuel combustion, and industrial and shipping emissions. Emissions from burning of biomass or biofuel were originally reported to be significant only in Denmark and Spain. Later, this source was shown to contribute relatively large fractions in rural and even urban areas [*Szidat et al.,* 2006; *Alfarra et al.,* 2007; *Puxbaum et al.,* 2007] suggesting that this source was not discriminated in the earlier studies.

[78] Information on urban areas in other world regions is largely qualitative, because many studies in these regions did not measure the complete suite of pollutants used for receptor modeling. Furthermore, they often use source profiles that were not locally measured and therefore may be unrepresentative [*Johnson et al.,* 2011]. Table 3.8 shows that in Latin America, traffic, oil combustion and small industry, including copper smelters, are important sources of fine particle mass. *Mugica et al.* [2009] attributed 42% of fine particulate matter in Mexico City to vehicles, but they were unable to separate wood burning due to their similarity with diesel sources. In Africa, open burning of biomass and refuse, residential coal combustion and traditional industries (brick making, lead smelters, foundries) are significant contributors. In East Asia, coal burning industries are dominant sources followed by traffic and biomass burning. Residential coal burning is a large wintertime contributor. In Southeast Asia, traffic is the dominant source in more urbanized locations while local burning (for cooking and brick making) is important in less urban locations. In South Asia, traffic and burning of refuse and biomass are important sources, followed by industrial sources. Brick kilns are important in some locations, while lumped small industrial sources contribute 10 to 30% of fine particle mass. Overall, where traffic is an important source, an aging motor vehicle fleet containing high emitters is of concern. Coal and biomass combustion for residential cooking and heating and small-scale industrial applications is widespread, likely under poor combustion conditions.

3.9.2. Receptor modeling in continental plumes

[79] Urban studies constrain sources that affect cities, but many emissions, such as residential solid-fuel burning or agricultural use of diesel engines, occur preferentially outside urban areas. Source apportionment studies have been applied to carbonaceous aerosol in the continental plume from South Asia. *Novakov et al.* [2000] suggested that fossil fuel was responsible for 80% of the BC in the continental outflow, while studies in Dhaka [*Salam et al.*, 2003] indicated a negligible contribution of biomass burning in South Asian cities. However, these findings relied on ratios between total carbon and BC that are representative of open biomass burning but not biofuel burning. Studies that do consider differences between emissions from biomass and biofuel burning estimate an approximately equal contribution of biofuel and fossil fuel [*Stone et al.,* 2007]. In continental outflow, a strong biofuel influence on total carbonaceous particles is indicated by single-particle measurements [74%, *Guazzotti et al.*, 2003] and radiocarbon measurements [66%, *Gustafsson et al*., 2009]. The radiocarbon measurements indicate that between one-half and two-thirds of the BC also result from biofuels. In Indian cities, fossil-fuel burning dominates fine particulate matter concentrations, but biofuel burning is not negligible, according to organic marker studies [*Chowdhury et al.*, 2007]. Fossil fuel and biofuel burning contribute 20 to 60% and 7 to 20%, respectively.

3.9.3. Summary of findings from receptor modeling

[80] Results from receptor modeling agree qualitatively that major BC sources identified by global or regional emission inventories are similar to the major sources of fine particulate matter. Traffic is the largest source in North and Latin America and Europe, and contributions from residential solid-fuel burning and open burning are found in Asia and Africa. This broad agreement lends confidence to the identification of the largest BC sources. However, receptor modeling of regional aerosols with specific source markers capable of resolving similar sources is needed before the approach can be extended beyond this qualitative

Accepted Article

assessment. Further examination of both urban and rural sources is required to constrain the dominant sources in continental plumes.

4. Constraints on black-carbon atmospheric abundance

4.1. Section summary

[1]

1. Black carbon concentrations, like those of all short-lived species, are variable in space and time and are largest around source regions. Constraints on black carbon abundance are provided by in-situ measurements of BC concentration and by ground- and satellite-based remote sensing of AAOD. Aerosol absorption inferred from satellite-based remote sensors is nearly global in coverage, but these data are less quantitative than ground-based data.

2. Ground-based remote sensing provides information on the atmospheric aerosol column burden and optical properties, which is directly relevant to radiative forcing. However, BC AAOD is inferred indirectly from these measurements. Aerosol can be sensed only when the sky is cloud-free, absorption sensing has large uncertainties when aerosol loading is low, and the interpretation of BC amount is confounded by the presence of other light-absorbing aerosol in the column.

3. National and global networks of measurements are used to evaluate chemical transport models that provide estimates of BC surface concentrations (in-situ monitoring) and column AAOD (ground-based remote sensing). Measurements are most sparse in some of the regions with the highest BC loadings: Africa and most of Asia. Measurements from field campaigns, which typically sample only one region over periods shorter than a year, can also be used to test processes within models more comprehensively, but within a limited domain and time.

4. Comparisons with in-situ observations indicate that many models simulate near-surface BC concentrations approximately correctly for North America and East Asia, have a slight high bias in Europe, and have a strong low bias in parts of Asia.

5. On the other hand, many model estimates of column BC AAOD over continents have a low bias in all regions. In many regions, this underestimate can be explained at least in part by the fact that these models do not account for aerosol internal mixing and, thus, their modeled mass absorption cross section (MAC_{BC}) is too low. However, even if this factor is taken into account, models would still underestimate AAOD in some regions.

6. Comparisons with satellite observations indicate that bottom-up estimates of aerosol emitted from biomass burning are too low by factors of two to four, and emission estimates should be revised upward.

7. Airborne campaigns measuring vertical profiles of BC now allow for comparisons of vertically resolved concentrations away from continents. These measurements suggest that models overpredict BC in remote Pacific regions – on average by a factor of five – and that the overestimate is generally greatest in the upper troposphere. An exception is in the Arctic, where models appear to underpredict upper tropospheric BC. While concentrations in these regions are generally low, the large spatial area and bright underlying surfaces means the contribution of Arctic BC to globally averaged radiative forcing may be significant.

8. These combined results suggest that modeled removal of BC is an important source of model error. Further, inter-model comparisons indicated that differences between modeled BC concentrations and AAOD can only be attributed in part to differences in assumed emissions; differences in vertical transport and aerosol removal also play a large role, and MAC_{BC} differs between models.

4.2. Introduction

[2] The impact of BC on climate depends on its atmospheric abundance. Aerosol concentrations vary in space and time, and coverage by observations is insufficient to capture all such variations. Therefore, atmospheric models must be used to determine global concentration fields, and these models can be partially evaluated by comparisons with available observational data. Figure

Accepted Article

4.1 shows modeled atmospheric absorption by two absorbing aerosols: BC and dust. The figure shows that BC, like all short-lived species, is most concentrated around source regions. For energy-related combustion, sources and concentrations are largest where population density is highest, as can be seen by comparing the east and west coasts of the United States, or Eastern Asia with Central Asia. Large BC concentrations also occur in and around biomass burning regions, especially South America and central Africa. Continental outflow also contains high concentrations, especially to the east of Asia and the west of Africa. Although BC is not well-mixed throughout the atmosphere, some of it is carried to remote regions. Most energy-related BC emissions occur in the Northern Hemisphere, and BC is found in remote regions there, including in the deep Arctic. In contrast, there is very little BC throughout large remote regions in the Southern Hemisphere.

[3] Section 4.3 discusses atmospheric absorption and extinction by absorbing species. This section highlights the fact that if all absorption is attributed to BC, then concentrations of BC using measured absorption would be overestimated, especially in dusty regions. In Section 4.4 we review measurements that report the spatial and temporal variation of BC concentrations. Section 4.5 examines how well global models simulate BC concentration over broad regions, and Section 4.6 compares modeled vertical BC distributions with observations. These evaluations are used in Section 5 to derive a best estimate of BC direct radiative forcing. Throughout this assessment, modeled BC concentrations are often drawn from an intercomparison project known as AeroCom (Aerosol Comparisons between Observations and Models [*Kinne et al.,* 2006; *Schulz et al.,* 2006]). The AeroCom results described here reflect the first round of model experiments, known as Phase I.

4.3. Atmospheric absorption and extinction by absorbing species

[4] Section 2.4 discussed measurements of BC mass concentration (with units of g m^{-3}). Another measure of particle abundance, albeit indirect, is AOD, which is the vertically integrated extinction of aerosols in an atmospheric column. Aerosol light extinction and AOD values are given for a specific wavelength; small (submicron) aerosols have higher AOD at shorter solar wavelengths. For illustration, if we neglect losses of sunlight to molecular scattering by gases, an aerosol AOD of 1.0 at a given wavelength indicates that only 37% [e^{-1}] of the direct solar beam at that wavelength reaches the surface without being scattered or absorbed, if the sun is directly overhead.

[5] Of particular relevance for inferring absorbing aerosol amount is the column single-scattering albedo (ω_0), which relates the amount of light scattered to the amount attenuated (similar to Equation 2.2). The value of ω_0 is influenced by microphysical properties (Section 2.4) and by compositional properties, which are quantified by refractive indices. These optical coefficients are usually determined through laboratory or in-situ measurements. The fraction of AOD attributable to absorption, or AAOD, is

$$\mathrm{AAOD} = \mathrm{AOD} \times (1 - \omega_0) \qquad (4.1)$$

where ω_0 denotes a column-averaged single-scattering albedo. For any species, the product of mass concentration (with units of g m^{-3}) and mass absorption cross section (MAC) ($m^2 g^{-1}$) is the absorption coefficient (m^{-1}). AAOD (dimensionless) is the result of integrating absorption coefficient over the entire atmospheric column, and is the quantity shown in Figure 4.1. AAOD is more closely related to BC column abundance than is AOD because BC is responsible for a much larger fraction of total absorption than of total extinction.

[6] As discussed in Section 2, atmospheric concentrations of BC are often inferred from observations of absorption. Absorption measured in the atmosphere is attributable to all light-absorbing aerosols: BC, mineral dust, soil, and light-absorbing organic carbon (*i.e.,* brown carbon) from combustion. If all AAOD is attributed to BC, then inferences of BC may be overestimated, especially in dusty regions. Measured absorption may also include contributions from nitrogen dioxide and ozone. The relative contributions of each component to AAOD are required to infer BC column abundance.

Accepted Article

[7] Figure 4.1 shows that although the regions most affected by BC and dust are somewhat different, both species make significant contributions to globally averaged absorption, and in some regions the contributions are equal. Dust has a much greater total AOD than does BC, but a smaller fraction of that AOD is absorption (*i.e.*, ω_0 is larger), so globally averaged AAOD of BC and dust are of similar magnitudes at visible wavelengths.

4.4. Observations of atmospheric black carbon concentrations

[8] Monitoring studies provide information about BC concentrations in the atmosphere. These studies incorporate either in-situ observations, in which sampled air is drawn into an instrument for measurement, or remote observations, which measure the intensity of light coming from the atmosphere, and from this infer information on the atmospheric distributions and properties of aerosols. In this section, we illustrate the contributions of different types of studies to the understanding of BC and other aerosol concentrations and properties (Table 4.1).

[9] Data gathered from intensive field campaigns or observational networks are subject to the limitations of the measurement techniques used, as discussed in Section 2. Furthermore, when measurements are made at a single point, the measured values may not represent an average of the surrounding area, so comparisons between these point measurements and the average of a large model grid box should be done cautiously [*e.g., Tegen et al.,* 1997; *Vignati et al.*, 2010]. Thus, model simulations of the BC burden are evaluated by comparison with observations, which themselves may be biased. If the bias were known for each observation, or if it were the same for all observations, it might not affect our understanding of BC's life cycle, but this is not the case. Some biases may depend on aerosol age, source type, or location, and these relationships are poorly known.

4.4.1. In-situ monitoring

[10] The in-situ BC measurement techniques described in Section 2, especially thermal-optical measurements on filter samples and optical measurements, have been employed in several intensive field campaigns (Section 4.4.1.1) and in routine monitoring networks (Section 4.4.1.2) at national or continental scales. The uses and limitations of these measurements are described in the following subsections, and inferences drawn from these measurements are discussed in Sections 4.5 and 4.6.

4.4.1.1. Intensive field campaigns

[11] Multi-investigator field campaigns have examined the nature of atmospheric aerosol in many world regions. Such campaigns typically take place over the course of a few weeks and provide 'snapshots' of regional aerosol. They often combine measurements from several platforms, beginning with heavily instrumented surface stations but also adding aircraft and shipboard platforms to measure vertical and horizontal distributions in continental plumes. Intensive campaigns provide information about aerosol composition, microphysical properties including scattering and absorption, and reaction rates. Because they incorporate large arrays of measurements, they provide a wealth of information on aerosol and gaseous precursors, and can often be used to evaluate some aspects of emission inventories. This type of observational approach generally has limited temporal and spatial coverage and, alone, does not provide the information required to determine the average influence of BC or other aerosols on climate. The value of this type of effort in the context of evaluating BC concentrations and climate impacts lies in the richness of simultaneous measurements that they provide. These studies provide detailed physical understanding for evaluation and the improvement of the modeling of aerosol processes.

[12] Examples of early field campaigns that studied carbonaceous particles included a mission to the Arctic [*Rosen et al.*, 1984] and the search for the light-absorbing component in the Denver Brown Cloud [*Groblicki et al.*, 1981]. Coordinated campaigns to study aerosol-climate interactions in particular regions began with the Aerosol Characterization Experiments (ACE) series of experiments [*Quinn and Coffman*, 1998; *Raes et al.,* 2000] and these have frequently examined the outflow regions from major source areas [*Russell et al.*, 1999; *Ramanathan et al.*, 2001a; *Mayol-Bracero et al.*, 2002; *Jacob et al.*, 2003; *Huebert et al.*, 2003].

Accepted Article

Large field campaigns in more recent years have focused on aerosol evolution and properties in large regions with high aerosol loadings [*Bates et al.*, 2005, *Querol et al.*, 2008, *Zhang et al.*, 2008b]. Equally intensive efforts have examined aerosol in urban areas or heavily source-influenced regions [*Watson et al.*, 2000; *Neususs et al.*, 2002; *Solomon et al.*, 2003; *Cabada et al.*, 2004; *Parrish et al.*, 2009; *Wang et al*., 2010].

[13] Intensive field campaigns have provided information on emissions in addition to aerosol properties. Experiments to evaluate emissions from open biomass burning [*Lindesay et al.*, 1996; *Kaufman et al.*, 1998; *Eck et al.*, 2003] have determined aerosol characteristics and emission ratios. Chemical and transport models have also been used in conjunction with measurements to evaluate regional emission inventories [*Rasch et al.*, 2001; *Dickerson et al.*, 2002; *Carmichael et al.*, 2003; *Minvielle et al.*, 2004]. The interaction between atmospheric models and campaign measurements can be iterative, as models have also been used to guide aircraft flights to intercept urban and biomass burning plumes.

[14] The long history of intensive measurements now allows analyses across many campaigns and pollutants. For example, *Clarke and Kapustin* [2010] combined aerosol and trace gas measurements from 11 campaigns to relate anthropogenic aerosol concentrations to concentrations of CCN, AOD, and CO. This type of relationship can be used to test modeled emissions and transport.

[15] One recent campaign relied on a single well-instrumented aircraft performing near-continuous vertical profiling over global scales in remote areas over a period of a few weeks [*Wofsy et al.,* 2011]. The sampling approach of reaching both high northern and southern latitudes was repeated five times in different seasons, so the spatial and temporal coverage is greater than intensive field campaigns. This type of measurement, along with vertical profile measurements in a single location over several years [*Andrews et al.*, 2011], can provide constraints on background aerosol loadings and removal processes. Here they are used to estimate biases in modeled vertical distributions of BC (Section 4.6.1) and to correct biases in modeled BC forcing efficiency (Section 5.6.1).

[16] Intensive field campaigns usually include both in-situ and remote-sensing measurements from multiple surface (either land- or ship-based) platforms and from one or more aircraft, as well as integrating satellite remote sensing measurements. Research aircraft often fly over surface stations and ships, so measurements can be compared between platforms and used to determine vertical profiles of the full aerosol column. This rich set of data allows comparisons of different techniques for measuring BC and other aerosol properties and applications of the same technique in different environments [*e.g., Livingston et al.,* 2000; *Schmid et al.,* 2003; *Doherty et al.,* 2005]. Understanding of the applicability and limitations of each type of measurement is fostered by comparisons between properties measured at the surface, columnar properties measured by satellite-based remote sensing, and vertically resolved information from aircraft measurements [*e.g., Redemann et al.,* 2000; *Magi et al.,* 2003].

4.4.1.2. Long-term in-situ monitoring

[17] Long-term monitoring networks usually combine relatively simple measurement techniques with tens or even hundreds of stations to create a widely spaced network of observations that operate under uniform techniques. Surface sites may be influenced by orography and local sources, although such effects are usually considered when selecting sites. Because network sites are spatially sparse and have relatively simple data products, they do not provide the same level of insight into the fine details of aerosol processes as intensive field campaigns. However, they do provide valuable information on aerosol trends and broad spatial concentration patterns, and these long records contribute strongly to evaluation of the modeling of emissions, transport, and removal.

[18] Table 4.2 lists the major networks contributing information on aerosol absorption and BC concentrations. Continuous in-situ measurements to monitor pollution levels were initiated as early as 1962 [*Novakov and Hansen*, 2004]. The IMPROVE network in the United States [*Malm et al.*, 1994] and the European Monitoring and Evaluation Programme network in Europe [*Kahnert et al.*, 2004] are among the most extensive, and have historically focused on chemical speciation rather than on aerosol properties. While

Accepted Article

they have achieved broad coverage within their regions, similar coverage is not available in many other world regions, such as South America and Africa. Monitoring stations are being developed throughout Asia [*Oanh et al.,* 2006; *Cao et al.*, 2007; *Ramana and Ramanathan,* 2006; *Marcq et al.*, 2010], although coverage is still poor. Two smaller groups of stations focus on global coverage to monitor aerosol properties relevant to climate in remote locations: those operated by the Climate Monitoring and Diagnostics Laboratory [*Sheridan and Ogren*, 1999] and the Global Atmosphere Watch (presently housed at http://gaw.tropos.de).

[19] As multiple measurement locations are required to evaluate emissions, transport and removal processes in global and regional models, measurements from all of these networks have been used for model evaluation [*Cooke et al.*, 2002; *Park et al.*, 2003; *Solmon et al.*, 2006; *Koch et al.*, 2009a]. Most national networks have rigorous quality control procedures that ensure comparability of their measurements among similar network stations. However, as discussed in Section 2, important differences in sampling or measurement practices may affect comparisons between networks.

4.4.2. Remote sensing

[20] Remote sensing methods measure changes in the amount of sunlight reaching the Earth's surface, or the amount of radiation leaving the Earth's atmosphere, rather than the actual atmospheric BC or aerosol content. Through a process known as *inversion*, the nature and quantity of aerosol is inferred from its observed physical effect on the light. The procedure is also called a *retrieval*, because aerosol properties are retrieved from observed changes in radiance. Radiance properties that may be measured include wavelength dependence, angular distribution, and polarization. These can be used to infer the columnar amount of aerosol, the average aerosol size, the presence of non-spherical particles (such as dust) and even estimates of columnar light absorption.

[21] Advantages of remote sensing are the multi-year nature of the measurements and the ability to obtain measurements without continuous maintenance. Remote measurements sense column properties of aerosol, rather than concentrations at the surface as are typically quantified by in-situ measurements. Column properties are more directly relevant for quantifying climate impacts. The relationship between surface in-situ observations and column data depends on many factors, including the stability of the boundary layer, the presence of atmospheric layers and measurement conditions that affect in-situ and remote measurements differently. When in-situ measurements are made from an aircraft that profiles the depth of the atmosphere, however, robust comparisons with column-integrated remote sensing measurements are possible. Disadvantages of passive remote sensing include a lack of specificity to individual chemical species and an inability to retrieve the properties of aerosols in distinct layers independently, such as a dust layer overlying a pollution layer.

[22] Information from retrievals may be used to infer the column burdens of chemical species that have distinctive physical or optical characteristics. However, many assumptions are required for these inferences, resulting in large uncertainties, especially at low optical depths (low concentrations). Furthermore, most remote sensing techniques can obtain valid data only in cloud-free conditions.

4.4.2.1. Ground-based remote sensing

[23] The utility of ground-based remote sensing for constraining BC atmospheric abundance is similar to that of long-term in situ sampling. Networks of measurements can be combined to evaluate model performance, but they do not provide fine-scale or global coverage. However, unlike ground-based in-situ measurements, they do measure the whole atmospheric column which is more directly relevant to radiative forcing.

[24] Passive, ground-based remote sensing with upward-looking sun or sky photometers can be used to estimate AAOD. AERONET is the largest global network of these photometers [*Holben et al.* 1998; *Dubovik et al.*, 2002]. These instruments use information measured at multiple wavelengths and multiple angles by sun- and sky-photometers [*Dubovik and King*, 2000]. Properties derived from the sky radiance measurements include the aerosol size distribution, AOD, and refractive indices at four solar wavelengths; from this, single-scattering albedo can be determined. However, the retrieved refractive indices are obtained for

Accepted Article

the total aerosol. No distinction is made between the fine and coarse mode aerosol components, which are compositionally different and have different refractive indices. Thus, when both dust and BC are present in an aerosol column, the retrieved imaginary refractive index (which dictates aerosol absorption) does not accurately reflect that of BC alone.

[25] We have calculated values of BC AOD from retrievals of AAOD at AERONET sites and use these values in Section 5 to produce a scaled estimate of BC direct radiative forcing. The process of extracting BC AAOD from total AAOD requires certain assumptions. Limitations in the derivation of AAOD and specifically BC AAOD are discussed next.

[26] First, AAOD data are overestimated in the AERONET Version 2.0 data product. Values of AAOD are based on aerosol extinction optical depth and single-scatter albedo, and single-scatter albedo can only be retrieved reliably for rather polluted conditions. For this reason the AERONET Version 2.0 values of AAOD are published only when AOD is greater than 0.33 at 550 nm. The exclusion of low-AAOD conditions introduces a significant sampling bias that *Reddy et al.* [2005a] estimate to be a factor of two. This issue, and its implication for inferred BC quantities, is explored further in Section 5.5.1 and Appendix B.

[27] Second, not all solar absorption by aerosol is caused by BC; some is due to dust and some to organic matter. Dust is less absorbing per mass than BC but its AOD is often much larger. The net effect is that global average dust AAOD is comparable to that of BC AAOD, but differently distributed in space and time. Thus, the BC contribution to AAOD needs to be isolated to use AERONET absorption for model evaluation. Dust particles tend to be larger than BC particles, so retrieved size distribution data might be used to attribute absorption by super-micron particles to dust, and absorption by submicron particles to BC and light-absorbing organic matter. However, AERONET retrievals provide a single ω_0 and refractive index for the entire size distribution. Although this refractive index can be used to estimate AAOD of the total aerosol, the composition and, hence, the refractive indices and ω_0 of the separate fine and coarse modes may differ greatly [*Quinn and Bates*, 2005]. As a consequence, a method is needed to apportion AAOD among the two modes. Separating the sub-micron AAOD into contributions of organic matter and BC would require a further inference not based on size distribution. The spectral absorption properties of the total aerosol have been combined with assumptions about the wavelength dependence of absorption for dust, BC and organic matter to estimate their contributions to AAOD [*Arola et al.*, 2011; *Chung et al.*, 2012].

[28] Third, sample biases may occur because AERONET AAOD retrievals are made only during daylight hours and in cloud-free conditions. Two potential sources of bias oppose each other. Clear conditions can be expected to favor larger concentrations and column burdens of BC because fires are more likely and because scavenging by clouds (*i.e.,* the primary removal mechanism for BC) cannot occur under clear skies. To estimate biases in retrievals of BC AAOD, we averaged modeled BC AAOD at AERONET locations only during days when AERONET retrievals were possible. Bias was determined by comparing with the average BC AAOD. For four AeroCom models, biases were regionally dependent, but the average was only 1%. This is consistent with a small global clear-sky bias in AOD found by *Zhang and Reid* [2009]. Another factor is that solar absorption by BC is enhanced when BC is coated by water, which may be much more likely in the vicinity of clouds. The model of *Jacobson* [2010] estimated solar absorption enhancement to be a factor of 2 to 4, depending on the size of the BC particle. Clear-sky measurements, which exclude partially cloudy scenes, likely miss this near-cloud absorption enhancement. To explore this sensitivity, we used the GATOR model [*Jacobson*, 2010], the only aerosol model that treats the full effect of optical focusing on absorption, to compare the AAOD for clear-sky versus all conditions. Although the global mean MAC_{BC} for cloudy conditions (14.4 m^2g^{-1}) was higher than for clear-sky (13.9 m^2g^{-1}) conditions, the global mean burden was greater by 35% and BC AAOD was 20% higher for clear sky conditions than for cloudy conditions, so it is unlikely that AERONET observations are missing large enhanced absorption under cloudy conditions. However, this finding is not specific to AERONET sites or days of retrieval.

[29] A method to infer BC column mass loading is to determine the volume concentrations of components of aerosol mixtures required to fit the AERONET retrieved total column refractive index. These can then be used, along with assumptions about

Accepted Article

densities, to determine the column mass of each component, including BC [*Schuster et al.,* 2005]. The BC column mass uncertainty is estimated at -15% to +40%, although the imaginary refractive indices used affect the retrieval and the AAOD. For analyses in this assessment, we use AAOD rather than inferred BC column loadings, as the former requires fewer assumptions.

4.4.2.2. Remote sensing from space

[30] Knowledge of BC concentrations is needed in regions with few or no ground sites, such as over oceans. Remote sensing from space-borne sensors on satellites has near-global coverage and can, therefore, fill observational gaps in ground-based networks. AOD can be inferred from retrievals from satellite data, but the procedure also requires general assumptions regarding environmental properties (*e.g.,* surface reflectance), and aerosol properties [*Torres et al.*, 1998; *Levy et al.*, 2007; *Kahn et al.*, 2010], so that uncertainties are greater than those in ground-based sensing. Satellite-based instruments that provide data on column aerosol absorption and, therefore, information specific to constraining light-absorbing aerosol, are discussed below.

[31] The longest satellite data record on aerosol absorption, dating to 1978, is provided by the TOMS sensor (Total Ozone Mapping Spectrometer, http://jwocky.gsfc.nasa.gov/aerosols/*aerosols_v8.html*). The TOMS Aerosol Index is a retrieved quantity that indicates whether the column aerosol is largely absorbing or scattering. Over the last decade, TOMS-type retrievals have been continued with measurements from OMI (Ozone Measurement Instrument, http://disc.sci.gsfc.nasa.gov/Aura/*data-holdings/OMI*). This instrument senses reflection and its spectral variability in the ultraviolet region (UV) of the solar spectrum [*Torres et al.,* 2002]. Aerosol retrieval at UV wavelengths has two advantages: first, surface contributions to the signal are small, especially over land, and second, small aerosols have stronger signals in the UV than at visible wavelengths. On the other hand, in addition to BC, both dust and organic carbon contribute to UV absorption. Another complication is a reduced sensitivity towards the surface, so that BC near the surface (approximately the lowest kilometer) may not be detected. Therefore, a separate estimate of the vertical distribution of aerosol is an essential element of the retrieval. In the past, the vertical profile of aerosol concentration was prescribed using estimates from global modeling; more recently aerosol profiles inferred from the CALIPSO space-borne lidar have been applied [*Winker et al.*, 2010]. Even with this constraint, this type of retrieval is mostly useful for identifying atmospheric aerosol from large events such as biomass burning [*Zhang et al.*, 2005].

[32] Satellite-based aerosol sensors that provide spectrally resolved information allow general estimates of aerosol size and separate contributions from fine and coarse particles. Moderate Resolution Imaging Spectroradiometer (MODIS) sensors have the greatest temporal resolution [*Remer et al.*, 2005]. Additional information on aerosol shape and difficult retrievals over bright surface come from polarization sensing [*e.g.*, POLDER, *Deuzé et al.*, 2001] and multiple views of the same scene [*e.g.*, Multi-angle Imaging Spectro-Radiometer (MISR), *Kahn et al.*, 2009a]. Active remote sensing with a space-borne lidar [CALIPSO, *Winker et al.*, 2010] offers information on aerosol vertical distribution. This information may provide estimates of total aerosol amount, or even total fine-mode aerosol, but they do not constrain the amount of absorbing aerosol.

[33] The satellite-based MISR instrument [*Kahn et al.*, 2009a] provides another constraint on aerosol absorption. The MISR instrument detects radiance at multiple angles and multiple wavelengths. This additional information is used to estimate surface radiance, and it allows inversion for additional aerosol properties, including estimates of aerosol absorption. The MISR standard retrieval algorithm identifies two to four classes of absorbing aerosol, rather than providing exact values of absorption. The atmosphere must be relatively uniform and cloud-free, and the mid-visible AOD must be at least 0.15 or 0.2 [*Chen et al.,* 2008; *Kahn et al.,* 2009c].

[34] While all these satellite-based instruments provide some constraint on atmospheric absorption, several factors limit their utility in determining global, annual average BC AAOD. Signals reaching satellite-based sensors are influenced by both atmospheric constituents and by the reflectance properties of the Earth's surface. This increases the uncertainty in AOD and, especially, AAOD, particularly over spatially heterogeneous or highly reflective surfaces. Thus, quantitative atmospheric aerosol

Accepted Article

absorption cannot be retrieved from existing satellite-based sensors. Conversion of AOD to AAOD requires use of an assumed column aerosol single-scatter albedo, such as from a model [*e.g.,* as employed by *Chung et al.*, 2012]. Although satellite retrievals may infer the separation between fine and coarse particles, they cannot distinguish AOD from BC versus that from other fine mode aerosols like OA or sulfate. The division must be estimated either from the relative magnitude of modeled concentration fields or from ground-based observations. The relatively coarse resolution at which most satellite sensors can provide retrieved aerosol fields also makes them susceptible to cloud contamination. Finally, while polar-orbiting satellites have nearly global coverage, data coverage at any given location is limited and does not always allow for sufficient sampling for good statistics.

4.5. Comparison between modeled and observed BC concentrations and AAOD

[35] Estimates of forcing by individual aerosol species, including BC, are all based on aerosol distributions generated by global chemistry transport models (CTMs). Even estimates that incorporate observations require model results to expand concentration fields beyond observed locations, or to separate observed aerosol influences among chemical species. Evaluation of BC concentrations in these models is therefore critical in assessing our understanding of climate forcing. A first-order evaluation of these models is accomplished by comparing either simulated aerosol concentrations or simulated optical depths with independent observations. This comparison requires long-term, spatially distributed aerosol measurements, so that observations from nationwide or global networks, such as the ones discussed above, are particularly useful.

[36] Comparisons between models and observations shed light on our understanding of the quantity of BC in the atmosphere, but they often cannot distinguish between various possible causes of model error. For example, a model could underestimate atmospheric concentrations if its emissions are too low or if its overall removal rate is too high.

[37] *Koch et al.* [2009a] evaluated the AeroCom suite of global models by comparing modeled BC concentrations with observations from several intensive campaigns and long-term in situ measurements. Figure 4.2 summarizes this comparison, showing the ratio between observed and modeled surface concentrations of BC. The figure shows that the median model predicts surface BC concentrations in the North America fairly closely, slightly overestimates BC in Europe, and clearly underestimates it in Asia. The global annual average difference among models in this suite was about 30% of the median concentration; variations in individual seasons can be greater.

[38] *Koch et al.* [2009] also compared modeled fields with values of AAOD inferred from AERONET. Modeled AAOD was lower than observed values in all regions. Column BC AAOD is the sum over altitude of the product of BC concentration and MAC_{BC}. Because most of the models used in the comparison do not represent internal mixing, the modeled MAC_{BC} (see Section 2.7) was underestimated. This bias could explain the disagreement in North America and Europe, but not in other areas of the world. However, AAOD data were not separated into contributions from BC and dust. A refined analysis, which considers this separation and incorporates more AERONET stations, appears in Section 5 and is more fully described in Appendix B.

[39] The sources of differences between model predictions are not completely understood. For any given location, the interquartile range of the concentrations predicted by the 15 models participating in AeroCom was a factor of about three, and the range excluding outliers was a factor of about five [*Kinne et al.,* 2006; *Schulz et al.,* 2006]. *Koch et al.* [2009a] provided sensitivity experiments to explore the sources of this variability by using one model from the suite (GISS, shown as symbols in Figure 4.2). Simulations with different emission inventories are given in red, and concentrations with removal rates increased or decreased by a factor of two are shown as blue squares. Filled symbols indicate base-case results. Varying removal rates and emissions do cause significant variations in a single model, but these uncertainties do not explain most of the inter-model differences. *Textor et al.* [2007] also found that inter-model differences were only partially explained by differences in emission inventories. Large differences in modeled horizontal and vertical transport are largely responsible for the diversity. Once BC is lifted into the free troposphere, removal processes are slower and its atmospheric lifetime may be extended.

Accepted Article

[40] Figure 4.3 compares modeled and observed values of BC AAOD. The left panel shows BC AAOD inferred from AERONET observations (see Appendix B). Although these values include absorption by organic matter, we use them as our observational estimate for BC AAOD. Section 10.4 discusses implications of this combination. Modeled BC AAOD from the 15 AeroCom models are shown in the middle panels of the figure. We use this particular collection because it contains a large number of consistent modeled fields, but this presentation excludes subsequent improvements in many of these models. The AAOD fields shown in Figure 4.1 and Figure 4.3 are from the AeroCom 'median model,' for which a median of the local (1°x1° grid resolution) values from all AeroCom models was calculated every month. These median fields, unlike averages, lose their additivity, but the use of median values excludes the influence of individual outlier models. Figure 4.3 also presents differences in BC AAOD between co-located AERONET and model median values, showing that these models tend to underestimate BC AAOD. The regional dependence of model biases are discussed further in Section 5.

[41] The quantity and representativeness of observation sites is fundamentally important in interpreting comparisons between models and measurements. North America and Europe have the best coverage of all long-term measurement sites, followed by Asia. The number of sites is not in proportion to the strength of emissions, and concentrations in regions with large emissions and, therefore, highest aerosol forcing, are relatively poorly constrained.

[42] Remote regions with low concentrations also have few measurement sites and hence are also poorly constrained. Although aerosol forcing in these regions is small, their large spatial coverage means that contribution to the global-average forcing may be important. Compared with BC concentrations measured during a field campaign over the remote Pacific Ocean [Figure 4.4; *Schwarz et al.,* 2010], the median model overpredicted remote BC concentrations by a factor of five. Some models, such as the lower quartile of the AeroCom model suite or GATOR [*Jacobson*, 2012], show better comparisons with these remote measurements.

[43] *Koch et al.* [2009a] note that model diversity in atmospheric BC concentrations is particularly high for the Arctic. Models almost universally underestimated concentrations in the free troposphere during spring, and they did not match the observed decrease in concentrations from spring to summer. This finding is based on a very limited data set from intensive field campaigns, but it is consistent with multi-year observations from surface sites in the Arctic, which show that most models underestimate BC concentrations in the winter and spring and generally do not capture strong seasonal variations in boundary-layer BC concentrations [*Shindell et al.*, 2008; *Huang et al.*, 2010; *Liu et al.*, 2011].

4.5.1. Estimating emissions by integrating models and observations

[44] The comparisons between modeled and observed BC concentrations and column absorption described above are a first step in evaluating model performance. More detailed evaluations have been conducted, usually focusing on inferring the most likely sources of error. The simplest of these compare the temporal or spatial dependence of atmospheric concentrations with that given by models. More complex approaches use a mathematically strict evaluation of sources and sinks using a formulation of Bayes' theorem, which has been demonstrated for CO_2, CO, and aerosols [*e.g., Chevallier et al.,* 2005; *Dubovik et al.*, 2008; *Chevallier et al.,* 2009; *Huneeus et al.*, 2012]. Evaluation methods that use measurements of atmospheric abundance in combination with modeled fields are broadly called *inverse methods*. Inverse modeling of gaseous concentrations on continental scales, particularly CO and oxides of nitrogen (NO_x), can also provide information about emission sources. Although this technique has usually been applied to infer emissions, it should not be forgotten that model processes such as transport and removal can also contribute to errors, and that the initial estimate of emissions has a strong influence on the inferred emissions. Here, we summarize the results of inverse modeling studies that have focused on particular regions.

[45] *1. North America.* An inverse model by *Hu et al.* [2009] found that USA BC emission estimates using data mainly from a rural network (IMPROVE) was about 30 to 35% lower than an estimate that also included urban sites. This implies that, in order to

Accepted Article

constrain concentrations on continental scales, measurements in high-concentration areas should be included if models have sufficient resolution, and that this inclusion may affect the total continental burden of aerosol. There are also differences in the thermal evolution methods for measuring BC (Section 2.3) between urban and rural sites in the United States. The former tends to use a transmittance-corrected thermal-optical method, while the latter corrects using reflectance and heats the sample to a lower temperature. Before performing an inverse estimate, these authors had to multiply the transmittance-corrected values by factors ranging from 1.7 to 2.6, depending on the season. The resulting emission estimates were similar to the bottom-up emission estimate in Figure 3.3. On the other hand, an inverse model by *Park et al.* [2003] estimated a BC emission rate of about 750 Gg yr^{-1}, which is about 70% higher than the bottom-up estimate.

[46] *Bhave et al.* [2007] used organic markers to show that USA emission estimates of total aerosol carbon (OC plus BC) from vehicle exhaust and biomass combustion were not biased. They did find a large unexplained source of total aerosol carbon unassociated with combustion, but this would not affect BC totals.

[47] Inverse modeling of carbon monoxide has indicated that inventories overestimate fossil-fuel sources in North America by a factor of three in summer and two in spring [*Miller et al.*, 2008]. *Kopacz et al.* [2010] found a large underestimation especially in winter, ascribing this difference to heating and poor vehicle efficiency at cold temperatures. Although BC model results in the United States do not appear highly biased, these findings indicate that some small sources that could affect BC emissions are not well understood.

[48] *2. Europe. Tsyro et al.* [2007] found that a model based on the IIASA inventory underestimated BC concentrations by about 20%. Significant over- and underestimates of BC were correlated with concentrations of levoglucosan, a tracer of wood smoke, indicating that biofuel or open biomass burning could be responsible for the difference. Modeled concentrations were generally too high in Northern Europe and too low in Southern Europe. Mobile source emissions were thought to be underestimated in Austria and some Eastern European countries.

[49] *3. East Asia. Hakami et al.* [2005] used BC concentrations observed in field campaigns to constrain emission over eastern Asia. They found that the magnitude of the total emission inventory given by *Streets et al.* [2003b] did not change significantly as a result of the assimilation. However, anthropogenic emissions over southeastern China were reduced while those in northeast China and Japan were increased. The increase in the industrialized regions is consistent with the low bias in estimates of CO emissions [*Kasibhatla et al.,* 2002*; Heald et al.*, 2004], which is more strongly associated with the more northern industrialized regions [*Yumimoto and Uno,* 2006]. The observed CO bias has been largely resolved by improving the fraction of small combustors [*Streets et al.*, 2006], as discussed in Section 3.6.4. *Tan et al.* [2004] suggested that modeled particulate carbon emissions in East Asia should increase in order to be consistent with observations, but they did not separate BC and OC nor account for the formation of secondary organic aerosol, which could increase atmospheric concentrations. Studies that compare ground and aircraft measurements with modeled BC values over the East China Sea estimate an annually averaged BC emission flux of 1920 Gg yr^{-1} [*Kondo et al.*, 2011c], close to bottom-up emission estimates for the late 2000s. Inverse modeling of NO_x emissions in East Asia indicates rapid growth in high-temperature sources [*Kurokawa et al.*, 2009], although high-NO_x sources are presently a small part of the East Asian BC inventory.

[50] *4. South Asia. Rasch et al.* [2001] estimated that increases of about 10 to 20% in fine-mode aerosols were needed in the model to match satellite observations over South Asia, but this study did not specifically identify biases in BC. *Dickerson et al.* [2002] suggested a BC emission rate of 2000-3000 Gg yr^{-1}, much higher than bottom-up estimates, based on atmospheric ratios of BC and CO that are much higher than is given by bottom-up estimates. *Menon et al.* [2010] also find that modeled concentrations in South Asia are much too low compared with in-situ measurements.

Accepted Article

[51] The inverse modeling studies discussed above rely on *in-situ* data from a small number of sites to represent continental-scale concentrations of aerosols. Satellite measurements have much broader spatial coverage and could produce global emission estimates. This approach has been applied in biomass burning regions, where optical depths are large and seasonal. *Freitas et al.* [2005] found that emission estimates derived from observed AOD were larger than bottom-up estimates. *Zhang et al.* [2005] used aerosol index from the TOMS instrument to estimate BC from biomass burning as 5700 to 6900 Gg yr^{-1}, depending on the assumptions used, and total smoke (BC plus OM) emissions as 60000 to 73000 Gg yr^{-1}. *Reid et al.* [2009] estimated that bottom-up emission estimates of particulate matter from biomass burning need to be enhanced by factors of 1.5 to 3. The global emission flux derived for 2006 to 2008 was about 140000 Gg yr^{-1}, as compared with the value of 30000 to 44000 Gg yr^{-1} BC plus POA given in Section 3.4.4, if OA is assumed to be 1.4 times OC. Similarly, *Kaiser et al*. [2012] derived a global average enhancement factor of 3.4 for the OA and BC resulting from biomass burning, summarizing several other top-down studies that recommended emissions two to four times larger than the bottom-up estimates. These studies indicate that BC emissions from biomass burning should be much larger than represented in models, although they may not scale linearly with total aerosol emissions. However, the fraction of the discrepancy attributable to BC is uncertain. Formation of SOA may contribute to the observed OA and particulate matter loading.

[52] In summary, inverse modeling studies have produced inconsistent results for North America, indicating that either BC emissions are estimated well or are too low by 70%. European BC concentrations appear slightly underestimated. East Asian concentrations appear reasonable, especially after the addition of small combustors. Although observations are limited, measurements in South Asia suggest that concentrations are greatly underestimated there. All of the studies described have used single models and await further confirmation. On the other hand, there is a consensus that aerosol concentrations, including BC, may be too low in biomass burning regions. Considering also the likely bias in emission factors (see Section 3.7.2.3), emission values that are greater than bottom-up estimates appear warranted.

4.6. Vertical distribution of BC

[53] As discussed in Sections 5 and 6, the vertical distribution of absorbing aerosol affects its forcing. Vertically resolved measurements below 8 km of the refractory aerosol concentration, which correlates strongly with BC concentration, have been carried out since the 1990s [*Clarke and Kasputin,* 2010]. Remotely piloted airborne sensors have measured optical properties and total aerosol absorption below 3 km [*Corrigan et al.,* 2008].

[54] BC vertical profiles extending through the troposphere have been made with a variety of measurement methods, but the development of the SP2 instrument (Section 2.5) has allowed measurements of vertical profiles of BC in very clean air where they were previously unobtainable [*Schwarz et al.,* 2006, *Schwarz et al.,* 2010]. These profiles extend vertically from near the surface to the lower stratosphere, as shown in Figure 4.4. Although BC vertical profiles are quite variable, in polluted regions they generally show a declining BC mass mixing ratio from the surface to about 4 km altitude, and relatively constant values up to well above the tropopause. However, in remote regions influenced by the transport of pollution from source regions, BC loadings tend to peak in the free troposphere or above. BC that has been lifted above the low altitude ranges where aerosol removal is fast due to precipitation is more likely to have a longer lifetime in the atmosphere.

[55] Important BC properties, such as mixing state (Section 2), also change with altitude. One set of vertical profile observations in the tropics indicates that the coatings of BC-containing particles become thicker and more prevalent with increasing altitude between the surface and the lower stratosphere [*Schwarz et al.,* 2008a]. The fraction of coated BC particles and the acquired coating mass depend on both the BC source and the history of the particle and the air it is contained in. Thus, MAC_{BC} (Section 2.7) can be expected to depend on altitude.

4.6.1. Comparison between modeled and observed vertical distributions

Accepted Article

[56] Correctly modeling the vertical distribution of AAOD is important for calculations of direct radiative forcing, as discussed in Section 5.6.1. *Schwarz et al.* [2010] compared the AeroCom set of models with a global-scale 'snapshot' of SP2 BC measurements from remote locations (Figure 4.4). The AeroCom model ensemble captured the vertical trends of BC concentration in the southern mid to high latitudes, but in northern mid and equatorial latitudes the models underestimated the decrease in concentration with altitude. This comparison in regions far from sources suggests that modeled removal of BC is an important source of error. However, the aircraft data in this comparison were obtained over a limited time range; in particular, the profile for the northernmost band (60-80ºN) was from a single flight. *Koch et al.* [2009a] also compared BC vertical distributions between AeroCom models and SP2 measurements from several intensive field campaigns, mainly over North America and the Arctic. That comparison indicated that models overestimate mid- and upper-troposphere BC at mid-latitudes, consistent with *Schwarz et al.* [2010], but underestimate BC in the Arctic. In urban areas, model predictions of column loadings were consistent with observations [*Schwarz et al.*, 2006], but the vertical distribution was not well predicted.

[57] Observations of the vertical distribution of AOD have become available in recent years with active remote sensing by the space-borne CALIOP lidar [*Winker et al.*, 2010 (BAMS)], for which multi-year averages are shown in Figure 4.5. AOD includes scattering and absorption by BC, dust, and other aerosol types (*e.g.*, sulfates, organics, and sea salt) with sizes greater than 0.1-µm diameter [*Omar et al.*, 2009]. Although chemical speciation is not possible, limited inferences about aerosol type can be obtained through depolarization data that identify non-spherical particles and permit estimates of dust contributions. Geographical distributions of full-column CALIOP AOD (Figure 4.5) are very similar to BC and dust AAOD from AeroCom models (Figures 4.1 and 4.3), with high loadings in South and East Asia, the Middle East, Africa, and Latin America. Maximum total AAOD values are a few percent of maximum AOD values. The panels in Figure 4.5 show that AOD is confined largely to altitudes below about 4 km. Although interpretation of CALIOP data is still undergoing refinement, these data also indicate that models tend to place aerosol at higher altitudes than is observed [*Koffi et al.,* 2012].

4.7. Causes of model biases

[58] The comparisons between models and observations and the inverse model studies discussed above provide some consistent messages regarding modeled atmospheric distributions of BC. In the following sections, these observations are used to adjust modeled BC AAOD and direct radiative forcing (Section 5) and cloud forcing (Section 6). The source of these model biases is less clear. Large underestimates in modeled BC concentrations strongly argue that there are low biases in emission estimates. However, it is difficult to attribute these biases wholly to errors in model emissions, because transport patterns and removal rates can also affect spatial distributions. Transport and removal rates are not independent factors, because aerosol transported to higher altitudes is less likely to be removed and, therefore, has a longer lifetime and greater horizontal transport.

[59] At least one model sensitivity study [*Koch et al.*, 2009a; Section 4.5, Figure 4.2] indicates that varying removal rates by a factor of two cannot fully explain the inter-model range in concentrations or the bias between models and observations. Significant over-estimates in BC concentrations over the remote Pacific are consistent with vertical transport that is too strong or scavenging rates that are too low, but significant under-estimates in concentrations in the Arctic free troposphere indicate opposite biases in these processes. Across-the-board adjustments such as altering wet scavenging rates may improve biases in one region but make them worse in another. It is likely that different regions have different sensitivities to each of these processes, requiring focused studies in regions where biases have been observed. For example, Garrett *et al.* [2010] argue that scavenging plays a dominant role in controlling Arctic BC distributions, but this may not be true in other regions such as the remote Pacific. Concentrations near sources are most sensitive to emissions, while concentrations in remote regions depend on transport and removal as well as emissions. Although concentration biases could be reduced by first constraining emissions with near-source concentration measurements and then focusing on transport and removal using measurements downstream from sources, such an activity is

Accepted Article

beyond the scope of this study, which instead resorted to an after-simulation adjustment that can be applied to all previous simulations that save the requisite information.

4.8. Summary of limitations in inferring black carbon atmospheric abundance

[60] Like all aerosols, BC concentrations are spatially and temporally variable. No measurement strategy provides global coverage of BC concentrations or of AAOD. Space-based sensors have varying limitations: they detect aerosol abundance but not composition (MODIS), provide qualitative measurements of absorption (MISR), or preferentially detect BC at greater altitudes (OMI). Estimating global distributions of BC or absorbing aerosol must therefore rely on modeled aerosol fields, which in turn are constrained by ground-based observations. Ground-based AERONET stations are widespread and produce reasonably accurate AAOD, but coverage is not complete and techniques to separate BC, OM and dust absorption from these observations are not yet mature. In-situ surface measurements have less coverage than AERONET, but greater specificity in identifying individual species. These measurements have been used to broadly evaluate modeled global fields, and to assess modeled emissions in selected regions. However, observations are sparse in some of the regions with the greatest emissions. A systematic evaluation of model biases caused by emissions, removal rates, and vertical transport, leveraging near-source and remote measurements, has not yet been accomplished.

5. Black-carbon direct radiative forcing

5.1. Section summary

[1]

1. Black carbon in the atmosphere reduces the planetary albedo by increasing the absorption of sunlight. The perturbation in the radiative balance resulting from this change is called black-carbon direct radiative forcing (BC DRF).

2. The best estimate for the BC DRF in the industrial-era is +0.71 W m^{-2} with an uncertainty range of +0.08 to +1.27 W m^{-2}. The best estimate of the global annual mean all-source BC DRF is +0.88 W m^{-2} with an uncertainty of +0.17 to +1.48 W m^{-2}. Locally, BC-DRF forcing can be larger, on the order of +10 W m^{-2}, for example, over regions of East and South Asia. These values are estimated by scaling modeled forcing to the observationally constrained estimate of BC absorption aerosol optical depth (BC AAOD), and reducing the estimated forcing by 15% to account for the incorrect vertical distribution of BC. Our estimate of BC AAOD includes absorption by organic aerosol (OA).

3. Most BC-DRF estimates originate with simulations of BC lifecycle and radiative transfer using global aerosol models. To improve confidence in these estimates, model-derived fields, such as aerosol optical depth, BC AAOD or BC distributions, are often adjusted to match observations of AOD, BC AAOD or concentration, either by direct scaling or by tuning removal rates.

4. BC DRF can be considered the product of four factors: emissions, lifetime, mass absorption cross section (MAC_{BC}), and radiative forcing per unit absorption optical depth (termed forcing efficiency). Diversity in previous global annual estimates of industrial-era BC DRF (+0.2 to 0.9 W m^{-2}) is caused by variations in modeling assumptions, as evident in the modeled diversity of these four factors: 6000 to 18000 Gg yr^{-1} for industrial-era BC emissions, 3.8 to 11.4 days for BC lifetime, 4.4 to 13.4 m^2g^{-1} for MAC_{BC}, and 90 to 270 W m^{-2} per AAOD for forcing efficiency.

5. BC emissions, lifetime, and mass absorption cross section - three of the governing factors - combine to produce BC AAOD, which can be constrained by measurements. Comparison with remote-sensing fields indicates that BC AAOD from most models appears too low. Applying regionally dependent scale factors to match observations increases globally averaged, industrial-era BC AAOD by a factor of 2.9, from 0.0017 to 0.0049. Some of the underestimate can be attributed to the lack of modeled enhanced absorption due to internal mixing, which would increase BC AAOD by about 50%.

Accepted Article

6. If the remaining model bias is caused by burdens that are too low, then model burdens should be increased by factors of 1.75 to 4 in five regions (Africa, South Asia, Southeast Asia, Latin America, Middle East, and the Pacific region). Simulated burdens in North America, Europe, and Central Asia are approximately correct considering uncertainty in BC AAOD and MAC.

7. The altitude of BC in the atmosphere and its location relative to clouds affects its interaction with solar radiation and hence the forcing efficiency. Solar absorption by BC above low clouds is particularly important and is poorly constrained in models. Limited observations suggest that most models overestimate high-altitude BC at tropical and mid-latitudes and, thus, BC DRF. Our central estimate of forcing includes a 15% reduction to account for this bias.

8. If all of the differences in modeled burden were attributed to emissions, global emissions would be 17000 Gg BC yr^{-1}, or a 87% increase above modeled emissions and a 100% increase above the bottom-up emissions in Section 3. Industrial-era emissions would be 13900 Gg BC yr^{-1}. These values are associated with concentrations in approximately the year 2005. We use the latter value as a best estimate of emissions throughout the remainder of this assessment, although poorly modeled aerosol lifetimes could also explain the discrepancies.

9. The interpretation of remote-sensing data involves assumptions that affect the amount of absorption and, hence, radiative forcing, that is attributed to BC versus dust. Uncertainties in this division are responsible for nearly half the uncertainty in BC forcing.

10. If OA does contribute significantly to absorption at 550 nm, then our estimate of observationally constrained BC DRF is biased high, but total forcing by OA would correspondingly become less negative or more positive. About 10% of our BC AAOD may be due to absorption by OA.

11. The uncertainty range (+0.08 to +1.27 W m^{-2}) for the best estimate of industrial-era BC DRF includes relative uncertainties of about 40% associated with the extrapolation of global BC AAOD, about 50% in the radiative forcing efficiency per unit BC AAOD, and asymmetric uncertainty due to the difficulty in separating BC AAOD from dust AAOD.

5.2. Introduction

[2] Direct radiative forcing by BC refers to the change in the energy balance at the top of the atmosphere due to absorption and scattering of sunlight by BC in the atmosphere. All estimates of BC DRF are based on the difference between radiative transfer calculations for the atmosphere with present-day BC and with a background level of BC. The BC spatial distribution is generally taken from global models of the BC atmospheric lifecycle, which includes emissions, transport, aging, and removal. As described in Section 1.3.2, the background level of BC for industrial-era radiative forcing is set by models using year-1750 emissions. For all-source radiative forcing, the background level of BC is zero. Thus, 'industrial-era' in this section, when used for any quantity including BC burden, means the difference between modeled quantities with present-day emissions and the same quantities modeled with 1750 emissions.

[3] As with aerosol concentrations, radiative forcing is highly variable in space and time. Global modeling of BC concentrations [*Liousse et al.*, 1996; *Cooke and Wilson*, 1996] and radiative forcing [*Penner et al.*, 1998] began in the mid-to-late 1990s. Since then, many groups have estimated both concentration and radiative forcing fields. An example of modeled direct forcing is illustrated in Figure 5.1, which shows radiative forcing simulated by the Community Atmosphere Model CAM5 [*Ghan et al.*, 2012]. As discussed in Section 1.3.2, any estimated industrial-era forcing depends on the selection of the 'pre-industrial background.' Industrial-era BC DRF is estimated to be negative in regions such as the eastern United States and the United Kingdom, due to declines in biomass burning since 1750. However, the emission inventories used for the background are associated with considerable uncertainties, especially for open burning. The largest forcing is over the Congo Basin in Africa and southeast China, and Bangladesh, with significant forcing also in the Amazon Basin, over northern India and Indonesia, and off the eastern coasts of South America and Africa where BC is transported over low clouds from distant fires.

Accepted Article

[4] To understand the factors that affect radiative forcing in models, it is useful to express the global-mean direct radiative forcing by BC, BC DRF, as the product of four factors [*Schulz et al.,* 2006]:

$$\text{BC DRF} = E \times L \times MAC_{BC} \times AFE \qquad (5.1)$$

where E is the global mean BC emission rate, L is the global mean lifetime of BC governed by removal, MAC_{BC} is the global-mean mass absorption cross section discussed in Section 2.7.3.3, and AFE is the global mean absorption forcing efficiency (forcing per aerosol absorption optical depth). This relationship is summarized in Figure 5.2. Three-dimensional models simulate many complex processes that are captured only to first order by the factors in Equation 5.1.

[5] Additional diagnostics shown in Figure 5.2 can be used to compare model results and identify the reasons for differences in simulated radiative forcing. Modeled L can be determined from the ratio of global mean column burden of BC to E, and global average MAC_{BC} is the ratio of the global mean absorption optical depth of BC to the global mean burden. Modeled AFE can be determined from the ratio of the global mean BC radiative forcing to BC AAOD, which is the global mean product of E, L, and MAC_{BC}. BC AAOD is a particularly powerful diagnostic that can be compared with atmospheric measurements and is therefore emphasized in this section. Although AOD can also be used to evaluate modeled aerosol quantities, atmospheric AOD is dominated by scattering and thus has large contributions from other non-absorbing aerosol components.

[6] Table 5.1 summarizes modeled global mean estimates of each term in Equation 5.1 as well as other model diagnostics. Many of these models were used as the basis for IPCC radiative forcing estimates [*Forster et al.,* 2007]. Estimates of industrial-era BC DRF range from +0.2 to +0.9 W m^{-2}. The large diversity is due to different model choices that affect one or more of the factors in Equation 5.1. Global emissions of BC range from 5700 to 18000 Gg yr^{-1}. Lifetime ranges from 3.3 to 10.6 days. Global mean MAC_{BC} ranges from 4.3 to 15 m^2g^{-1}. AFE ranges from 91 to 270 W $m^{-2}AAOD^{-1}$ (Table 5.2). Because the correlation among these four factors can be negative [*Schulz et al.*, 2006], and because no model has maximum or minimum values of all four factors, the diversity in the radiative forcing in Table 5.2 (+0.2 to +0.9 W m^{-2}) is much smaller than the diversity estimated by multiplying the minima and maxima of the four factors (+0.05 to +3.7 W m^{-2}). The lower net diversity in simulated BC DRF is to some extent due to tuning simulations to match observational constraints on BC concentration and AOD. The best estimates of each component are summarized in Sections 5.3 through 5.6 before providing a best estimate of BC DRF in Section 5.7.

5.3. Emission, lifetime, and burden

[7] As discussed in Section 3, BC emission rates used in estimates of radiative forcing vary regionally and globally [*Haywood and Boucher,* 2000; *Bond et al.,* 2004]. Commonly used values of global industrial-era emissions are 6300 Gg yr^{-1} for AeroCom [*Schulz et al.,* 2006], but emissions as high as 18000 Gg yr^{-1} have been used [*Chin et al.,* 2002]. For the Climate Model Intercomparison Program simulations for the IPCC Fifth Assessment Report, the value was 5700 Gg yr^{-1} for present-day emissions [*Lamarque et al.*, 2010].

[8] Column burden is proportional to BC emissions and to modeled lifetime. Lifetime is determined by removal, which is represented differently in each model and varies by location and season. Global average lifetime for BC varies by a factor of more than three for the models reported in Table 5.1. Removal in precipitation plays a large role in aerosol lifetime [*Ogren and Charlson*, 1983], which is difficult to represent accurately at the coarse resolution of global modeling [*Rasch et al.,* 2000; *Textor et al.,* 2007; *Croft et al.,* 2010]. Differences in dry deposition contribute to uncertainty as well [*Easter et al.*, 2004; *Bauer et al.,* 2008; *Vignati et al.,* 2010]. Because removal processes depend on altitude, aerosol lofting also affects lifetime. For example, *Koch et al.* [2007] showed that lofting of biomass-burning aerosols from South America led to longer lifetimes compared with African emissions. Most developers of aerosol models have applied surface observations of BC concentrations and surface and satellite

Accepted Article

retrievals of AOD to constrain emissions or the treatment of scavenging, so one would expect the product of emissions and lifetime (burden) to agree broadly with observations [*Vignati et al.,* 2010].

[9] Early models used a limited number of parameters to account for subgrid variability in precipitation and the efficiency with which particles are scavenged. These scavenging treatments used crude parameters that were applied globally. More advanced models treat the coating of BC with hygroscopic material to form particles that are more readily activated to form cloud droplets and scavenged more efficiently. The representation of scavenging affects the magnitude and seasonality of BC concentrations, especially at remote locations [*Croft et al.*, 2005]. Model representation of the BC seasonal cycle in the Arctic improves with more accurate microphysical treatments [*Vignati et al.*, 2010; *Lund and Berntsen,* 2012; *Park et al.*, 2011].

[10] The global mean column burden of BC ranges from 0.11 to 0.53 mg m^{-2} in Table 5.1. The studies with the largest radiative forcing estimate [MACR-Assim; *Ramanathan and Carmichael,* 2008; *Chung et al.*, 2012] did not calculate a burden, but the BC simulation [*Chin et al.,* 2002] that the studies relied on for absorption far from AERONET sites [*Chung et al.,* 2005] had a global mean BC column burden of 0.6 mg m^{-2}. Some of the models did not constrain the combination of emissions and lifetime with BC concentration measurements [*Vignati et al.,* 2010], including the model that estimated the largest BC burden [*i.e.,* SPRINTARS, Table 5.2; *Takemura et al.*, 2005]. Some of the diversity in the column burden of BC in Table 5.1 can be attributed to differences in emissions. Yet many of the estimates used the same BC emission inventory and still yielded BC burdens differing by more than a factor of two (0.16 to 0.38 mg m^{-2}) due to differences in lifetime [*Schulz et al.,* 2006]. As discussed in Section 4.3, most models simulate surface BC concentrations within a factor of two of measurements in most regions, with weak over-predictions in Europe, under-predictions in biomass burning regions, and large under-predictions for eastern and southern Asia [*Koch et al.,* 2009a].

[11] Vertical lofting of BC affects its prospects for wet scavenging and hence its lifetime. Vertical profiles of BC show that simulated concentrations have large biases in the free troposphere [*Koch et al.,* 2009a]. High biases of a factor of 3 to 15 (average 8) are found in tropospheric BC concentrations above the boundary layer at tropical and subtropical latitudes, while most models underestimate the BC concentrations in the Arctic troposphere, on average by a factor of 2.5 [Table 8 of *Koch et al.*, 2009a]. Adjustments to simple scavenging treatments cannot reproduce these observed distributions; increased removal in tropical regions would reduce the over-prediction at high altitudes there (see Section 4.4) but would enhance the low bias in the Arctic troposphere where abundances may be controlled by scavenging processes [*Garrett et al.*, 2010]. However, improved treatments of scavenging may result in greater fidelity.

5.4. Mass absorption cross section

[12] Section 2.5 discussed measured and modeled MAC of BC and particles that contain BC. Section 2.5 also summarized how mixing of BC with other aerosol components would increase MAC_{BC}, and field measurements have found that BC particles are largely mixed with other components. Since MAC depends on refractive index, water content, particle size and mixing with other aerosol components, measured MAC_{BC} data provide a useful diagnostic check for models when information about each variable is also known.

[13] The global mean MAC_{BC} listed in Table 5.1 ranges from 4.3 to 15 m^2g^{-1}, with the AeroCom median around about 6.5 m^2g^{-1}. Many models have MAC_{BC} values similar to the *Bond and Bergstrom* [2006] estimate of 7.5 ± 1.2 m^2g^{-1} for freshly emitted, externally mixed BC, and a few others are close to the estimates of about 12.5 m^2g^{-1} for internally mixed aerosol. Two models (LSCE and BCC-AGCM) are much lower than this range. If models that assumed external mixing were excluded or adjusted for the increase in MAC_{BC}, the model average MAC_{BC} and the average estimated DRF would increase [*Jacobson*, 2000; *Myhre et al.,* 2009]. The internally mixed value of MAC_{BC} may be an upper limit on the global mean value because the actual global mean depends on how much of the BC is mixed with other components throughout the atmosphere.

Accepted Article

[14] All global models that represent internal mixing report a large increase in absorption and positive forcing for internally mixed particles. *Haywood and Shine* [1995] reported doubled forcing due to internal versus external mixing in a simple model. *Jacobson* [2001a] was the first to confirm that finding with realistic BC spatial distributions and accounting for the evolution of mixing state. *Chung and Seinfeld* [2002] found a forcing increase of 36% for BC with homogeneous internal mixing compared with external mixing. *Bauer et al.* [2010] included a core-shell representation in a multi-modal model. *Flanner et al.* [2007] and *Myhre et al.* [2009] associated internally mixed values of MAC_{BC} with aged BC, and *Adachi et al.* [2010] explored several mixing assumptions in a global model. Model treatment of aging and mixing affects both absorption and lifetime, often with compensating effects. *Ghan et al.* [2012] found that two treatments of BC produced similar forcing estimates, as internally mixed BC had higher MAC_{BC} but was removed faster. *Stier et al*. [2006a] found regional differences in which effect of BC mixing state dominates.

5.5. Scaling modeled BC AAOD to observations

[15] BC AAOD is the product of three of the factors that determine BC DRF (*i.e.,* E, L, and MAC_{BC} in Equation 5.1), and constraining this product can reduce uncertainty in radiative forcing. In this section, we present an estimate of observationally constrained BC AAOD that is used to produce scaled forcing estimates in Section 5.7.

[16] Measurements of AAOD are sparsely distributed, and many models underestimate BC AAOD, as shown in Figure 4.3. In Section 4.4.2.1, we cautioned that both sampling bias and dust absorption could produce a high bias in BC AAOD inferred from AERONET AAOD. Comparisons between model and observationally derived total AAOD in *Koch et al*. [2009a] include contributions from both BC and dust. As a result, either or both BC and dust could be responsible for model discrepancies. However, AAOD comparisons for regions and seasons not affected by dust still show that many models simulate too little absorption in the atmosphere and, therefore, underestimate BC DRF.

[17] To obtain an estimate of BC AAOD constrained more closely by observations, a method was developed to scale modeled BC AAOD fields using BC AAOD inferred from the AERONET ground-based network. Appendix B gives the details and background of this method. Briefly, sampling biases in the AERONET retrievals of total AAOD were removed, and BC AAOD was estimated from total aerosol AAOD by subtracting the contribution to AAOD by dust. This process allocates all non-dust absorption to BC. To the extent that organic aerosol contributes to AAOD, our estimate of BC AAOD is biased high. Biases in the AeroCom median model BC AAOD were quantified by calculating the ratio of the observationally constrained and modeled values at the same month and location. The scale factors so determined were then extended to other grid boxes within the region, including outflow from that region over the ocean. This expansion of scale factors relies on the spatial distribution of BC in the AeroCom median model.

[18] BC AAOD estimated this way is found to be much greater than modeled BC AAOD, so the procedure increases the globally averaged estimate of total BC AAOD from 0.0021 before scaling to 0.0060 after scaling. As discussed in Section 5.9, causes of the resulting BC AAOD changes would likely have affected pre-industrial BC AAOD as well, so we applied the same scaling factors to pre-industrial BC AAOD. Hence, the global mean industrial-era BC AAOD increases by the same factor, from 0.0017 before scaling to 0.0049 after scaling. These increases in BC AAOD are large, but previous estimates that employ observations have also found BC AAOD much greater than model values (see Section 5.8).

5.5.1. Sensitivities in AAOD scaling

[19] A summary of modeled BC AAOD values before scaling is presented in Table 5.2 and summarized in Figure 5.3. Industrial-era, global-mean BC AAOD from models without any scaling ranges from 0.0006 to 0.0035, with two models that included internal mixing giving values above 0.0030 and the remainder lying within 30% of the median value. Figure 5.3 also shows BC AAOD estimates scaled to observations for industrial-era sources and for all sources. For both scaled and unscaled fields, all-source BC AAOD is higher than the industrial-era average by about 23%.

Accepted Article

[20] Error bars in the scaled estimates in Figure 5.3 reflect uncertainty in the spatial distribution of BC in the model used to extend scaling to regions without observations. This uncertainty is estimated by applying the full scaling procedure to three additional modeled fields (SPRINTARS, GOCART, and UMI) that were chosen to represent high and low average BC AAOD. The scaled value of global BC AAOD ranges from 0.0046 for SPRINTARS to 0.0064 for UMI, so the highest initial model field results in the lowest scaled value.

[21] The BC AAOD values derived in Appendix B are very sensitive to assumptions imposed in the use of the AERONET data fields, as discussed in Appendix B. To demonstrate this, Figure 5.3 shows estimates of all-source BC AAOD with three different changes in basic assumptions used in deriving BC AAOD from AERONET observations. The revised AERONET fields are then used to rescale the AeroCom model fields and a new global estimate is calculated. First, BC AAOD is separated from total AAOD by combining the AERONET size distribution for submicron particles and the retrieved AERONET refractive index. This method of separation reduces the mean BC AAOD from the baseline estimate of 0.0060 to 0.0034, but does not account for the differing properties of submicron and super-micron aerosol. This method ascribes a relatively small AAOD to BC and a large AAOD to dust. Second, the selection of AERONET stations introduces an uncertainty of 30%. When four different subsets of stations were used for the scaling of all-source BC AAOD, global averages ranged from 0.0057 to 0.0071. The analysis presented here includes this uncertainty. Third, if all absorption were attributed to BC, the modeled BC-AAOD field would increase by a factor of 1.33 to 0.0086. Fourth, the AERONET Version 2.0 data exclude low-AOD conditions, so that average AAOD values in that dataset are biased high. If the AERONET Version 2.0 data were used, estimated BC AAOD would increase by a factor of 2.2, to 0.0143 (not shown in Figure 5.3 due to limited scale). The interpretation applied here does not suffer from this bias because of the method used to interpret the AERONET data. BC-DRF estimates relying on averages of published AERONET AAOD data cannot account for this bias and are expected to be much greater than those derived in this assessment. These sensitivity calculations highlight the importance of clearly stating assumptions and their consequences when using AERONET observations to scale modeled fields of absorbing aerosol. Other uncertainties in this analysis, used to set bounds on BC DRF, are discussed in Section 5.7.3.

5.5.2. Reasons for low bias in modeled AAOD

[22] Because BC AAOD is the product of MAC_{BC} and BC burden (see Section 5.2), the mismatch between modeled and observed BC AAOD may derive from errors in modeling both factors. Apportionment is considered separately for AAOD resulting from open biomass burning and energy-related combustion in the ten regions shown in Figures 3.1 to 3.3.

[23] We first assume that the MAC_{BC} scale factor for all months and regions is 1.5 (*i.e.,* the approximate ratio between the MAC of internally and externally mixed BC). Most models in the Phase I AeroCom group described here did not account for internal mixing and the AeroCom median BC AAOD at each grid box likely represents aerosol with this lower MAC_{BC}. We also assume that AAOD attributable to open burning and energy-related sources are proportional to their emissions; that is, aerosol lifetimes from the two sources are similar in each month. The scaled BC AAOD values for each source are then averaged over the year to produce an annual BC AAOD, and then divided by the original BC AAOD to give an annually averaged scaling factor.

[24] Figure 5.4 displays the annual scale factors for each region and source group. Although our assumption of similar lifetimes between the source groups may be questionable, the method should produce dissimilar scale factors if more correction is needed during months with high or low biomass burning. The bars for each scale factor show the portions attributable to BC burden (closed) and MAC_{BC} (open). The middle panel of Figure 5.4 also shows the annual fraction of BC AAOD attributed to energy-related emissions versus biomass burning emissions, and also shows estimates of the amount attributed to dust in each region. This fraction is not a true estimate of regional dust AAOD, as it does not account for the difference in the dust spatial distribution. Instead, it shows the amount of AAOD that would be added if BC-AAOD fields were scaled to total AAOD instead of BC AAOD. Regions with a high apparent dust fraction have greater uncertainty in BC AAOD because of the difficulties in separating the two.

Accepted Article

The narrow blue box shows the dust fraction that would be inferred using an alternate technique: applying the AERONET-retrieved refractive index to the fine fraction of the retrieved size distribution. Finally, the rightmost panel of Figure 5.4 shows the contribution of each land region to scaled global BC AAOD. These percentages do not sum to 100% because 35% of the BC AAOD occurs over oceans. Over half of this BC AAOD, or 20% of the global total, occurs in outflow regions for which scaling was affected by adjacent continents.

[25] Burden scale factors greater than unity (solid bars) in Figure 5.4 indicate that the AeroCom median model usually underestimates the burden. Differences between energy-related and biomass burning scaling factors are small, indicating that corrections are not wholly attributable to either one. The greatest burden underestimates, by factors of three to four, are found in South and Southeast Asia. Most other regions require significant increases of 60 to 160%. Modeled burdens are more realistic, within 40%, in North America, EECCA, and Europe; this analysis is consistent with surface observations in Europe (see Figure 4.2 and Section 4.5). Some regions requiring large scaling factors are dominated by energy-related emissions, and the underestimate must occur in those emissions. In other regions, particularly Africa and Southeast Asia, open burning is a large fraction of BC AAOD. Uncertainties in attribution between BC and dust are greatest when apparent dust fractions are large, which could affect the global burden greatly in Africa. Section 5.9 discusses the implications for emission rates, and compares the findings presented here with previous model-measurement comparisons.

5.6. Forcing efficiency

[26] Radiative effects of BC are estimated by comparing radiative transfer calculations with and without BC emissions, accounting for scattering and absorption by the surface and by gases, clouds and other aerosol components throughout the atmosphere. Aerosol optical properties are important inputs to determine the magnitude and location of aerosol absorption and scattering. However, once the optical depths and single-scattering albedo are known, variations in global-average radiative forcing per absorption optical depth are largely driven by environmental variables, especially the reflectivity of the underlying surface. BC aerosol alters the ToA net energy balance much more over a bright reflective surface or cloud layer than above a dark one [*Haywood and Shine,* 1995; *Chyilek and Coakley,* 1974]. This sensitivity produces the three-fold diversity in the global mean absorption forcing efficiencies (AFE) listed in Table 5.2, with values ranging from 91 to 270 W m^{-2}AAOD^{-1}. Figure 5.5 shows the spatial distribution of annually averaged AFE from the AeroCom median model. It tends to be higher for aerosol located over land and stratus clouds, and the highest values occur over snow.

5.6.1. Vertical location of BC

[27] Top-of-atmosphere AFE is enhanced considerably when BC is located over clouds compared with over the dark ocean surface. Thus, some of the diversity in AFE is caused by differences in the BC vertical distribution because elevated BC is more likely to overlie low clouds [*Haywood and Ramaswamy*, 1998]. BC over low clouds increases forcing disproportionately compared with BC in clear skies, while BC under clouds has a decreased contribution [*Haywood and Ramaswamy*, 1998; *Zarzycki and Bond*, 2010]. Greater solar flux at high altitudes can also increase forcing by high-altitude BC [*Samset and Myhre*, 2011]. Comparing forcing from models that all use the same emissions, the model with the lowest AFE of 91 W m^{-2}AAOD^{-1} places 14% of the total BC mass above 5 km, and the model that simulates the highest forcing efficiency of 270 W m^{-2}AAOD^{-1} has 37% of its BC above 5 km. *Textor et al.* [2006] find that the fraction of the simulated BC mass above 5 km ranges from 7 to 37% for 16 AeroCom models. Direct forcing by BC can be greatly intensified when aerosol-cloud collocation on sub-grid scales is considered [*Chand et al.*, 2009], and this is not treated in global models or in this estimate.

[28] How realistic are simulated vertical distributions of BC? As discussed in Section 4.5, recent measurements have shown that aerosol models generally simulate too much BC in the upper troposphere, especially at tropical and mid-latitudes [*Schwarz et al.,* 2010]. Models also underestimate the decrease in aerosol extinction with altitude [*Yu et al.,* 2010]. Adjustments to reduce these

Accepted Article

biases are likely to put more of the BC below rather than above clouds and, hence, reduce estimates of the ToA radiative forcing by BC. Thus, the highest values of AFE shown in Table 5.2 are probably unrealistic. *Zarzycki and Bond* [2010] estimate that radiative forcing would decrease by approximately 15% if a model with an intermediate BC vertical profile was scaled to match measured profiles. *Koffi et al.* [2012] compared AeroCom models and CALIPSO measurements and found that aerosol was too high by about 400 m (range of 50 to 1080 m) in source regions. This finding also suggests a forcing decrease of approximately 15% when combined with the sensitivities given by *Samset and Myhre* [2011].

5.6.2. Horizontal location of BC

[29] Some of the diversity in AFE could also be due to differences in the BC horizontal distribution, particularly with respect to the albedo of the underlying surface or the amount of sunlight at different latitudes. *Kinne et al.* [2006] find the greatest diversity in the simulated BC burden is in polar regions, *Textor et al.* [2006] find that the fraction of BC mass between 80° and 90° N varies greatly in the AeroCom models, and *Shindell et al.* [2008] find that all BC models in their study simulate far too little BC at Barrow and Alert (both in the Arctic), particularly during winter and early spring.

5.7. All-source and industrial-era BC DRF

[30] Figure 5.6 summarizes the two major determinants of direct radiative forcing—BC AAOD and AFE—for the model results reported in Tables 5.1 and 5.2. Figure 5.6(top) shows that modeled radiative forcing has a strong relationship with modeled AAOD. AFE is the ratio between forcing and AAOD, and varies among models. Figure 5.6(bottom) shows larger AFE for models with more BC above 5-km altitude, which suggests that AFE can be strongly affected by the amount of BC above 5-km altitude.

5.7.1. Scaled estimates of BC DRF

[31] Many of the models with results reported in Tables 5.1 and 5.2 simulate too little BC AAOD compared to atmospheric observations and, therefore, too little BC DRF. If modeled values of AFE were trustworthy, then a best estimate of all-source radiative forcing could result from multiplying those values by a best estimate of BC AAOD for every grid cell and season and averaging over the globe. A map of the increase in radiative forcing obtained by applying this method with the AeroCom median model is shown in Figure 5.7. Because we do not have all the modeled forcing fields to perform this scaling, we capture the diversity in AFE by scaling each of the model-based estimates of industrial-era radiative forcing using the observation-based estimate of industrial-era BC AAOD, which has a global annual mean of 0.0049. These estimates are only approximate because the scaling ignores regional and seasonal variations. However, this scaling method does improve absorption fields that are too low when models do not include internal mixing or sufficient emissions.

[32] Table 5.2 shows the industrial-era BC-DRF values from each model, scaled by the ratio of the observationally based BC AAOD to the modeled BC AAOD. These scaled values range from +0.48 to +1.32 W m^{-2}, with a mean and standard deviation of +0.84 ± 0.21 W m^{-2}. Radiative forcing is increased for all models because all models simulate a lower BC AAOD. Similarly, this scaling can be used to estimate DRF by all BC sources. Model BC-DRF values scaled to the total BC AAOD of 0.0060 are also listed in Table 5.2. Estimates range from +0.59 to +1.63 W m^{-2}, with a mean and standard deviation of +1.03 ± 0.26 W m^{-2}.

5.7.2. Central estimate of BC DRF

[33] For a central estimate of BC DRF, we use an average of the scaled radiative forcing estimates in Table 5.2. However, Section 4.6 showed that most models overpredict BC at high altitudes, leading to an overestimate of BC DRF. Therefore, we estimate a central value of 15% less than the mean of all estimates to compensate for the tendency of models to place BC at too high altitudes and, hence, produce an unrealistically high radiative forcing efficiency, as discussed in Sect. 5.6.1.

[34] With this scaling, the central estimate of global annual DRF by industrial-era BC is +0.71 W m^{-2}. The central estimate of DRF by all-source BC is +0.88 W m^{-2}. These values may be considered an observationally constrained model average. This

Accepted Article

estimate includes forcing due to atmospheric absorption by organic carbon since our estimate of BC AAOD includes absorption by both BC and OA. In Section 10 total aerosol DRF from sources that emit BC is estimated, and there we do not account for atmospheric absorption by OA, so while BC DRF may be biased high the total forcing by emissions from sources that include both BC and OA do not include this bias.

[35] The modeled forcing discussed above was calculated only at visible wavelengths, except for the work of *Jacobson* [2010]. Aerosols can also interact with infrared radiation, especially in source regions [*Lubin and Simpson*, 1994]. *Reddy et al.* [2005b] estimated infrared forcing by BC as +0.006 W m^{-2}. *Jacobson* [2001b] presented a graphical summary in which ToA direct infrared forcing by BC was small relative to forcing at visible wavelengths. Therefore, we assume that the central estimate given above encompasses infrared forcing, even if most models have neglected it.

5.7.3. Uncertainties in BC DRF

[36] A 90% confidence range for BC DRF is based on independent uncertainties in the industrial-era BC AAOD and the radiative forcing efficiency, AFE. The final estimate of uncertainty is higher than reflected in the diversity of scaled BC DRF estimates listed in Table 5.2, which do not account for uncertainty in BC AAOD.

[37] Appendix B provides an estimate of the uncertainty in BC AAOD. Uncertainties are caused by the spatial patterns of BC AAOD used in filling gaps between AERONET sites, ambiguity in how the scale factor is defined, the limited number of AERONET sites, clear-sky biases in the BC AAOD, the influence of BC transport from sources to oceanic regions, and the impacts of fine-mode dust and OA on the estimate of BC AAOD. The industrial-era BC-AAOD estimate has an additional 18% uncertainty due to a 50% uncertainty in the estimate of the pre-industrial background. We assume that the overall uncertainty of the total AAOD retrieval contributes to the above-mentioned sources of uncertainty, although the degree of this contribution is unknown, and we thus do not account separately for it. One factor that could decrease the BC DRF is the attribution of more AAOD to dust. As discussed in Appendix B, we allow this factor to introduce an asymmetric uncertainty. The 90% uncertainty range is from 0.0023 to 0.0088 for all-source BC AAOD and from 0.0014 to 0.0078 for industrial-era BC AAOD.

[38] The uncertainty in AFE is estimated as 1.6 times the standard deviation of the model AFE values listed in Table 5.2. This uncertainty of 40% is attributable to the vertical location of BC relative to clouds [*Zarzycki and Bond,* 2010], the effect of surface albedo, the temporal covariance of the clouds and BC, and the choice of radiative transfer code [*Boucher et al.,* 1998]. *Schulz et al.* [2006] attributed a variation in total aerosol cloudy-sky radiative forcing of ±0.26 W m^{-2} among 9 AeroCom models mainly to diversity in forcing above clouds. However, this diversity in AFE has not been apportioned to individual sources of uncertainty.

[39] Our final estimate of 90% uncertainty bounds comes from combining the uncertainties in AAOD and the 49% uncertainty in AFE. The global annual DRF by industrial-era BC is estimated to have an uncertainty range of +0.08 to +1.27 W m^{-2} about the central estimate of +0.71 W m^{-2}. This range spans all scaled estimates listed in Table 5.2. The uncertainty range for all-source BC is +0.17 to +1.48 W m^{-2} about the central estimate of +0.88 W m^{-2}.

[40] A final uncertainty not estimated here is caused by interpretation of AERONET remote-sensing data. Such data sets are subject to periodic revision, and changes in the interpretation would shift the estimate of AAOD and forcing presented here.

5.8. Previous observationally scaled radiative-forcing estimates

[41] Three previous studies have reported similar estimates of all-source BC DRF by scaling to AERONET data. *Sato et al.* [2003] scaled modeled fields to the AERONET Version 2.0 product to obtain modeled forcing of +1.0 W m^{-2}. As discussed previously (Section 5.5.1), this product eliminates low-AOD observations, with the result that the average AAOD has a high bias, and any scaling of BC AAOD using that product is also biased high. The *Sato et al.* BC AAOD relied on data from earlier years, so their value of 0.006 is not as high as our value extracted from AERONET Version 2.0 averages (0.0143).

Accepted Article

[42] *Ramanathan and Carmichael* [2008] estimated forcing of +0.9 W m^{-2} by combining modeled fields with AERONET data, MODIS data, and estimated ω_0. Modeled fields were based on *Chung et al.* [2005], which reports BC AAOD of about 0.0068. Both BC AAOD and AFE are similar to those derived here, and the DRF estimate for all-source BC (+0.9 W m^{-2}) is similar to the value given here. *Chung et al.* [2005] also point out that correcting MODIS AOD with those of AERONET decreases the estimated global AOD by 25%.

[43] The most recent observationally based estimate, by *Chung et al.* [2012], used a combination of AERONET retrievals, partitioning to distinguish BC AAOD from contributions by dust and organic carbon, satellite retrievals of AOD, and model estimates of single-scattering albedo. Their estimate of BC AAOD (0.0077) is 28% larger than our best estimate. However, this study also estimates a relatively low AFE value (97 W m^{-2} $AAOD^{-1}$); applying this value to our best estimate of BC AAOD produces a BC DRF that is much smaller than that of most estimates in Table 5.2. *Chung et al.* [2012] estimate an uncertainty range for all-source BC AAOD of 0.006 to 0.009. The lower bound is much higher than ours, because we have more strongly weighted the possibility that more AAOD is attributable to dust.

5.9 Implications of increased BC AAOD

5.9.1 Apportionment of bias in BC AAOD

[44] It is of interest to attribute the model bias in BC AAOD to causes beyond the division between MAC_{BC} and burden presented in Figure 5.4. The required burden scaling could be caused by emissions, by atmospheric lifetime, or a combination of the two. Inverse modeling that explored adjustment of both removal processes and emissions might help to apportion the bias with more confidence, but these studies are beyond the scope of this assessment. However, because the scaling factors were mainly determined using land-based AERONET observations, they are less strongly affected by modeled removal than they would be if the observation sites were very distant from sources. Sensitivity studies reported by *Koch et al.* [2009], as shown in Figure 4.2, show that the ratios between observed and modeled concentrations could change by 10% if aging rates were altered by a factor of two in either direction. An exception to this finding is North America, for which altered lifetimes would alter the comparison more greatly, but modeled burdens in that region are modeled reasonably well. It is likely that underestimates of emissions are a major cause of the observed discrepancies.

5.9.1 Revised estimate of BC emissions

[45] Emission rates that would be required to match observations were estimated by applying the monthly regional scale factors described above to modeled emissions in each region. Then, annual emissions were determined by summing the monthly emissions. Table 5.3 shows the annual scaled totals for energy-related and open-burning emissions and compares them with the bottom-up emission estimates in Section 3. This division between energy-related and open-burning scale factors depends on the modeled seasonality of these major source groups, as well as the assumption that monthly scale factors for each group are equal. The scaling of emission totals is more robust than the apportionment of scaling between the two categories.

[46] Table 5.3 summarizes these scaled annual emissions. Three emission estimates are given in the table: modeled emissions, which are an estimate of the median used by AeroCom models; scaled emissions, which are inferred using the burden scale factors applied to monthly emissions; and current emissions, which are the bottom-up estimates summarized in Section 3. Current emission estimates are different than those used by the AeroCom models that produced the fields for analysis. Although energy-related emissions are similar, modeled open-burning emissions in AeroCom models were about 35% higher than the most current values.

[47] Scaled estimates for all-source annual emissions are 17000 Gg BC yr^{-1}, a factor of 2.2 increase over current emission estimates and modeled values. Because AERONET observations from years 2000 to 2009 were used for scaling, this emission estimate is approximately associated with the year 2005. In this simple scaling exercise, energy-related and open-biomass

Accepted Article

emissions are scaled each month resulting in similar scaling for annual totals which are 10100 Gg BC yr^{-1} and 6800 Gg BC yr^{-1}, respectively. Table 5.3 also gives estimates of industrial-era emissions, inferred by subtracting the scaled pre-industrial emission values. The industrial-era total is 9750 Gg BC yr^{-1} for energy-related emissions and 4200 Gg BC yr^{-1} for open biomass emissions.

[48] The industrial-era emission estimate of about 13900 GgC yr^{-1} is the value obtained with a simple scaling of AAOD. However, several caveats apply to the method described here. First, this scaling method neglects the fact that burden in some regions may be caused by emissions in other regions. According to tagged-tracer modeling given in *Bond et al.* [2011], Middle Eastern concentrations are affected by South Asian emissions; Southeast Asian concentrations have significant contributions from both South Asia and East Asia; and the Pacific region is affected by all Asian emissions. However, the model used tends to over-transport aerosol, as evidenced by atmospheric burdens at high altitudes. A true inverse modeling approach would give a better estimate of emissions in each region, but modeled transport and removal should be more thoroughly evaluated before embarking on such a study. We caution that inferred emissions in Southeast Asia and the Pacific are particularly uncertain.

[49] Second, as discussed above, uncertainties in modeled lifetimes could also contribute to errors in burdens. Changes in modeled lifetime were shown to alter modeled BC by about 10% at the observation sites (see Figure 4.2), which would alter inferred emissions by the same amount. Third, the MAC_{BC} scale factor used here is also simplified because it assumes that BC is always internally mixed and, therefore, amplifies absorption at the observation sites. If BC were externally mixed at observation sites, the MAC_{BC} scale factor would decrease and the burden scale factor would increase. If the appropriate MAC_{BC} scaling were a 20% increase instead of 50%, all-source emissions would be estimated as 21000 Gg BC yr^{-1}. For an assumed increase of 80%, the estimate would be 14000 Gg BC yr^{-1}. Finally, observations are sparse in many of the regions with the largest emissions and the largest estimated increases. In the absence of more definitive studies that explain biases in aerosol absorption, the central value is used as a best estimate of industrial-era BC emissions throughout this assessment.

5.9.2 Scaling of modeled AAOD in the context of other evidence

[50] Inverse modeling studies and other comparisons between models and measurements were discussed in Section 4.5.1. As these studies have attributed errors to emission biases rather than modeling of any other factor, we compare them with the emission increases in Table 5.3.

[51] Scaled emissions for total biomass burning BC of 6800 Gg yr^{-1} are in good agreement with the upper limit derived by *Zhang et al.* [2005]. The increase by a factor of 2.5 falls within the large uncertainty ranges for biomass smoke given by *Reid et al.* [2009] and *Kaiser et al.* [2012]. Carbon monoxide measurements do not indicate such a large discrepancy, so either modeled emission factors or modeled aerosol lifetimes are suspect. Section 3.7.2.3 discussed some reasons why modeled biomass burning emission factors could be too low. These proposed adjustments should also apply to the pre-industrial background used here and, hence, the scaling described here is also represented in our estimate of pre-industrial AAOD.

[52] The finding that small to moderate emission increases are required in North America and Europe is in reasonable agreement with inverse modeling studies. Scaled emissions in Figure 5.4 suggest that emissions for East Asia should increase as suggested by *Kondo et al.* [2011c], but by 90% instead of 30%. Since inverse modeling by *Hakami et al.* [2005] suggested that BC emissions in East Asia were approximately correct at an earlier date, the increased emissions may be related to growth, estimated as 30 to 50% [*Lu et al.*, 2011]. The higher emission estimates for South Asia are 30% greater than those estimated by *Dickerson et al.* [2003] for a much earlier year, and they agree with observations that modeled burdens in that region are too low by about a factor of 4 to 5.

[53] Scaled global energy-related emissions are estimated at 10100 Gg yr^{-1}, with 80% of the increase appearing in Africa, South, East, and Southeast Asia. Although the apportionment between energy-related emissions and biomass burning is not certain, it would be difficult for the small amount of biomass burning in South and East Asia to cause such a large discrepancy. Applying the higher BC emission factors recommended by *Cooke et al.* [1999] for power generation would cause much greater discrepancies in

Accepted Article

North America and Europe than currently exist. The evidence points to underestimation of emissions in regions with low regulation, so that sources such as poorly operating vehicles, industrial installations, or high solid-fuel combustion may be responsible.

[54] Land regions of Latin America, Africa, Southeast Asia, and the Pacific region (see Figure 3.1) are, together, responsible for 40% of the global BC AAOD, and suggested scaling factors in these regions are 2 to 3.5. Especially uncertain are findings for Africa, where 25% of global AAOD is found, and partitioning between BC and dust affects inferences about the magnitude of BC AAOD. Inverse modeling studies or continent-wide comparisons with long-term measurements have not been reported for these regions.

[55] In summary, we find that global AAOD from AeroCom models is low compared to that suggested by observations, that this underestimate occurs in particular regions, and that it cannot be fully explained by the absorption enhancement produced by internal mixing or by uncertainties in retrievals. Modeled absorption is reasonable in regions with the best measurement coverage, relevant emission measurements, and low biomass-burning emissions: North America and Europe. The dominance of different source categories and larger uncertainties in the other regions (Figure 3.3, Section 3.7.1) that require increased scaling to match observations suggests that poorly modeled emissions are a potential cause. Studies using space-based remote sensing indicate that modeled aerosol concentrations and absorption from biomass burning are too low (Section 4.5.1), and an independent line of argument indicates that biomass-burning emission factors could lead to underestimates of absorption (Section 3.7.2.3). Surface measurements in South and East Asia indicate that models using the emissions summarized in Section 3 would underestimate observed BC concentrations (Section 4.5.1). In Asia, where emissions have increased since the global emission fields were developed (Section 3.8), some of the underestimation is to be expected. Although we cannot fully exclude modeled lifetimes, instrumental uncertainties, and the division of remotely-sensed AAOD into BC and dust components in some regions (particularly Africa) as explanatory factors, multiple lines of evidence support the position that AeroCom models using year-2000 BC emissions substantially underestimate absorption and direct radiative forcing. Despite the inherent limitations of these models, they are required to produce estimates of global forcing, because global space-based observations cannot separate radiative impact by chemical component. Model fields scaled to observations are therefore used to develop our best estimate of direct radiative forcing.

5.10. Summary of uncertainties in BC DRF

[56] The discussion in this section shows that several factors affecting BC radiative forcing are not well constrained. First, the most quantitative and widespread data set for determining atmospheric absorption is remote sensing provided by AERONET, but use of these observations requires an estimate of the division between AAOD attributable to BC and dust. Different plausible assumptions can greatly alter the inferred BC AAOD, up to a factor of two. Parameters retrieved from AERONET observations, such as size distributions or wavelength dependence of absorption, have been used in interpreting AAOD data, but these have not been thoroughly evaluated with *in-situ* measurements. Second, the dust refractive index may have large variability within regions [*Moosmüller et al.*, 2012; *Wagner et al.*, 2012] and could greatly affect the estimate of dust AAOD and the inference of BC AAOD. Third, despite the uncertainties, observations indicate more BC AAOD than is modeled by about a factor of 2.5. A simple scaling procedure indicates that a large increase in emission estimates is warranted for biomass burning and for energy-related sources in developing regions. Emission factors may explain low biases in modeled biomass burning emissions, but the cause of errors in energy-related emissions is unknown. Fourth, despite the fact that emission rates are implicated in underestimates of BC AAOD, a full attribution of differences in BC distributions to errors in model emissions, transport or removal rates is not yet possible. No simple adjustment to modeled transport can explain the range of model biases (see Section 4.7). Fifth, the contribution of absorbing organic aerosol to AAOD has not been elucidated. Attribution of some of the absorption to OA rather than BC would reduce the

Accepted Article

direct forcing estimate for BC and make that of OA less negative or more positive. Finally, model evaluations are limited in regions that contribute large fractions of the global AAOD, because few long-term observations are available.

[57] Although present-day observations can be used to adjust modeled forcing terms, a lack of understanding of the causes of bias limits the accuracy of modeled forcing for the past and future. Further, vertical transport and therefore location of BC is poorly modeled, so that modeled absorption forcing efficiency also contains errors. While biases in BC distributions in the Arctic produce only small errors in global, annual average BC AAOD (and thus forcing), they produce large biases in forcing within the Arctic, where BC may contribute to greater-than-expected warming and declines in sea ice [*Quinn et al.*, 2008, 2011]. In subsequent sections, horizontal and vertical distributions are shown to affect the interaction with clouds (Section 6) and forcing in snow and sea ice (Section 7). Thus, a lack of understanding of process fundamentals and the resulting modeled biases are large sources of uncertainty in all BC forcing terms.

[58] The amount of aerosol in the pre-industrial atmosphere is also poorly known. Biomass burning produced much of this aerosol, and pre-industrial estimates used here were based on the emissions given by *Dentener et al.* [2006]. Although biomass burning has increased overall during the industrial era, charcoal records suggest that activity in some regions was similar between 1750 and today [*Marlon et al.*, 2008]. Although this pre-industrial background does not affect the estimate of total radiative forcing, it does affect industrial-era forcing and temperature change since pre-industrial times. We retain conventional nomenclature and refer to this background value as that of 1750, but we caution that it represents a reference atmosphere rather than a true pre-industrial value.

6. Black carbon interactions with clouds

6.1. Section Summary

[1]

1. Black carbon may change cloud cover, emissivity, or brightness in four ways: 1) by changing the vertical temperature structure of the atmosphere, which could shift cloud distributions (semi-direct effect); 2) by changing the number concentration of liquid cloud droplets and the lifetime of liquid clouds; 3) by changing phase partitioning and precipitation in mixed-phase clouds; and 4) by changing ice particle number concentration. These effects may cause either positive or negative radiative forcing. Very few model studies isolate the influence of BC on each effect. All aerosol effects on clouds are highly uncertain, and the isolated effects of BC have even greater relative uncertainty.

2. Many of the cloud effects described here may be considered rapid adjustments, either to direct radiative forcing or to the presence of BC. However, all effects can be quantified in units of climate forcing, a practice we continue here for consistency with previous studies and for convenience.

3. In the semi-direct effect, cloud cover can increase or decrease, depending on region and conditions. Some studies examining regional cloud reduction have suggested a positive forcing, but global model studies indicate that the BC semi-direct effect averages -0.1 ± 0.2 W m^{-2} for industrial-era forcing if all BC is emitted at the surface. An additional -0.28 W m^{-2} is added to the lower uncertainty range to account for the potential reduction of high-level clouds from biomass-burning BC, making the 90% uncertainty range –0.44 to +0.1 W m^{-2} over the industrial era. Major uncertainties include poorly modeled BC vertical distributions and the fidelity of modeled cloud responses.

4. BC has two competing indirect effects on liquid clouds. First, adding BC increases the aerosol number concentration. If the number of cloud droplets also increased, negative forcing by clouds would increase, but BC-rich particles are inferior cloud-forming particles. Second, BC particles may also serve as sites to collect soluble material, reducing overall cloud droplet number concentration and producing a positive forcing. BC alone is estimated to have an indirect climate forcing of about -0.1

Accepted Article

W m^{-2}. Many studies do not separate this effect from the semi-direct effect discussed above, so an isolated estimate is difficult to obtain. Therefore, we estimate the combined industrial-era climate forcing from liquid-cloud and semi-direct effects as -0.2 (with a 90% uncertainty range of -0.61 to +0.1 W m^{-2}).

5. Greater absorption by BC within cloud droplets decreases cloud albedo, heats clouds, and dissipates them. This is a special case of the semi-direct effect that we estimate separately as a climate forcing of +0.2 W m^{-2}, with a 90% uncertainty range of -0.1 to +0.9 W m^{-2} over the industrial era. Model results for this effect are very sensitive to the representation of optical properties for the mixed BC and cloud droplet.

6. The liquid-cloud indirect effect is sensitive to BC particle size and to mixing with other particles. Many model studies indicate that particles emitted from biofuel combustion appear to have more negative forcing per emission than do particles from fossil-fuel combustion, possibly because of size or co-emitted POA.

7. The BC mixed-phase indirect effect acts on clouds that are part liquid and part ice. BC may act as ice nuclei (IN) that enhance ice formation and increase ice fall-out. An estimate for this effect is +0.18 ± 0.18 W m^{-2} for industrial-era climate forcing and 90% uncertainty range, but the magnitude would be reduced for BC mixed with sulfate.

8. In the ice-cloud indirect effect, greater IN concentrations either increase or decrease the concentrations of ice particles and the lifetime of cirrus clouds, depending on conditions. Cirrus clouds affect both shortwave and longwave radiative fluxes. The cloud cover change and forcing may, therefore, be positive or negative. Two model studies estimate effects of opposite signs: -0.4 and +0.4 W m^{-2}. Laboratory and field observations suggest that both BC concentration and BC's ability to act as IN are probably less than assumed in these model estimates. We estimate an industrial-era climate forcing of 0 ± 0.4 W m^{-2} (90% uncertainty range) for this highly uncertain effect, which excludes the effects of aviation. These effects are sensitive to assumptions about BC's role as IN and to the number concentration and mixing state of BC particles in the free and upper troposphere. Ice-cloud effects also depend on the assumed background conditions, including concentrations of other IN and updraft velocities.

9. Few modeling and measurement studies are able to constrain cloud-absorption, mixed-phase and ice-cloud indirect effects. Consequently the uncertainties are large. Model diversity, rather than true uncertainty propagation, provide uncertainties in cloud radiative forcing.

6.2. Introduction

[2] Clouds and their responses to aerosol addition introduce a large uncertainty in the understanding of total climate forcing and climate response [*Heintzenberg and Charlson,* 2009]. The general term 'indirect effects' refers to the suite of climate forcings that aerosols impose through the modification of cloud properties [*Forster et al.,* 2007; *Denman et al.,* 2007]. Aerosol indirect effects on clouds have been extensively studied, but the influence of BC alone has received less attention. Although BC makes a small contribution to aerosol mass load in the atmosphere, it may play an important role in determining the CCN or IN particle number concentration that in turn alters indirect effects. Aerosol indirect effects and BC's role in the indirect effect differ depending on the cloud phase: liquid, ice or 'mixed' containing both liquid and ice, and these are discussed individually. Furthermore, absorption by BC embedded within cloud droplets is greater than that of BC alone or with coatings.

[3] Figure 6.1 summarizes the mechanisms by which BC can influence clouds. A brief overview is given here before the detailed discussions in the remainder of this section. The first general class of effects involves perturbations to the atmospheric temperature structure, which affect cloud distributions. These mechanisms are commonly termed 'semi- direct effects,' a term that is sometimes used to describe evaporation of cloud droplets when absorbing aerosols heat a cloud layer [*Hansen et al.,* 1997; *Ramanathan et al.,* 2001b]. Additional BC radiative effects have also been documented whereby cloud cover may be either enhanced or reduced, depending on factors such as its altitude relative to cloud cover [*e.g.*, *Hansen et al.,* 2005; *Johnson et al.,* 2004], and meteorological

Accepted Article

conditions. BC's semi-direct effects are a rapid adjustment to BC direct radiative forcing, through local warming of the atmosphere. Some model calculations treat this adjustment as a distinct forcing term. Following these studies, and consistent with other treatments in this assessment, we review semi-direct estimates in forcing units.

[4] Another general category, commonly termed 'indirect effects,' involves changes in concentrations of cloud droplets or ice crystals that alter cloud brightness, emissivity and lifetime, which produce a radiative forcing. This category includes the groups titled 'liquid-cloud effects,' 'mixed-phase cloud effects,' and 'ice-cloud effects' in Figure 6.1. These cloud effects are driven by changes in the number of CCN or IN, aerosols on which cloud droplets or ice particles may form. The process of forming a stable liquid droplet or ice particle is known as activation. In principle, any particle can activate in either liquid or ice clouds if high enough supersaturation is reached. However, when many aerosol types are present, the particles that activate the most easily do so first and have the greatest potential influence on the resulting number concentration of cloud particles. Microphysical characteristics of a particular type of aerosol are thus very important in determining its cloud effects.

[5] Warm cloud indirect effects include two components. The cloud albedo effect (*i.e.,* the first indirect or Twomey effect [*Twomey*, 1959]) refers to the change in radiation caused by a change in cloud albedo or brightness resulting from a change in the cloud droplet size distribution. Increased CCN lead to more and smaller cloud liquid droplets for a given cloud water content (case LC1 in Figure 6.1). This effect can be observed in ship-track studies [*e.g.*, *Ferek et al.,* 1998]. However, if BC attracts condensing gases that would otherwise form particles, the net result is a decrease in CCN and cloud droplets and is, therefore, a positive radiative forcing (case LC2) [*Bauer et al.*, 2010].

[6] The cloud lifetime effect (LC3, second indirect effect) refers to the fact that in the presence of increased aerosol concentrations, more and smaller cloud droplets form, and these collide less efficiently. Factors such as drop evaporation rates and depletion of water vapor can also alter cloud lifetimes. While cloud resolving models suggest that this effect could lead to either an increase or decrease in liquid water [*Ackerman et al.*, 2004; *Sandu et al.*, 2008], the GCMs are parameterized such that this effect can only lead to longer cloud lifetimes with greater overall cloud reflectivity [*Lohmann and Feichter*, 2005]. Thus, although this forcing could be either positive or negative, GCM global estimates of LC3 are always negative. Altered lifetime also plays a role in mixed-phase clouds, where temperatures typically fall between 0 and -35ºC. Two competing effects have been suggested: first, glaciation, which refers to an increase in ice nuclei causing more frequent glaciation of supercooled clouds, and second, de-activation. In the glaciation effect, ice crystals grow at the expense of water droplets because of the difference in vapor pressure between water and ice, referred to as the Bergeron-Findeisen effect. An increase in IN would enhance this process, causing clouds to precipitate more readily (case MC1 in Figure 6.1) and thereby reducing cloud amount [*Lohmann*, 2002]. However, deactivation occurs when sulfur or secondary organic aerosol coat IN and make them less efficient [*Girard et al.,* 2005] in mixed-phase clouds by changing the mode of freezing from contact to immersion freezing. In global climate models this leads to less sedimentation and more cloud cover [*Storelvmo et al.,* 2008; *Hoose et al.,* 2008] (case MC2 in Figure 6.1).

[7] BC may also affect cirrus clouds that occur at high altitude in the upper troposphere [*Kärcher and Spichtinger*, 2009]. Aerosol particles at these high altitudes have long atmospheric lifetimes [*e.g.*, 4 - 30 days; *Williams et al.*, 2002] and, therefore, extended opportunities for mixing with other aerosol components. Thin, high cirrus clouds are believed to have net positive cloud forcing [*Chen et al.,* 2000]. Absorption of infrared radiation and re-emission at colder temperatures dominates scattering of solar radiation, which results in a net positive forcing. Efficient IN may either increase or reduce cirrus cloud forcing. Cirrus cloud particles are mostly formed through homogeneous ice nucleation. Even a small number of particles can initiate heterogeneous freezing well below the homogeneous freezing threshold, depleting some of the supersaturated water vapor, partially preventing homogeneous formation of solution droplets and reducing the number of particles [*e.g.*, *Kärcher et al.*, 2006]. Early onset of nucleation from a few efficient BC particles affects forcing less than enhanced sedimentation, yielding case IC1 in Figure 6.1. If

Accepted Article

high concentrations of IN already exist, heterogeneous freezing dominates the cloud and additional IN increase the number concentration of cloud particles (case IC2 in Figure 6.1).

[8] Some challenges are common in obtaining forcing from models of aerosol-cloud interactions. First, models use different emission levels and input assumptions, and variation in values of direct forcing may result from these differences alone. Second, each model study may have a different set of impacts, such as treating aerosol interactions with only liquid or ice clouds, or allowing certain climate responses. The net effect on radiation is usually inferred from two sets of simulations— one with and one without perturbed pollution conditions [*Lohmann et al.*, 2010]—so that the individual effects contributing to the changes are difficult to distinguish without well-designed diagnostics. The combination of varying inputs and inconsistent selection of effects makes global cloud-forcing estimates difficult to compare. Third, some aerosol-induced changes are best simulated at scales smaller than a global model grid box. Physical confirmation of the factors governing cloud dynamics and cloud microphysical interactions must also occur on relatively small scales. Cloud-resolving models (CRMs) and large-eddy simulations (LES) may be most appropriate for modeling these scales, but these simulations do not have the spatial extent to calculate globally averaged forcing, and do not always agree with the results of global models that use coarser resolutions. The reasons for these disagreements is not always understood, making it difficult to infer a global, annual average forcing from either set of model studies. Fourth, some effects that cause cloud redistribution on large scales are best simulated with global models, but their broad spatial or temporal extent makes their existence and magnitude difficult to confirm. Fifth, the fidelity of aerosol-cloud simulations depends on accurate representation of the cloud amount and location, yet these factors are not often verified in the model studies. Finally, interannual and spatial variability of modeled cloud forcing is large compared with the magnitude of the aerosol-induced changes. Therefore, extracting statistically significant changes is challenging.

[9] While aerosol effects on clouds are complex, accounting for them is critical because they may induce changes similar to or greater than aerosol direct forcing. For a perspective on all aerosol effects, *Denman et al.* [2007] summarized studies ranging from a mean of -1.2 W m^{-2} with a range of -0.2 to -2.3 W m^{-2} for the total effect of all anthropogenic aerosols on climate, including direct forcing, cloud albedo, cloud lifetime, and semi-direct effects. Using a combination of ten models and input from relationships observed by satellite, *Quaas et al.* [2009] estimated the total aerosol effect on stratiform clouds as -1.5 ± 0.5 W m^{-2}. The global annual mean climate forcing for just the first indirect effect of all aerosols has been estimated from GCMs with some guidance from satellite observations as -0.7 W m^{-2} with a range between -0.3 and -1.8 W m^{-2} [*Forster et al., 2007*]. Notably, *Lohmann et al.* [2010] showed that estimates of total anthropogenic aerosol effects have become smaller with time. GCMs have added processes, such as aerosol effects on mixed-phase clouds, or treating rain as a prognostic variable, which place more emphasis on accretion instead of autoconversion. These more advanced GCMs arrive at smaller total anthropogenic cloud forcing compared with earlier versions. GCMs that are constrained by satellite data also predict a smaller total anthropogenic aerosol effect.

[10] This assessment mainly presents global, annually averaged climate forcing by semi-direct and indirect effects. However, forcing within a given region may differ significantly from this average. For example, in the Arctic the combined semi-direct and indirect effect of aerosols may produce a much smaller negative forcing than on the global average, or possibly even a positive forcing [*Koch et al.,* 2009b; *Jacobson*, 2010; *Alterskjær et al.*, 2010], because of the Arctic's high surface albedo and because changes in cloud emissivity due to aerosol microphysical effects may produce significant positive forcing in late winter and spring [*Garrett and Zhao*, 2006].

[11] In summary, BC may affect clouds by perturbing the atmospheric thermal structure, or by changing liquid cloud droplet number concentration, ice crystal number concentration, or some combination of the two in mixed-phase clouds. Each of these processes affects the distributions or reflectivity of clouds, which, in turn, alters the radiative balance of the Earth. As such, these are rapid adjustments to the climate system that can be quantified as adjusted forcings (see Section 1.3 and Table 1.1). The role of

Accepted Article

BC in each of these cloud effects is presented below, including increased absorption by BC inclusions in cloud droplets (Section 6.3); semi-direct effects (Section 6.4); indirect effects on liquid clouds (Section 6.5) and mixed and ice phase clouds (Section 6.6). Although modeled cloud forcing depends on assumed emission rates or simulated atmospheric burden, this dependence may not be linear, so scaling modeled forcing to the new emission rates or forcing determined in Section 5 is also discussed for each effect. Best estimates of adjusted forcings are calculated for the combined semi-direct and liquid-cloud effects for mixed-phase clouds and ice clouds. These estimates are followed by a discussion of uncertainties (Section 6.7). All cloud forcings discussed here are industrial-era forcings; all-source forcings are not estimated. Clouds in a clean atmosphere are much more susceptible to change than clouds in an atmosphere with even a small aerosol background [*Boucher and Pham*, 1997], so cloud forcing is always calculated against a pre-industrial background.

6.3. Black-carbon semi-direct effects on cloud cover

[12] Atmospheric BC absorbs solar radiation, perturbs the temperature structure of the atmosphere and, therefore, influences the cloud distribution. The first of these effects to be documented, the original semi-direct effect, is the evaporation and dissolution of clouds by BC suspended near or within clouds [*Hansen et al*., 1997]. Since then, numerous studies have demonstrated this effect, as well as additional mechanisms by which BC either increases or reduces cloud cover. Some of these studies use cloud-scale models, some are observational – typically with focus on a particular region – and some use global models. *Koch and Del Genio* [2010] reviewed many studies on this topic, which are summarized here. The top segment of Figure 6.1 summarizes a framework proposed by *Koch and Del Genio* [2010] to classify previous studies.

[13] Each of the effects shown in the top portion of Figure 6.1 is the result of a rapid adjustment to the initial direct radiative forcing by BC. Following the terminology defined in Section 1, the sum of the direct effect and the semi-direct effect can be interpreted as a single 'adjusted forcing.' However, model studies to date have either calculated the semi-direct effect as an independent forcing; derived a combined forcing for the semi-direct and liquid cloud effects; or report a reduced efficacy for BC direct radiative forcing, attributing this decrease to semi-direct effects. Because semi-direct effects are diverse, all changes other than cloud microphysical changes might be grouped under this label [*e.g., Ghan et al.*, 2012]. For consistency with the existing literature, we also discuss the semi-direct effect here as a climate forcing term and include the efficacy studies in our estimate of that forcing.

6.3.1. Cloud scale and regional studies

[14] The altitude of BC relative to a cloud or potential cloud layer plays an important role in determining the cloud response. For aerosols embedded near cloud, cloud evaporation is enhanced due to their heating and reduction of relative humidity (Figure 6.1, case SD4). This effect was demonstrated in the LES experiments of *Ackerman et al.* [2000] for trade cumulus and *Hill and Dobbie* [2008] and *Johnson et al.* [2004] for marine stratocumulus clouds.

[15] Absorbing aerosols aloft increase atmospheric stability. Increased stability over stratocumulus clouds reduces cloud-top entrainment of overlying dry air, and tends to strengthen the underlying clouds (Figure 6.1, case SD1). LES experiments by *Johnson et al.* [2004] showed that absorbing aerosols above cloud increased cloud cover, because they increased the difference in potential temperature across the inversion, decreased entrainment rate, and caused a shallower, moister boundary layer with higher liquid-water path. The same model had demonstrated cloud reduction when absorbing aerosols were within the cloud layer (Figure 6.1, case SD4). *Brioude et al.* [2009] analyzed satellite cloud observations and modeled biomass-burning tracers for a field study near the coast of California. They found that biomass-burning aerosols enhanced cloud cover, especially for high-humidity conditions and for low lower tropospheric stability conditions, when the aerosols increased lower tropospheric stability. Similarly, *Wilcox* [2012] analyzed satellite data of subtropical, South Atlantic biomass-burning smoke overlying marine stratocumulus clouds and found that the smoke enhanced the cloud liquid-water path, countering more than 60% of the smoke direct radiative effect.

Accepted Article

[16] While the stabilizing effect of absorbing aerosols aloft can enhance stratocumulus cloud cover, they may suppress cumulus cloud development (Figure 6.1, case SD2). *Fan et al.* [2008] performed experiments in a cloud-resolving model for the Houston area, and demonstrated that absorbing aerosols aloft decreased the temperature lapse rate, leading to a more stable atmosphere and decreased convection. MODIS observational studies for the Amazon biomass burning season by *Koren et al.* [2004; 2008] also demonstrated cumulus cloud cover reduction due to increased smoke. They argued that smoke plumes stabilized the boundary layer, reducing convective activity and boundary layer cloud formation. The smoke also reduced radiation penetration to the surface, therefore reducing evaporation and atmospheric moisture. *Ten Hoeve et al.* [2011] used satellite observations of biomass-burning regions to show that cloud optical depth increased with AOD for low values, consistent with cloud brightening (case LC1). At higher AOD values, cloud optical depth decreased with AOD, possibly due to cloud evaporation (case SD4).

[17] On the other hand, in some land regions, lofted absorbing aerosols may enhance upper level convection, promoting low-level moisture convergence of oceanic air masses, which could increase continental clouds (Figure 6.1, case SD3). Monsoon enhancement due to lofted absorbing aerosols (known as the 'Elevated Heat Pump' hypothesis) was shown in the global model studies of *Lau et al.* [2006], *Randles and Ramaswamy* [2008], and *Chung et al.* [2002]. However, global climate models are limited by relatively coarse spatial resolution, which may preclude accurate representation of aerosol transport over the Tibetan Plateau. In a study using observed vertically resolved aerosol distributions over the Tibetan Plateau and surrounding regions, *Kuhlmann and Quaas* [2010] use observed surface albedo and a radiative transfer model to show that aerosols do not produce the large elevated heating needed to drive the Elevated Heat Pump. In the non-monsoon season, wintertime pollution as observed in the Indian Ocean Experiment reduced the meridional temperature gradient in the global model study of *Ramanathan et al.* [2005], which included a coupled ocean response. These SST shifts were found to enhance precipitation over sub-Saharan Africa [*Chung and Ramanathan*, 2006]. Many studies predicting enhanced convergence over land indicate a shift in clouds and precipitation rather than an overall enhancement.

[18] BC below cloud generally promotes convective activity and can enhance cloud cover (Figure 6.1, case SD6). Cloud resolving model studies of *McFarquhar and Wang* [2006] for trade wind cumuli demonstrated that absorbing aerosols placed below cloud promoted vertical motion and increased liquid water path. Similarly, LES experiments of *Feingold et al.* [2005] found that Amazon smoke emitted at the surface could destabilize the surface layer and increase convection and cloud cover. However, smoke at cloud level decreased cloud cover and promoted dissipation in both of these studies.

6.3.2. Global model semi-direct estimates

[19] Consistent with the variety of responses found in regional studies, global model studies also find regional variations and global-average forcing includes positive and negative forcing effects over all regions. Although semi-direct effects cause positive forcing in some regions, most models indicate that the global average is negative. Table 6.1 tabulates the studies discussed here.

[20] *Wang* [2004] performed experiments in the NCAR model, with and without BC. One type of experiment included an ocean temperature response; a second experiment had fixed observed sea-surface temperatures. He found that BC in the experiments with ocean response had enhanced convective activity and cloud cover in the northern branch of the intertropical convergence zone, with a smaller magnitude reduction in clouds and convective activity in the south. The cloud forcing change (*i.e.,* the difference between all-sky and clear-sky radiative flux change due to BC) was -0.16 W m^{-2} at the ToA. However the simulation using observed sea-surface temperatures gave a cloud forcing of -0.06 W m^{-2}. BC did not warm the climate in these experiments, due to compensating cooling from increased cloud cover.

[21] In sensitivity studies of a coupled transient climate model study, *Koch et al.* [2011b, Section 6] showed that removal of BC from 1970 to 2000 would not have caused significant climate cooling. BC removal cooled the atmospheric column, but it also reduced low-level stability and caused a decrease in low-level clouds. Therefore the surface air temperatures were not significantly

Accepted Article

decreased, probably due to the loss of low-level clouds. *Koch et al.* [2011a] did not isolate the forcing by the semi-direct effect from that of the direct effect, so it is not included in Table 6.1.

[22] *Roeckner et al.* [2006] performed future transient climate simulations in the ECHAM5 model, with one simulation including projected increases for carbonaceous aerosols (37% BC and 25% particulate organic matter relative to year 2000). This model included indirect as well as direct and semi-direct effects and did not separately diagnose the individual forcings, so it is not included in Table 6.1. Increased BC in a region caused cooling there, mostly near African biomass burning regions. In these regions, liquid water path and precipitation increased, possibly due to enhanced instability (Figure 6.1, case SD6); the additional cloud cover reduced surface solar radiation and cooled the surface. For this study, the increased organic carbon together with the indirect effects might also contribute to the increased cloud cover.

[23] Some global model studies show reduced high-level clouds from BC, also a cooling effect (Figure 6.1, case SD5; *Penner et al.*, 2003; *Menon and Del Genio*, 2007; *Jacobson*, 2010). Small-scale models have also simulated this effect [*Fan et al.*, 2008]. *Penner et al.* [2003] found a negligible semi-direct effect for fossil-fuel and biomass burning in the GRANTOUR GCM when all aerosols were injected at the surface. However, when biomass-burning aerosols were injected aloft, they found a net negative semi-direct cloud climate forcing response to carbonaceous aerosols (both BC and organic carbon), mostly due to loss of high-level clouds. In most other studies, BC aerosols were injected at the surface and the response was smaller. *Menon and Del Genio* [2007] also reported a negative semi-direct effect of -0.08 W m^{-2} in their GISS simulations due to decreased long-wave cloud forcing and loss of high-level clouds, mostly in biomass burning regions. This study did not specify how the semi-direct effect was calculated nor what was used for emissions in the baseline and forcing scenarios, so it is not included in Table 6.1. *Lohmann and Feichter* [2001] obtained a negative direct plus semi-direct effect of -0.1 W m^{-2} in their ECHAM simulations. However, this value was smaller than the interannual standard deviation. The semi-direct forcing was not isolated, so this study is also not included in Table 6.1. *Ghan et al.* [2012] isolated liquid-cloud effects by setting aerosol refractive indices to zero, allowing an estimate of the semi-direct effect by difference. Changes in shortwave and longwave radiation were of similar magnitudes and totaled -0.10 to +0.08 W m^{-2} depending on the aerosol representation.

[24] Some studies report BC direct radiative forcing 'efficacy' of less than one instead of calculating a negative semi-direct forcing as a rapid adjustment to the direct forcing. The definition of efficacy is temperature change per forcing relative to that for CO_2, so that efficacy of less than one indicates that a mechanism acts to reduce the positive direct radiative forcing (see Table 1.1). In some cases these studies indicate that either increased low-to-mid level or decreased upper-level cloud changes are responsible for radiative forcing efficacies less than one [*e.g., Roberts and Jones*, 2004; *Hansen et al.,* 2005; *Yoshimori and Broccoli,* 2008]. It is noteworthy that BC radiative forcing efficacy estimates are consistently about 0.6 to 0.8. If we assume that the reduced BC radiative forcing efficacy is entirely due to cloud cover changes, we can infer BC semi-direct forcing estimates for these models. This is justified by the fact that adjusted forcing efficacies for absorbing aerosol are much closer to 1.0, implying that rapid adjustment accounts for most of the small radiative forcing efficacy [*Shine et al.,* 2003*; Hansen et al.*, 2005; *Crook et al., 2011*].

[25] *Roberts and Jones* [2004] found that the radiative forcing efficacy of BC was 0.62, due mostly to reduction of high-altitude clouds. *Hansen et al.* [2005] found BC radiative forcing efficacy of 0.78 for fossil-fuel BC and 0.58 for biomass-burning BC and direct forcing values of +0.49 W m^{-2} and +0.19 W m^{-2}, respectively. If their smaller than 1.0 radiative forcing efficacies are all due to rapid adjustment of clouds, the semi-direct effect forcings are -0.11 and -0.08 W m^{-2}, respectively. *Yoshimori and Broccoli* [2008] had efficacy of 0.59 for direct BC radiative forcing of +0.99 W m^{-2}, giving a maximum semi-direct effect forcing of -0.4 W m^{-2}. *Jones et al.* [2007] report a BC radiative forcing efficacy of 0.71 for BC forcing of +0.39 W m^{-2}, for an inferred semi-direct effect of -0.11 W m^{-2}. *Chung and Seinfeld* [2005] calculated a 0.70 radiative forcing efficacy for 0.33 W m^{-2} direct forcing, giving a -0.1 W m^{-2} semi-direct effect. These efficacy studies give a range of -0.4 to -0.08 W m^{-2} of inferred semi-direct effect of BC. The

Accepted Article

finding of a narrow range of efficacies implies that this effect is approximately linear with direct forcing. The range is altered to -0.30 to -0.15 W m^{-2} when each study is scaled to either direct forcing of +0.71 W m^{-2} (for those studies that reported forcing) or to industrial-era emissions of 13900 Gg yr^{-1}. These scaled estimates are given in Table 6.1.

[26] Our estimate of the climate forcing from the BC semi-direct effect for emissions that do not have significant lofting, scaled to 13900 Gg yr^{-1} emissions, is -0.1 ± 0.2 W m^{-2}. The central value is the average of the *Wang* [2004] climate forcing estimate, scaled as described above, the near-zero sum of fossil-fuel and biomass values from *Penner et al.* [2003], the *Ghan et al.* [2012] value, and the five efficacy estimates scaled to a BC climate forcing of +0.71 W m^{-2}. Most of these estimates come from studies that isolate pure BC, but the *Penner et al.* [2003] estimate is for BC and OC. All estimates used in this average came from models where emissions were injected at the surface. The magnitude of our uncertainty estimate is larger than the standard deviation of the studies, but reflects interannual variability and sensitivity analyses reported by individual studies.

[27] The semi-direct estimate is influenced by the five studies that cast the response in terms of radiative forcing efficacy. These studies may have included other climate responses in addition to changes in cloud amount, so we caution against comparing this value with pure estimates of the semi-direct effect.

[28] As noted above, *Penner et al.* [2003] also estimated a large negative semi-direct effect when all aerosols from open biomass burning were injected aloft (-0.39 W m^{-2}). This estimate was given for a larger emission rate; scaled to our anthropogenic biomass-burning estimate of 4000 Gg BC yr^{-1}, the additional semi-direct forcing would be -0.28 W m^{-2}, with a 100% uncertainty given by the interannual variability. We do not have estimates of the quantity of biomass burning aerosol that is lofted, but it is less than 100%. We have added this value as an asymmetric uncertainty to the lower bound of the semi-direct forcing. When we estimate forcing by individual source categories (Section 10), this uncertainty for lofted aerosol is attributed entirely to biomass-burning emissions. All other BC emissions are emitted near the surface.

[29] Semi-direct effects are strongly dependent on the amount of absorption [*e.g., Johnson et al.,* 2004; *Fan et al.,* 2008; *Randles and Ramaswamy,* 2008; *Perlwitz and Miller*, 2010; *Wang,* 2004]. For example, *Perlwitz and Miller* [2010] showed that in GISS model climate simulations, dust with sufficiently large and absorbing AOD caused global mean cloud cover to increase. For weakly absorbing dust, mean cloud cover decreased. *Johnson et al.* [2004] showed that absorbing aerosols above stratocumulus cloud level strongly increase cloud cover, an effect that did not appear with scattering aerosols. Two global model studies found net decreased cloud cover in response to total pollution aerosols, and positive semi-direct effect [*Allen and Sherwood*, 2010; *Lohmann and Feichter*, 2005], but BC effects were not separated in these studies.

[30] Although global models simulate a negative semi-direct effect, the models have substantial uncertainties. Because cloud enhancement is caused mostly by BC above cloud level, model BC altitude distributions must be accurate. As discussed in Section 5.6.1, models are especially diverse in their simulated altitude distribution of BC, and measurements to verify vertical distributions are sparse (Section 4.6). Many of the models that simulate negative semi-direct effects overestimate BC at high altitude, when compared with a few available BC measurements over North America [*Koch et al.*, 2009a]. Further, global model cloud schemes may not be able to reproduce some small-scale features that would influence the semi-direct effect, such as cloud layer thickness, cloud-top entrainment, cloud fraction and the tendency to drizzle, which are affected by the scale of interactions among radiation, turbulence and moist physics on small horizontal and vertical scales. However, the models should capture many larger-scale features, such as stabilizing or destabilizing of the boundary layer, cloud burn-off, and impacts on larger circulation.

[31] Model cloud responses to absorbing aerosols have not been compared carefully with cloud-scale model and field studies for specific conditions. The framework presented here, and in greater detail in *Koch and Del Genio* [2010], requires ongoing revision as future studies provide information.

6.3.3 Increased absorption by cloud droplet inclusions

Accepted Article

[32] Absorption by BC increases when it is covered with non-absorbing material (Graßl, 1975; Section 2.7.3.2), including water. This increase affects both the amount of atmospheric absorption attributable to BC and the estimated absorption that is collocated with clouds, with both effects possibly leading to positive forcing. The lack of simulated absorption by mixed or cloud-borne BC in most models probably affects the general prediction of the global average semi-direct effect.

[33] Forcing due to altered cloud albedo was first estimated by *Chyìlek et al.* [1984; 1996] as 1 to 3 W m^{-2} in a simple analysis that assumed fixed volume fractions of BC within cloud droplets. *Chuang et al.* [2002] used a chemical transport model to estimate the positive forcing as +0.07 W m^{-2}, although it was not clear how they determined the fraction of BC within droplets. Models that simulate the dynamics of aerosols and clouds find that, although more than 90% of BC in the atmosphere passes through and is removed by clouds, the short residence time of BC in clouds results in only a few percent of the global BC burden being present in cloud droplets at a given time [*Jacobson*, 2012; *Ghan et al.*, 2012]. *Stier et al.* [2007] and *Ghan et al.* [2012] estimated direct forcing by BC in droplets as +0.02 W m^{-2} and less than +0.01 W m^{-2}, respectively, using the Bruggeman mixing rule to represent BC-droplet absorption. The dynamic effective medium approximation predicts the greatest absorption increase for wetted particles [*Jacobson*, 2006]. It is consistent with the small number of laboratory studies measuring absorption at high relative humidity (see Section 2.7.1) and results in a direct forcing change of +0.05 to 0.07 W m^{-2}. Another mechanism involves droplet heating by BC and subsequent deactivation of CCN, but this has been shown to be insignificant at appreciable supersaturation levels [*Conant et al.*, 2002].

[34] A potentially greater forcing results from cloud burnoff when cloud-borne BC increases absorption within clouds. The forcing results summarized in the preceding paragraph do not account for this effect. The choice of model to represent absorption by BC residing within cloud droplets greatly affects the modeled absorption and, thus, the thermodynamic effect on clouds. In the model with lower absorption described above, cloud absorption caused a small negative semi-direct effect [-0.07 W m^{-2}, *Ghan et al.*, 2012]. However, predicted heating rates within clouds are 2 to 2.3 times greater when the dynamic effective medium approximation is used, compared with a core-shell treatment [*Jacobson*, 2012]. *Jacobson* [2010] found an increase in temperature of +0.18K for fossil-fuel soot and +0.31 K for fossil-fuel plus biofuel soot and gases, when cloud absorption by BC and its resulting feedbacks were included versus excluded (see their Figure 1a). With the equilibrium climate-sensitivity of this model (0.6 K (W m^{-2})$^{-1}$), these temperature changes correspond to a forcing increase of +0.30 W m^{-2} for the effect of cloud absorption by fossil-fuel soot effect alone. Cloud absorption by fossil fuel plus biofuel soot and gases has a greater forcing of +0.52 W m^{-2}, but these simulations may include effects other than those of BC. All of these forcing estimates include the small forcing change caused by cloud albedo. When the soot-only values are scaled to our industrial-era emission rate of 13900 Gg yr^{-1}, this climate forcing would be +0.76 W m^{-2}. However, some plausible optical treatments produce much lower in-cloud heating rates in *Jacobson* [2012] and lower forcing in *Jacobson* [2006].

[35] The cloud absorption effect is highly uncertain because there are few measurements of aerosol optical properties at cloud conditions, or of the relationship between in-cloud aerosol absorption and cloud dissipation. Although it is difficult to assign a central estimate under these circumstances, we average the negative estimate of *Ghan et al.* [2012] and an average of the highest and a mid-range estimate from the Jacobson studies (+0.54 W m^{-2}) to obtain a very uncertain central estimate of +0.2 W m^{-2} for this effect, with uncertainty bounds of (-0.1, +0.9) W m^{-2}. The upper bound comes from using the highest forcing-per-emission obtained from *Jacobson* [2010] for the case of fossil fuel and biofuel soot.

6.4. BC indirect effects on liquid clouds

[36] Although aerosol liquid-cloud indirect effects have been extensively studied, only a few studies isolate the influence of BC alone. Many models do not have adequate sophistication to simulate aerosol microphysics, including mixing between BC and other aerosol species and the evolution of aerosol size distribution. Earlier model studies had minimal treatment of the aerosol

Accepted Article

microphysics that are important for capturing the gaseous and aerosol interactions that dominate CCN concentrations and, hence, the BC indirect effect. Below we review earlier literature, discuss the importance of aerosol microphysics, and summarize results from studies that include the microphysics of aerosol-cloud interactions.

[37] Two simple global model studies estimated the effect of BC on liquid-cloud indirect effects and found a negative BC indirect effect. *Hansen et al.* [2005] estimated that BC contributed 5% of the aerosol indirect effect in a model study with the net indirect effect magnitude prescribed, and parameterized so that cloud cover and cloud albedo are augmented proportionately to the logarithm of the aerosol number concentration. Aerosol number concentration was derived from aerosol mass and assumed size, and aerosols were externally mixed. *Chuang et al.* [2002] estimated the liquid-cloud effects of carbonaceous aerosols, using a parameterization of cloud droplet number concentration (CDNC or the number of cloud droplets per volume of cloud). CDNC was parameterized based on Köhler theory, but without explicit aerosol microphysics. They estimated that carbonaceous aerosols from biomass-burning and fossil fuels contributed 63% and 28% of the indirect effect, respectively; these aerosols contained both BC and organic carbon. Sulfate had a smaller effect because of its lower burden. The total indirect effect was approximately proportional to the atmospheric burden but the effects of different species were slightly less than additive.

[38] BC could have a substantial influence on the indirect effect due to its potentially large contribution to aerosol number concentration rather than aerosol mass. However, number concentration of aerosol and BC mass are not linearly related. BC also provides a surface upon which volatile inorganic or organic compounds may condense. In the absence of BC, sulfate might preferentially nucleate fresh particles and additional sulfate would condense upon pure sulfate particles. In general, larger particles make better CCN or IN, although CCN activity increases when BC is internally mixed with soluble species such as sulfate or OA, while there is evidence that IN activity is optimal for unmixed or pure BC. CCN activation for BC is discussed in Section 2.8, where methodology for applying Köhler theory to a BC-solute mixture is described. Activation depends upon particle size, moles of solute in the particle, and water supersaturation in the environment (see also Figures 2.4 and 2.5). The indirect effect dependence on particle number concentration is also non-linear. Additional particles generally have a greater effect on clouds in clean conditions and relatively less in more polluted environments [*e.g., Twomey*, 1991; *Lohmann et al.,* 2005; *Hoose et al.,* 2008]. Given these non-linearities, it is difficult to model BC-cloud effects without models that include detailed aerosol microphysical schemes.

[39] Several model studies used aerosol microphysical schemes in simulations of the warm-cloud indirect effect of BC (Table 6.2). These model studies were done by comparing a simulation with all aerosols with another simulation in which BC, or BC and OA, have been removed. For consistency, we report all results as the response to the addition of BC. Below, we discuss the forcing changes actually reported by each study. However, each investigation used different changes in emissions, and Table 6.2 shows values scaled to the relevant BC emission rate.

[40] *Kristjansson* [2002] calculated a BC indirect forcing of -0.1 W m^{-2} (5-10 % of the total aerosol indirect effect), with regional values reaching about -0.25 W m^{-2} in more polluted regions where BC was an important component of the accumulation mode aerosols. In some remote oceanic regions the sign was positive because BC reduced aerosol hygroscopicity.

[41] *Chen et al.* [2010a] modeled liquid-cloud indirect effects due to BC and OA emissions. Their results show that 50% of present-day BC and OA emissions from fossil fuel cause a -0.13 W m^{-2} indirect forcing, and 50% of all BC and OA emissions (including biomass-burning emissions) cause a -0.31 W m^{-2} indirect forcing. Fossil-fuel BC particles were assumed to have quite small sizes of 25 nm diameter at emission (compare to Section 2.6.2). The indirect effects more than offset the calculated direct effects for fossil fuel and all carbonaceous emissions of +0.07 and +0.12 W m^{-2}, respectively. In the *Chen et al.* model experiments, indirect effects were isolated from semi-direct effects by running the simulation without aerosol-radiation coupling. The authors also estimated the standard deviation of the forcing over multiple years, which was as large or greater than the forcings for 15-year simulations. While the absolute change in BC+OA emissions was larger for biomass emissions and, therefore, one would expect a

Accepted Article

larger effect, *Chen et al.* also attribute the larger forcing mostly to the larger size of the biomass and biofuel combustion particles as well as to the greater hygroscopicity of the non-fossil-fuel emissions.

[42] *Bauer et al.* [2010] performed three BC reduction experiments. Adding either fossil-fuel BC or fossil-fuel plus biofuel BC decreased CDNC, probably because BC reduces the number of pure sulfate aerosols. The semi-direct effect in these cases was negative (more low-level clouds). The combined warm cloud indirect plus semi-direct effects resulted in positive forcing when fossil-fuel BC only was added, but negative forcing when a mix of biofuel and fossil-fuel BC was added. Adding biofuel combustion emissions apparently produces a larger semi-direct effect, especially at high latitudes of both hemispheres, perhaps due to lofted BC in these regions (Section 5.2). A third experiment tested the combined effect of BC and OA from biofuels only. In this case aerosols caused increased CDNC and cloud cover with a larger negative forcing. The indirect effect was found to depend greatly on assumed particle sizes, with a factor of two decrease or increase in diameter producing a 45% increase and 30% decrease in magnitude, respectively.

[43] *Koch et al.* [2011a] presented a multi-model study of the effects of BC and OA from fossil-fuel and biofuel burning. Six models examined alterations in cloudy-sky fluxes due to the same emission changes. The response to fossil-fuel BC was -0.08 to +0.31 W m^{-2} with an average of +0.08 W m^{-2}, while the response to 50% of biofuel BC and OA ranged from -0.20 to +0.08 W m^{-2} with an average of -0.10 W m^{-2}. Cloud response in this study was diagnosed using the difference in cloudy-sky fluxes between simulations with and without BC, except for one model (GISS, reported separately by *Bauer et al.* [2010] and discussed above). Therefore, these values include not only cloud semi-direct effects and warm-cloud indirect effects but also direct radiative forcing in cloudy skies, which can be more than half of the direct radiative forcing [*Zarzycki and Bond*, 2010]. Removing the above-cloud direct forcing effect would result in more negative liquid-cloud effect.

[44] Many model studies do not separate microphysical effects from semi-direct effects, although such a division could be useful for comparing across studies that do estimate these effects separately. To isolate liquid-cloud microphysical effects in the *Koch et al.* [2011a] study, we estimated semi-direct and direct radiative forcing in cloudy skies for each model. Adjusted values, scaled to our emission estimates, are summarized in Table 6.2.

[45] *Spracklen et al.* [2011] modeled liquid-cloud effects, comparing CCN against observations. They found that the contribution of carbonaceous aerosols was required to explain observed CCN concentrations. Their estimate of forcing for BC plus OA emissions from fossil-fuel and biofuel combustion was -0.23 W m^{-2} and reached -0.34 W m^{-2} with the addition of BC and OA emissions from biomass burning. *Storelvmo* [2012] found that BC had only a +0.01 W m^{-2} indirect effect in a study using four modes to represent BC and OA, while -0.25 W m^{-2} was attributed to OA.

[46] *Jacobson* [2010] studied the effects of fossil fuel and biofuel combustion on climate. Fossil-fuel emissions, including BC, OA (some of which absorbs light) and primary sulfate, caused a net decrease in liquid cloud cover. Biofuel combustion emissions, including these species as well as co-emitted gaseous species, caused a net increase in liquid cloud cover. In this case the cloud effects include the semi-direct effect, which is reported to be a cloud loss in this model. *Jacobson* [2010] argued that fossil-fuel emissions contain fewer hygroscopic particles and, therefore, have lesser indirect effect, while the more hygroscopic biofuel combustion particles affect liquid clouds more significantly. This study includes all effects (direct, liquid, mixed, semi-direct, and ice clouds, as well as cryosphere forcing) and they were not separated.

[47] For the studies discussed above, the mean value of the isolated liquid-cloud indirect effect, when scaled to the magnitude of industrial-era BC, from the three studies that modeled all carbonaceous aerosol, is about -0.1 W m^{-2}. These three models give similar forcings when scaled to emissions of 13900 GgC yr^{-1}. We use the model variation from the *Koch et al.* [2011a] study, about 0.2 W m^{-2}, as the total uncertainty in this effect. However, models are frequently unable to distinguish separate mechanisms, so the separation between liquid-cloud indirect effect and semi-direct effect is somewhat arbitrary. We therefore estimate the combined

Accepted Article

indirect and semi-direct effect, excluding forcing by cloud droplet inclusions, as -0.2 ± 0.3 W m^{-2}, where the central value is the sum of the separate estimates and the uncertainties have been added in quadrature. This value is more robust than the separate estimates. When the asymmetric uncertainty due to lofted biomass emissions is also added, the uncertainty bounds become -0.82 to 0.08 W m^{-2}.

[48] A common result among the models summarized in *Koch et al.* [2011a] is that aerosol emissions from biofuel combustion cause larger indirect effects per mass than do emissions from fossil fuel. Table 6.2 shows how the studies discussed above were scaled for emission rate and, in one case, particle size. Studies that isolate fossil-fuel or diesel emissions suggest a small positive liquid-cloud forcing, scaled to emissions, averaging +0.08 W m^{-2}, while those that isolate biofuel combustion emissions have a small negative forcing averaging -0.08 W m^{-2}. However, studies that examine the two in combination estimate a larger negative forcing that is greater than the near-zero sum. This finding suggests that the liquid-cloud system contains significant nonlinearities so that the total effect is not equal to the sum of the parts. In contrast, *Spracklen et al.* [2011] attribute greater negative forcing to fossil-fuel and biofuel particles compared with particles emitted from open-burning.

[49] Biofuel and fossil-fuel combustion emissions are different in four ways that may affect cloud responses. The first is chemical; the ratio of organic to black carbon is larger for biofuel and organic carbon is generally more hygroscopic than BC. However, some models do not explicitly treat the difference in hygroscopicity, so that modeled BC and OA particles are identical. Second, co-emitted aerosol species or precursors also affect the number of particles. For example, altering biofuel sources to remove 1 Gg of BC also removes about 4 Gg of primary OC, so it could reduce primary particle number concentrations much more effectively than altering fossil-fuel sources to achieve the same reduction. Third, models assume different emitted particle sizes. Both *Chen et al.* [2010a] and *Bauer et al.* [2010] assumed larger particle size in biofuel combustion emissions than in fossil-fuel emissions. Since particles must grow large enough to act as CCN, biofuel combustion particles are closer to activation than fossil-fuel particles. Conversely, an assumption of smaller diameter yields many more particles for the same mass emission. The modeled indirect effect depends on assumptions about source-specific particle size, number concentration and composition, but such observations are limited. Fourth, cloud response has a regional dependence. Fossil-fuel consumption is more prevalent at temperate latitudes, where cloud types and atmospheric dynamics differ greatly from tropical regions. Few models have conducted experiments that isolate sensitivities to these factors.

6.5. BC indirect effects on mixed-phase and ice clouds

[50] The influence of aerosols on both mixed-phase and ice clouds depends upon whether they can effectively nucleate ice. Typical IN are mineral dust, biological particles and possibly BC. Although coating of BC with sulfate or organic material increases its ability to act as a CCN, coatings might reduce BC's IN activity, although there is less evidence for this change. In order to have an influence on ice particle formation, it is not enough that BC have the capability to serve as IN; it must also be equally or more efficient than other types of aerosols.

6.5.1. Laboratory evidence for BC effectiveness as IN

[51] The mechanisms by which BC can affect ice clouds require that it activates heterogeneously. In general, IN need to be larger than 0.1 μm in order to have ice-active sites [*Marcolli et al.,* 2007]. Such sites can be thought of as imperfections that aid ice nucleation and may result from surface roughness or crevasses. IN activity is thought to be favored for hydrophilic particles, particles with crystallographic structure or with chemical bonds similar to those of water [*Pruppacher and Klett*, 2010]. These requirements mean that dust and crystalline sulfate are good IN and organic carbon or sulfuric acid are poor IN. The IN behavior of BC is open to question. Two parameters are commonly reported to convey the effectiveness of IN. First, the ice nucleation threshold is the supersaturation with respect to ice at which the IN activates (*e.g.*, a threshold of 1.5 means that the particle initiates

Accepted Article

nucleation of ice crystals at a relative humidity with respect to ice, RH_i, of 150%). Second, the ice-active fraction is the fraction of particles that serve as IN under any conditions.

[52] Figure 6.2 summarizes laboratory studies that have examined IN activity of BC-containing samples as a function of temperature. It includes particles from various sources and with different degrees of aging or processing [*Kärcher et al.,* 2007]. The figure shows the nucleation threshold of each material, and the dashed (solid) curves indicate the point where supercooled solution droplets (pure water droplets) activate by homogeneous nucleation. In order for BC to compete with solution droplets such as sulfate, it should activate at a lower threshold (*i.e.,* those aerosols that fall below the dashed line in Figure 6.2). Graphite spark-generated aerosol samples (two red areas in Figure 6.2) made efficient heterogeneous IN [*Möhler et al.,* 2005a], but they are probably least chemically similar to atmospheric BC-containing particles. The remainder of the samples lie near the homogeneous nucleation line. Thus, despite differences in nucleation threshold definitions and other aspects between studies, the vast majority of studies suggest that combustion particles from a large number of sources are inefficient ice nuclei, regardless of the mode of nucleation [*Kärcher et al.,* 2007].

[53] While some studies suggest that coatings reduce the ice nucleation efficiency of BC [*Möhler et al.,* 2005a; *Crawford et al.,* 2011], others find that they do not significantly alter the IN behaviour of BC [*Friedman et al.,* 2011] or even enhance it [*DeMott et al.,* 1999] or that the influence of sulfuric acid coatings depends on the organic matter within the soot [*Crawford et al.,* 2011]. This contrasts with BC CCN activity in liquid clouds, which is always enhanced by coating.

[54] Extensive comparisons of the IN and CCN activity of BC-containing aerosol were reported by *Koehler et al.* [2009], using samples of different hygroscopicity and surface porosity. Larger particles were more ice-active than smaller ones, although the size range investigated was limited. The processes that promote water adsorption facilitated both CCN activation and ice nucleation. At 233K, no combustion aerosol particles nucleated ice better than did aqueous solutions of similarly sized particles. At 216–221K, 1 in 100 particles of oxidized combustion aerosol and 1 in 1000 particles of non-oxidized combustion aerosol and aviation kerosene promoted heterogeneous nucleation of ice. BC particles coated with soluble material behaved like fully soluble particles with the same liquid volume and water activity. This suggests, overall, a limited role for BC in promoting ice nucleation.

[55] Biomass burning emissions, composed of BC and OA, also have limited IN activity, due to inhibition by organic carbon. *DeMott et al.* [2009a] found that biomass-burning aerosol from controlled laboratory burns had the same or lower nucleation activity when compared with liquid solution particles. Aerosol with high OC:BC ratios impeded heterogeneous ice nucleation most strongly. A similar impact has been reported for organic coatings on emissions from propane flames [*Möhler et al.,* 2005b]. At warmer temperatures, significant IN activity of polydisperse samples of small biomass burning particles (number mode diameters 60–140 nm) has been observed only when they have low organic carbon fraction and high water-soluble ion content, associated with flaming fires [*Petters et al.,* 2009]. At warmer temperatures (*i.e.,* greater than 240 K), dynamic cloud chamber studies of acetylene combustion emissions suggest no significant IN activity [*DeMott*, 1990], in agreement with the biomass burning aerosol studies.

[56] In contrast, many laboratory studies suggest that mineral dust particles are good to moderate IN as long as they remain uncoated with soluble material [*Kärcher et al*., 2007, Section 4.2 and references therein]. The IN activity of dust particles decreases once coated with soluble material, so that the few processed mineral dust particles reaching the upper troposphere and lower stratosphere (UTLS) are likely those with moderate IN activity [*Wiacek and Peter*, 2009]. Therefore, dust is a major competitor for BC with regard to ice formation. Other competitors include some crystalline inorganic and organic phases within partially soluble aerosols such as ammonium sulfate [*Abbatt et al.,* 2006], oxalic acid [*Zobrist et al.,* 2006], biological particles [*Pratt et al.,* 2009], or mineral dusts with lead [*Cziczo et al.,* 2009].

Accepted Article

[57] The laboratory studies summarized in Figure 6.2 employed a wide array of combustion sources and surrogates of BC-containing particles for measurements of IN activity. These studies do not provide fully conclusive information about the behaviour of BC in the atmosphere for two reasons. First, not all studies provide sufficient information to judge their relevance for cloud formation (*i.e.,* ice active fractions and presence of solutes). Second, most studies have not investigated potentially important atmospheric processes that could affect the particles' IN activity, such as surface oxidation or cloud processing. Moreover, a fundamental understanding of the physico-chemical nature of ice nucleation is lacking, although there is some progress in linking source-dependent surface properties of BC-containing aerosol and their ability to adsorb water [*Popovicheva et al.,* 2008].

6.5.2. BC effects on mixed-phase clouds

[58] Mixed-phase clouds occur at temperatures between 0°C and approximately -35ºC because water droplets and ice crystals can co-exist at these temperatures. The water vapor pressure in a mixed-phase cloud lies between water and ice saturation, so the cloud is supersaturated with respect to ice. In these clouds, an increase in IN promotes ice nucleation, and subsequently large ice particles grow in the supersaturated environment. Eventually this cloud completely becomes an ice cloud (glaciate). This process is called the Bergeron-Findeisen process. As the ice crystals grow in a supersaturated environment, they grow rapidly and start to sediment. The overall effect may be a reduction in cloud cover, causing a positive forcing (Figure 6.1, case MC1). Reduction in IN may cause the opposite effect (case MC2).

6.5.2.1. Mechanisms

[59] Ice formation in mixed-phase clouds occurs by heterogeneous freezing, with the aid of insoluble IN [*Pruppacher and Klett*, 2010]. Heterogeneous freezing can be initiated either by collision of a supercooled cloud droplet and an IN (contact mode), or from within a cloud droplet on an IN that is immersed in it (immersion mode). Condensation freezing refers to the condensation of water vapor onto a nucleus followed by freezing. Immersion and condensation freezing are conceptually similar and are not easily distinguishable in measurements. At relative humidities below 100% with respect to water but above 100% with respect to ice, nucleation of ice directly on bare IN could take place (deposition mode). Based on lidar observations of Saharan dust particles, *Ansmann et al.* [2008] argue that the time available for deposition nucleation may be too short and, hence, is negligible for mixed-phase clouds. Contact nucleation is initiated at higher temperatures than immersion nucleation [*e.g., Shaw et al.,* 2005; *Fornea et al.,* 2009], but it is limited by collision rates, especially for accumulation mode particles that are large enough to serve as IN. Therefore, the immersion mode may be the most important ice-forming mechanism in mixed-phase clouds.

6.5.2.2. Experimental studies

[60] Laboratory and field measurements give conflicting views on the viability of BC as an effective IN. As summarized above, laboratory results indicate that BC appears to be one of the least efficient IN in the atmosphere, because it nucleates ice at colder temperatures than IN with natural sources such as mineral dust and biological particles. Laboratory studies also suggest that deposition nucleation of ice on most types of BC particles is not important above 243 K and below water saturation [*Dymarska et al.,* 2006]. In contrast, in-situ observations of lower tropospheric mixed phase clouds find an enrichment of BC in ice particle residuals [*Cozic et al.,* 2008; *Targino et al.,* 2009], so there must be some mechanism for BC to enter ice clouds. BC may act as a contact IN at temperatures between 245 and 251 K [*Diehl and Mitra,* 1998; *Fornea et al.,* 2009].

6.5.2.3. Modeling results

[61] Parameterizations have been developed to represent ice formation affected by mineral dust and BC particles in both contact and immersion modes [*Diehl et al.,* 2006; *Phillips et al.,* 2008]. A GCM study using the parameterization of *Diehl et al.* [2006] found that BC did induce a glaciation effect. However, the importance of BC acting as a contact IN, and hence the glaciation effect, decreases in the presence of natural aerosols such as dust that are more efficient IN than BC [*Lohmann and Diehl*, 2006]. The glaciation effect also decreases with increased sulfate coating thickness. The results also depend on the model's parameterization of

Accepted Article

the Bergeron-Findeisen process. Taking into account all these uncertainties, the glaciation effect of all BC emissions on mixed-phase clouds was estimated as +0.12 and +0.20 W m^{-2} for two different parameterizations [*Lohmann and Hoose*, 2009; see also Table 6.2].

[62] *Storelvmo et al.* [2011] also studied BC impacts on mixed-phase clouds, including the opposing effects of albedo and lifetime. The magnitude and sign of the forcing depended on the ice-active fraction of BC and the parameterization chosen. Forcing became negative when another parameterization [*DeMott et al.,* 2010] was used, but this treatment led to ice crystal sizes that did not agree with observations. When using an intermediate case for ice-active fraction, this study found a forcing of +0.16 ± 0.08 W m^{-2}, which is used in this assessment in calculating our central estimate of the BC effect on mixed-phase clouds. *Yun and Penner* [2012] also studied the anthropogenic effects of BC and OM on mixed-phase clouds. The effect depends greatly on the contact freezing parameterization; it is +0.15 W m^{-2} when a parameterization from *Phillips et al.* [2008] is used, but +0.83 W m^{-2} when the older and simpler *Young* [1974] version is used. However, in the latter treatment, this study also allowed OM to participate in contact nucleation of ice.

[63] While other model studies have not produced forcing estimates, they generally agree that BC addition reduces mixed-phase clouds through enhanced glaciation. *Ekman et al.* [2007] studied the influence of BC particles on continental convective clouds using a cloud-resolving model. They found that BC increased heterogeneous ice nucleation, thereby increasing the latent heat release and updraft velocities in the convective plume. As a result, total precipitation increased and clouds were reduced. One regional climate model study found that externally mixed BC aerosols increase riming and enhance orographic precipitation and cloud loss [*Muhlbauer and Lohmann*, 2009]. In contrast, internally mixed BC aerosols decreased riming rates and orographic precipitation.

[64] Our estimate for mixed-phase cloud indirect effects due to modeled emissions is +0.15 ± 0.16 W m^{-2} based upon estimates of *Lohmann and Hoose* [2009], *Storelvmo et al.* [2011] and *Yun and Penner* [2012] using the *Phillips et al.* [2008] freezing parameterization. Sensitivity experiments in *Storelvmo et al.* [2011] (experiments BC, BC10, and BC01) show that forcing is approximately proportional to the log of ice-active nuclei. To account for the increased industrial-era emissions reported in Section 5, we scale the forcing according to the relationship between these studies, and retain the same relative uncertainties, for a forcing of +0.18 ± 0.18 W m^{-2}.

6.5.3. BC effects on ice-phase clouds

[65] Pure ice-phase clouds (cirrus clouds), wich form at temperatures below -35ºC, often reside at high altitude and usually exert positive forcing. As discussed in Section 6.5.1, BC IN activity may either increase or decrease this forcing.

6.5.3.1. Mechanisms

[66] In cirrus clouds, there are no water droplets and, therefore, no contact nucleation, so heterogeneous ice nucleation in these clouds can only occur in the deposition, immersion, or condensation modes. In these clouds, the total concentration of nucleated ice crystals may either increase or decrease depending on temperature, cooling rate, and number of BC particles [*Kärcher et al.,* 2006]. If heterogeneous nucleation dominates unperturbed clouds (especially in slowly cooling air masses), BC could contribute to this nucleation by increasing the number concentration of IN and thereby decrease the mean size of ice crystals. This leads to longer lifetimes of high clouds that exert a net warming effect, resulting in a positive forcing (case IC2, Figure 6.1; *Kärcher et al.,* 2006). At higher cooling rates, adding IN tends to retard or even prevents homogeneous freezing, which decreases the number of ice crystals, resulting in a negative cloud forcing (case IC1, Figure 6.1; *Kärcher et al.,* 2006). In the UTLS, airborne measurements of relative humidity and cirrus indicate that the latter scenario occurs preferentially under typical atmospheric conditions [*Haag et al.,* 2003].

Accepted Article

[67] Figure 6.3 shows the results of an IN parameterization demonstrating how the number concentration of combustion aerosol affects the total concentration of nucleated ice crystals in the presence of dust IN and liquid background aerosols. Updraft velocities govern the rate at which a developing cloud is cooled and, therefore, the formation rate of new ice crystals, so they play an important role in the initial cloud properties. The two panels show different cloud updraft speeds, where the updraft rate increases the cooling rate. If all IN are combustion aerosols and their concentration decreases (black curves), ice-crystal number concentration is determined by homogeneous nucleation and unaffected by the addition of BC. As more IN are added, more of them nucleate heterogeneously and take up water. As a result, fewer ice crystals form homogeneously and the total ice-crystal number concentration decreases. (This reduction in ice crystals with IN, corresponding to case IC1 in Figure 6.1, contrasts with liquid clouds where addition of CCN causes increased CDNC.) The resulting larger particles have a shorter atmospheric lifetime, leading to a decrease in cirrus clouds and negative longwave forcing. IN can consist of either combustion particles or dust (Figure 6.3, colored curves). When IN are numerous enough, heterogeneous nucleation dominates the formation of ice crystals, and the suppression of homogeneous nucleation has little effect on the final number concentration. Therefore, the addition of IN causes an increase in the number concentration of ice crystals (case IC2 in Figure 6.1). Under some conditions, ice formation on combustion aerosol could entirely suppress homogeneous freezing.

[68] At small updraft rates (top panel), few ice crystals form and the influence of adding IN occurs at lower combustion aerosol number concentration. Large updraft velocities (bottom panel) cause the formation of a large number of ice crystals, since homogeneous freezing dominates ice formation (the number of aerosol droplets is not a limiting factor). In this case, BC is not capable of causing a notable indirect effect. At intermediate updraft velocities, BC depletes the air mass of moisture, causing much fewer (but still more than BC) background particles to freeze homogenously. This discussion, focused largely on microphysics, addresses only processes that affect the initial ice crystal concentration in single air parcels. This sensitivity study gives a first-order estimate of IN in young clouds, but does not quantify the changes in the cloud as it evolves and, therefore, does not reflect global averages.

6.5.3.2. Field evidence for BC acting as IN

[69] Laboratory studies indicate that IN activity of BC is, at best, moderate. Field studies, summarized below, confirm these findings. They indicate that homogeneous freezing is the prevalent ice formation mode [*DeMott et al.,* 2003; *Cziczo et al.,* 2004a]. This is consistent with the ubiquity of high ice supersaturations in cloud free areas of the upper troposphere [*Jensen et al.,* 2001; *Haag et al.,* 2003; *Kahn et al.,* 2009b] and with the fact that total cirrus ice-crystal number densities often far exceed estimated IN concentrations [*Gayet et al*., 2002; *Hoyle et al*., 2005].

[70] Field measurements using single-particle mass spectrometry, electron microscopy, and X-ray emission or particle elastic scattering analysis demonstrate that BC and organic carbon are present in the troposphere and lower stratosphere [*Murphy et al.,* 2007; *Nguyen et al.,* 2008]. Often the predominant particles are composed of organic carbon that originates mainly from surface sources. Even particles that reach the stratosphere may have acquired small amounts of carbon during transport through the upper troposphere. Some measurements suggest that BC's effectiveness as an IN is greatest if it is uncoated, but this finding is not yet definitive. Presumably, uncoated BC rarely exists in the UTLS region and, because it is difficult to detect thin coatings on BC, the number of such particles in this region is poorly known.

[71] A constraint that could ascertain whether BC affects ice cloud formation would be direct airborne sampling of particles at high altitudes, along with simultaneous characterization of their chemical composition and measurements of their ice-forming properties. Ice nuclei counters have been employed in several ground-based and airborne measurements [*Rogers et al.,* 1998; *DeMott et al.,* 2003; *Cziczo et al.,* 2004b; *Richardson et al.,* 2007; *Stith et al.,* 2009; *Prenni et al.*, 2009*; Froyd et al.,* 2009]. In qualitative agreement with most laboratory studies, some of these field measurements support the notion that mineral particles can

Accepted Article

act as IN in cirrus clouds, while BC-containing aerosol is less ice-active, although it often present in ice-nucleating aerosol. However, without adequate characterization of particle composition and properties, field measurements can infer correlations between IN components and heterogeneous ice nucleation but cannot distinguish the processes by which certain particles partition in cirrus ice; therefore, they cannot provide causal links.

[72] This conclusion is particularly true for measurements of cirrus ice crystal residues that show enhancements in insoluble components relative to ambient particles, throughout the troposphere and in aircraft corridors [*Heintzenberg et al.,* 1996; *Ström and Ohlsson*, 1998; *Twohy and Gandrud*, 1998; *Petzold et al.*, 1998; *Twohy and Poellot*, 2005]. Inertial scavenging of BC particles by ice crystals in clouds was found to be more important than ice nucleation in explaining observed BC-to-ice mass ratios at temperatures of 228–248 K [*Baumgardner et al.,* 2008; *Stith et al.*, 2011].

[73] Field data sets that measure IN concentrations have not distinguished BC-containing particles from other particles. Such measurements may be viewed as the maximum concentrations of ice-active BC for comparison with models. Measurements over continental areas and in aircraft corridors reveal highly variable IN number concentrations of 0.1–500 L^{-1}, with 60% of data lying in the range 2–20 L^{-1} [*Rogers et al.,* 1998]. Other data sets point to typical background northern hemispheric IN concentrations of 10 to 30 L^{-1} [*DeMott et al.,* 2003; *Haag et al.,* 2003]. Data in the Arctic report lower values (*i.e.,* less than 1 L^{-1}) with local maxima of 50 L^{-1} [*Prenni et al.,* 2009]. IN concentrations of 100 to 500 L^{-1} are rare and have only been detected locally in dust storms [*DeMott et al.,* 2009b; *Stith et al.,* 2009].

[74] The minimum BC ice active fraction present in lower and mid tropospheric biomass burning plumes required to exert regional impact was estimated to be 10^{-4} or higher [*Petters et al*., 2009]. A comparison of upper tropospheric refractory particle concentrations of about 10,000 L^{-1} [*Minikin et al*., 2003] with inferred IN concentrations of about 10 L^{-1} [*Haag et al.,* 2003] yields a BC ice active fraction of 10^{-3}, when assuming that BC contributed 100% by number to the refractory particles. The latter assumption is likely an overestimate, so the BC ice active fraction in nature was probably smaller.

6.5.3.3. Modeling evidence for BC atmospheric abundance and mixing state

[75] As discussed in Section 2, BC particles are commonly mixed with sulfate or organic carbon within a day. If most BC particles in the UTLS are coated, then BC acting as deposition IN, in which ice forms directly on bare BC, would be rare in the upper troposphere.

[76] Most global models are not well validated in terms of UTLS aerosol speciation and particle number concentrations, in particular for BC [*Koch et al.,* 2009a; *Lohmann and Hoose,* 2009]. Problems in simulating tropospheric BC vertical distribution, mixing state, and other properties are mainly tied to poorly parameterized physical and chemical processes that affect BC lifetime, and, to a smaller degree, to uncertainties in emission inventories [*Textor et al.,* 2007]. One particularly uncertain process is scavenging in ice clouds.

[77] One climate model has specifically compared UTLS aerosol number and mass concentrations with observations [*Aquila et al.,* 2011]. This model tracks the properties and distribution of potential ice nuclei (defined as the sum of dust and BC particles) separately from soluble particles, so that internally and externally mixed BC are explicitly represented. The zonal mean ratio of externally mixed potential IN to the total potential IN number is 0.5–2% throughout most of the free troposphere. These values are much smaller than suggested by observations [*Schwarz et al.,* 2008a], but internally mixed particles are not distinguished as easily by the measurements as they are in the model. Simulated transformation times from external to internal mixtures are predicted to be larger for dust than for BC, implying a larger (but still small) fraction of bare dust particles relative to BC in tropospheric accumulation mode IN. These model results suggest the need for careful examination of observed IN mixing state.

[78] For BC particles (or IN in general) to exert a significant effect on ice formation, their ice nucleation thresholds should lie well below the homogeneous freezing limit for fully soluble aerosol particles, and the number concentration of the ice active population

Accepted Article

should be 10 L^{-1} or larger for typical updraft velocities and temperatures in the upper troposphere [*Kärcher et al.,* 2006]. However, as summarized above, BC particles from a wide range of sources do not appear to be potent IN (see Figure 6.2). Therefore, it is realistic to assume an ice nucleation threshold that is close to but below the homogeneous freezing threshold, as was chosen for the simulations in Figure 6.3. While Figure 6.3 explores the effect of BC on IN, the possible range of influence of BC on cirrus properties depend on the details of the ice active fraction and other factors that are not included in those simulations.

[79] Resolving moderate impacts of IN, where ice is formed at supersaturations slightly below the homogeneous freezing threshold, and validating IN impacts on cirrus will be very challenging in UTLS in situ measurements, given the present difficulties in measuring relative humidity and cooling rates on the scale of individual clouds. *Kärcher and Ström* [2003] emphasized the crucial role of dynamical forcing in cirrus formation; small uncertainties in estimating cooling rates in cirrus generating cells can easily mask any indirect effect exerted by IN. Furthermore, it is questionable whether the effects of IN on optically thin ice clouds can be unraveled by means of satellite observations [*Chylek et al.,* 2006; *Seifert et al.,* 2007; *Massie et al.,* 2007].

6.5.3.4. Global model studies of BC effects on cirrus

[80] Three model studies have estimated the carbonaceous aerosol effect on ice clouds (Table 6.2). This effect is the difference between present-day conditions and pre-industrial (background) conditions, and estimates of forcing are, therefore, strongly affected by the nucleation regime in the background atmosphere. If homogeneous nucleation is most common in the pre-industrial atmosphere (left side of Figure 6.3 or an environment with few IN), BC decreases ice particle number concentration and forcing is negative. If heterogeneous nucleation was dominant in the pre-industrial case (toward the upward slope of Figure 6.3 or an environment with more dust), BC increases ice particle number concentration and forcing becomes positive. A predominance of droplets or sulfate particles corresponds to natural conditions with homogeneous nucleation, while predominance of refractory particles like dust would result in heterogeneous domination. The influence of adding IN on ice formation is largely controlled by cloud-scale dynamics, and changes in the dynamic regime since the pre-industrial era are not fully included in this forcing estimate.

[81] *Penner et al.* [2009] used off-line estimates from a CTM aerosol scheme coupled to the NCAR CAM3. They used two parameterizations that allowed for competition between homogeneous and heterogeneous nucleation in an aerosol mass-only and a 3-mode, 2-moment versions of the model. Sulfate droplets were assumed to act as homogeneous freezing agents, BC was assumed to be coated with soluble material and, therefore, to act as immersion IN, and dust was assumed to act as IN in the deposition or condensation mode. For the more sophisticated (3-mode) parameterization, two different ice nucleation schemes gave a forcing from fossil-fuel and biomass burning emissions of -0.3 to -0.4 W m^{-2}. The dominant effect was that heterogeneous IN activity of BC decreased relative humidity with respect to ice, inhibited homogeneous nucleation, decreased the number concentration of ice particles and reduced positive forcing by high-level clouds.

[82] The mass-only version of the aerosol model was applied by *Liu et al.* [2009a] in the NCAR CAM3 global model with a double moment ice microphysical scheme. Adding BC resulted in increased high-level clouds, especially over polar regions but also somewhat over tropical regions. The resulting change in forcing due to BC emitted at the surface was +0.22 W m^{-2} or +0.39 W m^{-2} when critical supersaturations of 1.2 to 1.3 or 1.4, respectively, were assigned to BC. The larger forcing for higher ice nucleation threshold is due to a larger decrease in negative shortwave contribution. The change in sign between this study and the *Penner et al.* [2009] results reflects the large uncertainty in this forcing, stemming from the fact that cirrus clouds affect both shortwave and longwave radiative fluxes, and the change in each is determined by specific cloud properties. The forcing is, therefore, a small value calculated by adding two large values of opposing sign, making it very sensitive to changes in the magnitude of either one. Similar uncertainties are seen in the estimation of the climate effects of aviation BC emissions, which are not included here. There are three major differences between this study and *Penner et al.* [2009]. In the pre-industrial atmosphere, homogeneous nucleation dominated in *Penner et al.* [2009] while heterogeneous nucleation dominated background conditions in

Accepted Article

Liu et al. [2009a]. *Liu et al.* used a prognostic treatment of the ice-crystal number concentration including source and sink terms while *Penner et al.* diagnosed ice-crystal number concentration from nucleation. *Liu et al.* [2009a] included climate feedbacks, so that aerosols in the UTLS region tended to enhance relative humidities there; however, they were unable to reproduce the observed supersaturations in the atmosphere, so that the modeled supersaturations were never high enough to allow homogeneous nucleation (see Figure 3 of *Liu et al.* [2007]).

[83] *Gettelman et al.* [2012] analyzed the BC effect on ice clouds as part of a more comprehensive study of ice nucleation in the CAM5 model, exploring the effect of parameterisation changes on background cloud properties and the aerosol indirect effect. They compared study pairs with 1850 and 2000 aerosol emissions. One member of the pair had fixed ice nuclei as a function of temperature and the other used a more complete parameterization, allowing competition between heterogeneous nucleation on dust with homogeneous nucleation on sulphate. The standard model used only coarse-mode dust as potential ice nuclei. BC was incorporated into this scheme by assuming it had the same ice nucleation properties as dust. The ice active fraction for BC was set to 0.1%, 2% and 100% in different simulations. Only the simulation assuming a 0.1% ice active fraction gave realistic ice water mass and cloud radiative properties, and this simulation was used to estimate the indirect effect. Forcings were estimated from the full ToA radiative-flux change, a cloud forcing change, and a cloud forcing change with a clear-sky flux change correction applied; the quoted result is the average of these three. This study estimates $+0.27 \pm 0.10$ W m^{-2} (1σ uncertainty) for the total ice cloud aerosol indirect effect. The BC component was -0.06 W m^{-2} and was not statistically significant.

[84] *Jacobson* [2010] included ice-cloud effects in a model of the effect of BC on climate. Ice crystal sizes increased slightly due to BC. The study used a temperature-dependent ice-nucleation threshold for uncoated BC (Section 6.5.1) that ranged between 1.15 and 1.35. These values are within the range for uncoated spark-generated soot at moderate and low temperatures, but below the range of coated soot in Figure 6.2. Cloud drop and ice-crystal number concentration were calculated by simultaneously solving the mass balance equations for water vapor, liquid, and ice, considering all aerosol and cloud particle sizes. BC in this model study is a more efficient IN than is observed in the laboratory. In the study, relative humidity increased at high altitudes and in the Arctic, and ice clouds increased due to BC, which are results similar to those in *Liu et al.* [2009a]. Forcing due to this IN mechanism was not isolated, but the direction of ice-cloud changes suggests a positive forcing.

[85] In a global model study by *Hendricks et al.* [2011], a multiple-mode ice microphysical scheme was applied in the ECHAM GCM to simulate IN effects on global cirrus properties. The ice nucleation parameterization by *Kärcher et al.* [2006] was applied to simulate the competition between homogeneous and heterogeneous ice formation. *Hendricks et al.* [2011] assumed that only small fractions of the modeled BC and mineral dust particles (0.25% and 1%, respectively) could act as IN, resulting in IN concentrations on the order of 10 L^{-1} at cirrus levels. BC and dust-related IN had similar contributions. Heterogeneous nucleation on both types of particles produced significant reductions in the mean cirrus ice particle number concentrations. The effect was most pronounced in the tropics, where the zonal mean annual average ice particle number concentration decreased by up to 20%. Reductions in the mean ice water content, likely resulting from efficient sedimentation and precipitation of large ice particles generated by heterogeneous nucleation, also occurred. This effect led to reductions in the zonal mean, annually averaged, water-vapor mixing ratio of up to 5% at cirrus levels. The BC contribution to these effects was comparable to that related to mineral dust IN only when the assumed ice nucleation threshold is significantly lower than that assumed for dust particles (threshold of 1.2 for BC and 1.3 for mineral dust). When a larger critical value (ice nucleation threshold of 1.40) was assumed for BC, heterogeneous freezing was dominated by mineral dust particles.

[86] Compared to the global model studies by *Liu et al.* [2009a] and *Penner et al.* [2009], *Hendricks et al.* [2011] and *Gettelman et al.* [2012] simulated a much smaller effect of BC on cirrus ice crystal number concentrations. These differences could result from either a smaller availability of active ice nuclei in the *Hendricks et al.* [2011] and *Gettelman et al.* [2012] studies or from

Accepted Article

differences in the representation of relative humidity and cooling rates. *Gettelman et al.* [2012] found that an ice active fraction of 0.1% gave realistic ice water content and radiative properties, and ice active fractions of 2% and 100% did not.

[87] Compared with the measurements discussed in Section 6.4.3.3, the *Liu et al.* [2009a] and *Penner et al.* [2009] studies may overestimate UTLS BC and IN and may, therefore, overestimate the magnitude of the ice-cloud indirect effect. *Liu et al.* [2009a] reported BC concentrations of about 300 to 3000 L^{-1}, which when compared to a few measurements were roughly a factor of two too high. *Penner et al.* [2009] reported reasonable agreement with measurements of IN from one field campaign, but the concentrations exceed those summarized in Section 6.4.3.3 for a more geographically diverse set of regions. IN concentrations in the UTLS region are smaller in *Liu et al.* [2009a] than in *Penner et al.* [2009].

[88] Our estimate of the BC influence on ice-cloud indirect effects is 0.0 ± 0.4 W m^{-2} based on the *Gettelman et al.* [2012] study and the average and range of *Liu et al.* [2009a] and *Penner et al.* [2009]. Both *Penner et al.* [2009] and *Liu et al.* [2009a] lack fidelity in some aspects, so that there is no clear choice between the two opposing results. However, we use them to bound the uncertainty range. Unlike all other cloud forcings, this estimate has not been scaled to our best estimate of industrial-era BC emission rate. For ice-cloud effects, many factors other than emission rate affect ice-active BC concentrations in the upper troposphere. Most models, including those used in the *Penner et al.* [2009] and *Liu et al.* [2009a] studies, overestimate these concentrations. Therefore, the model results may represent an upper bound on the magnitude of ice-cloud impact. In the *Gettelman et al.* [2012] study, the BC ice cloud impact was not significant.

6.5.3.5. Aircraft impacts on high ice-cloud properties

[89] BC emissions from aviation are a very small fraction of direct forcing because they are a very small fraction of global emissions. However, aviation emissions of BC provide an especially potent source of potential ice nuclei [*Kärcher et al.,* 1996; *Schröder et al.,* 1998]. The *Liu et al.* [1999] and *Penner et al.* [2009] modeling studies estimate the effect of aviation BC alone on ice cloud to be between -0.16 W m^{-2} to +0.26 W m^{-2}. Aviation emissions potentially have a larger effect on ice clouds than comparable emissions at the surface [*Lee et al.*, 2010]. The total BC climate forcing in Figure 9.1 explicitly excludes aviation emissions. We mention these studies here because they may provide additional clues about how BC particles affect cirrus clouds, although BC emitted from aviation may undergo less mixing with tropospheric particles and gases.

[90] Although contrails would form even in the absence of BC emissions, the optical properties of the contrails and cirrus impacts depend on BC emission levels [*Kärcher and Yu,* 2009; *Lee et al.,* 2010]. Water supersaturated conditions during contrail ice formation below approximately 225 K activate even rather hydrophobic BC particles into rapidly freezing water droplets [*Kärcher et al.,* 1996; *Koehler et al.,* 2009]. A decrease in ice cloud particle size for cirrus clouds altered by aircraft may imply that aircraft BC increases the concentration of available IN for these aged contrails or cirrus clouds [*Lee et al.,* 2010]. *Jacobson et al.* [2011] found that an assumption of efficient ice nuclei (*i.e.,* ice nucleation threshold of 1.35 at 185 K) was required for a good match with observed contrail cloud fractions. The model study of *Hendricks et al.* [2005] suggests that aircraft BC increases IN by 10 to 40% in aircraft cruise altitudes in northern midlatitudes. However, the ice nucleating properties of aircraft exhaust for the exact composition and coating of exhaust particles, at the temperature and water vapor conditions in cirrus, remain poorly known. The impact of aircraft BC emissions on cirrus cloud formation in the absence of contrail formation remains very uncertain.

6.6. Comprehensive modeling of BC cloud effects

[91] Although the discussion above has separated effects on individual cloud types, one series of model results [*Jacobson*, 2001b; *Jacobson*, 2002; *Jacobson*, 2004; *Jacobson,* 2010] has implemented a progressively more complex treatment of BC that does not separate forcing by mechanism or by cloud type. Because individual forcing values cannot be extracted from these studies, it is not possible to discuss them in the framework described in the remainder of the section. However, if these models results are greatly different than the forcing values assembled in the remainder of this assessment, then the causes of these differences should be

Accepted Article

sought. Therefore, we evaluate these model results for consistency with our estimated forcing. The studies give shortwave and longwave irradiance changes, but those values are not effective forcings because they also include climate responses. Instead, our comparison is largely based on the reported temperature responses divided by the GHG climate sensitivity of the model [0.6 K (W m^{-2})$^{-1}$, *Jacobson*, 2002]. This quotient gives an approximate effective forcing.

[92] *Jacobson* [2004a] included direct forcing, snow forcing, and responses of liquid, mixed, and ice clouds to estimate a temperature increase of +0.27 K for fossil fuel and biofuel combustion emissions. When the effective snow forcing of +0.18 W m^{-2} (see Table 7.1 and Section 8) is subtracted from the total effective forcing, an effective forcing of +0.31 W m^{-2} is obtained. This value is similar to the purely direct-forcing total of +0.36 W m^{-2} expected for the emission rates used in that study and the direct forcing of the model reported earlier [*Jacobson,* 2001b]. From this we infer that the balance of positive and negative forcing exerted by liquid, mixed, and ice clouds is near zero, comparable to the values assessed above when ignoring the cloud absorption effect. On the other hand, aerosol from open biomass burning caused a negative temperature change of -0.17 K [*Jacobson*, 2004b].

[93] *Jacobson* [2010] used slightly different emission rates for fossil-fuel and biofuel combustion and reported a temperature change of +0.38 K (*i.e.,* equivalent to about 0.45 W m^{-2} after removing cryosphere forcing) when cloud absorption was ignored, again similar to the emission-based projection of direct aerosol forcing of +0.39 W m^{-2} and indicating a negligible net cloud influence. However, when cloud absorption by BC in droplets was included in the simulation, the temperature change was +0.69 K, an increase of +0.31 K (+0.52 W m^{-2}). This potentially large effect was considered in Section 6.3.1.

6.7. Summary of uncertainties in estimating indirect effects

[94] For all aerosols, model estimates of indirect effects have a much larger relative spread for indirect effects compared with direct effects. For example, the uncertainty estimate for the cloud albedo effect is double that of the aerosol direct effect [*Forster et al.*, 2007].

6.7.1. Model uncertainties beyond aerosol-cloud interactions

[95] Aspects of the environment beyond aerosol-cloud interactions have not been addressed nor accounted for in this section. In addition to aerosol effects on clouds, atmospheric dynamics plays a decisive role in cloud formation, properties, and lifetimes [*Heintzenberg and Charlson,* 2009]. If these dynamical relationships are incorrectly represented in models, the resulting errors could overwhelm the magnitude of aerosol influence. Some studies argue that offsetting mechanisms, or 'buffering,' may reduce the magnitude of perturbations caused by aerosols [*Stevens and Feingold*, 2009].

[96] In some models, the representation of clouds themselves is inaccurate, either in total coverage, location, or optical thickness [*Soden and Held*, 2005; *Bony and Dufresne*, 2005; *Cesana and Chepfer*, 2012]. Global models also suffer from inconsistency between ice microphysics and cloud coverage [*Kärcher and Burkhardt*, 2008], and there are uncertainties in specifying subgrid-scale vertical velocities, which control the relative roles of IN and liquid particles during cirrus formation [*Kärcher and Ström*, 2003]. These factors may introduce larger uncertainties in determining the indirect effect than do assumptions about variations in the properties of the aerosols, but they have not been evaluated in previous literature and are not included in the uncertainty estimated here.

6.7.2. Aerosol-cloud interactions

[97] Uncertainties in BC's influence on clouds are of four general types. First, there are process uncertainties regarding the effects of aerosols on clouds generally and of the role of BC more particularly, and modeled aerosol microphysics and cloud responses have not yet been strongly constrained by observations. A current challenge is obtaining sufficient observational information on aerosol number concentration, size, mixing state and chemical composition in various regions and altitudes. Cloud-scale measurements determining collocated relative humidity, vertical air motion, and CCN or IN activity and number concentration provide important constraints on these processes. Cloud-resolving models also allow a more detailed evaluation of the importance

Accepted Article

of individual processes, yet forcing values obtained from models of individual clouds have yet to be reconciled with global average forcing predicted by GCMs. Many models have only recently represented aerosol microphysics and the coupling to both the vapor phase and cloud microphysics. Including these factors changes the magnitude, and sometimes even the sign, of the reported effects.

[98] Only a few model studies have focused on particular types of aerosol-cloud effects, and the influence of BC in those changes. Studies frequently lack consistent diagnostics and experimental designs for isolating effects of particular species or emission sectors, in particular regions, or of individual cloud impact mechanisms. Discerning which effects are reported is sometimes difficult; reported liquid-cloud forcing sometimes includes semi-direct responses and even a portion of direct forcing. This inconsistency causes a lack of comparability among model results that is frequently ignored when such reports are tabulated.

[99] Modeling of changes in mixed-phase clouds, ice clouds, and increased absorption in cloud droplets is a relatively new research area. A much smaller number of studies provide these estimates, compared with studies on liquid clouds. Aerosol microphysical effects on convective clouds are poorly known and generally not included in models. For cold ice clouds, GCM cloud schemes do not yet reconcile the physical treatments of fractional coverage, supersaturation and microphysics.

[100] With few exceptions, modeling of aerosol influence on clouds has been illustrative and has not addressed sensitivities nor constrained sensitive parameters with observations. Models agree that forcing usually increases as emissions increase, yet some studies do not even report the emission rates used, again making comparability difficult. Forcing may not be linear with regard to emissions or other inputs such as particle size, but sensitivity studies are not available to provide more constrained scaling for cases when modeled aerosol concentrations differ from observed values. Uncertainties estimated for cloud effects are obtained from model diversity rather than from true uncertainty propagation, as the latter has not been achieved with current models and scientific understanding.

[101] Multiple indirect effects exist and the combination of forcings may be nonlinear. Forcing inferred from satellite observations may include the combined response, but in-situ observations may be more likely to isolate individual effects. A constraining approach that combines the strengths of all approaches has not yet appeared.

[102] Because of sub-linearity in cloud response to increasing aerosol concentrations, the dependence of industrial-era forcing on assumed pre-industrial values is even greater for indirect effects than for direct effects. To determine the impacts of future aerosol changes and for comparison with temperature changes in recent years, examining changes from present-day conditions could provide a more reliable measure than comparison with a nominal pre-industrial condition [*Menon et al.*, 2002a].

Accepted Article

Accepted Article

7. Cryosphere changes: Black carbon in snow and ice

7.1. Section summary

[1]

1. Light-absorbing particles in snow can significantly reduce snow albedo. Because of the high albedo of snow, even aerosol with relatively high single-scatter albedo (*e.g.,* aerosol with a high OA:BC ratio) causes positive radiative forcing.

2. Small initial snow albedo reductions may have a large adjusted forcing because the resulting warming affects the snow morphology (grain size), snow sublimation rates, and snow melt rates, all of which enhance BC-induced snowpack albedo reductions, leading to an amplification of the radiative forcing. Albedo feedback triggered by this forcing drives a large surface temperature response (Section 8).

3. The best estimates for all-source and industrial-era adjusted forcing by BC in snow are +0.04 W m^{-2} and +0.035 W m^{-2}, respectively. The all-source estimate is derived by scaling the results of a suite of model studies to achieve consistent estimates of forcing from all present-day sources (fossil-fuel, biofuel and biomass burning). Measurements of the BC content of Arctic snow were also used to adjust two of the model studies' derived forcing for biases in snow BC concentrations. Industrial-era forcing is calculated by scaling by the ratio of industrial-era to all-source BC emissions, accounting for changes 1750 to present day in the fraction of global emissions from fossil-plus-bio-fuel and from open biomass burning which are deposited to snow. Changes in snow and ice cover 1750 to present day are not accounted for. These central estimates also do not account for forcing by BC in sea ice but do account for forcing by BC in snow on sea ice

4. The bounds for all-source snow BC adjusted forcing are estimated at +0.01 W m^{-2} to +0.09 W m^{-2} and for industrial-era forcing at +0.008 W m^{-2} and +0.078 W m^{-2}. These bounds include rapid adjustments in snow grain size and surface snow BC concentrations due to changes in sublimation and melt rates resulting from the initial snow albedo reduction due to BC. They are based on results of model sensitivity studies applying low and high values of snow cover fraction, rate of snow aging and resulting grain size evolution, scavenging of BC out of the snowpack during melt, and BC emissions, as well as a model estimate of the reduction in forcing by BC caused by the concurrent presence of light-absorbing soil dust. These bounds do not account for uncertainty in how forcing is affected by patchy snow cover, by uncertainties in modeled cloud cover and vegetation cover, or for possible biases in modeled mid-latitude snow BC concentrations.

5. The best estimate for all-source and industrial-era radiative forcings by BC in melting snow-free sea ice are +0.012 W m^{-2} and +0.011 W m^{-2}, respectively. These forcings do not account for rapid adjustments that may amplify the initial radiative forcing. They are derived using Arctic-wide averages for sea-ice BC concentration, sea-ice area, melt pond fraction, snow cover fraction, and solar irradiance. The bounds on sea-ice BC radiative forcing are +0.008 and +0.017 W m^{-2} for all-source forcing and +0.007 and +0.016 W m^{-2} for industrial-era forcing, based on independently calculating negative and positive deviations from the mean given by realistic possible minima and maxima in these factors.

6. Chemical analysis of springtime surface snow samples indicate that most BC and other light-absorbing particles in the North American and Russian Arctic snow and in Greenland are associated with biomass burning. Fossil fuel plays a prominent role in the high-latitude Arctic Ocean and in Greenland in the summertime, but in Greenland concentrations are low. Indirect evidence indicates that pollution may also play a significant role in the Arctic north of Europe, where concentrations are higher.

7. A large fraction of particulate light absorption in Arctic snow (about 30 to 50%) is due to non-BC constituents. Most of the absorption appears to be due to light-absorbing organic carbon from biofuel and agricultural or boreal forest burning. The

forcing estimates given above account for only BC. The total forcing by a source which emits both BC and light-absorbing organic carbon is larger than is given by BC forcing alone.

8. In some regions, especially areas with thin and patchy snow cover or mountainous regions, soil dust significantly lowers snow albedo, lessening the influence of BC. Models do not capture these potentially large sources of local dust to the snowpack and, therefore, may be overestimating BC forcing and this is not accounted for here.

9. There is evidence that snow BC concentrations in the Arctic, Europe and N. America were higher in the early and mid 20th century than presently. Also, snow cover is declining with time. Thus, snow BC forcing is likely decreasing in many regions.

10. BC in glacial snow is a concern primarily because of its possible role in altering melt cycles of glaciers in regions that rely on glacial melt to balance the water supply through the seasons. Forcing due to BC in snow in the Himalaya and Tibetan Plateau is significant in the limited model studies available to date, but there are indications these estimates are biased high due to overestimates in modeled snow BC concentrations and snow cover or by not accounting for the role of dust and soil in snow reducing snow albedo. The available measurements of glacial snow BC in this region show high spatial variability and a springtime maximum that coincides with a maximum in dust deposition to snow, emphasizing the need for accurate model representation of both BC and dust in snow.

7.2. Introduction

[2] Light-absorbing particles in snow can significantly reduce snow albedo and increase the amount of absorbed solar radiation because the albedo of pristine snow at visible wavelengths is high and because snow scatters visible radiation very efficiently, producing a large photon path length that amplifies the influence of impurities [Figure 7.1; *Warren and Wiscombe*, 1980b; *Warren*, 1982; *Chyilek et al.,* 1983b]. In contrast to atmospheric aerosol radiative forcing, which may be positive or negative depending on the underlying surface albedo and what species are co-emitted with BC, aerosols with a visible-band single-scatter albedo less than that of ice grains (about 0.9999+), which includes nearly all species except sulfate sea salt, exert a positive radiative forcing when incorporated into surface layers of optically thick pure snowpacks (Figure 7.2). Thus, even sources with a high OA:BC ratio produce a warming when deposited on snow exposed to sunlight.

[3] Critically, the large climate effects from BC in snow do not come from the initial change in snow albedo but from the rapid adjustments that follow (Figure 7.3). Increased solar heating with lower snow albedo affects the snow aging process, in general causing more rapid growth of the snow effective grain size through warmer snowpack temperatures. Coarse-grained snow has a lower albedo than fine-grained snow (*GRA* in Figure 7.3), and the reduction in albedo due to BC increases with grain size (*GRB* in Figure 7.3) (see also Figure 7 of *Warren and Wiscombe* [1980b] and Figure 7.1) so the accelerated aging caused by the warmer snowpack further reduces the snowpack albedo, again increasing the amount of absorbed sunlight. The *GRA* and *GRB* feedback processes lead to earlier melt onset. (A competing effect of BC in snow may be to reduce the snowpack temperature gradient, which could slow the rate of snow aging [*Flanner and Zender*, 2006], but this effect has not been studied in-depth). BC accumulates at the surface with snow sublimation, and sublimation may increase or decrease as surface air temperatures increase, depending on ambient humidity changes. This either enhances or decreases surface snow BC concentrations, albedo reduction and warming (*SBC* in Figure 7.3). When melt commences, some of the hydrophobic BC is left at the snow surface [*Conway et al.,* 1996; *Doherty et al.,* 2010, Figure 10], increasing surface snow BC concentrations, further lowering the snow albedo and accelerating melting [*Flanner et al.,* 2007; *MBC* in Figure 7.3]. Climate changes driven by reduced snow and ice albedo may affect atmospheric transport pathways and wet and dry deposition rates, in turn affecting snow BC concentrations, albedo, and climate forcing (see *DAC* in Figure 7.3). The magnitude and direction of the feedback is currently unknown. On the other hand, accelerated melting caused by BC in snow leads to earlier exposure of the underlying surface (vegetation, soil, sea ice, etc.), which has a dramatically lower albedo [about 0.2 for tundra or soil, *Bøggild et al.,* 2010; 0.3-0.6 for sea ice, *Perovich et al.,* 2002] than snow

Accepted Article

[about 0.8 for new snow; about 0.7 for melting snow; Figure 1 of *Warren and Wiscombe* [1985]] and thereby warms the surface and adjacent atmosphere, a process commonly known as the snow albedo feedback (*SAF* in Figure 7.3). The *SAF* feedback only occurs when melt of seasonal snow uncovers a land or ocean surface; the melting of snow on ice sheets (*e.g.,* on Greenland) or on mountain glaciers reveals an almost equally high albedo sub-layer so the strong albedo feedback is missing. The *SAF* feedback facilitates large temperature changes (Section 8) in response to the BC snow and ice forcings discussed here. BC-induced changes in snow cover occur on a weeks to months time-scale, but the climate system also has a longer-term (months to years) memory for snow cover [*e.g., Dery and Brown,* 2007]. Northern hemisphere albedo feedback is strongest in springtime when the combined effect of snow cover and insolation is maximum and the snowpack is at or near its melt point [*e.g., Hall and Qu,* 2006; *Flanner et al.,* 2011]. Melt onset and local albedo feedback vary with latitude and altitude, however, for example, occurring later in the year on parts of the Greenland plateau that experience melt and in high-elevation mountain areas.

[4] The rapid adjustments *GRB*, *MBC, SBC,* and *DAC* affect the concentrations of BC in the snow (*MBC* and *SBC*) or the change in albedo for a given BC concentration (*GRB*) and constitute 'rapid adjustments' to the initial radiative forcing, as defined in Section 1.3.2 and Table 1.1. Modeled radiative forcing is the net effect of the initial radiative forcing and these rapid adjustments, which together constitute what we have defined here as the adjusted forcing (Table 1.1). The rapid adjustments *GRA* and *SAF* affect the climate state itself (*i.e.,* the snow cover, *SAF*, and snow grain size, *GRA*), increasing the efficacy of the adjusted forcing. Together the adjusted forcing and high efficacy of that forcing produce an enhanced climate forcing – the effective forcing (see Section 9).

7.3. Modeled forcing

[5] *Warren and Wiscombe* [1985] and *Vogelmann et al.* [1988] originally highlighted the climatic importance of snow albedo reduction by pollutants by examining the potential impacts of a 'nuclear winter' scenario. At around the same time, measurements demonstrated that sufficient BC was already present in snow around the Arctic margin to affect climate [*Clarke and Noone,* 1985; *Warren and Wiscombe,* 1985, Figure 2]. In contrast, concentrations in Antarctica are too small to be climatically important [*Chýlek et al.,* 1987; *Warren and Clarke,* 1990; *Bisiaux et al.,* 2012]. The subject received little attention again until 2004, when *Hansen and Nazarenko* [2004] and *Jacobson* [2004] published model studies on climate forcing by changes to snow and ice albedos. *Hansen and Nazarenko* used the small number of BC-in-snow measurements available at the time to estimate the change in visible-wavelength (λ less than 770nm) snow albedo due to BC for the Arctic (2.5%), Greenland (1%) and other snow-covered areas in the northern hemisphere (5%). The authors imposed these snow albedo changes and then calculated the radiative forcing and climate response. Subsequent studies have either followed the model of *Hansen and Nazarenko* [2004] in applying regionally uniform snow albedo changes [*Wang et al.*, 2011]; have scaled albedo changes based on model-derived BC deposition rates [*Hansen et al.,* 2005, 2007; and *Shindell and Faluvegi,* 2009, which used as input the radiative forcing from *Hansen et al.*, 2005]; or have prognostically determined the concentrations of BC in snow [*Jacobson*, 2004; *Flanner et al.,* 2007; *Flanner et al.,* 2009; *Koch et al.,* 2009b; *Rypdal et al.,* 2009a; *Skeie et al.*, 2011], then calculated the change in snow albedo and finally the forcing and climate response. All of these studies (Table 7.1) indicate that BC in snow produces warming both in the Arctic and across the northern hemisphere and that the climate efficacy of BC in snow is about 2 to 4 times that of CO_2, so that BC in snow has larger climatic effects than its small direct radiative forcing would suggest.

[6] These studies have raised interest because they indicate that BC may be playing a significant role in two critical areas: the unexpectedly rapid warming of the Arctic and the retreat of mountain glaciers, particularly in areas such as the Himalaya which has high levels of pollution and where local populations rely heavily on a seasonally balanced hydrologic cycle with glacial melt as a water supply in summer [*Menon et al.,* 2010]. BC in snow may also have contributed to the marked decline in Eurasian springtime snow cover since 1979, which has not been reproduced by models that only account for warming due to GHGs [*Flanner et al.*,

Accepted Article

2009]. Accurately modeling these climatic effects requires, first, accurate representation of BC deposition fluxes (*i.e.,* the endpoint of emissions, transport, and deposition along the transport pathway), snow accumulation rates, meltwater scavenging of BC in the snowpack, and snow and sea-ice distributions and cloud cover. All of these vary from model to model. Second, climate forcing calculations must account for the feedback processes shown in Figure 7.3, not all of which are included in current studies (Table 7.2). Finally, the climate response to the radiative forcing and rapid adjustments must be accurately represented (Section 8, Climate Response).

[7] Interpretation across different model studies is complicated by the fact that they differ in terms of which feedbacks are included in each model (Figure 7.3 and Table 7.2) and in that different sources and types of light-absorbing aerosol are used in different models for the baseline and forcing scenarios. Adjusted forcing by BC in the cryosphere was calculated by *Jacobson* [2004] and *Flanner et al.* [2009] using as a baseline a snowpack that included light-absorbing soil dust, which lowers the initial albedo of the snowpack and, therefore, reduces the impact of adding other light-absorbing aerosol (Figure 7.4). None of the other studies in Table 7.2 included the impact of soil dust on snow BC radiative forcing. Some model studies calculated forcing due to fossil-fuel and biofuel (FF+BF) combustion emissions only [*Jacobson*, 2004; *Rypdal*, 2009a; *Skeie et al.*, 2011], but others calculated the effect of all sources: fossil-fuel, biofuel and biomass burning (FF+BF+BB; *Hansen and Nazarenko,* 2004; *Hansen et al.,* 2005, 2007; *Flanner et al.,* 2007, 2009; *Koch et al.,* 2009b]. Finally, while most studies have calculated the total forcing for a given (near present-day) year, *Hansen et al.* [2005, 2007], *Koch et al.* [2009b] and *Skeie et al.* [2011] focused on the change in forcing from pre-industrial to present, defined in these studies as 1880 to 2000, 1890 to 1995 and 1750 to 2000, respectively.

[8] Here the aim is to produce best estimates of the all-source and industrial-era adjusted forcing by BC in the cryosphere and to put uncertainty bounds on that estimate. Some of the sources of uncertainty in this estimate can be quantified using existing measurements and model studies, but for other critical factors the necessary studies do not yet exist to bound the uncertainty. Sections 7.3.1 to 7.3.6 discuss factors that affect snow BC radiative forcing and rapid adjustments that amplify that forcing. Existing measurements of snow BC concentrations are then used to calculate a best-guess estimate of all-source adjusted forcing for snow BC. Model sensitivity studies are used to estimate the possible range of this forcing, based on the uncertainties that can be bounded. Industrial-era forcing is calculated by scaling the all-source forcing by the ratio of industrial-era to all-source BC emissions.

7.3.1. BC concentrations in snow and sea ice and the resulting change in albedo

[9] Studies have used a range of values for present-day and pre-industrial emissions of BC (Table 7.1). Here we use observed snow and ice BC concentrations in the present day to account for biases in the net effects of modeled emissions, transport, wet and dry depositional processes, and post-depositional processes such as snow sublimation and melting. However, no such constraint can be placed on pre-industrial snow and ice concentrations so derived industrial-era forcing relies on quite uncertain estimates of pre-industrial emissions (Section 3) and on modeled BC atmospheric transport, BC deposition rates, snow and ice cover, and climate in 1750.

[10] The change in albedo for a given concentration of BC is a function of snow grain size and of the presence of other impurities, as well as of the effective mass absorption cross section of BC in snow. As with atmospheric BC, this cross section depends on BC mixing state with and the nature of other constituents in the BC-containing particles. In snow, it also depends on whether the BC is incorporated into the snow or on the surface of snow grains. *Warren* [1982] mentioned the possibility of a factor-of-two enhancement of absorption by situating BC particles inside snow grains, citing *Ackerman and Toon's* [1981] computation for BC inside sulfate aerosols. *Chyilek et al.* [1983b] then modeled this effect for snow, obtaining a factor-of-two enhancement. *Flanner et al.* [2007; 2009] obtain about a 50% enhancement for their assumptions of the mixing state.

Accepted Article

[11] All model studies considered here other than *Hansen and Nazarenko* [2004], *Hansen et al.* [2005; 2007], and *Wang et al.* [2011] determine deposition of BC to surface snow prognostically, accounting for time-dependent emissions, transport, in-atmosphere chemical processing and aging, and wet and dry deposition rates that depend on aerosol hygroscopicity or age. However, the treatment of atmospheric aerosol processes varies considerably from model to model. For example, *Jacobson* [2004] determines BC aging by solving coagulation, condensation, and dissolution among multiple, independent, aerosol size bins and resolves cloud-borne and interstitial BC within these bins, whereas other studies track BC in a single mode and assume fixed BC aging rates, internal mixing times, and in-cloud BC fractions [*e.g., Flanner et al,* 2007, 2009; *Koch et al.,* 2009]. The *DAC* feedback in Figure 7.3 depends on modeled climate changes due to cryosphere BC forcing, as well as how modeled transport and deposition rates depend, for example, on mixing with other constituents, cloud properties, and precipitation patterns. This feedback does not exist at all in models where albedo changes are prescribed. These factors result in differences in modeled deposition rates of BC to surface snow. Comparisons between modeled and measured surface snow concentrations are discussed in Section 7.4.

[12] Calculated albedo change for a given snow BC concentration is also handled differently across models. The *Jacobson* [2004] study explicitly calculates the changes in solar albedo of snow and snow thermal-IR emissivity as a function of zenith angle by solving radiative transfer through the atmosphere, snow and ice grains together, by adding a snow or ice layer to the bottom of the atmospheric layers, and solving for the upward divided by downward irradiance at the top of the snow layer. The calculation is done for both interstitial BC particles and BC inclusions within snow grains, treated with a core-shell approximation. *Jacobson et al.* [2004] found that the modeled effect of BC on emissivity is small, as also shown in Table 2 of *Warren* [1982]. Effects of BC on IR emissivity are disregarded in all other model studies. The *Flanner et al.* [2007; 2009] studies explicitly calculate the change in solar snow albedo by solving radiative transfer through multiple layers of snow, based on theory from *Warren and Wiscombe* [1980b] and the two-stream, multiple scattering radiative approximation of *Toon et al.* [1989]. The snow albedo is then added interactively at each time step as a bottom boundary condition to an atmospheric model that accounts for the effects of atmospheric optics (*e.g.,* aerosol, clouds, etc.) on downwelling solar radiation. They treat sulfate-coated and interstitial BC species with coated BC absorbing about 50% more solar radiation per mass of BC. *Koch et al.* [2009b] parameterizes the change in albedo based on the study of *Warren and Wiscombe* [1985], which treated the BC as being externally mixed with the snow and accounts for absorption enhancement through multiple scattering in the snow. This parameterization provides a spectrally averaged change in albedo, with dependence on snow grain size and BC concentration, but it ignores the zenith-angle and atmospheric optical dependence of the albedo. *Rypdal et al.* [2009a] and *Skeie et al.* [2011] use look-up tables of albedo based on snow grain size and BC concentration; these tables are based on Mie theory and radiative transfer calculations. Radiative transfer calculations are done with a multi-stream model using the discrete ordinate method [*Stamnes et al.*, 1988], where two snow layers have been added below their atmospheric layers. *Hansen and Nazarenko* [2004], *Hansen et al.* [2005; 2007], and *Wang et al.* [2011] impose albedo changes so there is no dependence on BC concentration or other factors.

[13] As with snow, BC concentrations in bare (non snow-covered) sea ice similarly depend on the amount of BC wet and dry deposition to the surface. However, because sea ice is usually snow-covered in the winter to spring season, the BC concentrations in multi-year summer ice are likely a strong function of how much BC resides in the winter and spring snowpack and on how much is retained in the sea ice during melting. A few measurements of sea-ice BC concentrations are available to test models; they indicate that BC in sea ice is comparable to that in snow from the same region [*Doherty et al.,* 2010].

[14] A given concentration of BC produces a larger change in albedo in sea ice than in snow, because the surface of sea ice behaves as large-grained snow. However, sea ice also can contain significant amounts of other light-absorbing impurities, such as sediment, which as discussed below may significantly decrease the forcing by BC. Only three studies in Table 7.1 include radiative forcing by BC in sea ice: *Jacobson* [2004], *Rypdal et al.* [2009a] and *Skeie et al.* [2011]. This may explain, in part, the relatively

Accepted Article

large forcing per emission of *Jacobson* [2004]. However, forcing by BC in snow on sea ice and by BC in sea ice were not separately diagnosed so it is not possible to know how large a role these forcings played in either study. Below independent estimates are made for forcing by BC in sea ice and its possible upper and lower bounds.

7.3.2. Snow-covered area

[15] Climate forcing by BC in snow is a direct function of the amount of land or ice area covered by snow, so seasonal and sub-gridscale variations in snow cover must be accurately represented. Models allow for fractional snow cover within model gridboxes by employing snow depth dependent parameterizations. The adjusted forcings calculated by *Flanner et al.* [2007] for low and high cases of snow cover are used here to help bound uncertainty in forcing due to errors in fraction of snow covered area.

[16] The allowance for fractional snow coverage within a gridbox might not, however, account for very small-scale snow patchiness, which occurs particularly in areas with low snowfall amounts or broken up sea ice. Melt rates are higher in patchy snow than in uniform snowpacks, and melt rates increase with degree of snow patchiness and exposed area [*Liston,* 1995, 1999, 2004; *Essery,* 1997]. Accounting for this patchiness is expected to have two competing effects: Patchy snow warms and starts to melt more quickly due to local heat advection, and when the snowpack is close to its melt point, the feedbacks enhance the effect of the initial direct forcing most powerfully. On the other hand, patchy snow on land is more likely to be loaded with local soil dust, thereby lowering the 'baseline' snowpack albedo and decreasing the impact of BC (Figure 7.4). It is not known if accurately accounting for these two effects would produce a larger or a smaller radiative effect by BC in snow, so this is an unbounded uncertainty.

7.3.3. Masking by clouds and vegetation

[17] The planetary albedo of cloud-covered areas is relatively insensitive to surface albedo, so cloud cover must be accurately represented. Similarly, BC in snow masked by vegetation contributes little to ToA forcing, so vegetative cover must be accurately represented. Both cloud cover and vegetation are sub-gridscale features, complicating their representation in models. Model representation of and forcing sensitivity to realistic ranges of cloud cover and vegetation have not been tested, and this is currently an unbounded uncertainty in cryosphere BC adjusted forcing.

7.3.4. Snow grain size

[18] As noted above, snow albedo is highly sensitive to snow grain size. Further, the change in albedo for a given snow BC concentration is greater in larger grained snow than in smaller grained snow (Figure 7.1). Thus, the snowpack BC concentration and snow-grain size must be well constrained down to the penetration depth of sunlight (about 30 cm for a typical snow density of 0.3 g cm^{-3}; *Warren and Wiscombe* [1980a], Figure 13c). 'Grain size' must also be defined consistently: in field measurements, reported values are optical grain sizes, which are proportional to the volume-to-area ratio [*e.g., Grenfell et al.,* 2005] and inversely proportional to the 'specific surface area' (*e.g.*, *Matzl and Schneebeli* [2006]). *Jacobson* [2004] and *Rypdal et al.* [2009a] and *Skeie et al.* [2011] use globally fixed snow-grain radii in their models of 150, 500 and 500 μm, respectively. Grain radii for new snow are less than 150μm, and for old, melting snow they are larger than 500 μm, so the feedbacks that involve grain size (*GRA, GRB* in Figure 7.3) are not captured. The net effect of applying a fixed snow grain size is not known. However, *Flanner et al.* [2007] used a model to determine how a reasonable range in snow aging rate (*i.e.*, the rate of grain size growth) affects the derived annual mean adjusted forcing. These results are used to help bound the possible range of forcings by BC in snow.

7.3.5. Albedo dependence on downwelling radiation

[19] In addition to being a function of snowpack properties, both pure and contaminated snow albedo depend on solar zenith angle and the fraction of direct versus diffuse solar radiation. Models that prescribe solar-zenith-angle-independent albedos may have a bias in clear-sky albedo of several percent for pristine snow [Figure 6 of *Wiscombe and Warren*, 1980], which is of the same

Accepted Article

magnitude as the albedo perturbation by BC. Direct and diffuse solar radiation must also be accurately represented, in turn requiring accurate representation of cloud cover.

7.3.6. Concentration of BC with sublimation and melting

[20] Precipitation rates and relative humidity in much of the Arctic are low, so in some areas appreciable (up to 30-50% [*Liston and Sturm*, 2004]) surface snow is lost to sublimation. This process removes snow water but leaves BC and other non-volatile particulate constituents at the snow surface, increasing their concentration. Similarly, variable fractions of BC are left behind at the snow surface with melt, depending on the hygroscopicity of accompanying constituents [*Conway et al.,* 1996]. *Flanner et al.* [2009] apply a 'scavenging efficiency' for BC with melt of 0.2 for hydrophilic BC and 0.03 for hydrophobic BC, based on the *Conway et al.* [1996] study. *Rypdal et al.* [2009a] and *Skeie et al.* [2011] leave all BC at the snow surface as the snow melts, and all other models cited here allow all BC to be washed away with snow melt water. While there is some observational evidence of BC remaining at the surface during melt [*Conway et al.,* 1996; *Xu et al.,* 2006; *Doherty et al.,* 2010], an appropriate BC scavenging ratio remains to be determined. A model sensitivity study which applies a range of melt scavenging efficiencies is used to help bound this source of uncertainty.

7.3.7. Representation of all light absorbing particles in snow

[21] Particulate matter in snow is never pure BC. BC from biomass, biofuel and fossil-fuel burning is accompanied by varying amounts of brown organic carbon. Other sources also produce light-absorbing carbon [*Andreae and Gelencsér,* 2006] and light-absorbing crustal material (*e.g.,* hematite in soil dust). Calculation of BC effects on snow and ice albedo and melt rates must consider *all* light-absorbing constituents in the snow. Glacial snow especially often has high concentrations of locally sourced soil dust and sand that significantly reduce its albedo. While the *Jacobson* [2004] and *Flanner et al.* [2009] studies included soil dust in snow in their baseline calculations, these models don't account for very local sources of coarse-grained (*i.e.,* much greater than 10-μm diameter) dust and sand, which have a very short atmospheric lifetime (*i.e,* less than a few days). Particularly in areas with patchy snow cover, local soil and sand may be present in the snow at high concentrations. This observation was made along the Arctic coast of Siberia (S. Warren and T. Grenfell, personal communication), in Inner Mongolia [*Huang et al.,* 2011] and on summertime Arctic sea ice (B. Light and T. Grenfell, personal communication) during snow and ice sampling surveys. The bias this introduces to modeled forcing cannot currently be bounded. However, the *Flanner et al.* [2009] model can be used to help constrain the impact of including dust deposition to snow. In this model, when dust is included the snow BC radiative forcing is decreased by about 25% for the global mean dust burden of 4.3 ppm calculated in the model. This result is consistent with Figure 7.4, which shows a snow albedo reduction of about 0.006 for a pristine snowpack with 20 ng g^{-1} of BC and an albedo reduction of about 0.005 for a snowpack with 4000 ng g^{-1} of dust and 20 ng g^{-1} of BC. These results indicate that the albedo reduction due to BC is 20% less in the presence of dust.

[22] Importantly, most studies that have measured [*Xu et al.,* 2006; *Ming et al.,* 2009] or estimated [*Yasunari et al.,* 2010; *Castelvecchi,* 2009] BC concentrations for Himalayan glaciers have estimated a significant radiative forcing, but this was by comparing clean (dust- and algae- free) snow to clean snow with BC added. In the spring season when the glacier snow starts to melt and when BC may have its maximum impact, it is also late in the dry season, with minimal precipitation and large dust events over the Tibetan Plateau and across the Himalaya [*Ming et al*., 2009; *Marinoni et al.*, 2010]. In addition to being exposed to dust from Central Asia and the Middle East, the south side of the Himalaya can experience significant dust loading from sources in northern India [*Marinoni et al.,* 2010]. Similarly, dust storms from the Sahara can account for a significant fraction of the impurities in Alpine snow [*Thevenon et al.,* 2009; *Haeberli,* 1977], and dust from the Colorado Plateau drives a very large radiative forcing of snowpack in the San Juan Mountains [*Painter et al.,* 2007]. The lower parts of many Himalayan glaciers are entirely hidden by thick debris cover [*Nakawo et al.,* 2000], actually inhibiting melt. Future studies must account for the effects of crustal

Accepted Article

and other light-absorbing material [*e.g.,* algae; *Jones et al.,* 2001] in mountain glaciers when determining the effects of BC on snow melt.

[23] Measurements from across the Arctic indicate that typically 30 to 50% of sunlight absorbed in the snowpack by impurities is due to constituents other than BC [*Doherty et al.,* 2010]. Either organic matter or soil dust could be responsible, and the spectral absorption measurements can not distinguish them, but chemical analysis of a geographically diverse subset of these Arctic samples indicates that the non-BC light absorbing particulate matter is overwhelmingly light-absorbing OC, not mineral dust [*Hegg et al.,* 2010]. These samples were collected specifically trying to avoid snow that obviously contained significant amounts of soil, dust, or sand, so they may somewhat underrepresent the role of these particles in snow. Regardless, these measurements make it clear that particles other than BC play a significant role in changing snow albedo. While *Flanner et al.* [2007; 2009] did not include snow OC light absorption in their published forcing calculations, they did test for the effect of OC on snow albedo and found it to be sufficiently small that omitting it would not significantly change their results. If organic matter is in fact a significant source of light absorption in snow, the forcing by sources high in OC (*i.e.,* BF and BB) would be larger because of the addition of light-absorbing OC. However, if biomass burning and soil dust emissions are considered a 'natural' source of aerosol, this would mean the natural snowpack has a lower albedo, thus lessening the effect of mitigating anthropogenic sources. On the other hand, mitigating biofuel-burning emissions or any burning which produces light-absorbing OC, or decreasing soil dust emissions would have a larger impact than would be implied by only considering the effect of BC.

[24] These results highlight the importance of determining not only the concentration of snow BC but also light-absorbing OC and soil dust in snow. In addition, while the wavelength dependence of absorption of BC has been studied and is relatively well-constrained to follow λ^{-1}, the wavelength dependence of absorption (or, equivalently, the size distribution and spectrally resolved indices of refraction) for light-absorbing organics and soil dust appear to be quite variable [*e.g., Bond,* 2001; *Kirchstetter et al.,* 2004; *Bergstrom et al.,* 2007; *Sun et al.,* 2007; *Russell et al.,* 2010], making estimates of the impact of OC and dust on light absorption in snow highly uncertain.

7.4. Measurements of BC in snow and comparison with models

[25] As shown in Table 7.1, model studies to date have used a range of assumptions about the sources and quantity of BC emissions. Similarly, atmospheric transport processes differ from model to model, as do deposition rates. For example for the suite in Table 7.1, the fraction of BC deposited to surface snow by wet (versus dry) deposition ranges from 71% [*Koch et al.,* 2009b] to 98% [*Jacobson*, 2004]. Measurements of snow BC concentrations can be used to test models for the combined influence of all of these factors. Data are available from the Arctic and sub-Arctic, a few mid-latitude locations in the northern hemisphere and the Antarctic. Here we limit model/measurement comparisons to northern hemisphere sites, because concentrations in Antarctic are too small (*i.e.,* generally less than 1 ng g^{-1}; *Chýlek et al.,* 1987; *Warren and Clarke,* 1990; *Bisiaux et al.*, 2012) to be important for forcing evaluations.

7.4.1. Measurement methods

[26] BC concentrations in snow have been measured using variations of the thermo-optical method [*Chýlek et al.,* 1987; *Cachier and Pertuisot,* 1994; *Lavanchy et al.,* 1999; *Xu et al.,* 2006; *Jenk et al.,* 2006; *Hagler et al.,* 2007a,b; *Legrand et al.,* 2007; *Ming et al.,* 2008; *Forsström et al.,* 2009; *Ming et al.,* 2009; *Thevenon et al.,* 2009; *Xu et al.,* 2009a,b; *Hadley et al.,* 2010] and with an SP2 instrument [*McConnell et al.,* 2007; *McConnell and Edwards,* 2008], both of which are described in Section 2.5. They have also been measured using a third, filter-based method that optically analyzes BC concentrations, used first by *Clarke and Noone* [1985] in the form of the IP Spectrophotometer and later with an improved instrument, the ISSW Spectrophotometer [*Grenfell et al.,* 2011; *Doherty et al.,* 2010]. Using the wavelength-dependence of the measured light absorption on the filter it is possible, assuming known BC MAC, to calculate the maximum possible BC concentration, an estimated BC concentration, and the fraction of absorbed

Accepted Article

solar radiation (integrated 300-750nm) that is due to species other than BC, such as light-absorbing organic carbon and crustal material [*Grenfell et al.,* 2011; *Doherty et al.,* 2010]. Here, modeled values are compared with BC concentrations from the IP and ISSW spectrophotometers, thermo-optical measurements and from the SP2.

7.4.2. Arctic and sub-Arctic snow

[27] Table 7.3 gives measured concentrations of BC in surface snow for various regions of the Arctic. Because the snow albedo feedback is greatest in spring, most of these measurements were of surface snow in March, April or early May; all are from snow that has not yet experienced melting (and therefore the feedback *MBC* in Figure 7.3) but which may have experienced sublimation (feedback *SBC* in Figure 7.3). These are compared to average surface snow (top 2 cm) concentrations from the *Flanner et al.* [2009] study and to the concentration of BC deposited in snow (via both wet and dry deposition) in the *Koch et al.* [2009b] study. Model average values were calculated using the modeled concentrations from the same month and location (gridbox) as the measurements. In addition, *Skeie et al.* [2011] include a comparison of their modeled snow BC concentrations with measured values reported by *Forsström et al.* [2009] and *Doherty et al.* [2010] for Arctic and sub-Arctic regions. These comparisons are imperfect but allow a first-order check of how well the models are representing BC deposition to the snowpack. The concentrations shown in Table 7.3 produce a change in snow albedo of less than 5%, which would not be visible to the human eye. In common images of snow visibly darkened by light-absorbing impurities, the impurities are often sand and soil, not BC.

[28] The comparison herein has been limited to two of the six studies which calculated snow BC concentrations (*Flanner et al.*, 2009 and *Koch et al.*, 2009b; Table 7.2) for which modeled snow BC is readily available, and to discussion of the *Skeie et al.* [2011] model and observation comparison. For reference, total, present-day BC emissions from *Flanner et al.* [2009] (7400 Gg yr^{-1}) and *Koch et al.* [2009b] (8200 Gg yr^{-1}) are between the central bottom-up all-source estimate of 7300 Gg yr^{-1} (Section 3) and the all-source emissions (10100 Gg yr^{-1}) based on a comparison of modeled and measured AAOD (Section 5). The *Hansen et al.* [2005] total present-day BC emissions (11000 Gg yr^{-1}) are larger than either of these estimates. *Jacobson et al.* [2004] total BC emissions are within 5% of the total emissions of *Flanner et al.* [2009], though there is a higher fraction of BB emissions in *Jacobson et al.* than in *Flanner et al.* (44% vs. 35%), and BB emissions are less likely to be deposited to snow [*Flanner et al.,* 2009; *Skeie et al.,* 2011]. The *Rypdal et al.* [2009a] FF+BF emissions are 13% and 18% higher, respectively, than those in *Flanner et al.* [2009] and *Koch et al.* [2009b] studies; *Rypdal et al.* [2009a] did not include BB emissions in their analysis. The *Flanner et al.* [2009] study was specifically run for a representative biomass-burning year and so is a better comparison to measurements than the *Flanner et al.* [2007] study, which explored two extreme (high and low) BB years. Differences in transport and deposition rates also affect the concentration of BC in snow, but this comparison still provides a first-order test of the models. Broad patterns in the observed spatial variability of snow BC concentrations are qualitatively consistent with the model results. Both have higher concentrations of BC in snow over northwestern Russia, Europe and Scandinavia than across the western Arctic and Greenland. However, there are important quantitative differences.

[29] The *Koch et al.* [2009b] modeled values are in agreement with the measured values for Arctic Canada and northern Russia, are biased high in the Arctic Ocean, and are biased low compared to the measurements in all regions other than Greenland, where they are about a factor of two too high. In contrast, the *Flanner et al.* [2009] model values are somewhat lower than the measured values for northern Russia, Barrow, and sub-Arctic Canada but are higher than the measured values at all other sites. The differences are particularly profound for the Scandinavian sites, where they are 1.6 to 3.4 times the measured concentrations. Notably, these sites also have the highest concentrations and so carry more weight than the other sites at similar latitudes in terms of global radiative forcing. For Greenland, values are shown for both spring (April) and summer (July to August). Only about 25% of the Greenland Ice Sheet is in the 'dry snow zone'; everywhere else some melting occurs during summer. There is a striking increase in Greenland values in the *Flanner et al.* model when moving from spring to summer that is also present in the measurements, but

Accepted Article

not as pronounced (Table 7.3). Based on the timing and spatial pattern of the increase it appears to be caused by the concentration of BC at the surface with melt, indicating that the *MBC* feedback (Figure 7.3) may be too strong in *Flanner et al.* [2009] study. The timing and extent of melt is clearly critical in this process and needs to be validated against observations; the limited data presented here are insufficient. Furthermore, improved model treatment may be needed for particle accumulation in perennial snow and ice-sheets, where (in the absence of glacier dynamics) snow either accumulates year after year or is 'capped.'

[30] *Skeie et al.* [2011] prognostically determined snow BC concentrations from all sources (FF+BF+BB) and compared these to measured concentrations. Their forcing was calculated for the FF+BF sources only, but biomass burning only accounted for 4 to 12% of BC in snow north of 65°N. Their comparison with the *Forsström et al.* [2009] measurements indicates that the modeled snow BC concentrations for 2001 to 2008 vary over about the same range as the measured concentrations in 2007 in Ny Ålesund, Svalbard. However, *Doherty et al.* [2010] find concentrations in this region that are about a factor of two higher than that measured by *Forsström et al.* The *Skeie et al.* modeled concentrations are much lower than is observed by *Forsström et al.* at the Scandinavian sites Pallas, Tromso and Abisko, sometimes by more than a factor of four and typically by a factor of two. The exception is in the later spring when the snow starts to melt and in the model all BC consolidates at the snow surface. At this time, modeled surface snow BC concentrations increase by approximately 10-fold. The comparison with the geographically broader snow BC data set of *Doherty et al.* [2010] only includes snow samples that had not yet experienced springtime melt. This comparison shows reasonable agreement for the Canadian and Alaskan Arctic and for Greenland, it indicates a low bias in the model over the Arctic Ocean, and it shows large model underestimates for the Canadian sub-Arctic, across Russia and in Svalbard. Model underestimates vary from about a factor of two (Svalbard) up to a factor of five (Eastern Russia). Notably, this is the region where BC concentrations (and, thus, forcing) are expected to be largest.

7.4.3. Mid-latitude snow measurements

[31] Few measurements of mid-latitude snow exist, despite the fact that the climate impacts of BC in snow at these latitudes may be larger than for Arctic snow because of the combination of higher BC concentrations and higher insolation. *Flanner et al.* [2007] include a comparison of their modeled values for 1998 and 2001 to those measured in the 1980's and 1990's at select mid-latitude sites in North America and Europe (see their Table 2). Modeled concentrations at some sites are about one third to one half the measured values (rural and urban Michigan, USA, and in Lithuania). At other sites they are about equal to the measured values (Cascade mountains in Washington State in the USA and the French Alps in Europe) or are higher by factors of about 1.5 to 7.7 (West Texas and New Mexico in the USA and Halifax, Nova Scotia, in Canada). *Hadley et al.* [2010] measured snow BC concentrations at three remote sites in Northern California and found they were a factor of two to four lower than predicted by *Flanner et al.* [2007] and *Qian* [2009]. The sparseness of these data and the mismatch between the years modeled versus the time of the measurements makes it difficult to draw conclusions.

[32] A snow survey described by *Huang et al.* [2011] provides the possibility of a more robust comparison of mid-latitude snow concentrations. Huang and colleagues sampled snow across north China, reporting concentrations, for example, in northeast China of 600 ± 300 ng g^{-1} at latitudes of 41 to 46°N that decreased to about 40 ng g^{-1} at more northerly latitudes (51°N). These values are based on visual estimates of filter samples; estimates for samples from central and western China were not provided.

[33] No other geographically broad data set exists of mid-latitude snow BC concentrations, so it is not possible at this time to bound how well models represent mid-latitude snow BC albedo reductions.

7.4.4. BC in mountain glaciers

[34] BC in mountain snow and glaciers is of concern primarily because of the potential for affecting melt rates and, therefore, the seasonality of trends in water supplies. The effect of BC in glacial snow differs from BC's effect on seasonal snow because in the former melting does not lead to exposure of the underlying Earth surface, except perhaps at the very margins of the glacier which

Accepted Article

are anyhow often loaded with light-absorbing soil dust. Thus, the powerful albedo feedback present for seasonal snow (SAF in Figure 7.3) is absent. On longer time-scales, if BC leads to glacial retreat, a positive albedo feedback would likely accelerate warming and melt near the glacial terminus.

[35] Few measurements exist of BC in mountain glaciers, and in most cases they do not permit separation of the role of local versus remote sources, nor are they accompanied by coincident measurements of other light-absorbing impurities. Using a global model to determine snowfall and aerosol deposition to glaciers is particularly difficult because of their small size relative to a model gridbox (Table 7.1), allowing for only one BC concentration per gridbox, regardless of, for example, the dramatic altitude variations in mountainous regions. As discussed above, forcing by BC in snow also depends on accurate representation of snow and glacier cover. The coarse resolution of most models makes this representation quite difficult in mountainous areas and in areas with sparse snow cover, such as the Tibetan Plateau (*e.g.,* Figure 2 of *Qian et al.*, 2011).

[36] Ice cores from the European Alps provide historical time series but don't reach present-day and are reflective of glacial ice concentrations, not snow concentrations. Nonetheless, they provide information on the trends in BC deposition to the European Alps and some indication of near-present-day levels. *Jenk et al.* [2006] found a 1900-1940 average BC concentration of 31 ng g^{-1} (range: 9 to 22 ng g^{-1}); *Thevonon et al.* [2009] found a 1950-1980 average of about 20 ng g^{-1}; and *Legrand et al.* [2007] reported concentrations for 1960-1990 of about 10 to 17 ng g^{-1}, with the peak concentrations around 1960 and a decline thereafter. These studies also indicate a shift in the dominant source of BC from biomass burning in the 19th century to coal and later to non-coal fossil fuel. Modeled snow concentrations for present day from *Flanner et al.* [2009] gridboxes corresponding to the measurement sites in these studies range from approximately 115 to 160 ng g^{-1} in January through March, then decline to about 10 to 50 ng g^{-1} in April. Summertime (May-August) concentrations are zero, because all surface snow is assumed to have melted and BC in the glacier itself is not accounted for. In contrast, BC in the deposited snow in the *Koch et al.* [2009b] model increases from about 20 to 25 ng g^{-1} in January to about 50 ng g^{-1} by early summer, much more in line with the measured concentrations in mid-20th century glacial ice.

[37] Analysis by *Xu et al.* [2006], *Xu et al.* [2009a,b] and *Ming et al.* [2009] of surface snow samples taken June-October in the Himalaya and in the Tibetan Plateau region yield typical concentrations of BC in surface snow of about 10 to 40 ng g^{-1}. Excluding samples collected from a site where the surrounding rock is rich in coal, the highest average surface snow concentration was 107 ng g^{-1} and the lowest less than 1 ng g^{-1}. However, samples from deeper in the glacial snow [*Xu et al.*, 2006; *Ming et al.*, 2009] and glacier cores [*Xu et al.*, 2009a,b] show that BC concentrations are a factor of about 3 to 6 higher outside the summer monsoon (October-May) than during the monsoon (June-September). BC concentrations are highest when snow cover is also highest (October-May), but the concentration maximum also corresponds to a maximum in dust deposition in this region [*Ming et al.*, 2009], so the impact of the BC on snow albedo is moderated. The only measurements from the south side of the Himalaya were from the East Rongbuk glacier on Mt. Everest, with concentrations of about 10 to 20 ng g^{-1} [*Xu et al.*, 2009b; *Ming et al.*, 2009].

[38] Snow samples in these studies were from summer and early fall, but in the model study of *Flanner et al.* [2009] almost all gridboxes corresponding to the sample sites are snow free from May through September. However, a qualitative comparison is possible of monthly averaged model snow BC concentrations from October-April for the gridboxes corresponding to the sample sites. Concentrations in the *Flanner et al.* [2009] model study decrease with latitude across the plateau, with the lowest concentrations corresponding to the measurements sites in northwest China. In contrast, this was where some of the higher concentrations were found in the measurements. Concentrations also are a strong function of season, increasing from about 20 to 30 ng g^{-1} in September (where there is snow) to a high of 70 to 500 ng g^{-1} (median 250 ng g^{-1}) in February. Concentrations remain high in March, but drop by about a third in April and by May are back to about 10 to 40 ng g^{-1}. Thus, both the measurements and the models show maximum concentrations in the spring, but the concentrations in the model are notably higher than in the

Accepted Article

measurements. The *Koch et al.* [2009b] modeled median concentrations are lower (January-May monthly median across sample sites of 30 to 45 ng g^{-1}), they don't exhibit a systematic latitudinal dependence, and they show only a moderate seasonal dependence, peaking in March-April. Thus, they are in better general agreement with the median measured concentrations but perhaps miss strong peaks in springtime BC concentrations seen in some of the measurements. *Kopacz et al.* [2011] compare their modeled snow BC concentrations with this same measurement data set and find both over- and under-estimates at individual sites but no overall systematic bias in the modeled values.

7.4.5. Trends in Arctic snow BC

[39] While most model studies (*e.g.,* as given in Table 7.1) have focused primarily on the role of BC in recent warming trends, anthropogenic emissions of BC in some regions were much higher in the past and are declining, while in others they are rapidly increasing above historical levels. A small number of ice core records of BC are available to test models' historical representation of BC trends, and atmospheric BC trends for the Arctic can be used as an indicator of likely trends of BC deposition to snow in this region, though atmospheric and snow concentrations are not directly related.

[40] Near-surface atmospheric measurements since 1989 at Alert, Ellesmere Island [82°30′N 62°19′W; *Sharma et al.*, 2006a; *Gong et al.*, 2010], and since 1998 at Ny Ålesund, Svalbard, Norway [78°55′N 11°56′E; *Hicks and Isaksson*, 2006; *Eleftheriadis et al.*, 2009; *Forsström et al.,* 2009] show that Arctic atmospheric BC concentrations have been declining in recent decades. Measurements starting in 1989 at Barrow, Alaska [71°19′N 156°37′W; *Sharma et al.*, 2006b] show moderate declines in atmospheric BC up to 2003, then a possible slight increase from 2003-2006. *Hirdman et al.* [2010a] argue that only a fraction of these trends is driven by changes in transport and that most of the observed trends are attributable to emissions changes in source regions, especially northern Eurasia.

[41] Ice cores from the Greenland plateau provide insight to longer-term Arctic trends. The Greenland cores reflect free-troposphere concentrations of BC and are most strongly influenced by fires and anthropogenic activity in North America [*McConnell et al.,* 2007]. These records indicate that Greenland snow, preceding any human activity, had BC concentrations of about 1.1 to 2.5 ng g^{-1} [*i.e.,* 4-6,000 ybp; *Chýlek et al.,* 1987], or about half the concentrations for the past few decades (1 to 4 ng g^{-1}) [*Cachier and Pertuisot,* 1994; *Chýlek et al.,* 1995; Table 7.3]. Ice core analyses by *McConnell et al.* [2007] and *McConnell and Edwards* [2008] that span the industrial era show that from 1788 to about 1850 Greenland had relatively low concentrations (about 2 ng g^{-1}) of BC associated with biomass or biofuel burning and then a rise occurred to an average of about 10 ng g^{-1} (D4 core) or about 20 ng g^{-1} (ACT2 core), peaking around 1910. After this, BC concentrations declined steadily through the 1940s, finally dropping sharply in 1952 to nearly pre-1850 values. This post-1850 peak in BC was associated with coal burning, with the decline in BC in the mid-1900's associated with air pollution controls, improved combustion and a fuel shift from coal to oil and gas. An ice core on Mt. Logan in the St. Elias range, Yukon, Canada [*Holdsworth et al.,* 1996], shows a similar BC increase starting in the mid-1800's, though these data only extend to about 1950 so it is not possible to determine if there was a subsequent decline. An ice core from the St. Elias range is being analyzed and may help elucidate century-timescale trends on that side of the Arctic (J. McConnell, personal communication).

[42] Notably, the early 20th century peak in BC in the Greenland ice core (about 1890-1950) leads by about 20 years a period of strong positive regional surface-air temperature anomalies from 1920 to 1965 [*e.g.,* see Figure 2 of *Polyakov et al.* [2002]; Figure 3 of *Shindell and Faluvegi* [2009]]. It is expected that the full climate response to a forcing lags the imposed forcing, because of the ocean's heat capacity, for example, so this does not necessarily negate the possibility that the high BC concentrations led to the observed warming. This warming has generally been attributed to solar and natural variability. However *Shindell and Faluvegi* [2009] point out that, in their model, only about half of the early 20th century Arctic (60° to 90°N) temperature rise can be attributed to the combined effects of GHGs, natural forcings and tropospheric O_3. Natural variability is unable to account for the remainder in

Accepted Article

most models, implying that a portion of the warming should be interpreted as due to aerosol climate forcing. In a model study of historic aerosol impacts on climate, *Koch et al.* [2011b] calculate a maximum in BC deposition to Arctic snow around 1950 and a peak BC radiative forcing between 1940 and 1970, with declines since then. The peak in radiative forcing correlates well with the Greenland trends of *McConnell et al.* [2007]. *Skeie et al.* [2011] modeled trends in snow BC radiative forcing by fossil-fuel and biofuel sources, reporting forcing relative to year 1750 in the year 1850 and then once per decade from 1900 to 2000. Forcing relative to 1750 is about 0.005 Wm^{-2} in 1850, more than doubles between 1850 and 1900 to about 0.013 Wm^{-2} and increases steadily from 1900 to 1960 to about 0.019 W m^{-2}. After this, forcing varies by about 0.03 W m^{-2} with no apparent trend from 1960 to 2000 [*Skeie et al.,* 2011, Figure 16b]. Thus, this study does not show a forcing peak in the mid-1900's, but it does indicate that snow BC forcing has not appreciably increased since 1960.

[43] In summary, both observations and model studies indicate that BC may in fact have played a significant role in the observed early 20th century Arctic warming. Further, radiative forcing by BC in Arctic snow likely has not increased since the mid-1900's and may instead be declining.

7.4.6. Trends in mountain snow

[44] Several ice core studies from the European Alps provide insight into trends and sources of BC in snow through the industrial era. These data show two features: first, a sharp increase in BC starting in the late 19th century and, second, a transition to fossil fuel as a significant source of BC. At the three locations studied, concentrations increased from the turn of the century to 1940-1950, with peak concentrations of about 15 to 25 ng g^{-1} [*Jenk et al.,* 2006; *Legrand et al.,* 2007; *Thevenon et al.,* 2009]. Only two of the three records extend past 1940 with one showing a slight increasing trend and the other showing a declining trend. These differences may be due to differences in exposure to local pollution sources.

[45] Trends in BC deposition to the Himalaya or Tibetan regions have been measured using ice cores from Mt. Everest [*Ming et al.,* 2008; *Xu et al.,* 2009b] and at four other sites on the Tibetan Plateau [*Xu et al.,* 2009b] using the thermal-optical method, with records extending about 1952-2004. These records show a great deal of spatial and temporal variability in concentrations, reflecting the variations in source regions and meteorology. Values typically average about 10-40 ng g^{-1}. However, some commonalities are apparent: all but the easternmost site show elevated concentrations from about 1950 (the earliest part of the record) to the early to mid-1970s, which *Xu et al*. attribute to eastern European sources. Concentrations then remain somewhat lower up until about 1990-1995, after which concentrations at most sites indicate increasing but variable concentrations. Thus, unlike the Arctic, it appears that BC radiative forcing may be increasing in the Himalaya.

7.5. Sources of BC to Arctic and Himalayan snow

[46] Currently, there are few sources of pollution within the Arctic itself so almost all BC is transported there from the mid-latitudes. In the winter and spring seasons, when BC deposition to snow is most climatically important, a 'dome' of cold air over the Arctic makes it difficult for air from lower latitudes to enter the Arctic troposphere. Typically, the front formed by this dome reaches to lower latitudes on the Eurasian side of the Arctic than on the North American side, making it easier for Eurasian sources to influence the Arctic troposphere [*Stohl*, 2006]. In order for air masses to cross the Arctic front, they must originate in cold, dry locations and, typically, follow surfaces of constant potential temperature into the Arctic [*Iversen*, 1984; *Law and Stohl,* 2007]. Thus, air masses originating along the relatively warmer, moister North American and Asian east coasts can not readily enter the Arctic troposphere. While they can be lifted (*e.g.*, in warm conveyor belts) to high altitudes where they can be transported over the Arctic, this pollution is unlikely to be deposited to the snow surface via wet or dry deposition, except on the high Greenland plateau.

[47] A model study by *Koch and Hansen* [2005] evaluating regional contributions to the Arctic haze found that Asian sources dominated total atmospheric column aerosol load, but near-surface concentrations were dominated by sources in Europe and Russia. *Stohl* [2006] also found lower tropospheric aerosol sources to be dominated by European and Russian emissions. This was

Accepted Article

reinforced by a multi-model study of pollutant transport to the Arctic from the source regions of North America, Europe, South Asia and East Asia, which found that the greatest impact on surface-deposited BC in the Arctic comes from European emissions [*Shindell et al.,* 2008], but this study did not include northern Eurasia as a source region. *Hirdman et al.* [2010b] used a Langrangian particle dispersion model and reanalysis data and found northern Eurasia to be the dominant source region associated specifically with high atmospheric concentrations of BC at Barrow, Alert and Svalbard. This finding is consistent with the *Koch and Hansen* [2005] and *Stohl* [2006] model studies and with other studies of the source of atmospheric BC at Barrow [*Polissar et al.*, 2001] and Svalbard [*Eleftheriadis et al.*, 2009].

[48] In the springtime, when deposition of BC to snow is climatically important, there is extensive agricultural burning in western Russia and widespread forest fires, particularly in the east. The former is clearly an anthropogenic source, and it may be that a significant fraction of the latter may be as well [*Mollicone et al.,* 2006]. Given this result, the high latitude of this region (50 to 70°N), the tendency of the Arctic front to drop to lower latitudes in the Russian sector, and the model findings cited above, the impact of northern Eurasian biomass burning emissions to Arctic-wide BC (and OC) in snow may be significant.

[49] Indeed, biomass burning appears to be the source of high-concentration plumes observed in the Arctic in recent years, with Russian biomass burning playing a particularly prominent role during the measurements of the International Polar Year (2007-2008) [*Stohl et al.,* 2007; *Warneke et al.,* 2009; *Paris et al.,* 2009; *Jacob et al.,* 2010]. Chemical analysis of snow samples from 36 sites across the Arctic (Alaska, Canada, Greenland, Russia, and the Arctic Ocean near the north pole) also indicates that the majority (in most cases, greater than 75%) of the BC in surface snow is associated with biomass or biofuel burning [*Hegg et al.,* 2009; *Hegg et al.,* 2010]. Those analyses are from a geographically broad but limited number of samples, all from 2007 to 2009, and they do not yet include samples from the Scandinavian sector of the Arctic, where both models and measurements [*Forsström et al.,* 2009; *Doherty et al.,* 2010] indicate that concentrations are relatively higher and more influenced by fossil-fuel burning than in the rest of the Arctic. These factors may be biasing the conclusions of *Hegg et al.* [2009 and 2010] toward the role of biomass or biofuel burning emissions in Arctic BC. The model experiments of *Flanner et al.* [2007] attribute 4.5 ng g^{-1} BC in Arctic snow to FF sources, 1.7 ng g^{-1} to BF sources, and 1.9 to 4.7 ng g^{-1} to BB sources, depending on the strength of the boreal fire year, also suggesting a potentially dominant contribution from biomass or biofuel sources. However, *Skeie et al.* [2011] attribute only about 10% of snow BC to biomass burning sources, and *Flanner et al.* [2009] attribute only 25% of present-day snow BC forcing to biomass burning in a "typical" biomass-burning year. Despite the uncertainty, it is important in the context of mitigation decisions to recognize that biomass and biofuel burning emissions may be a significant source of BC to Arctic snow.

[50] Consistent with Greenland's physical location, the *Shindell et al.* [2008] multi-model study determined that surface-deposited BC in Greenland comes predominantly from North America and Europe in the fall and winter. In the spring, synoptic systems in Asia loft pollutants to higher altitudes, where they can be transported long distances. Accordingly, they calculated that for the Greenland Ice Sheet – most of which is at high altitudes – BC deposition is most strongly influenced in the spring by East Asian emissions. *Hirdman et al.* [2010b] similarly found that the surface air at Summit, Greenland, was strongly influenced by East Asian emissions in the summer, whereas other Arctic sites were not. They emphasize that the high altitude of the Greenland plateau makes it unique in the Arctic in being exposed to free troposphere air. Consistent with these findings, chemical analysis of surface snow samples from the Greenland plateau indicate that the BC is largely from biomass or biofuel burning sources in the spring and that fossil-fuel sources dominate in the summer [*Hegg et al.,* 2009, 2010]. In any case, as noted above, the Greenland Ice Sheet has very low concentrations of BC in its surface snow (*i.e.,* typically less than 3 ng g^{-1}) and so the radiative forcing by BC in Greenland snow is likely small, except during the melting season when BC becomes concentrated at the surface (Figure 10a of *Doherty et al.* [2010]).

Accepted Article

[51] At lower latitudes, sources of BC in snow can be either local or the end-point of long-range transport and can be highly variable not only with season but even within a day, due to the influence of, for example, thermal winds in lifting pollution from populated areas up onto the high mountain glaciers [*Marinoni et al.,* 2010]. Local sources of BC, terrain, and meteorology are sufficiently varied that it is difficult to make generalized statements about the sources of BC to Himalayan snow using a global model. Acknowledging this, *Kopacz et al.* [2011] used a chemical transport model to determine the seasonally resolved source of BC in year 2001 to the atmospheric column above one site on Mt. Everest and four sites across the Tibetan Plateau. They found that BC in the atmosphere above the Everest site was predominantly from India, China and Nepal; at the eastern Tibetan Plateau sites it was primarily from western China, secondarily from India, and also influenced by emissions in Nepal, the Middle East and Pakistan; and at the western Tibetan Plateau site it was primarily from western China and secondarily from Pakistan and the Middle East. At all sites, source regions varied with season, with atmospheric BC concentrations at a minima in the summer, consistent with measurements [*Xu et al.*, 2006; *Xu et al.,* 2009a,b; *Ming et al.*, 2009]. *Lu et al.* [2012] used a combination of emissions data and modeling to study the source regions and types for BC transported to the boundary layer over the Himalaya and Tibetan Plateau region as a whole for the period 1996 to 2010. They found that India, other South Asian countries and China were the dominant source regions, but there were also significant contributions from biomass burning in Russia and from the Middle East. The majority of the BC came from residential fuel combustion, with industry and land transport playing secondary roles, agricultural burning a small but significant role and, in some years, open forest burning made a notable contribution. Over the period studied, total contributions of BC to the region increased by over 40%, which they link to emissions increases in China and India.

[52] These studies focus on the source of BC to the atmosphere, either the entire column [*Kopacz et al.*, 2011], or the boundary layer [*Lu et al.*, 2012]. Forcing due to reduced snow albedo is driven by BC deposited to snow, which is determined not only by atmospheric BC distributions but by their incorporation into precipitation and inclusion in the surface snowpack. It remains to be seen if the sources of BC in snow on the Himalaya and Tibetan Plateau are the same as for the atmosphere above it. Further, because of the extreme terrain variations in this region, accurate representation of BC distributions, sources and deposition to snow will likely require the use of a high-resolution regional model.

7.6. Estimate of forcing by BC in the cryosphere

7.6.1 Adjusted forcing by BC in snow

[53] Forcing by BC in snow results from the radiative forcing due to the initial albedo reduction when BC is deposited in snow and the rapid adjustment to that forcing through the positive feedbacks *MBC*, *SBC* and *GRB* (Figure 7.3), resulting in the adjusted forcing. Comparable values of global, annual average forcing by BC in snow are calculated by scaling forcing as derived in model studies to the common base of present-day forcing due to all sources (FF+BF+BB). The *Flanner et al.* [2009] and *Koch et al.* [2009b] modeled adjusted forcings are then scaled based on the biases found in the measurement-model comparison of snow BC concentrations. From these, a representative central estimate is determined. In addition, all studies are normalized to forcing per emission ($\mu W\ m^{-2}$ per $GgC\ yr^{-1}$) to isolate differences in total emissions from differences in all other model processes that lead to cryosphere BC climate forcing (Table 7.2). For studies that do not report present-day forcing by BC emissions from FF+BF only, the adjusted forcing is calculated by scaling total to FF+BF emissions, in order to provide comparable forcings for what roughly might be considered the minimum 'anthropogenic' BC. Industrial-era (1750 to 2010) forcing is estimated by scaling total present-day forcing based on the ratio of present-day to pre-industrial BC emissions. In scaling by emissions, we use two model studies to account for differences in the amount of biomass burning versus fossil and biofuel burning emissions that are deposited to snow. Finally, the model sensitivity studies of *Flanner et al.* [2007] and runs from *Flanner et al.* [2009] are used to establish low and high uncertainty forcing bounds based on uncertainties in emissions, rate of snow aging (grain size), the efficiency with which BC is

Accepted Article

scavenged from surface snow during snow melt, snow cover fraction, the light absorption efficiency of BC, and the reduction in snow BC radiative forcing due to the presence of dust in the snow.

[54] This analysis does not encompass all sources of uncertainty in snow BC adjusted forcing, only those where information is available to set bounds. There are two weaknesses in this approach. First, forcing does not scale linearly with snow BC concentration. This affects both our uncertainty analysis and the scaling of all-source to industrial-era forcing, which is based on scaling by emissions. As with other agents, the forcing increase per unit mass of additional BC decreases with increasing BC amount, as indicated in Figure 3a of *Flanner et al.* [2007]. Second, snow BC concentrations do not scale linearly with global, annual average changes in BC emissions, since the amount of BC deposited in snow from any given source depends on its location and season – *i.e.,* a large increase in sub-Saharan Africa biomass burning has very little effect on BC concentrations in Arctic snow. We attempt to account for this using information from models on the relative role of biomass burning in snow forcing versus its fraction of global, annual emissions. However, there are likely significant but unquantified uncertainties associated with this adjustment, especially for pre-industrial snow BC forcing.

[55] The relative roles of biomass burning, fossil fuel and biofuel burning in BC cryosphere forcing is a function of their relative emissions, seasonal timing of emissions, and of the fraction of each that are deposited to surface snow and ice. The present-day fraction of emissions due to BB reported in the studies in Table 7.2 range from a low of 30% in a low BB year (2001; *Flanner et al.* [2007]) to a high of 47% in a high BB year (1998; *Flanner et al.* [2007]), with the rest falling in the range 35 to 45% (all other studies in Table 7.1). *Flanner et al.* [2009] attributed 25% of present-day BC-in-snow forcing to biomass burning emissions. However, *Skeie et al.* [2011] attribute only 10% of the present-day BC in snow north of 65°N to BB. In both studies biomass burning is about 35% of global, annual average present-day BC emissions, so this discrepancy must be due to differences in modeled source locations, aerosol transport, BC mixing ratios in falling snow, and dry deposition rates from BB versus BF+FF sources, and to feedbacks included in the two models (Table 7.2). Seasonality and non-linearities in forcing per change in snow BC concentration may also be contributing, since *Flanner et al.* [2009] report the fraction of forcing whereas *Skeie et al.* [2011] report the fraction of BC in snow due to BB. The source attribution analyses of *Hegg et al.* [2009; 2010] indicate that both of these studies may be underestimating the fraction of cryosphere forcing by BC from biomass burning. Further, the 35% of total emissions attributed to BB by *Flanner et al.* [2009] and *Skeie et al.* [2011] is at the low end of the range (35-45%) by all studies in Table 7.1. Therefore, the higher value of 25% is selected as the best estimate of the fraction of present-day BC cryosphere forcing due to biomass burning. *Skeie et al.* [2011] also reported that in the year 1750, 20% of snow BC north of 65°N was from biomass burning sources. For consistency with the assumption that present-day cryosphere forcing due to BB is higher than reported by *Skeie et al.*, we estimate that approximately 30% of pre-industrial (*i.e.,* before 1750) forcing by BC in snow was due to BB.

[56] As noted earlier, *Hansen and Nazarenko* [2004] conducted a sensitivity study based on uniformly imposed albedo changes. *Wang et al.* [2011] followed this approach, applying similar fixed, snow albedo changes within a few broadly defined regions. Thus, there is no basis for applying adjustments for emission sources or amounts to these two studies' reported forcings. The focus of these studies was understanding the climate response to the imposed albedo change, rather than on accurately modeling the forcing. Therefore, these two studies are not included here in determining the estimate or bounds on BC cryosphere forcing.

[57] *Jacobson* [2004] did not report a forcing value in his study, only the climate response. The adjusted forcing value of 0.06 W m^{-2} for FF+BF emissions shown in Table 7.1 is an estimate based on this study provided by M. Z. Jacobson. Biomass burning was included in the baseline, with fossil-fuel and biofuel burning emissions as the forcing agents. All-source adjusted forcing is estimated as 0.08 W m^{-2} using the assumption that 25% of present-day BC cryosphere forcing is due to BB emissions. This all-source forcing is used to calculate forcing per emission, based on the emissions reported by *Jacobson* [2004].

Accepted Article

[58] *Hansen et al.* [2005] (whose radiative forcing distribution was used directly by *Shindell and Faluvegi,* 2009]) followed the approach of *Hansen and Nazarenko* [2004] of imposing a snow albedo change, rather than prognostically calculating snow BC concentrations. However, in this updated study they scaled the imposed albedo based on the deposition rates from the study of *Koch* [2001]. *Hansen et al.* [2005] note they use the emissions of *Koch* [2001] in this context, but emission amounts were also not reported by *Koch* [2001]. The FF emissions provided by D. Koch (private communication) for this study were based on global, annual averages from *Penner et al.* [2001] for year 2000, with 1880 emissions approximated as 10% of the year 2000 emissions, and both biomass and biofuel burning emissions were taken from *Liousse et al.* [1996] (D. Koch, personal communication), resulting in the BC emissions shown in Table 7.1. To get atmospheric abundances, *Hansen et al.* [2005] scaled these BC emissions by a factor of 1.9, so that their global, annual average direct (atmospheric) radiative forcing by BC matched the 1 W m^{-2} given by *Sato et al.* [2003] based on AERONET observations. The model-measurement discrepancy could result from a bias in emissions, deposition rates or BC mass absorption efficiency, so it is not clear how the model might be biased in terms of light absorption by deposited aerosol. It is specified that the "…resulting albedo effect in the region of Arctic sea ice in our present model is only several tenths of 1%, as opposed to the 1.5% spectrally integrated (2.5% visible wavelengths) albedo change assumed by [*Hansen and Nazarenkeo* (2004)]." [*Hansen et al.*, 2005; also, see their Figure 16]. The *Hansen and Nazarenko* [2004] and *Hansen et al.* [2005] studies did not include the feedbacks *MBC*, *SBC* or *GRA* (Table 7.2), so their forcing is a direct radiative forcing due to the initial albedo change alone. This albedo change results in a preindustrial-to-present (1880 to 2000) radiative forcing by BC in snow of 0.08 W m^{-2}, which was later revised down to 0.05 W m^{-2} after correcting for a programming error that caused the modeled albedo change in *Hansen et al.* [2005] to be too high in partially snow-covered land gridboxes and too low for snow on sea ice [*Hansen et al*., 2007]. In Table 7.1, the present-day adjusted forcings for FF+BF+BB and for FF+BF only are calculated based on the corrected 0.05 W m^{-2} forcing value. Scaling is done by accounting for the change in emissions 1850 to 2000 and by assuming that the fraction of snow BC forcing due to BB is 30% in 1880 and 25% in 2000. Forcing per emission is calculated from this all-source forcing.

[59] The studies of *Flanner et al.* [2007, 2009] calculated present-day adjusted forcing for all emission sources (FF+BF+BB) as well as calculating forcing for (FF+BF) emissions only, as given in Table 7.1. *Koch et al.* [2009b] report both preindustrial-to-present (1890 to 1995) and present day (1995) adjusted forcing for all sources (FF+BF+BB). Present-day forcing from FF+BF only is calculated by assuming that 75% of present-day forcing is due to these sources.

[60] *Rypdal et al.* [2009a] do not include biomass burning emissions in either their baseline or forcing scenarios, including BC emissions only from fossil-fuel and closed-container biofuel burning. The amount of open- versus closed-container biofuel BC emissions is not sufficiently constrained to apply an adjustment to account for this missing source of BC. Total present-day forcing including biomass burning is calculated by scaling the reported FF+BF forcing, assuming the latter accounts for 75% of total present-day forcing. Forcing per emission is calculated using the sum of the *Rypdal et al.* [2009a] reported FF+BF emissions and the *Flanner et al.* [2009] 'typical year' BB emissions of 2700 GgC yr^{-1}.

[61] *Skeie et al.* [2011], using the same model as *Rypdal et al.* [2009a], reported an industrial-era (1750 to 2000) forcing by FF and BF of only 0.016 W m^{-2}. This gives a forcing per emission for FF+BF of 3.9 μW m^{-2} (GgC yr^{-1})$^{-1}$, which in turn yields FF+BF forcing of 0.018 W m^{-2} for present-day (year 2000) emissions. Assuming 25% of present-day BC cryosphere forcing is due to biomass burning emissions, present-day all-source forcing is 0.024 W m^{-2}. This implies an industrial-era forcing by FF+BF+BB of 0.021 W m^{-2}.

[62] With all studies adjusted to the common metrics of all-source forcing and forcing per emissions, a greater degree of convergence is reached. Total present-day adjusted forcings from the five most recent studies that prognostically calculated forcing span a range of a factor of two (0.024 to 0.050 W m^{-2}). The *Hansen et al.* [2005] and *Jacobson* [2004] forcings are notably higher

Accepted Article

at 0.07 and 0.08 W m^{-2}, respectively. However, when normalized to forcing per emission, all but the *Jacobson* [2004] study fall in the range of 3 to 7 (μW m^{-2})(GgC yr^{-1})$^{-1}$. If the high biomass-burning year (1998) of *Flanner et al.* [2009] is excluded, this range narrows to 3 to 6 (μW m^{-2})(GgC yr^{-1})$^{-1}$.

[63] The *Jacobson* [2004] study stands out in two regards: it includes forcing by BC in bare (non-snow-covered) sea ice as well as by BC in snow, and it includes UV and blue absorption of certain types of OC in the derived forcing. *Rypdal et al.* [2009a] and *Skeie et al.* [2011] also include forcing by BC in sea ice but otherwise all other studies discussed only include light absorption by BC and only in snow (not sea ice). Other studies include BC in snow on sea ice, but not in the sea ice itself. *Flanner et al.* [2007] excluded light absorption by OC in snow because a sensitivity study indicated that snow forcing from OC was a factor of 200 smaller than BC but acknowledged that modern optical measurements of light-absorbing OC could alter this conclusion. The inclusion of BC in sea ice and OC absorption might explain why the forcing per emission of the *Jacobson* [2004] study is higher than in the other studies. However, the forcing provided is estimated, not calculated, so it is not possible to know the fraction of forcing due to BC in sea ice versus snow or due to OC versus BC, and it is difficult to know quantitatively how much these factors account for the comparatively high adjusted forcing and forcing per emission of the *Jacobson* [2004] study. The *Rypdal et al.* [2009a] forcing per emission is more in line with that from the other studies, though again it is not known what fraction of this forcing is due to BC in snow versus bare sea ice. On the other hand, forcing per emission in the *Skeie et al.* [2011] study, which also included BC in sea ice, are lower than in the other studies.

[64] The comparison of measured versus modeled snow BC concentrations (Section 7.4) allow us to make a first-order adjustment for biases in the *Flanner et al.* [2009], *Koch et al.* [2009b] and *Skeie et al.* [2011] studies for all-source adjusted forcing. The results of this comparison (Table 7.3) indicate that the *Flanner et al.* [2009] model tends to overestimate snow BC concentrations, particularly in locations with relatively higher concentrations (*e.g.,* Scandinavia). There are also indications that this model may exaggerate the enhancement of surface snow BC concentrations with melt, and therefore feedback process *MBC* (Figure 7.3). The *Koch et al.* [2009b] model, on the other hand, tends to underestimate snow BC concentrations (Table 7.3), and it does not include the *MBC* feedback at all. Some data indicate that this feedback is significant (Dye-3 Greenland samples of *Clarke and Noone* [1985] and work in Norway, Greenland and Alaska [*Doherty et al.,* 2010; *Doherty et al.,* unpublished results]), if perhaps not as large as is given by *Flanner et al.* [2009]. The *Skeie et al.* [2011] comparison indicates that the model tends to underestimate surface snow BC concentrations in many locations by a factor of approximately two to five for cold snow. Once the snow starts to melt the modeled *MBC* feedback leads to large increases in surface snow BC amounts because none of the BC is washed away with the melt water. Based on these data, the all-source adjusted radiative forcing for FF+BF+BB from *Flanner et al.* [2009] is scaled down from 0.047 W m^{-2} to 0.04 W m^{-2}, and the forcing from *Koch et al.* [2009b] is scaled up from 0.03 W m^{-2} to 0.04 W m^{-2}. The *Flanner et al.* [2009] study accounted for dust impurities in the snowpack (which lessens the impact of adding BC) and so should be a more accurate representation of snow BC forcing than is given by *Flanner et al.* [2007]. Applying a correction factor to the all-source forcing derived from the reported *Skeie et al.* [2011] industrial-era FF+BF forcing based on the comparison to observations is somewhat more difficult. The low bias in modeled concentrations, especially in areas where forcing is expected to be greatest, is both large and variable. While forcing is likely biased low by at least a factor of two for cold snow (*i.e.*, winter to early spring), once the surface snow starts to melt it is assumed that all meltwater BC remains at the snow surface, maximizing the *MBC* feedback (Figure 7.3). Thus, adjusted forcing is likely underestimated initially but overestimated once the model snowpack warms to the point of melting. It is unclear what the net effect on adjusted forcing would be of increased cold snow BC concentrations coupled with a more realistic, reduced *MBC* feedback. However, an approximate doubling of the all-source radiative forcing from the *Skeie et al.* [2011] study from 0.024 W m^{-2} is reasonable given the reported large underestimates in snow BC concentrations across much of the Arctic. A comparison of snow BC concentrations is not made for the *Rypdal et al.* [2009a] study, but notably the emissions

Accepted Article

and forcing are intermediate to the *Flanner et al.* [2009] and *Koch et al.* [2009b] values. With this suite of information, the best estimate of all-source adjusted forcing by BC in snow is estimated to be 0.04 W m^{-2}. This yields a forcing per emission of 5 (μW m^{-2})(GgC yr^{-1})$^{-1}$ for the spatial and temporal emission patterns applied in the models.

[65] Industrial-era adjusted forcing is estimated from the total present-day forcing through scaling by the ratio of industrial era to all-source BC emissions, accounting for changes in the relative fractions of FF+BF versus BB from the industrial era to present day and accounting for differences in the fractions of FF+BF versus BB emissions that are deposited to snow. Caveats in this scaling are that significant uncertainties are associated with the pre-industrial BC emissions, especially from biomass burning; that forcing does not necessarily scale linearly with emissions; and that for forcing by BC in the cryosphere the forcing-per-emission is very sensitive to the season and location of the emissions. Biomass-burning emissions in 1750 were of the emissions. Biomass-burning emissions in 1750 were approximately 39% of present-day biomass-burning emissions and industrial-era FF+BF emissions were approximately 4% of present-day emissions (see "scaled" values in Table 5.3). In present-day, about 25% of the BC-in-snow forcing is due to biomass-burning emissions and 75% to fossil-fuel and biofuel-burning emissions, and in 1750 the split was about 30%/70% (Section 7.6.1, para. [55]). Thus, biomass forcing in 1750 was about 0.005 W m^{-2} (0.04 W m^{-2} × 0.25 × 0.39 x (30/25)) and FF+BF forcing was 0.001 W m^{-2} (0.04 W m^{-2} × 0.75 × 0.04 x (70/75)), for a total forcing in 1750 of 0.006 W m^{-2}. This yields an industrial-era forcing from all sources of 0.034 W m^{-2}. This forcing is the difference between present-day forcing and forcing in 1750. As noted earlier, snow (and likely sea ice) forcing in the later 1800's and early 1900's may have been greater than in 1750 or present-day.

[66] As noted earlier, it is not possible at this time to account for all known sources of uncertainty in model calculations of the radiative forcing and feedbacks that amplify that forcing as rapid adjustments. However, it is certain that snow BC radiative forcing is greater than zero (Section 7.1; Figure 7.2). Further, it is amplified by the rapid adjustments *GRA*, *SBC* and *MBC* (Section 7.1; Figure 7.3). Thus, the bounds on snow BC forcing are asymmetric about the best estimate.

[67] *Flanner et al.* [2007] calculated ranges of global-mean adjusted forcings resulting from plausible uncertainty bounds of different factors. Ranges of BC emissions produced a forcing range of -46% to +100% of their central estimate; ranges of snow aging (effective grain size): -42% to +58%; ranges of the fraction of BC scavenged from the snowpack with melt: -31% to +8%; ranges of snow cover fraction: -17% to +8%; and ranges of BC mass absorption efficiency -12% to +12%. From these results, uncertainty in three of the factors that directly affect snow BC radiative forcing (emissions or, equivalently, snow BC concentrations; BC absorption efficiency; and snow cover) can be determined, as well as for two of the feedback processes that amplify snow BC radiative forcing (*MBC* and *GRA*; Figure 7.3). Some bounds can also be placed on the uncertainty in BC radiative forcing due to the presence of soil dust using the *Flanner et al.* [2009] study model, where including dust deposition decreased BC adjusted forcing by 20% relative to adding combustion aerosol to a pristine snowpack. Based on this result, the role of dust in reducing BC forcing is allowed to be as low as 10% or as high as 40%.

[68] The lower (upper) bounds on snow BC adjusted forcing are calculated by adding in quadrature the forcing from low (high) bounds in emissions, rate of snow aging, BC mass absorption efficiency, and snow cover fraction, and using the high (low) bounds in the efficiency of BC scavenging with melt and in the role of dust in reducing snowpack albedo. The resulting lower and upper bounds on the forcing are calculated by subtracting 79% and adding 117% of the central estimate, giving an all-source adjusted forcing uncertainty range of 0.01 to 0.09 W m^{-2} with a central estimate of 0.04 W m^{-2} and an industrial-era forcing of 0.034 W m^{-2} with a range of 0.007 to 0.074 W m^{-2}. These bounds do not account for uncertainty in how forcing is affected by patchy snow cover or by uncertainties in modeled cloud cover and vegetation cover. They also do not account for possible biases in modeled mid-latitude snow BC concentrations.

7.6.2. Radiative forcing by BC in sea ice

Accepted Article

[69] As noted above, both the *Jacobson et al.* [2004] and *Rypdal et al.* [2009a] studies include forcing by BC in bare sea ice in their calculated climate impact of BC in the cryosphere. However, since these studies don't separate forcing by BC in snow versus in sea ice they cannot be used to estimate forcing by BC in sea ice, and the other studies considered don't include forcing by BC in bare sea ice. Therefore, an independent first-order estimate of this forcing is provided here. This estimate only accounts for the direct radiative forcing by BC in sea ice, and does not include feedbacks that may alter sea ice BC concentrations as the ice warms.

[70] After the snow melts in June on Arctic sea ice, the surface then consists of a mixture of puddles ('melt ponds') and drained hummocks. The hummocks have a surface granular layer that resembles coarse-grained snow, with effective grain radii about 2 mm. The BC content of the surface granular layer has been measured in several summer expeditions; it is similar to that of the springtime snow that recently covered it. The median is about 8 ng g^{-1} with estimated bounds of 3 and 15 ng g^{-1} from tables in *Doherty et al.* [2010]. The corresponding broadband albedo reductions under overcast sky (the normal situation in summer) are 0.010 and 0.028, respectively.

[71] The radiative forcing of BC in sea ice is bounded as follows. Only the months June, July, August, and September are considered because the ice is assumed to be completely snow-covered in all other months. (New ice forming in winter is not immediately snow-covered, but it is exposed to very little sunlight in the dark winter.)

1. The upper bound on sea ice area is taken as the average for 1978 to 1987 (Figure 3.1.45 of *Gloersen et al.,* 1992]; the lower bound as that of the extreme summer of 2007 (Table 1 of *Comiso et al.,* 2008]. These estimates of 'ice area' are of ice only; they are smaller than the tabulated 'ice extent' because the extent includes areas of open water within the ice pack.

2. Melt-pond fractions are given in Figure 3 of *Fetterer and Untersteiner* [1998]; 100% uncertainty is assumed to get upper and lower bounds for each month.

3. The average snow depth for each month is given in Figure 13 of *Warren et al.* [1999]; using these data the snow-cover fractions are estimated and an approximately 50% uncertainty assumed to get upper and lower bounds.

4. The year-to-year variability in downward solar irradiance is mainly determined by varying extent and thickness of the widespread stratus clouds covering the Arctic Ocean in summer. The mean monthly values of surface solar irradiance are adopted, as given in Figure 5 of *Fletcher* [1968] and tabulated in Table 1 of *Maykut and Untersteiner* [1971]; 15% is added or subtracted to get upper and lower bounds.

These values are shown in Table 7.4 and used to estimate the lower and upper bounds on all-source radiative forcing by BC in bare sea ice. The uncertainties are combined in quadrature. For example, for June the relative standard deviations for ice area, non-ponded fraction, non-snow-covered fraction, downward solar flux, and albedo reduction are 0.095, 0.02, 0.33, 0.15, and 0.5, respectively, giving a combined relative standard deviation of 0.625. The bounding values for global annual radiative forcing at the surface are 0.008 and 0.017 W m^{-2}. The central estimate is 0.012 W m^{-2}. As for BC in snow, the industrial-era sea-ice forcing is estimated to be 85% of the all-source forcing (*i.e.*, 0.010 W m^{-2} with bounds of 0.006 and 0.015 W m^{-2}).

7.6.3. Forcing by BC in snow in the Himalaya and Tibetan Plateau

[72] The Himalaya and Tibetan Plateau comprise a large area of seasonal snow cover and a high concentration of glaciers. This region is also in close proximity to East and South Asia, where BC emissions are large (Figure 3.3) and increasing (Section 3.8), consistent with observed increasing concentrations of BC in glacial snow at some sites [*Ming et al.*, 2009, *Xu et al.*, 2009a, *Lu et al.*, 2012]. These aspects have led to the hypothesis that greater than average warming rates [*Xu et al.,* 2009a] and observed acceleration of glacial melt rates [*Lau et al.*, 2010] in this region may be in part caused by BC in snow.

[73] Indeed, the model study of *Flanner et al.* [2009] found that the largest annual average forcing due to BC in snow is over the Tibetan Plateau, namely 1.3 W m^{-2} averaged over the whole region. The forcing averaged only over snow-covered surfaces reached a maximum of about 10 to 20 W m^{-2} in spring. These forcings are adjusted forcings in that they include the feedbacks *MBC*, *SBC*

Accepted Article

and *GRB* (Figure 7.3). This model study also included reduction in snow albedo due to dust, which moderates the forcing by BC. However, this model may be over-estimating snow BC concentrations in this region, especially in spring (Section 7.4.4), as well as overestimating snow cover on the Tibetan Plateau [*Qian et al.*, 2011], both of which would lead to a high bias in modeled radiative forcing. Modeled snow dust concentrations have not been evaluated.

[74] Using snow BC concentrations that show general agreement with measured values, *Kopacz et al.* [2011] calculate snow-cover averaged radiative forcing at the sites measured by *Xu et al.* [2006], *Xu et al.* [2009a,b] and *Ming et al.* [2009] of 4 to 16 W m^{-2}, with minima in the winter (4 to 8 W m^{-2} across the different sites) and maxima in summer (8 to 16 W m^{-2}). Total surface forcing (*i.e.*, accounting for snow covered area) is not calculated, and the reported forcings are instantaneous, not adjusted forcings. The forcing is also calculated as the difference between radiative fluxes for clean snow and for snow with BC only; reduction in albedo due to dust or soil in the snow is not accounted for.

[75] A robust estimate of forcing by BC in snow in the Tibetan Plateau region is thus hindered by limited measurements of snow BC concentrations, which show large spatial and seasonal variations; limited knowledge of snow dust concentrations in a region subject to dust storms that occur in the same season as maximum deposition of BC to snow; and the inherent difficulty of using a global model to accurately represent snow cover and atmospheric transport and deposition of BC and dust in a region that is mountainous and in close proximity to a range of intense BC and dust emission sources.

Accepted Article

Accepted Article

8. Climate response to black carbon forcings

8.1. Section summary

[1]

1. The BC direct, in-snow and in-sea-ice radiative forcings cause the troposphere and the top of the cryosphere to warm, which induces further rapid adjustments and climate response in the form of cloud, circulation, surface temperature, snow cover and precipitation changes. BC microphysical effects on clouds also induce adjustments and climate response but models have not yet separated the full climate responses to these complicated and uncertain climate forcing mechanisms and their adjustments (see Section 6).
2. BC direct radiative forcing causes a surface warming that is concentrated in the Northern Hemisphere but may exhibit a different pattern to that of the forcing. In-cloud absorption by BC, semi-direct effects and the efficacy of high latitude BC-in-snow and BC-in-sea-ice forcings need to be properly accounted for in the overall climate forcing estimate of BC. This can be done through the concept of the effective forcing, which scales a radiative or adjusted forcing with its climate efficacy.
3. Climate models show that effective forcing and adjusted forcing are equal within their respective uncertainties for most effects other than snow and ice forcing. This justifies deriving the radiative effects associated with the semi-direct effect from the efficacy of the radiative forcing by atmospheric BC.
4. There is a three-fold range across model studies in temperature response per radiative forcing but only a two-fold range in temperature response per adjusted forcing. Therefore, differences in rapid adjustments included in different models account for a fraction of the range of reported temperature responses.
5. The all-source BC-in-snow adjusted forcing (0.01 to 0.09 W m^{-2} globally averaged) drives equilibrium climate warming of 0.05 to 0.20 K in recent climate model studies. Climate response is greatest during local spring and over mid-to-high northern latitudes. The efficacy of this adjusted forcing is much greater than 1 primarily because all radiative energy is deposited directly within the cryosphere, causing earlier melt of snowpack and driving strong albedo feedback. The adjusted-forcing efficacy is estimated to be 3 with a range of 2 to 4.
6. Various studies suggest regional circulation and precipitation changes in response to the BC climate forcing. These changes include a northward shift in the Inter-Tropical Convergence Zone and changes in Asian monsoon systems where concentrations of absorbing aerosols are large.
7. The suggested impact of BC on glacier melting is potentially important but no model studies sufficiently resolve the glacier energy budget, aerosol transport and circulation changes in regions of complex topography to assess the importance of this process.

8.2. Introduction to climate forcing, feedback and response

[2] A climate forcing is a mechanism that induces a change in the climate system. Most climate forcings are radiative forcings, whereby the induced climate change originates from a modification in the radiative budget of the Earth. More specifically, a radiative forcing is defined by the IPCC as the change in ToA net radiation caused by a climate agent, after stratospheric adjustment, but with everything else being held fixed [*Forster et al.,* 2007]. There also exist some rapid adjustments (*e.g.,* some aspects of land use, microphysical effects on precipitation, or the CO_2 physiological forcing). Such forcings do not have an initial radiative driver but after a rapid adjustment lead to a radiative energy change in the climate system. We term radiative forcings and rapid adjustments as 'adjusted forcings' (see Table 1.1 and Section 1.3).

[3] The climate system responds to a radiative imbalance through a complex set of mechanisms (called feedbacks), eventually returning to a near equilibrium state [*Boer and Yu,* 2003; *Soden and Held,* 2006]. Climate models show that the equilibrium global temperature change in response to a climate agent is generally linear in radiative forcing, and the proportionality coefficient between these two quantities, denoted λ, is called the climate sensitivity (unit K $(W\ m^{-2})^{-1}$). Climate models further show that, although the climate sensitivity is model-dependent, it is relatively independent of the climate agent under consideration (within ±20 to 30%, except for snow albedo forcings discussed below). One can define the climate efficacy of a climate agent as the ratio of the climate sensitivity for this climate agent to that for the forcing by CO_2 [*Hansen et al.,* 2005]. Efficacies can be defined for either radiative forcing or adjusted forcing (Table 1.1).

[4] Some studies have shown that climate responses can be categorized into fast feedbacks, also known as rapid adjustments, which respond to forcings on a short timescale (typically days), and slow feedbacks, which are associated with the global surface temperature response and respond on longer timescales [*Gregory et al.,* 2004; *Andrews and Forster,* 2008]. Different climate agents can induce very different rapid adjustments, whereas slow feedbacks appear to be less dependent on the climate agent. BC affects climate in a number of ways, but those discussed in Sections 5 to 7 may all be considered either radiative forcings or rapid adjustments. The direct effect is a radiative forcing. The microphysical effects on clouds are partly radiative forcings and partly rapid adjustments. The cloud semi-direct effect cannot easily be dissociated from the direct effect that causes it and should be seen as a rapid adjustment to the direct radiative forcing rather than a separate forcing, although it can be quantified as a change in radiative flux (*i.e.,* a climate forcing). However, in this assessment the semi-direct effect is included in a single liquid-cloud effect (which also includes BC microphysical effects on clouds) because modeling procedures make the two difficult to separate (see Section 6). This calculation also uses the climate efficacy of the direct-effect radiative forcing to determine the semi-direct effect, assuming the efficacy of the adjusted forcing would be one. The snow albedo effect is a combination of radiative forcing and adjustments, some rapid and some less rapid, which tend to amplify this initial forcing (Figure 7.3). The rapid adjustments can be combined with the radiative forcing to produce an adjusted forcing. This amplified forcing produces further changes in snow cover that drive a snow albedo feedback; this amplifies the temperature response, leading to a high efficacy even when an adjusted forcing is used in determining efficacy.

[5] The response of climate to a relatively uniform radiative forcing such as that of long-lived GHGs, although still uncertain, has been studied in many models and aspects of its response pattern are consistent among climate models. The response to more heterogeneous radiative forcings is less well understood and there has been little work in the literature to compare different climate models. Although, there is no direct relationship between the patterns of climate response and the patterns of radiative forcing, except on large scales [*Forster et al.,* 2000]. *Shindell et al.* [2010] performed a multi-model analysis to quantify these scales, using the results of four GCMs. They found that inhomogeneous aerosol forcing caused an impact locally in those GCMs, but the impacts were not confined to those areas and extended quite far in the zonal direction - at least 12000 km - while extending only about 3500 km (or 30° longitude) in the meridional (consistent with modeled transport and modeled removal timescales in the atmosphere). This relationship is illustrated in Figure 8.1, which shows the geographic distributions of BC emissions, burden, direct radiative forcing and surface-temperature response for a particular model. The climate response to a regional radiative forcing, such as that by BC, has a regional and a global component. While the patterns of burden and direct radiative forcing are quite similar, there is no correspondence between the fine-scale patterns of radiative forcing and the surface temperature response. However, both the forcing and the surface temperature response are concentrated in the extratropics of the northern hemisphere.

8.3. Surface temperature response to atmospheric black carbon

8.3.1. Global-mean temperature change

Accepted Article

[6] Earlier studies on the climate effect of large injections of smoke and dust aerosols (*i.e.,* so-called nuclear winter) are relevant to understanding forcing by BC. *Cess et al.* [1985] showed that for increasing smoke loadings there is a transition from a surface-troposphere heating, induced by the convective coupling of the surface and the troposphere to a surface cooling when this convective coupling breaks down as the vertical structure of the atmosphere is modified. The climate response to BC may differ from a nuclear winter because the aerosol is concentrated in the lower atmosphere and, if the presence of co-emitted species is limited, it may be more absorbing than smoke. *Cook and Highwood* [2004], *Hansen et al.* [2005] and *Ban-Weiss et al.* [2011] added BC to different altitude ranges and showed that radiative forcing was not an effective measure of determining the surface temperature response to BC. The efficacy of the radiative forcing term could even change sign. In contrast, the efficacy of the adjusted forcing that accounted for semi-direct effects was much closer to unity [*Shine et al.,* 2003; *Hansen et al.,* 2005; *Crook et al.,* 2011; *Ban-Weiss et al.,* 2011]. The most consistent forcing measure appears to be calculated by allowing tropospheric response but no global mean surface temperature response, either from fixing surface temperature everywhere [*Shine et al.,* 2003] or using a regression method [*Ban-Weiss et al.,* 2011]. *Hansen et al.* [2005] further showed that for BC in snow the large efficacy of the high-latitude forcing needs to be properly accounted for (see below). The adjusted forcing implicitly accounts for some of the variable efficacy of the direct radiative forcing. The adjusted forcing or the effective forcing (*i.e.,* forcing weighted by efficacy (see Table 1.1)) is a more appropriate measure of BC's ultimate effect on global average temperature.

[7] Table 8.1 reports BC radiative forcing, adjusted forcing, effective forcing, and surface-temperature response from various climate models. Note that these experiments are generally based on unrealistic BC perturbations and, as such, they are representative of sensitivity rather than the expected magnitude of temperature change or forcing. Therefore, the results in Table 8.1 should be used qualitatively. Quantitative temperature changes are estimated in Section 9, employing our revised forcing estimate. The different models vary in their experimental designs (*e.g.,* BC alone versus BC and co-emitted species, slab ocean model versus fully coupled ocean-atmosphere model), emission rates, and treatment of the effects of BC on climate. Some have a more sophisticated treatment of BC optics, some are better documented in their ability to simulate the present-day climate and the historical period, and some simulate better cloud properties than others. Nevertheless, these results show that effective forcing and adjusted forcings from a single model agree to within their respective uncertainties, justifying our approach for calculating the semi-direct effect. While there is a large range in equilibrium temperature responses across the studies the spread in temperature response per radiative forcing is smaller, covering a three-fold range. When the forcings are appropriately scaled to account for rapid adjustments agreement is even better, with only a two-fold range in temperature response per adjusted forcing. This finding suggests that differences in rapid adjustments or aerosol processes included in each model are responsible for some of the difference in global average temperature change.

[8] The climate models clearly differ in their cloud responses. For instance, fossil-fuel BC causes an increase in high-level clouds in the model of *Jacobson* [2010] due to an enhancement of upper-tropospheric water vapor due to surface warming and evaporation and a decrease in low clouds due to enhanced BC warming, including that within cloud drops and interstitially between cloud drops, as discussed in Section 6.3.3. These experiments, unlike most other studies, considered OA and other co-emitted species, and included the microphysical effects of BC on liquid and ice clouds.

8.3.2. Regional surface temperature change

[9] As discussed in the introduction, the pattern of surface temperature response can be quite different from the pattern of forcing. The temperature response to BC is a combination of regional response and hemispheric response, with polar and land amplification. There is a reasonable agreement among models that the BC warming is concentrated in the Northern Hemisphere with some polar amplification (Figure 8.2). However, there is disagreement on the relative warming of the different continents, with some models showing significant warming over North America and Eurasia while others do not. It is unlikely that the differences in

Accepted Article

experimental setup and range of BC effects included in the four models presented in Figure 8.2 are sufficient to explain the diversity of results. Some of the model differences could be due to differences in forcing and climate efficacy (or sign of the semi-direct effect). It is difficult, however, to attribute the differences among the models to a particular process or reason without performing a more comprehensive intercomparison. While some models include more BC forcing mechanisms that have been evaluated at different scales (*e.g.,* GATOR), others have been more thoroughly tested regarding their ability to represent the global historical temperature record and climate variability (*e.g.,* NCAR CAM, GISS, and HadGEM2).

[10] There are few systematic studies of the regional impact of BC aerosols from different regions with the exception of the work by *Shindell and Faluvegi* [2009], who looked at the regional impact of atmospheric BC from four latitudinal bands in the GISS climate model. A summary of their results relevant to BC is shown in Figure 8.3. BC in the 28°N-60°N band is most efficient at inducing warming in the 60°N-90°N band and vice versa. Tropical (28°S to 28°N) BC warms all latitudinal bands, with forcing efficiency increasing in moving from lower to higher latitudes. Finally, it should be noted that atmospheric BC in the 60°N-90°N band cools the surface in that region, possibly because the coupling between the atmosphere and the surface is not strong enough to overwhelm the decrease in solar radiation at the surface induced by BC or because of resulting changes in northward heat transport due to a decreasing latitudinal temperature gradient. These experiments account only for forcing by atmospheric BC; in this same model, when surface forcing from BC deposited to snow and ice is accounted for, the total forcing by BC in the 60°N-90°N latitude band is positive (warming).

[11] It has been further suggested by *Ramanathan and Carmichael* [2008] that absorbing aerosols could have contributed to the observed melting of snowpacks and glaciers in the Himalayan region on the basis that layers of BC aerosol (the so-called atmospheric brown cloud) heat the atmosphere at altitudes up to 3 to 5 km. Evidence for the effectiveness of this mechanism remains elusive. *Menon et al.* [2010] simulate a small decrease in snow and ice cover over the Himalaya associated with the increase in emissions from 1990 to 2000. However their simulations use observed climatological sea-surface temperatures and neglect any response from the ocean. Moreover it is unclear to what extent the precipitation changes in their simulations are statistically significant. *Kuhlmann and Quaas* [2010] used lidar measurements from the CALIPSO satellite to assess the importance of aerosols for atmospheric heating rates. They found that i) in higher layers the shortwave heating was partly balanced by longwave cooling, ii) the contribution of aerosols to atmospheric heating rate over the Tibetan Plateau was relatively small (typically 0.02 K day^{-1}) as compared to neighboring regions (0.2 K day^{-1}), and iii) a large fraction of the aerosol was dust, or at least classified as such by CALIPSO. However, *Kuhlmann and Quaas* did not estimate the impact of the aerosol on the surface energy balance. While it is possible that atmospheric BC aerosols have contributed to the melting of snowpack and glacier in the Himalayan region, appropriate testing of the hypothesis would require robust ensembles of high-resolution simulations that can resolve the complex atmospheric flow and surface radiative budget over this region.

8.4. Precipitation changes due to black-carbon direct and semi-direct effects

[12] The separation between rapid adjustment and slow feedbacks is particularly useful for examining precipitation responses to forcing. *Andrews et al.* [2010] studied the rapid adjustment associated with a range of climate agents, including BC. They showed that the rapid adjustment in global-mean precipitation correlates negatively with the atmospheric radiative forcing (*i.e.,* the difference between ToA and surface radiative forcing) while the slow response is proportional to the global-mean surface temperature change. Since BC aerosols are responsible for significant atmospheric radiative forcing through absorption of solar radiation, the reduction in precipitation due to the rapid adjustment can dominate over the increase due to the slow feedback. One model showed a global reduction in precipitation of around 0.7% from BC rapid adjustments [*Andrews et al.,* 2010]. This result has been confirmed by *Ming et al.* [2010] who found that the decrease in precipitation due to atmospheric heating could dominate over the increase in precipitation due to surface warming for some vertical distributions of the BC aerosol.

Accepted Article

[13] Both *Wang* [2007] and *Jones et al.* [2007] found that BC strengthens the Hadley cell in the Northern Hemisphere but weakens it in the Southern hemisphere. This leads to a northward shift in the Inter Tropical Convergence Zone (ITCZ), which appears to be a robust feature of the climate response to BC also supported by earlier experiments [*Roberts and Jones,* 2004; *Chung and Seinfeld,* 2005].

[14] A number of studies have investigated the regional climate responses to BC in particular regions of the world, generally focusing on precipitation changes. Many of these studies examine Asia because of the large concentrations of absorbing aerosols there. Using the GISS model, *Menon et al.* [2002b] simulated a surface warming over most regions in response to absorbing aerosols but a moderate cooling over China. The model also simulates increased precipitation in southern China and over India with a band of decreased precipitation to the south. Zhang et al. (2009b) obtained the opposite result using the Community Atmosphere Model (CAM3) when considering carbonaceous aerosol (BC + OC) together. In this case, surface temperature increased in southern China and India and total cloud cover and precipitation decreased. Using the same model, *Liu et al.* [2009b] found that sulfate and BC aerosols have the effect of weakening East Asia monsoons in both the summer and winter seasons.

[15] *Lau et al.* [2006] used the GEOS GCM with fixed sea surface temperature to show that absorption of solar radiation by dust heats the air on the northern and southern slopes of the Tibetan Plateau, which can then rise and create a positive temperature anomaly in the mid-to-upper troposphere over the Tibetan Plateau. On the southern side, the atmospheric heating is reinforced by anthropogenic emissions of BC over the Indian subcontinent. This can lead to an intensification of the Indian summer monsoon and surface warming over the Tibetan Plateau. While *Lau et al.* found that the effect of BC is important in initiating the monsoon rainfall anomalies over India, it is not enough to produce statistically significant change in the monsoon regime on its own (*i.e.,* without the synergy with dust absorption). Like most of the other earlier studies looking at the regional climate response to BC, this study was performed with an atmosphere-only model, which is a significant limitation because sea surface temperatures are not allowed to respond to the forcing by BC. One could imagine anthropogenic aerosols causing a decrease in sea surface temperature, for example, during the winter monsoon over the Indian Ocean, with consequences for the summer monsoon.

[16] *Wang et al.* [2009a] used the NCAR Community Climate Model version 3 (CAM3) coupled to a slab ocean model to investigate the response of the Indian summer monsoon to scattering and absorbing aerosols. They found that absorbing aerosols cause a northward shift in rainfall (both during the onset of the monsoon and averaged over the monsoon period) that is only weakly offset by the effect of scattering aerosols.

[17] *Meehl et al.* [2008] performed a six-member ensemble of 20th-century simulations with a fully coupled ocean-atmosphere climate model, which confirmed some of the earlier results found with atmospheric models coupled to a slab ocean. In their experiments, BC and OA aerosols increase lower tropospheric heating over south Asia and reduce the amount of solar radiation reaching the surface during the dry season, enhancing precipitation over India in the months of March-April-May. With the onset of the monsoon, the reduced surface temperatures in the Bay of Bengal, Arabian Sea, and over India that extend to the Himalaya act to reduce monsoon rainfall over India itself, with some small increases over the Tibetan Plateau. Precipitation over China generally decreases due to the BC effects. Analysis of single ensemble members from the multiple-forcings experiment suggests that the observed increasing precipitation trends over southern China appear to be associated with natural variability connected to surface temperature changes in the northwest Pacific Ocean. *Rotstayn et al.* [2007] suggest that the effects of Asian aerosols on rainfall could be seen in Australia with an increase in cloudiness and rainfall during the period 1951 to 1996, especially in northwestern Australia. *Bollasina et al.* [2011] and *Shindell et al.* [2012] investigated the impact of aerosol forcing on the South Asian monsoon in the GFDL and GISS GCMs, respectively. *Shindell et al*. found distinct perturbations to the South Asian monsoon as well as to precipitation in the Sahel and southern Europe. *Bollasina et al.* found similar changes and suggested that the changes were part of

Accepted Article

large-scale circulation changes and had little to do with direct local forcing. *Shindell et al* showed that the precipitation responses were in many places similar to those induced by GHGs, but with much greater amplitude per unit forcing.

[18] *Tosca et al.* [2010] also applied the NCAR CAM3 model with a slab ocean model to explore effects of biomass burning emissions over the western equatorial Pacific during intense El Niño episodes, such as the 1997-1998 event. They found that BC and OA emissions from extreme fire years caused sea surface temperature to cool and the atmosphere to warm and that this reduced precipitation by about 10% over greater Indonesia, potentially exacerbating local drought conditions because evapotranspiration reductions were smaller than precipitation changes.

[19] Generally, these studies show that atmospheric heating by BC can have significant effects on precipitation, causing a global reduction via rapid adjustment processes. Model studies have also shown that BC can alter regional precipitation by about 10% and affect circulation patterns such as the monsoon.

8.5. Climate response to the snow albedo effect

[20] BC deposited to snowpack can significantly reduce snow and ice albedo because of the approximately five order-of-magnitude difference in mass absorption cross section between ice and BC, and strong multiple scattering within snow, which enables small mixing ratios of impurities to absorb a disproportionate amount of radiative energy (*e.g., Warren and Wiscombe,* 1980]. BC-induced snow albedo changes exert a small global-mean forcing through radiative forcing and rapid adjustments (*i.e.,* all-source adjusted forcing range of +0.01 to +0.09 W m^{-2} in Section 7), but models indicate that snow albedo forcing is unusually effective at warming climate, even when rapid adjustments are accounted for. The high efficacy of the adjusted forcing stems from the following factors:

1. By definition, all of the forcing energy associated with this mechanism is deposited directly within the cryosphere, a component of the Earth System responsible for strong positive feedback [*e.g., Budyko,* 1969] through the snow (and ice) albedo feedback (*SAF* in Figure 7.3). Warming of snow and sea ice by deposited BC exacerbates this feedback mechanism in comparison to forcing mechanisms that distribute energy more evenly throughout the planetary envelope, such as GHG forcing.

2. The mechanism operates mostly at high latitudes, which are uniquely susceptible to surface energy forcings because of stable atmospheric conditions. Smaller lapse rates in high-latitude regions induce shallower mixed layers that permit surface energy forcings to drive larger surface temperature changes. In stratified conditions, the mass of air responding to a surface energy forcing is small, and the energy is not transferred efficiently throughout the system. This condition breaks down with strong warming, however, so that larger forcings have smaller efficacies. It is weaker during summer, when insolation (and therefore radiative forcing via darkening of snow or ice) is greatest [*Forster et al.,* 2000].

3. In some studies, feedbacks driven by changes in snow grain size may also contribute to larger efficacy [*Flanner et al.,* 2007] (*GRA* in Figure 7.3). The reasoning for this result is that BC absorption warms snowpacks so that they age more rapidly, which lowers snow albedo in the near-infrared spectrum. A key uncertainty associated with this process is that snowpack temperature gradient is often a greater controller of snow age than mean temperature [*Flanner and Zender,* 2006], and the influence of absorbing impurities on temperature gradient depends on many factors, including the vertical distribution of impurities and solar absorption, snowpack thermal conductivity, and snowpack-atmosphere coupling.

The relative roles of these three factors are uncertain. *Bellouin and Boucher* [2010] obtained a large climate efficacy in idealized model experiments that do not include the third factor.

[21] Climate response to BC in snow is particularly strong during boreal spring (March-May) over mid- to high-latitudes [*Flanner et al.,* 2009; *Wang et al.*, 2011]. Increasing springtime insolation and widespread snow cover in the Northern Hemisphere drive the greatest radiative forcing during this season, and climate response and efficacy are large when the mechanism induces earlier snow melt, as the contrast in albedo between snow-covered and snow-free surfaces is generally much greater than the reduction in albedo

Accepted Article

caused by BC. A source of enhanced springtime forcing is the retention of impurities at the snow surface during melt (*MBC* in Figure 7.3; Section 7.3.5), but the importance of this effect is largely uncertain and likely varies considerably with location and type of snowpack. *Koch et al.* [2011b] have suggested that, even absent the *MBC* feedback (Table 7.2), 20% of Arctic warming and snow–ice cover loss is a consequence of the BC albedo effect.

[22] Table 8.2 reports estimates of the BC snow albedo forcing, surface temperature response, and climate efficacy from different model studies. The equilibrium change in global-mean surface temperature ranges from +0.06 to +0.20 K for the trustworthiest experiments. The climate response is more localized than for the BC direct and semi-direct effect with most of the warming over the Arctic region and the Tibetan Plateau and Himalaya. Equilibrium Arctic temperature responses reported from three simulations [*Flanner et al.,* 2007; *Koch et al.,* 2009b] are 0.50, 0.50, and 1.6 K (the latter occurring with strong boreal fire BC emissions in 1998). Climate efficacy for the adjusted forcing is much larger than 1 in all models with most models showing values of 2.0 or more. Based on the spread of adjusted-forcing efficacies given in Table 8.2, the efficacy of the adjusted forcing by BC in the cryosphere is estimated to be 3, with a range of 2 to 4. These efficacies are used in Section 9 to derive effective forcings due to BC in snow and sea ice (Table 1.1).

[23] Most studies of the climate impact of BC in snow have focused on the global, annual impact or on impacts in the Arctic. However, because most of the energy from this forcing directly impacts snowpack temperatures, local impacts may be large, especially where snow melt is relied upon as a water source. Recognizing this, *Qian et al.* [2009] applied the Weather Research and Forecasting (WRF) regional model to study the influence of BC deposition on western North America snowpack. They found the largest response during late winter and early spring, with increased net solar radiation caused by reduced snow cover, and subsequent increases in surface air temperature. Climate changes and deposition of BC on snow were both largest over the central Rockies and southern Alberta, where shifts in regional stream flow were also found. An experiment with doubling of regional BC emissions showed a much greater-than-linear climate response in this region. *Qian et al.* [2011] used a global model to look at the influence of BC and dust on the Tibetan Plateau snowpack with a specific focus on the impacts on the Asian hydrological cycle and monsoon climate. In this study, BC and dust in snow were found to produce 5 to 25 W m^{-2} adjusted forcing during spring, reducing spring snowpack over the Tibetan Plateau more than does warming by anthropogenic CO_2 and atmospheric BC. However, *Qian et al.* acknowledge that the global model used grossly overpredicts snow cover in this region (their Figure 2) and, therefore, likely also forcing by BC and dust in snow. These studies highlight the possible strong regional impacts of BC in snow, but also emphasize the need for studies that can account for the large variations in terrain, snow cover and BC deposition, especially in mountainous terrain.

8.6. Detection and attribution of climate change due to black carbon

[24] As Sections 8.3 to 8.5 have outlined there is evidence of regional climate responses to BC that is manifest in observations. In particular, there is some evidence for a BC effect on: 1) regional temperature and precipitation changes [*e.g., Menon et al.,* 2010], 2) Arctic temperatures and snow-ice cover [*e.g.*, *Flanner et al.,* 2009*; Koch et al.,* 2011b], 3) monsoon and other circulation changes [*e.g.*, *Rotstayn et al.,* 2007*; Bollasina et al.,* 2011*; Shindell et al.,* 2012] and 4) Himalayan and North American snow and ice cover [*Qian et al.,* 2009*; Qian et al.,* 2011]. However, it should be noted that none of these studies formally attribute changes to BC in a statistically rigorous sense.

[25] It is desirable to find a confirmation of the model results on the climate response to BC in the observational climate records. Methods have been developed to detect and attribute climate change to particular climate agents by regressing the spatial and temporal patterns of climate change simulated by the models against the observed patterns. Scaling factors that maximize the fit to the observations provide a measure of whether a particular forcing is detected, by testing the hypothesis that the scaling factors are consistent with a value of zero. When a particular combination of forcings is detected, the scale factors can be used to reconstruct

Accepted Article

the contribution of each individual forcing to temperature change. Detection and attribution methods have established that the anthropogenic "…greenhouse gas forcing has very likely caused most of the observed global warming over the last 50 years." The cooling due to sulfate aerosols could also be detected [*Hegerl et al.,* 2007]. However, it has proven to be more difficult to detect the warming due to BC.

[26] *Jones et al.* [2005] included fossil-fuel BC in a detection and attribution analysis with GHG and sulfate aerosols. While the introduction of BC did not affect the attribution of the warming to GHGs, it was not possible to detect the pattern due to BC because it was too similar to the cooling pattern of sulfate aerosols. The influence of carbonaceous aerosols (BC and OA from fossil-fuel and biomass burning sources) was detected by *Nagashima et al.* [2006] in the mid part of the 20th century. However the relative contribution from BC cannot be deduced from this study.

[27] *Jones et al.* [2011] revisited their earlier work using an ensemble of HadGEM1 model simulations that include different combinations of the GHGs, sulfate aerosols, BC, and natural radiative forcings. They used their detection and attribution method to examine the climate influence of BC from fossil-fuel and biofuel combustion sources. The BC forcing included the direct and semi-direct effect but not the snow albedo effect. The climate response to BC was obtained as the difference between a simulation with all forcings and a simulation with all forcings except that from BC. BC was found to have a detectable contribution to the warming over the period 1950-1999 but not over the period 1900-1999 or 1957-2006. The attributed climate change due to BC was 0.41 K(century)$^{-1}$ (range 0.20 to 0.60 K(century) $^{-1}$) for the period 1950-1999. This corresponds to a warming of about 0.20 K (range 0.10 to 0.30 K) for the 50-year period. Global warming by industrial-era BC would be about twice as large because 1950 emissions of BC were about half of present-day emissions. Moreover, any committed warming would add only slightly to the equilibrium climate response. Accounting for the snow albedo effect would possibly improve the detection and narrow the uncertainties in the scale factors but would not necessarily result in a larger contribution of BC to the observed warming because the scale factor can compensate for the missing warming in the climate simulations. For the period 1957-2006, the attributed climate change due to BC –not statistically significant– is 0.10 K(century) $^{-1}$ (range -0.03 to 0.21 K(century) $^{-1}$). Failure to detect the climate response to BC over this period can be due to the discontinuities introduced in the simulations by merging the historical emission inventories until 2000 with the SRES emission projections after 2000.

[28] In conclusion it can be said that the global warming due to BC can be detected in the observational temperature record but the detection remains very sensitive to the modeling assumptions. The deduced contribution of BC to the observed warming is comparable to that obtained from models alone but it is not accurate enough to constrain further the various estimates obtained from the models so far. Inclusion of the pattern of warming due to the snow albedo effect and regression of the simulated patterns against both the observed surface and vertical temperature change patterns could contribute to a better detection of the BC signal.

8.7. Conclusions

[29] Figure 8.4 summarizes our knowledge on the effects of BC on climate. There is agreement among climate models that BC causes a warming that is essentially located in the northern hemisphere. Existing studies have different experimental configurations and consider different processes by which BC affects climate, making comparisons between them difficult. However, there is a smaller range in surface temperature response per unit effective forcing than in effective forcing. Climate models also consistently simulate a northward shift in the Intertropical Convergence Zone in response to BC forcing. Other changes in precipitation are likely, especially the Asian monsoon systems as these regions experience large burdens of BC. However, there is no agreement among models on the patterns of rainfall changes in these regions. High-resolution simulations with coupled ocean-atmosphere models over the Asian region could better address the issue of circulation and precipitation changes due to BC. Darkening of snow and ice surfaces by BC is associated with enhanced melting and an amplification of the surface temperature response in these regions, but the role of BC on glacier melting in the Himalayan and Tibetan Plateau region remains unclear. The climate response

Accepted Article

to the indirect effect of BC on liquid and ice clouds has not been studied in isolation of the direct and semi-direct effects and remains largely unknown. Detection and attribution studies, which seek the expected patterns of the climate response to the BC forcing in the observational records, have had some limited success, probably because of imperfect modeling assumptions but also because of the disruptive effect of sulfate aerosols.

Accepted Article

Accepted Article

9. Synthesis of black-carbon climate effects

9.1. Section summary

[1]

1. The industrial-era (1750 to 2005) climate forcing of BC is made up of components from its direct radiative forcing, its effect on cloud microphysics, rapid adjustments to its atmospheric heating, and the effect of BC deposited on snow and sea ice.

2. Employing radiative forcing alone is inadequate for assessing the climate role of BC in terms of its globally averaged, surface temperature response. In particular, semi-direct effects and the efficacy of high-latitude forcing terms need to be properly accounted for.

3. The level of scientific understanding of these components is generally assessed as low or very low, making their uncertainty bounds difficult to characterize accurately. It is also difficult to quantify how uncertainties of different terms are correlated, making errors difficult to combine.

4. With these caveats the industrial-era total climate forcing of BC is assessed to be +1.1 W m^{-2} with a 90% uncertainty range of +0.17 to 2.1 W m^{-2}, allowing for the correlation of emission uncertainty. This climate forcing has a larger uncertainty range and is likely greater than the radiative forcing from the BC direct effect (+0.71 W m^{-2} with a 90% uncertainty range of +0.08 to +1.27 W m^{-2}). This best estimate of black carbon forcing ranks it as the second most important individual climate-warming agent after carbon dioxide when both direct and indirect effects are included.

5. In terms of equilibrium global-mean surface temperature change the total BC climate-forcing estimate for the industrial era would correspond to a warming between 0.1 and 2.0 K. Note that not all this warming has been realized in the present day as the climate takes more than a century to reach equilibrium and many co-emitted species have a cooling effect, countering the global-mean warming of BC.

6. In addition to the direct radiative forcing of BC, adding the positive climate forcings and accounting for the efficacies of BC in snow and BC in sea ice increases the best estimate of forcing. Semi-direct and liquid-cloud effects add negative climate forcing, and cloud absorption and mixed-cloud changes add positive climate forcing. The total of BC cloud effects is estimated to be positive. Including these effects makes the estimate of total BC climate forcing estimate considerably more uncertain than that of direct radiative forcing. In particular, the two positive cloud terms have a very low level of scientific understanding. Without these terms, BC total climate forcing would be +0.65 W m^{-2} with a 90% uncertainty of +0.03 to +1.1 W m^{-2}.

7. The components of BC climate forcing in addition to the direct radiative forcing are cloud, cloud droplet inclusions, and semi-direct effects (+0.23 W m^{-2} with a 90% uncertainty range of -0.47 to 1.0 W m^{-2}); and BC in snow and BC in ice (+0.13 W m^{-2} with a 90% uncertainty range +0.04 to +0.33 W m^{-2}). See Table 0.1 for a further breakdown of forcing components.

9.2. Introduction

[2] Earlier sections have discussed emissions of BC, the mechanisms by which BC affects the Earth's radiative balance and BC's various effects on climate. Here we synthesize these discussions to provide best estimates and uncertainty bounds for the role of BC in the current climate using the metric of globally averaged climate forcing. Section 8 pointed out that regional changes and especially changes to the hydrological cycle are how we experience climate change, and that such impacts are not represented by global forcing metrics. Nonetheless, in this assessment we have chosen to use a global forcing metric as it is more comparable across mechanisms and better constrained than other choices.

9.3. Global climate forcing definition

[3] We are ultimately interested in quantifying the impact of BC emissions on the Earth's climate. The definition of radiative forcing employed in IPCC reports [*Forster et al.,* 2007] is the change in net energy (down minus up) at the tropopause since 1750 due to a given mechanism or climate forcing agent, after allowing stratospheric temperatures to adjust to radiative equilibrium. As discussed in Section 1.3.2, we retain this definition of forcing relative to a base year, but use the term 'industrial-era forcing' to indicate that the forcing is based on time rather than wholly attributable to anthropogenic activity. The overall global climate response to BC (encompassing direct, snow, sea-ice and cloud effects) is also very different from the response to other forcing agents such as the long-lived GHGs (Section 8). BC emissions affect clouds, snow and sea ice (see Sections 6 and 7). In IPCC reports, some of these effects are classified as part of the cloud albedo effect or represented separately as BC snow albedo forcing, while others are considered part of the climate response. In this assessment 'rapid adjustments' to the forcing are included in the total climate forcing term. Rapid adjustments are where the atmosphere, land or cryosphere responds to the forcing on a relatively short timeframe compared to that of the global-mean temperature response (see Table 1.1 and Section 1.3). In addition for both BC in snow and BC in sea ice we implicitly include both the rapid adjustment of the snowpack and the climate response to the BC snow and ice albedo changes (*i.e.,* the snow albedo feedback) by accounting for the efficacy of BC snow and ice albedo change in our climate forcing estimate, employing the concept of 'effective forcing' discussed next.

[4] The notion of effective forcing means that the radiative forcing is scaled by an efficacy which incorporates the relative strengths of climate feedbacks. This effective forcing is then more representative of the actual radiative impacts of BC [*e.g.*, *Hansen et al.*, 2005; also see Table 1.1 and 8.1]. Alternatively, forcings can be calculated from fixed sea-surface temperature experiments or regression techniques [*Hansen et al.*, 2005, *Andrews et al.,* 2010]. In practice, diverse forcing definitions are used in the different studies we assess and care is required when comparing reported forcings (see Section 8 and Table 8.1). For example, the separation of BC forcing into direct, cloud-albedo forcing and semi-direct forcing is not straightforward (see Section 6). In this assessment we have been particularly careful to include all relevant terms when assessing the total climate forcing from BC without double counting (see Section 1.3.2).

9.4. BC global climate forcing components and uncertainties

[5] In this section, we summarize the best estimates of individual climate forcing components for global BC emissions in 2005, compared to 1750. These values are shown in Figure 9.1 along with 90% uncertainty range estimates. The combined climate forcings represent the known direct and indirect (cloud, snow and ice) radiative forcings from BC changes plus all known rapid adjustments of clouds and the snowpack (Section 7.4). They also capture the high efficacy of high-latitude snow and ice forcings. The sum of these terms represents the total climate forcing of BC. Table 9.1 summarizes each of the terms evaluated, describes their relation to the forcing definitions described in Section 1.3.2, explains how the uncertainty range was determined, and identifies where in this assessment the radiative forcing is estimated in detail. It also presents our general level of scientific understanding, which, following IPCC terminology [*Forster et al.*, 2007], is based on an assessment of the nature of assumptions involved, the uncertainties prevailing about the processes that govern the forcing, and the resulting confidence in the numerical value of the estimate. The following sections review these choices.

9.4.1. BC direct forcing

[6] The best estimate and range of the direct BC radiative forcing arises from scaled AeroCom model results based on observationally constrained estimates of BC AAOD from AERONET sites (see Section 5). The finding that large increases in modeled concentrations are warranted in some regions is broadly consistent with comparisons with *in-situ* measurements and space-based observations (Sections 4.5.1 and 5.9.2). Emission factors may be the cause of low biomass-burning emissions (Section 3.7.2.3). The reason for apparent underestimates in energy-related emissions is unknown, but they occur preferentially in regions with lower emission regulations and sparse combustion source measurements. The uncertainty range comes from a 60 to 70%

Accepted Article

uncertainty in BC AAOD and a 50% uncertainty in absorption forcing efficiency, due to uncertainties, respectively, in the amount of atmospheric absorption attributed to BC and dust and in the underlying reflectivity of the surface and atmosphere, particularly the presence of clouds below BC (Section 5.7). Our assessment of the direct radiative forcing from BC is a +0.71 W m^{-2} best estimate with a 90% uncertainty range of +0.08 W m^{-2} to 1.27 W m^{-2}. Fossil-fuel BC emission contributes approximately +0.29 W m^{-2}, biofuel +0.22 W m^{-2}, and open burning +0.20 W m^{-2} (see Section 10). Figure 9.1 also presents the pre-industrial background plus industrial-era direct forcing from BC. This is comprised of emissions from all anthropogenic and natural sources. This all-source climate forcing is evaluated to be +0.88 W m^{-2} with a 90% uncertainty range of +0.17 to +1.48 W m^{-2}.

9.4.2. BC cloud indirect effects

[7] BC effects on clouds, discussed in Section 6, are particularly poorly constrained. Many GCM cloud schemes do not reconcile treatments of clouds with small-scale cloud models. The vertical location of BC-containing particles relative to clouds is not well modeled. BC must be collocated with clouds for microphysical effects, and the sign and magnitude of semi-direct effects depend on the BC location relative to the cloud and cloud type. There are general uncertainties regarding the microphysical effects of all aerosols on clouds, and effects of individual species are even more uncertain. Only a few model studies with appropriate diagnostics have focused on the role of BC on these cloud effects. Modeled aerosol microphysics and cloud responses have not yet been closely constrained by observations or comparison with cloud-resolving models. The magnitude of aerosol-induced cloud changes is small compared to the spatial and inter-annual variability in modeled cloud forcing, so quantifying changes due to aerosol forcing is difficult. Our best attempt at assessing likely ranges for these cloud effects is discussed below. These ranges are based on a combination of model results and subjective assessment (see Table 9.1 and Section 6). Modeling of aerosol influence on clouds has not elucidated sensitivities to all factors, so it is not possible to develop a true uncertainty as we have for other forcing terms. Instead, the uncertainty is based on model diversity.

9.4.2.1. Liquid cloud and semi direct effects

[8] The semi-direct effect follows from the in-situ heating of the atmosphere from the direct radiative forcing of BC. Heating causes several observed and modeled effects on cloud properties and their distribution, via changes in atmospheric stability and regional circulation. These cloud rapid adjustments can be quantified in W m^{-2}. There is good agreement in models that realistic distributions of BC have a semi-direct effect that yields a negative forcing. Our best estimate of the climate forcing from the semi-direct effect (-0.10 ± 0.2 W m^{-2}) is based on two modeling studies that explicitly calculate the forcing and on five model studies that calculated a reduced radiative-forcing efficacy of BC direct forcing. The reduced efficacy was interpreted as being an adjustment in cloud distributions resulting from BC direct forcing and, therefore, a semi-direct forcing. Semi-direct effects are more properly associated with the 'rapid adjustment' component of the direct radiative forcing term. Yet, for consistency with how the cloud indirect effects are estimated in climate models, this forcing is combined with the warm liquid-cloud forcing estimate.

[9] Climate forcing due to changes in warm liquid clouds occurs principally from changes in cloud microphysics. Uncertainty results from lack of constraint on particle size, number and composition. A small amount of BC may reduce CCN by suppressing new particle formation. BC with co-emitted OA make more and better CCN, causing increased cloud albedo and an overall negative radiative forcing. This estimate is based on a limited number of microphysical models that have isolated the effect caused by BC.

[10] BC also causes additional rapid adjustments to cloud, inducing both semi-direct and cloud lifetime changes. These semi-direct and lifetime effects are also included in the estimate of the warm liquid-cloud climate forcing, as the models used to estimate this effect have not separated the microphysical component. The main uncertainty arises from the fact that lifetime effects are inferred from total anthropogenic aerosol studies and the impact of BC aerosol on cloud lifetime has not yet been isolated. The

Accepted Article

climate forcing for the BC effect on liquid cloud including rapid adjustment and semi-direct effects is assessed to be -0.2 W m^{-2} with a 90% uncertainty range of -0.61 to +0.10 W m^{-2}.

9.4.2.2. BC inclusion in cloud drops

[11] BC, when present in cloud drops, changes their absorption characteristics and increases absorption within a cloud. A small number of studies have assessed this radiative forcing and have explored assumptions about the optical properties of mixed particles and their shape. Uncertainties arise due to different optical representations of the BC and droplet combination, which affects in-cloud heating rates, leading to rapid adjustments. This adjustment would be separate from other semi-direct effects. The climate forcing for the effect of BC inclusion in cloud drops, including their rapid adjustment, is assessed to be +0.2 W m^{-2} with a 90% uncertainty range of -0.1 W m^{-2} to +0.9 W m^{-2}.

9.4.2.3. Mixed-phase cloud effect

[12] Climate forcing through changes in mixed-phase clouds is a mixture of radiative forcing and rapid adjustments. BC acts as an ice nucleus and can thereby produce increased glaciation rates, changes in precipitation, and changes in lifetime (Section 6.6.2). The forcing estimate is based on a range of three studies employing anthropogenic BC emissions that has been scaled to total BC emissions in year 2005. Confidence in this forcing value and range is very low as the physical processes are not properly understood. Major uncertainties are that this estimate is based largely on a single model and does not have any observational constraint. The climate forcing for the BC effect on mixed phase cloud is assessed to be +0.18 W m^{-2} with a 90% uncertainty range of +0.0 to +0.36 W m^{-2}.

9.4.2.4. Ice cloud effect

[13] BC may affect ice clouds via two mechanisms. First, BC could increase the number of ice particles, which can lead to increased cloud amounts and positive forcing. Second, it can lead to increased numbers of supercooled solution droplets, thereby reducing the atmospheric relative humidity and cloud cover, and resulting in negative forcing. Both these effects are seen in modeling studies. Our estimate of the BC influence on ice-cloud is based on two modeling approaches that lead to forcings of different signs for total BC emissions, and a third modeling study that found no significant effect (see Section 6.5.3.4). This climate forcing term is also a mixture of radiative forcing and rapid adjustment. The climate forcing for the BC effect on ice-cloud is assessed to be 0.0 W m^{-2} with a 90% uncertainty range of -0.4 to +0.4 W m^{-2}.

9.4.3. BC in snow and cryosphere changes

[14] The BC-in-snow forcing estimates arise from changes in snowpack reflectivity and rapid adjustments to that forcing, constituting an adjusted forcing. The best estimate and range is based on a number of model results adjusted based on comparisons to observations of Arctic snow BC concentrations (Section 7.4 and 7.6.1). The lower (upper) bounds on snowpack BC forcing are calculated by adding in quadrature the forcing from low (high) bounds in emissions, rate of snow aging, BC mass absorption efficiency, and snow cover fraction, and using the high (low) bounds in the efficiency of BC scavenging with melt and in the role of dust in reducing snowpack albedo. The range in forcing does not account for uncertainty in the patchiness of snow cover or uncertainties in modeled cloud cover and vegetation cover. It also does not account for possible biases in modeled mid-latitude snow BC concentrations.

[15] The climate forcing for snowpack shown on Figure 9.1 scales the adjusted forcing by an efficacy of 3 (2 to 4 range) to give an effective forcing that accounts for both rapid adjustments in the snowpack, the strong impact of this forcing on near-surface temperature and the strong snow albedo feedback (see Section 8). The industrial-era effective forcing for BC in snow is assessed to be +0.11 W m^{-2} with a 90% uncertainty range of +0.016 to +0.31 W m^{-2}. The all-source effective forcing is assessed to be +0.12 W m^{-2} with a 90% uncertainty range of +0.02 to +0.36 W m^{-2}.

9.4.4. BC in sea ice

Accepted Article

[16] Radiative forcing by BC on summertime sea ice after snow has melted (bare sea ice) is assessed separately and only includes forcing by the direct change in ice albedo with the inclusion of BC; unlike BC in snow this forcing does not account for rapid adjustments to the snowpack and, thus, is a radiative forcing. Most model studies to date have not included this forcing by BC on bare sea ice, and those that have do not separately diagnose this forcing term. While snow BC forcing is dominant in the spring, bare sea-ice forcing arises due to the enhanced absorption of sunlight in June-July-August-September in the Arctic Ocean. The radiative forcing bounds presented in Section 7 are based on estimates of sea-ice coverage, melt-pond area, area of sea ice covered in snow, sea-ice grain size, cloud cover and average solar irradiance (Section 7.6.2). The climate forcing in Figure 9.1 scales the direct radiative forcing of sea ice by an efficacy of 3 (2 to 4 range). Currently, no modeling study has explicitly calculated this efficacy for BC in sea ice so we assume the same efficacy as for BC-in-snow effects, as forcing by BC in sea ice directly warms the sea ice and leads to ice melt and, thus, also leads to enhanced albedo feedback. The industrial-era effective forcing for BC in sea ice is assessed to be +0.033 W m^{-2} with a 90% uncertainty range of +0.014 to +0.064 W m^{-2}. The all-source effective forcing is estimated to be +0.036 W m^{-2} with a 90% uncertainty range of +0.016 to +0.068 W m^{-2}.

9.4.5. Net effect of BC and co-emitted species

[17] It is important to remember that BC is not emitted in isolation. Co-emitted aerosol species such as organic matter, sulfate, and O_3 precursors also affect climate, and many mitigation actions could affect all of these species. Thus, 'climate forcing by BC' is a useful paradigm for exploring physical effects, but it is not a practical one: this forcing could neither be measured individually nor removed from the aerosol mix through mitigation actions.

[18] The lower two bars in Figure 9.1 demonstrate how the total climate forcing by BC (top bar), compares with the total climate forcing from the mix of BC and its co-emitted species (bottom bar). These combined forcing values require estimates of climate forcing by non-BC species, and Section 10 describes how we estimate and combine these values based on previous literature. These additional climate-forcing terms are introduced in Figure 9.1 to remind the reader of the close coupling between BC and co-emitted species. The remainder of this section continues the discussion of BC alone, and Section 10 explores the question of co-emitted species in more depth.

9.5. Uncertainties in BC global climate forcings

[19] Uncertainties in BC global climate forcings arise from many potential sources as discussed below. Except as noted, we have assumed that diversity in model results already reflects these uncertainties.

9.5.1. Atmospheric burden, emissions, and rate of deposition

[20] Concentrations of BC in the atmosphere and in snow are affected by emissions, lifetime and removal rates. The range of lifetime estimates is largely due to uncertainties in wet deposition, leading to uncertain concentrations in both the atmosphere and cryosphere. Uncertainties in deposition rates appear to lead to large errors in the atmospheric burden in remote areas (Section 4). In the Arctic, variations in wet deposition strongly affect atmospheric BC concentrations [*Garrett et al.*, 2010] and wet deposition rates directly affect surface snow and ice concentrations. Our atmospheric direct forcing estimate is constrained by observations (Section 5), although this constraint itself has significant uncertainties. If modeled BC emission rates were larger, they would not have a great effect on forcing estimated here, as models would have a larger burden, and a lower correction to observations would result. A similar argument applies to atmospheric lifetime, although observational constraints are less stringent over oceans. In-situ observations of surface snow concentrations have similarly been used to adjust for apparent biases in modeled surface snow concentrations (Section 7), though this adjustment does not account for interannual variability in snow concentrations.

[21] Large uncertainties in atmospheric burden estimates may result from interpretation of observations. It is difficult to distinguish absorption optical depth attributable to dust from that attributable to BC (Sections 4 and 5). Also important for direct radiative forcing and cloud effects is the atmospheric vertical distribution of BC. Vertical distribution varies between models and

Accepted Article

can lead to factor of two differences in direct forcing (Section 5). Uncertainties in BC distribution, especially aloft, may cause large changes in cloud effects that are affected by BC concentration (Section 6). Although recent observations can help constrain this uncertainty range for the direct forcing, this has not been possible for the cloud effect terms, where this uncertainty is assumed to be captured by the range of model forcing results (Section 6).

9.5.2. Selection of pre-industrial emissions

[22] Industrial-era BC forcing depends on the magnitude and distribution of pre-industrial emissions and on atmospheric aerosol transport pathways and deposition rates in the pre-industrial climate. Forcing by BC in the cryosphere further depends on the distribution of snow and ice cover in 1750. Shifts in the latitudinal distribution of emissions affect BC atmospheric lifetimes, forcing efficiency, proximity to clouds, and deposition to surface snow and ice. Pre-industrial open burning emissions are particularly uncertain, and changes in assumptions about both the magnitude and location of these emissions would alter the estimate of pre-industrial forcing. Presently, the largest open-burning emissions are in sub-tropical Africa and South America and are largely anthropogenic (Section 3). In contrast, in 1750 there was likely significant open burning from land-clearing activities at northern mid-latitudes. The assumed pre-industrial level of aerosol particularly affects non-linear cloud forcing terms.

9.5.3. Scaling to emission rate or atmospheric burden

[23] We assume in this work that the components of BC forcing generally scale with global emissions or atmospheric burdens. This assumption is reasonably valid for direct forcing. For cloud and cryosphere forcing (see Sections 6 and 7), this scaling may be valid for small deviations from the modeled state, but it has not been properly evaluated for many of the effects considered here. In particular this linear scaling may not hold over highly polluted regions or for large estimated changes. For cryosphere BC forcing, changes in the latitudinal distribution of BC emissions between pre-industrial and present-day makes scaling by emissions to estimate pre-industrial forcing particularly uncertain. This is accounted for using modelled estimates of the fraction of total emissions from biomass burning deposited to snow in 1750 versus in present-day.

[24] Emissions of co-emitted species and other aerosol, such as dust, also affect direct forcing, cloud forcing and snow and ice forcing by BC. Uncertainties in the regional pattern of emission are also important for global forcing, as BC emitted in different regions can give different climate forcing per emission due to longer atmospheric lifetime, snow deposition, or above-cloud fraction.

9.5.4. Dependence on atmospheric and surface state

[25] Climate forcing estimates depend on the latitudinal distribution of BC, background clouds, surface albedo, the presence of other aerosol, and especially on the relative vertical distributions of clouds and BC. Underlying surface reflectivity, particularly from distributions of snow and ice, are important both for BC-in-snow forcing and accurate determination of the direct effect. For BC in snow we use uncertainties from one model study to derive the bounds in present-day forcing, which include uncertainty in snow cover. For BC in sea ice, bounds are calculated based on a range in sea-ice cover, snow cover on sea ice, melt ponds on sea ice, and cloud cover. Changes in snow and ice cover from pre-industrial to present-day are not accounted for in the industrial-era estimates of BC cryosphere forcing (Section 7). For the other terms, uncertainty due to atmospheric state has not been explicitly estimated, but it is assumed to be captured by the range of model results employed.

9.6. Total forcing estimates and comparison with previous work

[26] The total climate forcing value and uncertainty in Figure 9.1 are estimated by combining the estimates and uncertainties of the individual forcing terms. The construction of this error is shown in Figure 9.2, which shows the error analysis for individual terms (top panel), the role of semi-direct effects and efficacy (middle panel) and the aggregate climate forcing terms (bottom panel). To combine errors we make a number of assumptions, outlined below.

Accepted Article

1. We assume that the total climate forcing of BC is represented by the sum of individual forcing terms. Efficacies are explicitly included in the individual bars for the BC-on-snow and BC-on-sea-ice terms, but not explicitly included for the other terms (see center panel of Figure 9.2). Our summation, therefore, assumes that the efficacy of the combination of the direct radiative forcing terms and the adjusted forcing from the cloud effects and semi direct effects would be equal to one and, therefore, comparable to the effective snow and sea-ice forcings. This implies that all rapid adjustment effects are accounted for and the resulting geographical pattern of forcing would not be that different to an equivalent forcing from CO_2 to make a material difference to the efficacy.

2. To account for covariance between errors in component terms, we assume that emission uncertainties provide the only commonality between the uncertainties of each term. We also assume that emission uncertainty has a negligible effect on the cloud forcing uncertainty, as the large uncertainties are caused by differences in model processes. Emission uncertainty accounts for 50% of the relative uncertainty in direct forcing (Section 5) and 32% of the relative uncertainty in snow and sea-ice effective forcing (Section 7). This leads to a 0.16 correlation between the direct forcing and the snow and sea-ice terms, and a correlation of 0.1 between the snow and sea-ice terms themselves.

3. We assume that uncertainties, shown by whiskers on the contributing forcings in Figure 9.1, represent a 90% (5%-95%) uncertainty range and construct the probability distribution functions (PDFs) in Figure 9.2 accordingly. The uncertainty of the total climate forcing also assumes that the distribution of probability within a given range is formed from combining either normal or log-normal distributions. Symmetric normal distributions are used for the mixed-phase cloud, ice-cloud and cloud-droplet inclusion effects. Asymmetric normal distributions are used for the direct effect and the liquid-cloud and semi-direct effects. Asymmetric log-normal distributions are used for the BC-in-snow and the BC-in-sea-ice effects.

[27] Using these assumptions a Monte Carlo model was run one million times to produce the estimate of climate forcing. The random number sequences generated are used to choose a point to sample in the forcing range, based on a fraction of the area under the probability distribution curve. The forcing value defined by the fractional area is then chosen to represent the forcing for that mechanism during the given iteration. Correlated errors are allowed for by making the appropriate fraction of the random numbers generated match between the direct forcing and the snow and sea-ice terms. To generate correlated errors a subset of the same random number sequences are used for the correlated forcing terms. For example, 10% of the random number sequence for snow and sea ice identically match, giving their million-point forcing series a correlation of 0.1. The PDFs for the different climate-forcing terms are shown in Figure 9.2. Using this methodology the individual forcing terms are combined to estimate the overall error shown in the total climate-forcing error bar in Figure 9.1 and the pdf (black line) shown in the bottom panel of Figure 9.2. The bottom panel also shows subgroups of terms from which the least certain terms are excluded in order to highlight the role of uncertainty in the best estimates. In this assessment we include all these uncertain terms in our best estimate of the total climate forcing of BC, acknowledging that they add large uncertainty.

[28] Our assessment is that the overall climate forcing for BC is more positive and more uncertain than that from the direct radiative forcing alone (*i.e.,* comparing red and solid black pdfs in the bottom panel of Figure 9.2). Introducing additional cloud forcing terms increase both the median and spread of climate forcing. Principal results from this uncertainty analysis combined with those in Sections 5, 6, and 7 are:

1. Radiative forcing from the BC direct effect is +0.71 W m^{-2}, with a 90% uncertainty range of +0.08 to +1.27 Wm^{-2}.

2. The estimate of all-source (*i.e.,* 1750 background plus industrial-era) direct radiative forcing of +0.88 W m^{-2} with a range of +0.17 to +1.48 W m^{-2} is similar to the +0.9 W m^{-2} given by *Ramanathan and Carmichael* [2008].

3. The globally averaged, industrial-era, total climate forcing from BC is +1.1 W m^{-2} with a 90% uncertainty range of +0.17 to +2.1 W m^{-2}. This distribution gives a 2% chance that the total effect of BC in isolation is actually a cooling effect (negative

Accepted Article

climate forcing), rather than a warming. It is, therefore, extremely likely (greater than 95% chance) that BC emissions acting alone lead to a present-day overall positive forcing and climate warming. This best estimate of black carbon forcing ranks it as the second most important individual climate-warming agent after carbon dioxide when both direct and indirect effects are included. For comparison, the radiative forcings including indirect effects from emissions of the two most significant long-lived greenhouse gases, carbon dioxide (CO_2) and methane (CH_4), in 2005 were +1.56 and +0.86 W m^{-2}, respectively (see Table 2.13 in IPCC [2007]). The Monte Carlo procedure produces a central estimate that is slightly different than a simple sum of the forcing terms.

4. Considering only radiative forcings ignores the changes imposed by rapid adjustments. For BC, all effects need to be considered to get a true representation of the climate forcing. These additional effects are demonstrated in the middle panel of Figure 9.2, where accounting for many semi-direct effects leads to a more-negative liquid-cloud climate forcing, and accounting for the higher efficacies of BC-in-snow and BC-in-ice forcings leads to a more positive forcing.

5. While there are large uncertainties in the role of BC effects on clouds, the best estimate of their combined net effect, including the semi-direct effect and cloud droplet inclusions, is +0.23 W m^{-2} with a 90% uncertainty range of -0.47 to +1.0 W m^{-2}. This value is also slightly different than a simple sum of the terms. Therefore, studies that exclude all these cloud effects may have a negative bias in forcing. Many model studies agree that semi-direct and liquid-cloud estimates are negative. However, only a few studies have examined how BC affects cloud absorption and subsequent burnoff, as well as mixed-phase clouds, and these poorly understood effects increase the total positive forcing from +0.65 to +1.1 W m^{-2}. Only one group has estimated the BC forcing effect for ice clouds, indicating that the magnitude could be large but the sign is unknown.

6. These cloud adjustments also significantly increase the uncertainty in their respective climate forcings and greatly increase the overall large uncertainty in the total climate forcing.

7. The combined BC on snow and BC on sea-ice effective forcing over the industrial era is estimated to be +0.13 W m^{-2} with a 90% uncertainty range of +0.04 to +0.33 W m^{-2}. The effects of BC on snow and ice is unequivocally a net positive forcing, so any study of BC climate forcing that does not include those effects is biased towards a smaller warming effect.

8. Uncertainties in cloud forcing are of a different character than uncertainties in direct or snow forcing, and are determined using model diversity rather than the more rigorous method of identifying governing factors and propagating uncertainties in those factors.

[29] The IPCC Fourth Assessment Report only considered radiative forcing of BC and did not consider its total climate forcing [*Forster et al.*, 2007]. IPCC estimated a 1750-to-2005 fossil-fuel BC direct radiative forcing of +0.2 ± 0.15 W m^{-2}, somewhat lower than our direct-forcing estimate of BC from fossil fuel of only +0.27 W m^{-2}. IPCC did not explicitly evaluate the direct forcing of other sources of BC, including biofuel combustion. Table 2.13 of *Forster et al.* [2007] lists the direct radiative forcing values for 'anthropogenic' BC as obtained from published studies and AeroCom models, which together yield an average of +0.34 W m^{-2} (+0.09 to +0.59 W m^{-2} range). This value is smaller than the best estimate found here of +0.71 W m^{-2} (+0.08 to +1.27 W m^{-2} range). The evolution of forcing estimates between the IPCC tabulation and the present assessment is explained as follows.

1. Some of the studies in the IPCC tabulation used relatively larger emission estimates. Forcing adjusted to a common bottom-up emission inventory would be lower, as reflected in the reported AeroCom average of +0.27 W m^{-2}

2. AAOD and, hence, forcing, increases by about 50% when the change in MAC_{BC} due to internal mixing is considered. Applying this correction to the IPCC value would give +0.41 W m^{-2}.

3. The apparent BC burden in the atmosphere is greater than that in the models. The adjustment required to match industrial-era observations, even after the consideration of increased MAC_{BC}, is an additional factor of 1.9, giving +0.77 W m^{-2}. This value is similar to the +0.84 average in Table 5.2, but not identical, because it is not based on the same models.

Accepted Article

4. The estimated model-average forcing was decreased by 15% to account for the fact that models place BC too high in the atmosphere. This adjustment to the IPCC estimate gives a radiative forcing of +0.65 W m^{-2}.

5. The remaining difference between the scaled IPCC value of +0.65 W m^{-2} and our direct-forcing estimate of +0.71 comes from the inclusion of model results published since the last IPCC report.

6. The higher value of forcing presented here is supported by observations of increased MAC_{BC} and underestimated atmospheric absorption. Therefore, our estimate is more robust than the purely model-based estimate in IPCC.

[30] Caution is required when considering total, global-average forcing as the sole metric for expressing the impact of BC emissions on climate change. The climate forcing of BC, and all aerosols, is much more regionally variable than for long-lived GHGs and this metric does not relate to expected precipitation changes (see Section 8). These factors may affect the consideration of how BC would be included in climate mitigation strategies (see Section 12).

[31] The equilibrium surface temperature change associated with the BC climate forcing can be estimated by multiplying the forcing values with estimates of climate sensitivity. *IPCC* [2007] estimated a 5 to 95% likely range for equilibrium warming from a $2xCO_2$ change of 2.0 to 4.5 K. Using a $2xCO_2$ RF of 3.7 W m^{-2} [*Forster et al.*, 2007] gives a climate sensitivity range between 0.54 and 1.22 K W^{-1} m^2. Combining errors of sensitivity in quadrature with the industrial-era total climate-forcing range for BC leads to an equilibrium warming for global mean temperature in the range of 0.1 to 2.0 K. This temperature change has not been realized in the present day as the Earth system takes more than a century to reach equilibrium, and many co-emitted species counter the warming of BC. For comparison, the estimated equilibrium warming from the combined effects of all short-lived species from BC-rich sources is between -1.5 and 1.4 K.

Accepted Article

10. Net climate forcing by black-carbon-rich source categories

10.1. Section summary

[1]

1. The net climate forcing of emissions from BC-rich source categories or individual source types depends on the effects of co-emitted species, such as organic carbon, sulfate, and gaseous constituents in addition to all effects of BC.
2. We use previously developed forcing-per-emission values to provide a comprehensive estimate of forcing from BC-rich source emissions. As for BC, large uncertainties are introduced in estimating cloud effects of co-emitted aerosols and aerosol precursors.
3. Attribution of direct forcing and cryosphere changes to emitting sources is relatively straightforward. For these effects, net forcing is positive for all BC-rich source categories.
4. Attribution of forcing by cloud changes and nitrate formation to emitting sources is uncertain because effects on cloud droplets are non-linear and complex. When this indirect forcing contribution is included, using a simple linear proportionality to emission rate, net climate forcing becomes neutral to negative for all source categories except diesel engines and, with greater uncertainty, some residential solid fuel.
5. Source categories are often heterogeneous. Individual sources within each category have different profiles of chemical emission components and may have relatively more positive or more negative forcing than the category average might indicate.
6. Our best estimate of the net climate forcing in the first year after emission from BC-rich sources is -0.06 W m^{-2} with 90% uncertainty bounds of (-1.45, +1.29) W m^{-2}. This net forcing would be +0.22 with a range of (-0.50, +1.08 W m^{-2}) if open burning emissions, which emit high levels of organic matter, were excluded. These values include all effects lasting less than one year, including those from aerosols and short-lived gases.
7. For most of these source categories, short-lived species have substantial forcing in the first year after emission, and this forcing is significant in comparison with forcing by emissions of all species over longer time scales. When climate forcing by all co-emitted species is integrated over 100 years, the magnitude of integrated forcing by short-lived species from each source category ranges from 5 to 75% of forcing by longer-lived species, including CH_4 and CO_2. The sign of short-lived species can be either positive, enhancing GHG warming, or negative.
8. Integrating net forcing by aerosols, O_3, CH_4, and CO_2 masks complex spatial patterns in forcing that differ over time. Climate forcing through effects on the CH_4 system tends to offset some of the effects of short-lived species. For diesel engines, longer-term negative forcing via NO_x offsets short-lived positive forcing; for biofuel sources, longer-term positive forcing via organic gases offsets short-lived negative forcing that is largely attributable to cloud effects.
9. *Reduction of aerosol concentrations by mitigating BC-rich source categories would be accompanied by small to no changes in short-term climate forcing.* In contrast, mitigation of other aerosol sources would increase positive short-term climate forcing. All aerosol that is emitted or formed in the lower atmosphere adversely affects public health, so mitigation of most BC-rich source categories offers a method of reducing health impacts with lower risk of adverse effects on climate.

10.2. Introduction

[2] Until this point, we have focused entirely on how BC affects radiative and climate forcing. However, BC is never emitted in isolation. Changes in source magnitudes affect all emitted species, whether those changes are deliberately chosen for mitigation, or occur without intention. Estimates of climate changes caused by BC forcing alone were summarized in the previous section, but those values do not reflect the net climate effect of altering sources whose emissions contain high concentrations of BC (*i.e.,* BC-rich sources).

Accepted Article

[3] In this section, we estimate the net climate forcing of emissions from BC-rich sources, considering the major emitted species. Some species that make minor contributions to mass have been ignored. In order to provide the net climate forcing by these sources, estimates of forcing by other species that are co-emitted with BC are also required. As in the presentation for BC, we require consideration of all effects. However, this assessment does not include recommendations for climate forcing by other species and we rely mainly on previous published summaries for these values. Therefore, the resulting quantification should be viewed cautiously. Although accounting for forcing by co-emitted species is fraught with uncertainty, ignoring these effects may convey a mistaken impression about the magnitude or even the sign of net climate forcing by BC-rich sources.

[4] We first discuss the approach to estimating net forcing values for a particular source activity. In Section 10.2, we describe methods to estimate forcing-per-emission values for each co-emitted species. Then, in Section 10.3, we estimate the net climate effect of the BC-rich source categories summarized in Section 3. These categories are aggregates of many individual source types, such as certain types of diesel engines or cooking stoves, whose emission component profile may differ from that of the aggregate category. Estimates of forcing for a few of these individual sources are summarized in Section 10.4. In these first sections, we present only forcing by short-lived species (*i.e.,* those with lifetimes less than one year). This near-immediate forcing is attributable primarily to aerosols, their precursors, and emitted O_3 precursors. In Section 10.5, this forcing in the very short term is compared with GHG forcing on decadal scales.

10.3. Approach to estimating forcing from BC-rich source categories

[5] Determining the net change in climate forcing per change in emission or per change in activity is the goal of this section. This quantitative measure may be thought of as the slope of a curve representing forcing versus activity, at present-day conditions. A fully comprehensive measure would aggregate all effects caused by all emitted pollutants from a particular source. Previous work on this topic has estimated the influence of a particular source either by summarizing direct forcing by all pollutants [*Fuglestvedt et al.*, 2010], or by examining the influence of all pollutants from source sectors with a model that represents multiple climate mechanisms [*Jacobson,* 2004; *Unger et al.* 2010].

[6] Missing in these progressive studies are systematic methods for incorporating scientific uncertainties, for incorporating findings from other studies that may differ, or for altering findings as knowledge advances. Here, we present the foundations of such a framework. Its essential elements are expert recommendations of the following for each chemical species emitted from a source:

1. Emission factors for a source activity;

2. Central values and uncertainties for the radiative forcings, obtained for a defined emission rate;

3. Central values and uncertainties for rapid adjustments, fast enough to be considered as part of a climate forcing, normalized to a defined emission rate.

[7] We begin with a source activity that emits I pollutants. Each pollutant may have J effects that are best expressed as radiative forcing values, and K effects that are expressed as rapid adjustments. To a first approximation, total climate forcing CF (in W m^{-2}) caused by an emission category (such as diesel), summed across all species emitted, is

$$CF = \sum_{i=1}^{I} EF_i \left(\sum_{j=1}^{J} rforc_{i,j} + \sum_{k=1}^{K} fresp_{i,k} \right) \qquad (10.1)$$

where FC is fuel consumption by the activity in kg s^{-1}, and EF_i is the emission factor of pollutant i (kg pollutant (kg fuel)$^{-1}$). The bracket contains forcing terms: $rforc_{i,j}$ is the change in radiative forcing for effect j and species i per emission rate of species i ((W

Accepted Article

m^{-2}) (kg s^{-1})$^{-1}$), and $fresp_{i,k}$ is the rapid adjustment for effect k and species i given in the same units. Each effect must be carefully distributed among the summations to avoid double counting. Further, this calculation assumes that forcings are additive. Although slight variants of the units given here are used in this section, the principle remains the same.

[8] Ideally the value $rforc_{i,j}$ would be determined as:

$$rforc_{i,j} = \left.\frac{\partial f_j}{\partial e_i}\right|_{PD} \qquad (10.2)$$

where f_j is the forcing via mechanism j, e_i is the emission of species i, the notation PD indicates present-day, and the partial derivative indicates that no other effects are operating and all other species are held constant. The same is true for the rapid adjustments. In practice, models usually provide total forcing or anthropogenic forcing, not partial derivatives. The assumption of linearity with respect to emission rate is adequate for many of the effects discussed here, but it breaks down for cloud microphysical forcings, as noted in the last section. Incremental changes in emissions are more realistic than removal or addition of entire source categories or pollutant categories. Model studies examining smaller emission changes may clarify whether total forcing divided by emission rate produces reasonable estimates for $rforc_{i,j}$ or $fresp_{j}$.

[9] Two other challenges in applying Equation 10.1 are interactions between species that affect forcing nonlinearly [*Stier et al.*, 2006b], and dependence of forcing on the region of emission [*Berntsen et al.*, 2006; *Naik et al.*, 2007; see Section 11]. We acknowledge that further development of Equation 10.1 should provide a method to account for these dependences. For the analysis here, we use total forcing divided by emission to approximate $rforc_{i,j}$ and $fresp_{i,j}$ for BC and all co-emitted species.

10.4. Climate forcing per emission for co-emitted aerosols and precursors

[10] Earlier sections of this assessment examined climate forcing by BC only. As discussed previously, we rely mainly on previous published summaries and analyses for forcing values of co-emitted species and have not evaluated the rigor of these estimates. Table 10.1 summarizes the basis for our best estimates of forcing per emission for sulfate and organic matter, for all effects that were previously given for BC, and the values used are given in Appendix C (Table C.1). The following subsections give more detail about the values chosen.

10.4.1. Direct effect for co-emitted aerosol and precursors

[11] Table 10.2 summarizes global mean estimates of direct radiative forcing and radiative forcing per emission for primary organic aerosol (POA) from a variety of studies. With little absorption, POA leads to a negative radiative forcing. Radiative forcing by total anthropogenic POA varies widely, from -0.06 to -0.49 W m^{-2}, with the smallest estimate coming from the study with one of the largest emissions. Consequently, the relative diversity in the radiative forcing per unit emission is even greater, with values ranging from -0.8 to -7.4 (μW m^{-2})(Gg yr^{-1})$^{-1}$. This diversity is largely due to uncertainty in the radiative forcing per unit mass, which varies from -24 to -198 W m^{-2} g^{-1}. Differences in radiative forcing per unit mass are more likely caused by assumptions about water uptake or optical properties than by differences in its vertical distribution, as most modeling studies do not represent absorption by OA. For radiative forcing by POA from fossil-fuel combustion, estimates of radiative forcing vary from -0.01 to -0.09 W m^{-2}, and the forcing per unit emission varies from -0.4 to -19 (μW m^{-2})(Gg yr^{-1})$^{-1}$, which is somewhat larger than that for total POA. A best estimate for POA radiative forcing per mass emitted with 90% uncertainty bounds is -4 ± 3 μW m^{-2} (Gg yr^{-1}) $^{-1}$, with greater magnitudes for POA from fossil-fuel combustion (-9 ± 9). With our increased estimate of 81000 Gg yr^{-1} (see Section 10.5), POA radiative forcing is -0.36 W m^{-2}.

Accepted Article

[12] Forcing by light-absorbing organic carbon, known as brown carbon, has not been explicitly considered here, although some of the models listed in Table 10.2 assume a small amount of absorption. *Park et al.* [2010] estimated that positive forcing by brown carbon over East Asia was about 15% as large as that of BC. *Jacobson et al.* [2001b] calculated forcing of all OA with some absorption and found smaller negative forcing of total OA than when no absorption was assumed. *Chung et al.* [2012] assigned about 20% of the carbonaceous aerosol AAOD to brown carbon and estimated that it had zero forcing rather than negative forcing. A fraction of our BC forcing estimate may in fact be attributable to brown carbon. If brown carbon contributes to atmospheric absorption, its contribution should be removed from the estimate of BC AAOD that is based on observations. The net forcing of brown carbon would be a combination of forcing by absorbing aerosol (presently subsumed in BC) and aerosol that is more highly scattering (presently subsumed in OA), and brown-carbon direct forcing would be about zero. Thus, although we have not explicitly isolated the contribution of brown carbon, the total forcing by BC and OA together would remain about the same.

[13] The most recent IPCC report provides a best estimate of -0.4 ± 0.2 W m^{-2} for direct radiative forcing by anthropogenic sulfate [*Forster et al.*, 2007]. Assuming the AeroCom estimate of 109,000 Gg S yr^{-1} [*Dentener et al.*, 2006], this translates to a range of -3.7 ± 1.8 (μW m^{-2})(Gg yr^{-1})$^{-1}$ for radiative forcing per mass of S emitted. Emissions used here are 96000 Gg S yr^{-1} from the GAINS database, giving -0.35 W m^{-2} direct forcing.

10.4.2. Liquid cloud effect for co-emitted aerosol and precursors

[14] The effect of co-emitted aerosol on liquid clouds has large uncertainties, both because estimates of the total liquid-cloud radiative forcing of anthropogenic aerosol vary widely, and because studies that isolate the contributions of individual pollutants or sources are scarce. (Exceptions are *Jacobson* [2002] and *Bauer et al.* [2010].) We adopt a preliminary approach to estimating changes in liquid-cloud forcing due to co-emitted species, which we describe first before listing several cautions.

[15] Our preliminary estimate of cloud climate forcing assumes that: (1) the liquid-cloud effect using AeroCom emissions has a central value of -0.9 W m^{-2} for the albedo effect and a range of -1.4 to -0.3 W m^{-2}, as summarized by *Isaksen et al.* [2009]; (2) the lifetime effect is negligible, as inferred from comparisons between GCMs and cloud-resolving models [*Wang et al.*, 2012]; (3) the liquid-cloud change in the studies contributing to the estimate is attributable to submicron species that are considered anthropogenic: BC, organic matter, and sulfate; (4) except for BC, the cloud effect may be apportioned among individual species by mass; and (5) the values of forcing per mass so determined can be used to scale to the new estimates of emission. The latter assumption is approximately justified if particle size is the dominant factor determining the number of CCN, because organic matter and sulfate have similar size distributions. Individual studies to determine liquid-cloud forcing may have used different emission rates; in particular, studies prior to the mid-2000s tended to use much higher OM emissions. However, *Quaas et al.* [2009] gave direct plus indirect forcing values of -1.25 W m^{-2} for 10 models even when they used the lower AeroCom emissions.

[16] Details of the liquid-cloud estimate are given in Appendix C (Table C.2 and C.3). Indirect forcing using AeroCom emissions is divided as -0.58 and -0.27 W m^{-2} for sulfate and organic matter, respectively. Sulfate is scaled to the total GAINS emission estimate and organic matter is scaled according to the regional BC scaling in Figure 5.4. Liquid-cloud indirect effect attributable to 96 Tg yr^{-1} of SO_2 emissions is estimated as -0.51 W m^{-2}, with an uncertainty range of -0.21 to -0.76 W m^{-2}. Liquid-cloud forcing attributable to 81 Tg yr^{-1} of organic matter is estimated as -0.74 W m^{-2} with an uncertainty range of -1.09 to -0.30 W m^{-2}. The apportionment by mass may overestimate negative forcing by organic matter, as its lower solubility has not been considered in the apportionment. However, a relationship with aerosol optical depth, as suggested by *Quaas et al.* [2009], would yield the same apportionment between sulfate and OA.

[17] Our treatment of liquid-cloud effects deserves several caveats. We caution that the liquid-cloud estimate for SO_2 and POA has not undergone a thorough examination as have the effects of BC. We have chosen to present a more realistic but less rigorous picture for net forcing by sources that are BC-rich, rather than a physically unrealistic depiction that evaluates BC alone. Modeling

Accepted Article

studies rarely examine the validity of apportioning total liquid-cloud effects among individual species, although *Chuang et al.* [2002] showed that cloud forcing per burden differed by less than 15% for sulfate only, carbonaceous aerosol only, and the combination.

[18] The relationship between cloud forcing, CCN, and emissions is not expected to be linear. Cloud forcing is more sensitive to increased particle concentration in a cleaner atmosphere, as demonstrated for global averages by *Boucher and Pham* [2002]. This is consistent with inferences of low indirect effect over land [*Ruckstuhl et al.*, 2010]. Therefore, our linear apportionment could overestimate the impact of the small fraction of total particle mass attributable to BC-rich sources.

[19] Studies disagree on the importance of primary particles, and the relationship between cloud forcing and the emission of primary particles such as BC or POA may not even be monotonic. One study indicates that primary particles play a larger role in cloud formation than other particles [*Adams and Seinfeld*, 2003], while others find that primary emissions suppress nucleation [*Bauer et al.*, 2010], and therefore have a much lower influence on CCN than would be expected in the absence of gas-particle interactions [*Merikanto et al.*, 2009].

[20] The discussion above indicates that the linear apportionment used here is a zero-order estimate. Yet, present understanding is insufficient to support a different apportionment. Although there is some evidence that forcing-per-emission values may be overestimated, models that account for microphysical interactions [*Bauer et al.*, 2010; *Koch et al.*, 2011a] have indicated greater forcing-per-emission of POA via liquid-cloud changes than our central value. The uncertainties given here reflect only the uncertainty in the magnitude of the indirect effect, not the uncertainty in apportionment, or regional differences in cloud behavior.

10.4.3. Other cloud effects for co-emitted aerosol and precursors

[21] Other cloud effects (*i.e.,* mixed-phase, ice-cloud and semi-direct effects) considered for BC are assumed negligible for sulfate and organic matter. These two species may influence water condensation and ice nucleation activity if they are emitted with BC (see Sections 2.8 and 6.6). This is particularly relevant for cold ice clouds, where BC particles do not become water droplets prior to ice formation. In this case, it is not possible to separate or scale cloud effects from the amount of co-emitted species. Two GCM studies [*Hoose et al.*, 2008; *Storelvmo et al.*, 2008] suggest that sulfate coating decreases the ability of mineral dust to act as IN. This increases the lifetime of supercooled water clouds, producing negative forcing. These effects have not yet been quantified and are not included here.

[22] In current understanding, aerosols with minimal light absorption have little effect on semi-direct forcing. All such changes are caused by light absorption that heats the atmosphere at various vertical locations (see Figure 6.1). We also do not include the effects of other absorbing material within cloud droplets, although absorbing OA may also contribute to enhanced cloud-droplet absorption [*Jacobson*, 2012]. As an approximation, we have captured the effect of absorbing aerosol by attributing all non-dust AAOD to BC and calculating all effects for that AAOD.

10.4.4. Snow albedo forcing for co-emitted aerosol

[23] *Doherty et al.* [2010] found that the light-absorbing aerosol in Arctic snow and sea ice had a strong wavelength dependence, and inferred from this the amount of light absorption due to BC versus other species, specifically brown carbon, mineral dust and soil dust. They reported that 40% of the spectrally weighted light absorption in snow and sea ice is due to these non-BC constituents. Because our estimate of snow albedo forcing was scaled to observations of BC, not of absorbing aerosol, total forcing must be increased to account for additional absorbing material. Only a small fraction of this absorption is due to mineral and soil dust, so we estimate global snow and sea-ice forcing by organic matter from combustion as 20% that of BC. We then scale this value to emissions of organic matter to produce an effective forcing per emission of 0.9 $\mu W\ m^{-2}\ (Gg\ yr^{-1})^{-1}$ with a range of 0 to 3.0, assuming an efficacy with a central value of 3 and an upper bound of 4. POA from solid-fuel combustion is known to absorb light,

Accepted Article

while other organic matter is not. Therefore, this forcing was applied only to POA emitted from solid fuel: biofuel, coal, and open biomass burning.

10.4.5. Forcing by co-emitted gaseous species

[24] Short-lived, co-emitted gaseous species considered here include carbon monoxide (CO), volatile organic compounds (VOCs), and NO_x. These species produce indirect forcing by interacting with tropospheric O_3 and CH_4 and, for NO_x, by producing nitrate. *Fuglestvedt et al.* [2010] summarized studies on radiative forcing by these compounds for the development of metrics. They did not provide recommendations for central values of forcing per emission, but a later study [*Uherek et al.*, 2010] used their summary to provide GWP values. We inferred a best estimate of forcing per emission using studies cited by *Fuglestvedt et al.* [2010], as shown in Appendix C (Table C.4). For each species, forcing is separated by mechanism, as suggested by *Shindell et al.* [2005]. All species increase O_3, representing a positive forcing that occurs within the first year. NO_x increases nitrate aerosol, giving a negative first-year forcing. These species also alter the lifetime of CH_4, causing forcing that lasts a few decades. CO and VOCs cause a positive forcing, while NO_x causes a negative forcing.

[25] Studies cited in *Fuglestvedt et al.* [2010] gave forcing values for the effects of NO_x emissions on CH_4 and tropospheric O_3 abundances but not for nitrate aerosol resulting from NO_x emission. We estimated a value of forcing per emission by nitrate by assuming that the nitrate forcing summarized by *Forster et al.* [2007] had the same emission base as that for O_3 from NO_x. This method is legitimate for short-lived species, such as nitrate and O_3 caused by emissions of NO_x or volatile organic compounds. (Present-day forcing values for long-lived species result from all historical emissions that remain in the atmosphere, and cannot be used to estimate forcing per emission.) While *Forster et al.* [2007] attributed all nitrate forcing to NO_x emissions, *Unger et al.* [2010] reported that sectors with substantial ammonia emissions also affect nitrate forcing. The nonlinearity of ammonium, sulfate, nitrate, and NO_x chemistry means that changes in nitrate forcing are difficult to attribute to particular sectors. We assign only 44% of the total nitrate forcing to NO_x emissions, based on the ratio of NO_x-related to total nitrate forcing reported by *Unger et al.* [2010].

10.4.6. Climate forcing by secondary organic aerosol

[26] Estimating the climate impact of sources using POA alone ignores the complex evolution of organic aerosol throughout the atmosphere. Emitted precursors lead to formation of substantial quantities of SOA [*de Gouw and Jimenez,* 2009]. Oxygenated organic aerosol, thought to be equivalent to SOA, is found wherever measurements are made [*Zhang et al.*, 2007]. SOA yields from diesel engines and wood stoves were estimated to be small in comparison to POA emissions [*Chan et al.*, 2009]. However, observed SOA appears to be much more prevalent than could be explained by models that treat identified SOA precursor molecules [*Robinson et al.*, 2007]. For that reason, mechanisms that account for SOA production have been proposed, using the fraction of emitted vapors with low volatility as inputs [*Donahue et al.*, 2006].

[27] SOA associated with individual sources has not been resolved in climate models. Direct forcing is often provided for POA alone [*Schulz et al.*, 2006], and models of cloud forcing have usually not distinguished POA versus SOA burdens. Simulations by *O'Donnell et al.* [2011] gave a direct effect due to SOA of -0.29 W m^{-2} and an indirect effect of +0.20 W m^{-2}. In this model, which did not include the volatility representation of SOA formation, 90% of the SOA burden came from biogenic sources.

[28] POA:BC ratios may underestimate the total atmospheric OA attributable to each source. Nevertheless, in this analysis, we neglect direct and indirect forcing by SOA. The single estimate of net SOA forcing given above is small, and the chain that relates precursor emissions to concentrations and global forcing is presently limited. We acknowledge, however, that this omission could be a source of bias.

10.4.7. Forcing in clear and cloudy skies

Accepted Article

[29] Modeled radiative forcing has been compared with clear-sky and cloudy-sky radiative fluxes observed from space [*Quaas et al.*, 2009; *Lohmann et al.*, 2010]. For that reason, we summarize the clear- and cloudy-sky forcing here. We assume that 30% of BC direct forcing takes place in clear skies [*Zarzycki and Bond*, 2010]. The remainder would be observed in cloudy skies. Clear-sky forcing includes 30% of BC direct forcing (+0.21 W m^{-2}), all OA and sulfate direct forcing, (-0.36 and -0.35 W m^{-2}, respectively), and nitrate direct forcing (-0.16 W m^{-2}) for a total of -0.66 W m^{-2}. Cloudy-sky forcing over liquid clouds includes BC direct forcing in cloudy skies (+0.50 W m^{-2}), BC liquid-cloud forcing including semi-direct effects (-0.20 W m^{-2}), the cloud absorption effect (+0.20 W m^{-2}), and liquid-cloud forcing by OA and sulfate (-0.74 and -0.51 W m^{-2}, respectively) for a total of -0.76 W m^{-2}. It is not clear whether the mixed-phase cloud forcing of +0.18 W m^{-2} would be observed in the analysis of radiances that primarily focus on liquid clouds. *Quaas et al.* [2009] scaled model estimates according to relationships determined from satellite observations to obtain forcing estimates of -0.38 W m^{-2} for clear-sky and -0.70 W m^{-2} for cloudy-sky fluxes. The total forcing estimated here is more negative for clear skies and similar for cloudy skies.

10.5. Net climate forcing by BC-rich source categories

[30] Using the values developed in the previous section, total climate forcing by BC-rich source categories can be estimated. Forcing per emission for each effect in W m^{-2} (Tg yr^{-1})$^{-1}$ is multiplied by total emissions, yielding units of W m^{-2}. Forcings by each species emitted within each category are then summed to provide the total industrial-era forcing representing the net forcing from each category. Annual emissions of BC, POA, SO_2, CO, non-methane volatile organic compounds (NMVOCs), and NO_x from each source category were summarized from the GAINS database for the year 2000 for energy-related emissions. Open burning estimates come from the RETRO database. Emissions were adjusted to reflect the observationally based scale factors given in Section 5.7, so that energy-related emissions were scaled by factors of 1.1 to 2.5, depending on the category, and open-burning estimates were increased by a factor of about 1.5. Emission rates used are given in Appendix C (Table C.5). For energy-related burning, we have assumed that the most uncertain factor is levels of activity with relatively high emission rates, and have adjusted those emissions associated with incomplete combustion (BC, POA, CO, NMVOC) with the scale factors used for BC. For open biomass burning, we assume that the cause of the uncertainty could be the low bias in emission factors of BC alone (see Section 3.7.2.3) and adjust only the BC emissions. Only the effects of POA are included here; some of the gaseous NMVOCs from these sources could form SOA after emission, adding to aerosol-driven forcing mechanisms. This possibility is discussed in Section 10.5.6.

[31] Figure 10.1 shows forcing by short-lived emissions in the BC-rich source categories summarized in Figure 3.2. These categories comprise 99% of the BC emissions, and the climate forcing includes all aerosol direct, indirect, and snow effects. We also include forcing changes caused by the interaction of CO, VOCs and NO_x with tropospheric O_3. These effects capture most of the forcing that occurs in the first year after emission.

[32] The forcings shown in Figure 10.1 result from the same treatment as applied in *Forster et al.* [2007]: that is, the values are those that would be observed if year-2000 emission rates continued indefinitely. It differs from IPCC figures because forcing is grouped by source category instead of by species, and because it gives total climate forcing values instead of direct forcing. The species chosen for this figure exert their forcing entirely within the first year after emission. Other emitted species or effects that act over longer time scales are discussed in Section 10.7. We have not included effective forcing due to vegetation changes [*Collins et al.*, 2010].

[33] The top bar in Figure 10.1 shows the forcing components that can be attributed to emissions with high confidence: direct forcing by aerosol and gases, effective cryosphere forcing, and cloud response to aerosol absorption. Attribution of liquid-cloud forcing to individual aerosol species or to particular sources is not well developed. We therefore segregate these forcing terms in the second (middle) bar, for which we have less confidence in attribution. The combined liquid-cloud effect, including the albedo

Accepted Article

and semi-direct effect, is separated from cloud effects that have larger uncertainties and were derived in fewer studies: the cloud absorption effect, the mixed-phase cloud effect, and the ice-cloud effect. Also included in this low-confidence bar is the negative forcing due to nitrate aerosol. The bottom bar shows estimated net forcing by each emission source, or the combination of high-confidence and low-confidence components.

[34] Uncertainties in aerosol forcing only, as discussed throughout this assessment for BC and in earlier sections for other aerosol species, are reflected in Figure 10.1. Uncertainties in emission factors and gaseous forcing are also important and are not represented here. A bar centered on the zero line means that forcing has equal probability of being positive or negative; a bar that barely crosses the zero line means that there is a slight uncertainty that the forcing has a different sign than the central estimate. In combining uncertainties, most of the effects are assumed to be independent. However, the best estimates and uncertainties for the effects of individual aerosol species on liquid clouds were derived by a simple subtraction. These cloud uncertainties are assumed to be fully correlated with each other.

[35] As the top bars in Figure 10.1 demonstrate, the net effect of direct and cryosphere forcing by aerosols and gases is positive with high confidence for many source categories. Inclusion of cloud forcing components (middle bar for each source) makes forcing more negative and increases uncertainty, especially when sources have comparatively large emissions of other aerosols or precursors. Cloud forcing also increases uncertainty in the sign of net forcings (lowest bar for each source). This simple apportionment is subject to several uncertainties, as detailed in Section 10.5.6.

[36] Positive and negative forcing components and sources of uncertainty differ among source categories, as discussed in more detail below. We also compare the values in Figure 10.1 with the few studies that have examined the total impact of economic sectors. This comparison must be interpreted in light of the fact that BC-rich source categories differ from total sectors.

10.5.1. Diesel engines

[37] Forcing that can be easily attributed to diesel emissions is positive with high confidence. Both cloud and nitrate forcing reduce the net forcing and increase uncertainty.

[38] BC is a large fraction of aerosol emissions from both on-road and off-road diesel engines. The relative impact of organic matter is low, and negative forcing in the high-confidence category comes primarily from the semi-direct effect. In the low-confidence group, negative cloud forcing, attributable to sulfur, approximately cancels the net positive cloud forcing by BC. This impact is greater in regions where low-sulfur fuel has not been mandated.

[39] In *Unger et al.* [2010], total cloud effects (including semi-direct effects) from all on-road engines are strongly positive and greater than one-half the direct BC forcing. *Bauer et al.* [2010] find that diesel emissions give positive cloud forcing equal to the direct forcing, but this study did not include sulfur emissions. *Jacobson* [2010] found a net decrease in cloud optical depth attributable to total fossil-fuel BC, OA, and sulfur, although this study examined the effect of only primary sulfur and aerosol components in order to examine the effect of end-of-pipe particulate controls. The effects of sulfur co-emitted with diesel engines have not been examined.

[40] Negative forcing by nitrate is also substantial in comparison with other forcing mechanisms, in agreement with *Unger et al.* [2010]. Neither *Bauer et al.* [2010] nor *Jacobson* [2010] considered changes in NO_x emissions.

10.5.2. Industrial coal

[41] Like diesel engines, industrial coal emissions (mostly from small industry) have a relatively large BC component and a small POA component. These emissions also include substantial sulfur, which causes negative forcing for both direct and cloud categories. These strong negative forcings agree with the results of *Unger et al.* [2010].

10.5.3. Residential solid fuel

Accepted Article

[42] Direct and snow forcings that are easily attributable to residential biofuel (top bar) are also strongly positive. Although POA-to-BC ratios are higher than for diesel engines, negative direct forcing by POA counteracts only about 20% of the BC direct forcing. This negative forcing would be greater if secondary organic aerosol was included here, but it still would not cancel BC forcing. In addition, absorption by OA deposited on snow and changes in tropospheric O_3 due to carbon monoxide and VOC add to positive forcing.

[43] Because these sources also emit POA, however, large negative forcing due to liquid-cloud interactions is predicted and introduces very large uncertainty. With our simple apportionment, these cloud changes are sufficient to make the net forcing near zero. NO_x emissions are low for these sources, so NO_x effects on either O_3 or nitrate forcing play very little role.

[44] A critical question is whether the cloud response due to residential solid fuels offsets the strong positive direct forcing. Models tend to agree that cloud interactions add some negative forcing for these sources, but they disagree on the magnitude. *Unger et al.* [2010] report a positive indirect effect, citing the portion of the semi-direct effect that burns off clouds, but without using aerosol microphysics. *Bauer et al*. [2010] added aerosol microphysics to the same GCM used by *Unger et al.* and found net negative cloud forcing three times greater than the positive direct forcing by BC. *Jacobson* [2010] shows increased cloud optical depth due to biofuel-burning emissions (including gases), but also finds a positive ToA forcing and a warming, suggesting that the cloud changes do not overwhelm the direct forcing. This study also includes ionic components of biofuel-burning emissions that affect water uptake and climate response.

[45] Residential coal emits more BC compared to POA than do residential biofuels. The sulfur-to-BC ratio is much higher than for residential biofuels, and much lower than for industrial coal. This category has net positive direct forcing mainly attributable to BC, and net negative cloud forcing mainly caused by sulfur. The result, with low certainty, is a slight net positive forcing.

10.5.4. Open biomass burning

[46] All three categories of open biomass burning emissions contain large POA fractions. As with residential solid fuel, the direct forcing by POA emissions does not fully counteract BC forcing, and forcing via O_3 has a substantial positive contribution. Once again, POA interaction with clouds is responsible for the large negative forcing, and large uncertainties. *Unger et al.* [2010] agree that cloud changes are large and negative. They also simulate a small negative nitrate forcing and a much larger POA direct forcing than calculated here.

10.5.5. Summary of BC-rich source categories

[47] For almost all source categories, net forcing that is easily attributable to individual species (*i.e.,* without clouds and nitrate) is positive with high confidence; that is, the lower limit of uncertainty is well above zero. Categories that emit relatively large quantities of sulfur are exceptions.

[48] The inclusion of forcing via clouds and nitrate makes the estimated impact of each category more negative and greatly increases the uncertainty. The origins of this negative, uncertain forcing differ among source categories. Sulfate effects on clouds are the primary cause for both residential and industrial coal. For diesel engines, the possible negative forcing comes from nitrate and cloud interactions with sulfate. Interactions between organic matter and clouds are the main source of uncertainty for residential biofuel and open biomass burning.

[49] Confidence in positive net forcing is highest for categories with relatively small quantities of co-emitted aerosols or precursors, such as diesel engines. Except for industrial coal, other energy-related combustion sources have a high probability of producing either positive or negative forcing. These source categories are quite heterogeneous, as discussed further in Section 10.6, so that individual emitters may still have net positive forcing.

10.5.6. Cumulative sum of forcing by BC-rich source categories

Accepted Article

[50] Figure 10.2 demonstrates the fact that BC forcing results from an aggregate of multiple sources by presenting the cumulative sum of source-category forcing from top to bottom. For example, the values listed for 'Industrial coal' are the forcing by industrial coal, on-road diesel and off-road diesel. This figure shows probability density functions for total climate forcing by BC alone (red line), for direct forcing by BC and all co-emitted species including organic matter and sulfate (purple line), and by all these species plus the forcing due to cloud changes (blue line). The highest point of each curve is the most likely value. The curve labeled 'Other BC sources' is the sum of all categories in Figure 10.1 and matches the total net forcing in Figure 9.1. In addition, Figure 10.2 includes forcing by emissions from two other source groups that emit large quantities of aerosols or precursors, but little BC (less than 1% of the global total).

[51] Figure 10.2 repeats some messages that appear in Figure 10.1. The best estimate of BC-only forcing is positive with high confidence, even when cloud forcing is considered. The best estimate of direct and snow forcing by BC and co-emitted species is also positive. However, when cloud forcing is considered, the best estimate of first-year forcing from many categories is only slightly positive because of the counteracting effects of co-emitted species. The figure also emphasizes the important distinctions between source categories. More than half the BC forcing in the aerosol mixture (red line in Figure 10.2) comes from diesel engines, industrial coal, and residential solid fuels (first six categories). These positive forcings are accompanied by negative direct and cloud forcings that result in climate forcing that is close to neutral (blue line in Figure 10.2). The remaining BC forcing comes from open burning, and it is accompanied by larger negative forcing. The thick black line separates BC-rich sources from others. The cumulative sum of forcing for the sources above that line is -0.06 W m^{-2} with 90% uncertainty bounds of (-1.45, +1.29 W m^{-2}). This total corresponds to the bars in Figure 9.1, which indicate the net climate effect of BC and co-emitted species. The total of all BC-rich sources excluding open biomass burning (*i.e.,* energy-related sources) is +0.21 W m^{-2} (-0.50, +1.08 W m^{-2}). This value is similar to the forcing estimate for energy-related emissions of BC and OA by *Kopp and Mauzerall* [2010]. However, this agreement is somewhat coincidental, as our estimate also includes direct and indirect sulfate forcing, semi-direct effects, cloud absorption, and mixed-phase and ice cloud effects. For that reason, our uncertainty is much greater than the *Kopp and Mauzerall* [2010] range of (+0.02, +0.37 W m^{-2}).

[52] The bottom two source categories in Figure 10.2 are power generation and a conglomeration of other low-BC sources. These categories emit very low BC amounts but are rich in sulfur and organic matter, and produce most of the net negative aerosol forcing. Including these two categories, forcing by aerosols, short-lived gases, and cloud changes is -0.70 W m^{-2} with 90% uncertainty bounds of (-2.32, +0.91 W m^{-2}). Thus, most of the net negative forcing is confined to source categories that are not BC-rich. All aerosol that is emitted or formed in the lower atmosphere adversely affects public health, so mitigation of most BC-rich source categories offers a method of reducing health impacts with a lower risk of increasing positive climate forcing.

[53] The green line in the bottom category shows the probability distribution due to aerosol sources alone, excluding short-lived gases. The total is -0.95 W m^{-2} with 90% uncertainty bounds of (-2.57, +0.67 W m^{-2}). The central value is slightly less negative than forcing estimated using an energy-balance approach and relying on observations [*Murphy et al.*, 2009]. However, our forcing estimate, which draws on ranges of modeled values, has much greater uncertainty bounds both above and below the central estimate than does the forcing estimate based on observations. It is possible that the broad uncertainty range from indirect effects is overstated.

10.6. Climate forcing by selected sources

[54] Figure 10.1 presents the magnitude of net forcing by sources in each category, emphasizing the sources with largest activities. These aggregated source categories are not homogeneous, but are made up of individual sources with different chemical emission profiles and rates. In Figure 10.3, we show forcing by individual sources that are contained within the major emitting categories. To do so, we obtain values for climate forcing per mass of fuel burned by multiplying emission factors (given in Table

Accepted Article

C.5), in mass of pollutant per mass of fuel burned, by the same forcing-per-emission values used for Figure 10.1 (see Table C.1 and C.4). Figure 10.3 shows total climate forcing per source activity, or quantity of fuel burned, emphasizing the difference in emission rates within categories. Sources with higher emission factors for a particular pollutant—usually those with the poorest combustion—have larger climate forcing per fuel burned. These sources are often easier or less expensive to mitigate (see Section 12). This presentation contrasts with Figure 10.1, which accentuates categories with large total emissions.

[55] The units of forcing in Figure 10.3 differ from those in Figure 10.1 and the standard treatment by IPCC because continuous emissions are not assumed. Instead, the forcing caused by consuming one kg of fuel is integrated over time to give units of ($\mu W\ m^{-2}$ yr) $(Gg\ fuel\ burned)^{-1}$. This difference is necessary because individual sources are unlikely to continue in perpetuity. However, the species or effects included in this figure have short atmospheric lifetimes, and this forcing occurs entirely during the first year after emission. For this reason, the values in this figure would be the same whether they represented continuous forcing for constant emissions, with units of $\mu W\ m^{-2}$ $(Gg\ fuel\ yr^{-1})^{-1}$, or integrated forcing from finite consumption, with units of $\mu W\ m^{-2}$ yr $(Gg\ fuel)^{-1}$. Likewise, the values in Figure 10.1 could represent integrated emissions from the year 2000, with units of $W\ m^{-2}$ yr.

[56] As in Figure 10.1, the top bar for each source includes direct forcing by aerosol and gases, cryosphere forcing, and cloud response to aerosol absorption. Other cloud responses and nitrate forcing are given in the middle bar, and the bottom bar shows the total of the two. Uncertainties are calculated in the same manner as for Figure 10.1 and, again, uncertainties in emission factors are not represented. Similar to the message in Figure 10.1, the sum of direct, cryosphere and semi-direct forcing by many source types is estimated to be positive. Cloud and nitrate forcing reduce the positive forcing and increase the possibility that the net forcing is negative.

[57] On-road diesel engines are a mix of low-emitting (controlled) engines using low-sulfur fuel and higher-emitting engines implemented in regions with limited regulations. The latter typically use fuel with higher sulfur content. Off-road diesel engines are presently more similar to the high-emitting engines. Modern engines with better combustion emit more NO_x and less PM, as seen in the positive forcing of NO_x on the ozone system. This positive forcing in the first year is counteracted by negative forcing in interactions with methane in later years (see Section 10.7). In contrast, the positive forcing by less advanced engines is dominated by BC.

[58] As in the category graph in Figure 10.1, direct and cloud forcing by sulfur are large for both residential and industrial coal sources. Industrial boilers have net negative forcing, but the high BC emission rates more than balance the negative forcing by sulfur for brick kilns and coal cooking stoves. This forcing is highly dependent on coal sulfur content. For example, the brick kiln emissions used in Figure 10.3 were measured in India, where sulfur content is low. The same source in a region with high-sulfur coal might have a different net forcing. Sources with poor combustion produce more BC compared with sulfur, and are more likely to have positive forcing.

[59] Wood used in many heating stoves (*i.e.,* conventional wood stoves) produces a higher POA:BC ratio than wood for cooking (*i.e.,* mud cooking stoves), while larger heating technologies (*i.e.,* 'wood boiler') can have low POA:BC ratios depending on the operation. This difference is apparent in Figure 10.3, which indicates a lower cloud impact from cooking with wood and a near-zero forcing. On the other hand, the best estimate of cooking stove emissions is net positive forcing, although the uncertainty is high. For this specific cooking type of stove, emission factors were taken from in-field measurements. Its net positive forcing contrasts with the net negative value for the entire source category given in Figure 10.1. This difference results from the choice of emission factors within the GAINS model (see Section 3.6.3). Emission factors specific to individual technologies need to be chosen carefully when sources, rather than categories, are scrutinized closely to determine the net effect on forcing.

[60] Profiles of field and forest burning are similar to the category graphs, with important contributions to direct forcing from organic matter and gases, and a net negative forcing due to cloud interactions with POA.

Accepted Article

[61] The values in Figure 10.3 represent the total climate impact of particular sources. They do not reflect the change caused by mitigation actions, which would be the difference between the current climate impact and the impact of the chosen alternative.

10.7. Comparison with forcing on longer time scales

[62] It is important to consider contributions to climate change beyond the first year after emission. Forcing results both from direct emissions of GHGs (*e.g.,* CO_2 and CH_4) and from short-lived air pollutants interacting with CH_4. While CH_4 is considered a shorter-lived pollutant in some discussions, its forcing is not contained solely within the first year after emissions as are the forcings of the other constituents discussed earlier in this section. Common practice is to integrate these forcings over 100 years after emission, and these integrated forcings are shown in Figure 10.4 as bars. Figure 10.4a shows the longer-lived forcings for year 2000 emissions within each source category in Figure 10.1, and Figure 10.4b shows the total forcing per mass of fuel burned for each individual source in Figure 10.3. For biofuel and open biomass burning, the contribution of CO_2 may not be treated as forcing in traditional GHG accounting, if the biomass consumed is regrown. Only combustion emissions are shown here, so, for example, refrigerants emitted from vehicles are not included.

[63] Figure 10.4 also shows the estimated forcing from Figures 10.1 and 10.3 for comparison (red circles). Because no forcing is exerted by these species or effects after the first year, the 100-year integral is identical to the values already given. The two types of forcing in the figure are distinct: one acts during the first year ('first-year forcing') and one requires longer integration times ('longer-term forcing'). These two groups form a mutually exclusive and collectively exhaustive set of forcing impacts by combustion emissions. Although forcing by CH_4 during the first year after emission is about 10% of its integrated forcing, we classify this as longer-term forcing because of the need for integration.

[64] First-year forcing by BC-rich source categories is substantial but not dominant, with absolute values ranging from 5 to 75% of the integrated long-term forcing. Furthermore, first-year values that appear small in comparison with long-term forcings are usually the small net of two larger values with opposing signs. Thus, emissions from these sources can immediately produce climate forcing that is significant in comparison with the long-term forcing, even if the latter is integrated over 100 years. Regardless of whether any of these sources are chosen for mitigation to reduce climate forcing, changes in these emitters will affect the radiation budget substantially in the near future.

[65] Of particular note are the opposing effects of first-year forcing and longer-term effects on CH_4 for two major source categories. For both on-and off-road diesel engines, the best estimate of first-year forcing is positive, although the uncertainty is high. However, this forcing is countered by the negative forcing after the first year, caused by NO_x emissions that reduce CH_4 concentrations. The opposite effect is seen in another large source, biofuel used for cooking. Its first-year forcing is estimated to be nearly neutral, largely due to the cancellation of cloud and direct forcing. The interaction of short-lived pollutants with the CH_4 budget opposes this negative forcing, and the best estimate of biofuel-burning emissions impact is a slightly positive forcing from aerosol, O_3 and CH_4 interactions. For both of these large BC-rich source categories, the combined forcing by aerosols, O_3 and CH_4 is deceptively small, masking large offsetting terms that may occur during different decades.

10.8. Cautions regarding net forcing estimates

[66] The values given here represent our best estimate of the global response to worldwide source categories, based on current knowledge. Nevertheless, they should be interpreted in light of the cautions below.

10.8.1. Constraints on emissions of BC and co-emitted species are limited

[67] Total emission estimates are acknowledged to contain uncertainty, and those used for Figures 10.1 and 10.2 are determined by scaling modeled atmospheric concentrations to observations. This analysis is hampered because the regions in which the greatest scaling occurs have few observations. We acknowledge that this scaling treatment is subject to many assumptions.

Accepted Article

[68] The net forcing and total rely on our assumption that BC and other products of incomplete combustion scale equally. This equal-scaling assumption, especially for OA and BC, affects net forcing in source categories where positive forcing by BC is balanced by negative direct and indirect forcing by OA. The large scaling of OA awaits confirmation beyond the general finding that emissions from biomass burning should increase, and the treatment here has increased OA direct and indirect forcing well above values summarized for the last IPCC report [*Forster et al.*, 2007]. If BC alone should be increased to match atmospheric absorption—perhaps due to poor measurements of BC mass at the point of emission—then all categories in Figure 10.1 would have greater positive forcing. On the other hand, if larger increases in particulate matter are required to match satellite observations—perhaps due to formation of secondary organic aerosol—then negative forcing in some categories would increase.

10.8.2 Forcing dependence on emitting region is not captured

[69] In developing the figures in this section, we applied globally averaged values of forcing per unit of emission. Some values of forcing per emission depend on the emitting region. The climate forcing per emission of short-lived pollutants depends on the region (and timing) of emission. Thus, the summed climate forcing of all species for a source category emitting in a particular region (or season) may have a different magnitude than the global average, or even a different sign. Atmospheric forcing per emission of BC may vary by about 50% [*Rypdal et al.*, 2009a], and cryosphere forcing is quite dependent on emitting region [*Reddy and Boucher*, 2007; *Shindell et al.*, 2008]. *Bond et al.* [2011] showed that direct radiative forcing by BC and OA is positive in any region when the OA-to-BC ratio was less than 12:1, but when cryosphere forcing was considered for regions near ice, even sources with an OA-to-BC ratio of 30:1 could have positive forcing.

[70] Forcing per emission by gases is also regionally dependent, especially for NO_x, for which values of forcing-per-emission vary by an order of magnitude between the tropics and higher latitudes [*Wild et al.*, 2001].

10.8.3 Regional impacts are not well captured by global averages

[71] As discussed at the end of Section 9, the presentation here measures impact in terms of globally averaged, ToA climate forcing. Globally averaged forcing does not reflect the strong regional impacts of short-lived climate forcers. Forcing that appears small in the global average may be significant over a smaller area and near zero over the rest of the globe. Such regional forcing may induce climate responses different than those of long-lived, well-mixed climate forcers (see Section 8).

[72] ToA climate forcing does not reflect some societally relevant changes, such as shifts in precipitation. Forcing that is zero at the top of the atmosphere but alters the distribution of radiation within the atmosphere may still have significant impacts.

10.8.4. Large uncertainties remain in deriving and apportioning cloud impacts

[73] Uncertainty about the sign of forcing is most directly attributable to the uncertainty in cloud forcing by co-emitted species and to lack of knowledge about the magnitude of the total indirect effect itself. This large uncertainty is not unique to BC-rich sources, but reflects the existing state of knowledge regarding clouds. In this analysis, we have included an estimate of cloud impacts because direct forcing alone may give a misleading impression of net impact in terms of both certainty and sign of effect.

[74] Using column burden to assign indirect forcing to OA or sulfate is one plausible method of apportioning the forcing and is consistent with some model studies. This or other methods of apportionment have not been explored by studies combining models and observations. The larger indirect effect predicted by scaling the OA burden has not been evaluated with observations, either.

[75] Reconciling modeled and observed indirect effects is an area of active research. Estimates of warm-cloud forcing have altered over time as models incorporate constraints from satellite measurements [*Lohmann et al.*, 2010]. If the best estimate of warm-cloud microphysical interactions is later revised to be less negative, estimates of net first-year forcing will become more positive for transportation and solid-fuel sources, and less negative for open-burning and sulfur-rich sources.

Accepted Article

[76] Negative forcing is ascribed to semi-direct effects of BC, but model responses may depend on BC overlying clouds, an assumption that is questionable in light of observations. If estimates of this effect were weakened (becoming less negative), forcing by all BC sources would also become less negative or more positive.

[77] Enhanced absorption within clouds is highly uncertain. If the forcing attributable to such absorption is as great as that estimated by *Jacobson* [2010], forcing by all BC-rich sources would become strongly positive. Forcing by sources that emit light-absorbing OA or OA precursors, such as biofuel and open biomass burning, would also have greater effects. This potentially large effect is included within our uncertainty bounds, but our central estimate has been more conservative.

[78] The net effect of BC and co-emitted species on mixed-phase and ice clouds depends on the fraction of BC that is ice-active. If BC is found to be ice-active in the upper troposphere, then the estimate of BC effects on ice clouds may warrant increased positive forcing estimates. On the other hand, if coatings or co-emitted species cause less ice nucleation, then mixed-phase cloud forcings may become more positive.

[79] Forcing by all cloud effects may depend strongly on the region of emission, on co-emissions, or on the environment in which emissions occur, but no study has examined such differences. A more robust treatment would involve examining each individual source with a model that includes all effects described in this assessment, and that also has the ability to examine sensitivity to critical model inputs.

10.8.5. Climate forcing by additional co-emitted species may affect total category forcing

[80] Although forcing by SOA is not included here, it is known to be a large fraction of the atmospheric aerosol. If SOA has a small negative forcing, as some models predict, and if BC-rich sources emit large quantities of SOA precursors, then net forcing estimates will become more negative.

[81] Ionic species such as magnesium and calcium are small fractions of emitted mass and were not included in this analysis. These species are included in biofuel simulations by *Jacobson* [2010], but their effects have not been isolated.

Accepted Article

Accepted Article

11. Emission metrics for black carbon

11.1 Section summary

[1]

1. The purpose of an emission metric like the Global Warming potential (GWP) or the Global Temperature Change Potential (GTP) is to put future climate impacts of unit emissions of compounds with different lifetimes and radiative efficiencies on a common scale. Such metrics can be useful not only in legally binding agreements, but also in assessments of net climate impact of different mitigation options affecting emissions of many compounds.

2. Physically based metrics like the GWP and the GTP for BC emissions can be calculated from estimates of global annual mean climate forcing normalized to BC emissions. For the GTP additional information about the response times of the climate system are needed.

3. Based on the total climate forcing of BC as given in Section 9, the $GWP_{20\text{-}yr}$, $GWP_{100\text{-}yr}$ and $GWP_{500\text{-}yr}$ for BC are 3200, 910 and 280, respectively. The $GTP_{20\text{-}yr}$, $GTP_{50\text{-}yr}$ and $GTP_{100\text{-}yr}$ estimates are 925, 150 and 130, respectively. Uncertainties are (-90, +100%) for the GWPs and (-90, +165%) for the GTPs.

4. The GWP and GTP metrics vary with the region where BC is emitted by about ±30% based on the results from two studies.

5. The GWP and GTP metric values (which are all relative to CO_2) increase with decreasing time horizon due to the short lifetime of BC (*i.e.,* removal within a few days to weeks via precipitation and contact with surfaces). The choice of time horizon is a value judgment related to the overall target of the climate policy being considered.

6. Current climate policies seem to move in the direction of achieving some temperature target. Under such an approach, the time horizon is initially long and the value of a short-lived forcer such as BC is small but grows as the temperature target is approached. A stricter temperature target implies the value of BC grows faster as the temperature target is approached.

7. BC is not well mixed in the atmosphere because of its short lifetime and has climate forcing mechanisms that differ from most GHGs. Thus, regional changes and impacts on climate variables other than temperature differentiate BC from how most GHGs affect climate. Metrics that attempt to place BC and GHGs on a common global scale are useful in the context of decision-making, but because of these differences any such metric should be used with caution.

8. Co-emission effects, discussed in Section 10, are not captured by BC metrics presented here but can be calculated in a similar approach.

11.2. Introduction

[2] The United Nations Framework Convention on Climate Change [UNFCCC, 1992, article 3] carried strong statements about the need for comprehensive (*i.e.,* across all components and sectors) measures that are also cost effective. To achieve this goal, climate policies may target not only CO_2 but also other compounds leading to warming of the system. To facilitate the evaluation of multiple species, a measure that puts climate impacts of emissions of different compounds on a common scale, or a *metric*, is needed [*IPCC*, 1990; *Kandlikar*, 1996; *Fuglestvedt et al.,* 2003; *Forster et al.,* 2007]. In this context, climate impacts are understood as all future impacts imposed from the time of the emission. Since BC has such a short lifetime compared to the long-lived GHGs, the length of time over which future impacts are evaluated (*e.g.,* through the choice of a time horizon in the common metric, the GWP, or through a discount rate) strongly influences the metric value. This is an inevitable challenge in constructing metrics as it fundamentally involves value judgments with respect to how one treats short-term versus long-term climate impacts [*e.g., O'Neill,* 2000; *IPCC*, 2009].

[3] Reductions are often presented in terms of total 'CO_2-equivalent' emissions. Based on a metric value M_{BC} for BC and the emissions of EM_{BC} of BC, CO_2-equivalent emissions that can be compared with similarly calculated emissions of other species, are calculated through

$$EM_{CO_2eq} = EM_{BC} \cdot M_{BC} \qquad (11.1)$$

[4] This CO_2-equivalent value means that emitting EM_{BC} kg of BC would have the same effect (in terms of the impact parameter used in the metric definition) as emitting $EM_{CO2\text{-}eq}$ kg of CO_2 at the same time. In a multi-component climate agreement, such as the Kyoto Protocol, a set of metric values are decided for each component included in the agreement. Note that the Kyoto Protocol does not include BC or other aerosol components. The overall commitments are given in terms of reductions in total CO_2-equivalent emissions, summed up over the all components included in the agreement, and it is then up to each party to the agreement to decide the composition of the total mitigation, depending on the costs of reducing the individual components. An alternative to this 'basket' approach would be to agree on commitments for individual components. The role of a metric would then be to provide guidance with respect to how much emissions of one component should be reduced relative to another component, involving the same value judgments discussed above. So-called 'multi-basket' approaches have also been proposed [*Fuglestvedt et al.,* 2000; *Rypdal et al.,* 2005; *Jackson*, 2009], where components with similar lifetimes are lumped in separate baskets. Again metrics can be used to help determine the targets for each basket.

[5] The use of metrics is not restricted to legal agreements, but is also very useful for comparing different policies or technological options [*e.g., Jacobson,* 2002] or in assessments of different economic sectors [*e.g., Fuglestvedt et al.,* 2008; *Boucher and Reddy*, 2008; *Berntsen and Fuglestvedt,* 2008].

[6] Metrics have been defined both in terms of physical and economic impacts on climate [*Kandlikar*, 1996; *Fuglestvedt et al.,* 2003, 2010; *Forster et al.,* 2007]. We limit the discussion here to physical metrics, especially those metrics that have already been used in climate change policy. Metrics based on economics are extensions of physical metrics and the extension is of a more generic nature, not particularly related to BC. Metrics based on economics can be designed to allow for cost-benefit optimization by taking damage cost functions into account [*Tol et al.,* 2012]. Different metric concepts can be defined to serve specific policies such as those with a long-term temperature target (*e.g.,* the maximum 2ºC as included in the 2009 Copenhagen Accord of the Conference of Parties-15 (COP-15) meeting) [*Manne and Richels,* 2001].

[7] Using Equation 11.1 to derive a value of CO_2-equivalent emissions does not ensure that all aspects of climate change are equivalent to those from actual CO_2 emissions, in particular for a very short-lived compound like BC. Equivalence is only obtained with respect to the physical impact chosen in calculating the metric [*O'Neill,* 2000]. Different combinations of compounds with equal total CO_2-equivalent emissions, for example, do not provide equivalence with respect to regional climate impacts or the temporal development of climate change. Although these latter impacts are the key end points of concern, they are farther down the causal chain and, thus, are more difficult to capture with simplified and policy-friendly metrics.

11.3. The GWP and GTP metrics

[8] Two purely physically based metrics, the GWP and the GTP, have been established in the literature. The absolute GWP (AGWP) can be defined as the integrated climate forcing (F) of a unit-mass pulse emission over a time horizon H. Using climate forcing can take efficacy into account as necessary. The AGWP for a component i with an atmospheric lifetime of τ_i and specific climate forcing of A_i (forcing per unit burden change, W m^{-2} kg^{-1}) can be calculated as:

Accepted Article

$$AGWP_i(H) \equiv \int_{t=0}^{H} F(t)dt = \int_{t=0}^{H} A_i \exp(-t/\tau_i)dt = A_i\tau_i(1-\exp(-H/\tau_i)) \approx A_i\tau_i \quad (11.2)$$

For all forcing mechanisms involving BC, τ_i is much less than H. The product A_i τ_i (W m^{-2} (kg yr^{-1})$^{-1}$) is the specific normalized climate forcing at steady state for a continuous unit emission. These values can be derived from model simulations that calculate the annual mean climate forcing (F_i) for a given emission, such as the values tabulated in Appendix C.

[9] The generic definition of the absolute GTP (AGTP) can be given as

$$AGTP_i(H) = \int_{0}^{H} F_i(t) \cdot R(H-t)dt \quad (11.3)$$

where an impulse-response function for the climate system $R(H-t)$ gives the surface temperature response at time H due to a climate forcing at time t [*Shine et al.,* 2005; *Fuglestvedt et al.,* 2010]. For both the GWP and the GTP the metric values are obtained by dividing the AGWPs and AGTPs by the corresponding AGWP or AGTP values for the reference gas CO_2. The AGWP values for CO_2 for 20, 100 and 500 years time horizon of $2.47 \cdot 10^{-14}$, $8.69 \cdot 10^{-14}$ and $28.6 \cdot 10^{-14}$ W m^{-2} yr (kg CO_2)$^{-1}$ are used to calculate the GWPs [*Forster et al.*, 2007]. *Joos et al.* [2012] show that there is an uncertainty of about ±27% in these values due to various assumptions. The AGTP values for CO_2 used here [*Fuglestvedt et al.*, 2010] are $6.8 \cdot 10^{-16}$, $5.8 \cdot 10^{-16}$ and $5.1 \cdot 10^{-16}$ K (kg CO_2)$^{-1}$ for 20, 50 and 100 year time horizons. The GTP is commonly referred to as an *end-point* metric since Equation 11.3 gives the global mean temperature response at time H.

[10] The Kyoto Protocol regulates a basket of six gases, or groups of gases, that are primarily long-lived GHGs. The global warming potential with a 100-year time horizon was chosen as the metric for use in this legal agreement. Metrics are most commonly defined for pulse emissions, since comparisons of future scenarios can readily be carried out by regarding each emission trajectory as a series of pulse emissions [*Berntsen and Fuglestvedt*, 2008]. A special case of a future scenario is constant sustained emissions. *Hansen et al.* [2007] used an alternative GWP defined as change in forcing per change in emission. *Jacobson* [2010] calculated a STRE (Surface Temperature Response per unit Emission) emission index that is defined for sustained emissions, but with a non-standard response function for CO_2.

[11] More recently some alternative physical metrics have been proposed. *Gillet and Matthews* [2010] and *Peters et al.* [2011] introduced the mean GTP and the integrated GTP (iGTP), which are equal concepts, while *Bond et al.* [2011] introduced the

Accepted Article

specific forcing pulse, which is identical to the AGWP without a time horizon and which may be applied to individual regions. The iGTP is a pulse-based emission metric integrating the temperature change from the time of the emission to a given time horizon. There is a close relation between the GWP and the iGTP, with larger differences for short-lived forcers and short time horizons. For BC with a time horizon of 20 years the iGTP is about 40% higher than the GWP [*Peters et al.*, 2011]. Although all of these metrics can be calculated from forcing or effective-forcing values, similar to the GWP and GTP, each is slightly different in the assumption of the response function desired for comparison.

11.4. Calculations of metric values for BC

[12] Based on Equations 11.2 and 11.3 above, metric values for BC emissions including all relevant processes can be calculated (*i.e.*, the processes summarized in Section 9) when the specific normalized climate forcings and the impulse-response function are given. Here we have used the impulse response function from *Boucher and Reddy* [2008]. The detailed method for calculating the AGTPs is given in *Fuglestvedt et al.* [2010] and is not comparable to the equilibrium temperature changes discussed in Section 8. Using the estimates for global climate forcing given in Section 9 (Figure 9.1) and the estimated industrial-era emissions of BC of 13900 Gg yr^{-1} (Section 3), the GTP and GWP values for direct BC forcing as well as for the total climate forcing of BC were derived as shown in Figure 11.1. Due to the short lifetime of all BC forcing mechanisms, the annual mean product $A_i\ \tau_i$ can be accurately estimated as the ratio between the annual mean climate forcings (Figure 9.1) and the annual emissions.

[13] Figure 11.1 gives global GWP values for the standard 100-year time horizon, as well as values for 20 and 500 years, and GTP values for 20, 50 and 100 years. Since the lifetimes for all forcing mechanisms discussed in Section 9 are much shorter than any of the time horizons chosen, each mechanism has the same relative contribution to either GWP or GTP. Although the total forcing assessed in this report is greater than that in previous estimates, the GWP has not increased correspondingly because the estimate of emissions has also increased. It should be noted that the values for GWP_{100} and GTP_{20} are about equal, which is a robust finding in general for short-lived climate forcers [*Fuglestvedt et al.,* 2010]. The GWP and GTP values for the direct effect as given in Figure 11.1 are about a factor 2 higher than the values given in *Fuglestvedt et al.* [2010]. This is partly because *Fuglestvedt et al.* only considered the direct effects of BC and partly because the estimate for the radiative forcing per unit emission for the direct effects used here (cf. Section 5) is higher than the values used by *Fuglestvedt et al.*

11.5. Uncertainties

[14] Relative uncertainties in metric values are assumed to be the same as those given in Section 9 for total climate forcing. Normalization of the observationally constrained climate forcing by uncertain annual emissions could in principle change the uncertainty range of the normalized forcing, either increasing or decreasing the uncertainty. Since the forcing estimates are commonly based on combinations of model results and measurements, rigorous propagation of uncertainty is difficult to determine. Although uncertainties in the metric values are of little practical use in formal agreements or trading schemes, where only the central estimates of the metrics are used, they become important when the metric values are used as a first-order assessment of the net effects of different mitigation options. For GTPs, the uncertainties are much larger than for GWPs due to uncertainties in the climate sensitivity and, hence, the temporal response of the climate system. For GTPs in Figure 11.1, a factor of 2 uncertainty in the impulse response function is included based on the result of *Fuglestvedt et al.* [2010] for GTP_{50} of BC.

[15] Uncertainties in the values of metrics can be classified as structural or scientific. Structural uncertainties refer to the consequences of using different types of metrics for a given application, or to choices about key aspects of a metric such as its time horizon and whether discounting is applied. Scientific uncertainties refer to the range of values that can be calculated for a given metric due to incomplete knowledge of the important aspects of the climate or economic system that relate some anthropogenic emission to climate impacts, damages, or mitigation costs [*IPCC*, 2009]. In previous sections of this paper we present the scientific

Accepted Article

uncertainties based on the uncertainties for each of the forcing mechanisms for BC as presented in Sections 5, 6 and 7, and illustrated in Figure 9.1. The structural uncertainties, which can be very large, are demonstrated by presenting numerical values for different metrics (GWP and GTP) and for a range of time horizons. The range is between 95 and 2400 for the central estimate for GTP_{20}, and between 120 and 1800 for GWP_{100}. The central value of GWP varies from 280 to 3200 for different time horizons, and that of GTP varies from 120 to 910. Thus, the scientific uncertainties are of the same magnitude as the structural uncertainties.

11.6. Shortcomings of global metrics

[16] Some important differences between BC and the long-lived GHGs are not well captured by globally averaged metrics. Because BC absorbs incoming shortwave radiation, BC in the atmosphere causes surface dimming and changes the vertical temperature profile differently than the long-lived GHGs. The various hydrological impacts caused by the dimming from BC are not captured in metrics that are based on global climate forcing or global mean surface temperature change.

[17] Another issue for BC and other short-lived climate forcers is that metric values for global impact (global mean climate forcing for the GWP and global mean temperature for the GTP) depend on the region of the emissions and also on the timing of the emissions due to the short lifetime of BC. Since there have been no studies of the climate forcing due to emissions during different seasons, metric values cannot be differentiated according to when the emission takes place. Two studies have calculated normalized radiative forcings or GWPs for the direct effect and the snow albedo effect for regional emissions [*Rypdal et al.,* 2009a; *Bond et al.,* 2011]. They both find a regional variability of ±30-40% for the direct effect, with the largest forcings typically found for emissions from regions located at low latitudes since there is more solar radiation available. For the snow albedo effect the regional variation is much larger with higher values for high latitude regions where the emitted BC is more likely to be deposited on snow surfaces. The snow albedo effect ranges from practically zero for emissions in the tropics to values that reach 30 to 60 % of the direct effect for emissions in Russia and the former Soviet Union [*Rypdal et al.* [2009a] and *Bond et al.* [2011], respectively], not including an enhanced efficacy factor for the snow albedo effect. Since there is a certain cancellation effect depending on the latitude of the emissions (*i.e.,* high direct forcing occurs with low snow-albedo forcing and vice versa) the total of the two mechanisms shows less regional dependence.

[18] In addition to the potential for different global impacts resulting from BC emitted in different regions, the impact on climate in a given region may depend on where the climate forcing occurs [*Shindell and Faluvegi,* 2009]. So far there has only been one GCM study on this topic, but if it proves to be a robust finding, the location where emission reductions occur to achieve a designed climate benefit will not be completely flexible [*Sarofim*, 2010].

11.7. Choice of time horizon

[19] The choice of time horizon for either the GWP or GTP metric is essentially a value judgement, conceptually related to discounting future costs of the impacts of climate change. As discussed by several authors [*Aaheim et al.,* 2006; *Bradford*, 2001; *Johansson et al.,* 2006; *Manne and Richels,* 2001; *Shine et al.,* 2007], for a cost-effective policy that sets a long-term limit on the allowed change in global temperatures [*e.g., COP-15*, 2009], the relative importance of different emissions (*i.e.,* the metric values) will depend on how far into the future that threshold is likely to be reached. Thus, if the global temperature continues to increase, the metric values of short-lived components will increase as global temperatures get closer to the temperature constraint. If a metric with a dynamic time horizon were incorporated in legally binding agreements or trading schemes, it would be important for the stakeholders to know not only the metric values at the time of the investment in emission reductions, but to have information about the potential change of the metric values over the lifetime of the investment due to shortening of the time horizon as global temperatures get closer to the temperature constraint. Once a threshold is set (*e.g.*, as the 2°C threshold agreed upon in the Copenhagen Accord [*COP-15*, 2009]) it is possible to estimate, with uncertainties, what is the relevant timeframe and how the

Accepted Article

metric values will evolve over time [*e.g., Manne and Richels,* 2001]. This information can be communicated to decision makers, so that it is taken into account when there are investments in new long-lasting equipment (*e.g.,* power-plants that will be in operation for 40–50 years).

[20] There has been some concern that a policy that increases the focus on short-lived climate forcers like BC would reduce the focus on reduction of CO_2 and other long lived GHGs, with possible severe irreversible long-term climate effects. An assessment by the U.S. National Academy of Sciences went so far as stating that CO_2 emission mitigation and short-term forcing emission mitigation are "…separate control knobs that affect entirely distinct aspects of the Earth's climate, and should not be viewed as substituting for one another" [*NRC*, 2011]. If a metric with a dynamic time-horizon were to be applied to all climate forcers in a cost-effective framework with a long-term temperature constraint (*e.g.,* in accordance with the Copenhagen accords [*COP-15*, 2009]), it can be shown that within this framework short- and long-lived climate forcers can be treated in a common framework and that an increased mitigation of BC does not displace additional CO_2 mitigation [*Berntsen et al.,* 2010]. This is because in a cost-effective framework increased mitigation of BC is only consistent with a higher metric value for BC, which is equivalent to a shorter time horizon. In this framework the only political decision that can shorten the time horizon is to lower the acceptable temperature threshold. The key to this argument is that with a lower threshold the total CO_2-equivalent emissions must be reduced significantly more. Due to the dominant role of CO_2 this means that even if the relative reductions of BC are enhanced, the absolute CO_2 reductions must also be greater if the temperature threshold is decreased [*Berntsen et al.,* 2010].

11.8. Towards metrics for the net effect of mitigation options

[21] As shown in Section 10 and further discussed in Section 12, any mitigation strategy targeting BC reductions will inevitably also change emissions of other species that affect climate. Metrics are suitable tools to make first-order estimates of the net effect of all emission changes [*Berntsen et al.,* 2006; *Boucher and Reddy,* 2008]. Using pre-calculated metrics for all the relevant species allows for much quicker assessments. Simulating the broader climate effects, including end-point risks and impacts, requires Earth system models which include full coupling between chemistry, radiation, dynamics, clouds, vegetation, etc. However, even if such an Earth system model is applied, the question of how to weigh responses occurring at different times in the future remains.

[22] Section 10 presented the net effect of short-lived emissions from individual source categories. This analysis required estimates of normalized climate forcing for individual species (Appendix C), largely drawing on the comprehensive review of *Fuglestvedt et al.* [2010] but also including the cloud forcing attributable to aerosols and precursors. Although this section presents metric values only for BC, GWPs and GTPs can be derived for the other species by dividing by the appropriate value of AGWP or AGTP for CO_2.

Accepted Article

Accepted Article

12. Mitigation considerations for BC-rich sources

12.1. Section summary

[1]

1. Prioritization of BC mitigation options is informed by science questions such as the magnitude of BC emissions by sector and region (Section 3), net climate forcing by categories including co-emissions (Section 10), impacts on the Arctic (Section 7), and direct effects on precipitation (Section 8.4). In addition, information on technical and financial feasibility, costs and benefits of mitigation, policy design, and implementation feasibility also inform mitigation options. The major sources of BC are presently in different stages of evolution with regard to technical and programmatic feasibility for near-term mitigation actions.

2. Regardless of net climate forcing or other climatic effects, all BC mitigation options bring health benefits through reduced particulate matter exposure.

3. The quality of cost estimates of BC mitigation vary, ranging from robust estimates, for example, for diesel retrofits in industrialized countries to poor estimates for sources such as improved brick kilns in developing countries or open burning.

4. Diesel engine sources of BC appear to offer the best mitigation potential to reduce near-term climate forcing. In developed countries, retrofitting older diesel vehicles and engines is a key mitigation strategy; in developing countries, transitioning a growing vehicle fleet to a cleaner fleet will be important.

5. Mitigating emissions from residential solid fuels may yield a reduction in net positive forcing, especially when the longer-term effects on the methane budget are considered. The net effect remains uncertain because of uncertain knowledge regarding the impacts of co-emitted species on clouds. Furthermore, for biomass use, technology and programs to accomplish mitigation are still emerging.

6. The net effect of small industrial sources depends on the sulfur content of individual sources, and the feasibility of mitigation is in the emerging phase. Net climate benefits may be possible from individual source types with low sulfur emissions when technology is available.

7. Estimation, and especially monetization, of the benefits of BC mitigation is a nascent field. CO_2-equivalency metrics serve as a first-order guide to estimating the climate benefits of BC mitigation but do not capture all potential objectives.

8. Unlike long-lived GHGs, the location, and in some cases timing, of BC emissions may change the climate forcing effect compared to the global average. For example, BC sources that affect the Arctic or other regions with extensive snow and ice cover may offer mitigation potential to reduce climate forcing for those regions. Such regionally specific benefits have not yet been quantified.

9. Mitigation considerations are ideally informed by how emissions are projected to change over time based on existing policies, so that emphasis is placed on sources whose emissions are expected to grow or remain significant.

12.2. Mitigation framework for comprehensive evaluation

[2] The introduction to this assessment describes a potential role for BC in climate mitigation. Because BC has a short atmospheric lifetime, changes in source activity affect radiative forcing within a few weeks and, therefore, actions that reduce emissions from BC-rich sources could contribute to managing the trajectory of climate forcing. Until this point, this assessment has focused wholly on climate-related physical science. We have treated the suite of climate forcings of BC comprehensively rather than limiting the analysis to direct forcing (Section 9), and we have broadened the examination of impacts beyond those of BC

alone by including co-emitted species (Section 10). In discussing mitigation in this section, we also take a comprehensive view by outlining factors beyond climate science: first, feasibility in technical and policy-related terms; second, health co-benefits from BC mitigation; and third, an economic assessment of whether benefits of mitigation are commensurate with costs. While these factors are important in evaluating mitigation potential, a detailed appraisal of the state of science and policy for mitigating each BC source and in each region is beyond the scope of this assessment. Additional analyses of the potential for BC mitigation can be found in reports such as *UNEP/WMO* [2011a; b], *Arctic Council Task Force on Short-Lived Climate Forcers* [2011] and *EPA* [2012].

[3] In considering the mitigation of a climate-forcing agent, several principal aspects are involved as illustrated in Figure 12.1. In the case of BC and co-emitted species, *scientific understanding* addresses what is known about the environmental and health effects of BC emissions and their accumulation in the atmosphere. The net impact of mitigation actions is proportional to the reduction in these effects. For climate, this net impact depends critically on understanding how actions affect both BC and co-emitted species.

[4] Mitigation is generally accomplished with alternatives that provide the same service or function with lower environmental impacts or by reducing the level of service. *Technical feasibility* refers to the availability of these workable alternatives. Even with scientific understanding and technical feasibility in hand, successful mitigation actions further depend on institutional and policy frameworks that can facilitate or enforce widespread implementation of mitigation options. This *programmatic feasibility* refers to the existence of an effective framework, which increases confidence that significant emission reductions could be achieved over a known time frame.

[5] The evolution of each of these principal aspects can be divided into four stages as illustrated in Figure 12.1. Scientific understanding moves from recognition of an effect (*nascent* stage), to simple estimation that may rely heavily on expert judgment (*emerging* stage). When increased attention to emission sources motivates more sophisticated quantification, advanced models and observations are applied (*solidifying* stage). When multiple estimates are available for the effects, the community can move toward consensus regarding their magnitude and importance (*mature* stage). The goal of this assessment has been moving the understanding of physical science toward the solidifying and mature stages with regard to climate effects.

[6] Evolution or growth of knowledge also occurs with regard to technical feasibility. This evolution often occurs separately from, but parallel to, the development of scientific understanding. It also has a nascent stage, where technical solutions are first envisioned. The emerging stage consists of initial, limited efforts to provide technical solutions and delivery programs. Not until the solidifying stage does the increased attention to environmental or health effects demand effective solutions, so that formal research, development, and evaluation approach completion. Resources are invariably required to support this leap in capacity. Finally, at the mature stage, the most promising technical mitigation options have been identified that can be carried out at the scales required and with well known costs and benefits. A similar evolution occurs in programmatic feasibility beginning with experimental interventions. Specialized programs then emerge that lead to pilot programs and finally to policies, regulations and institutions that can facilitate, enforce and implement mitigation plans at regional, national or even international scales.

[7] The major sources of BC are presently in different stages with regard to technical and programmatic feasibility. This disparity does not diminish the importance of any source, but it does mean that the near-term feasibility of mobilizing mitigation activities differs among source categories. Section 12.4 gives a brief review of what is known about technical and policy-related feasibility for each of the major BC-rich source categories.

12.3. Costs and benefits of mitigation

[8] Mitigation actions generally have both benefits and costs. If the benefits exceed the costs then the action is generally considered desirable. On the other hand, if the costs exceed the benefits, then the action is generally not considered desirable. Formally, a policy is considered optimal if the marginal benefit of the next unit of reductions equals the marginal costs of that unit of reductions, and the current net benefits resulting from that action are greater than zero.

Accepted Article

[9] If the benefits of mitigation have been valued in monetary terms, then a cost-benefit approach is possible, but when benefits are difficult or impossible to estimate, the approach of cost effectiveness is often used. Cost effectiveness does not attempt to equate cost and benefits, but rather to identify the least-cost method of reaching a given goal, or most effective use of a given quantity of resources. The goal still requires a metric for comparison; often this is the total quantity of pollutants reduced, or in more sophisticated analyses the reduction in physical impacts or damages associated with lower emissions. For example, cost effectiveness can be calculated based on cost per Mg BC reduced, per Mg CO_2 equivalent (see Section 11), or per degree of global mean temperature reduction. In the case of a cost-benefit analysis, the cost can be compared to the monetized benefits (where feasible for health, climate, or both) of mitigation. Because cost is an important part of such analyses, it is discussed in the next section. Although earlier sections presented emissions in terms of Gg per year, costs are usually tabulated in terms of Mg reductions (1 Gg = 1000 Mg).

[10] The engineering costs of a reduction measure can include capital costs, installation or adoption costs, and fixed or variable operating costs such as changes in fuel demand, future maintenance needs, or labor demands. Estimating the reductions could involve calculating the expected difference in emissions between the baseline and a new projection or using an approximation of calculating the annual reductions multiplied by the expected lifetime of the mitigation project.

12.3.1 Health benefits

[11] BC is one component of particulate matter that can have adverse effects on human health [*Pope et al.,* 2009]. The location of the emission source affects exposure and, hence, the magnitude of health benefit that can come from mitigating that source. To date, public health agencies have not addressed the health effects of BC specifically; rather, the health effects of BC have generally been considered to be associated with the health effects that have been linked to $PM_{2.5}$. As a result, the mitigation literature has traditionally focused on PM rather than explicitly on the BC component. Presently, there is a growing literature on efforts to isolate the specific health effects of BC exposure. As with climate forcing, however, mitigation affects all emissions from a source, so that health effects of BC alone may not be a good estimate of potential benefits from mitigation.

[12] Short-term exposure to $PM_{2.5}$ is likely to be causally associated with mortality from cardiopulmonary diseases, hospitalization and emergency department visits for cardiopulmonary diseases, increased respiratory symptoms, decreased lung function, and physiological changes or biomarkers for cardiac changes [*EPA,* 2009a]. Long-term exposure to $PM_{2.5}$ is likely to be causally associated with mortality from cardiopulmonary diseases and lung cancer, and effects on the respiratory system such as decreased lung function or the development of chronic respiratory disease [*EPA,* 2009a]. Epidemiological evidence explicitly linking BC to such health effects is limited [*Smith et al.,* 2009], and simply assigning a fraction of $PM_{2.5}$ health effects to the portion of $PM_{2.5}$ made up by BC is not common, as there are known differential toxicities among PM components, uncertainties about how different mixtures of particulate materials may change toxicity, as well as heterogeneity in the exposure of a population to different PM components. Several studies [*Jannsen et al.*, 2011; *Ostro et al.,* 2010; *Smith et al.,* 2010; *Bell et al.,* 2009; *Brunekreef et al.,* 2009; *Cooke et al.,* 2007] describe attempts to differentiate health outcomes among specific components or sources of $PM_{2.5}$.

[13] A study by *Fann et al.* [2009] monetized, on a US dollar per Mg basis (USD Mg^{-1}), the health benefits of reducing carbonaceous particulate material by assuming a differentiated proximity of the receptor populations to sources of carbonaceous PM versus other PM components. *Fann et al.* estimated the health benefits of reducing carbonaceous PM to be on the order of 72 thousand to 2.8 million USD Mg^{-1} in the USA. *UNEP/WMO* [2011a; b] and *Shindell et al.* [2012] assessed the global health benefits of implementing a number of BC measures and found a reduction in annual premature deaths due to outdoor air pollution of 2.3 million (+2.2/-1.6) persons over 30 years of age in 2030. Using a country-specific value of a statistical life, these studies determined a monetized benefit of this mortality reduction of USD 5.1 trillion (+4.7/-3.6). Residential solid-fuel sources of BC also produce high indoor exposures whose effects have been monetized [*Mehta and Shahpar*, 2004].

Accepted Article

12.3.2. Valuing climate benefits of BC mitigation

[14] While earlier sections in this assessment discussed climate impact, no value was placed on the reduction of these impacts for use in a cost-benefit assessment. With regard to climate change, the term 'benefits' refers to the avoided risks and impacts (see Figure 8.4) associated with less climate change that would be the result of decreased BC emissions. No direct monetization of the benefits of BC reductions for climate change has yet been reported in the literature.

[15] One possible approach to valuation is using metrics (for example, GWP, see Section 11) to convert BC emissions into estimates of CO_2-equivalent emissions. BC mitigation estimates in these CO_2-equivalent units would then represent first-order, proxy measures for the climate benefits of BC mitigation actions. Furthermore, the CO_2-equivalent metric also provides a first-order approximation for how the BC mitigation measures compare to other CO_2 and GHG mitigation options. Using the GWP estimates presented in Figure 11.1, costs of BC mitigation options expressed as USD per tonne of CO_2-equivalent emissions could be compared to consider their competitiveness alongside a range of current monetized per-tonne CO_2 emission estimates. Higher (or lower) CO_2 prices, and a higher (or lower) GWP for BC, would imply more (or fewer) BC mitigation options would be considered to be cost-effective for climate purposes (not accounting for the health benefits described in the previous section).

[16] Monetizing climate benefits of CO_2 reduction is even more uncertain than estimation of health benefits. Impacts of CO_2 emissions are felt globally, over long time periods, are difficult to quantify, and affect a large number of health, economic and environmental systems. Despite these uncertainties, there have been a number of attempts to quantify and monetize these impacts in USD $(\text{Mg } CO_2)^{-1}$ (equivalent to USD $(\text{tonne } CO_2)^{-1}$) units (referred to as the social cost of CO_2). A meta-analysis of the literature found a median value for the social cost of CO_2 emissions of 47 USD $(\text{Mg C})^{-1}$ under one set of assumptions, with a wide uncertainty range [*Tol,* 2008]. A recent U.S. Department of Energy rule presented a range of values from 17 to 238 USD $(\text{Mg C})^{-1}$ for the year 2010 [Table IV.19 of *DOE*, 2010]. The few existing policies to date that have resulted in a CO_2 market price can provide another means of gauging acceptable monetization values, as these policies implicitly assigned a value to the reduction of emissions; however, such prices are determined in a manner much different than the analytical approach described above. One example is the European Union Emission Trading Scheme, where European Union Allowance futures prices ranged from about 30 to 90 USD $(\text{Mg C})^{-1}$ during 2011 [see www.theice.com].

[17] It may be feasible to use CO_2-equivalent emissions of BC and the social cost of CO_2 to approximate a monetization of the climate benefits of BC reductions. Along with monetized estimates of the health benefits, this valuation would enable comparison of the net benefits of a BC reduction measure to the net costs of that measure. For example, *UNEP/WMO* [2011b] and *Shindell et al.* [2012] found a net present climate benefit of USD 225 billion (+118/-212) from the reduction of BC and co-emitted species in the year 2030 due to the implementation of several BC measures. However, there are many caveats about using the social cost of CO_2 in such an analysis. Most estimates of the social cost of CO_2 come from evaluating impacts that occur decades in the future. Some estimates of the social cost of carbon even show near-term benefits from slight warming which are outweighed by the larger negative impacts from more extreme warming in the future. In contrast, BC has a very short lifetime. Therefore, both impacts of CO_2 and the resulting valuation should differ from those of BC.

[18] Additionally, several BC impacts are not captured in a globally averaged, climate-forcing based metric. Depending on the location of emission, sources may affect snow- and ice-dominated regions such as the Arctic and the Himalaya. They may also affect climate in ways not represented by global-average climate forcing such as changes in the Asian monsoons (see Section 8). Some of these issues are outlined in Sections 7 and 8, but targeted scientific studies have not yet supported quantification of these additional factors. Therefore, these inquiries are in the emerging phase.

12.4. Technical and programmatic feasibility for individual BC-rich source categories

Accepted Article

[19] We briefly review here key mitigation options for each of the major emission source categories, and discuss the mitigation potential for each source with regard to the key factors presented above. The potential for reducing climate forcing presented here is largely based on the global results for emission and forcing categories shown in Figs. 3.2, 3.3, 10.1, and 10.3. A key caveat is that the analysis in Sections 3 and 10 reflect the contribution of all emissions from a given source sector, whereas a mitigation technology may not reduce all of those emissions proportionally. In particular, mitigation that improves combustion without altering activity rates affects only non-CO_2 gases, aerosols, and aerosol precursors.

[20] To date, almost no policies have specifically sought to reduce BC. Most related policies have addressed the more aggregated particulate matter, of which BC is a component, for purposes of improving local air quality and public health. There is therefore a significant amount of literature on the potential and costs of PM emission reductions, but much less literature focused on mitigation options addressing BC specifically.

[21] Many of the mitigation options for PM are identical for BC, but this is not always the case. While a number of studies estimate the costs of mitigating PM, mitigation measures often affect primary PM emissions in a different manner than they affect secondary PM precursor emissions, and sometimes lead to differing reductions of the components of primary PM such as POA and BC. Therefore, mitigation analyses that explicitly determine effects on BC emissions are important. Furthermore, reductions in PM have typically been sought in areas of high concentration, mainly urban areas, and are most easily developed for sources for which end-of-pipe mitigation options are available, such as power plants, vehicles and some industrial processes. Research into mitigation for sources that are more rural in nature is just beginning, especially for those sources that are predominantly located in developing countries, and many of these sources may be important for climate change considerations.

12.4.1. Diesel engines

[22] Mitigating BC emissions from on-road and off-road diesel sources appears to offer the best potential to reduce net forcing because the net climate forcing is positive and larger than found for other principal source categories. These off-road sources include agricultural, construction and other land-based mobile equipment. From these sources, more than the others in Figure 3.2, the emission ratio of BC:POA is higher, which reduces the magnitude of negative aerosol forcing terms relative to direct positive forcing. For Euro II heavy-duty vehicles as shown in Figure 10.3, NO_x emissions are a substantial contributor to the climate impacts, with offsetting O_3 (warming) and nitrate (cooling) effects in the short term and additional longer-term negative forcing from the NO_x interaction with methane. Therefore, for some diesel sources, the net impact of mitigation options depends on how co-emitted NO_x is affected.

[23] Reductions in mobile-source emissions have been pursued since the 1960s, and technology to reduce emissions from diesel engines is mature. Programs to implement this technology differ by region and type of engine use.

1. In industrialized countries such as the USA, European Union, and Japan, PM emission standards already effectively control BC emissions from most new diesel vehicles. With the introduction of more stringent PM standards, diesel emissions in these countries are projected to decrease. The rate of reduction largely depends on how quickly older vehicles are retired and replaced with cleaner new vehicles [*EPA*, 2012]. In these countries, continued enforcement and monitoring will be important to deliver the expected emission reductions. Further mitigation of BC from diesel engines is available mainly from retrofits and accelerated vehicle retirement.

2. In some developing countries, higher-emitting vehicles are still being sold. Accelerating implementation of advanced emission standards in these countries, which requires the use of low-sulfur fuels, would lead to reductions of BC. Monitoring to ensure compliance is also required.

Accepted Article

3. Even in countries with on-road vehicle emission standards, some unregulated or poorly controlled sources remain. For example, regulations may not cover some stationary diesel engines or off-road sources, and better inspection and maintenance programs could address poorly maintained, high-emitting vehicles.

4. Finally, work still remains to determine the most effective ways to apply existing technology to marine and other off-road engines.

[24] The costs of a diesel particulate-filter retrofit for a heavy duty truck ranging from 5,000 to 17,000 USD per vehicle have been reported [*Schrooten et al.,* 2006; *CARB,* 2009], and in some locations (such as the USA, and particularly California) there have been investments of hundreds of millions of dollars in such retrofits. A diesel particulate filter reduces more BC when installed on a large truck than on a small truck if all else is equal, while older vehicles are more polluting per mile but have a shorter remaining lifetime. Therefore, the cost-effectiveness of a diesel retrofit will depend on both the type and age of a vehicle. *Sarofim et al.* [2010] analyzed the potential of diesel retrofits for on-road vehicles to reduce BC emissions in the USA; the study focused on diesel engines that do not meet the more rigorous particulate emission standards that were introduced in the USA in 2007. The study found that costs ranged from 36 thousand USD Mg^{-1} to 318 thousand USD Mg^{-1} BC abated, depending on the age and type of vehicle being retrofitted. The study did not address high emitters or any abatement options besides retrofits. *UNEP* [2011] reported comparable costs for heavy-duty diesel vehicles (*i.e.,* 120 to 200 thousand USD per Mg BC). Installation of filters in new diesel vehicles costs less than retrofitting older vehicles [*EPA*, 2012].

[25] Most developing countries have not yet implemented strict emission standards, and in many cases their fuels are still too sulfur rich to be compatible with diesel particulate filters. Except in the United States, Canada, the European Union, Japan, and some large metropolitan areas in Asia, sulfur fuel levels of 50 ppm or less are not common [see appendix 4 of EPA, 2012]. Diesel particulate filters can be used with low sulfur fuel (50 ppm) but are more effective when the sulfur content is even lower [*Blumberg et al.,* 2003]. Diesel oxidation catalysts, which can be used to reduce PM emissions even with fuel compositions of several-hundred-ppm sulfur, are ineffective at controlling BC. Some projections [*e.g., Streets*, 2007] reflect the possibility that BC emissions could continue to grow in the transport sector in these regions absent policy interventions, given projected growth in vehicle fleets. *Shindell et al.* [2011] found climate benefits in 2030 as a result of applying European emission standards for diesel vehicles in India and Latin America, with health benefits resulting from the tighter standards in all regions. However, reductions of organic carbon and sulfates make the net climate effect less clear or even lead to warming in some other developing countries such as China.

[26] Non-retrofit reduction options also exist. Reduction of idling through regulation, education, electrification of rest stops, and other means has been explored [*e.g., EPA*, 2009b]. Improved inspection and maintenance, accelerated vehicle retirement, improved efficiency, smart transport algorithms to plan shipping routes, low emission zones, and shifting transport modes to rail and non-motorized transport, can also lead to decreased emissions. These abatement possibilities may generate fuel savings, as well as GHG reductions. Biodiesel use may also lead to lower particulate emissions [*EPA*, 2002].

[27] Diesel retrofits are a good example of how mitigation options do not always reduce all POA species proportionally. Diesel oxidation catalysts reduce OC emissions but offer little BC mitigation benefit [*Shah et al.,* 2007], whereas diesel particulate filters reduce BC with equal or greater effectiveness to other PM components. Diesel particulate filters are also a case where mitigation of some pollutants (BC and POA) may lead to changes in emissions of other pollutants such as an increased NO_2 to NO ratio leading to the potential for higher local O_3 concentrations [*Millstein and Harley,* 2010] or a possible fuel penalty resulting from increased back pressure. As with any end-of-pipe abatement technology, the net climate effect of the installation of a diesel particulate filter will be different from the net effect of the diesel category overall because a filter does not reduce all pollutants equally.

Accepted Article

[28] Technical mitigation of diesel engines is in the mature stage for end-of-pipe control, but may have reached only the solidifying stage for retrofit programs. In addition, programs that promote mitigation are in a wide range of phases in less-industrialized countries.

12.4.2. Industry

[29] Figure 10.1 shows that emissions from industrial sources as a whole are likely to produce net negative direct and indirect climate forcings due to co-emissions, especially sulfur. However, industrial sources are quite heterogeneous, and the aggregated value in Figure 10.1 masks the fact that individual source profiles have more positive or more negative forcing. For example, emissions from the Bull's trench brick kiln shown in Figure 10.3, which is an Indian brick kiln using low-sulfur coal, likely produces positive forcing. Other industrial coal combustion activities discussed in Section 3 include small boilers, process heat for brick and lime kilns, and coke production for the steel industry. Knowledge regarding this source category is in an emerging state. Data availability for both activity and emission factors for these sources are poor; estimates of emission magnitudes and composition sometimes have no measurement support.

[30] Extensive work has addressed emission reductions from industrial and manufacturing sources, but these measures may not apply to installations such as brick kilns or coke ovens, which are widespread in developing countries and almost completely absent in developed countries. Likewise, although technical and programmatic feasibility is in advanced stages in industrialized countries, it is still in emerging stages in the developing countries where most BC emissions occur.

[31] Lower-emitting technology and controls exist for both brick kilns [*Heierli and Maithel,* 2008] and coke ovens [*Polenski and McMichael*, 2002; *EPA*, 2008]. These alternatives usually require complete replacement of the installation with more modern technology and thus require large capital outlays (at least 25,000 USD for a more energy efficient technology identified by *Heierli and Maithel* [2008]). To the extent that lower-emitting technologies emit less BC per unit fuel, they would be more beneficial for climate purposes than technologies that strictly improve efficiency (and would therefore reduce BC or sulfur per unit output in equal proportions).

[32] *Rypdal et al.* [2009a] found that industrial source abatement makes up a significant fraction of the least expensive abatement options globally based on extrapolating GAINS model cost curves to the developing world. *Rypdal et al.* did not consider fuel switching as a mitigation option, which is especially important for reductions of residential combustion emissions. *Streets* [2007] found that East Asia was a source of potential industrial reductions of BC emissions, but that existing regulations have already captured a large portion of those reductions in other regions.

[33] In some regions, both coke ovens and brick kilns are being phased out due to developing government action. The fraction of coke produced by traditional or beehive ovens in China has declined after the 1990s [*Huo et al.,* 2012], and several South Asian countries have introduced regulations to limit brick kiln operation near urban areas. Improved kilns could also improve efficiency for charcoal production and thereby reduce emissions in Kenya [*Bailis,* 2009]. Potential for addressing these sources could be large. Replacement of a single industrial source would reduce larger quantities of emissions than a replacement of a residential or mobile source and, thus, transaction costs could be lower.

12.4.3. Residential solid fuel: Heating

[34] As shown in Figures 3.2 and 3.3, wood for heating purposes is a significant source in northern regions such as Europe, North America, and central Asia [see also *Arctic Council Task Force*, 2011]. Figure 10.1 shows little to no potential for reducing global climate forcing from conventional wood stoves by targeting BC emissions because co-emitted species contribute a negative climate forcing, and the net effect of emissions from the residential heating category is uncertain in sign. Like industrial sources, this sector is also heterogeneous. Figure 10.3 shows that wood boilers specifically offer potential to reduce positive forcing associated with BC emissions. Further, the potential for mitigating climate forcing might be greater in certain regions such as the Arctic. *Quinn et*

Accepted Article

al. [2011] states that OA co-emitted with BC is unlikely to offset positive climate forcing due to BC when emissions reach the Arctic. Over snow and ice covered surfaces, even OA may exert a positive forcing. Furthermore, as noted in Section 6.2, the net aerosol indirect and semi-direct effects in the Arctic may lead to a smaller negative forcing or even positive forcing compared with the global average. *UNEP/WMO* [2011a; b] explored the effect of widespread adoption of pellet stoves and boilers in industrialized countries as well as use of coal briquettes in China, Russia and Eastern Europe, and found that the combination resulted in 0.05°C of avoided warming globally and 0.1°C of avoided warming in the Arctic by 2040.

[35] Wood stoves serving single-family homes can be used as the primary source of heat or as a supplement to conventional heating systems. Stove emissions can be reduced through changes in the stove technology or changes in the nature of the fuel. In the USA, emission limits have been in place for new stoves since 1988. Three major categories of stoves meet modern particulate emission standards: non-catalytic, catalytic, or pellet stoves. Non-catalytic stoves include baffles and secondary combustion chambers for emission reductions whereas catalytic stoves reduce emissions through the use of metals that increase oxidation rates. Catalytic stoves are slightly cleaner and more efficient, but are more expensive and require more maintenance and upkeep. Pellet stoves are designed to burn pellets of sawdust, wood, or other biomass materials. In Europe, several countries (*e.g.*, Nordic countries, Germany, Sweden, and Austria) have introduced voluntary eco-labeling of stoves with standards for efficiency and emissions. Some countries (*e.g.,* Austria, Sweden, Norway, Denmark, Germany) also issued national emission standards for small residential installations; the most comprehensive at this time is a German law from 2010 (*Federal Law Gazette*, 2010). Finally, the European Commission Renewable Directive (2009/28/EC) set combustion efficiency standards while the Ecodesign Directive (2009/125/EC) is being extended to include small residential combustion of solid fuels. These developments mean that the technical feasibility of alternatives is in the mature phase, although programmatic feasibility for widespread implementation may vary considerably by country. While pellet stoves are cleaner than many other options, they may not be cost-effective for users who harvest their own wood for fuel. Prices for these kinds of stoves range from 1000 to 3000 USD; one estimate suggests that the cost-effectiveness of reductions for replacement of a wood stove ranges from 130 USD $(\text{Mg PM})^{-1}$ for a non-catalytic stove to almost 1000 USD $(\text{Mg PM})^{-1}$ for a pellet stove [*Houck and Eagle*, 2006]. Few studies have examined the relative BC to POA ratios for each of these technologies and, therefore, the net climate effect of switching to a less polluting technology may differ from the net climatic impact of the entire category.

[36] Larger boilers for multi-family homes may also be wood-fired, and such installations are found in several European countries. These boilers can range from 150 kW up to 1 MW in size. Little information is available about the quantities and technologies used in these installations. Cyclones are sometimes used to reduce PM emissions in older installations, but more advanced controls would be required for effective removal of submicron particles, including BC. Newly built installations are often efficient, low-emission pellet, chip, or sawdust boilers.

12.4.4. Residential solid fuel: Cooking

[37] Figure 10.1 shows a slight net positive forcing, with large uncertainty, from biofuel cooking based on emission factors within the GAINS model. Positive forcing by BC is offset by direct and indirect effects of co-emitted organic matter. In contrast, Figure 10.3 shows a more strongly positive forcing from residential cooking stoves based on in-field measurements, so careful scrutiny of specific technologies is necessary to have confidence in the net effect of mitigation choices. For wood use, changes in the methane budget caused by direct methane and CO emissions add positive forcing in the long-term. Therefore, mitigation options that reduce all products of incomplete combustion have the potential to reduce long-term forcing even if first-year forcing is uncertain.

[38] Residential solid fuel is used for cooking primarily in developing countries, and consists of wood, agricultural residues, dung, charcoal, and coal. Improved household energy solutions have been sought for several years. In the early 1980s, forest depletion was the main reason for concern. More recently, in addition to forest depletion, concern is also driven by high PM

Accepted Article

exposures resulting from indoor solid-fuel use; these exposures lead to severe respiratory ailments and premature deaths numbering in the millions annually [*Smith et al.,* 2004]. These activities have largely taken place in the context of development programs without the large-scale investment in environmental measurement or engineering solutions that characterizes the move toward mature technology development.

[39] Stove improvements and fuel switching are the main solutions to reduce environmental and health impacts of household energy use. Early programs that focused on stove efficiency did not always improve air quality [*Smith et al.,* 2007], implying that they had little effect on BC. Since that time, stove improvements have included insulating combustion chambers, adding chimneys, and managing air-fuel mixing before and after combustion [*Bryden et al*., 2006]. Chimneys can reduce indoor air pollution and improve combustion by adding draft through the chamber, although some of the reduction in indoor pollution is accomplished by shifting the particulate matter outside [*Johnson et al.*, 2006]. Improved stove design has resulted from the advent of emission testing by non-governmental organizations [*MacCarty et al.*, 2010], and efforts to promote mass manufacture are also occurring. More advanced combustion technology coupled with a broader understanding of the field has resulted in renewed interest [*World Bank*, 2011]. Nevertheless, understanding of in-use efficiency and emissions as compared with laboratory performance is still limited [*Roden et al.,* 2009; *Johnson et al.,* 2006; *Johnson et al.,* 2008; *Christian et al.,* 2010], with in-use emissions typically higher than those measured in laboratory settings. While enhancing efficiency of these stoves decreases total emissions, field measurements indicate that particulate emission per unit fuel is reduced by only up to 50% [*Roden et al.,* 2009]. Much of the emission reduction may be POA rather than BC, so that not all mitigation options may reduce total climate forcing.

[40] Air flow management in stoves and cleaner fuels may be required to reduce emissions further. The former can be accomplished either with fans that introduce secondary air or with gasification stoves, which separate fuel devolatilization and combustion. Both fan stoves [*Jetter and Kariher*, 2009] and gasification stoves [*Mukunda et al.*, 2010] show very good emission performance in laboratory settings, but they are rare enough in the field that in-use performance is not well characterized. Stoves without chimneys are in the 10-20 USD range, while those with chimneys require more material, individual installation and presently range from 40-100 USD. Gasifier stoves are typically 50-100 USD.

[41] Emissions from residential cooking are greatly reduced when the users switch to modern fuels such as liquefied petroleum gas, kerosene, or electricity [*Smith et al.*, 2000a; b]. Cleaner fuels can also be provided by processing solid fuels and producing briquettes, pellets, and charcoal made from either wood or agricultural waste. Some programs deliver both stove and fuel [*Zhi et al.*, 2009], because performance depends on the combination of the two. However, emissions from fuel production in addition to end-use must be considered in the calculation of climate impact [*Bailis et al.*, 2005].

[42] Implementation of cookstove replacement programs is challenging. Cookstove initiatives that do not offer affordable, reliable operation that meets the needs of the main user in real-world settings may not have long-term success [*Hanna et al.,* 2012]. Historical programs in China had some success in delivering better wood stoves with chimneys [*Smith et al.,* 2007, *Sinton et al.,* 2004] but a large, long-standing national program in India may not have affected emissions. These are examples of the importance of addressing implementation feasibility alongside cost and environmental attributes. Most recently, the Global Alliance for Clean Cookstoves was launched as a public-private initiative to address public health and climate change by "…creating a thriving global market for clean and efficient household cooking solutions." Technical and programmatic feasibility for this source category is in the emerging phase.

12.4.5. Open burning

[43] Figures 10.1 and 10.3 show either near-zero or net negative forcing estimates for current baseline emissions from agricultural burning, forest burning and grassland burning. The negative climate forcing from co-emitted POA is substantial for each category, even offsetting the long-term positive forcing caused by effects on the methane budget. These sources, therefore, are not good

Accepted Article

candidates for BC-focused mitigation actions, if near-term global climate change is the main concern. The exception here, as with residential heating, is if some burning sources affect the Arctic or other snow- and ice-dominated areas or have other significant regional climate impacts [Section 7; *Quinn et al.*, 2011].

[44] Work on open burning reduction for BC mitigation is moving from the nascent to the emerging phase of analysis in Figure 12.1. For open burning sources the preliminary nature of the analysis, resistance to changing management practices, and difficulties in quantifying reductions may present barriers to implementing mitigation options.

[45] *Sarofim et al.* [2010] analyzed biomass burning abatement potential in the USA by considering mitigation options such as using propane burners on stacked crop residues, backing fires, conservation tillage, soil incorporation, central processing sites, and a number of forestry prescribed-burn mitigation options [derived from *Ottmar et al.,* 2001; *EPA,* 1992, 2005; *Massey,* 1997; *WRAP,* 2002; *USDA,* 2005]. Some of the options are estimated to have negative costs: mainly conservation tillage for agriculture [*Massey,* 1997], but also mechanical removal of small trees followed by use of the biomass as feedstock for electricity generation facilities [*USDA,* 2005]. The remaining options for reducing BC emissions for less than 40 thousand USD $(Mg)^{-1}$ all relate to adoption of practices to reduce emissions from prescribed burning of forests or grasslands. While this analysis serves as a representative example of how to develop mitigation cost estimates for open burning, extension of this analysis to regions outside the USA is only appropriate for regions with similar properties in terms of managed forests, grasslands, and agricultural practices.

12.4.6. Other sources

[46] Marine shipping contributes about 2% of global BC emissions, but may constitute a larger fraction of direct BC emissions in remote regions. In particular, the Arctic is a sensitive region with few other direct sources of BC emissions, where the high surface albedo due to snow and ice cover will reduce the cooling by co-emissions, and where there is potential for increased ship routes in the future as sea ice recedes (though the reduction of sea-ice cover will also lead to a reduced albedo and, therefore, a smaller BC impact over time). If sulfate emissions from ships are controlled for non-climate reasons, the BC-to-sulfate ratio will increase and increase the probability that mitigation would have net climate benefits. For example, new regulations of the United Nations International Maritime Organization will require sulfur content in fuel for marine vessels to be reduced to 0.5% by 2020 [*Winebrake et al.,* 2009], and some proposed and existing Emission Control Areas currently have stricter standards than the global standard of 4.5%. However, the fact that most BC emissions from ships occur over low-albedo surfaces in regions where hydrological impacts are less critical means that mitigation of emissions globally is less likely to have climate benefits.

[47] There is interest in better quantifying BC emissions from oil and gas flaring but the work in this area is still preliminary [*Arctic Council Task Force*, 2011]. As shown in Table 3.5, there are a number of other smaller BC sources such as power generation and gasoline engines that have traditionally not been a major target of BC mitigation analysis. However, there have been some exceptions. *Shindell et al.* [2011] show that BC reductions are a key contributor to net cooling resulting from tighter gasoline vehicle standards. There has also been occasional interest in the impacts of BC emissions from aviation despite being less than 1% of global emissions. However, due in part to the altitude of the emissions [*Hendricks et al.,* 2005; *Koch et al.,* 2005] there is little BC mitigation data available for these sources.

12.5. International perspective on BC reductions in aggregate

[48] In addition to understanding the BC mitigation opportunities and potential for each individual source, as briefly provided above, we present here a more macro perspective for evaluating BC mitigation.

12.5.1. Projected future emissions

[49] Mitigation considerations are informed by how emissions are projected to change over time. Future emission drivers include economic development, implementation of air quality policies, technological changes, fuel consumption and quality (including

Accepted Article

sulfur content), land-use change, and behavioral changes. When using projections to prioritize mitigation, it is important to differentiate between those projections which are solely based on existing policies and drivers, and those that make projections based on a presumption of future regulations due to, for example, an assumption that a richer society will demand cleaner air. For projections based on existing regulations, sectors where emissions are expected to grow over time or remain significant are of more importance than those where emissions are expected to decline – however, for projections which include assumptions about future policies, it is important not to discount mitigation actions that are assumed but not yet implemented. A few studies have looked at future BC projections: *Streets et al.* [2004], *Streets* [2007], *Streets et al.* [2011], *Cofala et al.* [2007], and *Rypdal et al.* [2009a] globally; *Klimont et al.* [2009] in Asia; *Sarofim et al.* [2010] and *EPA* [2012] in the USA, *Rypdal et al.* [2009b] in the USA, European Union, and China; and *Walsh* [2008] for the global transport sector. Using the RAINS (Regional Air Pollution Information and Simulation) model, *Cofala et al.* [2007] estimated a 17% reduction of global anthropogenic BC emissions by 2030 relative to present, mainly due to reductions in the mobile sector (diesel particulate controls) and the domestic sector (less coal use and replacement of traditional stoves). *Streets* [2007] also shows global reductions in BC emissions of 9 to 34% by 2030 relative to present, and highlights some regions and sectors where projected emissions may increase under some scenarios over that time period. The changes depend on assumptions about growth, technology development, and environmental policy creation and enforcement. The growth regions and sectors include residential emissions in Africa, open biomass burning emissions in South America, and transportation emissions in the developing world. Projections by *Streets et al.* [2011] show similar regional differentiation in future trends but with less overall global BC emissions decline by 2030. In these projections, decreases between 2005 and 2030 in Northeast Asia, Southeast Asia, the Pacific, North America and Europe due to further air pollution legislation result in slight net global decreases despite increases in most other regions. It has also been suggested that retreat of Arctic sea ice may increase marine shipping in the Arctic [*Granier et al.*, 2006; *Corbett et al.,* 2010], which might lead to increased emissions in a region with higher sensitivity to carbonaceous emissions due to snow albedo effects.

[50] Because of the short atmospheric lifetime of BC, the timescale of projections most pertinent to mitigation decisions are those on timescales similar to the lifetime of infrastructure investments (*i.e.,* two to three decades). Nevertheless, for a long-term perspective, it is also instructive to view how BC and co-emissions of POA are projected within the models that have traditionally been used to produce long-term (*i.e.,* out to year 2100 or even beyond) GHG emission scenarios. Long-term emission scenarios have been developed for the climate projections of the forthcoming IPCC Fifth Assessment Report (www.ipcc.ch), scheduled for publication in 2013. These emission scenarios are referred to as 'Representative Concentration Pathways' and based on scenarios from four modeling teams (available at http://www.iiasa.ac.at/web-apps/tnt/RcpDb). These pathways are named according to their 2100 radiative forcing level as reported by the individual modeling teams (the four range from 2.6 to 8.5 W m^{-2}). The radiative forcing estimates are based on the forcing of GHGs and other forcing agents, including BC and OC. The Representative Concentration Pathways do not represent specific futures with respect to climate policy action (or no action). Any differences can be attributed in part to differences between models and scenario assumptions (scientific, economic, and technological). Across the four modeling scenarios, projected patterns of global BC emissions are similar: emissions after 2010 decrease steadily, reaching about half of 2010 emissions by the end of the century (Figure 12.2) [*RCP Database*, 2009]. Sectorally, there are more differences: global emissions in each major sector increase in at least one model out to 2020, and one model shows an increase in global open burning emissions even out to 2030. Regionally, several scenarios show emission growth in Asia (especially transport) and the Middle East and Africa regions (residential and commercial). Organic carbon emissions show a somewhat less consistent pattern, where, depending on the modeling team or scenario, emissions are projected to remain relatively steady or decline more gradually throughout the century. The economic models that produce these scenarios treat emissions in aggregate and lack engineering

Accepted Article

details, especially after 2030. Therefore, the projection of declining BC and POA emissions is not based on specific policies or technology shifts, but on the assumption that cleaner fuels are used and emission factors decline as income increases.

12.5.2. Comprehensive international assessments of BC mitigation actions

[51] Few studies have examined the potential for BC mitigation across multiple emission sources and across multiple regions within a common economic modeling framework. Simple analyses include those of *Bond and Sun* [2005], *Montgomery et al.* [2009], and *Kandlikar et al.* [2009], who assessed costs and benefits of a few BC mitigation options. Diesel engine retrofits and replacements, cookstove replacements, and super-emitting vehicles are analyzed in all three studies, in addition to gasoline engine and industrial kiln upgrades in a subset of the studies. All three studies identified cookstoves as having the most promising cost-benefit characteristics, whether to achieve climate benefits alone or both climate and health benefits. These studies considered neither the counteracting role of co-emitted aerosols and precursors on indirect effects, nor the additional longer-term positive forcing by co-emitted gases, which could change the results of the analysis.

[52] Analyses by *UNEP/WMO* [2011a; b] and *Rypdal et al.* [2009a] assessed future mitigation strategies to reduce the climate impact of BC and POA from contained combustion. *Rypdal et al.* [2009a] developed cost curves for each of 12 major world regions to describe the technical mitigation potential and costs of reducing BC, as well as co-emitted OC. The cost curves for Europe were generated by the RAINS model, while extrapolations were made for other regions due to lack of detailed region-specific data on technology availability and costs. Because of this extrapolation, the analysis excluded viable alternatives for some sources, especially those for which knowledge is still emerging or is in the early stages of solidifying. For example, small industrial sources and cooking stoves are not widely used in Europe, so replacement technologies were not present in RAINS. Fuel switching was not considered as an option either. These omissions mean that some BC mitigation opportunities are not captured by the analysis. Under these assumptions, in the year 2030, 418 Gg of BC yr^{-1} could be reduced for 4 billion USD annually, 775 Gg for 30 billion USD, and 1200 Gg for 126 billion USD. In comparison, the *Rypdal et al.* study projected that 4400 Gg BC will be emitted in 2030 under current legislation.

[53] While mitigation in the transport sector dominated the suite of feasible reductions in 2030 in the *Rypdal et al.* [2009a] analysis, emission reductions from industrial process activities (such as coke ovens in China and brick kilns in India) are less expensive and, therefore, made up the majority of the first quartile of emissions reductions, as ranked by cost effectiveness.

[54] *UNEP/WMO* [2011a; 2011b] identified several BC mitigation measures that could produce a net global-mean cooling effect. Measures were initially chosen from the GAINS database using one specific value of GWP from the literature. The opportunities identified included tightening of diesel emission standards (*i.e.,* including use of particle filters), brick kiln and coke oven modernization, cookstove improvements, use of efficient pellet stoves for residential heating as well as substitution of coal by coal briquettes, and reduction of agricultural waste burning. Impacts and uncertainties of the selected measures were then evaluated in more detail. The ultimate analysis of temperature impacts was based on modeling the change in radiative forcing when the mitigation measures were applied in two climate models. The percentage of industrial-era forcing reductions achieved by the measures was scaled by a best estimate and central range of industrial-era forcings. Thus, as in this assessment, modeled BC DRF was increased based on the models' underestimate of BC AAOD relative to observational constraints.

[55] Total BC climate forcing is larger in this assessment (+1.1 W m^{-2}, with uncertainty range of (+0.17 to, +2.1) W m^{-2}) than in the UNEP/WMO Assessment (+0.60, (0.0, +1.0) W m^{-2}) [*UNEP/WMO*, 2011a; b]. Large uncertainties are attributed to indirect effects in both reports. Major differences of our BC forcing compared with the UNEP/WMO assessment are the adjustment to observed absorption, which increases direct forcing; explicit inclusion of the cloud absorption effect; and selection of more negative liquid-cloud effect and more positive mixed-phase cloud effect based on tabulating individual studies.

Accepted Article

[56] Additional differences between the two assessments are attributable to the treatment of co-emitted POA, especially its indirect effect. The present assessment attributed indirect forcing to different aerosol species based on total atmospheric mass. Given the lack of constraints from the literature and the lower solubility of OA, the UNEP/WMO Assessment instead attributed indirect effects entirely to sulfate. The total net forcing from co-emitted POA is much smaller in the UNEP/WMO assessment, so that climate benefits of measures tend to be larger than those estimated here. Both assessments stress the uncertainty in attribution of aerosol indirect effects to individual species, and both include large ranges in assessed climate impact.

[57] In the UNEP/WMO Assessment, BC measures were grouped into 'technical' and 'regulatory' groups. The technical group included primarily diesel measures and the emission reductions produced net cooling, as also suggested here. The regulatory group of measures had impacts whose range encompassed zero, as also found here.

[58] *Shindell et al.* [2012] used the same emission scenarios described above along with detailed climate modeling, and found global mean temperature impacts consistent with the simplified estimates in the UNEP/WMO Assessment. In that model, the combined indirect and semi-direct aerosol forcings resulting from the measures were negative and, hence, augmented rather than offset the reductions in BC DRF. In addition to radiative forcing and global mean climate response, both the UNEP/WMO Assessment and *Shindell et al.* [2012] estimated the impacts of the mitigation measures on health, crop yields, and Arctic temperatures, with large regional precipitation shifts attributed to BC in the climate modeling study.

12.6. Policy delivery mechanisms

[59] At the international level, there are forums and agreements where BC mitigation strategies could be addressed. The eight-nation Arctic Council is currently exploring mitigation opportunities for BC, and the Convention on Long-Range Transboundary Air Pollution is exploring the question of how BC could be addressed within its current structure. In 2012, a growing number of nations have announced their support of the voluntary Climate and Clean Air Coalition [http://www.unep.org/ccac] to Reduce Short-Lived Climate Pollutants. Barriers include questions about addressing both long-lived GHGs and short-lived forcers such as BC in a common framework (see Section 11), and concerns about the consequences of de-emphasizing the importance of long-lived GHGs.

[60] Even if international agreement occurs to move forward with BC reductions, implementation must take place within individual countries. Existing air quality policies may offer the means to deliver near-term mitigation strategies for BC in developed countries and, where such policy frameworks exist, in developing countries where most growth in BC emissions is expected to occur. For example, existing vehicle emission standards for new vehicles, and scrappage and retrofit programs may provide a means of implementing additional BC mitigation in the transportation sector. Other sources may require additional infrastructure for implementation on a large scale, such as reductions of residential cooking emissions in remote areas of developing countries. Some important BC emission sources, such as remote open burning, may lack a policy or program infrastructure supporting reduction. The portfolio of regulations, policies, and programs capable of delivering BC mitigation varies by country, and in some cases could even vary within a country where some air-quality or land-use policies are administered at sub-national levels.

12.7. Synthesis of considerations for identifying important mitigation options

[61] Table 12.1 provides a matrix that presents multiple criteria discussed in this section, and evaluated elsewhere in this assessment, to help identify important mitigation strategies. It summarizes the level of understanding for the following key considerations for identifying promising mitigation opportunities for BC: the magnitude of the emission source (and thus a first-order indication of technical mitigation potential), the potential to reduce net climate forcing, the potential to benefit sensitive regions such as the Arctic, the availability of technologies and management practices, the costs of these strategies, potential health

Accepted Article

benefits, and implementation feasibility. Not all of the factors for all emission sources can currently be quantified with uniform, or even robust, levels of understanding. The 'level of understanding' evaluations in this table are intended to be illustrative and are informed both by quantitative analysis from previous sections of this assessment and by qualitative judgment for some of the non-science factors briefly discussed in this section.

[62] There is considerable variation across BC sources regarding the potential to reduce globally averaged, positive net climate forcing, with many broad emission categories such as residential coal burning, field burning and forest burning offering at best uncertain potential in this regard. If controlling some of these sources preferentially reduces climate forcing in the Arctic or other snow- and ice-dominated regions, or avoids interference with the Asian Monsoon, climate benefits not reflected in Figure 10.3 may accrue. With regard to technical feasibility, there are known emission mitigation options for most BC sources. However, there is variation in the degree to which these mitigation options are characterized with regard to impacts on BC and co-emissions and costs. Programmatic feasibility also varies. Some emission sources are already associated with a policy infrastructure to deliver mitigation practices at large scale (*e.g.,* diesel sources), whereas other sources (*e.g.,* forest burning) are less amenable to near-term and large-scale policy intervention.

[63] While health effects are not evaluated in this report, there is always the potential to obtain some degree of health benefits by mitigating BC emissions. Emissions that preferentially occur in populated areas have large health impacts, while emissions that occur indoors expose fewer people, but at higher concentrations. The lowest health impacts occur for outdoor emissions that occur at low population density. *UNEP/WMO* [2011a; b] and *Anenberg et al.* [2012] provide detailed evaluations of health impacts from outdoor air.

[64] Diesel sources of BC appear to offer the most promising mitigation opportunities in terms of near-term forcing and maturity of technology and delivery programs. Although some options, such as diesel retrofits, may be costly relative to other BC mitigation options, they may also deliver significant health benefits. Mitigating emissions from residential solid fuels may yield a reduction in net positive forcing. The near-term net effect remains uncertain because of uncertain knowledge regarding the impacts of co-emitted species on clouds, but longer-term forcing by co-emitted species interacting with the methane budget is positive. Furthermore, the evolution of feasibility is still in the emerging phase for these sources. The net effect of small industrial sources depends greatly on the sulfur content of individual sources, and the feasibility of mitigation is in the emerging phase. Individual source types that have low sulfur emissions and for which alternative technology is available could offer net climate benefits.

Accepted Article

Accepted Article

Acknowledgments

This assessment is a contribution of the IGBP-IGAC/WCRP-SPARC Atmospheric Chemistry and Climate Initiative (AC&C). The authors acknowledge financial and technical support from the International Global Atmospheric Chemistry (IGAC) project (http://igac.jisao.washington.edu/index.php), C. Koblinsky of the Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA), H. Maring of the Radiation Sciences Program of the National Aeronautic and Space Administration (NASA), Rose Kendall of CSC, and Beth Tully of Tully Graphics. IGAC funding for this project is via the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) under NOAA Cooperative Agreement NA10OAR4320148, Contribution No. 2035. The authors are grateful to Ray Minjares and the International Council on Clean Transportation (ICCT) and Catherine Witherspoon of the ClimateWorks Foundation for encouragement to undertake this effort. The authors wish to thank the AeroCom modeling community and the AERONET data providers for their great help in providing basic data sets, further analyzed here. Olivier Boucher is thanked for his substantial contribution to section 8 and his careful review and subsequent discussion with the author team on the entire manuscript. We also thank N. Riemer of the University of Illinois for particle-resolved simulation results in Figure 2.5, N. Mahowald of Cornell University for dust fields in Figure 4.1, and D. M. Winker of NASA for providing the CALIPSO data in Figure 4.5. A. Heil is thanked for providing information on biomass fuel loads and M. O. Andreae for providing updates of his biomass burning emission factor compilation. E. Baum, J. Bachmann, R. Minjares, K. Ram, V. Ramanathan, and D. Zaelke are thanked for reading and providing comments that improved the document. T. C. Bond acknowledges support for related work under U.S. EPA RD-83503401, NASA RD-83503401, NSF ATM 08-52775, and DOE DE-SC0006689. Piers Forster acknowledges support from a Royal Society Wolfson Research Merit award. N. Bellouin was supported by the Joint DECC/Defra Met Office Hadley Centre Climate Programme (GA01101). S. Ghan was supported by the U.S. Department of Energy (DOE), Office of Science, Scientific Discovery through Advanced Computing (SciDAC) program, and the DOE Decadal and Regional Climate Prediction using Earth System Models (EaSM) program. The Pacific Northwest National Laboratory is operated for the DOE by Battelle Memorial Institute under contract DE-AC06-76RLO 1830. Y. Kondo was supported by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), strategic international cooperative program of Japan Science and Technology Agency (JST), and the global environment research fund of the Japanese Ministry of the Environment (A-1101). For P. K. Quinn's work, this is NOAA PMEL contribution no. 3786. M. Schulz received funding support through the EUCAARI project (EU-FP6 Contract 34684). M. Z. Jacobson received funding from the U.S. National Science Foundation. J. W. Kaiser was supported by the European Union Seventh Research Framework Programme (MACC project, contract number 218793). S. G. Warren acknowledges support from U.S. NSF grant ARC-06-12636. The views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

Appendix A. Author contributions

The development of this assessment required a large, diverse group of dedicated authors. They synthesized multiple topics in the individual sections and interlinked the topics throughout. Each section required lead-author commitment equivalent to the production of a typical journal paper. The publication of this assessment in a peer-reviewed journal necessitates a first author, thereby precluding the section lead authors from receiving the lead-author credit normally accorded for this level of effort. The author order begins with the first author and three coordinating lead authors (Doherty, Fahey and Forster) followed by the lead authors and contributing authors in alphabetical order. The table below acknowledges the principal contributions of each author in an attempt to further recognize their substantial investment in this assessment. The role of coordinating lead authors was shared by T. C. Bond, S. J. Doherty, D. W. Fahey, and P. M. Forster.

Table A.1. Author principal contributions

Section – topic	Lead authors	Contributing authors
1 – Introduction	T. C. Bond	
2 – Measurements and microphysical properties	P. K. Quinn Y. Kondo	S. Ghan U. Lohmann J. P. Schwarz
3 – Emissions	C. Venkataraman M. G. Schultz	T. C. Bond S. K. Guttikunda P. K. Hopke J. W. Kaiser Z. Klimont
4 – Constraints on abundance	S. Kinne T. C. Bond	M. Schulz
5 – Direct radiative forcing	S. Ghan M. Schulz S. Kinne T. C. Bond H. Zhang	
6 – Cloud effects	D. Koch B. Kärcher	T. Storelvmo U. Lohmann
7 – Cryosphere changes	S. J. Doherty M. G. Flanner	S. G. Warren
8 – Climate response	P. M. Forster	N. Bellouin D. Koch

Accepted Article

Accepted Article

M. G. Flanner
S. J. Doherty
M. Z. Jacobson
D. Shindell
C. S. Zender

9 – Synthesis — P. M. Forster
D. W. Fahey
10 – Net climate forcing — T. C. Bond
11 – Emission metrics — T. Berntsen
12 – Mitigation considerations — B. J. DeAngelo
M. C. Sarofim
S. Zhang

Accepted Article

Appendix B. Using sky-photometer aerosol absorption optical depth retrievals to constrain black carbon models

B.1. Background and methods

[1] Aerosol absorption optical depth (AAOD) associated with BC column amounts is a key factor controlling model estimates of BC DRF. The diversity in modeled BC AAOD is one of the major factors contributing to diversity in estimates of BC DRF. To reduce BC-DRF uncertainty, we use retrievals from a global network of ground-based sun-/sky-radiance observations (AERONET) to adjust the BC AAOD simulated by models. Our AAOD estimates use measurements that cover complete annual cycles for 2000 to 2010 at 171 land sites distributed worldwide, and data from an additional 78 sites with incomplete annual cycles. By applying some assumptions, detailed below, values of BC column absorption (BC AAOD) can be extracted from the AERONET retrievals. These values can be compared to those simulated by models at the same location and time, and regional scale factors for BC AAOD can be determined from the ratio of observationally estimated to simulated BC AAOD. These scale factors are used in this assessment to reduce the bias in models used to determine BC DRF.

[2] Sun and sky radiance observations [*Dubovik and King,* 2000] in the mid-visible range allow inference of the aerosol column absorption in terms of the AAOD (= AOD × [1-ω_0]) from retrievals of AOD and single-scattering albedo (ω_0) at 550nm. Regular retrievals for cloud-free conditions with identical instrumentation at many AERONET locations [*Holben et al.,* 1998] provide extensive coverage over continents and islands. A comparison of AAOD retrievals with in-situ measurements showed good agreement from 300 to 700 nm and a possible high bias in AERONET AAOD at 880 nm [*Corrigan et al*., 2008, Figure 16]. However, because retrievals of ω_0 are less certain at low AOD [*Dubovik et al.,* 2000], absorption data for low AOD cases were removed from the official AERONET Version 2.0 product. This filter introduces a positive bias for local statistics of AAOD because only cases with high AOD are counted. To remove this AAOD bias, missing refractive index data in the Version 2.0 data product have been recovered from the lower quality Version 1.5 data product, so that now low AOD cases are included as well. This procedure adds noise to the retrieved AAOD data set, but is expected to reduce the sampling bias (*O. Dubovik*, personal communication). However, a small positive sampling bias may still exist, because values of ω_0 greater than one (negative absorption) are excluded from the data set. The retrieved AAOD is very similar to that from an alternative procedure in which ω_0 is retrieved only from high-AOD observations at each station and applied to all AOD values at that station, thus maximizing the use of Version 2.0 data. The mean AAOD averaged over all samples at all AERONET sites is 0.018 using the Version 1.5 ω_0, which is a factor of 2 smaller than the mean value (0.040) from the version 2.0 retrieval of AAOD.

[3] Refractive indices at 440 nm and 670 nm inferred from the AERONET data are interpolated to 550 nm. Real refractive indices are interpolated linearly and imaginary refractive indices are interpolated in log-log space, which would produce spectral absorption that is well described by the absorption Ångström exponent (Eqn. 2.1). In the mid-visible solar spectral region, non-BC contributions to absorption are mainly from relatively coarse dust particles. To separate BC AAOD from total AAOD, we assume that BC controls the mid-visible absorption of small (*i.e.,* 'fine-mode') aerosol particles and dust controls the absorption of particles larger than 1 μm diameter. This implies that any mid-visible absorption by organic matter, brown carbon or small-sized dust is attributed to BC. This separation by size is possible because the AERONET inversion method provides detailed size-distribution data. We estimate dust AAOD from the super-micron part of the retrieved size distribution and an assumed refractive index of 1.55 + 0.0015*i* [Table 1 of *Dubovik et al*., 2002]. Finally, BC AAOD is estimated as the difference between the AERONET total AAOD and the dust AAOD. All calculations are performed at 550 nm.

[4] The AERONET retrieval also provides an estimate of the refractive index, but it applies to the entire aerosol in the column which almost always contains a combination of constituents and, thus, the index is not applicable for individual components of the

column aerosol such as BC, OA and dust. Thus, we use an assumed value for the dust refractive index rather than a retrieved value from AERONET to calculate the dust contribution to total AAOD. Similarly, assuming the imaginary part of the retrieved refractive index applies to submicron particles yields BC AAOD estimates that are two low if the dust absorption dominates the retrieved refractive index, because the retrieval is strictly valid only for the entire size distribution (see Section B.2).

[5] If AERONET stations provided globally uniform high-resolution coverage for ocean as well as land locations, the AERONET BC-AAOD retrievals could be directly used to constrain model simulations. However, Figure 4.3 shows that, although there are hundreds of AERONET stations distributed across the Earth, coverage is limited to land and is far from homogeneous over land. Additional assumptions are required for locations without AERONET data.

[6] To fill in the gaps between stations we use spatial distributions of BC AAOD from AeroCom simulations [*Kinne et al.,* 2006]. Median values of the set of 15 AeroCom models are used for each month and mapped onto a 1°x1° latitude-longitude grid. The model ensemble median is, henceforth, referred to as the AeroCom median. The AeroCom BC AAOD is estimated from the BC AOD saved for each model. Based on Mie theory and the assumption of the same BC size distribution (*i.e.,* lognormal with 0.065-μm number mode radius and geometric standard deviation of 1.7) and refractive index (1.7, 0.7*i*) for all models, we use an ω_0 of 0.36 for BC to convert from BC AOD to BC AAOD. To compare AeroCom models that estimate only industrial-era BC AAOD with AERONET observations of total AAOD, we rely on one AeroCom model (LOA) to provide the industrial-era fraction of BC (*i.e.,* (all-source BC AAOD - pre-industrial BC AAOD) / (all-source BC AAOD)), thus estimating a pre-industrial background AAOD of 0.0004. Using global mean values for both the industrial-era and all-source BC AAOD this ratio in the LOA model is 0.80, but the ratio among model grid boxes (1°x1°) varies widely, from near zero in regions with large natural emissions to 97% in regions with large anthropogenic emissions. Modeled global mean values without any scaling are 0.00172 for industrial era BC AAOD and 0.00212 for all-source BC AAOD.

[7] The AeroCom BC-AAOD values do not agree with the AERONET retrievals, so the BC-AAOD distribution from AeroCom is scaled to agree with the AERONET retrievals at the station locations. Errors in emissions or BC scavenging vary spatially, producing different biases, so separate scale factors are calculated for each region (Table B.1, Figure 3.1). For each region, all AERONET data available for a given month are combined, and from this data set a characteristic regional value is calculated using the average values between the 25% and 75% percentiles. This average is chosen instead of the mean to avoid the impacts of extreme outliers. The same quantity is determined for the AeroCom median field at the locations of AERONET observations. These averages are referred to as the "characteristic values" from AERONET and AeroCom. The ratios of the AERONET to AeroCom characteristic values then define the regional (monthly) scale factors.

[8] Table B.1 lists annual mean characteristic values of BC AAOD for each region from the AERONET retrievals and from the AeroCom median model at the same month and locations as the AERONET retrievals. The ratios of the characteristic values (AERONET/AeroCom), also listed in Table B.1, define regional scale factors that can be applied to the AeroCom BC AAOD within each region to compensate for regional AeroCom biases. According to Table B.1 the ratios are larger than 1 for all regions, but vary widely from region to region (*e.g.,* 1.6 to 6.2 for annual means) and from month to month within a region (*e.g.,* 0.6 to 10.5). The global annual mean of the resulting scaled AeroCom BC AAOD is 0.00605, which is smaller than the values listed in Table B.1 for AERONET locations only. The table lists BC AAOD at AERONET sites where AAOD is higher than the global average, so the global mean after scaling is smaller than the average of the values in the table. This estimate of BC AAOD attributes all fine-mode absorption to BC. When combined with an estimate of fine-mode AOD from MODIS [*Remer et al.*, 2008], this AAOD yields a global, annual average fine-mode single scatter albedo of 0.92.

[9] After scaling to AERONET observations, all-source BC AAOD is 0.00605, and industrial-era BC AAOD is 0.00489, assuming the same scaling applies to pre-industrial background BC AAOD because the same biases in BC emission factors, lifetime

Accepted Article

and optics apply to pre-industrial and present day simulations. The global average all-source BC AAOD and the industrial-era BC AAOD both increase by a factor of 2.9 because the same scaling is applied to pre-industrial conditions. These fractional increases depend on the value of ω_0 assumed in deriving unscaled BC AAOD from the model BC AOD fields, but the scaled BC AAOD value does not. If a more-absorbing aerosol (*i.e.,* lower ω_0) had been chosen, the unscaled model BC AAOD would be greater, the final BC AAOD would be identical, and the percentage increase would be lower. This has no implications for BC DRF, but it does have implications for the scaling of emissions to account for the scaling of BC AAOD.

B.2. Uncertainties

[10] Table B.2 summarizes estimates of eight sources of uncertainty (95% confidence) in BC AAOD and how each is estimated. We assume the eight factors contributing to uncertainty are uncorrelated, so that they can be added in quadrature. Two of the uncertainties are asymmetric. The lower and upper uncertainties for all-source BC AAOD are estimated to be -65% and +69%, respectively. For industrial-era BC AAOD, the uncertainties are -64% and +80%, respectively.

1. Impact of model spatial pattern. The regional monthly BC AAOD scale factors are based on existing data-pairs (AeroCom/AERONET) for each region and month. The derived scale factor is then applied to all data-points of the reference model in that region and month. However, spatial distributions can vary significantly among models, which introduces uncertainty. To quantify this uncertainty, the analysis was performed after replacing the AeroCom median field with fields from three individual models. This resulted in the following scaled all-source BC AAOD values: AeroCom median model: 0.0060; SPRINTARS: 0.0046; GOCART: 0.0052; and UMI: 0.0064. From the standard deviation of these values we derive a 29% uncertainty due to the model spatial pattern.

2. Characteristic value. The BC AAOD scale factors for each month and region are based on characteristic values of BC AAOD at the AERONET sites. In this study the characteristic value is defined by the 3-PDF mean. Other statistical calculations lead to the following all-source BC-AAOD values: average of the 25, 50 and 75 percentile values of the probability distribution: 0.00577; median value: 0.00596; mean: 0.00733; 7 percentiles between 10% and 90% averaged: 0.0635; average over values between the 25% and 75% percentiles: 0.00641; and interpercentile range of values between 10% and 90% percentiles averaged: 0.00582. From the standard deviation of these estimates we derive a 16% uncertainty due to the statistical derivation of the BC AAOD characteristic values.

3. Limited AERONET sites and sampling. To quantify the influence of the limited number of AERONET sites used, sub-samples were used to re-estimate the scale factors. Using half of all available AERONET sites in four randomly different ways produced the following global all-source scaled AeroCom BC-AAOD values: 0.0061; 0.0064; 0.0071; and 0.0057. From this we derive a 13% uncertainty due to the limited AERONET network coverage.

4. Clear-sky bias of AERONET. A related sampling uncertainty is that AERONET data are acquired only during times of direct sunlight whereas model-simulated BC-AAOD values refer to all times (Section 4.4.2.1). This bias is estimated with four AeroCom models (GEOS-Chem, GOCART, OSLO-CTM2 and SPRINTARS) because AERONET retrievals are not possible under cloudy conditions. Simulated BC AAOD on days with AERONET BC-AAOD retrievals were compared to simulated values on all days. Averaging across all models and AERONET sites yields an annual average clear-sky bias of 1% ± 5%, with the largest bias in SE Asia (15%). An uncertainty of ±5% is therefore applied to our estimate of global, annual average BC AAOD. No correction is made for the 1% annual bias. The effect on radiative forcing could be different than the effect on AAOD depending on the location of BC relative to clouds, but we have not accounted for this uncertainty.

5. Transport to unsampled regions. Scaling burdens over land areas, where AERONET stations are located, should also affect burdens in regions affected by continental outflow. The land-based definition in Figure 3.1 neglects this influence. To address

Accepted Article

this deficiency we extended some regions with large BC outflows partway across the oceans. This procedure increased the global mean BC AAOD by 16%, so we estimate the associated uncertainty to be 16%.

6. Dust impact on estimated BC AAOD. The attribution of AAOD between BC and dust is one of the largest uncertainties. Here we have taken a specific approach to removing dust absorption from the total AAOD, but doing so requires imperfect assumptions. We estimate an asymmetric uncertainty due to the partitioning of AAOD between dust and BC by performing other estimates of BC AAOD from AERONET and propagating these through the model extension. The upper bound of AAOD is obtained by assuming a smaller imaginary refractive index for dust, 0.0006. This yields a BC AAOD of 0.0074, 23% larger than the estimate with imaginary refractive index of 0.0015. For the lower bound, we use the AERONET retrieved refractive index for the total column aerosol, assume that it applies to particles smaller than 1-μm diameter, assume that all absorption by these particles is due to BC, and then integrate absorption over the retrieved sub-1-μm size distribution to estimate BC AAOD. This procedure yields a global mean all-source BC AAOD of 0.0034, 43% smaller than the value estimated from our primary approach. Using the refractive index retrieved for the entire size distribution provides a lower bound for BC AAOD because fine-mode absorption is generally greater than dust absorption, as evidenced by the fact that AERONET ω_0 is usually lower than dust ω_0. This method ascribes an AAOD of 0.0052 to non-BC material. For comparison, AeroCom models have a median AOD of 0.023 for dust, and compare reasonably well with AERONET observations in dusty regions [*Huneeus et al.*, 2011]. Even with a relatively low ω_0 of 0.95, modeled dust AAOD would be only 0.0011.

7. Organic matter impact on BC AAOD. To extract the AAOD associated with BC, it was assumed that, after contributions of larger (dust) aerosol sizes to absorption are removed, the remaining absorption by small particles can be attributed to BC. However, organic aerosol may absorb and is contained in small particles, and it is usually co-emitted with BC. Initial tests with AeroCom median AOD maps for OA and BC and a plausible OA mid-visible imaginary part of the refractive index of 0.005 yielding a co-albedo of 0.027 suggest that 20% of the AAOD of small particles could be attributable to OA. Such an attribution would reduce our estimate of BC AAOD. An asymmetric uncertainty of (0, 20%) is applied to account for this possibility. *Chung et al.* [2012] concluded that absorption by OA is sufficient to offset scattering, so we have not reduced the best estimate of BC DRF for that reason. Estimates of forcing per emission developed in Section 10 may be reasonably accurate, as long as both BC and OA are emitted from the same source.

8. Pre-industrial contribution to BC. Compared with all-source BC, industrial-era BC has an additional uncertainty because the preindustrial background is unknown. The relative uncertainty in preindustrial BC emissions may be comparable to the estimated 50% uncertainty in emissions from biomass burning [*Akagi et al.*, 2011; *Vermote et al.*, 2009]. However, the uncertainty in applying the scaling adjustment to preindustrial AAOD is greater than 50%. We use the previously estimated AAOD of 0.0004 as a low estimate for this preindustrial background, and the scaled estimate of 0.0012 as a high estimate. The low pre-industrial value is subtracted from the high value of AAOD for a high estimate, and vice versa.

[11] We acknowledge that there are other sources of uncertainty in using AERONET data that have not been quantified here. These include interpolation of AAOD to 550 nm; removal of climatological NO_2 absorption from the aerosol absorption values; and accounting for dust that absorbs in the fine mode or BC that absorbs in the coarse mode. In addition, the AERONET algorithm is subject to periodic revision and updates that could affect the inferences here.

Accepted Article

Table B.1. Comparison of BC AAOD from the AeroCom median model and AERONET retrievals in selected regions [a]

Region	# pairs	AeroCom AAOD	AERONET AAOD	Ratio	Min factor (month)	Max factor (month)
North America	140-220	0.0024	0.0047	1.96	x 1.5 (Oct)	x 2.3 (Jul)
South America	80-110	0.0049	0.0084	2.49	x 1.5 (Jul)	x 4.0 (Sep)
Middle East	20-35	0.0042	0.0110	2.63	x 1.9 (Feb)	x 4.2 (Oct)
Africa	70-110	0.0052	0.0170	3.29	x 2.4 (Mar)	x 5.0 (Oct)
Europe	90-120	0.0052	0.0083	1.59	x 1.1 (May)	x 2.3 (Nov)
EECCA	40-60	0.0079	0.0133	1.68	x 0.6 (Jun)	x 3.2 (Jan)
South Asia	15-20	0.0069	0.0427	6.20	x 4.1 (Jun)	x 8.1 (Nov)
East Asia	30-60	0.0099	0.0280	2.84	x 1.9 (Jul)	x 3.4 (Jan)
Southeast Asia	25-30	0.0053	0.0252	4.75	x 3.1 (Nov)	x 8.2 (Apr)
Japan/Oceania	35-40	0.0015	0.0053	3.57	x 1.1 (Jul)	x 10.5 (Dec)
Polar land	0-6			1.00		
All oceans	140-210	0.0049	0.0132	2.04	x 1.6 (May)	x 2.6 (Jan)

[a] Annual averages of monthly interquartile averages of BC AAOD by region. The columns show the (unadjusted) AeroCom median values at AERONET data locations, the AERONET suggested values, the resulting AERONET to AeroCom annual ratio as well as minimum and maximum regional ratios by month. The reliability of these ratios increases with the number of matching points (column 2), which varies not only by region but also with season.

Table B.2. Uncertainties for AeroCom scaled BC AAOD based on AERONET observations [a]

#	Uncertainty source	Methodology	Uncertainty [b]
1	Impact of model spatial pattern	Comparison of 4 AeroCom models	± 29 %
2	Characteristic value	PDF statistics	± 16 %
3	Limited AERONET sampling	Subsample AERONET sites	± 18 %
4	Clear-sky bias of AERONET	Use modeling subsamples	(-10, 0)%
5	Transport into unsampled regions	Extension of large BC source regions	± 10 %
6	Dust impact on fine-mode AAOD	Estimate using AERONET refractive	(-54, +44)% [c]

Accepted Article

		index for small particles	(-44, +23)% [d]
7	Organic matter impact on fine AAOD	Estimated absorption of model organic matter	(-20, 0)%
8	BC AAOD industrial-era component	Assumed uncertainty in background	(0.0004, 0.0012) [c]
	All-source AAOD (#1-7)		(-64, +47) %
	Industrial-era AAOD (#1-8)		(-73, +61) %

[a] Uncertainties added in quadrature.

[b] Values in brackets indicate low and high values of asymmetric uncertainties.

[c] Used for industrial-era AAOD only.

[d] Used for all-source AAOD only

Accepted Article

Appendix C. Data supporting co-emitted species forcings in Section 10

Table C.1. Estimates of forcing per emission for aerosol species and precursor SO_2, grouped by effect category [a]

Effect	Central	Low	High
BC atmosphere [b]	51.1	6.5	90.6
BC snow and sea ice	10.3	3.4	24.8
BC liquid clouds [c]	-14.4	-35.8	7.0
BC other clouds [d]	27.3	38.2	59.4
POA atmosphere			
Fossil fuel	-8.6	-17.0	-0.1
Biofuel and open biomass	-4.2	-7.1	-1.2
POA snow [e]	0.9	0.0	3.0
POA clouds	-9.2	-13.5	-3.8
SO_2 atmosphere	-3.7	-5.5	-1.8
SO_2 clouds	-5.3	-7.9	-2.2

[a] Units are $(\mu W\ m^{-2})\ (Gg\ yr^{-1})^{-1}$. Effects correspond to those shown in Figures 10.1 and 10.2.

[b] Includes direct forcing.

[c] Includes liquid-cloud albedo and semi-direct effects.

[d] Includes cloud absorption effect and changes in mixed-phase and ice clouds.

[e] Applied to biofuel and open biomass only.

Table C.2. Determination of fraction used to apportion indirect effect

	Sulfate	Organic matter
Total industrial-era burden (mg m^{-2}) [a]	2.12	1.32
Industrial-era burden, considering	2.83	1.32

Accepted Article

associated species (mg m^{-2}) [b]		
Fraction used in apportionment	0.68	0.32

[a] From *Schulz et al.* [2006].

[b] Scaling for sulfate accounts for the mass ratio of $(NH_4)_2SO_4$ to that of $SO_4^{=}$.

Accepted Article

Table C.3. Estimates of liquid-cloud indirect effect for sulfate and organic matter [a]

Effect	Central	Low	High	Emission base (Gg yr^{-1})
Total liquid-cloud effect [b]				
Cloud albedo effect	-0.9	-1.4	-0.3	
BC liquid-cloud effect				
This assessment	-0.10	-0.32	0.12	13900
Scaled to cloud study emission rate	-0.04	-0.26	0.14	6100 [c]
Sulfate and POA liquid-cloud effect [d]				
Remaining	-0.86	-1.26	-0.35	
Sulfate (68%)	-0.58	-0.86	-0.24	109000
Organic matter (32%)	-0.27	-0.40	-0.11	30000
Scaled to final emissions in this study				
Sulfate	-0.51	-0.76	-0.21	96000
Organic matter	-0.74	-1.09	-0.30	81000

[a] All values given are forcings in W m^{-2}.

[b] From *Isaksen et al.* [2009]. These values do not include semi-direct effects.

[c] Although some cloud studies could have used a different emission rate, we assumed that the most common rate was the anthropogenic net given in *Dentener et al.* [2006].

[d] Determined for cloud-study emission rates. Fractions for apportionment are from Table C.2.

Accepted Article

Table C.4. Estimates of forcing per emission for co-emitted gaseous species [a]

Forcing and $GWP_{100\text{-yr}}$	CO	NMVOCs	NO_x (as N)	CH_4
Forcings ($\square W\ m^{-2}$) ($Gg\ yr^{-1}$)$^{-1}$				
via short-lived O_3	0.09 [b]	0.21 [c]	2.8 [d]	-
via CH_4	0.15 [b]	0.18 [c]	-3.8 [d]	2.2 [b,e]
via nitrate	0	0	-2.0 [f]	-
Total	0.24	0.39	-3.2	
$GWP_{100\text{-yr}}$ (dimensionless)	2.8	4.54	-38	

[a] Short-lived O_3 and nitrate forcings are included in first-year forcing shown in Figures 10.1, 10.2 and 10.3. Longer-lived CH_4 forcing is shown in integrated forcing in Figure 10.4.

[b] Calculations begin with the $GWP_{100\text{-yr}}$ from *Fuglestvedt et al.* [2010] based on an average of the two models reported in Berntsen et al. [2005]. Multiplied by 100-year integral of CO_2 forcing of ($0.0086\ mW\ m^{-2}$) ($Gg\ yr^{-1}$)$^{-1}$. Separation of CO into O_3 and CH_4 mechanisms was taken from *Shindell et al.* [2005].

[c] Six VOCs from *Collins et al.* [2002] with weighting recommended by *Fuglestvedt* [2010].

[d] *Wild et al.* [2001] global average.

[e] Although CH_4 does affect short-lived O_3, the resulting forcing is assumed to be included in its total GWP and is subsumed in longer-term forcing. While not precisely accurate for representing first-year forcing, this allocation makes a very small difference.

[f] Calculation begins with total nitrate forcing as given in *Forster et al.* [2007], multiplied by 0.44 to account for the fact that NO_x produces only a fraction of nitrate forcing, with the remainder attributable to ammonia emissions (see text). Forcing-per-emission values are obtained by assuming the same N emission base as the forcing for O_3 attributed to NO_x in *Forster et al.* [2007], so that the ratio between the forcing-per-emission values is the same as the ratio between the forcing values.

Accepted Article

Table C.5. Emission rates used for Figures 10.1, 10.2, and 10.4(a) [a]

Category	BC	POA	SO_2 (as S)	CO	CH_4	NMVOC	NO_x (as N)	CO_2
On-road	1630	1100	1500	42000	700	4400	6300	2342
Off-road	810	600	900	7000	0	2800	2400	922
Industry	850	1600	9900	51000	0	500	1100	4372
Wood/cook	4060	25300	1200	362000	17100	85200	500	7638
Wood/heat	230	900	100	8000	600	2700	0	344
Coal	930	1100	2500	32000	200	1300	100	2090
Ag fields	280	1500	100	15000	1800	2400	0	414
Forests	1470	22100	2000	96000	5800	7000	900	2349
Savannas	2230	21800	1800	121000	4200	6300	2100	5278
Other rich	1160	4100	3300	557000	3200	70500	7500	10234
Power	20	0	50100	2000	0	700	6300	7328
Other low	100	300	22500	51000	244500	19300	3900	5092
Industrial-era total	13770	80400	95900	1344000	278100	203100	31100	48403

[a] All emissions are in Gg yr^{-1} except CO_2, which is in Tg. Values are developed beginning with year 2000 emissions given by GAINS (see Table 3.5) and RETRO, scaled to inferred BC emission rates in each region using the scale factors given in Section 5 and Appendix B.

Table C.6. Emission factors in (g kg^{-1}) used to develop Figure 10.3 and 10.4(b)

Emission source	BC	POA	SO_2	CO	CH_4	NMVOC	NO_x	CO_2
Euro II heavy-duty vehicle [a]	0.47	0.1	0.9	7	0.2	1.4	35.3	3087
Pre-regulation truck [a]	2.39	1.3	11.9	11	0.4	3.0	11.2	3087
Bull's Trench brick kiln [b]	2.44	0.1	10.5	41	1.5	0.3	0.0	2182
Industrial coal boiler [c]	0.01	0.0	5.2	5	0.4	0.7	2.1	1947
Mud cooking stove [d]	0.80	5.7	0.3	67	5.6	2.7	1.0	1833
Conventional wood stove [e]	0.36	3.9	0.2	130	15.0	23.6	2.8	1833
Wood boiler [f]	1.09	1.5	0.3	105	9.0	14.0	1.2	1833

Accepted Article

Coal cooking stove [g]	0.58	0.8	0.2	166	0.9	0.5	2.2	2130
Field burning [h]	0.69	4.6	0.4	92	2.7	7.0	1.2	1833
Forest burning [h]	0.56	11.2	1.0	107	4.7	5.7	1.4	1833

[a] GAINS implementation of COPERT4 emission factors [*Ntziachristos and Samaras,* 2009].

[b] *Greentech* [2011], except CH_4 and NMVOC values which were not measured. For those gases, one-half of *Zhang et al.* [2000] values for coal stoves were used, assumed to scale approximately with CO emissions.

[c] *Wang et al.* [2009b]

[d] *Roden et al.* [2009] in-field data for BC, POA, and CO; *Smith et al.* [2000a; b] for other gases.

[e] *McDonald et al.* [2000], except SO_2, CH_4 and NMVOC from *EPA* [1996].

[f] *Johansson et al.* [2004]; *Rau* [1989].

[g] *Zhang et al.* [2000]; *Zhi et al.* [2008].

[h] *Andreae and Merlet* [2001], except CO_2 from carbon balance.

Accepted Article

Accepted Article

Supplemental Information

Table S.1. Country groups corresponding to regions in Figure 3.1

North America

Canada

St. Pierre & Miquelon

United States of America

Latin America

Mexico

Antigua/Barbuda

Argentina

Aruba

Bahamas

Barbados

Belize

Bermuda

Bolivia

Brazil

Cayman Island

Chile

Colombia

Costa Rica

Cuba

Dominica

Dominican Republic

Ecuador

El Salvador

Falkland Islands

French Guiana

Grenada

Guadeloupe

Guatemala

Guyana

Haiti

Honduras

Jamaica

Martinique

Mexico

Netherlands Antilles
Nicaragua
Other Latin America
Panama
Paraguay
Peru
St. Kitts & Nevis
St. Lucia
St. Vincent & Grenadines
Suriname
Trinidad & Tobago
Turks & Caicos Islands
U.S. Virgin Islands
Uruguay
Venezuela

Middle East
Bahrain
Cyprus
Iran
Iraq
Israel
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syrian Arab Republic
United Arab Emirates
Yemen

Africa
Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi

Accepted Article

Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Congo
Cote d'Ivoire
Dem. Republic Congo
Djibouti
Egypt
Equatorial Guinea
Eritrea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea Bissau
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria
Other Africa
Reunion
Rwanda-Urundi
Sao Tome & Principe
Senegal
Seychelles
Sierra Leone

Accepted Article

Somalia
South Africa
St. Helena
Sudan
Swaziland
Tanzania
Togo
Tunisia
Uganda
Western Sahara
Zambia
Zimbabwe

Europe
Albania
Austria
Belgium
Bosnia-Herzegovina
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Faeroe Islands
Finland
France
Germany
Gibraltar
Greece
Greenland
Hungary
Iceland
Ireland
Italy
Latvia
Liechtenstein
Lithuania
Luxembourg

Accepted Article

Macedonia

Malta

Monaco

Netherlands

Norway

Poland

Portugal

Romania

Serbia and Montenegro

Slovak Republic

Slovenia

Spain

Sweden

Switzerland

Turkey

United Kingdom

Eastern Europe, Caucasus and Central Asia (EECCA)

Armenia

Azerbaijan

Belarus

Georgia

Kazakhstan

Kyrgyzstan

Moldova

Russian Federation

Tajikistan

Turkmenistan

Ukraine

Uzbekistan

South Asia

Afghanistan

Bangladesh

Bhutan

India

Maldives

Nepal

Pakistan

Accepted Article

Sri Lanka

East Asia

China

Korea, North

Korea, South

Macau

Mongolia

Taiwan

Southeast Asia

Brunei Darussalam

Cambodia

Laos

Malaysia

Myanmar

Philippines

Singapore

Vietnam

Thailand

Pacific

American Samoa

Australia

Cook Islands

Fiji

French Polynesia

Guam

Japan

Kiribati

Marshall Islands

Micronesia

Nauru

New Caledonia

New Zealand

Niue

Pacific Islands

Papua New Guinea

Samoa

Accepted Article

Solomon Islands

Tonga

Vanuatu

Wake Island

Accepted Article

Accepted Article

References

Aaheim, H. A., J. S. Fuglestvedt, and O. Godal (2006), Costs savings of a flexible multi-gas climate policy, *Energ. J.*, *S13*, 485-502.

Abbatt, J. P. D., S. Benz, D. J. Cziczo, Z. Kanji, U. Lohmann, and O. Möhler (2006), Solid ammonium sulfate aerosols as ice nuclei: A pathway for cirrus cloud formation, *Science*, *313* (5794), 1770-1773, doi: 10.1126/science.1129726.

Abdul-Razzak, H., and S. J. Ghan (2000), A parameterization of aerosol activation 2. Multiple aerosol types, *J. Geophys. Res.*, *105* (D5), 6837-6844, doi: 10.1029/1999JD901161.

Abel, S. J., J. M. Haywood, E. J. Highwood, J. Li, and P. R. Buseck (2003), Evolution of biomass burning aerosol properties from an agricultural fire in southern Africa, *Geophys. Res. Lett.*, *30* (15), doi: 10.1029/2003GL017342.

Abu-Allaban, M., A. W. Gertler, and D. H. Lowenthal (2002), A preliminary apportionment of the sources of ambient PM_{10}, $PM_{2.5}$, and VOCs in Cairo, *Atmos. Environ.*, *36* (35), 5549-5557, doi: 10.1016/S1352-2310(02)00662-3.

Ackerman, A. S., O. B. Toon, D. E. Stevens, A. J. Heymsfield, V. Ramanathan, and E. J. Welton (2000), Reduction of tropical cloudiness by soot, *Science*, *288* (5468), 1042-1047, doi: 10.1126/science.288.5468.1042.

Ackerman, A. S., M. P. Kirkpatrick, D. E. Stevens, and O. B. Toon (2004), The impact of humidity above stratiform clouds on indirect aerosol climate forcing, *Nature*, *432* (7020), 1014-1017, doi: 10.1038/nature03174.

Ackerman, T. P., and O. B. Toon (1981), Absorption of visible radiation in atmosphere containing mixtures of absorbing and nonabsorbing particles, *Appl. Opt.*, *20* (20), 3661-3667, doi: 10.1364/AO.20.003661.

Adachi, K., S. H. Chung, and P. R. Buseck (2010), Shapes of soot aerosol particles and implications for their effects on climate, *J. Geophys. Res.*, *115,* D15206, doi: 10.1029/2009JD012868.

Adams, P. J., and J. H. Seinfeld (2003), Disproportionate impact of particulate emissions on global cloud condensation nuclei concentrations, *Geophys. Res. Lett.*, *30* (5), 1239, doi: 10.1029/2002GL016303.

Akagi, S. K., R. J. Yokelson, C. Wiedinmyer, M. J. Alvarado, J. S. Reid, T. Karl, J. D. Crounse, and P. O. Wennberg (2011), Emission factors for open and domestic biomass burning for use in atmospheric models, *Atmos. Chem. Phys.*, *11*, 4039-4072, doi: 10.5194/acp-11-4039-2011.

Alfaro, S. C., S. Lafon, J. L. Rajot, P. Formenti, A. Gaudichet, and M. Maille (2004), Iron oxides and light absorption by pure desert dust: An experimental study, *J. Geophys. Res.*, *109,* D08208, doi: 10.1029/2003JD004374.

Alfarra, M. R., A. S. H. Prevot, S. Szidat, J. Sandradewi, S. Weimer, V. A. Lanz, D. Schreiber, M. Mohr, and U. Baltensperger (2007), Identification of the mass spectral signature of organic aerosols from wood burning emissions, *Environ. Sci. Technol.*, *41* (16), 5770-5777, doi: 10.1021/es062289b.

Allen, R. J., and S. C. Sherwood (2010), Aerosol-cloud semi-direct effect and land-sea temperature contrast in a GCM, *Geophys. Res. Lett.*, *37,* L07702, doi: 10.1029/2010GL042759.

Alterskjær, K., J. E. Kristjaànsson, and C. Hoose (2010), Do anthropogenic aerosols enhance or suppress the surface cloud forcing in the Arctic?, *J. Geophys. Res.*, *115*, D22204, doi: 10.1029/2010JD014015.

Amann, M., I. Bertok, J. Borken-Kleefeld, J. Cofala, C. Heyes, L. Hoglund-Isaksson, Z. Kilmont, B. Nguyen, M. Posch, P. Fafaj, R. Sandler, W. Schopp, F. Wagner, and W. Winiwarter (2011), Cost-effective control of air quality and greenhouses gases in Europe: Modeling and policy applications, *Environ. Modell. Softw.*, *26* (12), 1489-1501, doi: 10.1016/j.envsoft.2011.07.012.

Andreae, M. O., and A. Gelencser (2006), Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols, *Atmos. Chem. Phys.*, *6*, 3131-3148, doi: 10.5194/acp-6-3131-2006.

Andreae, M. O., and P. Merlet (2001), Emission of trace gases and aerosols from biomass burning, *Global Biogeochem. Cycles*, *15* (4), 955-966, doi: 10.1029/2000GB001382.

Andrews, E., P. J. Sheridan, and J. A. Ogren (2011), Seasonal differences in the vertical profiles of aerosol optical properties over rural Oklahoma, *Atmos. Chem. Phys.*, *11*, 10661-10676, doi: 10.5194/acp-11-10661-2011.

Andrews, T., and P. M. Forster (2008), CO_2 forcing induces semi-direct effects with consequences for climate feedback interpretations,

© 2013 American Geophysical Union. All Rights Reserved.

Geophys. Res. Lett., *35* (L04), 802, doi: 10.1029/2007GL032273.

Andrews, T., P. M. Forster, O. Boucher, N. Bellouin, and A. Jones (2010), Precipitation, radiative forcing and global temperature change, *Geophys. Res. Lett.*, *37,* L14701, 701, doi: 10.1029/2010GL043991.

Anenberg, S. C., J. Schwartz, D. Shindell, M. Amann, G. Faluvegi, Z. Klimont, G. Janssens-Maenhout, L. Pozzoli, R. V. Dingenen, E. Vignati, L. Emberson, N. Z. Muller, J. J. West, M. Williams, V. Demkine, W. K. Hicks, J. Kuylenstierna, F. Raes, and V. Ramanathan (2012), Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission controls, *Environ. Health. Perspect.*, *120* (6), 831-839.

Ansmann, A., M. Tesche, D. Althausen, D. Müller, P. Seifert, V. Freudenthaler, B. Heese, M. Wiegner, G. Pisani, P. Knippertz, and O. Dubovik (2008), Influence of Saharan dust on cloud glaciation in southern Morocco during the Saharan Mineral Dust Experiment, *J. Geophys. Res.*, *113,* D04210, doi: 10.1029/2007JD008785.

Aoki, T., H. Motoyoshi, Y. Kodama, T. J. Yasunari, S. Konosuke, and H. Kobayashi (2006), Atmospheric aerosol deposition on snow surfaces and its effect on albedo, *Scientific Online Letters on the Atmosphere (SOLA)*, *2*, 13-16, doi: 10.2151/sola.2006-004.

Aquila, V., J. Hendricks, A. Lauer, N. Riemer, H. Vogel, D. Baumgardner, A. Minikin, A. Petzold, J. P. Schwarz, J. R. Spackman, B. Weinzierl, M. Righi, and M. Dall'Amico (2011), MADE-in: A new aerosol microphysics submodel for global simulation of insoluble particles and their mixing state, *Geosci. Model Dev.*, *4*, 325-355, doi: 10.5194/gmd-4-325-2011.

Arctic Council (2011), *An Assessment of Emissions and Mitigation Options for Black Carbon for the Arctic Council*, 173 pp., Arctic Council Task Force on Short-Lived Climate Forcers, Arctic Council.

Arellano, A. F., P. S. Kasibhatla, L. Giglio, G. R. van der Werf, and J. T. Randerson (2004), Top-down estimates of global CO sources using MOPITT measurements, *Geophys. Res. Lett.*, *31* (1), L01104, doi: 10.1029/2003GL018609.

Arellano, A. F., P. S. Kasibhatla, L. Giglio, G. R. van der Werf, J. T. Randerson, and G. J. Collatz (2006), Time-dependent inversion estimates of global biomass-burning CO emissions using Measurement of Pollution in the Troposphere (MOPITT) measurements, *J. Geophys. Res.*, *111* (D9), 303, doi: 10.1029/2005JD006613.

Arnott, W. P., H. Moosmüller, and C. F. Rogers (1997), Photoacoustic spectrometer for measuring light absorption by aerosol: Instrument description, *Atmos. Environ.*, *33* (17), 2845-2852.

Arola, A., G. Schuster, G. Myhre, S. Kazadzis, S. Dey, and S. N. Tripathi (2011), Inferring absorbing organic carbon content from AERONET data, *Atmos. Chem. Phys.*, *11*, 215-225, doi: 10.5194/acp-11-215-2011.

Ashbaugh, L. L., W. C. Malm, and W. Z. Sadeh (1985), A residence time probability analysis of sulfur concentrations at Grand-Canyon-National-Park, *Atmos. Environ.*, *19* (8), 1263-1270.

Assamoi, E. M., and C. Liousse (2010), A new inventory for two-wheel vehicle emissions in West Africa for 2002, *Atmos. Environ.*, *44* (32), 3985-3996, doi: 10.1016/j.atmosenv.2010.06.048.

Bahadur, R., Y. Feng, L. M. Russell, and V. Ramanathan (2011), Impact of California's air pollution laws on black carbon and their implications for direct radiative forcing, *Atmos. Environ.*, *45*, 1162-1167, doi: 10.1016/j.atmosenv.2010.10.054.

Bailis, R. (2009), Modeling climate change mitigation from alternative methods of charcoal production in Kenya, *Biomass Bioenerg.*, *33* (11), 1491-1502, doi: 10.1016/j.biombioe.2009.07.001.

Bailis, R., M. Ezzati, and D. M. Kammen (2005), Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa, *Science*, *308* (5718), 98-103, doi: 10.1126/science.1106881.

Banta, J. R., J. R. McConnell, R. Edwards, and J. P. Engelbrecht (2008), Delineation of carbonate dust, aluminous dust, and sea salt deposition in a Greenland glaciochemical array using positive matrix factorization, *Geochem. Geophys. Geosyst.*, *9* (7), Q07013, doi: 10.1029/2007GC001908.

Ban-Weiss, G. A., L. Cao, G. Bala, and K. Caldeira (2011), Dependence of climate forcing and response on the altitude of black carbon aerosols, *Climate Dyn.*, *38*, 897-911, doi: 10.1007/s00382-011-1052-y.

Bates, T. S., P. K. Quinn, D. J. Coffman, J. E. Johnson, and A. M. Middlebrook (2005), Dominance of organic aerosols in the marine boundary layer over the Gulf of Maine during NEAQS 2002 and their role in aerosol light scattering, *J. Geophys. Res.*, *110* (D18), 202,

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

doi: 10.1029/2005JD005797.

Battye, W., K. Boyer, and T. G. Pace (2002), *Methods for improving global inventories of black carbon and organic carbon particulates*, Report No. 68-D-98-046, prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC, by EC/R Inc., Chapel Hill, NC.

Bauer, S. E., D. L. Wright, D. Koch, E. R. Lewis, R. McGraw, L. S. Chang, S. E. Schwartz, and R. Ruedy (2008), MATRIX (Multiconfiguration Aerosol TRacker of mIXing state): An aerosol microphysical module for global atmospheric models, *Atmos. Chem. Phys.*, *8* (20), 6003-6035, doi: 10.5194/acp-8-6003-2008.

Bauer, S. E., S. Menon, D. Koch, T. C. Bond, and K. Tsigaridis (2010), A global modeling study on carbonaceous aerosol microphysical characteristics and radiative forcing, *Atmos. Chem. Phys.*, *10*, 4543-4592, doi: 10.5194/acpd-10-4543-2010.

Baumgardner, D., R. Subramanian, C. Twohy, J. Stith, and G. Kok (2008), Scavenging of black carbon by ice crystals over the northern Pacific, *Geophys. Res. Lett.*, *35,* L22815, doi: 10.1029/2008GL035764.

Bell, M. L., K. Ebisu, R. D. Peng, J. M. Samet, and F. Dominici (2009), Hospital admissions and chemical composition of fine particle air pollution, *Am. J. Resp. Crit. Care*, *179* (12), 1115-1120, doi: 10.1164/rccm.200808-1240OC.

Bellouin, N., and O. Boucher (2010), Climate response and efficacy of snow forcing in the HadGEM2-AML climate model, *Hadley Centre Technical Note*, No. 82, 8 pp., Met Office, United Kingdom.

Bergstrom, R. W. (1973), Extinction and absorption coefficients of the atmospheric aerosol as a function of particle size, *Contrib. Atmos. Phys.*, *46*, 223-234.

Bergstrom, R. W., P. B. Russell, and P. Hignett (2002), Wavelength dependence of the absorption of black carbon particles: predictions and results from the TARFOX experiment and implications for the aerosol single scattering albedo, *J. Atmos. Sci.*, *59* (3), 567-577.

Bergstrom, R. W., P. Pilewskie, P. B. Russell, J. Redemann, T. C. Bond, P. K. Quinn, and B. Sierau (2007), Spectral absorption properties of atmospheric aerosols, *Atmos. Chem. Phys.*, *7* (23), 5937-5943, doi: 10.5194/acp-7-5937-2007.

Berntsen, T., and J. S. Fuglestvedt (2008), Global temperature responses to current emissions from the transport sectors, *P. Natl. Acad. Sci. USA*, *105 (49)*, 19254-19159.

Berntsen, T. K., J. S. Fuglestvedt, M. M. Joshi, K. P. Shine, N. Stuber, M. Ponater, R. Sausen, D. A. Hauglustaine, and L. Li (2005), Response of climate to regional emissions of ozone precursors: Sensitivities and warming potentials, *Tellus B*, *57* (4), 283-304, doi: 10.1111/j.1600-0889.2005.00152.x.

Berntsen, T., J. Fuglestvedt, G. Myhre, F. Stordal, and T. F. Berglen (2006), Abatement of greenhouse gases: Does location matter?, *J. Climate*, *74*, 377-411.

Berntsen, T. K., K. Tanaka, and J. S. Fuglestvedt (2010), Does black carbon abatement hamper CO_2 abatement?, *Climatic Change Lett.*, *103*, 627-633, doi: 10.1007/s10584-010-9941-3.

Bhave, P. V., G. A. Pouliot, and M. Zheng (2007), Diagnostic model evaluation for carbonaceous $PM_{2.5}$ using organic markers measured in the southeastern US, *Environ. Sci. Technol.*, *41* (5), 1577-1583, doi: 10.1021/es061785x.

Birch, M. E., and R. A. Cary (1996), Elemental carbon-based method for monitoring occupational exposures to particulate diesel exhaust, *Aerosol Sci. Technol.*, *25*, 221-241.

Bisiaux, M. M., R. Edwards, J. R. McConnell, M. A. J. Curran, T. D. Van Ommen, A. M. Smith, T. A. Neumann, D. R. Pasteris, J. E. Penner, and K. Taylor (2012), Large scale changes in 20th century black carbon deposition to Antarctica, *Atmos. Chem. Phys.*, *12*, 4107-4115, doi: 10.5194/acp-12-4107-2012.

Blumberg, K., M. P. Walsh, and C. Pera (2003), *Low-Sulfur Gasoline and Diesel: The Key to Lower Vehicle Emissions,* prepared for the International Council on Clean Transportation. (http://www.walshcarlines.com/mpwdocs.html), edited.

Boer, G. J., and B. Yu (2003), Climate sensitivity and response, *Climate Dyn.*, *20* (4), 415-429, doi: 10.1007/s00382-002-0283-3.

Bøggild, C. E., R. E. Brandt, K. J. Brown, and S. G. Warren (2010), The ablation zone in northeast Greenland: Ice types, albedos and impurities, *J. Glaciol.*, *56*, 101-113, doi: 10.3189/002214310791190776.

Bollasina, M. A., Y. Ming, and V. Ramaswamy (2011), Anthropogenic aerosols and the weakening of the south Asian summer monsoon,

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Science, *334* (6055), 502-505, doi: 10.1126/science.1204994.

Bonasoni, P., P. Laj, A. Marinoni, M. Sprenger, F. Angelini, J. Arduini, U. Bonafe, F. Calzolari, T. Colombo, S. Decesari, C. Di Biagio, A. G. di Sarra, F. Evangelisti, R. Duchi, M. C. Facchini, S. Fuzzi, G. P. Gobbi, M. Maione, A. Panday, F. Roccato, K. Sellegri, H. Venzac, G. P. Verza, P. Villani, E. Vuillermoz, and P. Cristofanelli (2010), Atmospheric brown clouds in the Himalayas: First two years of continuous observations at the Nepal Climate Observatory-Pyramid (5079 m), *Atmos. Chem. Phys.*, *10* (15), 7515-7531, doi: 10.5194/acp-10-7515-2010.

Bond, T. C. (2001), Spectral dependence of visible light absorption by carbonaceous particles emitted from coal combustion, *Geophys. Res. Lett.*, *28* (21), 4075-4078.

Bond, T. C., and R. W. Bergstrom (2006), Light absorption by carbonaceous particles: An investigative review, *Aerosol Sci. Technol.*, *40* (1), 27-67.

Bond, T. C., and H. Sun (2005), Can reducing black carbon emissions counteract global warming?, *Environ. Sci. Technol.*, *39* (16), 5921-5926, doi: doi: 10.1021/es0480421.

Bond, T. C., T. L. Anderson, and D. Campbell (1999), Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols, *Aerosol Sci. Technol.*, *30*, 582-600.

Bond, T. C., D. G. Streets, K. F. Yarber, S. M. Nelson, J. H. Woo, and Z. Klimont (2004), A technology-based global inventory of black and organic carbon emissions from combustion, *J. Geophys. Res.*, *109* (D14), 203, doi: 10.1029/2003JD003697.

Bond, T. C., G. Habib, and R. W. Bergstrom (2006), Limitations in the enhancement of visible light absorption due to mixing state, *J. Geophys. Res.*, *111* (D20), 211, doi: 10.1029/2006JD007315.

Bond, T. C., E. Bhardwaj, R. Dong, R. Jogani, S. K. Jung, C. Roden, D. G. Streets, and N. M. Trautmann (2007), Historical emissions of black and organic carbon aerosol from energy-related combustion, 1850-2000, *Global Biogeochem. Cycles*, *21* (2), doi: 10.1029/2006GB002840.

Bond, T. C., C. Zarzycki, M. G. Flanner, and D. M. Koch (2011), Quantifying immediate radiative forcing by black carbon and organic matter with the Specific Forcing Pulse, *Atmos. Chem. Phys.*, *11* (4), 1505-1525, doi: 10.5194/acp-11-1505-2011.

Bony, S., and J.-L. Dufresne (2005), Marine boundary layer clouds at the heart of tropical cloud feedback uncertainties in climate models, *Geophys. Res. Lett.*, *32,* L20806, doi: 10.1029/2005GL023851.

Borghesi, A., and G. Guizzetti (1991), Graphite (C), in *Handbook of Optical Constants of Solids, Volume II*, edited by E. D. Palik, 449-460 pp., Academic Press, Boston, MA.

Boucher, O., and M. Pham (2002), History of sulfate aerosol radiative forcings, *Geophys. Res. Lett.*, *29* (9), 1308, doi: 10.1029/2001GL014048.

Boucher, O., and M. S. Reddy (2008), Climate trade-off between black carbon and carbon dioxide emissions, *Energ. Policy*, *36*, 193-200.

Boucher, O., S. E. Schwartz, T. P. Ackerman, T. L. Anderson, B. Bergstrom, B. Bonnel, P. , A. Dahlback, Y. Fouquart, Q. Fu, R. N. Halthore, J. M. Haywood, T. Iversen, S. Kato, S. Kinne, A. Kirkevag, K. R. Knapp, A. Lacis, I. Laszlo, M. I. Mishchenko, S. Nemesure, V. Ramaswamy, D. L. Roberts, P. Russell, M. E. Schlesinger, G. L. Stephens, R. Wagener, M. Wang, J. Wong, and F. Yang (1998), Intercomparison of models representing direct shortwave radiative forcing by sulfate aerosols, *J. Geophys. Res.*, *103* (D14), 16979-16998.

Bradford, D. F. (2001), Global change - Time, money and tradeoffs, *Nature*, *410* (6829), 649-650, doi: 10.1038/35070707.

Brem, B. T., F. C. M. Gonzalez, S. R. Meyers, T. C. Bond, and M. J. Rood (2012), Laboratory-measured optical properties of inorganic and organic aerosols at relative humidities up to 95%, *Aerosol Sci. Technol.*, *46* (2), 178-190, doi: 10.1080/02786826.2011.617794.

Brimblecombe, P. (1977), London air-pollution, 1500-1900, *Atmos. Environ.*, *11* (12), 1157-1162, doi: 10.1016/0004-6981(77)90091-9.

Brioude, J., O. R. Cooper, G. Feingold, M. Trainer, S. R. Freitas, D. Kowal, J. K. Ayers, E. Prins, P. Minnis, S. A. McKeen, G. J. Frost, and E. Y. Hsie (2009), Effect of biomass burning on marine stratocumulus clouds off the California coast, *Atmos. Chem. Phys.*, *9* (22), 8841-8856, doi: 10.5194/acp-9-8841-2009.

Brunekreef, B., R. Beelen, G. Hoek, L. Schouten, S. Bausch-Goldbohm, P. Fischer, B. Armstrong, E. Hughes, M. Jerrett, and P. van den

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Brandt (2009), Effects of long-term exposure to traffic-related air pollution on respiratory and cardiovascular mortality in the Netherlands: The NLCS-AIR study, *Research Report*, 139, Health Effects Institute, Boston, MA.

Bryden, M., D. Still, P. Scott, G. Hoffa, D. Ogle, R. Bailis, and K. Goyer (2006), Design principles for wood burning cook stoves, EPA-402-K-05-004, Aprovecho Research Center.

Budyko, M. I. (1969), The effect of solar radiation variations on the climate of the Earth, *Tellus*, *21* (5), 611-619.

Bueno, P. A., D. K. Havey, G. W. Mulholland, J. T. Hodges, K. A. Gillis, R. R. Dickerson, and M. R. Zachariah (2011), Photoacoustic measurements of amplification of the absorption cross section for coated soot aerosols, *Aerosol Sci. Technol.*, *45*, 1217-1230, doi: 10.1080/02786826.2011.587477.

Cabada, J. C., S. Rees, S. Takahama, A. Khlystov, S. N. Pandis, C. I. Davidson, and A. L. Robinson (2004), Mass size distributions and size resolved chemical composition of fine particulate matter at the Pittsburgh supersite, *Atmos. Environ.*, *38* (20), 3127-3141, doi: 10.1016/j.atmosenv.2004.03.004.

Cachier, H., and M. H. Pertuisot (1994), Particulate carbon in Arctic ice, *Analusis*, *22* (7), M34-M37.

Cao, G. L., X. Y. Zhang, and F. C. Zheng (2006), Inventory of black carbon and organic carbon emissions from China, *Atmos. Environ.*, *40* (34), 6516-6527, doi: 10.1016/j.atmosenv.2006.05.070.

Cao, J. J., F. Wu, J. C. Chow, S. C. Lee, Y. Li, S. W. Chen, Z. S. An, K. K. Fung, J. G. Watson, C. S. Zhu, and S. X. Liu (2005), Characterization and source apportionment of atmospheric organic and elemental carbon during fall and winter of 2003 in Xi'an, China, *Atmos. Chem. Phys.*, *5*, 3127-3137, doi: 10.5194/acp-5-3127-2005.

Cao, J. J., S. C. Lee, J. C. Chow, J. G. Watson, K. F. Ho, R. J. Zhang, Z. D. Jin, Z. X. Shen, G. C. Chen, Y. M. Kang, S. C. Zou, L. Z. Zhang, S. H. Qi, M. H. Dai, Y. Cheng, and K. Hu (2007), Spatial and seasonal distributions of carbonaceous aerosols over China, *J. Geophys. Res.*, *112,* D22s11, doi: 10.1029/2006JD008205.

Cappa, C. D., D. A. Lack, J. B. Burkholder, and A. R. Ravishankara (2008), Bias in filter-based aerosol light absorption measurements due to organic aerosol loading: Evidence from laboratory measurements, *Aerosol Sci. Technol.*, *42* (12), 1022-1032, doi: 10.1080/02786820802389285.

Cappa, C. D., T. B. Onasch, P. Massoli, D. R. Worsnop, T. S. Bates, E. S. Cross, P. Davidovits, J. Hakala, K. L. Hayden, B. T. Jobson, K. R. Kolesar, D. A. Lack, B. M. Lerner, S.-M. Li, D. Mellon, B. Nuaaman, J. S. Olfert, T. Petäjä , P. K. Quinn, C. Song, R. Subramanian, E. J. Williams, and R. A. Zaveri (2012), Radiative absorption enhancements due to the mixing state of atmospheric black carbon, *Science*, *337*, 1078-1081, doi: 10.1126/science.1223447.

CARB (2009), Technical Support Document: Proposed Regulation for In-use On-road Diesel Vehicles, 303, Table XIII-301 pg. 175 pp., California Air Resources Board, Sacramento, CA.

Carmichael, G. R., Y. Tang, G. Kurata, I. Uno, D. G. Streets, N. Thongboonchoo, J.-H. Woo, S. Guttikunda, A. White, T. Wang, D. R. Blake, E. Atlas, A. Fried, B. Potter, M. A. Avery, G. W. Sachse, S. T. Sandholm, Y. Kondo, R. W. Talbot, A. Bandy, D. Thorton, and A. D. Clarke (2003), Evaluating regional emission estimates using the TRACE-P observations, *J. Geophys. Res.*, *108* (D21), 8810, doi: 10.1029/2002JD003116.

Castelvecchi, D. (2009), Subcontinental smut: Is soot the culprit behind melting himalayan glaciers?, *Sci. Amer.*, *December 15*, http://www.scientificamerican.com/article.cfm?id=subcontinental-smut-himalayas.

Cavalli, F., M. Viana, K. E. Yttri, J. Genberg, and J.-P. Putaud (2010), Toward a standardised thermal-optical protocol for measuring atmospheric organic and elemental carbon: The EUSAAR protocol, *Atmos. Meas. Tech., 3 (1)*, 79-89, doi: 10.5194/amt-3-79-2010.

Cesana, G., and H. Chepfer (2012), How well do climate models simulate cloud vertical structure? A comparison between CALIPSO-GOCCP satellite observations and CMIP5 models, *Geophys. Res. Lett.*, *39,* L20803, doi: 10.1029/2012GL053153.

Cess, R. D., G. L. Potter, S. J. Ghan, and W. L. Gates (1985), The climatic effects of large injections of atmospheric smoke and dust - a study of climate feedback mechanisms with one-dimensional and 3-dimensional climate models, *J. Geophys. Res.*, *90* (D7), 2937-2950.

Chakrabarty, R. K., H. Moosmüller, L.-W. A. Chen, K. Lewis, W. P. Arnott, C. Mazzoleni, M. K. Dubey, C. E. Wold, W. M. Hao, and S. M. Kreidenweis (2010), Brown carbon in tar balls from smoldering biomass combustion, *Atmos. Chem. Phys., 10* (13), 6363-6370, doi:

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

10.5194/acp-10-6363-2010.

Chan, A. W. H., K. E. Kautzman, P. S. Chhabra, J. D. Surratt, M. N. Chan, J. D. Crounse, A. Kurten, P. O. Wennberg, R. C. Flagan, and J. H. Seinfeld (2009), Secondary organic aerosol formation from photooxidation of naphthalene and alkylnaphthalenes: implications for oxidation of intermediate volatility organic compounds (IVOCs), *Atmos. Chem. Phys.*, *9*, 3049-3060, doi: 10.5194/acp-9-3049-2009.

Chan, T. W., L. Huang, W. R. Leaitch, S. Sharma, J. R. Brook, J. G. Slowik, J. P. D. Abbatt, P. C. Brickell, J. Liggio, S.-M. Li, and H. Mossmüller (2010), Observations of OM/OC and specific attenuation coefficients (SAC) in ambient fine PM at a rural site in central Ontario, Canada, *Atmos. Chem. Phys., 10* (5), 2393-2411, doi: 10.5194/acp-10-2393-2010.

Chan, T. W., J. R. Brook, G. J. Smallwood, and G. Lu (2011), Time-resolved measurements of black carbon light absorption enhancement in urban and near-urban locations of southern Ontario, Canada, *Atmos. Chem. Phys., 11* (20), 10407-10432, doi: 10.5194/acp-11-10407-2011.

Chand, D., R. Wood, T. L. Anderson, S. K. Satheesh, and R. J. Charlson (2009), Satellite-derived direct radiative effect of aerosols dependent on cloud cover, *Nature Geosci.*, *2* (3), 181-184, doi: 10.1038/ngeo437.

Charalampopoulos, T. T., H. Chang, and B. Stagg (1989), The effects of temperature and composition on the complex refractive-index of flame soot, *Fuel*, *68* (9), 1173-1179.

Charlson, R. J., and M. J. Pilat (1969), Climate: The influence of aerosols, *J. Appl. Met.*, *8* (5), 1001-1002.

Chen, T., W. B. Rossow, and Y. C. Zhang (2000), Radiative effects of cloud-type variations, *J. Climate*, *13*, 264-286, doi: 10.1175/1520-0442(2000)013<0264:REOCTV>2.0.CO;2.

Chen, W. T., R. A. Kahn, D. Nelson, K. Yau, and J. H. Seinfeld (2008), Sensitivity of multiangle imaging to the optical and microphysical properties of biomass burning aerosols, *J. Geophys. Res.*, *113* (D10), 203, doi: 10.1029/2007JD009414.

Chen, W. T., Y. H. Lee, P. J. Adams, A. Nenes, and J. H. Seinfeld (2010a), Will black carbon mitigation dampen aerosol indirect forcing?, *Geophys. Res. Lett.*, *37,* L09801, doi: 10.1029/2010GL042886.

Chen, L. W. A., J. G. Watson, J. C. Chow, D. W. DuBois, and L. Herschberger (2010b), Chemical mass balance source apportionment for combined $PM_{2.5}$ measurements from U. S. non-urban and urban long-term networks, *Atmos. Environ.*, *44* (38), 4908-4918, doi: 10.1016/j.atmosenv.2010.08.030.

Cheng, Y., K.-B. He, M. Zheng, F.-K. Duan, Z.-Y. Du, Y.-L. Ma, J.-H. Tan, F.-M. Yang, J.-M. Liu, X.-L. Zhang, R. J. Weber, M. H. Bergin, and A. G. Russell (2011), Mass absorption efficiency of elemental carbon and water-soluble organic carbon in Beijing, China, *Atmos. Chem. Phys., 11 (22)*, 11497-11510, doi: 10.5194/acp-11-11497-2011.

Chevallier, F., M. Fisher, P. Peylin, S. Serrar, P. Bousquet, F. M. Breon, A. Chedin, and P. Ciais (2005), Inferring CO_2 sources and sinks from satellite observations: Method and application to TOVS data, *J. Geophys. Res.*, *110* (D24), 309, doi: 10.1029/2005JD006390.

Chevallier, F., A. Fortems, P. Bousquet, I. Pison, S. Szopa, M. Devaux, and D. A. Hauglustaine (2009), African CO emissions between years 2000 and 2006 as estimated from MOPITT observations, *Biogeosciences*, *6* (1), 103-111.

Chin, M., P. Ginoux, S. Kinne, O. Torres, B. N. Holben, B. N. Duncan, R. V. Martin, J. A. Logan, A. Higurashi, and T. Nakajima (2002), Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and Sun photometer measurements, *J. Atmos. Sci.*, *59* (3), 461-483.

Chin, M., T. Diehl, O. Dubovik, T. F. Eck, B. N. Holben, A. Sinyuk, and D. G. Streets (2009), Light absorption by pollution, dust, and biomass burning aerosols: A global model study and evaluation with AERONET measurements, *Ann. Geophys.*, *27* (9), 3439-3464, doi: 10.5194/angeo-27-3439-2009.

Chow, J. C., J. G. Watson, L. C. Pritchett, W. R. Pierson, C. A. Frazier, and R. G. Purcell (1993), The DRI thermal/optical reflectance carbon analysis system: Description, evaluation and applications in U.S. air quality studies, *Atmos. Environ.*, *27A* (8), 1185-1201, doi: 10.1016/0960-1686(93)90245-T.

Chow, J. C., J. G. Watson, D. Crow, D. H. Lowenthal, and T. Merrifield (2001), Comparison of IMPROVE and NIOSH carbon measurements, *Aerosol Sci. Technol.*, *34* (1), 23-34.

Chow, J. C., and J. G. Watson (2002), Review of $PM_{2.5}$ and PM_{10} apportionment for fossil fuel combustion and other sources by the

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

chemical mass balance receptor model, *Energy & Fuels*, *16* (2), 222-260, doi: 10.1021/Ef0101715.

Chow, J. C., J. G. Watson, L.-W. A. Chen, W. P. Arnott, and H. Moosmüller (2004), Equivalence of elemental carbon by thermal/optical reflectance and transmittance with different temperature protocols, *Environ. Sci. Technol.*, *38*, 4414-4422.

Chowdhury, Z., M. Zheng, J. J. Schauer, R. J. Sheesley, L. G. Salmon, G. R. Cass, and A. G. Russell (2007), Speciation of ambient fine organic carbon particles and source apportionment of $PM_{2.5}$ in Indian cities, *J. Geophys. Res.*, *112* (D15), doi: D15303, doi: 10.1029/2007JD008386.

Christian, T. J., R. J. Yokelson, B. Cardenas, L. T. Molina, G. Engling, and S. C. Hsu (2010), Trace gas and particle emissions from domestic and industrial biofuel use and garbage burning in central Mexico, *Atmos. Chem. Phys.*, *10* (2), 565-584, doi: 10.5194/acp-10-565-2010.

Chuang, C. C., J. E. Penner, J. M. Prospero, K. E. Grant, G. H. Rau, and K. Kawamoto (2002), Cloud susceptibility and the first aerosol indirect forcing: Sensitivity to black carbon and aerosol concentrations, *J. Geophys. Res.*, *107* (D21), 4564, doi: 10.1029/2000JD000215.

Chung, C. E., and V. Ramanathan (2006), Weakening of North Indian SST gradients and the monsoon rainfall in India and the Sahel, *J. Climate*, *19* (10), 2036-2045.

Chung, C. E., V. Ramanathan, and J. T. Kiehl (2002), Effects of the south Asian absorbing haze on the northeast monsoon and surface-air heat exchange, *J. Climate*, *15* (17), 2462-2476.

Chung, C. E., V. Ramanathan, D. Kim, and I. A. Podgorny (2005), Global anthropogenic aerosol direct forcing derived from satellite and ground-based observations, *J. Geophys. Res.*, *110* (D24), 207, doi: 10.1029/2005JD006356.

Chung, C. E., V. Ramanathan, and D. Decremer (2012), Observationally constrained estimates of carbonaceous aerosol radiative forcing, *Proc. Natl. Acad. Sci. U. S. A*, *109* (29), doi: 10.1073/pnas.1203707109.

Chung, S. H., and J. H. Seinfeld (2002), Global distribution and climate forcing of carbonaceous aerosols, *J. Geophys. Res.*, *107*, doi: 10.1029/2001JD001397.

Chung, S. H., and J. H. Seinfeld (2005), Climate response of direct radiative forcing of anthropogenic black carbon, *J. Geophys. Res.*, *110* (D11), 102, doi: 10.1029/2004JD005441.

, P., and J. A. Coakley (1974), Aerosols and climate, *Science, 183,* 75-77.

Chyìlek, P., and J. Wong (1995), Effect of absorbing aerosol on global radiation budget, *Geophys. Res. Lett.*, *22* (8), 929-931.

, P., V. Ramaswamy, A. Ashkin, and J. M. Dziedzic (1983a), Simultaneous determination of refractive-index and size of spherical dielectric particles from light-scattering data, *Appl. Opt.*, *22* (15), 2302-2307, doi: 10.1364/AO.22.002302.

, P., V. Ramaswamy, and V. Srivastava (1983b), Albedo of soot-contaminated snow, *J. Geophys. Res.*, *88* (C15), 10837-10843, doi: 10.1029/JC088iC15p10837.

, P., V. Ramaswamy, and R. J. Cheng (1984), Effect of graphitic carbon on the albedo of clouds, *J. Atmos. Sci.*, *41* (21), 3076-3084, doi: 10.1175/1520-0469(1984)041<3076:EOGCOT>2.0.CO;2.

, P., V. Srivastava, L. Cahenzli, R. G. Pinnick, R. L. Dod, T. Novakov, T. L. Cook, and B. D. Hinds (1987), Aerosol and graphitic carbon content of snow, *J. Geophys. Res.*, *92* (D8), 9801-9809, doi: 10.1029/JD092iD08p0980.

, P., B. Johnson, P. A. Damiano, K. C. Taylor, and P. Clement (1995), Biomass burning record and black carbon in the GISP2 Ice Core, *Geophys. Res. Lett.*, *22* (2), 89-92, doi: 10.1029/94GL02841.

, P., G. B. Lesins, G. Videen, J. G. D. Wong, R. G. Pinnick, D. Ngo, and J. D. Klett (1996), Black carbon and absorption of solar radiation by clouds, *J. Geophys. Res.*, *101* (D18), 23365-23371, doi: 10.1029/96JD01901.

, P., M. K. Dubey, U. Lohmann, V. Ramanathan, Y. J. Kaufman, G. Lesins, J. Hudson, G. Altmann, and S. Olsen (2006), Aerosol indirect effect over the Indian Ocean, *Geophys. Res. Lett.*, *33,* L06806, doi: 10.1029/2005GL025397.

Clarke, A., and V. Kapustin (2010), Hemispheric aerosol vertical profiles: Anthropogenic impacts on optical depth and cloud nuclei, *Science*, *329* (5998), 1488-1492, doi: 10.1126/science.1188838.

Clarke, A. D., and K. J. Noone (1985), Soot in the Arctic snowpack - A cause for perturbations in radiative transfer, *Atmos. Environ.*, *19*

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

(12), 2045-2053, doi: 10.1016/0004-6981(85)90113-1.

Clarke, A. D., Y. Shinozuka, V. N. Kapustin, S. Howell, B. Huebert, S. Doherty, T. Anderson, D. Covert, J. Anderson, X. Hua, K. G. Moore II, C. McNaughton, G. Carmichael, and R. Weber (2004), Size distributions and mixtures of dust and black carbon aerosol in Asian outflow: Physiochemistry and optical properties, *J. Geophys. Res.*, *109,* D15S09, doi: 10.1029/2003JD004378.

Clarke, A., C. McNaughton, V. Kapustin, Y. Shinozuka, S. Howell, J. Dibb, J. Zhou, B. Anderson, V. Brekhovskikh, H. Turner, and M. Pinkerton (2007), Biomass burning and pollution aerosol over North America: Organic components and their influence on spectral optical properties and humidification response, *J. Geophys. Res.*, *112,* D12s18, doi: 10.1029/2006JD007777.

Cofala, J., M. Amann, Z. Klimont, K. Kupiainen, and L. Hoglund-Isaksson (2007), Scenarios of global anthropogenic emissions of air pollutants and methane until 2030, *Atmos. Environ.*, *41* (38), 8486-8499, doi: 10.1016/j.atmosenv.2007.07.010.

Collins, W. D., P. J. Rasch, B. A. Boville, J. J. Hack, J. R. McCaa, D. L. Williamson, B. P. Briegleb, C. M. Bitz, S.-J. Lin, and M. Zhang (2006), The formulation and atmospheric simulation of the Community Atmosphere Model Version 3 (CAM3), *J. Climate*, *19*, 2144-2161, doi: 10.1175/JCL13760.1.

Collins, W. J., R. G. Derwent, C. E. Johnson, and D. S. Stevenson (2002), The oxidation of organic compounds in the troposphere and their global warming potentials *Climatic Change*, *52* (4), 453-479, doi: 10.1023/A:1014221225434.

Collins, W. J., S. Sitch, and O. Boucher (2010), How vegetation impacts affect climate metrics for ozone precursors, *J. Geophys. Res.*, *115,* D23308, doi: 10.1029/2010JD014187.

Comiso, J. C., C. L. Parkinson, R. Gersten, and L. Stock (2008), Accelerated decline in the Arctic sea ice cover, *Geophys. Res. Lett.*, *35* (1), 703, doi: 10.1029/2007GL031972.

Conant, W. C., A. A. Nenes, and J. H. Seinfeld (2002), Black carbon radiative heating effects on cloud microphysics and implications for the aerosol indirect effect - 1. Extended Kohler theory, *J. Geophys. Res.*, *107*, 4604, doi: 10.1029/2002jd002094.

Conny, J. M., D. B. Klinedienst, S. A. Wight, and J. L. Paulsen (2003), Optimizing thermal-optical methods for measuring atmospheric elemental (black) carbon: A response surface study, *Aerosol Sci. Technol., 37 (9),* 703-723, doi: 10.1080/02786820300920.

Conway, H., A. Gades, and C. F. Raymond (1996), Albedo of dirty snow during conditions of melt, *Water Resour. Res.*, *32* (6), 1713-1718.

Cook, J., and E. J. Highwood (2004), Climate response to tropospheric absorbing aerosols in an intermediate general-circulation model, *Quart J. Roy. Meteor. Soc.*, *130* (596), 175-191, doi: 10.1256/qj.03.64.

Cooke, R. M., A. M. Wilson, J. T. Tuomisto, O. Morales, M. Tainio, and J. S. Evans (2007), A probabilistic characterization of the relationship between fine particulate matter and mortality: Elicitation of European experts, *Environ. Sci. Technol.*, *41* (18), 6598-6605, doi: 10.1021/es0714078.

Cooke, W. F., and J. J. N. Wilson (1996), A global black carbon aerosol model, *J. Geophys. Res.*, *101* (D14), 19395-19409.

Cooke, W. F., C. Liousse, H. Cachier, and J. Feichter (1999), Construction of a 1° x 1° fossil fuel emission data set for carbonaceous aerosol and implementation and radiative impact in the ECHAM4 model, *J. Geophys. Res.*, *104* (D18), 22137-22162.

Cooke, W. F., V. Ramaswamy, and P. Kasibhatla (2002), A general circulation model study of the global carbonaceous aerosol distribution, *J. Geophys. Res.*, *107* (D16), doi: 10.1029/2001JD001274.

COP-15 (2009), COP-15, Copenhagen Accord, Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session, United Nations Framework Convention on Climate Change, http://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php2009, 2009.

Corbett, J. J., D. A. Lack, J. J. Winebrake, S. Harder, J. A. Silberman, and M. Gold (2010), Arctic shipping emissions inventories and future scenarios, *Atmos. Chem. Phys.*, *10*, 9689-9704, doi: 10.5194/acpd-10-9689-2010.

Corrigan, C. E., G. C. Roberts, M. V. Ramana, D. Kim, and V. Ramanathan (2008), Capturing vertical profiles of aerosols and black carbon over the Indian Ocean using autonomous unmanned aerial vehicles, *Atmos. Chem. Phys.*, *8* (3), 737-747, doi: 10.5194/acp-8-737-2008.

Cozic, J., S. Mertes, B. Verheggen, D. J. Cziczo, S. J. Gallavardin, S. Walter, U. Baltensperger, and E. Weingartner (2008), Black carbon enrichment in atmospheric ice particle residuals observed in lower tropospheric mixed phase clouds, *J. Geophys. Res.*, *113* (D15), 209,

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

doi: 10.1029/2007JD009266.

Crawford, I., O. Möhler, M. Schnaiter, H. Saathoff, D. Liu, G. McMeeking, C. Linke, M. Flynn, K. N. Bower, P. J. Connolly, M. W. Gallagher, and H. Coe (2011), Studies of propane flame soot acting as heterogeneous ice nuclei in conjuntion with single particle soot photometer measurements., *Atmos. Chem. Phys.*, *11* (18), 9549-9561, doi: 10.5194/acp-11-9549-2011.

Croft, B., U. Lohmann, and K. von Salzen (2005), Black carbon ageing in the Canadian Centre for Climate modeling and analysis atmospheric general circulation model, *Atmos. Chem. Phys.*, *5*, 1931-1949, doi: 10.5194/acp-5-1931-2005.

Croft, B., U. Lohmann, R. V. Martin, P. Stier, S. Wurzler, J. Feichter, C. Hoose, U. Heikkila, A. van Donkelaar, and S. Ferrachat (2010), Influences of in-cloud aerosol scavenging parameterizations on aerosol concentrations and wet deposition in ECHAM5-HAM, *Atmos. Chem. Phys.*, *10* (4), 1511-1543, doi: 10.5194/acp-10-1511-2010.

Crook, J. A., P. M. Forster, and N. Stuber (2011), Spatial patterns of modeled climate feedback and contributions to temperature response and polar amplification, *J. Climate*, *24*, 3575-3592, doi: 10.1175/2011JCLI3863.1

Cross, E. S., T. B. Onasch, A. Ahern, W. Wrobel, J. G. Slowik, J. Olfert, D. A. Lack, P. Massoli, C. D. Cappa, J. P. Schwarz, J. R. Spackman, D. W. Fahey, A. Sedlacek, A. Trimborn, J. T. Jayne, A. Freedman, L. R. Williams, N. L. Ng, C. Mazzolen, M. Dubey, B. Brem, G. Kok, R. Subramanian, S. Freitag, A. Clarke, D. Thornhill, L. C. Marr, C. E. Kolb, D. R. Worsnop, and P. Davidovits (2010), Soot Particle Studies—Instrument Inter-Comparison—Project Overview, *Aerosol Sci. Technol.*, *44* (8), 592-611, P

Cziczo, D. J., P. J. DeMott, S. D. Brooks, A. J. Prenni, D. S. Thomson, D. Baumgardner, J. C. Wilson, S. M. Kreidenweis, and D. M. Murphy (2004a), Observations of organic species and atmospheric ice formation, *Geophys. Res. Lett.*, *31* (12), 116, doi: 10.1029/2004GL019822.

Cziczo, D. J., D. M. Murphy, P. K. Hudson, and D. S. Thomson (2004b), Single particle measurements of the chemical composition of cirrus ice residue during CRYSTAL-FACE, *J. Geophys. Res.*, *109* (D4), 201, doi: 10.1029/2003JD004032.

Cziczo, D. J., O. Stetzer, A. Worringen, M. Ebert, S. Weinbruch, M. Kamphus, S. J. Gallavardin, J. Curtius, S. Borrmann, K. D. Froyd, S. Mertes, O. Möhler, and U. Lohmann (2009), Inadvertent climate modification due to anthropogenic lead, *Nature Geosci.*, *2* (5), 333-336, doi: 10.1038/ngeo499.

Darby, D. A., L. H. Burckle, and D. L. Clark (1974), Airborn dust on Arctic pack ice, its composition and fallout rate, *Earth Planet Sci. Lett*, *24* (2), 166-172.

De Angelis, M., J. P. Steffensen, M. Legrand, H. Clausen, and C. Hammer (1997), Primary aerosol (sea salt and soil dust) deposited in Greenland ice during the last climatic cycle: Comparison with east Antarctic records, *J. Geophys. Res.*, *102* (C12), 26681-26698.

de Gouw, J. A., and J. L. Jimenez (2009), Organic aerosols in the Earth's atmosphere, *Environ. Sci. Technol.*, *43*, 7614-7618, doi: 10.1021/es9006004.

DeMott, P. J. (1990), An exploratory-study of ice nucleation by soot aerosols, *J. Appl. Meteorol.*, *29* (10), 1072-1079.

DeMott, P. J., Y. Chen, S. M. Kreidenweis, D. C. Rogers, and D. E. Sherman (1999), Ice formation by black carbon particles, *Geophys. Res. Lett.*, *26*, 2429-2432, doi: 10.1029/1999GL900580.

DeMott, P. J., D. J. Cziczo, A. J. Prenni, D. M. Murphy, S. M. Kreidenweis, D. S. Thomson, R. Borys, and D. C. Rogers (2003), Measurements of the concentration and composition of nuclei for cirrus formation, *P. Natl. Acad. Sci. USA*, *100* (25), 14655-14660, doi: 10.1073/pnas.2532677100.

DeMott, P. J., M. D. Petters, A. J. Prenni, C. M. Carrico, S. M. Kreidenweis, J. L. Collett, and H. Moosmüller (2009a), Ice nucleation behavior of biomass combustion particles at cirrus temperatures, *J. Geophys. Res.*, *114* (D16), 205, doi: 10.1029/2009JD012036.

DeMott, P. J., K. Sassen, M. R. Poellot, D. Baumgardner, D. C. Rogers, S. D. Brooks, A. J. Prenni, and S. M. Kreidenweis (2009b), African dust aerosols as atmospheric ice nuclei, *Geophys. Res. Lett.*, *36* (L07), 808, doi: 10.1029/2009GL037639.

DeMott, P. J., A. J. Prenni, Z. Liu, S. M. Kreidenweis, M. D. Petters, C. H. Twohy, M. S. Richardson, T. Eidhammer, and D. C. Rogers (2010), Predicting global atmospheric ice nuclei distributions and their impact on climate, *P. Natl. Acad. Sci. USA*, *107*, 11217-11222, doi: 10.1073/pnas.0910818107.

Denman, K. L., G. Brasseur, A. Chidthaisong, P. Ciais, P. M. Cox, R. E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Lohmann, S. Ramachandran, P. L. da Silva Dias, S. C. Wofsy, and X. Zhang (2007), Couplings between changes in the climate system and biogeochemistry, in *Climate change 2007: The physical science basis*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tigor and H. L. Miller, 129-234 pp., Cambridge University Press, Cambridge, United Kingdom.

Dentener, F., S. Kinne, T. Bond, O. Boucher, J. Cofala, S. Generoso, P. Ginoux, S. Gong, J. J. Hoelzemann, A. Ito, L. Marelli, J. E. Penner, J.-P. Putaud, C. Textor, M. Schulz, G. R. v. d. Werf, and J. Wilson (2006), Emissions of primary aerosol and precursor gases in the years 2000 and 1750: Prescribed data-sets for AeroCom, *Atmos. Chem. Phys.*, *6*, 4321-4344, doi: 10.5194/acp-6-4321-2006.

Déry, S. J., and R. D. Brown (2007), Recent northern hemisphere snow cover extent trends and implications for the snow-albedo feedback, *Geophys. Res. Lett.*, *34* (22), L22504, doi: 10.1029/2007GL031474.

Deuzé, J. L., F. M. Bréon, C. Devaux, P. Goloub, M. Herman, B. Lafrance, F. Maignan, A. Marchand, F. Nadal, G. Perry, and D. Tanré (2001), Remote sensing of aerosol over land surfaces from POLDER/ADEOS-1 polarized measurements, *J. Geophys. Res.*, *106*, 4913-4926, doi: 10.1029/2000JD900364.

Deville, R. E. L., N. Riemer, and M. West (2011), Weighted Flow Algorithms (WFA) for stochastic particle coagulation, *J. Comput. Phys.*, *230* (23), 8427-8451, doi: 10.1016/j.jcp.2011.07.027.

Dickerson, R. R., M. O. Andreae, T. Campos, O. L. Mayol-Bracero, C. Neususess, and D. G. Streets (2002), Analysis of black carbon and carbon monoxide observed over the Indian Ocean: Implications for emissions and photochemistry, *J. Geophys. Res.*, *107* (D19), 8017, doi: 10.1029/2001JD000501.

Diehl, K., and S. K. Mitra (1998), A laboratory study of the effects of a kerosene-burner exhaust on ice nucleation and the evaporation rate of ice crystals, *Atmos. Environ.*, *32* (18), 3145-3151.

Diehl, K., M. Simmel, and S. Wurzler (2006), Numerical sensitivity studies on the impact of aerosol properties and drop freezing modes on the glaciation, microphysics, and dynamics of clouds, *J. Geophys. Res.*, *111* (D07), 202, doi: 10.1029/2005JD005884.

Dippel, B., H. Jander, and J. Heintzenberg (1999), NIR FT Raman spectroscopic study of flame soot, *Phys. Chem. Chem. Phys., 1*, 4707-4712.

Dobbins, R. A., and C. M. Megaridis (1991), Absorption and scattering of light by polydisperse aggregates, *Appl. Opt., 30* (33), 4747-4754.

DOE, U. S. Department of Energy (2010), Final Rule Technical Support Document: Energy Efficiency Program for Commercial and Industrial Equipment: Small Electric Motors, Appendix 15A. Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 13. http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf.

Doherty, S. J., P. K. Quinn, A. Jefferson, C. M. Carrico, T. L. Anderson, and D. Hegg (2005), A comparison and summary of aerosol optical properties as observed in situ from aircraft, ship, and land during ACE-Asia, *J. Geophys. Res.*, *110* (D4), 201, doi: 10.1029/2004JD004964.

Doherty, S. J., S. G. Warren, T. C. Grenfell, A. D. Clarke, and R. E. Brandt (2010), Light-absorbing impurities in Arctic snow, *Atmos. Chem. Phys.*, *10* (23), 11647-11680, doi: 10.5194/acp-10-11647-2010.

Donahue, N. M., A. L. Robinson, C. O. Stanier, and S. N. Pandis (2006), Coupled partitioning, dilution, and chemical aging of semivolatile organics, *Environ. Sci. Technol.*, *40* (8), 2635-2643, doi: 10.1021/es052297c.

Draine, B. T., and P. J. Flatau (1994), Discrete-dipole approximation for scattering calculations, *J. Opt. Soc. Am. A, 11* (4), 1491-1499.

Dubovik, O., and M. D. King (2000), A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements, *J. Geophys. Res.*, *105* (D16), 20673-20696.

Dubovik, O., A. Smirnov, B. N. Holben, M. D. King, Y. J. Kaufman, T. F. Eck, and I. Slutsker (2000), Accuracy assessment of aerosol optical properties retrieved from Aerosol Robotic Network (AERONET) Sun and sky radiance measurements, *J. Geophys. Res.*, *105* (D8), 9791-9806.

Dubovik, O., B. Holben, T. F. Eck, A. Smirnov, Y. J. Kaufman, M. D. King, D. Tanre, and I. Slutsker (2002), Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J. Atmos. Sci.*, *59* (3), 590-608.

Dubovik, O., T. Lapyonok, Y. J. Kaufman, M. Chin, P. Ginoux, R. A. Kahn, and A. Sinyuk (2008), Retrieving global aerosol sources from satellites using inverse modeling, *Atmos. Chem. Phys.*, *8* (2), 209-250, doi: 10.5194/acp-8-209-2008.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Dusek, U., G. P. Reischl, and R. Hitzenberger (2006a), CCN activation of pure and coated carbon black particles, *Environ. Sci. Technol., 40* (4), 1223-1230.

Dusek, U., G. P. Frank, L. Hildebrandt, J. Curtius, J. Schneider, S. Walter, D. Chand, F. Drewnick, S. Hings, D. Jung, S. Borrmann, and M. O. Andreae (2006b), Size matters more than chemistry for cloud-nucleating ability of aerosol particles, *Science, 312* (5778), 1375-1378.

Dymarska, M., B. J. Murray, L. M. Sun, M. L. Eastwood, D. A. Knopf, and A. K. Bertram (2006), Deposition ice nucleation on soot at temperatures relevant for the lower troposphere, *J. Geophys. Res.*, *111* (D04), 204, doi: 10.1029/2005JD006627.

Easter, R. C., S. J. Ghan, Y. Zhang, R. D. Saylor, E. G. Chapman, N. S. Laulainen, H. Abdul-Razzak, L. R. Leung, X. D. Bian, and R. A. Zaveri (2004), MIRAGE: Model description and evaluation of aerosols and trace gases, *J. Geophys. Res.*, *109* (D20), 210, doi: 10.1029/2004JD004571.

Eck, T. F., B. N. Holben, D. E. Ward, M. M. Mukelabai, O. Dubovik, A. Smirnov, J. S. Schafer, N. C. Hsu, S. J. Piketh, A. Queface, J. Le Roux, R. J. Swap, and I. Slutsker (2003), Variability of biomass burning aerosol optical characteristics in southern Africa during the SAFARI 2000 dry season campaign and a comparison of single scattering albedo estimates from radiometric measurements, *J. Geophys. Res.*, *108* (D13), 8477, doi: 10.1029/2002JD002321.

Ekman, A. M. L., A. Engstrom, and C. Wang (2007), The effect of aerosol composition and concentration on the development and anvil properties of a continental deep convective cloud, *Quart J. Roy. Meteor. Soc.*, *133* (627), 1439-1452, doi: 10.1002/qj.108.

Eleftheriadis, K., S. Vratolis, and S. Nyeki (2009), Aerosol black carbon in the European Arctic: Measurements at Zeppelin station, Ny-Ålesund, Svalbard from 1998-2007, *Geophys. Res. Lett.*, *36,* L0809, doi: 10.1029/2008GL035741.

Elvidge, C. D., K. Baugh, B. Tuttle, D. Ziskin, T. Ghoshet, M. Zhizhin, and D. Pack (2009), Improving satellite data estimation of gas flaring volumes: Year two final report to the GGFR.

Engelbrecht, J. P., L. Swanepoel, J. C. Chow, J. G. Watson, and R. T. Egami (2002), The comparison of source contributions from residential coal and low-smoke fuels, using CMB modeling, *Environ. Sci. Technol.*, *5* (2), 157-167.

EPA (1992), Particulate matter best available control measure technical guidance documents for prescribed burning and fugitive dust, U. S. Environmental Protection Agency, Research Triangle Park, NC.

EPA (1996), Compilation of Air Pollution Emission Factors, Vol. 1, Stationary Point and Area Sources, AP42, Fifth Edition, U.S. Environmental Protection Agency, Washington, DC.

EPA (2002), A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions, U. S. Environmental Protection Agency, Draft Technical Report, Ann Arbor, MI.

EPA (2005), AirControlNET Version 4.1 Documentation Report, Prepared by E.H. Pechan & Associates Inc., Springfield, VA.

EPA (2008), Emission Factor Documentation for AP-42: Section 12.2, Coke Production. Finalized by RTI International for U.S. Environmental Protection Agency., Research Triangle Park, NC.

EPA (2009a), Integrated Science Assessment for Particulate Matter, U. S. Environmental Protection Agency, Washington, DC.

EPA (2009b), Available from http://www.epa.gov/ne/eco/diesel/idling.html.

EPA (2012), Report to Congress on Black Carbon, US Environmental Protection Agency, Washington, DC, in preparation.

Essery, R. (1997), Modelling fluxes of momentum, sensible heat and latent heat over heterogeneous snow cover, *Quart J. Roy. Meteor. Soc.*, *123* (543), 1867-1883.

Etyemezian, V., M. Tesfaye, A. Yimer, J. C. Chow, D. Mesfin, T. Nega, G. Nikolich, J. G. Watson, and M. Wondmagegn (2005), Results from a pilot-scale air quality study in Addis Ababa, Ethiopia, *Atmos. Environ.*, *39* (40), 7849-7860, doi: 10.1016/j.atmosenv.2005.08.033.

Eyring, V., I. S. A. Isaksen, T. Berntsen, W. J. Collins, J. J. Corbett, O. Endresen, R. G. Grainger, J. Moldanova, H. Schlager, and D. S. Stevenson (2010), Transport impacts on atmosphere and climate: Shipping, *Atmos. Environ. 44*, 4735-4771, doi: 10.1016/j.atmosenv.2009.04.059.

Fan, J. W., R. Y. Zhang, W. K. Tao, and K. I. Mohr (2008), Effects of aerosol optical properties on deep convective clouds and radiative forcing, *J. Geophys. Res.*, *113* (D08), 209, doi: 10.1029/2007JD009257.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Fann, N., C. Fulcher, and B. Hubbell (2009), The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution, *Air Quality, Atmosphere & Health*, *2* (3), doi: 10.1007/s11869-009-0044-0.

Federal Law Gazette (2010, First Regulation implementing the Federal Pollution Control Act, Ordinance on small and medium-sized combustion plants - 1.BimSchV, 26 January 2010, Federal Law Gazette, Part I, No. 4, Bonn, 2010.

Feingold, G., H. L. Jiang, and J. Y. Harrington (2005), On smoke suppression of clouds in Amazonia, *Geophys. Res. Lett.*, *32* (2), 804, doi: 10.1029/2004GL021369.

Ferek, R. J., D. A. Hegg, P. V. Hobbs, P. Durkee, and K. Nielsen (1998), Measurements of ship-induced tracks in clouds off the Washington coast, *J. Geophys. Res.*, *103* (D18), 23199-23206.

Fernandes, S. D., N. M. Trautmann, and D. G. Streets (2007), Global biofuel use, 1850-2000, *Global Biogeochem. Cycles*, *21* (2), doi: 10.1029/2006GB002836.

Fetterer, F., and N. Untersteiner (1998), Observations of melt ponds on Arctic sea ice, *J. Geophys. Res.*, *103* (C11), 24821-24835, doi: 10.1029/98JC02034.

Fialho, P., M. C. Freitas, F. Barata, B. Vieira, A. D. A. Hansen, and R. E. Honrath (2006), The Aethalometer calibration and determination of iron concentration in dust aerosols, *J. Aerosol. Sci.*, *37* (11), 1497-1506, doi: 10.1016/j.jaerosci.2006.03.002.

Flanner, M. G., and C. S. Zender (2006), Linking snowpack microphysics and albedo evolution, *J. Geophys. Res.*, *111* (D12), 208, doi: 10.1029/2005JD006834.

Flanner, M. G., C. S. Zender, J. T. Randerson, and P. J. Rasch (2007), Present-day climate forcing and response from black carbon in snow, *J. Geophys. Res.*, *112* (D11), 202, doi: 10.1029/2006JD008003.

Flanner, M. G., C. S. Zender, P. G. Hess, N. M. Mahowald, T. H. Painter, V. Ramanathan, and P. J. Rasch (2009), Springtime warming and reduced snow cover from carbonaceous particles, *Atmos. Chem. Phys.*, *9* (7), 2481-2497, doi: 10.5194/acp-9-2481-2009.

Flanner, M. G., K. M. Shell, M. Barlage, D. K. Perovich, and M. A. Tschudi (2011), Radiative forcing and albedo feedback from the Northern Hemisphere cryosphere between 1979 and 2008, *Nature Geosci.*, *4*, 151-155, doi: 10.1038/ngeo1062.

Fletcher, J. O. (1968), The influence of the Arctic pack ice on climate, *Meteor. Monogr.*, *8* (30), 93-99.

Fornea, A. P., S. D. Brooks, J. B. Dooley, and A. Saha (2009), Heterogeneous freezing of ice on atmospheric aerosols containing ash, soot, and soil, *J. Geophys. Res.*, *114,* D13201, doi: 10.1029/2009JD011958.

Forsström, S., J. Ström, C. A. Pedersen, E. Isaksson, and S. Gerland (2009), Elemental carbon distribution in Svalbard snow, *J. Geophys. Res.*, *114* (D19), 112, doi: 10.1029/2008JD011480.

Forster, P. M., M. Blackburn, R. Glover, and K. P. Shine (2000), An examination of climate sensitivity for idealised climate change experiments in an intermediate general circulation model, *Climate Dyn.*, *16* (10-11), 833-849.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D. W. Fahey, J. Haywood, J. Lean, D. C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz , and R. Van Dorland (2007), Changes in atmospheric constituents and in radiative forcing, in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, Cambridge University Press, New York, NY.

Freitas, S. R., K. M. Longo, M. Diasb, P. L. S. Diasb, R. Chatfield, E. Prins, P. Artaxo, G. A. Grell, and F. S. Recuero (2005), Monitoring the transport of biomass burning emissions in South America, *Environ. Fluid Mech.*, *5* (1-2), 135-167.

Friedlander, S. K. (1973), Chemical element balances and identification of air-pollution sources, *Environ. Sci. Technol.*, *7* (3), 235-240.

Friedman, B., G. Kulkarni, J. Beránek, A. Zelenyuk, J. A. Thornton, and D. J. Cziczo (2011), Ice nucleation and droplet formation by bare and coated soot particles, *J. Geophys. Res.*, *116,* D17203, doi: 10.1029/2011JD015999.

Froyd, K. D., D. M. Murphy, T. J. Sanford, D. S. Thomson, J. C. Wilson, L. Pfister, and L. Lait (2009), Aerosol composition of the tropical upper troposphere, *Atmos. Chem. Phys.*, *9* (13), 4363-4385.

Fuglestvedt, J. S., T. Berntsen, O. Godal, and T. Skodvin (2000), Climate implications of GWP based reductions in greenhouse gas emissions, *Geophys. Res. Lett.*, *27*, 409-412.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Fuglestvedt, J. S., T. K. Berntsen, O. Godal, R. Sausen, K. P. Shine, and T. Skodvin (2003), Metrics of climate change: Assessing radiative forcing and emission indices, *Climatic Change*, *58* (3), 267-331.

Fuglestvedt, J. S., T. Berntsen, G. Myhre, K. Rypdal, and R. B. Skeie (2008), Climate forcing from the Transport Sectors, *P. Natl. Acad. Sci. USA*, *105 (2)*, 454-458.

Fuglestvedt, J. S., K. P. Shine, T. Berntsen, J. Cook, D. S. Lee, A. Stenke, R. B. Skeie, G. J. M. Velders, and I. A. Waitz (2010), Transport impacts on atmosphere and climate: Metrics, *Atmos. Environ.*, *44* (37), 4648-4677, doi: 10.1016/j.atmosenv.2009.04.044.

Fuller, K. A. (1995), Scattering and absorption cross sections of compounded spheres. III. Spheres containing arbitrarily located spherical inhomogeneities, *J. Opt. Soc. Am. A*, *12* (5), 893-904, doi: 10.1364/JOSA.A.12.000893.

Fuller, K. A., W. C. Malm, and S. M. Kreidenweis (1999), Effects of mixing on extinction by carbonaceous particles, *J. Geophys. Res.*, *104* (D13), 15941-15954, doi: 10.1029/1998JD100069.

Fung, K. (1990), Particulate carbon speciation by MnO_2 oxidation, *Aerosol Sci. Technol., 12*, 122-127.

Garrett, T. J., and C. Zhao (2006), Increased Arctic cloud longwave emissivity associated with pollution from mid-latitudes, *Nature*, *440*, 787-789, doi: 10.1038/nature04636.

Garrett, T. J., C. Zhao, and P. C. Novelli (2010), Assessing the relative contributions of transport efficiency and scavenging to seasonal variability in Arctic aerosol, *Tellus B*, *62* (3), 190-196, doi: 10.1111/j.1600-0889.2010.00453.x.

Gayet, J. F., F. Auriol, A. Minikin, J. Strom, M. Seifert, R. Krejci, A. Petzold, G. Febvre, and U. Schumann (2002), Quantitative measurement of the microphysical and optical properties of cirrus clouds with four different in situ probes: Evidence of small ice crystals, *Geophys. Res. Lett.*, *29* (24), 2230, doi: 10.1029/2001GL014342.

Gelencsér, A. (2005), Carbonaceous Aerosol, 350 pp, Springer, Dordrecht, The Netherlands.

Gettelman, A., X. Liu, D. Barahona, U. Lohmann, and C. Chen (2012), Climate impacts of ice nucleation, *J. Geophys. Res.*, *117,* D20201, doi: 10.1029/2012JD017950.

Ghan, S. J., G. Guzman, and H. Abdul-Razzak (1998), Competition between sea salt and sulfate particles as cloud condensation nuclei, *J. Atmos. Sci.*, *55* (22), 3340-3347, doi: 10.1175/1520-0469(19980055<3340:CBSSAS>2.0.CO;2.

Ghan, S. J., X. Liu, R. C. Easter, R. Zaveri, P. J. Rasch, J.-H. Yoon, and B. Eaton (2012), Toward a minimal representation of aerosols in climate models: Comparative decomposition of aerosol direct, semidirect, and indirect radiative forcing, *J. Climate*, *25* (19), 6461-6476, doi: http://dx.doi.org/10.1175/ JCLI-D-11-00650.1.

Giglio, L., T. Loboda, D. P. Roy, B. Quayle, and C. O. Justice (2009), An active-fire based burned area mapping algorithm for the MODIS sensor, *Remote Sens. Environ.*, *113* (2), 408-420, doi: 10.1016/j.rse.2008.10.006.

Gildemeister, A. E., P. K. Hopke, and E. Kim (2007), Sources of fine urban particulate matter in Detroit, MI, *Chemosphere*, *69* (7), 1064-1074, doi: 10.1016/j.chemosphere.2007.04.027.

Gillett, N. P., and H. D. Matthews (2010), Accounting for carbon cycle feedbacks in a comparison of the global warming effects of greenhouse gases, *Environ. Res. Lett.*, *5,* 034011, doi: 10.1088/1748-9326/5/3/034011.

Girard, E., J. P. Blanchet, and Y. Dubois (2005), Effects of Arctic sulphuric acid aerosols on wintertime low-level atmospheric ice crystals, humidity and temperature at Alert, Nunavut, *Atmos. Res.*, *73* (1-2), 131-148, doi: 10.1016/j.atmosres.2004.08.002.

Gloersen, P., W. J. Campbell, D. J. Cavalieri, J. C. Comiso, and C. L. Parkinson (1992), Arctic and Antarctic sea-ice, 1978-1987: Satellite passive-microwave observations and analysis *NASA Publication*, SP-511, 290 pp., NASA, Washington, DC.

Goldammer, J. G., and B.Seibert (1990), in *Fire in the tropical biota. Ecosystem processes and global challenges* edited by J. G. Goldammer, 11-31 pp., Springer-Verlag, Berlin-Heidelberg-New York, NY.

Gong, S. L., T. L. Zhao, S. Sharma, D. Toom-Sauntry, D. Lavoue, X. B. Zhang, R. Leaitch, and L. A. Barrie (2010), Identification of trends and inter-annual variability of sulphate and black carbon in the Canadian High Arctic: 1981 to 2007, *J. Geophys. Res.*, *115*, D07305, doi: 10.1029/2009JD012943.

Gotschi, T., M. E. Hazenkamp-Von Arxb, J. Heinrich, R. Bono, P. Burney, B. Forsberg, D. Jarvis, J. Maldonado, D. Norback, W. B. Stern, J. Sunyer, K. Toren, G. Verlato, S. Villani, and N. Kunzli (2005), Elemental composition and reflectance of ambient fine particles at 21

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

European locations, *Atmos. Environ.*, *39* (32), 5947-5958, doi: 10.1016/j.atmonsenv.2005.06.049.

Graber, E. R., and Y. Rudich (2006), Atmospheric HULIS: How humic-like are they? A comprehensive and critical review, *Atmos. Chem. Phys.*, *6*, 729-753, doi: 10.5194/acp-6-729-2006.

Grahame, T. J., and R. B. Schlesinger (2007), Health effects of airborne particulate matter: Do we know enough to consider regulating specific particle types or sources?, *Inhal. Toxicol.*, *19* (6-7), 457-481, doi: 10.1080/08958370701382220.

Granier, C., U. Niemeier, J. H. Jungclaus, L. Emmons, P. Hess, J. F. Lamarque, S. Walters, and G. P. Brasseur (2006), Ozone pollution from future ship traffic in the Arctic northern passages, *Geophys. Res. Lett.*, *33* (13), 807, doi: 10.1029/2006GL026180.

Graßl, H. (1975), Albedo reduction and radiative heating of clouds by absorbing aerosol particles, *Cont. Atmos. Phys., 48*, 199-210.

Greentech (2011), Monitoring of brick kilns and strategies for cleaner brick production in India, Shakti Sustainable Energy, Greentech Knowledge Solutions, New Delhi, India.

Gregory, J. M., W. J. Ingram, M. A. Palmer, G. S. Jones, P. A. Stott, R. B. Thorpe, J. A. Lowe, T. C. Johns, and K. D. Williams (2004), A new method for diagnosing radiative forcing and climate sensitivity, *Geophys. Res. Lett.*, *31* (3), 205, doi: 10.1029/2003GL018747.

Grenfell, T. C., S. P. Neshyba, and S. G. Warren (2005), Representation of a nonspherical ice particle by a collection of independent spheres for scattering and absorption of radiation: 3. Hollow columns and plates, *J. Geophys. Res.*, *110* (D17), 203, doi: 10.1029/2005JD005811.

Grenfell, T. C., S. J. Doherty, A. D. Clarke, and S. G. Warren (2011), Light absorption by particulate impurities in snow and ice determined by spectrophotometric analysis of filters, *Appl. Opt.*, *50* (14), 2037-2048.

Groblicki, P. J., G. T. Wolff, and R. J. Countess (1981), Visibility-reducing species in the Denver "brown cloud"-- I. Relationships between extinction and chemical composition, *Atmos. Environ.*, *15* (12), 2473-2484.

Guazzotti, S. A., D. T. Suess, K. R. Coffee, P. K. Quinn, T. S. Bates, A. Wisthaler, A. Hansel, W. P. Ball, R. R. Dickerson, C. Neusüss, P. J. Crutzen, and K. A. Prather (2003), Characterization of carbonaceous aerosols outflow from India and Arabia: Biomass/biofuel burning and fossil fuel combustion, *J. Geophys. Res.*, *108* (D15), 4485, doi: 10.1029/2002JD003277.

Guenther, A., T. Karl, P. Harley, C. Wiedinmyer, P. I. Palmer, and C. Geron (2006), Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature), *Atmos. Chem. Phys., 6*, 3181-3210.

Gundel, L. A., R. L. Dod, H. Rosen, and T. Novakov (1984), The relationship between optical attenuation and black carbon concentration for ambient and source particles, *Sci. Total Environ.*, *36*, 197-202.

Gustafsson, O., M. Krusa, Z. Zencak, R. J. Sheesley, L. Granat, E. Engstrom, P. S. Praveen, P. S. P. Rao, C. Leck, and H. Rodhe (2009), Brown clouds over South Asia: Biomass or fossil fuel combustion?, *Science*, *323* (5913), 495-498, doi: 10.1126/science.1164857.

Guttikunda, S. K., and P. Jawahar (2012), Application of SIM-air modeling tools to assess air quality in Indian cities, *Atmos. Environ.*, *62*, 551-561, http://dx.doi.org/10.1016/j.atmosenv.2012.08.074.

Haag, W., B. Karcher, J. Strom, A. Minikin, U. Lohmann, J. Ovarlez, and A. Stohl (2003), Freezing thresholds and cirrus cloud formation mechanisms inferred from in situ measurements of relative humidity, *Atmos. Chem. Phys.*, *3 (5)*, 1791-1806, doi: 10.5194/acp-3-1791-2003.

Hadley, O. L., C. E. Corrigan, T. W. Kirchstetter, S. S. Cliff, and V. Ramanathan (2010), Measured black carbon deposition on the Sierra Nevada snow pack and implication for snow pack retreat, *Atmos. Chem. Phys.*, *10*, 7505-7513, doi: 10.5194/acpd-10-7505-2010.

Haeberli, W. (1977), Sahara dust in the Alps - A short review, *Z. Gletscher. Glazialgeol.*, *13*, 206-208.

Hagler, G. S. W., M. H. Bergin, E. A. Smith, and J. E. Dibb (2007a), A summer time series of particulate carbon in the air and snow at Summit, Greenland, *J. Geophys. Res.*, *112* (D21), 309, doi: 10.1029/2007JD008993.

Hagler, G. S. W., M. H. Bergin, E. A. Smith, J. E. Dibb, C. Anderson, and E. J. Steig (2007b), Particulate and water-soluble carbon measured in recent snow at Summit, Greenland, *Geophys. Res. Lett.*, *34* (16), L16505, doi: 10.1029/2007GL030110.

Hakami, A., D. K. Henze, J. H. Seinfeld, T. Chai, Y. Tang, G. R. Carmichael, and A. Sandu (2005), Adjoint inverse modeling of black carbon during the Asian Pacific Regional Aerosol Characterization Experiment, *J. Geophys. Res.*, *110* (D14), 301, doi: 10.11029/12004JD005671.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Hall, A., and X. Qu (2006), Using the current seasonal cycle to constrain snow albedo feedback in future climate change, *Geophys. Res. Lett.*, *33* (3), L03502, doi: 10.1029/2005GL025127.

Hallberg, A., J. A. Ogren, K. J. Noone, K. Okada, J. Heintzenberg, and I. B. Svenningson (1994), The influence of aerosol particle composition on cloud droplet formation, *J. Atmos. Chem., 19*, 153-171.

Hallett, J., J. G. Hudson, and C. F. Rogers (1989), Characterization of combustion aerosols for haze and cloud formation, *Aerosol Sci. Technol., 10*, 70-83.

Hansen, A. D. A., H. Rosen, and T. Novakov (1982), Real-time measurement of the absorption coefficient of aerosol particles, *Appl. Opt.*, *21* (17), 3060-3062.

Hansen, J., and L. Nazarenko (2004), Soot climate forcing via snow and ice albedos, *P. Natl. Acad. Sci. USA*, *101* (2), 423-428, doi: 10.1073/pnas.2237157100.

Hansen, J., M. Sato, and R. Ruedy (1997), Radiative forcing and climate response, *J. Geophys. Res.*, *102* (D6), 6831-6864.

Hansen, J. E., M. Sato, R. Ruedy, A. Lacis, and V. Oinas (2000), Global warming in the twenty-first century: An alternative scenario, *P. Natl. Acad. Sci. USA*, *97* (18), 9875-9880.

Hansen, J., M. Sato, R. Ruedy, L. Nazarenko, A. Lacis, G. A. Schmidt, G. Russell, I. Aleinov, M. Bauer, S. Bauer, N. Bell, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, M. Kelley, N. Kiang, D. Koch, J. Lean, J. Lerner, K. Lo, S. Menon, R. Miller, P. Minnis, T. Novakov, V. Oinas, J. Perlwitz, J. Perlwitz, D. Rind, A. Romanou, D. Shindell, P. Stone, S. Sun, N. Tausnev, D. Thresher, B. Wielicki, T. Wong, M. Yao, and S. Zhang (2005), Efficacy of climate forcings, *J. Geophys. Res.*, *110* (D18), D18104, doi: 10.1029/2005JD005776.

Hansen, J., M. Sato, P. Kharecha, G. Russell, D. W. Lea, and M. Siddall (2007), Climate change and trace gases, *Philos. Trans. R. Soc. A-Math. Phys. Eng. Sci.*, *365* (1856), 1925-1954, doi: 10.1098/rsta.2007.2052.

Haynes, B. S., and H. G. Wagner (1981), Soot formation, *Prog. Energy Combust. Sci., 7*, 229-273.

Haywood, J., and O. Boucher (2000), Estimates of the direct and indirect radiative forcing due to tropospheric aerosols: A review, *Rev. Geophys.*, *38* (4), 513-543.

Haywood, J. M., and V. Ramaswamy (1998), Global sensitivity studies of the direct radiative forcing due to anthropogenic sulfate and black carbon aerosols, *J. Geophys. Res.*, *103* (D6), 6043-6058.

Haywood, J. M., and K. P. Shine (1995), The effect of anthropogenic sulfate and soot aerosol on the clear sky planetary radiation budget, *Geophys. Res. Lett.*, *22* (5), 603-606.

Hazenkamp-von Arx, M. E., T. Gotschi, U. Ackermann-Liebrich, R. Bono, P. Burney, J. Cyrys, D. Jarvis, L. Lillienberg, C. Luczynska, J. A. Maldonado, A. Jaen, R. de Marco, Y. H. Mi, L. Modig, L. Bayer-Oglesby, F. Payo, A. Soon, J. Sunyer, S. Villani, J. Weyler, and N. Kunzli (2004), $PM_{2.5}$ and NO_2 assessment in 21 European study centres of ECRHS II: Annual means and seasonal differences, *Atmos. Environ.*, *38* (13), 1943-1953, doi: 10.1016/j.atmosenv.2004.01.016.

Heald, C. L., D. J. Jacob, D. B. A. Jones, P. I. Palmer, J. A. Logan, D. G. Streets, G. W. Sachse, J. C. Gille, R. N. Hoffman, and T. Nehrkorn (2004), Comparative inverse analysis of satellite (MOPITT) and aircraft (TRACE-P) observations to estimate Asian sources of carbon monoxide, *J. Geophys. Res.*, *109* (D23), 306, doi: 10.1029/2004JD005185.

Heald, C. L., and D. V. Spracklen (2009), Atmospheric budget of primary biological aerosol particles from fungal spores, *Geophys. Res. Lett.*, *36,* L09806, doi: 10.1029/2009GL037493.

Hegerl, G. C., F. W. Zwiers, P. Braconnot, N. P. Gillett, Y. Luo, J. A. Marengo Orsini, N. Nicholls, J. E. Penner, and P. A. Stott (2007), Understanding and attributing climate change, in *Climate change 2007: The physical science basis*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tigor and H. L. Miller, 129-234 pp., Cambridge University Press, Cambridge, United Kingdom.

Hegg, D. A., S. G. Warren, T. C. Grenfell, S. J. Doherty, T. V. Larson, and A. D. Clarke (2009), Source attribution of black carbon in Arctic snow, *Environ. Sci. Technol.*, *43* (11), 4016-4021.

Hegg, D. A., S. G. Warren, T. C. Grenfell, S. J. Doherty, and A. D. Clarke (2010), Sources of light-absorbing aerosol in Arctic snow and

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

their seasonal variation, *Atmos. Chem. Phys.*, *10*, 10923-10938, doi: 10.5194/acp-10-10923-2010.

Heidenreich, R. D., W. M. Hess, and L. L. Ban (1968), A test object and criteria for high resolution electron microscopy, *J. Appl. Crystallogr.*, *1* (1-19).

Heierli, U., and S. Maithel (2008), Brick by brick: The Herculean task of cleaning up the Asian brick industry, edited by P. Osborn, Swiss Agency for Development and Cooperation (SDC), Natural Resources and Environment Division, Berne, Switzerland.

Heintzenberg, J. (1980), Particle size distribution and optical properties of Arctic haze, *Tellus*, *32*, 251-260.

Heintzenberg, J., K. Okada, and J. Strom (1996), On the composition of non-volatile material in upper tropospheric aerosols and cirrus crystals, *Atmos. Res.*, *41* (1), 81-88.

Heintzenberg, J., and R. J. Charlson (Eds.) (2009), *Clouds in the Perturbed Climate System:* Their Relationship to Energy Balance, Atmospheric Dynamics, and Precipitation. Strüngmann Forum Report, Volume 2, ISBN-10: 0-262-01287-1, The MIT Press, Cambridge, MA.

Heller, W. (1965), Remarks on refractive index mixture rules, *J. Phys. Chem.*, *69*, 1123-1129.

Hendricks, J., B. Karcher, U. Lohmann, and M. Ponater (2005), Do aircraft black carbon emissions affect cirrus clouds on the global scale?, *Geophys. Res. Lett.*, *32*, L12814, doi: 10.1029/2005GL022740.

Hendricks, J., B. Kärcher, and U. Lohmann (2011), Effects of ice nuclei on cirrus clouds in a global climate model, *J. Geophys. Res.*, *116*, D18206, doi: 10.1029/2010JD015302.

Hess, W. M., and C. R. Herd (1993), Microstructure, morphology, and general physical properties, in *Carbon Black*, edited by J.-B. Donnet, R. C. Bansal and M.-J. Wang, Marcel Dekker, New York, NY.

Hess, M., P. Koepke, and I. Schult (1998), Optical properties of aerosols and clouds: The software package OPAC, *Bull. Amer. Meteorol. Soc.*, *79* (5), 831-844.

Hicks, S., and E. Isaksson (2006), Assessing source areas of pollutants from studies of fly ash, charcoal, and pollen from Svalbard snow and ice, *J. Geophys. Res.*, *111* (D2), D02113, doi: 10.1029/2005JD006167.

Hien, P. D., V. T. Bac, and N. T. H. Thinh (2004), PMF receptor modelling of fine and coarse PM_{10} in air masses governing monsoon conditions in Hanoi, northern Vietnam, *Atmos. Environ.*, *38* (2), 189-201, doi: 10.1016/j.atmosenv.2003.09.064.

Higuchi, K., and A. Nagoshi (1977), Effect of particulate matter in surface snow layers on the albedo of perennial snow patches, *Isotopes and Impurities in Snow and Ice, IAHS*, Publ. No. 118, 95-97 pp., International Association of Hydrological Sciences, Washington, DC.

Hill, A. A., and S. Dobbie (2008), The impact of aerosols on non-precipitating marine stratocumulus. II: The semi-direct effect, *Quart J. Roy. Meteor. Soc.*, *134* (634), 1155-1165, doi: 10.1002/qj.277.

Hirdman, D., J. F. Burkhart, H. Sodemann, S. Eckhardt, A. Jefferson, P. K. Quinn, S. Sharma, J. Ström, and A. Stohl (2010a), Long-term trends of black carbon and sulphate aerosol in the Arctic: Changes in atmospheric transport and source region emissions, *Atmos. Chem. Phys.*, *10*, 9351-9368, doi: 10.5194/acp-10-9351-2010.

Hirdman, D., H. Sodemann, J. F. Burkhart, A. Jefferson, T. Mefford, P. K. Quinn, S. Sharma, J. Ström, and A. Stohl (2010b), Source identification of short-lived air pollutants in the Arctic using statistical analysis of measurement data and particle dispersion model output, *Atmos. Chem. Phys.*, *10*, 669-693, doi: 10.5194/acp-10-669-2010.

Hitzenberger, R., A. Petzold, H. Bauer, P. Ctyroky, P. Pouresmaeil, L. Laskus, and H. Puxbaum (2006), Intercomparison of thermal and optical measurement methods for elemental carbon and black carbon at an urban location, *Environ. Sci. Technol., 40 (20)*, 6377-6383, doi: 10.1021/es051228v.

Holben, B. N., T. F. Eck, I. Slutsker, D. Tanre, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagan, Y. J. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Smirnov (1998), AERONET - A federated instrument network and data archive for aerosol characterization, *Remote Sens. Environ.*, *66*, 1-16.

Holdsworth, G., K. Higuchi, G. A. Zielinski, P. A. Mayewski, M. Wahlen, B. Deck, P. , B. Johnson, and P. Damiano (1996), Historical biomass burning: Late 19th century pioneer agriculture revolution in northern hemisphere ice core data and its atmospheric interpretation, *J. Geophys. Res.*, *101* (D18), 23317-23334, doi: 10.1029/96JD01158.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Hoose, C., U. Lohmann, R. Erdin, and I. Tegen (2008), The global influence of dust mineralogical composition on heterogeneous ice nucleation in mixed-phase clouds, *Environ. Res. Lett.*, *3* (2), 5003, doi: 10.1088/1748-9326/3/2/025003.

Hopke, P. K. (2010), The Application of Receptor Modeling to Air Quality Data, Pollution Atmosphérique, *Special Issue*, 91-109.

Hopkins, R. J., A. V. Tivanski, B. D. Marten, and M. K. Gilles (2007), Chemical bonding and structure of black carbon reference materials and individual carbonaceous atmospheric aerosols, *J. Aerosol Sci, 38 (6)*, 573-591, doi: 10.1016/j.jaerosci.2007.03.009.

Horvath, H. (1997), Systematic deviations of light absorption measurements by filter transmission methods, *J. Aerosol Sci.*, *28*, S55-S56.

Houck, J. E., and B. N. Eagle (2006), Control Analysis and Documentation for Residential Wood Combustion in the MANE-VU Region, OMNI Environmental Services.

Houthuijs, D., O. Breugelmans, G. Hoek, E. Vaskovi, E. Mihalikova, J. S. Pastuszka, V. Jirik, S. Sachelarescu, D. Lolova, K. Meliefste, E. Uzunova, C. Marinescu, J. Volf, F. de Leeuw, H. van de Wiel, T. Fletcher, E. Lebret, and B. Brunekreef (2001), PM_{10} and $PM_{2.5}$ concentrations in Central and Eastern Europe: Results from the Cesar study, *Atmos. Environ.*, *35* (15), 2757-2771.

Hoyle, C. R., B. P. Luo, and T. Peter (2005), The origin of high ice crystal number densities in cirrus clouds, *J. Atmos. Sci.*, *62* (7), 2568-2579.

Hu, Y. T., S. L. Napelenok, M. T. Odman, and A. G. Russell (2009), Sensitivity of inverse estimation of 2004 elemental carbon emissions inventory in the United States to the choice of observational networks, *Geophys. Res. Lett.*, *36* (L15), 806, doi: 10.1029/2009GL039655.

Huang, J., Q. Fu, W. Zhang, X. Wang, R. Zhang, H. Ye, and S. G. Warren (2011), Dust and black carbon in seasonal snow across northern China, *Bull. Am. Meteor. Soc.*, *92*, 175-781.

Huang, L., S. L. Gong, C. Q. Jia, and D. Lavoue (2010), Importance of deposition process in simulating the seasonality of the Arctic black carbon aerosol, *J. Geophys. Res.*, *115,* D17207, doi: 10.1029/2009JD013478.

Huang, P.-F., B. J. Turpin, M. J. Pipho, D. B. Kittleson, and P. H. McMurry (1994), Effects of water condensation and evaporation on diesel chain-aggregate morphology, *J. Aerosol Sci, 23* (3), 447-459.

Huebert, B. J., T. S. Bates, P. B. Russell, G. Shi, Y. J. Kim, K. Kawamura, G. Carmichael, and T. Nakajima (2003), An overview of ACE-Asia: strategies for quantifying the relationships between Asian aerosols and their climatic impacts, *J. Geophys. Res.*, *108* (D23), 8633, doi: 10.1029/2003JD003550.

Huneeus, N., M. Schulz, Y. Balkanski, J. Griesfeller, J. Prospero, S. Kinne, S. Bauer, O. Boucher, M. Chin, F. Dentener, T. Diehl, R. Easter, D. Fillmore, S. Ghan, P. Ginoux, A. Grini, L. Horowitz, D. Koch, M. C. Krol, W. Landing, X. Liu, N. Mahowald, R. Miller, J. J. Morcrette, G. Myhre, J. Penner, J. Perlwitz, P. Stier, T. Takemura, and C. S. Zender (2011), Global dust model intercomparison in AeroCom phase I, *Atmos. Chem. Phys.*, *11*(15), 7781-7816, doi: 10.5194/acp-11-7781-2011.

Huneeus, N., F. Chevallier, and O. Boucher (2012), Estimating aerosol emissions by assimilating observed aerosol optical depth in a global aerosol model, *Atmos. Chem. Phys.*, *12,* 4585-4606, doi: 10.5194/acpd-12-4585-2012.

Huntzicker, J. J., R. L. Johnson, J. J. Shah, and R. A. Cary (1982), Analysis of organic and elemental carbon in ambient aerosols by a thermal-optical method, in *Particulate Carbon: Atmospheric Life Cycle*, edited by G. T. Wolff and R. L. Klimisch, 79-88 pp., Plenum Press, New York, NY.

Huo, H., Y. Lei, Q. Zhang, L. Zhao, and K. He (2012), China's coke industry: Recent policies, technology shift, and implication for energy and the environment, *Energ. Policy, 51,* 397-404 (2012) http://dx.doi.org/10.1016/j.enpol.2012.08.041.

Ichoku, C., and Y. J. Kaufman (2005), A method to derive smoke emission rates from MODIS fire radiative energy measurements, *IEEE Trans. Geosci. Remote Sens.*, *43* (11), 2636-2649.

IPCC (1990), Intergovernmental Panel on Climate Change (IPCC): The Scientific Assessment, UNEP/WMO, Cambridge, United Kingdom.

IPCC (2007), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change, 996 pp., Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

IPCC (2009), IPCC Expert Meeting on the Science of Alternative Metrics Meeting Report, 82 pp., Grand Hotel, Oslo, Norway.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Isaksen, I. S. A., C. Granier, G. Myhre, T. K. Berntsen, S. B. Dalsoren, M. Gauss, Z. Klimont, R. Benestad, P. Bousquet, W. Collins, T. Cox, V. Eyring, D. Fowler, S. Fuzzi, P. Jockel, P. Laj, U. Lohmann, M. Maione, P. Monks, A. S. H. Prevot, F. Raes, A. Richter, B. Rognerud, M. Schulz, D. Shindell, D. S. Stevenson, T. Storelvmo, W. C. Wang, M. van Weele, M. Wild, and D. Wuebbles (2009), Atmospheric composition change: Climate-Chemistry interactions, *Atmos. Environ.*, *43* (33), 5138-5192, doi: 10.1016/j.atmosenv.2009.08.003.

Iskander, M. F., H. Y. Chen, and J. E. Penner (1991), Resonance optical absorption by fractal agglomerates of smoke aerosols, *Atmos. Environ., 25A* (11), 2563-2569.

Ito, A., and J. Penner (2005), Historical emissions of carbonaceous aerosols from biomass and fossil fuel burning for the period 1870-2000, *Global Biogeochem. Cycles*, *19* (2), doi: 10.1029/2004GB002374.

Jackson, S. C. (2009), Parallel pursuit of near-term and long-term climate mitigation *Science*, *326* (5952), 526-527, doi: 10.1126/science.1177042.

Jacob, D. J., J. H. Crawford, M. M. Kleb, V. S. Connors, R. J. Bendura, J. L. Raper, G. W. Sachse, J. C. Gille, L. Emmons, and C. L. Heald (2003), Transport and Chemical Evolution over the Pacific (TRACE-P) aircraft mission: Design, execution, and first results, *J. Geophys. Res.*, *108* (D20), 1-19, doi: 10.1029/2002JD003276.

Jacob, D. J., J. H. Crawford, H. Maring, A. D. Clarke, J. E. Dibb, L. K. Emmons, R. A. Ferrare, C. A. Hostetler, P. B. Russell, H. B. Singh, A. M. Thompson, G. E. Shaw, E. McCauley, J. R. Pederson, and J. A. Fisher (2010), The Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) mission: Design, execution, and first results, *Atmos Chem Phys*, *10* (11), 5191-5212, doi: 10.5194/acp-10-5191-2010.

Jacobson, M. Z. (2000), A physically-based treatment of elemental carbon optics: Implications for global direct forcing of aerosols, *Geophys. Res. Lett.*, *27* (2), 217-220, doi: 10.1029/1999GL010968.

Jacobson, M. Z. (2001a), Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols, *Nature*, *409*, 695-697.

Jacobson, M. Z. (2001b), Global direct radiative forcing due to multicomponent anthropgenic and natural aerosols, *J. Geophys. Res.*, *106*, 1551-1568, doi: 10.1029/2000JD900514.

Jacobson, M. Z. (2002), Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming, *J. Geophys. Res.*, *107* (D19), 4410, doi: 10.1029/2001JD001376.

Jacobson, M. Z. (2004), Climate response of fossil fuel and biofuel soot, accounting for soot's feedback to snow and sea ice albedo and emissivity, *J. Geophys. Res.*, *109* (D21), D21201, doi: 10.1029/2004JD004945.

Jacobson, M. Z. (2006), Effects of externally-through-internally-mixed soot inclusions within clouds and precipitation on global climate, *J. Phys. Chem. A*, *110* (21), 6860-6873, doi: 10.1021/jp056391r.

Jacobson, M. Z. (2010), Short-term effects of controlling fossil-fuel soot, biofuel soot and gases, and methane on climate, Arctic ice, and air pollution health, *J. Geophys. Res.*, *115*, doi: D14209, doi: 10.1029/2009JD013795.

Jacobson, M. Z., J. T. Wilkerson, A. D. Naiman, and S. K. Lele (2011), The effects of aircraft on climate and pollution. Part I: Numerical methods for treating the subgrid evolution of discrete size- and composition-resolved contrails from all commercial flights worldwide, *J. Comput. Phys.*, *230*, 5115-5132, doi: 10.1016/j.jcp.2011.03.031.

Jacobson, M. Z. (2012), Investigating cloud absorption effects: Global absorption properties of black carbon, tar balls, and soil dust in clouds and aerosols, *J. Geophys. Res.*, *117*, D06205, doi: 10.1029/2011JD017218.

Janssen, N. A., G. Hoek, M. Simic-Lawson, P. Fischer, L. van Bree, H. ten Brink, M. Keuken, R. W. Atkinson, H. R. Anderson, B. Brunekreef, and F. R. Cassee (2011), Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM_{10} and $PM_{2.5}$, *Environ. Health Perspect.*, *119*, 1691-1699, doi: 10.1289/ehp.1003369.

Janzen, J. (1979), The refractive index of carbon black, *J. Colloid Interf. Sci.*, *69* (3), 436-447.

Janzen, J. (1980), Extinction of light by highly nonspherical strongly absorbing colloidal particles - spectrophotometric determination of volume distributions for carbon-blacks, *Appl. Opt.*, *19* (17), 2977-2985, doi: 10.1364/AO.19.002977.

Jenk, T. M., S. Szidat, M. Schwikowski, H. W. Gäggeler, S. Brütsch, L. Wacker, H. A. Synal, and M. Saurer (2006), Radiocarbon analysis

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

in an Alpine ice core: Record of anthropogenic and biogenic contributions to carbonaceous aerosols in the past (1650-1940), *Atmos. Chem. Phys.*, *6* (12), 5381-5390, doi: 10.5194/acp-6-5381-2006.

Jensen, E. J., O. B. Toon, S. A. Vay, J. Ovarlez, R. May, T. P. Bui, C. H. Twohy, B. W. Gandrud, R. F. Pueschel, and U. Schumann (2001), Prevalence of ice-supersaturated regions in the upper troposphere: Implications for optically thin ice cloud formation, *J. Geophys. Res.*, *106* (D15), 17253-17266.

Jetter, J. J., and P. Kariher (2009), Solid-fuel household cook stoves: Characterization of performance and emissions, *Biomass Bioenerg.*, *33*, 294-305, doi: 10.1016/j.biombioe.2008.05.014.

Johansson, D. J. A., U. M. Persson, and C. Azar (2006), The cost of using global warming potentials: Analysing the trade off between CO_2, CH_4 and N_2O, *Climatic Change*, *77* (3-4), 291-309, doi: 10.1007/s10584-006-9054-x.

Johansson, L. S., B. Leckner, L. Gustavsson, D. Cooper, C. Tullin, and A. Potter (2004), Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets, *Atmos. Environ.*, *38* (25), 4183-4195, doi: 10.1016/j.atmosenv.2004.04.020.

Johnson, B. T., K. P. Shine, and P. M. Forster (2004), The semi-direct aerosol effect: Impact of absorbing aerosols on marine stratocumulus, *Quart J. Roy. Meteor. Soc.*, *130* (599), 1407-1422, doi: 10.1256/qj.03.61.

Johnson, K. S., B. de Foy, B. Zuberi, L. T. Molina, M. J. Molina, Y. Xie, A. Laskin, and V. Shutthanandan (2006), Aerosol composition and source apportionment in the Mexico City metropolitan area with PIXE/PESA/STIM and multivariate analysis, *Atmos. Chem. Phys.*, *6*, 4591-4600, doi: 10.5194/acp-6-4591-2006.

Johnson, M., R. Edwards, C. A. Frenk, and O. Masera (2008), In-field greenhouse gas emissions from cookstoves in rural Mexican households, *Atmos. Environ.*, *42* (6), 1206-1222, doi: 10.1016/j.atmosenv.2007.10.034.

Johnson, M. R., and A. R. Coderre (2011), An analysis of flaring and venting activity in the Alberta upsteam oil and gas industry, *J. Air Waste Manage. Assoc.*, *61* (2), 190-200, doi: 10.3155/1047-3289.61.2.190.

Johnson, M. R., R. W. Devillers, and K. A. Thomson (2011a), Quantitative field measurement of soot emission from a large gas flare using Sky-LOSA, *Environ. Sci. Technol.*, *45* (1), 345-350, doi: 10.1021/es102230y.

Johnson, T. M., S. Guttikunda, G. J. Wells, P. Artaxo, T. C. Bond, A. G. Russell, J. G. Watson, and J. West (2011b), Tools for Improving Air Quality Management: A Review of Top-down Source Apportionment Techniques and Their Application in Developing Countries, ESMAP Publication Series, The World Bank, Washington, DC, USA.

Jones, A., J. M. Haywood, and O. Boucher (2007), Aerosol forcing, climate response and climate sensitivity in the Hadley Centre climate model, *J. Geophys. Res.*, *112* (D20), 211, doi: 10.1029/2007JD008688.

Jones, G. S., A. Jones, D. L. Roberts, P. A. Stott, and K. D. Williams (2005), Sensitivity of global-scale climate change attribution results to inclusion of fossil fuel black carbon aerosol, *Geophys. Res. Lett.*, *32* (14), 701, doi: 10.1029/2005GL023370.

Jones, G. S., N. Christidis, and P. A. Stott (2011), Detecting the influence of fossil fuel and bio-fuel black carbon aerosols on near surface temperature changes, *Atmos. Chem. Phys.*, *11*, 799-816, doi: 10.5194/acpd-11-799-2011.

Jones, H. G., J. W. Pomeroy, D. A. Walker, and R. W. Hoham (Eds.) (2001), *Snow Ecology*, 398 pp., Cambridge University Press, New York, NY.

Joos, F., R. Roth, J. S. Fuglestvedt, G. P. Peters, I. G. Enting, W. v. Bloh, V. Brovkin, E. J. Burke, M. Eby, N. R. Edwards, T. Friedrich, T. L. Frölicher, P. R. Halloran, P. B. Holden, C. Jones, T. Kleinen, F. Mackenzie, K. Matsumoto, M. Meinshausen, G.-K. Plattner, A. Reisinger, J. Segschneider, G. Shaffer, M. Steinacher, K. Strassmann, K. Tanaka, A. Timmermann, and A. J. Weaver (2012), Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: A multi-model analysis, *Atmos. Chem. Phys. Discuss.*, *12*, 19799-19869, doi: 10.5194/acpd-12-19799-2012.

Junker, C., and C. Liousse (2008), A global emission inventory of carbonaceous aerosol from historic records of fossil fuel and biofuel consumption for the period 1860–1997, *Atmos. Chem. Phys., 8*, 1195-1207, doi: 10.5194/acp-8-1195-2008.

Kahn, R. A., D. L. Nelson, M. J. Garay, R. C. Levy, M. A. Bull, D. J. Diner, J. V. Martonchik, S. R. Paradise, E. G. Hansen, and L. A. Remer (2009a), MISR aerosol product attributes and statistical comparisons with MODIS, *IEEE Trans. Geosci. Remote Sens.*, *47* (12), 4095-4114, doi: 10.1109/tgrs.2009.2023115.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Kahn, B. H., A. Gettelman, E. J. Fetzer, A. Eldering, and C. K. Liang (2009b), Cloudy and clear-sky relative humidity in the upper troposphere observed by the A-train, *J. Geophys. Res.*, *114,* D00h02, doi: 10.1029/2009JD011738.

Kahn, R., A. Petzold, M. Wendisch, E. Bierwirth, T. Dinter, M. Esselborn, M. Fiebig, B. Heese, P. Knippertz, D. Muller, A. Schladitz, and A. Von Hoyningen-Huene (2009c), Desert dust aerosol air mass mapping in the western Sahara, using particle properties derived from space-based multi-angle imaging, *Tellus B*, *61* (1), 239-251, doi: 10.1111/j.1600-0889.2008.00398.x.

Kahn, R. A., B. J. Gaitley, M. J. Garay, D. J. Diner, T. F. Eck, A. Smirnov, and B. N. Holben (2010), Multiangle Imaging SpectroRadiometer global aerosol product assessment by comparison with the Aerosol Robotic Network, *J. Geophys. Res.*, *115*, D23209, doi: 10.1029/2010JD014601.

Kahnert, M. (2010), On the discrepancy between modeled and measured mass absorption cross sections of light absorbing carbon aerosols, *Aerosol Sci. Technol.*, *44* (6), 453-460, doi: 10.1080/02786821003733834.

Kahnert, M., M. Lazaridis, S. Tsyro, and K. Torseth (2004), Requirements for developing a regional monitoring capacity for aerosols in Europe within EMEP, *J. Environ. Monit.*, *6* (7), 646-655, doi: 10.1039/b315136k.

Kaiser, J. W., Suttie, M., Flemming, J., Morcrette, J.-J., Boucher, O., and Schultz, M. G. (2009), Global real-time fire emission estimates based on space-borne fire radiative power observations, *AIP Conf. Proc.*, *1100*, 645-648, doi: 10.1063/1.3117069.

Kaiser, J. W., A. Heil, M. O. Andreae, A. Benedetti, N. Chubarova, L. Jones, J.-J. Morcrette, M. Razinger, M. G. Schultz, M. Suttie, and G. R. van der Werf (2012), Biomass burning emissions estimated with a global fire assimilation system based on observed fire radiative power, *Biogeosciences*, *9*, 527-554, doi: 10.5194/bg-9-527-2012.

Kandlikar, M. (1996), Indices for comparing greenhouse gas emissions: Integrating science and economics, *Energ. Econ.*, *18*, 265-281.

Kandlikar, M., C. Reynolds, and A. Grieshop (2009), A perspective paper on black carbon mitigation as a response to climate change, *Report prepared for the Copenhagen Consensus on Climate*, Copenhagen Consensus Center, Frederiksberg, Denmark.

Kärcher, B., and U. Burkhardt (2008), A cirrus cloud scheme for general circulation models, *Q. J. R. Meteorol. Soc.*, *134*, 1439-1461, doi: 10.1002/qj.301.

Kärcher, B., and P. Spichtinger (2009), Cloud-controlling factors of cirrus, in *Clouds in the perturbed climate system: Their relationship to energy balance, atmospheric dynamics, and precipitation*, edited by J. Heintzenberg and R. J. Charlson, 235-268 pp., MIT Press, Cambridge, MA.

Kärcher, B., and J. Strom (2003), The roles of dynamical variability and aerosols in cirrus cloud formation, *Atmos. Chem. Phys.*, *3*, 823-838, doi: 10.5194/acp-3-823-2003.

Kärcher, B., and F. Yu (2009), Role of aircraft soot emissions in contrail formation, *Geophys. Res. Lett.*, *36,* L01804, doi: 10.1029/2008GL036649.

Kärcher, B., T. Peter, U. M. Biermann, and U. Schumann (1996), The initial composition of jet condensation trails, *J. Atmos. Sci.*, *53* (21), 3066-3083.

Kärcher, B., J. Hendricks, and U. Lohmann (2006), Physically based parameterization of cirrus cloud formation for use in global atmospheric models, *J. Geophys. Res.*, *111* (D1), 205, doi: 10.1029/2005JD006219.

Kärcher, B., O. Möhler, P. J. DeMott, S. Pechtl, and F. Yu (2007), Insights into the role of soot aerosols in cirrus cloud formation, *Atmos. Chem. Phys.*, *7* (16), 4203-4227, doi: 10.5194/acp-7-4203-2007.

Kasibhatla, P., A. Arellano, J. A. Logan, P. I. Palmer, and P. Novelli (2002), Top-down estimate of a large source of atmospheric carbon monoxide associated with fuel combustion in Asia, *Geophys. Res. Lett.*, *29* (19), doi: 10.1029/2002GL015581.

Kasischke, E. S., and N. H. F. French (1995), Locating and estimating the areal extent of wildfires in Alaskan boreal forests using multiple-season AVHRR NDVI composite data, *Remote Sens. Environ.*, *51* (2), 263-275.

Kaufman, Y. J., P. V. Hobbs, V. W. J. H. Kirchhoff, P. Artaxo, L. A. Remer, B. N. Holben, M. D. King, D. E. Ward, E. M. Prins, K. M. Longo, L. F. Mattos, C. A. Nobre, J. D. Spinhirne, Q. Ji, A. M. Thompson, J. F. Gleason, S. A. Christopher, and S.-C. Tsay (1998), Smoke, clouds, and radiation-- Brazil (SCAR-B) experiment, *J. Geophys. Res.*, *103* (D24), 31783-31808.

Keene, W. C., R. M. Lobert, P. J. Crutzen, J. R. Maben, D. H. Scharffe, T. Landmann, C. Hely, and C. Brain (2006), Emissions of major

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

gaseous and particulate species during experimental burns of southern African biomass, *J. Geophys. Res.*, *111* (D4), 301, doi: 10.1029/2005JD006319.

Khalizov, A. F., H. X. Xue, L. Wang, J. Zheng, and R. Y. Zhang (2009), Enhanced light absorption and scattering by carbon soot aerosol internally mixed with sulfuric acid, *J. Phys. Chem. A*, *113*, 1066-1074, doi: 10.1021/jp807531n.

Kim, D., C. Wang, A. M. L. Ekman, M. C. Barth, and P. J. Rasch (2008), Distribution and direct radiative forcing of carbonaceous and sulfate aerosols in an interactive size-resolving aerosol-climate model, *J. Geophys. Res.*, *113* (D16), 309, doi: 10.1029/2007JD009756.

Kim, E., and P. K. Hopke (2007), Source identifications of airborne fine particles using positive matrix factorization and US environmental protection agency positive matrix factorization, *J. Air Waste Manage. Assoc.*, *57* (7), 811-819, doi: 10.3155/1047-3289.57.7.811.

Kinne, S., M. Schulz, C. Textor, S. Guibert, Y. Balkanski, S. E. Bauer, T. Berntsen, T. F. Berglen, O. Boucher, M. Chin, W. Collins, F. Dentener, T. Diehl, R. Easter, J. Feichter, D. Fillmore, S. Ghan, P. Ginoux, S. Gong, A. Grini, J. E. Hendricks, M. Herzog, L. Horowitz, L. Isaksen, T. Iversen, A. Kirkavag, S. Kloster, D. Koch, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, G. Lesins, X. Liu, U. Lohmann, V. Montanaro, G. Myhre, J. E. Penner, G. Pitari, S. Reddy, O. Seland, P. Stier, T. Takemura, and X. Tie (2006), An AeroCom initial assessment - optical properties in aerosol component modules of global models, *Atmos. Chem. Phys.*, *6*, 1815-1834, doi: 10.5194/acp-6-1815-2006.

Kirchstetter, T. W., T. Novakov, and P. V. Hobbs (2004), Evidence that the spectral dependence of light absorption by aerosols is affected by organic carbon, *J. Geophys. Res.*, *109* (D21), D21208, doi: 10.1029/2004JD004999.

Kirchstetter, T. W., J. Aguiar, S. Tonse, and T. Novakov (2008), Black carbon concentrations and diesel vehicle emission factors derived from coefficient of haze measurements in California: 1967-2003, *Atmos. Environ.*, *42*, 480-491.

Kirkevag, A., and T. Iversen (2002), Global direct radiative forcing by process-parameterized aerosol optical properties, *J. Geophys. Res.*, *107* (D20), 4433, doi: 10.1029/2001JD000886.

Klimont, Z., J. Cofala, J. Xing, W. Wei, C. Zhang, S. Wang, K. J., P. Bhandari, R. Mathura, P. Purohit, P. Rafaj, A. Chambers, M. Amann, and J. Hao (2009), Projections of SO_2, NO_x, and carbonaceous aerosol emissions in Asia, *Tellus B*, *61* (4), 602-617, doi: 10.1111/j.1600-0889.2009.00428.x.

Knox, A., G. J. Evans, J. R. Brook, X. Yao, C. H. Jeong, K. J. Godri, K. Sabaliauskas, and J. G. Slowik (2009), Mass absorption cross-section of ambient black carbon aerosol in relation to chemical age, *Aerosol Sci. Technol.*, *43* (6), 522-532, doi: 10.1080/02786820902777207.

Koch, D. (2001), Transport and direct radiative forcing of carbonaceous and sulfate aerosols in the GISS GCM, *J. Geophys. Res.*, *106* (D17), 20311-20332, doi: 10.1029/2001JD900038.

Koch, D., and A. D. Del Genio (2010), Black carbon semi-direct effects on cloud cover: Review and synthesis, *Atmos. Chem. Phys.*, *10* (16), 7685-7696, doi: 10.5194/acp-10-7685-2010.

Koch, D., and J. Hansen (2005), Distant origins of Arctic black carbon: A Goddard Institute for Space Studies ModelE experiment, *J. Geophys. Res.*, *110* (D4), 204, doi: 10.1029/2004JD005296.

Koch, D., T. C. Bond, D. Streets, N. Unger, and G. R. van der Werf (2007), Global impacts of aerosols from particular source regions and sectors, *J. Geophys. Res.*, *112,* D02205, doi: 10.1029/2005JD007024.

Koch, D., M. Schulz, S. Kinne, C. McNaughton, J. R. Spackman, Y. Balkanski, S. Bauer, T. Berntsen, T. C. Bond, O. Boucher, M. Chin, A. Clarke, N. De Luca, F. Dentener, T. Diehl, O. Dubovik, R. Easter, D. W. Fahey, J. Feichter, D. Fillmore, S. Freitag, S. Ghan, P. Ginoux, S. Gong, L. Horowitz, T. Iversen, A. Kirkevag, Z. Klimont, Y. Kondo, M. Krol, X. Liu, R. Miller, V. Montanaro, N. Moteki, G. Myhre, J. E. Penner, J. Perlwitz, G. Pitari, S. Reddy, L. Sahu, H. Sakamoto, G. Schuster, J. P. Schwarz, O. Seland, P. Stier, N. Takegawa, T. Takemura, C. Textor, J. A. van Aardenne, and Y. Zhao (2009a), Evaluation of black carbon estimations in global aerosol models, *Atmos. Chem. Phys.*, *9* (22), 9001-9026, doi: 10.5194/acp-9-9001-2009.

Koch, D., S. Menon, A. Del Genio, R. Ruedy, I. Alienov, and G. A. Schmidt (2009b), Distinguishing aerosol impacts on climate over the past century, *J. Climate*, *22* (10), 2659-2677, doi: 10.1175/2008jcli2573.1.

Koch, D., Y. Balkanski, S. E. Bauer, R. C. Easter, S. Ferrachat, S. J. Ghan, C. Hoose, T. Iversen, A. Kirkevag, J. E. Kristjansson, X. Liu, U.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Lohmann, S. Menon, J. Quaas, M. Schulz, O. Seland, T. Takemura, and N. Yan (2011a), Soot microphysical effects on liquid clouds, a multi-model investigation, *Atmos. Chem. Phys.*, *11* (3), 1051-1064, doi: 10.5194/acp-11-1051-2011.

Koch, D., S. Bauer, A. Del Genio, G. Faluvegi, J. R. McConnell, S. Menon, R. L. Miller, D. Rind, R. Ruedy, G. A. Schmidt, and D. Shindell (2011b), Coupled aerosol-chemistry-climate twentieth century transient model investigation: Trends in short-lived species and climate responses, *J. Climate*, *24*, 2693-2714, doi: 10.1175/2011JCL13582.1.

Köhler, K. A., P. J. DeMott, S. M. Kreidenweis, O. B. Popovicheva, M. D. Petters, C. M. Carrico, E. D. Kireeva, T. D. Khokhlova, and N. K. Shonija (2009), Cloud condensation nuclei and ice nucleation activity of hydrophobic and hydrophilic soot particles, *Phys. Chem. Chem. Phys.*, *11* (36), 7906-7920, doi: 10.1039/b905334b.

Koffi, B., M. Schulz, F.-M. Breon, J. Griesfeller, D. Winker, Y. Balkanski, S. Bauer, T. Berntsen, M. Chin, W. D. Collins, F. Dentener, T. Diehl, R. Easter, S. Ghan, P. Giroux, S. Gong, L. W. Horowitz, T. Iversen, A. Kirkevåg, D. Koch, M. Kroll, G. Myhre, P. Stier, T. Takemura, (2012), Application of CALIOP layer product to evaluate the vertical distribution of aerosols estimated by global models: AeroCom phase I results, *J. Geophys. Res.*, 117, D10201, 2012 doi:10.1029/2011JD016858.

Kondo, Y., L. Sahu, M. Kuwata, Y. Miyazaki, N. Takegawa, N. Moteki, J. Imaru, S. Han, T. Nakayama, N. T. K. Oanh, M. Hu, Y. J. Kim, and K. Kita (2009), Stabilization of the mass absorption cross section of black carbon for filter-based absorption photometry by the use of a heated inlet, *Aerosol Sci. Technol.*, *43* (8), 741-756, doi: 10.1080/02786820902889879.

Kondo, Y., L. Sahu, N. Moteki, F. Khan, N. Takegawa, X. Liu, M. Koike, and T. Miyakawa (2011a), Consistency and traceability of black carbon measurements made by laser-induced incandescence, thermal-optical transmittance, and filter-based photo-absorption techniques, *Aerosol Sci. Technol.*, *45* (2), 295-312, doi: 10.1080/02786826.2010.533215.

Kondo, Y., H. Matsui, N. Moteki, L. Sahu, N. Takegawa, M. Kajino, Y. Zhao, M. J. Cubison, J. L. Jimenez, S. Vay, G. S. Diskin, B. Anderson, A. Wisthaler, T. Mikoviny, H. E. Fuelberg, D. R. Blake, G. Huey, A. J. Weinheimer, D. J. Knapp, and W. H. Brune (2011b), Emissions of black carbon, organic, and inorganic aerosols from biomass burning in North America and Asia in 2008, *J. Geophys. Res.*, *116*, D08204, doi: 10.1029/2010JD015152.

Kondo, Y., N. Oshima, M. Kajino, R. Mikami, N. Moteki, N. Takegawa, R. L. Verma, Y. Kajii, S. Kato, and A. Takami (2011c), Emissions of black carbon in East Asia estimated from observations at a remote site in the East China Sea, *J. Geophys. Res.*, *116,* D16201, doi: 10.1029/2011JD015637.

Koop, T., B. P. Luo, A. Tsias, and T. Peter (2000), Water activity as the determinant for homogeneous ice nucleation in aqueous solutions, *Nature*, *406* (6796), 611-614.

Koopmans, A., and J. Koppejan (1997), Agricultural and forest residues: generation, utilization and availability, in *Regional Consultation on Modern Applications of Biomass Energy, FAO*, edited, Kuala Lumpur.

Kopacz, M., D. J. Jacob, J. A. Fisher, J. A. Logan, L. Zhang, I. A. Megretskaia, R. M. Yantosca, K. Singh, D. K. Henze, J. P. Burrows, M. Buchwitz, I. Khlystova, W. W. McMillan, J. C. Gille, D. P. Edwards, A. Eldering, V. Thouret, and P. Nedelec (2010), Global estimates of CO sources with high resolution by adjoint inversion of multiple satellite datasets (MOPITT, AIRS, SCIAMACHY, TES), *Atmos. Chem. Phys.*, *10* (3), 855-876.

Kopacz, M., D. L. Mauzerall, J. Wang, E. M. Leibensperger, D. K. Henze, and K. Singh (2011), Origin and radiative forcing of black carbon transported to the Himalayas and Tibetan Plateau, *Atmos. Chem. Phys.*, *11*, 2837-2852, doi: 10.5194/acp-11-2837-2011.

Kopp, R. E., and D. L. Mauzerall (2010), Assessing the climatic benefits of black carbon mitigation, *Proc. Natl. Acad. Sci. USA*, *107*, 11703-11708, doi: 10.1073/pnas.0909605107.

Koren, I., Y. J. Kaufman, L. A. Remer, and J. V. Martins (2004), Measurement of the effect of Amazon smoke on inhibition of cloud formation, *Science*, *303* (5662), 1342-1345, doi: 10.1126/science.1089424.

Koren, I., J. V. Martins, L. A. Remer, and H. Afargan (2008), Smoke invigoration versus inhibition of clouds over the Amazon, *Science*, *321* (5891), 946-949, doi: 10.1126/science.1159185.

Kristjansson, J. E. (2002), Studies of the aerosol indirect effect from sulfate and black carbon aerosols, *J. Geophys. Res.*, *107* (D15), 4246, doi: 10.1029/2001JD000887.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Kuhlmann, J., and J. Quaas (2010), How can aerosols affect the Asian summer monsoon? Assessment during three consecutive pre-monsoon seasons from CALIPSO satellite data, *Atmos. Chem. Phys.*, *10* (10), 4673-4688, doi: 10.5194/acp-10-4673-2010.

Kupiainen, K., and Z. Klimont (2007), Primary emissions of fine carbonaceous particles in Europe, *Atmos. Environ.*, *41*, 2156-2170, doi: 10.1016/j.atmosenv.2006.10.066.

Kurokawa, J., K. Yumimoto, I. Uno, and T. Ohara (2009), Adjoint inverse modeling of NO_x emissions over eastern China using satellite observations of NO_2 vertical column densities, *Atmos. Environ.*, *43* (11), 1878-1887, doi: 10.1016/j.atmosenv.2008.12.030.

Kuwata, M., Y. Kondo, M. Mochida, N. Takegawa, and K. Kawamura (2007), Dependence of CCN activity of less volatile particles on the amount of coating observed in Tokyo, *J. Geophys. Res.*, *112,* D11207, doi: 10.1029/2006JD007758.

Kuwata, M., Y. Kondo, and N. Takegawa (2009), Critical condensed mass for activiation of black carbon as cloud condensation nuclei in Tokyo, *J. Geophys. Res.*, *114,* D20202, doi: 10.1029/2009JD012086.

Laborde, M., P. Mertes, P. Zieger, J. Dommen, U. Baltensperger, and M. Gysel (2012), Sensitivity of the Single Particle Soot Photometer to different black carbon types, *Atmos. Meas. Tech.*, *5*, 1031-1043, doi: 10.5194/amt-5-1031-2012.

Lack, D. A., and C. D. Cappa (2010), Impact of brown and clear carbon on light absorption enhancement, single scatter albedo and absorption wavelength dependence of black carbon, *Atmos. Chem. Phys.*, *10* (9), 4207-4220, doi: 10.5194/acp-10-4207-2010.

Lack, D. A., E. R. Lovejoy, T. Baynard, A. Pettersson, and A. R. Ravishankara (2006), Aerosol absorption measurement using photoacoustic spectroscopy: Sensitivity, calibration, and uncertainty developments, *Aerosol Sci. Technol.*, *40* (9), 697-708, doi: 10.1080/02786820600803917.

Lack, D. A., C. D. Cappa, D. S. Covert, T. Baynard, P. Massoli, B. Sierau, T. S. Bates, P. K. Quinn, E. R. Lovejoy, and A. R. Ravishankara (2008), Bias in filter-based aerosol light absorption measurements due to organic aerosol loading: evidence from ambient measurements, *Aerosol Sci. Technol.*, *42* (12), 1033-1041.

Lack, D. A., C. D. Cappa, E. S. Cross, P. Massoli, A. T. Ahern, P. Davidovits, and T. B. Onasch (2009), Absorption enhancement of coated absorbing aerosols: Validation of the photo-acoustic technique for measuring the enhancement, *Aerosol Sci. Technol.*, *43* (10), 1006-1012, doi: 10.1080/02786820903117932.

Lack, D. A., J. M. Langridge, R. Bahreinia, C. D. Cappa, A. M. Middlebrook, and J. P. Schwarz (2012), Brown carbon and internal mixing in biomass burning particles, *P. Natl. Acad. Sci. USA*, doi: 10.1073/pnas.1206575109.

Lall, A. A., and S. K. Friedlander (2006), On-line measurement of ultrafine aggregate surface area and volume distributions by electrical mobility analysis: I. Theoretical analysis, *J. Aerosol. Sci.*, *37* (3), 260-271, doi: 10.1016/j.jaerosci.2005.05.021.

Lamarque, J. F., T. C. Bond, V. Eyring, C. Granier, A. Heil, Z. Klimont, D. Lee, C. Liousse, A. Mieville, B. Owen, M. G. Schultz, D. Shindell, S. J. Smith, E. Stehfest, J. Van Aardenne, O. R. Cooper, M. Kainuma, N. Mahowald, J. R. McConnell, V. Naik, K. Riahi, and D. P. van Vuuren (2010), Historical (1850-2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application, *Atmos. Chem. Phys.*, *10* (15), 7017-7039, doi: 10.5194/acp-10-7017-2010.

Lance, S., A. Nenes, C. Mazzoleni, M. K. Dubey, H. Gates, V. Varutbangkul, T. A. Rissman, S. M. Murphy, A. Sorooshian, R. C. Flagan, J. H. Seinfeld, G. Feingold, and H. H. Jonsson (2009), Cloud condensation nuclei activity, closure, and droplet growth kinetics of Houston aerosol during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS), *J. Geophys. Res.-Atmos., 114*, doi: 10.1029/2008JD011699.

Lau, K. M., M. K. Kim, and K. M. Kim (2006), Asian summer monsoon anomalies induced by aerosol direct forcing: The role of the Tibetan Plateau, *Climate Dyn.*, *26* (7-8), 855-864, doi: 10.1007/s00382-006-0114-z.

Lau, W. K. M., M. K. Kim, K. M. Kim, and W. S. Lee (2010), Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols, *Environ. Res. Lett.*, *5* (2), doi: 10.1088/1748-9326/5/2/025204.

Lavanchy, V. M. H., H. W. Gäggeler, U. Schotterer, M. Schwikowski, and U. Baltensperger (1999), Historical record of carbonaceous particle concentrations from a European high-alpine glacier (Colle Gnifetti, Switzerland), *J. Geophys. Res.*, *104* (D17), 21227-21236, doi: 10.1029/1999JD900408.

Law, K. S., and A. Stohl (2007), Arctic air pollution: Origins and impacts, *Science*, *315* (5818), 1537-1540, doi: 10.1126/science.1137695.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Lee, D. S., G. Pitari, V. Grewe, K. Gierens, J. E. Penner, A. Petzold, M. J. Prather, U. Schumann, A. Bais, T. Berntsen, D. Iachetti, L. L. Lim, and R. Sausen (2010), Transport impacts on atmosphere and climate: Aviation, *Atmos. Environ.*, *44* (37), 4678-4734, doi: 10.1016/j.atmosenv.2009.06.005.

Lee, K. B., M. W. Thring, and J. M. Beér (1962), On the rate of combustion of soot in a laminar soot flame, *Combustion and Flame*, *6*, 137-145.

Lee, S. H., D. M. Murphy, D. S. Thomson, and A. M. Middlebrook (2002), Chemical components of single particles measured with Particle Analysis by Laser Mass Spectrometry (PALMS) during the Atlanta SuperSite Project: Focus on organic/sulfate, lead, soot, and mineral particles, *J. Geophys. Res.*, *107* (D1-D2), 4003, doi: 10.1029/2000JD000011.

Lefohn, A. S., J. D. Husar, and R. B. Husar (1999), Estimating historical anthropogenic global sulfur emission patterns for the period 1850-1990, *Atmos. Environ.*, *33* (21), 3435-3444.

Legrand, M., S. Preunkert, M. Schock, M. Cerqueira, A. Kasper-Giebl, J. Afonso, C. Pio, A. Gelencsér, and I. Dombrowski-Etchevers (2007), Major 20th century changes of carbonaceous aerosol components (EC, WinOC, DOC, HULIS, carboxylic acids, and cellulose) derived from Alpine ice cores, *J. Geophys. Res.*, *112* (D23), D23S11, doi: 10.1029/2006JD008080.

Lei, Y., Q. Zhang, K. B. He, and D. G. Streets (2011), Primary anthropogenic aerosol emission trends for China, 1990–2005, *Atmos. Chem. Phys.*, *11*, 931-954, doi: 10.5194/acp-11-931-2011.

Levy, R. C., L. A. Remer, S. Mattoo, E. F. Vermote, and Y. J. Kaufman (2007), Second-generating operational algorithm: Retrieval of aerosol properties over land from inversion of Moderate Resolution Imaging Spectroradiometer spectral reflectance, *J. Geophys. Res.*, *112*, D13211, doi: 10.1029/2006JD007811.

Lewis, K., W. P. Arnott, H. Moosmüller, and C. E. Wold (2008), Strong spectral variation of biomass smoke light absorption and single scattering albedo observed with a novel dual-wavelength photoacoustic instrument, *J. Geophys. Res.*, *113,* D16203, doi: 10.1029/2007JD009699.

Lewis, K. A., W. P. Arnott, H. Moosmüller, R. K. Chakrabarty, C. M. Carrico, S. M. Kreidenweis, D. E. Day, W. C. Malm, A. Laskin, J. L. Jimenez, I. M. Ulbrich, J. A. Huffman, T. B. Onasch, A. Trimborn, L. Liu, and M. I. Mishchenko (2009), Reduction in biomass burning aerosol light absorption upon humidification: roles of inorganically-induced hygroscopicity, particle collapse, and photoacoustic heat and mass transfer, *Atmos. Chem. Phys., 9* (22), 8949-8966, doi: 10.5194/acp-9-8949-2009.

Li, J., M. Posfai, P. V. Hobbs, and P. R. Buseck (2003), Individual aerosol particles from biomass burning in southern Africa: 2, Compositions and aging of inorganic particles, *J. Geophys. Res.*, *108* (D13), 8484, doi: 10.1029/2002JD002310.

Liley, J. B., D. Baumgardner, Y. Kondo, K. Kita, B. R. Blake, M. Koike, T. Machida, N. Takegawa, S. Kawakami, T. Shirai, and T. Ogawa (2003), Black carbon in aerosol during BIBLE B, *J. Geophys. Res.*, *108* (D3), doi: 10.1029/2001JD000845.

Lin, C.-I., M. Baker, and R. J. Charlson (1973), Absorption coefficient of atmospheric aerosol: a method for measurement, *Appl. Opt.*, *12* (6), 1356-1363.

Lindesay, J. A., M. O. Andreae, J. G. Goldammer, G. Harris, H. J. Annegarn, M. Garstang, R. J. Scholes, and B. W. vanWilgen (1996), International geosphere-biosphere programme international global atmospheric chemistry SAFARI-92 field experiment: Background and overview, *J. Geophys. Res.*, *101* (D19), 23521-23530.

Liousse, C., J. E. Penner, C. Chuang, J. J. Walton, H. Eddleman, and H. Cachier (1996), A global three-dimensional model study of carbonaceous aerosols, *J. Geophys. Res.*, *101* (D14), 19411-19432.

Liston, G. E. (1995), Local advection of momentum, heat, and moisture during the melt of patchy snow covers, *J. Appl. Meteorol.*, *34* (7), 1705-1715.

Liston, G. E. (1999), Interrelationships among snow distribution, snowmelt, and snow cover depletion: Implications for atmospheric, hydrologic, and ecologic modeling, *J. Appl. Meteorol.*, *38* (10), 1474-1487.

Liston, G. E. (2004), Representing subgrid snow cover heterogeneities in regional and global models, *J. Climate*, *17* (6), 1381-1397.

Liston, G. E., and M. Sturm (2004), The role of winter sublimation in the Arctic moisture budget, *Nordic Hydrology*, *35* (4-5), 325-334.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Liu, J., S. Fan, L. W. Horowitz, and H. Levy II (2011), Evaluation of factors controlling long-range transport of black carbon to the Arctic, *J. Geophys. Res.*, *116,* D04307, doi: 10.1029/2010JD015145.

Liu, L., and M. I. Mishchenko (2005), Effects of aggregation on scattering and radiative properties of soot aerosols, *J. Geophys. Res., 110,* D11211, doi: 11210.11029/12004JD005649.

Liu, X., J. E. Penner, S. J. Ghan, and M. Wang (2007), Inclusion of Ice Microphysics in the NCAR Community Atmospheric Model Version 3 (CAM3), *J. Climate*, *20*, 4526-4547, doi: 10.1175/JCL14264.1.

Liu, X. H., J. E. Penner, and M. H. Wang (2009a), Influence of anthropogenic sulfate and black carbon on upper tropospheric clouds in the NCAR CAM3 model coupled to the IMPACT global aerosol model, *J. Geophys. Res.*, *114* (D03), 204, doi: 10.1029/2008JD010492.

Liu, Y., J. R. Sun, and B. Yang (2009b), The effects of black carbon and sulphate aerosols in China regions on East Asia monsoons, *Tellus B*, *61* (4), 642-656, doi: 10.1111/j.1600-0889.2009.00427.x.

Liu, Y. Q., J. Stanturf, and S. Goodrick (2010), Trends in global wildfire potential in a changing climate, *Forest Ecol. Manag.*, *259*, 685-697, doi: 10.1016/j.foreco.2009.09.002.

Liu, X., R. C. Easter, S. J. Ghan, R. Zaveri, P. Rasch, J.-F. Lamarque, A. Gettelman, H. Morrison, F. Vitt, A. Conley, S. Park, R. Neale, C. Hannay, A. Eckman, P. Hess, N. Mahowald, W. Collins, M. Iacono, C. Bretherton, M. Flanner, and D. Mitchell (2012), Toward a minimal representation of aerosols in climate models: Description and evaluation in the Community Atmosphere Model CAM5, *Geosci. Model Dev.*, *5*, 709-739, doi: 10.5194/gmd-5-709-2012.

Livingston, J. M., V. N. Kapustin, B. Schmid, P. B. Russell, P. K. Quinn, T. S. Bates, P. A. Durkee, P. J. Smith, V. Freudenthaler, M. Wiegner, D. S. Covert, S. Gasso, D. Hegg, D. R. Collins, R. C. Flagan, J. H. Seinfeld, V. Vitale, and C. Tomasi (2000), Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE-2, and comparison with selected land, ship, aircraft, and satellite measurements, *Tellus B*, *52* (2), 594-619.

Lobert, J. M., D. H. Scharffe, W.-M. Hao, T. A. Kuhlbusch, R. Seuwen, P. Warneck, and P. J. Crutzen (1991), Experimental evaluation of biomass burning emissions: nitrogen and carbon containing compounds, in *Global biomass burning: Atmospheric, climatic, and biospheric implications*, edited by J. S. Levine, Massachussetts Institute of Technology.

Lohmann, U. (2002), A glaciation indirect aerosol effect caused by soot aerosols, *Geophys. Res. Lett.*, *29* (4), 1052, doi: 10.1029/2001GL014357.

Lohmann, U., and K. Diehl (2006), Sensitivity studies of the importance of dust ice nuclei for the indirect aerosol effect on stratiform mixed-phase clouds, *J. Atmos. Sci.*, *63* (3), 968-982.

Lohmann, U., and J. Feichter (2001), Can the direct and semi-direct aerosol effect compete with the indirect effect on a global scale?, *Geophys. Res. Lett.*, *28* (1), 159-161, doi: 10.1029/2000GL012051.

Lohmann, U., and J. Feichter (2005), Global indirect aerosol effects: A review, *Atmos. Chem. Phys.*, *5*, 715-737, doi: 10.5194/acp-5-715-2005.

Lohmann, U., and C. Hoose (2009), Sensitivity studies of different aerosol indirect effects in mixed-phase clouds, *Atmos. Chem. Phys.*, *9* (22), 8917-8934, doi: 10.5194/acp-9-8917-2009.

Lohmann, U., P. Stier, C. Hoose, S. Ferrachat, S. Kloster, E. Roeckner, and J. Zhang (2007), Cloud microphysics and aerosol indirect effects in the global climate model ECHAM5-HAM, *Atmos. Chem. Phys.*, *7* (13), 3425-3446, doi: 10.5194/acp-7-3425-2007.

Lohmann, U., L. Rotstayn, T. Storelvmo, A. Jones, S. Menon, J. Quaas, A. M. L. Ekman, D. Koch, and R. Ruedy (2010), Total aerosol effect: radiative forcing or radiative flux perturbation?, *Atmos. Chem. Phys.*, *10* (7), 3235-3246, doi: 10.5194/acp-11-931-2011.

Lu, Z., Q. Zhang, and D. G. Streets (2011), Sulfur dioxide and primary carbonaceous aerosol emissions in China and India, 1996-2010, *Atmos. Chem. Phys.*, *11*, 9839-9864, doi: 10.5194/acp-11-9839-2011.

Lu, Z., D. G. Streets, Q. Zhang, and S. Wang (2012), A novel back-trajectory analysis of the origin of black carbon transported to the Himalayas and Tibetan Plateau during 1996-2010, *Geophys. Res. Lett.*, *39,* L01809, doi: 10.1029/2011GL049903.

Lubin, D., and A. S. Simpson (1994), The longwave emission signature of urban pollution: Radiometric FTIR measurement, *Geophys. Res. Lett.*, *21* (1), 37-40, doi: 10.1029/93GL03374.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Lund, M. T., and T. Berntsen (2012), Parameterization of black carbon aging in the OsloCTM2 and implications for regional transport to the Arctic, *Atmos. Chem. Phys.*, *12*, 6999-7014, www.atmos-chem-phys.net/12/6999/2012/, doi: 10.5194/acpd-11-6999-2012.

Luo, C., N. Mahowald, and J. del Corral (2003), Sensitivity study of meteorological parameters on mineral aerosol mobilization, transport and distribution, *J. Geophys. Res.*, *108* (D15), 4447, doi: 10.1029/2003JD0003483.

MacCarty, N., D. Still, and D. Ogle (2010), Fuel use and emissions performance on fifty cooking stoves in the laboratory and related benchmarks of performance, *Energ. Sust. Dev.*, *14*, 161-171.

Mack, M. C., M. S. Bret-Harte, T. N. Hollingsworth, R. R. Jandt, E. A. G. Schuur, G. R. Shaver, and D. L. Verbyla (2011), Carbon loss from an unprecedented Arctic tundra wildfire, *Nature*, *475* (7357), 489-492, doi: 10.1038/nature10283.

Magi, B. I., P. V. Hobbs, B. Schmid, and J. Redemann (2003), Vertical profiles of light scattering, light absorption, and single scattering albedo during the dry, biomass burning season in southern Africa and comparisons of in situ and remote sensing measurements of aerosol optical depths, *J. Geophys. Res.*, *108* (D13), 8504, doi: 10.1029/2002JD002361.

Mahowald, N. M., D. R. Muhs, S. Levis, P. J. Rasch, M. Yoshioka, C. S. Zender, and C. Luo (2006), Change in atmospheric mineral aerosols in response to climate: Last glacial period, preindustrial, modern, and doubled carbon dioxide climates, *J. Geophys. Res.*, *111,* D10202, doi: 10.1029/2005JD006653.

Mallet, M., J. C. Roger, S. Despiau, O. Dubovik, and J. P. Putaud (2003), Microphysical and optical properties of aerosol particles in urban zone during ESCOMPTE, *Atmos. Res., 69* (1-2), 73-97.

Mallet, M., J. C. Roger, S. Despiau, J. P. Putaud, and O. Dubovik (2004), A study of the mixing state of black carbon in urban zone, *J. Geophys. Res., 109*, D04202, doi: 04210.01029/02003JD003940.

Malm, W. C., J. F. Sisler, D. Huffman, R. A. Eldred, and T. A. Cahill (1994), Spatial and seasonal trends in particle concentration and optical extinction in the United States, *J. Geophys. Res.*, *99* (D1), 1347-1370.

Manne, A. S., and R. G. Richels (2001), An alternative approach to establishing trade-offs among greenhouse gases, *Nature*, *410* (6829), 675-677.

Manoli, E., D. Voutsa, and C. Samara (2002), Chemical characterization and source identification/apportionment of fine and coarse air particles in Thessaloniki, Greece, *Atmos. Environ.*, *36* (6), 949-961.

Marcolli, C., S. Gedamke, T. Peter, and B. Zobrist (2007), Efficiency of immersion mode ice nucleation on surrogates of mineral dust, *Atmos. Chem. Phys.*, *7* (19), 5081-5091, doi: 10.5194/acp-7-5081-2007.

Marcq, S., P. Laj, J. C. Roger, P. Villani, K. Sellegri, P. Bonasoni, A. Marinoni, P. Cristofanelli, G. P. Verza, and M. Bergin (2010), Aerosol optical properties and radiative forcing in the high Himalaya based on measurements at the Nepal Climate Observatory-Pyramid site (5079 m a.s.l.), *Atmos. Chem. Phys.*, *10* (13), 5859-5872, doi: 10.5194/acp-10-5859-2010.

Marinoni, A., P. Cristofanelli, P. Laj, R. Duchi, F. Calzolari, S. Decesari, K. Sellegri, E. Vuillermoz, G. P. Verza, P. Villani, and P. Bonasoni (2010), Aerosol mass and black carbon concentrations, two year-round observations at NCO-P (5079 m, Southern Himalayas), *Atmos. Chem. Phys.*, *10*, 8551-8562, www.atmos-chem-phys.net/10/8551/2010/, doi: 10.5194/acpd-10-8551-2010.

Marley, N. A., J. S. Gaffney, J. C. Baird, C. A. Blazer, P. J. Drayton, and J. E. Frederick (2001), An empirical method for the determination of the complex refractive index of size-fractionated atmospheric aerosols for radiative transfer calculations, *Aerosol Sci. Technol.*, *34*, 535-549.

Marlon, J. R., P. J. Bartlein, C. Carcaillet, D. G. Gavin, S. P. Harrison, P. E. Higuera, F. Joos, M. J. Power, and I. C. Prentice (2008), Climate and human influences on global biomass burning over the past two millennia, *Nature Geosci.*, *1*, 697-702, doi: 10.1038/ngeo313.

Martins, J. V., P. Artaxo, C. Liousse, J. S. Reid, P. V. Hobbs, and Y. Kaufman (1998a), Effects of black carbon content, particle size, and mixing on light absorption by aerosol from biomass burning in Brazil, *J. Geophys. Res.*, *103* (D24), 32041-32050.

Martins, J. V., P. V. Hobbs, R. E. Weiss, and P. Artaxo (1998b), Sphericity and morphology of smoke particles from biomass burning in Brazil, *J. Geophys. Res.*, *103* (D24), 32051-32057.

Massey, R. (1997), No-tillage and conservation tillage: Economic considerations, University of Missouri Extension Publication G355,

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

University of Missouri, Columbia, MO.

Massie, S. T., A. Heymsfield, C. Schmitt, D. Muller, and P. Seifert (2007), Aerosol indirect effects as a function of cloud top pressure, *J. Geophys. Res.*, *112* (D6), 202, doi: 10.1029/2006JD007383.

Matzl, M., and M. Schneebeli (2006), Measuring specific surface area of snow by near infrared photography, *J. Glaciol.*, *52*, 558-564.

Maykut, G. A., and N. Untersteiner (1971), Some results from a time-dependent thermodynamic model of sea ice, *J. Geophys. Res.*, *76* (6), 1550-1575, doi: 10.1029/JC076i006p01550.

Mayol-Bracero, O. L., R. Gabriel, M. O. Andreae, T. W. Kirchstetter, T. Novakov, J. Ogren, P. Sheridan, and D. G. Streets (2002), Carbonaceous aerosols over the Indian Ocean during the Indian Ocean Experiment (INDOEX): Chemical characterization, optical properties, and probable sources, *J. Geophys. Res.*, *107* (D19), 8030, doi: 10.1029/2000JD000039.

McConnell, J. R., and R. Edwards (2008), Coal burning leaves toxic heavy metal legacy in the Arctic, *P. Natl. Acad. Sci. USA*, *105* (34), 12140-12144, doi: 10.1073/pnas.0803564105.

McConnell, J. R., R. Edwards, G. L. Kok, M. G. Flanner, C. S. Zender, E. S. Saltzman, J. R. Banta, D. R. Pasteris, M. M. Carter, and J. D. W. Kahl (2007), 20th-century industrial black carbon emissions altered Arctic climate forcing, *Science*, *317* (5843), 1381-1384, doi: 10.1126/science.1144856.

McCormick, R. A., and J. H. Ludwig (1967), Climate modification by atmospheric aerosols, *Science*, *156* (3780), 1358-1359, doi: 10.1126/science.156.3780.1358.

McDonald, J. D., B. Zielinska, E. M. Fujita, J. C. Sagebiel, J. C. Chow, and J. G. Watson (2000), Fine particle and gaseous emission rates from residential wood combustion, *Environ. Sci. Technol.*, *34*, 2080-2091.

McFarquhar, G. M., and H. L. Wang (2006), Effects of aerosols on trade wind cumuli over the Indian Ocean: Model simulations, *Quart J. Roy. Meteor. Soc.*, *132* (616), 821-843, doi: 10.1256/qj.04.179.

McFiggans, G., P. Artaxo, U. Baltensperger, H. Coe, M. C. Facchini, G. Feingold, S. Fuzzi, M. Gysel, A. Laaksonen, U. Lohmann, T. F. Mentel, D. M. Murphy, C. D. O'Dowd, J. R. Snider, and E. Weingartner (2006), The effect of physical and chemical aerosol properties on warm cloud droplet activation, *Atmos. Chem. Phys.*, *6*, 2593-2649, doi: 10.5194/acp-6-2593-2006.

Medalia, A. I., and F. A. Heckman (1969), Morphology of aggregates-- II. Size and shape factors of carbon black aggregates from electron microscopy, *Carbon*, *7*, 569-582.

Medalia, A. I., and L. W. Richards (1972), Tinting strength of carbon black, *J. Colloid Interf. Sci.*, *40* (2), 233-252.

Medina, J., A. Nenes, R. E. P. Sotiropoulou, L. D. Cottrell, L. D. Ziemba, P. J. Beckman, and R. J. Griffin (2007), Cloud condensation nuclei closure during the International Consortium for Atmospheric Research on Transport and Transformation 2004 campaign: Effects of size-resolved composition, *J. Geophys. Res., 112 (D10)*, doi: 10.1029/2006JD007588.

Meehl, G. A., J. M. Arblaster, and W. D. Collins (2008), Effects of black carbon aerosols on the Indian monsoon, *J. Climate*, *21* (12), 2869-2882, doi: 10.1175/2007jcli1777.1.

Mehta, S., and C. Shahpar (2004), The health benefits of interventions to reduce indoor air pollution from solid fuel use: A cost-effectiveness analysis, *Energy for Sustainable Development*, *8* (3), doi: 10.1016/S0973-0826(08)60466-4.

Menon, S., and A. D. Genio (2007), Evaluating the impacts of carbonaceous aerosols on clouds and climate, in *Human-Induced Climate Change: An Interdisciplinary Assessment* edited by M. E. Schlesinger, H. Kheshgi, J. B. Smith, F. C. D. L. Chesnaye, J. M. Reilly, T. Wilson and C. Kolstad, 34-48 pp., Cambridge University Press.

Menon, S., A. D. Del Genio, D. Koch, and G. Tselioudis (2002a), GCM Simulations of the aerosol indirect effect: Sensitivity to cloud parameterization and aerosol burden, *J. Atmos. Sci.*, *59* (3), 692-713, doi: 10.1175/1520-0469(2002)059<0692:gsotai>2.0.co;2.

Menon, S., J. Hansen, L. Nazarenko, and Y. F. Luo (2002b), Climate effects of black carbon aerosols in China and India, *Science*, *297* (5590), 2250-2253.

Menon, S., D. Koch, G. Beig, S. Sahu, J. Fasullo, and D. Orlikowski (2010), Black carbon aerosols and the third polar ice cap, *Atmos. Chem. Phys.*, *10* (10), 4559-4571, doi: 10.5194/acp-10-4559-2010.

Merikanto, J., D. V. Spracklen, G. W. Mann, S. J. Pickering, and K. S. Carslaw (2009), Impact of nucleation on global CCN, *Atmos. Chem.*

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Phys., *9* (21), 8601-8616, doi: 10.5194/acp-9-8601-2009.

Mikhailov, E. F., S. S. Vlasenko, I. A. Podgorny, V. Ramanathan, and C. E. Corrigan (2006), Optical properties of soot-water drop agglomerates: An experimental study, *J. Geophys. Res.*, *111*, D07209, doi: 10.1029/2005JD006389.

Miller, R. L., I. Tegen, and J. Perlwitz (2004), Surface radiative forcing by soil dust aerosols and the hydrologic cycle, *J. Geophys. Res.*, *109* (D4), 203, doi: 10.1029/2003JD004085.

Miller, S. M., D. M. Matross, A. E. Andrews, D. B. Millet, M. Longo, E. W. Gottlieb, A. I. Hirsch, C. Gerbig, J. C. Lin, B. C. Daube, R. C. Hudman, P. L. S. Dias, V. Y. Chow, and S. C. Wofsy (2008), Sources of carbon monoxide and formaldehyde in North America determined from high-resolution atmospheric data, *Atmos. Chem. Phys.*, *8* (24), 7673-7696, doi: 10.5194/acp-8-7673-2008.

Millstein, D. E., and R. A. Harley (2010), Effects of retrofitting emission control systems on in-use heavy diesel vehicles, *Environ. Sci. Technol.*, *44* (13), 5042-5048, doi: 10.1021/es1006669.

Ming, J., H. Cachier, C. Xiao, D. Qin, S. Kang, S. Hou, and J. Xu (2008), Black carbon record based on a shallow Himalayan ice core and its climatic implications, *Atmos. Chem. Phys.*, *8* (5), 1343-1352, doi: 10.5194/acp-8-1343-2008.

Ming, J., C. Xiao, H. Cachier, D. Qin, X. Qin, Z. Li, and J. Pu (2009), Black Carbon (BC) in the snow of glaciers in west China and its potential effects on albedos, *Atmos. Res.*, *92* (1), 114-123.

Ming, Y., V. Ramaswamy, P. A. Ginoux, and L. H. Horowitz (2005), Direct radiative forcing of anthropogenic organic aerosol *J. Geophys. Res.*, *110*, D20208, doi: 10.1029/2004JD005573.

Ming, Y., V. Ramaswamy, and G. Persad (2010), Two opposing effects of absorbing aerosols on global-mean precipitation, *Geophys. Res. Lett.*, *37* (L13), 701, doi: 10.1029/2010GL042895.

Minikin, A., A. Petzold, J. Strom, R. Krejci, M. Seifert, P. van Velthoven, H. Schlager, and U. Schumann (2003), Aircraft observations of the upper tropospheric fine particle aerosol in the Northern and Southern Hemispheres at midlatitudes, *Geophys. Res. Lett.*, *30* (10), 1503, doi: 10.1029/2002GL016458.

Minvielle, F., G. Cautenet, M. O. Andreae, F. Lasserre, G. Foret, S. Cautenet, J. F. Leon, O. L. Mayol-Bracero, R. Gabriel, P. Chazette, and R. Roca (2004), Modelling the transport of aerosols during INDOEX 1999 and comparison with experimental data - 1: carbonaceous aerosol distribution, *Atmos. Environ.*, *38* (12), 1811-1822, doi: 10.1016/j.atmosenv.2003.07.017.

Mishchenko, M. I., L. Liu, L. D. Travis, and A. A. Lacis (2004), Scattering and radiative properties of semi-external versus external mixtures of different aerosol types, *J. Quant. Spectrosc. Radiat. Transfer, 88*, 139-147.

Moffet, R. C., and K. A. Prather (2009), In-situ measurements of the mixing state and optical properties of soot with implications for radiative forcing estimates, *P. Natl. Acad. Sci. USA*, *106* (29), 11872-11877.

Möhler, S., S. Büttner, C. Linke, M. Schnaiter, H. Saathoff, O. Stetzer, R. Wagner, M. Krämer, A. Mangold, V. Ebert, and U. Schurath (2005a), Effect of sulfuric acid coating on heterogeneous ice nucleation by soot aerosol particles, *J. Geophys. Res.*, *110*, D11210, doi: 10.1029/2004JD005169.

Möhler, O., C. Linke, H. Saathoff, M. Schnaiter, R. Wagner, A. Mangold, M. Kramer, and U. Schurath (2005b), Ice nucleation on flame soot aerosol of different organic carbon content, *Meteor. Z.*, *14* (4), 477-484, doi: 10.1127/0941-2948/2005/0055.

Molina, M., D. Zaelke, K. M. Sarma, S. O. Andersen, V. Ramanathan, and D. Kaniaru (2009), Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO_2 emissions, *P. Natl. Acad. Sci. USA*, *106* (49), 20616-20621, doi:10.1073/pnas.0902568106.

Mollicone, D., H. D. Eva, and F. Achard (2006), Human role in Russian wild fires, *Nature*, *440* (7083), 436-437, doi: 10.1038/440436a.

Montgomery, W. D., R. E. Baron, and S. D. Tuladhar (2009), An analysis of black carbon mitigation as a response to climate change, Report prepared for the Copenhagen Consensus on Climate, Copenhagen Consensus Center, Frederiksberg, Denmark.

Moosmüller, H., W. P. Arnott, C. F. Rogers, J. L. Bowen, J. A. Gillies, W. R. Pierson, J. F. Collins, T. D. Durbin, and J. M. Norbeck (2001), Time-resolved characterization of diesel particulate emissions. 2. Instruments for elemental and organic carbon measurements, *Environ. Sci. Technol.*, *35* (10), 1935-1942.

Moosmüller, H.; R. K. Chakrabarty, and W. P. Arnott (2009), Aerosol light absorption and its measurement: A review, *J. Quant. Spectrosc.*

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Radiat. Transfer 110 (11), 844-878 doi: 10.1016/j.jqsrt.2009.02.035.

Moosmüller, H., R. K. Chakrabarty, K. M. Ehlers, and W. P. Arnott (2011), Absorption Angström coefficient, brown carbon, and aerosols: Basic concepts, bulk matter, and spherical particles, *Atmos. Chem. Phys., 11* (3), 1217-1225, doi: 10.5194/acp-11-1217-2011.

Moosmüller, H., J. P. Engelbrecht, M. Skiba, G. Frey, R. K. Chakrabarty, and W. P. Arnott (2012), Single scattering albedo of fine mineral dust aerosols controlled by iron concentration, *J. Geophys. Res.*, *117,* D11210, doi: 10.1029/2011JD016909.

Morrison, H., and A. Gettelman (2008), A new two-moment bulk stratiform cloud microphysics scheme in the Community Atmosphere Model, version 3 (CAM3). Part I: Description and numerical tests *J. Climate*, *21* (15), 3642-3659, doi: 10.1175/2008JCL12105.1.

Moss, R. H., J. A. Edmonds, K. A. Hibbard, M. R. Manning, S. K. Rose, D. P. v. Vuuren, T. R. Carter, S. Emori, M. Kainuma, T. Kram, G. A. Meehl, J. F. B. Mitchell, N. Nakicenovic, K. Riahi, S. J. Smith, R. J. Stouffer, A. M. Thomson, J. P. Weyant, and T. J. Wilbanks (2010), The next generation of scenarios for climate change research and assessment, *Nature*, *463*, 747-756, doi: 10.1038/nature08823.

Moteki, N., and Y. Kondo (2007), Effects of mixing state on black carbon measurements by laser-induced incandescence, *Aerosol Sci. Technol.*, *41* (4), 398-417, doi: 10.1080/02786820701199728.

Moteki, N., and Y. Kondo (2010), Dependence of laser-induced incandescence on physical properties of black carbon aerosols: Measurements and theoretical interpretation, *Aerosol Sci. Technol.*, *44* (8), 663-675, doi: 10.1080/02786826.2010.484450.

Moteki, N., Y. Kondo, Y. Miyazaki, N. Takegawa, Y. Komazaki, G. Kurata, T. Shirai, D. R. Blake, T. Miyakawa, and M. Koike (2007), Evolution of mixing state of black carbon particles: Aircraft measurements over the western Pacific in March 2004, *Geophys. Res. Lett.*, *34,* L11803, doi: 10.1029/2006GL028943.

Moteki, N., Y. Kondo, and S. Nakamura (2010), Method to measure refractive indices of small nonspherical particles: Application to black carbon particles, *J. Aerosol. Sci.*, *41* (5), 513-521, doi: 10.1016/J.JAEROSCI.2010.02.013.

Moulliot, F., and C. B. Field (2005), Fire history and the global carbon budget: a 1°×1° fire history reconstruction for the 20th century, *Global Change Biology*, *11*, 398-420, doi: 10.1111/j.1365-2486.2005.00920.x.

Mugica, V., E. Ortiz, L. Molina, A. De Vizcaya-Ruiz, A. Nebot, R. Quintana, J. Aguilar, and E. Alcantara (2009), PM composition and source reconciliation in Mexico City, *Atmos. Environ.*, *43* (32), 5068-5074, doi: 10.1016/j.atmosenv.2009.06.051.

Muhlbauer, A., and U. Lohmann (2009), Sensitivity studies of aerosol-cloud interactions in mixed-phase orographic precipitation, *J. Atmos. Sci.*, *66* (9), 2517-2538, doi: 10.1175/2009jas3001.1.

Mukunda, H. S., S. Dasappa, P. J. Paul, N. K. S. Rajan, M. Yagnaraman, D. R. Kumar, and M. Deogaonkar (2010), Gasifier stoves - science, technology and field outreach, *Curr. Sci.*, *98* (5), 627-638.

Mullins, J., and A. Williams (1987), The optical properties of soot: a comparison between experimental and theoretical values, *Fuel*, *66*, 277-280.

Murphy, D. M., and T. Koop (2005), Review of the vapour pressures of ice and supercooled water for atmospheric applications, *Quart J. Roy. Meteor. Soc.*, *131* (608), 1539-1565, doi: 10.1256/qj.04.94.

Murphy, D. M., D. J. Cziczo, P. K. Hudson, and D. S. Thomson (2007), Carbonaceous material in aerosol particles in the lower stratosphere and tropopause region, *J. Geophys. Res.*, *112* (D4), 203, doi: 10.1029/2006JD007297.

Murphy, D. M., S. Solomon, R. W. Portmann, K. H. Rosenlof, P. M. Forster, and T. Wong (2009), An observationally based energy balance for the Earth since 1950, *J. Geophys. Res.*, *114* (D17), 107, doi: 10.1029/2009JD012105.

Murphy, D. M., J. C. Chow, E. M. Leibensperger, W. C. Malm, M. Pitchford, B. A. Schichtel, J. G. Watson, and W. H. White (2011), Decreases in elemental carbon and fine particle mass in the United States, *Atmos. Chem. Phys.*, *11*, 4679-4686, doi: 10.5194/acp-11-4679-2011.

Myhre, G., T. F. Berglen, M. Johnsrud, C. R. Hoyle, T. K. Berntsen, S. A. Christopher, D. W. Fahey, I. S. A. Isaksen, T. A. Jones, R. A. Kahn, N. Loeb, P. Quinn, L. Remer, J. P. Schwarz, and K. E. Yttri (2009), Modelled radiative forcing of the direct aerosol effect with multi-observation evaluation, *Atmos. Chem. Phys.*, *9*, 1365-1392, doi: 10.5194/acp-9-1365-2009.

Naeher, L. P., M. Brauer, M. Lipsett, J. T. Zelikoff, C. D. Simpson, J. Q. Koenig, and K. R. Smith (2007), Woodsmoke health effects: A review, *Inhal. Toxicol.*, *19* (1), 67-106.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Nagashima, T., H. Shiogama, T. Yokohata, T. Takemura, S. A. Crooks, and T. Nozawa (2006), Effect of carbonaceous aerosols on surface temperature in the mid twentieth century, *Geophys. Res. Lett.*, *33* (4), 702, doi: 10.1029/2005GL024887.

Naik, V., D. L. Mauzerall, L. W. Horowitz, M. D. Schwarzkopf, V. Ramaswamy, and M. Oppenheimer (2007), On the sensitivity of radiative forcing from biomass burning aerosols and ozone to emission location, *Geophys. Res. Lett.*, *34* (3), L03818, doi: 10.1029/2006GL028149.

Nakawo, M., C. F. Raymond, and A. Fountain (Eds.) (2000), *Debris-Ccovered Glaciers*, 288 pp, IAHS Publication 264, International Association of Hydrological Sciences Press, Oxforshire, United Kingdom.

Nelson, J. (1989), Fractality of sooty smoke: Implications for the severity of nuclear winter, *Nature, 339*, 611-613.

Nenes, A., and J. H. Seinfeld (2003), Parameterization of cloud droplet formation in global climate models, *J. Geophys. Res.*, *108* (D14), doi: 10.1029/2002JD002911.

Neususs, C., H. Wex, W. Birmili, A. Wiedensohler, C. Koziar, B. Busch, E. Bruggemann, T. Gnauk, M. Ebert, and D. S. Covert (2002), Characterization and parameterization of atmospheric particle number-, mass-, and chemical-size distributions in central Europe during LACE 98 and MINT, *J. Geophys. Res.*, *107* (D21), 8127, doi: 10.1029/2001JD000514.

Nguyen, H. N., B. G. Martinsson, J. B. Wagner, E. Carlemalm, M. Ebert, S. Weinbruch, C. A. M. Brenninkmeijer, J. Heintzenberg, M. Hermann, T. Schuck, P. F. J. van Velthoven, and A. Zahn (2008), Chemical composition and morphology of individual aerosol particles from a CARIBIC flight at 10 km altitude between 50 degrees N and 30 degrees S, *J. Geophys. Res.*, *113* (D23), 209, doi: 10.1029/2008JD009956.

Novakov, T., and C. E. Corrigan (1995), Thermal characterization of biomass smoke particles, *Microchim. Acta*, *119*, 157-166.

Novakov, T., and J. E. Hansen (2004), Black carbon emissions in the United Kingdom during the past four decades: An empirical analysis, *Atmos. Environ.*, *38* (25), 4155-4163.

Novakov, T., M. O. Andreae, R. Gabriel, T. W. Kirchstetter, O. L. Mayol-Bracero, and V. Ramanathan (2000), Origin of carbonaceous aerosols over the tropical Indian Ocean: Biomass burning or fossil fuels?, *Geophys. Res. Lett.*, *27* (24), 4061-4064.

Novakov, T., V. Ramanathan, J. E. Hansen, T. W. Kirchstetter, M. Sato, J. E. Sinton, and J. A. Satahye (2003), Large historical changes of fossil-fuel black carbon aerosols, *Geophys. Res. Lett.*, *30* (6), 1324, doi: 10.1029/2002GL016345.

NRC (2011), National Research Council, Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia, The National Academies Press, Washington, DC.

Oanh, N. T. K., N. Upadhyaya, Y. H. Zhuang, Z. P. Hao, D. V. S. Murthy, P. Lestari, J. T. Villarin, K. Chengchua, H. X. Co, N. T. Dung, and E. S. Lindgren (2006), Particulate air pollution in six Asian cities: Spatial and temporal distributions, and associated sources, *Atmos. Environ.*, *40* (18), 3367-3380, doi: 10.1016/j.atmosenv.2006.01.050.

O'Donnell, D., K. Tsigaridis, and J. Feichter (2011), Estimating the direct and indirect effects of secondary organic aerosols using ECHAM5-HAM, *Atmos. Chem. Phys.*, *11*, 8635-8659, doi: 10.519/acp-11-8635-2011.

Ogren, J. A., and R. J. Charlson (1983), Elemental carbon in the atmosphere: Cycle and lifetime, *Tellus*, *35B*, 241-254.

Ohara, T., H. Akimoto, J. Kurokawa, N. Horii, K. Yamaji, X. Yan, and T. Hayasaka (2007), An Asian emission inventory of anthropogenic emission sources for the period 1980-2020, *Atmos. Chem. Phys.*, *7* (16), 4419-4444, doi: 10.5194/acp-7-4419-2007.

Omar, A. H., D. M. Winker, M. A. Vaughan, Y. Hu, C. R. Trepte, R. A. Ferrare, K.-P. Lee, C. A. Hostetler, C. Kittaka, R. R. Rogers, R. E. Kuehn, and Z. Liu (2009), The CALIPSO automated aerosol classification and lidar ratio selection algorithm, *J. Atmos. Oceanic Technol.*, *26*, 1994–2014, doi: 10.1175/2009JTECHA1231.1.

O'Neill, B. C. (2000), The jury is still out on global warming potentials, *Clim. Change*, *44* (427-443).

Ostro, B., M. Lipsett, P. Reynolds, D. Goldberg, A. Hertz, C. Garcia, K. D. Henderson, and L. Bernstein (2010), Long-term exposure to constituents of fine particulate air pollution and mortality: Results from the California teachers study, *Environ. Health Perspect.*, *118* (3), 363-369, doi: 10.1289/ehp.0901181.

Ottmar, R. D., J. L. Peterson, B. Leenhouts, and J. E. Core (2001), Smoke management: techniques to reduce or redistribute emissions. In: Smoke management guide for prescribed and wildland fire: 2001 Edition, National Wildfire Coordination Group.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Paatero, P. (1997), Least squares formulation of robust non-negative factor analysis, *Chemometr. Intell. Lab.*, *37* (1), 23-35.

Painter, T. H., A. P. Barrett, C. C. Landry, J. C. Neff, M. P. Cassidy, C. R. Lawrence, K. E. McBride, and G. L. Farmer (2007), Impact of disturbed desert soils on duration of mountain snow cover, *Geophys. Res. Lett.*, *34* (12), 502, doi: 10.1029/2007GL030284.

Parashar, D. C., R. Gadi, T. K. Mandal, and A. P. Mitra (2005), Carbonaceous aerosol emissions from India, *Atmos. Environ.*, *39* (40), 7861-7871, doi: 10.1016/j.atmosenv.2005.08.034.

Paris, J. D., A. Stohl, P. Nédélec, M. Y. Arshinov, M. V. Panchenko, V. P. Shmargunov, K. S. Law, B. D. Belan, and P. Ciais (2009), Wildfire smoke in the Siberian Arctic in summer: Source characterization and plume evolution from airborne measurements, *Atmos. Chem. Phys.*, *9* (23), 9315-9327, doi: 10.5194/acp-9-9315-2009.

Park, K., D. B. Kittelson, M. R. Zachariah, and P. H. McMurry (2004), Measurement of inherent material density of nanoparticle agglomerates, *J. Nanopart. Res.*, *6* (267-272).

Park, R. J., D. J. Jacob, M. Chin, and R. V. Martin (2003), Sources of carbonaceous aerosols over the United States and implications for natural visibility, *J. Geophys. Res.*, *108* (D12), 4355, doi: 10.1029/2002JD003190.

Park, R. J., M. J. Kim, J. I. Jeong, D. Youn, and S. Kim (2010), A contribution of brown carbon aerosol to the aerosol light absorption and its radiative forcing in East Asia, *Atmos. Environ.*, *44* (11), 1414-1421, doi: 10.1016/j.atmosenv.2010.01.042.

Park, S. H., S. L. Gong, V. S. Bouchet, W. Gong, P. A. Makar, M. D. Moran, C. A. Stroud, and J. Zhang (2011), Effects of black carbon aging on air quality predictions and direct radiative forcing estimation, *Tellus B*, *63*, 1026-1039, doi: 10.1111/j.1600-0889.2011.00558.x.

Parrish, D. D., D. T. Allen, T. S. Bates, M. Estes, F. C. Fehsenfeld, G. Feingold, R. Ferrare, R. M. Hardesty, J. F. Meagher, J. W. Nielsen-Gammon, R. B. Pierce, T. B. Ryerson, J. H. Seinfeld, and E. J. Williams (2009), Overview of the second texas air quality study (TexAQS II) and the gulf of mexico atmospheric composition and climate study (GoMACCS), *J. Geophys. Res.*, *114,* D00f13, doi: 10.1029/2009JD011842.

Patterson, E. M., and C. K. McMahon (1984), Absorption characteristics of forest fire particulate matter, *Atmos. Environ.*, *18* (11), 2541-2551.

Pechony, O., and D. T. Shindell (2010), Driving forces of global wildfires over the past millennium and the forthcoming century, *P. Natl. Acad. Sci. USA*, *107* (45), 19167-19170, doi: 10.1073/pnas.1003669107.

Penner, J. E., H. Eddleman, and T. Novakov (1993), Towards the development of a global inventory for black carbon emissions, *Atmos. Environ.*, *27A* (8), 1277-1295.

Penner, J. E., C. C. Chuang, and K. Grant (1998), Climate forcing by carbonaceous and sulfate aerosols, *Climate Dyn.*, *14* (12), 839-851.

Penner, J. E., M. Andreae, H. Annegarn, L. Barrie, J. Feichter, D. Hegg, A. Jayaraman, R. Leaitch, D. Murphy, J. Nganga, and G. Pitari (2001), Aerosols: Their direct and indirect effects, in IPCC, 2001: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 289-348 pp., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Penner, J. E., S. Y. Zhang, and C. C. Chuang (2003), Soot and smoke aerosol may not warm climate, *J. Geophys. Res.*, *108* (D21), 4657, doi: 10.1029/2003JD003409.

Penner, J. E., Y. Chen, M. Wang, and X. Liu (2009), Possible influence of anthropogenic aerosols on cirrus clouds and anthropogenic forcing, *Atmos. Chem. Phys.*, *9* (3), 879-896.

Perlwitz, J., and R. L. Miller (2010), Cloud cover increase with increasing aerosol absorptivity: A counterexample to the conventional semidirect aerosol effect, *J. Geophys. Res.*, *115* (D08), 203, doi: 10.1029/2009JD012637.

Perovich, D. K., T. C. Grenfell, B. Light, and P. V. Hobbs (2002), Seasonal evolution of the albedo of multiyear Arctic sea ice, *J. Geophys. Res.*, *107* (C10), 8044, doi: 10.1029/2000JC000438.

Peters, G. P., B. Aamaas, T. Berntsen, and J. S. Fuglestvedt (2011), The integrated global temperature change potential (iGTP) and relationships between emission metrics, *Environ. Res. Lett.*, *6,* 044021, doi: 10.1088/1748-9326/6/4/044021.

Petters, M. D., M. T. Parsons, A. J. Prenni, P. J. DeMott, S. M. Kreidenweis, C. M. Carrico, A. P. Sullivan, G. R. McMeeking, E. Levin, C. E. Wold, J. L. Collett, and H. Moosmüller (2009), Ice nuclei emissions from biomass burning, *J. Geophys. Res.*, *114* (D07), 209, doi:

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

10.1029/2008JD011532.

Petzold, A., and R. Niessner (1996), Photoacoustic soot sensor for in-situ black carbon monitoring, *Appl. Phys. B-Lasers Opt., 63* (2), 191-197.

Petzold, A., J. Strom, S. Ohlsson, and F. P. Schroder (1998), Elemental composition and morphology of ice-crystal residual particles in cirrus clouds and contrails, *Atmos. Res.*, *49* (1), 21-34.

Petzold, A., H. Schloesser, P. J. Sheridan, W. P. Arnott, J. A. Ogren, and A. Virkkula (2005a), Evaluation of multiangle absorption photometry for measuring aerosol light absorption, *Aerosol Sci. Technol.*, *39*, 40-51.

Petzold, A., M. Gysel, X. Vancassel, R. Hitzenberger, H. Puxbaum, S. Vrochticky, E. Weingartner, U. Baltensperger, and P. Mirabel (2005b), On the effects of organic matter and sulphur-containing compounds on the CCN activation of combustion particles, *Atmos. Chem. Phys.*, *5*, 3187-3203.

Philippin, S., A. Wiedensohler, and F. Stratmann (2004), Measurements of non-volatile fractions of pollution aerosols with an eight-tube volatility tandem differential mobility analyzer (VTDMA-8), *J. Aerosol. Sci.*, *35* (2), 185-203, doi: 10.1016/j.jaerosci.2003.07.004.

Phillips, V. T. J., P. J. DeMott, and C. Andronache (2008), An empirical parameterization of heterogeneous ice nucleation for multiple chemical species of aerosol, *J. Atmos. Sci.*, *65* (9), 2757-2783, doi: 10.1175/2007jas2546.1.

Polenske, K. R., and F. C. McMichael (2002), A Chinese cokemaking process-flow model for energy and environmental analyses, *Energ. Policy*, *30* (10), 865-883, doi: 10.1016/S0301-4215(01)00147-1.

Polissar, A., P. Hopke, and J. Harris (2001), Source regions for atmospheric aerosol measured at Barrow, Alaska, *Environ. Sci. Technol.*, *35*, 4214-4226.

Polyakov, I. V., G. V. Alekseev, R. V. Bekryaev, U. Bhatt, R. L. Colony, M. A. Johnson, V. P. Karklin, A. P. Makshtas, D. Walsh, and A. V. Yulin (2002), Observationally based assessment of polar amplification of global warming, *Geophys. Res. Lett.*, *29* (18), 1878, doi: 10.1029/2001GL011111.

Pope, C. A., M. Ezzati, and D. W. Dockery (2009), Fine-particulate air pollution and life expectancy in the united states, *N. Engl. J. Med.*, *360* (4), 376-386.

Popovicheva, O., N. M. Persiantseva, N. K. Shonija, P. Demott, K. Köhler, M. Petters, S. Kreidenweis, V. Tishkova, B. Demirdjian, and J. Suzanne (2008), Water interaction with hydrophobic and hydrophilic soot particles, *Phys. Chem. Chem. Phys.*, *10*, 2332-2344, doi: 10.1039/B718944N.

Pósfai, M., J. R. Anderson, P. R. Buseck, and H. Sievering (1999), Soot and sulfate particles in the remote marine troposphere, *J. Geophys. Res.*, *104* (D17), 21685-21693.

Pósfai, M., R. Simonics, J. Li, P. V. Hobbs, and P. R. Buseck (2003), Individual aerosol particles from biomass burning in southern Africa: 1. Compositions and size distributions of carbonaceous particles, *J. Geophys. Res.*, *108* (D13), 8483, doi: 10.1029/2002JD002291.

Power, M. J., J. Marlon, N. Ortiz, P. J. Bartlein, S. P. Harrison, F. E. Mayle, A. Ballouche, R. H. W. Bradshaw, C. Carcaillet, C. Cordova, S. Mooney, P. I. Moreno, I. C. Prentice, K. Thonicke, W. Tinner, C. Whitlock, Y. Zhang, Y. Zhao, A. A. Ali, R. S. Anderson, R. Beer, H. Behling, C. Briles, K. J. Brown, A. Brunelle, M. Bush, P. Camill, G. Q. Chu, J. Clark, D. Colombaroli, S. Connor, A.-L. Daniau, M. Daniels, J. Dodson, E. Doughty, M. E. Edwards, W. Finsinger, D. Foster, J. Frechette, M.-J. Gaillard, D. G. Gavin, E. Gobet, S. Haberle, D. J. Hallett, P. Higuera, G. Hope, S. Horn, J. Inoue, P. Kaltenrieder, L. Kennedy, Z. C. Kong, C. Larsen, C. J. Long, J. Lynch, E. A. Lynch, M. McGlone, S. Meeks, S. Mensing, G. Meyer, T. Minckley, J. Mohr, D. M. Nelson, J. New, R. Newnham, R. Noti, W. Oswald, J. Pierce, P. J. H. Richard, C. Rowe, M. F. S. Goni, B. N. Shuman, H. Takahara, J. Toney, C. Turney, D. H. Urrego-Sanchez, C. Umbanhowar, M. Vandergoes, B. Vanniere, E. Vescovi, M. Walsh, X. Wang, N. Williams, J. Wilmshurst, and J. H. Zhang (2008), Changes in fire regimes since the Last Glacial Maximum: An assessment based on a global synthesis and analysis of charcoal data, *Climate Dyn.*, *30*, 887-907, doi: 10.1007/s00382-007-0334-x.

Pratt, K. A., P. J. DeMott, J. R. French, Z. Wang, D. L. Westphal, A. J. Heymsfield, C. H. Twohy, A. J. Prenni, and K. A. Prather (2009), In situ detection of biological particles in cloud ice-crystals, *Nature Geosci.*, *2* (6), 397-400, doi: 10.1038/ngeo521.

Prenni, A. J., P. J. Demott, D. C. Rogers, S. M. Kreidenweis, G. M. McFarquhar, G. Zhang, and M. R. Poellot (2009), Ice nuclei

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

characteristics from M-PACE and their relation to ice formation in clouds, *Tellus B*, *61* (2), 436-448, doi: 10.1111/j.1600-0889.2009.00415.x.

Pruppacher, H. R., and J. D. Klett (1997), *Microphysics of clouds and precipitation*, 954 pp., Kluwer Academic Publishers, Dordrecht, The Netherlands.

Puxbaum, H., A. Caseiro, A. Sanchez-Ochoa, A. Kasper-Giebl, M. Claeys, A. Gelencser, M. Legrand, S. Preunkert, and C. Pio (2007), Levoglucosan levels at background sites in Europe for assessing the impact of biomass combustion on the European aerosol background, *J. Geophys. Res.*, *112,* D23s05, doi: 10.1029/2006JD008114.

Qian, Y., W. I. Gustafson, L. R. Leung, and S. J. Ghan (2009), Effects of soot-induced snow albedo change on snowpack and hydrological cycle in western United States based on Weather Research and Forecasting chemistry and regional climate simulations, *J. Geophys. Res.*, *114* (D03), 108, doi: 10.1029/2008JD011039.

Qian, Y., M. G. Flanner, L. R. Leung, and W. Wang (2011), Sensitivity studies of the impacts of Tibetan Plateau snowpack pollution on the Asian hydrologic cycle and monsoon climate, *Atmos. Chem. Phys.*, *11*, 1929-1948, doi: 10.5194/acp-11-1929-2011.

Quaas, J., Y. Ming, S. Menon, T. Takemura, M. Wang, J. E. Penner, A. Gettelman, U. Lohmann, N. Bellouin, O. Boucher, A. M. Sayer, G. E. Thomas, A. McComiskey, G. Feingold, C. Hoose, J. E. Kristjansson, X. Liu, Y. Balkanski, L. J. Donner, P. A. Ginoux, P. Stier, B. Grandey, J. Feichter, I. Sednev, S. E. Bauer, D. Koch, R. G. Grainger, A. Kirkevag, T. Iversen, O. Seland, R. Easter, S. J. Ghan, P. J. Rasch, H. Morrison, J. F. Lamarque, M. J. Iacono, S. Kinne, and M. Schulz (2009), Aerosol indirect effects - general circulation model intercomparison and evaluation with satellite data, *Atmos. Chem. Phys.*, *9* (22), 8697-8717, doi: 10.5194/acp-9-8697-2009.

Querol, X., J. Pey, M. C. Minguillon, N. Perez, A. Alastuey, M. Viana, T. Moreno, R. M. Bernabe, S. Blanco, B. Cardenas, E. Vega, G. Sosa, S. Escalona, H. Ruiz, and B. Artinano (2008), PM speciation and sources in Mexico during the MILAGRO-2006 Campaign, *Atmos. Chem. Phys.*, *8* (1), 111-128, doi: 10.5194/acp-8-111-2008.

Quinn, P. K., and T. S. Bates (2005), Regional aerosol properties: Comparisons of boundary layer measurements from ACE 1, ACE 2, aerosols99, INDOEX, ACE asia, TARFOX, and NEAQS, *J. Geophys. Res.*, *110* (D14), 202, doi: 10.1029/2004JD004755.

Quinn, P. K., and D. J. Coffman (1998), Local closure during the First Aerosol Characterization Experiment (ACE1): Aerosol mass concentration and scattering and backscattering coefficients, *J. Geophys. Res.*, *103* (D13), 16575-16596.

Quinn, P. K., T. S. Bates, E. Baum, N. Doubleday, A. M. Fiore, M. Flanner, A. Fridlind, T. J. Garrett, D. Koch, S. Menon, D. Shindell, A. Stohl, and S. G. Warren (2008), Short-lived pollutants in the Arctic: Their climate impact and possible mitigation strategies, *Atmos. Chem. Phys.*, *8*, 1723-1725.

Quinn, P. K., A. Stohl, A. Arneth, T. Berntsen, J. F. Burkhart, J. Christensen, M. Flanner, K. Kupiainen, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng (2011), The impact of black carbon on Arctic Climate, 128 pp., Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Raes, F., T. Bates, F. McGovern, and M. Van Liedekerke (2000), The 2nd aerosol characterization experiment (ACE-2): General overview and main results, *Tellus B*, *52* (2), 111-125.

Ram, K., M. M. Sarin, and P. Hegde (2010), Long-term record of aerosol optical properties and chemical composition from a high-altitude site (Manora Peak) in Central Himalaya, *Atmos. Chem. Phys.*, *10* (23), 11791-11803, doi: 10.5194/acp-10-11791-2010.

Ramachandran, G., and P. C. Reist (1995), Characterization of morphological changes in agglomerates subject to condensation and evaporation using multiple fractal dimensions, *Aerosol Sci. Technol., 23*, 431-442.

Ramana, M. V., and V. Ramanathan (2006), Abrupt transition from natural to anthropogenic aerosol radiative forcing: Observations at the ABC-Maldives Climate Observatory, *J. Geophys. Res.*, *111* (D20), doi: 10.1029/2006JD007063.

Ramanathan, V., and G. Carmichael (2008), Global and regional climate changes due to black carbon, *Nature Geosci.*, *1* (4), 221-227, doi: 10.1038/ngeo156.

Ramanathan, V., P. J. Crutzen, J. Lelieveld, A. P. Mitra, D. Althausen, J. Anderson, M. O. Andreae, W. Cantrell, G. R. Cass, C. E. Chung, A. D. Clarke, J. A. Coakley, W. D. Collins, W. C. Conant, F. Dulac, J. Heintzenberg, A. J. Heymsfield, B. Holben, S. Howell, J. Hudson, A. Jayaraman, J. T. Kiehl, T. N. Krishnamurti, D. Lubin, G. McFarquhar, T. Novakov, J. A. Ogren, I. A. Podgorny, K. Prather, K.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Priestley, J. M. Prospero, P. K. Quinn, K. Rajeev, P. Rasch, S. Rupert, R. Sadourny, S. K. Satheesh, G. E. Shaw, P. Sheridan, and F. P. J. Valero (2001a), Indian ocean experiment: An integrated analysis of the climate forcing and effects of the great Indo-Asian haze, *J. Geophys. Res.*, *106* (D22), 28371-28398, doi: 10.1029/2001JD900133.

Ramanathan, V., P. J. Crutzen, J. T. Kiehl, and D. Rosenfeld (2001b), Atmosphere - Aerosols, climate, and the hydrological cycle, *Science*, *294* (5549), 2119-2124.

Ramanathan, V., C. Chung, D. Kim, T. Bettge, L. Buja, J. T. Kiehl, W. M. Washington, Q. Fu, D. R. Sikka, and M. Wild (2005), Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle, *P. Natl. Acad. Sci. USA*, *102* (15), 5326-5333, doi: 10.1073/pnas.0500656102.

Ramanathan, V., F. Li, M. V. Ramana, P. S. Praveen, D. Kim, C. E. Corrigan, H. Nguyen, E. A. Stone, J. J. Schauer, G. R. Carmichael, B. Adhikary, and S. C. Yoon (2007), Atmospheric brown clouds: Hemispherical and regional variations in long-range transport, absorption, and radiative forcing, *J. Geophys. Res.*, *112,* D22S21, doi: 10.1029/2006JD008124.

Ramanathan, V., and Y. Y. Xu (2010), The Copenhagen Accord for limiting global warming: Criteria, constraints, and available avenues, *P. Natl. Acad. Sci. USA*, *107* (18), 8055-8062, doi: doi:10.1073/pnas.1002293107.

Randles, C. A., and V. Ramaswamy (2008), Absorbing aerosols over Asia: A Geophysical Fluid Dynamics Laboratory general circulation model sensitivity study of model response to aerosol optical depth and aerosol absorption, *J. Geophys. Res.*, *113* (D21), 203, doi: 10.1029/2008JD010140.

Rasch, P. J., J. Feichter, K. Law, N. Mahowald, J. Penner, C. Benkovitz, C. Genthon, C. Giannakopoulos, P. Kasibhatla, D. Koch, H. Levy, T. Maki, M. Prather, D. L. Roberts, G.-J. Roelofs, D. Stevenson, Z. Stockwell, S. Taguchi, M. Kritz, M. Chipperfield, D. Baldocchi, P. McMurry, L. Barrie, Y. Balkanski, R. Chatfield, E. Kjellstrom, M. Lawrence, H. N. Lee, J. Lelieveld, K. J. Noone, J. Seinfeld, G. Stenchikov, S. Schwartz, C. Walcek, and D. Williamson (2000), A comparison of scavenging and deposition processes in global models: Results from the WCRP Cambridge Workshop of 1995, *Tellus*, *52B*, 1025-1056.

Rasch, P. J., W. D. Collins, and B. E. Eaton (2001), Understanding the Indian Ocean Experiment (INDOEX) aerosol distributions with an aerosol assimilation, *J. Geophys. Res.*, *106* (D7), 7337-7355.

Rau, J. A. (1989), Composition and size distribution of residential wood smoke particles, *Aerosol Sci. Technol.*, *10* (1), 181-192, doi: 10.1080/02786828908959233.

RCP Database (2009), Representative Concentration Pathways (RCP) Database (Version 2.0), International Institute for Applied Systems Analysis (IIASA), http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=about., edited.

Reddy, M. S., and O. Boucher (2007), Climate impact of black carbon emitted from energy consumption in the world's regions, *Geophys. Res. Lett.*, *34*, L11802, doi: 10.1029/2006GL028904.

Reddy, M. S., and C. Venkataraman (2002a), Inventory of aerosol and sulphur dioxide emissions from India: Part I - fossil fuel combustion, *Atmos. Environ.*, *36*, 677-697.

Reddy, M. S., and C. Venkataraman (2002b), Inventory of aerosol and sulphur dioxide emissions from India, Part II - biomass combustion, *Atmos. Environ.*, *36* (4), 699-712, doi: 10.1016.S1352-2310(01)00464-2.

Reddy, M. S., O. Boucher, N. Bellouin, M. Schulz, Y. Balkanski, J. L. Dufresne, and M. Pham (2005a), Estimates of global multicomponent aerosol optical depth and direct radiative perturbation in the Laboratoire de Meteorologie Dynamique general circulation model, *J. Geophys. Res.*, *110,* D10s16, doi: 10.1029/2004jd004757.

Reddy, M. S., O. Boucher, Y. Balkanski, and M. Schulz (2005b), Aerosol optical depths and direct radiative perturbations by species and source type, *Geophys. Res. Lett.*, *32* (12), 803, doi: 10.1029/2004GL021743.

Redemann, J., R. P. Turco, K. N. Liou, P. B. Russell, R. W. Bergstrom, B. Schmid, J. M. Livingston, P. V. Hobbs, W. S. Hartley, S. Ismail, R. A. Ferrare, and E. V. Browell (2000), Retrieving the vertical structure of the effective aerosol complex index of refraction from a combination of aerosol in situ and remote sensing measurements during TARFOX, *J. Geophys. Res.*, *105* (D8), 9949-9970.

Reff, A., P. V. Bhave, H. Simon, T. G. Pace, G. A. Pouliot, J. D. Mobley, and M. Houyoux (2009), Emissions inventory of $PM_{2.5}$ trace elements across the United States, *Environ. Sci. Technol.*, *43* (15), 5790-5796, doi: 10.1021/es802930x.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Reid, J. S., P. V. Hobbs, C. Liousse, J. v. Martins, R. E. Weiss, and T. F. Eck (1998), Comparisons of techniques for measuring shortwave absorption and black carbon content of aerosols from biomass burning in Brazil, *J. Geophys. Res.*, *103* (D24), 32031-32040.

Reid, J. S., R. Koppmann, T. F. Eck, and D. P. Eleuterio (2005), A review of biomass burning emissions part II: Intensive physical properties of biomass burning particles, *Atmos. Chem. Phys.*, *5*, 799-825, doi: 10.5194/acp-5-799-2005.

Reid, J. S., E. J. Hyer, E. M. Prins, D. L. Westphal, J. L. Zhang, J. Wang, S. A. Christopher, C. A. Curtis, C. C. Schmidt, D. P. Eleuterio, K. A. Richardson, and J. P. Hoffman (2009), Global monitoring and forecasting of biomass-burning smoke: Description of and lessons from the fire locating and modeling of burning emissions (FLAMBE) program, *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.*, *2* (3), 144-162, doi: 10.1109/jstars.2009.2027443.

Remer, L. A., Y. J. Kaufman, D. Tanre, S. Mattoo, D. A. Chu, J. V. Martins, R. R. Li, C. Ichoku, R. C. Levy, R. G. Kleidman, T. F. Eck, E. Vermote, and B. N. Holben (2005), The MODIS aerosol algorithm, products, and validation, *J. Atmos. Sci.*, *62* (4), 947-973.

Remer, L. A., R. G. Kleidman, R. C. Levy, Y. J. Kaufman, D. Tanre, S. Mattoo, J. V. Martins, C. Ichoku, I. Koren, H. B. Yu, and B. N. Holben (2008), Global aerosol climatology from the MODIS satellite sensors, *J. Geophys. Res.*, *113,* D14S07, doi: 10.1029/2007JD009661.

Richardson, M. S., P. J. DeMott, S. M. Kreidenweis, D. J. Cziczo, E. J. Dunlea, J. L. Jimenez, D. S. Thomson, L. L. Ashbaugh, R. D. Borys, D. L. Westphal, G. S. Casuccio, and T. L. Lersch (2007), Measurements of heterogeneous ice nuclei in the western United States in springtime and their relation to aerosol characteristics, *J. Geophys. Res.*, *112* (D2), 209, doi: 10.1029/2006JD007500.

Riddle, S. G., M. A. Robert, C. A. Jakober, M. P. Hannigan, and M. J. Kleeman (2008), Size-resolved source apportionment of airborne particle mass in a roadside environment, *Environ. Sci. Technol., 42* (17), 6580-6586.

Riemer, N., M. West, R. A. Zaveri, and R. C. Easter (2009), Simulating the evolution of soot mixing state with a particle-resolved aerosol model, *J. Geophys. Res.*, *114* (D9), 202, doi: 10.1029/2008JD011073.

Roberts, D. L., and A. Jones (2004), Climate sensitivity to black carbon aerosol from fossil fuel combustion, *J. Geophys. Res.*, *109* (D16), 202, doi: 10.1029/2004JD004676.

Robinson, A. L., N. M. Donahue, M. K. Shrivastava, E. A. Weitkamp, A. M. Sage, A. P. Grieshop, T. E. Lane, J. R. Pierce, and S. N. Pandis (2007), Rethinking organic aerosols: Semivolatile emissions and photochemical aging, *Science*, *315*, 1259-1262, doi: 10.1126/science.1133061.

Roden, C. A., T. C. Bond, S. Conway, A. B. S. Pinel, N. MacCarty, and D. Still (2009), Laboratory and field investigations of particulate and carbon monoxide emissions from traditional and improved cookstoves, *Atmos. Environ.*, *43* (6), 1170-1181, doi: 10.1016/j.atmosenv.2008.05.041.

Rodhe, H., O. Akesson, and C. Persson (1972), An investigation into regional transport of soot and sulfate aerosols, *Atmos. Environ.*, *6* (9), 675-693, doi: 10.1016/0004-6981(72)90025-x.

Roeckner, E., P. Stier, J. Feichter, S. Kloster, M. Esch, and I. Fischer-Bruns (2006), Impact of carbonaceous aerosol emissions on regional climate change, *Climate Dyn.*, *27* (6), 553-571, doi: 10.1007/s00382-006-0147-3.

Rogers, D. C., P. J. DeMott, S. M. Kreidenweis, and Y. L. Chen (1998), Measurements of ice nucleating aerosols during SUCCESS, *Geophys. Res. Lett.*, *25* (9), 1383-1386.

Rose, D., S. S. Gunthe, H. Su, R. M. Garland, H. Yang, M. Berghof, Y. F. Cheng, B. Wehner, P. Achtert, A. Nowak, A. Wiedensohler, N. Takegawa, Y. Kondo, M. Hu, Y. Zhang, M. O. Andreae, and U. Poschl (2011), Cloud condensation nuclei in polluted air and biomass burning smoke near the mega-city Guangzhou, China -Part 2: Size-resolved aerosol chemical composition, diurnal cycles, and externally mixed weakly CCN-active soot particles, *Atmos. Chem. Phys., 11 (6)*, 2817-2836, doi: 10.5194/acp-11-2817-2011.

Rosen, H., A. D. A. Hansen, L. Gundel, and T. Novakov (1978), Identification of the optically absorbing component in urban aerosols, *Appl. Opt.*, *17* (24), 3859-3861.

Rosen, H., A. D. A. Hansen, L. Gundel, and T. Novakov (1979), Identification of the graphitic carbon component of source and ambient particulates by Raman spectroscopy and an optical attenuation technique, in *Carbonaceous Particles in the Atmosphere*, pp. 229-232, Lawrence Berkeley Laboratory, Berkeley, CA.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Rosen, H., A. D. A. Hansen, and T. Novakov (1984), Role of graphitic carbon particles in radiative transfer in the Arctic haze, *Sci. Total Environ.*, *36* (JUN), 103-110.

Rotstayn, L. D., W. J. Cai, M. R. Dix, G. D. Farquhar, Y. Feng, P. Ginoux, M. Herzog, A. Ito, J. E. Penner, M. L. Roderick, and M. H. Wang (2007), Have Australian rainfall and cloudiness increased due to the remote effects of Asian anthropogenic aerosols?, *J. Geophys. Res.*, *112* (D9), 202, doi: 10.1029/2006JD007712.

Rotstayn, L. D., M. D. Keywood, B. W. Forgan, A. J. Gabric, I. E. Galbally, J. L. Gras, A. K. Luhar, G. H. McTainsh, R. M. Mitchell, and S. A. Young (2009), Possible impacts of anthropogenic and natural aerosols on Australian climate: A review, *Int. J. Climatol.*, *29*, 461-479, doi: 10.1002/joc.1729.

Roy, D. P., P. E. Lewis, and C. O. Justice (2002), Burned area mapping using multi-temporal moderate spatial resolution data - a bi-directional reflectance model-based expectation approach, *Remote Sens. Environ.*, *83* (1-2), 263-286.

Ruckstuhl, C., J. R. Norris, and R. Philipona (2010), Is there evidence for an aerosol indirect effect during the recent aerosol optical depth decline in Europe?, *J. Geophys. Res.*, *115*, D04204, doi: 10.1029/2009JD012867.

Russell, L. (2003), Aerosol organic-mass-to-organic-carbon ratios, *Environ. Sci. Technol.*, *37*, 2982-2987.

Russell, P. B., P. V. Hobbs, and L. L. Stowe (1999), Aerosol properties and radiative effects in the United States East Coast haze plume: An overview of the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX), *J. Geophys. Res.*, *104* (D2), 2213-2222.

Russell, P. B., R. W. Bergstrom, Y. Shinozuka, A. D. Clarke, P. F. DeCarlo, J. L. Jimenez, J. M. Livingston, J. Redemann, O. Dubovik, and A. Strawa (2010), Absorption Angstrom Exponent in AERONET and related data as an indicator of aerosol composition, *Atmos. Chem. Phys.*, *10* (3), 1155-1169, doi: 10.5194/acp-10-1155-2010.

Rypdal, K., F. Stordal, J. S. Fuglestvedt, and T. Berntsen (2005), Introducing top-down methods in assessing compliance with the Kyoto Protocol, *Climate Policy*, *5 (4)*, 393-405.

Rypdal, K., N. Rive, T. K. Berntsen, Z. Klimont, T. K. Mideksa, G. Myhre, and R. B. Skeie (2009a), Costs and global impacts of black carbon abatement strategies, *Tellus B*, *61* (4), 625-641, doi: 10.1111/j.1600-0889.2009.00430.x.

Rypdal, K., N. Rive, T. Berntsen, H. Fagerli, Z. Klimont, T. K. Mideksa, and J. S. Fuglestvedt (2009b), Climate and air quality-driven scenarios of ozone and aerosol precursor abatement, *Environ. Sci. Policy*, *12* (7), 855-869, doi: 10.1016/j.envsci.2009.08.002.

Sahu, S. K., G. Beig, and C. Sharma (2008), Decadal growth of black carbon emissions in India, *Geophys. Res. Lett.*, *35* (2), doi: 10.1029/2007GL032333.

Sakurai, H., K. Park, P. H. McMurry, D. D. Zarling, D. B. Kittelson, and P. J. Ziemann (2003), Size-dependent mixing characteristics of volatile and nonvolatile components in diesel exhaust aerosols, *Environ. Sci. Technol.*, *37*, 5487-5495.

Salam, A., H. Bauer, K. Kassin, S. M. Ullah, and H. Puxbaum (2003), Aerosol chemical characteristics of a mega-city in Southeast Asia (Dhaka-Bangladesh), *Atmos. Environ.*, *37* (18), 2517-2528, doi: 10.1016/s1352-2310(03)00135-3.

Samset, B. H., and G. Myhre (2011), Vertical dependence of black carbon, sulphate and biomass burning aerosol radiative forcing, *Geophys. Res. Lett.*, *38*, L24802, doi: 10.1029/2011GL049697.

Sandu, I., J. L. Brenguier, O. Geoffroy, O. Thouron, and V. Masson (2008), Aerosol impacts on the diurnal cycle of marine stratocumulus, *J. Atmos. Sci.*, *65* (8), 2705-2718, doi: 10.1175/2008jas2451.1.

Sarofim, M., B. DeAngelo, R. Beach, K. Weitz, M. Bahner, and A. Zapata (2010), Marginal abatement curves for U.S. black carbon emissions, *J. Integr. Environ. Sci.*, *7* (S1), 279-288, doi: 10.1080/19438151003774455.

Satheesh, S. K., and V. Ramanathan (2000), Large differences in tropical aerosol forcing at the top of the atmosphere and Earth's surface, *Nature*, *405*, 60-63, doi: 10.1038/35011039.

Sato, M., J. Hansen, D. Koch, A. Lacis, R. Ruedy, O. Dubovik, B. Holben, M. Chin, and T. Novakov (2003), Global atmospheric black carbon inferred from AERONET, *P. Natl. Acad. Sci. USA*, *100* (11), 6319-6324, doi: 10.1073/pnas.0731897100.

Schauer, J. J., W. F. Rogge, L. M. Hildemann, M. A. Mazurek, and G. R. Cass (1996), Source apportionment of airborne particulate matter using organic compounds as tracers, *Atmos. Environ.*, *30* (22), 3837-3855.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Schmid, B., J. Redemann, P. B. Russell, P. V. Hobbs, D. L. Hlavka, M. J. McGill, B. N. Holben, E. J. Welton, J. R. Campbell, O. Torres, R. A. Kahn, D. J. Diner, M. C. Helmlinger, D. A. Chu, C. Robles-Gonzalez, and G. de Leeuw (2003), Coordinated airborne, spaceborne, and ground-based measurements of massive thick aerosol layers during the dry season in southern Africa, *J. Geophys. Res.*, *108* (D13), 8496, doi: 10.1029/2002JD002297.

Schmid, H., L. Laskus, H. J. Abraham, U. Baltensperger, V. Lavanchy, M. Bizjak, P. Burba, H. Cachier, D. Crow, J. Chow, T. Gnauk, A. Even, H. M. t. Brink, K.-P. Giesen, R. Hitzenberger, C. Huegelin, W. Maenhaut, C. Pio, A. Carvalho, J.-P. Putaud, D. Toom-Sauntry, and H. Puxbaum (2001), Results of the "carbon conference" international aerosol carbon round robin test stage I, *Atmos. Environ.*, *35*, 2111-2121.

Schnaiter, M., H. Horvath, O. Möhler, K.-H. Naumann, H. Saathoff, and O. Schock (2003), UV-VIS-NIR spectral optical properties of soot and soot-containing aerosols, *J. Aerosol Sci.*, *34*, 1421-1444, doi: 10.1016/S0021-8502(03)00361-6.

Schnaiter, M., C. Linke, O. Möhler, K.-H. Naumann, H. Saathoff, R. Wagner, U. Schurath, and B. Wehner (2005), Absorption amplification of black carbon internally mixed with secondary organic aerosol, *J. Geophys. Res.*, *110* (D19), 204, doi: 10.1029/2005JD006046.

Schröder, F. P., B. Karcher, A. Petzold, R. Baumann, R. Busen, C. Hoell, and U. Schumann (1998), Ultrafine aerosol particles in aircraft plumes: In situ observations, *Geophys. Res. Lett.*, *25* (15), 2789-2792.

Schrooten, L., I. De Vlieger, F. Lefebre, and R. Torfs (2006), Costs and benefits of an enhanced reduction policy of particulate matter exhaust emissions from road traffic in Flanders, *Atmos. Environ.*, *40* (5), 904-912, doi: 10.1016/j.atmosenv.2005.10.013.

Schultz, M. G., A. Heil, J. J. Hoelzemann, A. Spessa, K. Thonicke, J. G. Goldammer, A. C. Held, J. M. C. Pereira, and M. van het Bolscher (2008), Global wildland fire emissions from 1960 to 2000, *Global Biogeochem. Cycles*, *22* (2), doi: 10.1029/2007GB003031.

Schultz, M. G., and M. Wooster (2008), Evaluation of a fire radiative power product derived from METEOSAT 8/9 and identification of operational user needs, FREEVAL final report, Band/Volume 23, Darmstadt, Germany.

Schulz, M., C. Textor, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, F. Dentener, S. Guibert, I. S. A. Isaksen, T. Iversen, D. Koch, A. Kirkevag, X. Liu, V. Montanaro, G. Myhre, J. E. Penner, G. Pitari, S. Reddy, O. Seland, P. Stier, and T. Takemura (2006), Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations, *Atmos. Chem. Phys.*, *6*, 5225-5246, doi: 10.5194/acp-6-5225-2006.

Schuster, G. L., O. Dubovik, B. N. Holben, and E. E. Clothiaux (2005), Inferring black carbon content and specific absorption from Aerosol Robotic Network (AERONET) aerosol retrievals, *J. Geophys. Res.*, *110*, D10S17, doi: 10.1029/2004JD004548.

Schuster, G. L., B. Lin, and O. Dubovik (2009), Remote sensing of aerosol water uptake, *Geophys. Res. Lett.*, *36* (L03), 814, doi: 10.1029/2008GL036576.

Schwarz, J. P., R. S. Gao, D. W. Fahey, D. S. Thomson, L. A. Watts, J. C. Wilson, J. M. Reeves, M. Darbeheshti, D. G. Baumgardner, G. L. Kok, S. H. Chung, M. Schulz, J. Hendricks, A. Lauer, B. Karcher, J. G. Slowik, K. H. Rosenlof, T. L. Thompson, A. O. Langford, M. Loewenstein, and K. C. Aikin (2006), Single-particle measurements of midlatitude black carbon and light-scattering aerosols from the boundary layer to the lower stratosphere, *J. Geophys. Res.*, *111* (D16), 207, doi: 10.1029/2006JD007076.

Schwarz, J. P., J. R. Spackman, D. W. Fahey, R. S. Gao, U. Lohmann, P. Stier, L. A. Watts, D. S. Thomson, D. A. Lack, L. Pfister, M. J. Mahoney, D. Baumgardner, J. C. Wilson, and J. M. Reeves (2008a), Coatings and their enhancement of black carbon light absorption in the tropical atmosphere, *J. Geophys. Res.*, *113* (D3), 203, doi: 10.1029/2007JD009042.

Schwarz, J. P., R. S. Gao, J. R. Spackman, L. A. Watts, D. S. Thomson, D. W. Fahey, T. B. Ryerson, J. Peischl, J. S. Holloway, M. Trainer, G. J. Frost, T. Baynard, D. A. Lack, J. A. de Gouw, C. Warneke, and L. A. Del Negro (2008b), Measurement of the mixing state, mass, and optical size of individual black carbon particles in urban and biomass burning emissions, *Geophys. Res. Lett.*, *35* (13), 810, doi: 10.1029/2008GL033968.

Schwarz, J. P., J. R. Spackman, R. S. Gao, L. A. Watts, P. Stier, M. Schulz, S. M. Davis, S. C. Wofsy, and D. W. Fahey (2010), Global-scale black carbon profiles observed in the remote atmosphere and compared to models, *Geophys. Res. Lett.*, *37* (L18), 812, doi: 10.1029/2010GL044372.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Sedlacek, A. J., E. R. Lewis, L. Kleinman, J. Xu, and Q. Zhang (2012), Determination of and evidence for non-core-shell structure of particles containing black carbon using the Single-Particle Soot Photmeter (SP2), *Geophys. Res. Lett.*, *39*, doi: 10.1029/2012GL050905.

Seifert, P., A. Ansmann, D. Mueller, U. Wandinger, D. Althausen, A. J. Heymsfield, S. T. Massie, and C. Schmitt (2007), Cirrus optical properties observed with lidar, radiosonde, and satellite over the tropical Indian Ocean during the aerosol-polluted northeast and clean maritime southwest monsoon, *J. Geophys. Res.*, *112* (D17), 205, doi: 10.1029/2006JD008352.

Shah, S. D., D. R. Cocker, J. W. Miller, and J. M. Norbeck (2004), Emission rates of particulate matter and elemental and organic carbon from in-use diesel engines, *Environ. Sci. Technol.*, *38*, 2544-2550.

Shah, S. D., D. R. Cocker, K. C. Johnson, J. M. Lee, B. L. Soriano, and J. W. Miller (2007), Reduction of particulate matter emissions from diesel backup generators equipped with four different exhaust aftertreatment devices, *Environ. Sci. Technol.*, *41* (14), 5070-5076, doi: 10.1021/es0614161.

Sharma, S., J. R. Brook, H. Cachier, J. Chow, A. Gaudenzi, and G. Lu (2002), Light absorption and thermal measurements of black carbon in different regions of Canada, *J. Geophys. Res.*, *107* (D24), 4771, doi: 10.1029/2002JD002496.

Sharma, S., E. Andrews, L. A. Barrie, J. A. Ogren, and D. Lavoué (2006a), Variations and sources of the equivalent black carbon in the high Arctic revealed by long-term observations at Alert and Barrow: 1989-2003, *J. Geophys. Res.*, *111*, D14208, doi: 10.1029/2005JD006581.

Sharma, S., E. Andrews, L. A. Barrie, J. A. Ogren, and D. Lavoué (2006b), Variations and sources of the equivalent black carbon in the high Arctic revealed by long-term observations at Alert and Barrow: 1989-2003, *J. Geophys. Res.*, *111,* D14208, doi: 10.1029/2005JD006581.

Shaw, R. A., A. J. Durant, and Y. Mi (2005), Heterogeneous surface crystallization observed in undercooled water, *J. Phys. Chem. B*, *109* (20), 9865-9868, doi: 10.1021/jp0506336.

Shea, R. W., B. W. Shea, J. B. Kauffman, D. E. Ward, C. I. Haskins, and M. C. Scholes (1996), Fuel biomass and combustion factors associated with fires in savanna ecosystems of South Africa and Zambia, *J. Geophys. Res.*, *101* (D19), 23551-23568, doi: 10.1029/95JD02047.

Sheesley, R. J., J. J. Schauer, and M. L. Orf (2010), Assessing the impact of industrial source emissions on atmospheric carbonaceous aerosol concentrations using routine monitoring networks, *J. Air Waste Manage. Assoc.*, *60* (2), 149-155, doi: 10.3155/1047-3289.60.2.149.

Sheridan, P. J., and J. A. Ogren (1999), Observations of the vertical and regional variability of aerosol optical properties over central and eastern North America, *J. Geophys. Res.*, *104* (D14), 16793-16805.

Shindell, D., and G. Faluvegi (2009), Climate response to regional radiative forcing during the twentieth century, *Nature Geosci.*, *2* (4), 294-300, doi: 10.1038/ngeo473.

Shindell, D. T., G. Faluvegi, N. Bell, and G. A. Schmidt (2005), An emissions-based view of climate forcing by methane and tropospheric ozone, *Geophys. Res. Lett.*, *32*, L04803.

Shindell, D. T., M. Chin, F. Dentener, R. M. Doherty, G. Faluvegi, A. M. Fiore, P. Hess, D. M. Koch, I. A. MacKenzie, M. G. Sanderson, M. G. Schultz, M. Schulz, D. S. Stevenson, H. Teich, C. Textor, O. Wild, D. J. Bergmann, I. Bey, H. Bian, C. Cuvelier, B. N. Duncan, G. Folberth, L. W. Horowitz, J. Jonson, J. W. Kaminski, E. Marmer, R. Park, K. J. Pringle, S. Schroeder, S. Szopa, T. Takemura, G. Zeng, T. J. Keating, and A. Zuber (2008), A multi-model assessment of pollution transport to the Arctic, *Atmos. Chem. Phys.*, *8* (17), 5353-5372, doi: 10.5194/acp-8-5353-2008.

Shindell, D., M. Schulz, Y. Ming, T. Takemura, G. Faluvegi, and V. Ramaswamy (2010), Spatial scales of climate response to inhomogeneous radiative forcing, *J. Geophys. Res.*, *115,* D19110, doi: 10.1029/2010jd014108.

Shindell, D., G. Faluvegi, M. Walsh, S. C. Anenberg, R. V. Dingenen, N. Z. Muller, J. Austin, D. Koch, and G. Milly (2011), Climate, health, agricultural and economic impacts of tighter vehicle-emission standards, *Nature Climate Change*, *1*, 59-66, doi: 10.1038/nclimate1066.

Shindell, D., J. C. I. Kuylenstierna, E. Vignati, R. van Dingenen, M. Amann, Z. Klimont, S. C. Anenberg, N. Muller, G. Janssens-

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Maenhout, F. Raes, J. Schwartz, G. Faluvegi, L. Pozzoli, K. Kupiainen, L. Höglund-Isaksson, L. Emberson, D. Streets, V. Ramanathan, K. Hicks, N. T. K. Oanh, G. Milly, M. Williams, V. Demkine, and D. Fowler (2012), Simultaneously mitigating near-term climate change and improving human health and food security, *Science*, *335* (6065), 183-189, doi: 10.1126/science.1210026.

Shine, K. P., J. Cook, E. J. Highwood, and M. M. Joshi (2003), An alternative to radiative forcing for estimating the relative importance of climate change mechanisms, *Geophys. Res. Lett.*, *30* (20), 2047, doi: 10.1029/2003GL018141.

Shine, K. P., J. S. Fuglestvedt, K. Hailemariam, and N. Stuber (2005), Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases, *Climatic Change*, *68*, 281-302.

Shine, K. P., T. K. Berntsen, J. S. Fuglestvedt, R. B. Skeie, and N. Stuber (2007), Comparing the climate effect of emissions of short- and long-lived climate agents, *Philos. Trans. R. Soc. A-Math. Phys. Eng. Sci.*, *365* (1856), 1903-1914, doi: 10.1098/rsta.2007.2050.

Shiraiwa, M., Y. Kondo, N. Moteki, N. Takegawa, Y. Miyazaki, and D. R. Blake (2007), Evolution of mixing state of black carbon in polluted air from Tokyo, *Geophys. Res. Lett.*, *34*, L16803, doi: 10.1029/2007GL029819.

Shiraiwa, M., Y. Kondo, N. Moteki, N. Takegawa, L. K. Sahu, A. Takami, S. Hatakeyama, S. Yonemura, and D. R. Blake (2008), Radiative impact of mixing state of black carbon aerosol in Asian outflow, *J. Geophys. Res.*, *113*, D24210, doi: 10.1029/2008JD010546.

Shiraiwa, M., Y. Kondo, T. Iwamoto, and K. Kita (2010), Amplification of light absorption of black carbon by organic coating, *Aerosol Sci. Technol.*, *44* (1), 46-54, doi: 10.1080/02786820903357686.

Simon, M., S. Plummer, F. Fierens, J. J. Hoelzemann, and O. Arino (2004), Burnt area detection at global scale using ATSR-2: The GLOBSCAR products and their qualification, *J. Geophys. Res.*, *109* (D14), doi: 10.1029/2003JD003622.

Sinton, J. E., K. R. Smith, J. W. Peabody, L. Yaping, Z. Xiliang, R. Edwards, and G. Quan (2004), An assessment of programs to promote improved household stoves in China, *Energy for Sustainable Development*, *8* (3), 33-52.

Skeie, R. B., T. Berntsen, G. Myhre, C. A. Pedersen, J. Ström, S. Gerland, and J. A. Ogren (2011), Black carbon in the atmosphere and snow, from pre-industrial times until present, *Atmos. Chem. Phys.*, *11*, 6809-6836, doi: 10.5194/acp-11-6809-2011.

Slowik, J. G., K. Stainken, P. Davidovits, L. R. Williams, J. T. Jayne, C. E. Kolb, D. R. Worsnop, Y. Rudich, P. F. DeCarlo, and J. L. Jimenez (2004), Particle morphology and density characterization by combined mobility and aerodynamic diameter measurements. Part 2: Application to combustion-generated soot aerosols as a function of fuel equivalence ratio, *Aerosol Sci. Technol.*, *38*, 1206-1222.

Slowik, J. G., E. S. Cross, J. H. Han, P. Davidovits, T. B. Onasch, J. T. Jayne, L. R. Williams, M. R. Canagaratna, D. R. Worsnop, R. K. Chakrabarty, H. Moosmüller, W. P. Arnott, J. P. Schwarz, R. S. Gao, D. W. Fahey, G. L. Kok, and A. Petzold (2007), An inter-comparison of instruments measuring black carbon content of soot particles, *Aerosol Sci. Technol.*, *41* (3), 295-314, doi: 10.1080/02786820701197078.

Smith, K. R., R. Uma, V. V. N. Kishore, K. Lata, V. Joshi, J. Zhang, R. A. Rasmussen, and K. A. Khalil (2000a), Greenhouse gases from small-scale combustion devices in developing countries: Household stoves in India, EPA-600/R-00-052, Environmental Protection Agency, Research Triangle Park, NC.

Smith, K. R., R. Uma, V. V. N. Kishore, J. Zhang, V. Joshi, and M. A. K. Khalil (2000b), Greenhouse implications of household stoves: An analysis for India, *Ann. Rev. Energy Environ.*, *25*, 741-763.

Smith, K. R., S. Mehta, and M. Maeusezahl-Feuz (2004), Indoor smoke from household solid fuels, 1435-1493 pp., World Health Organization, Geneva, Switzerland.

Smith, K. R., K. Dutta, C. Chengappa, P. P. S. Gusain, O. Masera, V. Berrueta, R. Edwards, R. Bailis, and K. N. Shields (2007), Monitoring and evaluation of improved biomass cookstove programs for indoor air quality and stove performance: Conclusions from the Household Energy and Health Project, *Energy for Sustainable Development*, *11* (2), 5-18.

Smith, K. R., M. Jerrett, H. R. Anderson, R. T. Burnett, V. Stone, R. Derwent, R. W. Atkinson, A. Cohen, S. B. Shonkoff, D. Krewski, C. A. Pope, M. J. Thun, and G. Thurston (2009), Health and climate change 5 public health benefits of strategies to reduce greenhouse-gas emissions: Health implications of short-lived greenhouse pollutants, *Lancet*, *374* (9707), 2091-2103, doi: 10.1016/s0140-6736(09)61716-5.

Smith, K. R., J. P. McCracken, L. Thompson, R. Edwards, K. N. Shields, E. Canuz, and N. Bruce (2010), Personal child and mother carbon

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

monoxide exposures and kitchen levels: Methods and results from a randomized trial of woodfired chimney cookstoves in Guatemala (RESPIRE), *J. Expo. Sci. Env. Epid.*, *20* (5), 406-416, doi: doi:10.1038/jes.2010.30.

Soden, B. J., and I. M. Held (2006), An assessment of climate feedbacks in coupled ocean-atmosphere models, *J. Climate*, *19* (23), 3354-3360, doi: 10.1175/JCLI3799.1.

Sofiev, M., R. Vankevich, M. Lotjonen, M. Prank, V. Petukhov, T. Ermakova, J. Kosk- inen, and J. Kukkonen (2009), An operational system for the assimilation of the satellite information on wild-land fires for the needs of air quality modelling and forecasting, *Atmos. Chem. Phys.*, *9* (18), 6833-6847, doi:10.5194/acp-9-6833-2009.

Soja, A. J., W. R. Cofer, H. H. Shugart, A. I. Sukhinin, P. W. Stackhouse, D. J. McRae, and S. G. Conard (2004), Estimating fire emissions and disparities in boreal Siberia (1998-2002), *J. Geophys. Res.*, *109,* D14s06, doi: 10.1029/2004JD004570.

Sokolik, I. N., and O. B. Toon (1996), Direct radiative forcing by anthropogenic airborne mineral aerosols, *Nature, 381*, 681-683.

Sokolov, A. P. (2006), Does model sensitivity to changes in CO_2 provide a measure of sensitivity to other forcings?, *J. Climate*, *19*, 3294-3306, doi: 10.1175/JCL13791.1.

Solmon, F., F. Giorgi, and C. Liousse (2006), Aerosol modelling for regional climate studies: Application to anthropogenic particles and evaluation over a European/African domain, *Tellus B*, *58* (1), 51-72, doi: 10.1111/j.1600-0889.2005.00155.x.

Solomon, P. A., W. Chameides, R. Weber, A. Middlebrook, C. S. Kiang, A. G. Russell, A. Butler, B. Turpin, D. Mikel, R. Scheffe, E. Cowling, E. Edgerton, J. St John, J. Jansen, P. McMurry, S. Hering, and T. Bahadori (2003), Overview of the 1999 Atlanta supersite project, *J. Geophys. Res.*, *108* (D7), 8413, doi: 10.1029/2001JD001458.

Song, Y., Y. H. Zhang, S. D. Xie, L. M. Zeng, M. Zheng, L. G. Salmon, M. Shao, and S. Slanina (2006), Source apportionment of $PM_{2.5}$ in Beijing by positive matrix factorization, *Atmos. Environ.*, *40* (8), 1526-1537, doi: 10.1016/j.atmosenv.2005.10.039.

Spracklen, D. V., K. S. Carslaw, U. Poschl, A. Rap, and P. M. Forster (2011), Global cloud condensation nuclei influenced by carbonaceous combustion aerosol, *Atmos. Chem. Phys.*, *11* (17), 9067-9087, doi: 10.5194/acp-11-9067-2011.

Stamnes, K., S. C. Tsay, W. Wiscombe, and K. Jayaweera (1988), Numerically stable algorithm for discrete-ordinate-method radiative-transfer in multiple-scattering and emitting layered media, *Appl. Opt.*, *27*, 2502-2509.

Stavrakou, T., and J. F. Müller (2006), Grid-based versus big region approach for inverting CO emissions using Measurement of Pollution in the Troposphere (MOPITT) data, *J. Geophys. Res.*, *111* (D15), 304, doi: 10.1029/2005JD006896.

Stevens, B., and G. Feingold (2009), Untangling aerosol effects on clouds and precipitation in a buffered system, *Nature*, *461* (7264), 607-613, doi: 10.1038/nature08281.

Stier, P., J. Feichter, S. Kinne, S. Kloster, E. Vignati, J. Wilson, L. Ganzeveld, I. Tegen, M. Werner, Y. Balkanski, M. Schulz, O. Boucher, A. Minikin, and A. Petzold (2005), The aerosol-climate model ECHAM5-HAM, *Atmos. Chem. Phys.*, *5*, 1125-1156.

Stier, P., J. H. Seinfeld, S. Kinne, J. Feichter, and O. Boucher (2006a), Impact of nonabsorbing anthropogenic aerosols on clear-sky atmospheric absorption, *J. Geophys. Res.*, *111* (D18), D18201, doi: 10.1029/2006JD007147.

Stier, P., J. Feichter, S. Kloster, E. Vignati, and J. Wilson (2006b), Emission-induced nonlinearities in the global aerosol system: Results from the ECHAM4-HAM aerosol-climate model, *J. Climate*, *19*, 3845-3862.

Stier, P., J. H. Seinfeld, S. Kinne, and O. Boucher (2007), Aerosol absorption and radiative forcing, *Atmos. Chem. Phys.*, *7*, 5237-5261.

Stith, J. L., V. Ramanathan, W. A. Cooper, G. C. Roberts, P. J. DeMott, G. Carmichael, C. D. Hatch, B. Adhikary, C. H. Twohy, D. C. Rogers, D. Baumgardner, A. J. Prenni, T. Campos, R. Gao, J. Anderson, and Y. Feng (2009), An overview of aircraft observations from the Pacific Dust Experiment campaign, *J. Geophys. Res.*, *114* (D05), 207, doi: 10.1029/2008JD010924.

Stith, J. L., C .H. Twohy, P. J. DeMott, D. Baumgardner, T. Campos, R. Gao, and J. Anderson (2011), 229Observations of ice nuclei and heterogeneous freezing in a Western Pacific extratropical storm, *Atmos. Chem. Phys., 11 (13)*, 6229-6243, doi: 10.5194/acp-11-6229-2011.

Stocks, B. J., J. A. Mason, J. B. Todd, E. M. Bosch, B. M. Wotton, B. D. Amiro, M. D. Flannigan, K. G. Hirsch, K. A. Logan, D. L. Martell, and W. R. Skinner (2002), Large forest fires in Canada, 1959-1997, *J. Geophys. Res.*, *108* (D1), doi: 10.1029/2001JD000484.

Stohl, A. (2006), Characteristics of atmospheric transport into the Arctic troposphere, *J. Geophys. Res.*, *111* (D11), D11306, doi:

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

10.1029/2005JD006888.

Stohl, A., T. Berg, J. F. Burkhart, A. M. Fjéraa, C. Forster, A. Herber, Ø. Hov, C. Lunder, W. W. McMillan, S. Oltmans, M. Sh iobara, D. Simpson, S. Solberg, K. Stebel, J. Ström, K. Tørseth, R. Treffeisen, K. Virkkunen, and K. E. Yttri (2007), Arctic smoke and ash; record high air pollution levels in the European Arctic due to agricultural fires in Eastern Europe in spring 2006, *Atmos. Chem. Phys.*, *7* (2), 511-534, doi: 10.5194/acp-7-511-2007.

Stone, E. A., G. C. Lough, J. J. Schauer, P. S. Praveen, C. E. Corrigan, and V. Ramanathan (2007), Understanding the origin of black carbon in the atmospheric brown cloud over the Indian Ocean, *J. Geophys. Res.*, *112* (D22), D22s23, doi: 10.1029/2006JD008118.

Storelvmo, T. (2012), Uncertainties in aerosol direct and indirect effects attributed to uncertainties in convective transport parameterizations, *Atmos. Res.*, *118*, 357-369, doi: 10.1016/j.atmosres.2012.06.022.

Storelvmo, T., J. E. Kristjansson, and U. Lohmann (2008), Aerosol influence on mixed-phase clouds in CAM-Oslo, *J. Atmos. Sci.*, *65* (10), 3214-3230, doi: 10.1175/2008jas2430.1.

Storelvmo, T., C. Hoose, and P. Eriksson (2011), Global modeling of mixed-phase clouds: The albedo and lifetime effects of aerosols, *J. Geophys. Res.*, *116*, D05207, doi: 10.1029/2010JD014724.

Streets, D. G., and K. Aunan (2005), The importance of China's household sector for the black carbon emissions, *Geophys. Res. Lett.*, *32*, 1-4.

Streets, D. G., K. F. Yarber, J. H. Woo, and G. R. Carmichael (2003a), Biomass burning in Asia: Annual and seasonal estimates and atmospheric emissions, *Global Biogeochem. Cycles*, *17* (4), 1099, doi: 10.1029/2003gb002040.

Streets, D. G., T. C. Bond, G. R. Carmichael, S. D. Fernandes, Q. Fu, D. He, Z. Klimont, S. M. Nelson, N. Y. Tsai, M. Q. Wang, J.-H. Woo, and K. F. Yarber (2003b), An inventory of gaseous and primary aerosol emissions in Asia in the year 2000, *J. Geophys. Res.*, *108* (D21), 8809, doi: 10.1029/2002JD003093.

Streets, D. G., T. C. Bond, T. Lee, and C. Jang (2004), On the future of carbonaceous aerosol emissions, *J. Geophys. Res.*, *109* (D24), doi: 10.1029/2004JD004902.

Streets, D. G., Q. Zhang, L. Wang, K. He, J. Hao, Y. Wu, Y. Tang, and G. R. Carmichael (2006), Revisiting China's CO emissions after the Transport and Chemical Evolution over the Pacific (TRACE-P) mission: Synthesis of inventories, atmospheric modeling, and observations, *J. Geophys. Res.*, *111* (D14), 306, doi: 10.1029/2006JD007118.

Streets, D. G. (2007), Dissecting future aerosol emissions: Warming tendencies and mitigation opportunities, *Climatic Change*, *81* (3-4), 313-330, doi: 10.1007/s10584-006-9112-8.

Streets, D. G., F. Yan, M. Chin, T. Diehl, N. Mahowald, M. Schultz, M. Wild, Y. Wu, and C. Yu (2009), Anthropogenic and natural contributions to regional trends in aerosol optical depth, 1980-2006, *J. Geophys. Res.*, *114*, doi: 10.1029/2008JD011624.

Streets, D., H. Akimoto, P. Artaxo, Z. Klimont, K. Kupiainen, G. Janssens-Maenhout, and H. Vallack (2011), Black Carbon and tropospheric ozone precursors: Driver, emissions and trends, in *Integrated Assessment of Black Carbon and Tropospheric Ozone*, edited, 282 p., United Nations Environment Programme, Nairobi, Kenya, and World Meteorological Organization, Geneva, Switzerland.

Ström, J., and S. Ohlsson (1998), In situ measurements of enhanced crystal number densities in cirrus clouds caused by aircraft exhaust, *J. Geophys. Res.*, *103* (D10), 11355-11361.

Subramanian, R., A. Y. Khlystov, and A. L. Robinson (2006), Effect of peak inert-mode temperature on elemental carbon measured using thermal-optical analysis, *Aerosol Sci. Technol.*, *40* (10), 763-780, doi: 10.1080/02786820600714403.

Subramanian, R., T. C. Bond, W. Thiansathit, N. T. K. Oanh, K. G. Duleep, I. Paw-armart, and E. Winijkul (2009), Source characterization to support quantification of co-benefits: A piggyback study in Bangkok, Thailand, *Environ. Sci. Technol.*, *43*, 4213-4218.

Sun, H., L. Biedermann, and T. C. Bond (2007), Color of brown carbon: A model for ultraviolet and visible light absorption by organic carbon aerosol, *Geophys. Res. Lett.*, *34* (17), L17813, doi: 10.1029/2007GL029797.

Szidat, S., T. M. Jenk, H. A. Synal, M. Kalberer, L. Wacker, I. Hajdas, A. Kasper-Giebl, and U. Baltensperger (2006), Contributions of fossil fuel, biomass-burning, and biogenic emissions to carbonaceous aerosols in Zurich as traced by C-14, *J. Geophys. Res.*, *111*, D07206, doi: 10.1029/2005JD006590.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Takemura, T., T. Nozawa, S. Emori, T. Y. Nakajima, and T. Nakajima (2005), Simulation of climate response to aerosol direct and indirect effects with aerosol transport-radiation model, *J. Geophys. Res.*, *110* (D2), 202, doi: 10.1029/2004JD005029.

Tan, Q., W. L. Chameides, D. Streets, T. Wang, J. Xu, M. Bergin, and J. Woo (2004), An evaluation of TRACE-P emission inventories from China using a regional model and chemical measurements, *J. Geophys. Res.*, *109,* D22305, doi: 10.1029/2004JD005071.

Targino, A. C., H. Coe, J. Cozic, J. Crosier, I. Crawford, K. Bower, M. Flynn, M. Gallagher, J. Allan, B. Verheggen, E. Weingartner, U. Baltensperger, and T. Choularton (2009), Influence of particle chemical composition on the phase of cold clouds at a high-alpine site in Switzerland, *J. Geophys. Res.*, *114* (D18), 206, doi: 10.1029/2008JD011365.

Tegen, I., P. Hollrig, M. Chin, I. Fung, D. Jacob, and J. Penner (1997), Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results, *J. Geophys. Res.*, *102* (D20), 23895-23915, doi: 10.1029/97JD01864.

Ten Hoeve, J. E., L. A. Remer, and M. Z. Jacobson (2011), Microphysical and radiative effects of aerosols on warm clouds during the Amazon biomass burning season as observed by MODIS: Impacts of water vapor and land cover, *Atmos. Chem. Phys.*, *11*, 3021-3036, doi: 10.5194/acp-11-3021-2011.

Textor, C., M. Schulz, S. Guibert, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, M. Chin, F. Dentener, T. Diehl, R. Easter, H. Feichter, D. Fillmore, S. Ghan, P. Ginoux, S. Gong, A. Grini, J. Hendricks, L. Horowitz, P. Huang, I. Isaksen, T. Iversen, S. Kloster, D. Koch, A. Kirkevåg, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, X. Liu, V. Montanaro, G. Myhre, J. Penner, G. Pitari, S. Reddy, Ø. Seland, P. Stier, T. Takemura, and X. Tie (2006), Analysis and quantification of the diversities of aerosol life cycles within AeroCom, *Atmos. Chem. Phys.*, *6*, 1777-1813, doi:. 10.5194/acp-6-1777-2006.

Textor, C., M. Schulz, S. Guibert, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, M. Chin, F. Dentener, T. Diehl, J. Feichter, D. Fillmore, P. Ginoux, S. Gong, A. Grini, J. Hendricks, L. Horowitz, P. Huang, I. S. A. Isaksen, T. Iversen, S. Kloster, D. Koch, A. Kirkevag, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, X. Liu, V. Montanaro, G. Myhre, J. E. Penner, G. Pitari, M. S. Reddy, O. Seland, P. Stier, T. Takemura, and X. Tie (2007), The effect of harmonized emissions on aerosol properties in global models - an AeroCom experiment, *Atmos. Chem. Phys.*, *7* (17), 4489-4501, doi: 10.5194/acp-7-4489-2007.

Thevenon, F., F. S. Anselmetti, S. M. Bernasconi, and M. Schwikowski (2009), Mineral dust and elemental black carbon records from an Alpine ice core (Colle Gnifetti glacier) over the last millennium, *J. Geophys. Res.*, *114* (D17), 102, doi: 10.1029/2008JD011490.

Thompson, L. G., S. Hastenrath, and B. Morales-Arnao (1979), Climatic ice core records from the tropical Quelccaya ice cap, *Science*, *203* (4386), 1240-1243.

Tol, R. S. J. (2008), The social cost of carbon: Trends, outliers and catastrophes, *Economics: The Open-Access, Open-Assessment E-Journal*, *2,* 2008-25.

Tol, R. S. J., T. K. Berntsen, B. C. O'Neill, J. S. Fuglestvedt, and K. P. Shine (2012), A unifying framework for metrics for aggregating the climate effect of different emissions, *Environ. Res. Lett.*, *7,* 044006, doi: 10.1088/1748-9326/7/4/044006.

Toon, O. B., C. P. McKay, T. P. Ackerman, and K. Santhanam (1989), Rapid calculation of radiative heating rates and photodissociation rates in Inhomogeneous multiple scattering atmospheres, *J. Geophys. Res.*, *94* (D13), 16287-16301, doi: 10.1029/JD094iD13p16287.

Torres, O., P. K. Bhartia, J. R. Herman, and Z. Ahmad (1998), Derivation of aerosol properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis, *J. Geophys. Res.*, *103*, 17099-17110, doi: 10.1029/98JD00900.

Torres, O., P. K. Bhartia, J. R. Herman, A. Sinyuk, P. Ginoux, and B. Holben (2002), A long-term record of aerosol optical depth from TOMS observations and comparison to AERONET measurements, *J. Atmos. Sci.*, *59* (3), 398-413.

Tosca, M. G., J. T. Randerson, C. S. Zender, M. G. Flanner, and P. J. Rasch (2010), Do biomass burning aerosols intensify drought in equatorial Asia during El Nino?, *Atmos. Chem. Phys.*, *10* (8), 3515-3528, doi: 10.5194/acp-10-3515-2010.

Tsyro, S., D. Simpson, L. Tarrason, Z. Klimont, K. Kupiainen, C. Pio, and K. E. Yttri (2007), Modeling of elemental carbon over Europe, *J. Geophys. Res.*, *112,* D23s19, doi: 10.1029/2006JD008164.

Turco, R. P., O. B. Toon, T. P. Ackerman, J. B. Pollack, and C. Sagan (1983), Nuclear winter: Global consequences of multiple nuclear explosions, *Science*, *222* (4630), 1283-1292.

Turetsky, M. R., E. S. Kane, J. W. Harden, R. D. Ottmar, K. L. Manies, E. Hoy, and E. S. Kasischke (2010), Recent acceleration of

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

biomass burning and carbon losses in Alaskan forests and peatlands, *Nature Geosci.*, *4*, 27-31, doi: 10.1038/ngeo1027.

Turpin, B. J., R. A. Cary, and J. J. Huntzicker (1990), An *in situ*, time-resolved analyzer for aerosol organic and elemental carbon, *Aerosol Sci. Technol.*, *12*, 161-171.

Twohy, C. H., and B. W. Gandrud (1998), Electron microscope analysis of residual particles from aircraft contrails, *Geophys. Res. Lett.*, *25* (9), 1359-1362.

Twohy, C. H., and M. R. Poellot (2005), Chemical characteristics of ice residual nuclei in anvil cirrus clouds: Evidence for homogeneous and heterogeneous ice formation, *Atmos. Chem. Phys.*, *5*, 2289-2297.

Twohy, C. H., P. J. DeMott, D. A. Pratt, R. Subramanian, G. L. Kok, S. M. Murphy, T. Lersch, A. J. Heymsfield, Z. E. Wang, K. A. Prather, and J. H. Seinfeld (2010), Relationships of biomass-burning aersols to ice in orographic wave clouds, *J. Atmos. Sci.*, *67* (8), 2437-2450, doi: 10.1175/2010JAS3310.1.

Twomey, S. A. (1959), The nuclei of natural cloud formation part II: The supersaturation in natural clouds and the variation of cloud droplet concentrations, *Geofis. Pura. Appl*, *43*, 227-242.

Twomey, S. A. (1991), Aerosols, clouds and radiation, *Atmos. Environ.*, *25A* (11), 2435-2442.

Uekoetter, F. (2005), The strange career of the Ringelmann smoke chart, *Environ. Monit. Assess.*, *106* (1-3), 11-26, doi: 10.1007/s10661-005-0756-z.

Uherek, E., T. Halenka, J. Borken-Kleefeld, Y. Balkanski, T. Berntsen, C. Borrego, M. Gauss, P. Hoor, K. Juda-Rezler, J. Lelieveld, D. Melas, K. Rypdal, and S. Schmid (2010), Transport impacts on atmosphere and climate: Land transport, *Atmos. Environ.*, *44* (37), 4772-4816, doi: 10.1016/j.atmosenv.2010.01.002.

UNECE (1999), Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to abate acidification, eutrophication and ground-level ozone. Adopted in Gothenburg, Sweden, on 30 November, 1999. http://www.unece.org/env/lrtap/multi_h1.html.

UNECE (2011), Options for revising the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone. ECE/EB.AIR/2011/8 revised at the 29th session of the Executive Body of the LRTAP Convention; http://www.unece.org/fileadmin/DAM/env/documents/2011/eb/ebbureau/ece.eb.air.2011.8.-REVISED_1612am_AK.doc.

UNEP (2011), Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers, 78 pp., United Nations Environment Programme, Nairobi, Kenya.

UNEP/WMO (2011a), Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers, 38 pp., United Nations Environment Programme, Nairobi, Kenya, and World Meteorological Organization, Geneva, Switzerland.

UNEP/WMO (2011b), Integrated Assessment of Black Carbon and Tropospheric Ozone, 282 pp., United Nations Environment Programme, Nairobi, Kenya, and World Meteorological Organization, Geneva, Switzerland.

UNFCCC (1992), United Nations Framework Convention on Climate Change, 24 pp., United Nations.

Unger, N., T. C. Bond, J. S. Wang, D. M. Koch, S. Menon, D. T. Shindell, and S. Bauer (2010), Attribution of climate forcing to economic sectors, *P. Natl. Acad. Sci. USA*, *107* (8), 3382-3387, doi: 10.1073/pnas.0906548107.

USDA (2005), A strategic assessment of forest biomass and fuel reduction treatments in Western states, *Gen. Tech. Rep.*, RMRS-GTR-149, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

van Aardenne, J. A., F. J. Dentener, J. G. J. Olivier, C. G. M. Klein Goldewijk, and J. Lelieveld (2001), A 1°×1° resolution data set of historical anthropogenic trace gas emissions for the period 1890-1990, *Global Biogeochem. Cycles*, *15* (4), 909-928, doi: 10.1029/2000gb001265.

van der Werf, G. R., J. T. Randerson, L. Giglio, G. J. Collatz, P. S. Kasibhatla, and A. F. Arellano Jr (2006), Interannual variability in global biomass burning emissions from 1997 to 2004, *Atmos. Chem. Phys.*, *6* (11), 3423-3441, doi: 10.5194/acp-6-3423-2006.

van der Werf, G. R., J. T. Randerson, L. Giglio, G. J. Collatz, M. Mu, P. S. Kasibhatla, D. C. Morton, R. S. DeFries, Y. Jin, and T. T. van Leeuwen (2010), Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009), *Atmos. Chem. Phys.*, *10*, 11707-11735.

Van Dingenen, R., F. Raes, J. P. Putaud, U. Baltensperger, A. Charron, M. C. Facchini, S. Decesari, S. Fuzzi, R. Gehrig, H. C. Hansson, R.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

M. Harrison, C. Huglin, A. M. Jones, P. Laj, G. Lorbeer, W. Maenhaut, F. Palmgren, X. Querol, S. Rodriguez, J. Schneider, H. ten Brink, P. Tunved, K. Torseth, B. Wehner, E. Weingartner, A. Wiedensohler, and P. Wahlin (2004), A European aerosol phenomenology-1: Physical characteristics of particulate matter at kerbside, urban, rural and background sites in Europe, *Atmos. Environ.*, *38* (16), 2561-2577, doi: 10.1016/j.atmosenv.2004.01.040.

Van-Hulle, P., M. Talbaut, M. Weill, and A. Coppalle (2002), Inversion method and experiment to determine the soot refractive index: application to turbulent diffusion flames, *Meas. Sci. Technol.*, *13* (3), 375-382.

Venkataraman, C., G. Habib, A. Eiguren-Fernandez, A. H. Miguel, and S. K. Friedlander (2005), Residential biofuels in south Asia: Carbonaceous aerosol emissions and climate impacts, *Science*, *307*, 1454-1456.

Venkataraman, C., G. Habib, D. Kadamba, M. Shrivastava, J. F. Leon, B. Crouzille, O. Boucher, and D. G. Streets (2006), Emissions from open biomass burning in India: Integrating the inventory approach with high-resolution Moderate Resolution Imaging Spectroradiometer (MODIS) active-fire and land cover data, *Global Biogeochem. Cycles*, *20,* Gb2013, doi: 10.1029/2005gb002547.

Vermote, E., E. Ellicott, O. Dubovik, T. Lapyonok, M. Chin, L. Giglio, and G. J. Roberts (2009), An approach to estimate global biomass burning emissions of organic and black carbon from MODIS fire radiative power, *J. Geophys. Res.*, *114,* D18205, doi: 10.1029/2008JD011188.

Viana, M., T. A. J. Kuhlbusch, X. Querol, A. Alastuey, R. M. Harrison, P. K. Hopke, W. Winiwarter, A. Vallius, S. Szidat, A. S. H. Prevot, C. Hueglin, H. Bloemen, P. Wahlin, R. Vecchi, A. I. Miranda, A. Kasper-Giebl, W. Maenhaut, and R. Hitzenberger (2008), Source apportionment of particulate matter in Europe: A review of methods and results, *J. Aerosol. Sci.*, *39* (10), 827-849, doi: 10.1016/j.jaerosci.2008.05.007.

Vignati, E., J. Wilson, and P. Stier (2004), M7: An efficient size-resolved aerosol microphysics module for large-scale aerosol transport models, *J. Geophys. Res.*, *109* (D22), D22202, doi: 10.1029/2003JD004485.

Vignati, E., M. Karl, M. Krol, J. Wilson, P. Stier, and F. Cavalli (2010), Sources of uncertainties in modelling black carbon at the global scale, *Atmos. Chem. Phys.*, *10* (6), 2595-2611, doi: 10.5194/acp-10-2595-2010.

Virkkula, A., N. C. Ahlquist, D. S. Covert, W. P. Arnott, P. J. Sheridan, P. K. Quinn, and D. J. Coffman (2005), Modification, calibration and a field test of an instrument for measuring light absorption by particles, *Aerosol Sci. Technol.*, *39*, 68-83.

Vogelmann, A. M., A. Robock, and R. G. Ellingson (1988), Effects of dirty snow in nuclear winter simulations, *J. Geophys. Res.*, *93* (D5), 5319-5332.

Wagner, R., T. Ajtai, K. Kandler, K. Lieke, C. Linke, T. Muller, M. Schnaiter, and M. Vragel (2012), Complex refractive indices of Saharan dust samples at visible and near UV wavelengths: A laboratory study, *Atmos. Chem. Phys.*, *12* (5), 2491-2512, doi: 10.5194/acp-12-2491-2012.

Walsh, M. P. (2008), Ancillary benefits for climate change mitigation and air pollution control in the world's motor vehicle fleets, *Annual Review of Public Health*, *29*, 1-9, doi: 10.1146/annurev.publhealth.29.091307.183257.

Wang, C. (2004), A modeling study on the climate impacts of black carbon aerosols, *J. Geophys. Res.*, *109* (D3), 106, doi: 10.1029/2003JD004084.

Wang, C. (2007), Impact of direct radiative forcing of black carbon aerosols on tropical convective precipitation, *Geophys. Res. Lett.*, *34* (5), 709, doi: 10.1029/2006GL028416.

Wang, C., D. Kim, A. M. L. Ekman, M. C. Barth, and P. J. Rasch (2009a), Impact of anthropogenic aerosols on Indian summer monsoon, *Geophys. Res. Lett.*, *36* (L21), 704, doi: 10.1029/2009GL040114.

Wang, S., X. Zhao, X. Li, W. Wei, and J. Hao (2009b), Emission characteristics of fine particles from grate firing boilers (in Chinese), *Environ. Sci.*, *30* (4), 963-968.

Wang, M., S. Ghan, X. Liu, T. S. L'Ecuyer, K. Zhang, H. Morrison, M. Ovchinnikov, R. Easter, R. Marchand, D. Chand, Y. Qian, and J. E. Penner (2012), Constraining cloud lifetime effects of aerosols using A-Train satellite observations, *Geophys. Res. Lett.*, *39,* L15709, doi: 10.1029/2012GL052204.

Wang, S. X., M. Zhao, J. Xing, Y. Wu, Y. Zhou, Y. Lei, K. B. He, L. X. Fu, and J. M. Hao (2010), Quantifying the air pollutants emission

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

reduction during the 2008 Olympic games in Beijing, *Environ. Sci. Technol.*, *44* (7), 2490-2496, doi: 10.1021/es9028167.

Wang, Z. L., H. Zhang, and X. S. Shen (2011), Radiative forcing and climate response due to black carbon in snow and ice, *Adv. Atmos. Sci.*, *28* (6), 1336-1344, doi: 10.1007/s00376-011-0117-5.

Ward, D. E., R. A. Susott, J. B. Kauffman, R. E. Babbitt, D. L. Cummings, B. Dias, B. N. Holben, Y. J. Kaufman, R. A. Rasmussen, and A. W. Setzer (1992), Smoke and fire characteristics for cerrado and deforestation burns in Brazil – BASE-B experiment, *J. Geophys. Res.*, *97* (D13), 14601-14619.

Warneke, C., R. Bahreini, J. Brioude, C. A. Brock, J. A. de Gouw, D. W. Fahey, K. D. Froyd, J. S. Holloway, A. Middlebrook, L. Miller, S. Montzka, D. M. Murphy, J. Peischl, T. B. Ryerson, J. P. Schwarz, J. R. Spackman, and P. Veres (2009), Biomass burning in Siberia and Kazakhstan as an important source for haze over the Alaskan Arctic in April 2008, *Geophys. Res. Lett.*, *36* (2), L02813, doi: 10.1029/2008GL036194.

Warren, S. G. (1982), Optical-properties of snow, *Rev. Geophys.*, *20* (1), 67-89.

Warren, S. G., and A. D. Clarke (1990), Soot in the atmosphere and snow surface of Antarctica, *J. Geophys. Res.*, *95* (D2), 1811-1816.

Warren, S. G., and W. J. Wiscombe (1980), A model for the spectral albedo of snow. II: Snow containing atmospheric aerosols, *J. Atmos. Sci.*, *37* (12), 2734-2745.

Warren, S. G., and W. J. Wiscombe (1985), Dirty snow after nuclear-war, *Nature*, *313* (6002), 467-470.

Warren, S. G., I. G. Rigor, N. Untersteiner, V. F. Radionov, N. N. Bryazgin, Y. I. Aleksandrov, and R. Colony (1999), Snow depth on Arctic sea ice, *J. Climate*, *12* (6), 1814-1829.

Watson, J. G., J. A. Cooper, and J. J. Huntzicker (1984), The effective variance weighting for least-squares calculations applied to the mass balance receptor model, *Atmos. Environ.*, *18* (7), 1347-1355.

Watson, J. G., J. C. Chow, D. H. Lowenthal, L. C. Pritchett, C. A. Frazier, G. R. Neuroth, and R. Robbins (1994), Differences in the carbon composition of source profiles for diesel-powered and gasoline-powered vehicles, *Atmos. Environ.*, *28* (15), 2493-2505.

Watson, J. G., J. C. Chow, J. L. Bowen, D. H. Lowenthal, S. Hering, P. Ouchida, and W. Oslund (2000), Air quality measurements from the Fresno Supersite, *J. Air Waste Manage. Assoc.*, *50* (8), 1321-1334.

Watson, J. G., J. C. Chow, D. H. Lowenthal, N. F. Robinson, C. F. Cahill, and D. L. Blumenthal (2002), Simulating changes in source profiles from coal-fired power stations: Use in chemical mass balance of $PM_{2.5}$ in the Mount Zirkel Wilderness, *Energy & Fuels*, *16* (2), 311-324, doi: 10.1021/Ef010202w.

Watson, J. G., J. C. Chow, and L.-W. A. Chen (2005), Summary of organic and elemental carbon/black carbon analysis methods and intercomparisons, *Aerosol Air Qual. Res.*, *5* (1), 65-102.

Watson, J. G., L. W. A. Chen, J. C. Chow, P. Doraiswamy, and D. H. Lowenthal (2008), Source apportionment: Findings from the US Supersites program, *J. Air Waste Manage. Assoc.*, *58* (2), 265-288, doi: 10.3155/1047-3289.58.2.265.

Weingartner, E., H. Burtscher, and U. Baltensperger (1997), Hygroscopic properties of carbon and diesel soot particles, *Atmos. Environ., 31* (15), 2311-2327.

Weingartner, E., H. Saathof, M. Schnaiter, N. Streit, B. Bitnar, and U. Baltensperger (2003), Absorption of light by soot particles: Determination of the absorption coefficient by means of aethalometers, *J. Aerosol. Sci.*, *34*, 1445-1463.

Wex, H., G. McFiggans, S. Henning, and F. Stratmann (2010), Influence of the external mixing state of atmospheric aerosol on derived CCN number concentrations, *Geophys. Res. Lett., 37,* L10805, doi: 10.1029/2010gl043337.

Whitby, E. R., and P. H. McMurry (1997), Modal aerosol dynamics modeling, *Aerosol Sci. Technol., 27* (6), 673-688.

Wiacek, A., and T. Peter (2009), On the availability of uncoated mineral dust ice nuclei in cold cloud regions, *Geophys. Res. Lett.*, *36* (L17), 801, doi: 10.1029/2009GL039429.

Wilcox, E. M. (2012), Direct and semi-direct radiative forcing of smoke aerosols over clouds, *Atmos. Chem. Phys.*, *12,* (1), 139-149, doi: 10.5194/acp-12-139-2012.

Wild, O., M. J. Prather, and H. Akimoto (2001), Indirect long-term global radiative cooling from NO_x emissions, *Geophys. Res. Lett.*, *28* (9), 1719-1722, doi: 10.1029/2000GL012573.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Williams, J., M. deReus, R. Krejci, H. Fischer, and J. Ström (2002), Application of the variability-size relationship to atmospheric aerosol studies: Estimating aerosol lifetimes and ages, *Atmos. Chem. Phys.*, *2*, 133-145, doi: 10.5194/acp-2-133-2002.

Winebrake, J. J., J. J. Corbett, E. H. Green, A. Lauer, and V. Eyring (2009), Mitigating the health impacts of pollution from oceangoing shipping: An assessment of low-sulfur fuel mandates, *Environ. Sci. Technol.*, *43* (13), 4776-4782, doi: 10.1021/es803224q.

Winker, D. M., J. Pelon, J. A. Coakley, S. A. Ackerman, R. J. Charlson, P. R. Colarco, P. Flamant, Q. Fu, R. M. Hoff, C. Kittaka, T. L. Kubar, H. Le Treut, M. P. McCormick, G. Megie, L. Poole, K. Powell, C. Trepte, M. A. Vaughan, and B. A. Wielicki (2010), The Calipso mission A Global 3D view of aerosols and clouds, *Bull. Amer. Meteorol. Soc.*, *91* (9), 1211-1229, doi: 10.1175/2010bams3009.1.

Wiscombe, W. J., and S. G. Warren (1980), A model for the spectral albedo of snow. I: Pure snow, *J. Atmos. Sci.*, *37*, 2712-2733.

Wofsy, S. C., and H. S. T. C. M. T. S. Team (2011), HIAPER Pole-to-Pole Observations (HIPPO): fine-grained, global-scale measurements of climatically important atmospheric gases and aerosols, *Philos. Trans. R. Soc. A-Math. Phys. Eng. Sci.*, *369* (1943), 2073-2086, doi: 10.1098/rsta.2010.0313.

Wonaschütz, A., R. Hitzenberger, H. Bauer, P. Pouresmaeil, B. Klatzer, A. Caseiro, and H. Puxbaum (2009), Application of the intergrating sphere method to separate the contributions of brown and black carbon in atmospheric aerosols, *Environ. Sci. Technol.*, *43* (4), 1141-1146, doi: 10.1021/es8008503.

Wooster, M. J., G. Roberts, G. L. W. Perry, and Y. J. Kaufman (2005), Retrieval of biomass combustion rates and totals from fire radiative power observations: FRP derivation and calibration relationships between biomass consumption and fire radiative energy release, *J. Geophys. Res.*, *110* (D24), 311, doi: 10.1029/2005JD006318.

World Bank (2011), Household Cookstoves, Environment, Health and Climate Change: A New look at an Old Problem, The International Bank for Reconstruction and Development/The World Bank, Washington, DC.

WRAP (2002), Non-burning management alternatives on agricultural lands in the western United States, Volume II: Non-burning management alternatives and implementation plan strategies, Western Air Regional Partnership, Prepared by Eastern Research Group, Inc. (ERG) , Sacramento, CA.

Xu, B., T. Yao, X. Liu, and N. Wang (2006), Elemental and organic carbon measurements with a two-step heatinggas chromatography system in snow samples from the Tibetan Plateau, *Ann. Glaciol.*, *43*, 257-262, doi: 10.3189/172756406781812122.

Xu, B., M. Wang, D. Joswiak, J. Cao, T. Yao, G. Wu, W. Yang, and H. Zhao (2009a), Deposition of anthropogenic aerosols in a southeastern Tibetan glacier, *J. Geophys. Res.*, *114,* D17209, doi: 10.1029/2008JD011510.

Xu, B., J. Cao, J. Hansen, T. Yao, D. R. Joswia, N. Wang, G. Wu, M. Wang, H. Zhao, W. Yang, X. Liu, and J. He (2009b), Black soot and the survival of Tibetan glaciers, *P. Natl. Acad. Sci. USA*, *106* (52), 22114-22118, doi: 10.1073/pnas.0910444106.

Yang, M., S. G. Howell, J. Zhuang, and B. J. Huebert (2009), Attribution of aerosol light absorption to black carbon, brown carbon, and dust in China - interpretations of atmospheric measurements during EAST-AIRE, *Atmos. Chem. Phys.*, *9* (6), 2035-2050, doi: 10.5194/acp-9-2035-2009.

Yasunari, T. J., P. Bonasoni, P. Laj, K. Fujita, E. Vuillermoz, A. Marinoni, P. Cristofanelli, R. Duchi, G. Tartari, and K. M. Lau (2010), Estimated impact of black carbon deposition during pre-monsoon season from Nepal Climate Observatory - Pyramid data and snow albedo changes over Himalayan glaciers, *Atmos. Chem. Phys.*, *10* (14), 6603-6615, doi: 10.5194/acp-10-6603-2010.

Yokelson, R. J., R. Susott, D. E. Ward, J. Reardon, and D. W. T. Griffith (1997), Emissions from smoldering combustion of biomass measured by open-path Fourier transform infrared spectroscopy, *J. Geophys. Res.*, *102* (D15), 18865-18877, doi: 10.1029/97JD00852.

Yoshimori, M., and A. J. Broccoli (2008), Equilibrium response of an atmosphere-mixed layer ocean model to different radiative forcing agents: Global and zonal mean response, *J. Climate*, *21* (17), 4399-4423, doi: 10.1175/2008jcli2172.1.

Yoshioka, M., N. Mahowald, A. Conley, W. Collins, D. Fillmore, C. Zender, and D. Coleman (2007), Impact of desert dust radiative forcing on Sahel precipitation: Relative importance of dust compared to sea surface temperature variations, vegetation changes and greenhouse gas warming, *J. Climate*, *20*, 1445-1467, doi: 10.1175/JCL14056.1.

Young, K. C. (1974), A numerical simulation of wintertime, orographic precipitation. Part I: Description of model microphysics and

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

numerical technique, *J. Atmos. Sci., 31*, 1735-1748.

Yu, H., M. Chin, D. M. Winker, A. H. Omar, Z. Liu, C. Kittaka, and T. Diehl (2010), Global view of aerosol vertical distributions from CALIPSO lidar measurements and GOCART simulations: Regional and seasonal variations, *J. Geophys. Res.*, doi: 10.1029/2009JD013364.

Yumimoto, K., and I. Uno (2006), Adjoint inverse modeling of CO emissions over Eastern Asia using four-dimensional variational data assimilation, *Atmos. Environ.*, *40* (35), 6836-6845, doi: 10.1016/j.atmosenv.2006.05.042.

Yun, Y., and J. E. Penner (2012), Global model comparison of heterogeneous ice nucleation parameterizations in mixed phase clouds, *J. Geophys. Res.*, *117,* D07203, doi: 10.1029/2011JD016506.

Zarzycki, C. M., and T. C. Bond (2010), How much can the vertical distribution of black carbon affect its global direct radiative forcing?, *Geophys. Res. Lett.*, *37*, L20807, doi: 10.1029/2010GL044555.

Zhang, H., Z.-L. Wang, Z.-Z. Wang, Q.-X. Liu, S. Gong, X.-Y. Zhang, Z.-P. Shen, P. Lu, X.-D. Wei, H.-Z. Che, and L. Li (2012), Simulation of direct radiative forcing of aerosols and their effects on East Asian climate using an interactive AGCM-aerosol coupled system, *Clim. Dyn.*, *38*, 1675-1693, doi: 10.1007/s00382-011-1131-0.

Zhang, J., K. R. Smith, Y. Ma, S. Ye, F. Jiang, W. Qi, P. Liu, M. A. K. Khalil, R. A. Rasmussen, and S. A.Thorneloe (2000), Greenhouse gases and other airborne pollutants from household stoves in China: A database for emission factors, *Atmos. Environ.*, *34*, 4537-4549.

Zhang, J., and J. S. Reid (2009), An analysis of clear sky and contextual biases using an operational over ocean MODIS aerosol product, *Geophys. Res. Lett.*, *36*, L15824, doi: 10.1029/2009GL038723.

Zhang, Q., J. L. Jimenez, M. R. Canagaratna, J. D. Allan, H. Coe, I. Ulbrich, M. R. Alfarra, A. Takami, A. M. Middlebrook, Y. L. Sun, K. Dzepina, E. Dunlea, K. Docherty, P. F. DeCarlo, D. Salcedo, T. Onasch, J. T. Jayne, T. Miyoshi, A. Shimono, S. Hatakeyama, N. Takegawa, Y. Kondo, J. Schneider, F. Drewnick, S. Borrmann, S. Weimer, K. Demerjian, P. Williams, K. Bower, R. Bahreini, L. Cottrell, R. J. Griffin, J. Rautiainen, J. Y. Sun, Y. M. Zhang, and D. R. Worsnop (2007), Ubiquity and dominance of oxygenated species in organic aerosols in anthropogenically-influenced Northern Hemisphere midlatitudes, *Geophys. Res. Lett.*, *34,* L13801, doi: 10.1029/2007gl029979.

Zhang, Q., D. G. Streets, G. R. Carmichael, K. B. He, H. Huo, A. Kannari, Z. Klimont, I. S. Park, S. Reddy, J. S. Fu, D. Chen, L. Duan, Y. Lei, L. T. Wang, and Z. L. Yao (2009a), Asian emissions in 2006 for the NASA INTEX-B mission, *Atmos. Chem. Phys.*, *9* (14), 5131-5153, doi: 10.5194/acp-9-5131-2009.

Zhang, H., Z.-L. Wang, P.-W. Guo, and Z.-Z. Wang (2009b), A modeling study of the effects of direct radiative forcing due to carbonaceous aerosol on the climate in East Asia, *Adv. Atmos. Sci.*, *26* (1), 57-66, doi: 10.1007/s00376-009-0057-5.

Zhang, S., J. E. Penner, and O. Torres (2005), Inverse modeling of biomass burning emissions using Total Ozone Mapping Spectrometer aerosol index for 1997, *J. Geophys. Res.*, *110,* D21306, doi: 10.1029/2004JD005738.

Zhang, Y. X., J. J. Schauer, Y. Zhang, L. Zeng, Y. Wei, Y. Liu, and M. Shao (2008a), Characteristics of particulate carbon emissions from real-world Chinese coal combustion, *Environ. Sci. Technol.*, *42*, 5068-5073.

Zhang, Y. H., M. Hu, L. J. Zhong, A. Wiedensohler, S. C. Liu, M. O. Andreae, W. Wang, and S. J. Fan (2008b), Regional integrated experiments on air quality over Pearl River Delta 2004 (PRIDE-PRD2004): Overview, *Atmos. Environ.*, *42* (25), 6157-6173, doi: 10.1016/j.atmosenv.2008.03.025.

Zheng, M., G. R. Cass, J. J. Schauer, and E. S. Edgerton (2002), Source apportionment of $PM_{2.5}$ in the southeastern United States using solvent-extractable organic compounds as tracers, *Environ. Sci. Technol.*, *36* (11), 2361-2371, doi: 10.1021/es011275x.

Zheng, M., L. G. Salmon, J. J. Schauer, L. M. Zeng, C. S. Kiang, Y. H. Zhang, and G. R. Cass (2005), Seasonal trends in $PM_{2.5}$ source contributions in Beijing, China, *Atmos. Environ.*, *39* (22), 3967-3976, doi: 10.1016/j.atmosenv.2005.03.036.

Zhi, G., Y. Chen, Y. Feng, S. Xiong, J. Li, G. Zhang, G. Sheng, and J. Fu (2008), Emission characteristics of carbonaceous particles from various residential coal-stoves in China, *Environ. Sci. Technol.*, *42* (9), 3310-3315, doi: 10.1021/es702247q.

Zhi, G. R., C. H. Peng, Y. J. Chen, D. Y. Liu, G. Y. Sheng, and J. M. Fu (2009), Deployment of coal briquettes and improved stoves: Possibly an option for both environment and climate, *Environ. Sci. Technol.*, *43*, 5586-5591, doi: 10.1021/es802955d.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Zhou, L., P. K. Hopke, and W. X. Zhao (2009), Source Apportionment of Airborne Particulate Matter for the Speciation Trends Network Site in Cleveland, OH, *J. Air Waste Manage. Assoc.*, *59* (3), 321-331, doi: 10.3155/1047-3289.s9.3.321.

Zobrist, B., C. Marcolli, T. Koop, B. P. Luo, D. M. Murphy, U. Lohmann, A. A. Zardini, U. K. Krieger, T. Corti, D. J. Cziczo, S. Fueglistaler, P. K. Hudson, D. S. Thomson, and T. Peter (2006), Oxalic acid as a heterogeneous ice nucleus in the upper troposphere and its indirect aerosol effect, *Atmos. Chem. Phys.*, *6* (10), 3115-3129, doi: 10.5194/acp-6-3115-2006.

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Table R.1. Acronyms and abbreviations

Acronym	Definition
AAOD	aerosol absorption optical depth
AeroCom	Aerosol Comparison between Observations and Models
AERONET	Aerosol Robotic NETwork
AGTP	absolute global temperature change potential
AGWP	absolute global warming potential
AOD	aerosol optical depth
BB	biomass burning
BC-DRF	black-carbon direct radiative forcing
CALIPSO	Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAM	Community Atmosphere Model
CAM3	Community Atmosphere Model3
CAM5	Community Atmosphere Model5
CAM-Oslo	Community Atmosphere Model-Oslo
CTM	chemical transport model
DRF	direct radiative forcing
ECHAM	European Centre HAmburg Model
EECCA	Eastern Europe, Caucasus and Central Asia
FF	fossil fuel
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GATOR	Gas, Aerosol, TranspOrt, Radiation model
GATOR-GCMOM	Gas, Aerosol, TranspOrt, Radiation - General Circulation, Mesoscale, and Ocean Model
GCM	global climate model
GHG	greenhouse gas
GISS	Goddard Institute for Space Studies
GOCART	Goddard Chemistry Aerosol Radiation

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

	and Transport model
GRA	albedo reduction via growth of snow grains with accelerating snow aging
GRB	increase in albedo reduction for a given BC concentration in coarse grained vs. fine-grained snow
GTP	global temperature change potential
GWP	global warming potential
HadGEM	Hadley Centre Global Environmental Model
HIPS	Hybrid Integrating Plate System
IE	indirect effect
IEA	International Energy Agency
IIE	ice cloud indirect effect
IMPACT	Lawrence Livermore National Laboratory (LLNL) Integrated Massively Parallel Atmospheric (IMPACT) Model
IMPROVE	Interagency Monitoring of Protected Visual Environments
IN	ice nuclei
IPCC	Intergovernmental Panel on Climate Change
ISSW	Integrating Sphere Sandwich Spectrophotometer
LES	large-eddy simulation
lidar	light detection and ranging
LOSU	level of scientific understanding
LSCE	Laboratoire des Sciences du Climat et de l'Environnement
MAC	mass absorption cross section
MBC	Increase in surface snow BC concentration via enhanced surface snow melt and retention of BC
MIE	mixed-phase cloud indirect effect
MISR	Multi-angle Imaging

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

	Spectroradiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MPI-HAM	Max Planck Institute-Meterology, Hamburg
MSC	mass scattering cross-section
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
OMI	Ozone Measurement Instrument
OPAC	Optical Properties of Aerosols and Clouds
PAS	photoacoustic spectrometer
ppm	part per million
PSAP	Particle Soot Absorption Photometer
RAINS	Regional Air Pollution Information and Simulation model
RETRO	Reanalysis of the TROposphere over the last 40 years
RF	radiative forcing
SAF	snow albedo feedback
SBC	change in surface snow BC concentration via change in sublimation
SPEW	Speciated Pollutant Emissions Wizard
SPRINTARS	
SP2	Single Particle Soot Photometer
SST	sea-surface temperature
ToA	top of the atmosphere
TRACE-P	Transport and Chemical Evolution over the Pacific
UIO-CTM	University of Oslo CCM
UMI	University of Michigan
USSR	Union of Soviet Socialist Republics

© 2013 American Geophysical Union. All Rights Reserved.

UTLS	upper-tropsphere-lower-stratosphere
UV	ultraviolet
WIE	warm cloud indirect effect
W	watt
WRF	Weather Research and Forecasting model

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Table R.2. Chemical definitions

Chemical	Definition
BC	black carbon
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
EC	elemental carbon
$MgCO_2$	megragram carbon dioxide
NMVOC	non-methane volatile organic compounds
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	sum of nitric oxide and nitrogen dioxide
OC	organic carbon
OM	organic matter
O_3	ozone
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5

© 2013 American Geophysical Union. All Rights Reserved.

	micron in diameter
POM	particulate organic matter
rBC	refractory black carbon
S	sulfur
SO_2	sulfur dioxide
VOC	volatile organic compounds

Accepted Article

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

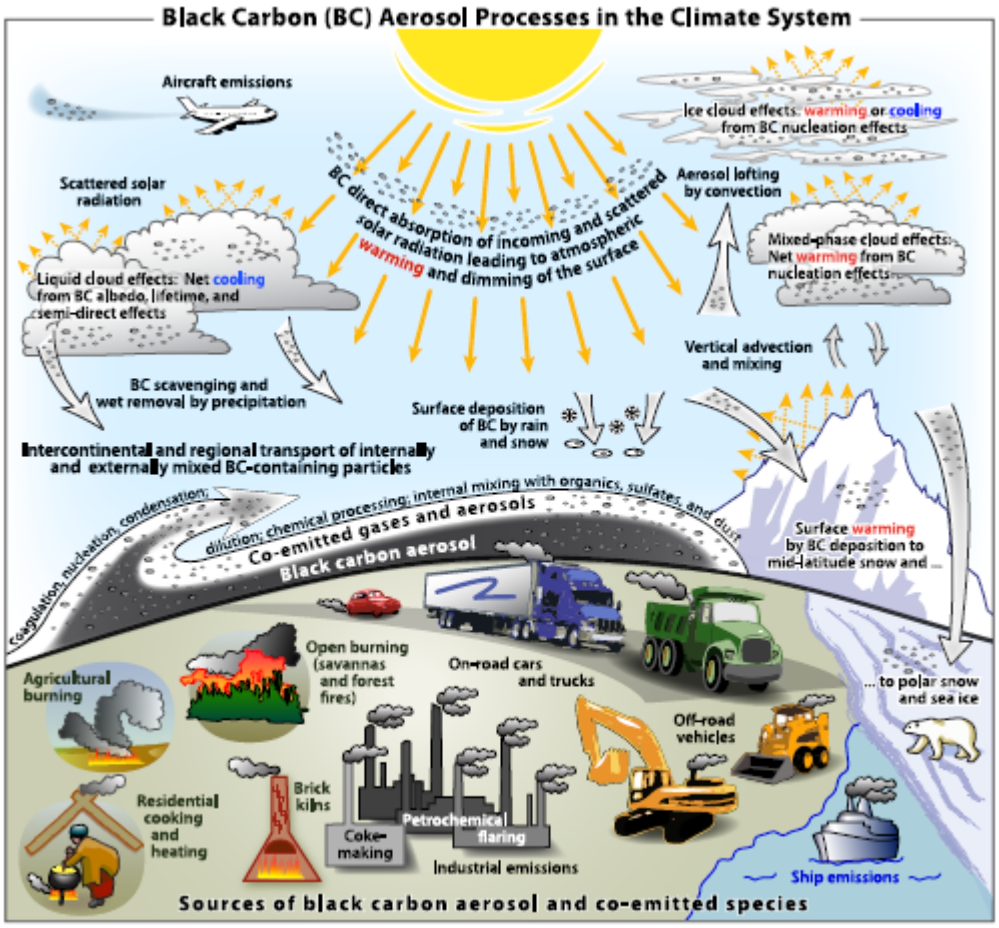


Figure 1.1. Schematic overview of the primary black-carbon emission sources and the processes that control the distribution of black carbon in the atmosphere and determine its role in the climate system.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

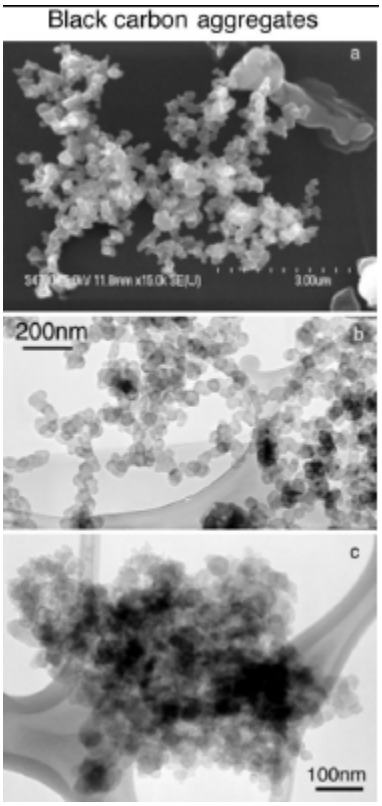


Figure 2.1. (a) Scanning electron microscope image of BC aggregates in young smoke from the Madikwe Game Reserve fire, South Africa, on 20 August 2000; (b) transmission electron microscope (TEM) image of chain-like BC aggregates in flaming smoke from the dambo fire near Kaoma, Zambia, on 5 September 2000; (c) TEM image of a compact BC aggregate in regional haze near Skukuza, South Africa, on 22 August 2000 [*Li et al.,* 2003). (Reproduced with permission of the American Geophysical Union).

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

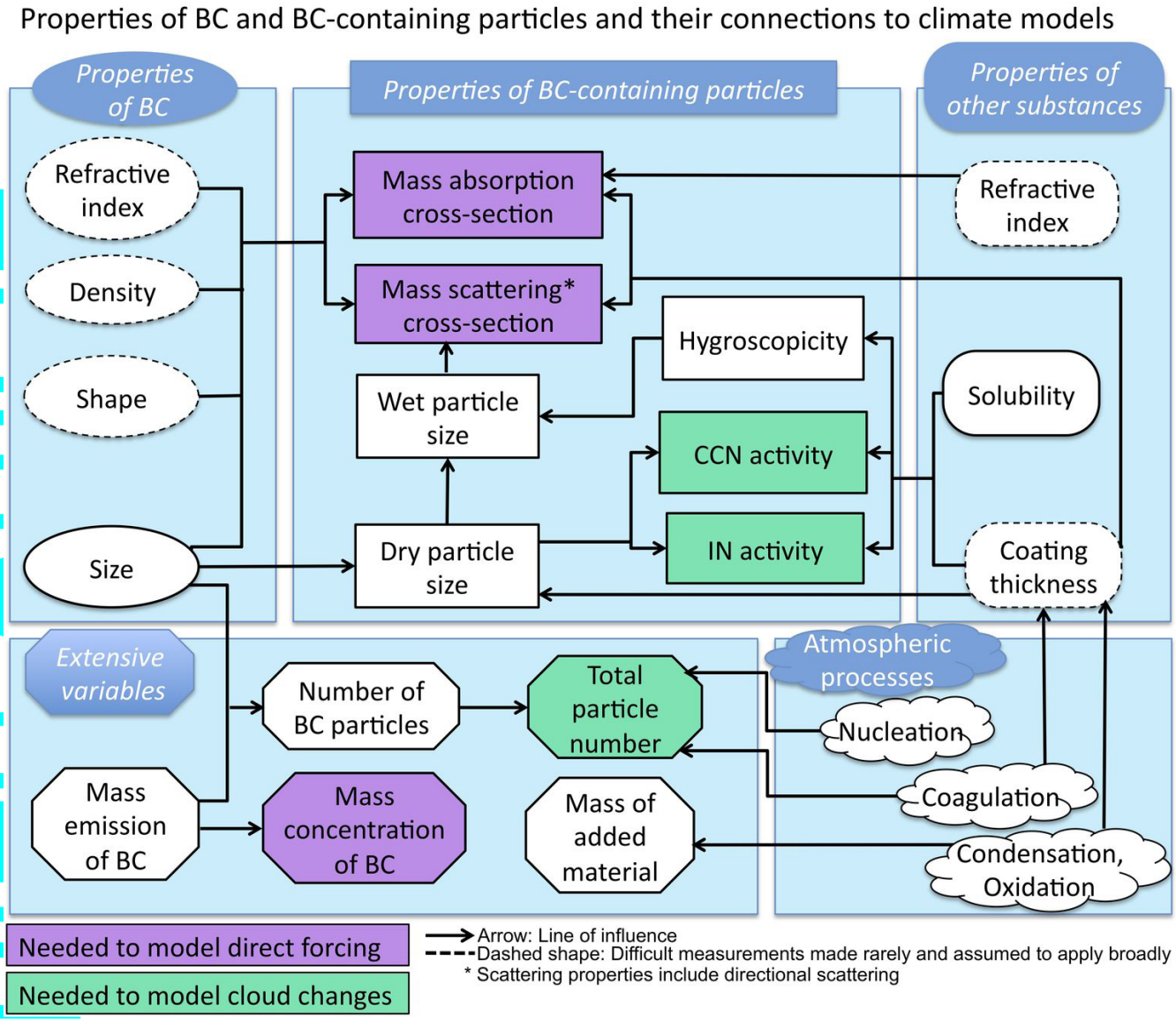


Figure 2.2. Schematic of the connections between properties of BC and BC-containing particles. A combination of these properties determines the contribution of BC and BC-containing particles to climate forcing. The properties depend on those of other substances produced in the atmosphere or co-emitted with BC, and on atmospheric processes such as nucleation and condensation. Mass and number of BC and BC-containing particles (extensive variables) depend, in part, on particle properties that affect the lifecycle of BC (not represented here).

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

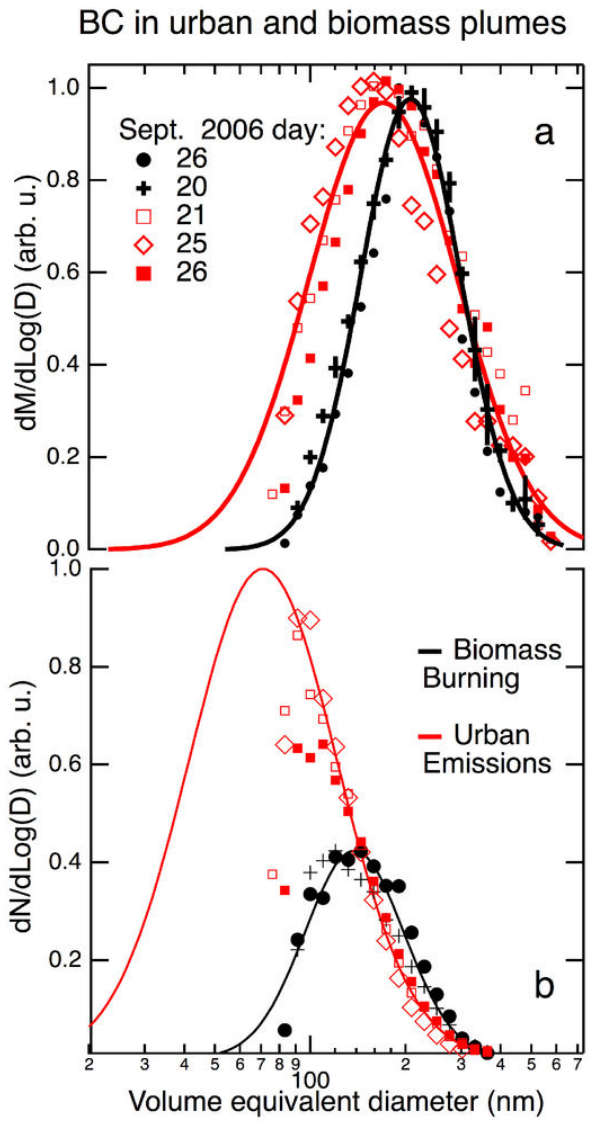


Figure 2.3. Mass and number size distributions of BC particles observed in three fresh urban (red) and two fresh biomass burning (black) plumes as identified in the legend. The measurements are made on board an aircraft using an in situ, single-particle detection instrument (SP2). The variable coatings on the BC particles is not shown. The observed mass (a) and number (b) amounts are plotted as symbols versus volume equivalent diameter based on assuming a spherical particle shape. The mass distributions are normalized to the same peak value. The observations are fit by a lognormal function between 90-600 nm (solid lines). The number distribution fits are those consistent with the fit to the respective mass distribution and are scaled to represent the same BC mass. From *Schwarz et al.* [2008b].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

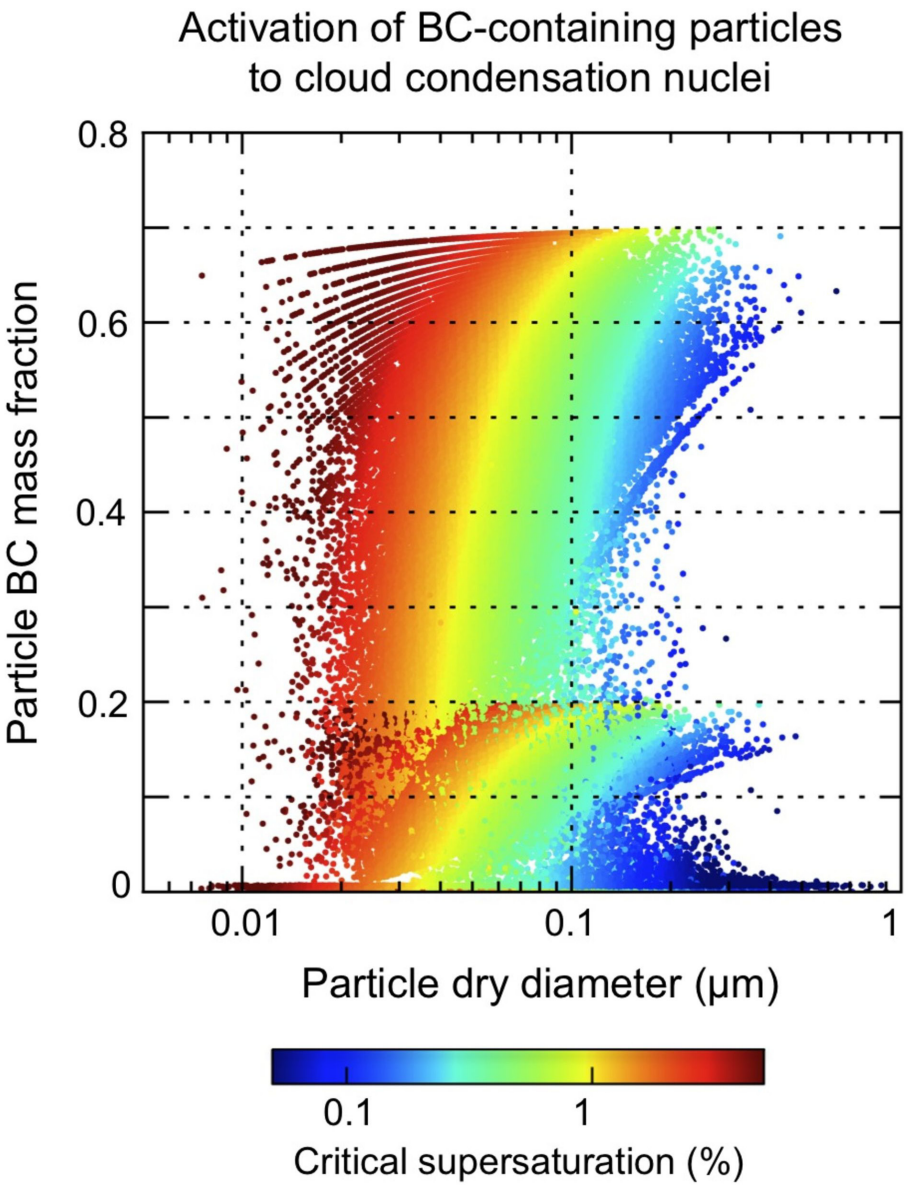


Figure 2.4. Critical supersaturation required to activate particles of varying size and BC content into cloud condensation nuclei. Higher supersaturation values mean that particles are less likely to become cloud droplets. Results are from a particle-resolved model that simulates coagulation and condensation in ambient air onto individual particles. The two branches show aged particles from diesel exhaust (70% BC) and gasoline exhaust (20% BC), assuming that Köhler theory describes activation. Particle diameter has the greatest effect on activation, with BC content inhibiting activation to a lesser extent. Figure is based on simulations [*Deville et al.*, 2011] of particle-resolved model [*Riemer et al.,* 2009].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

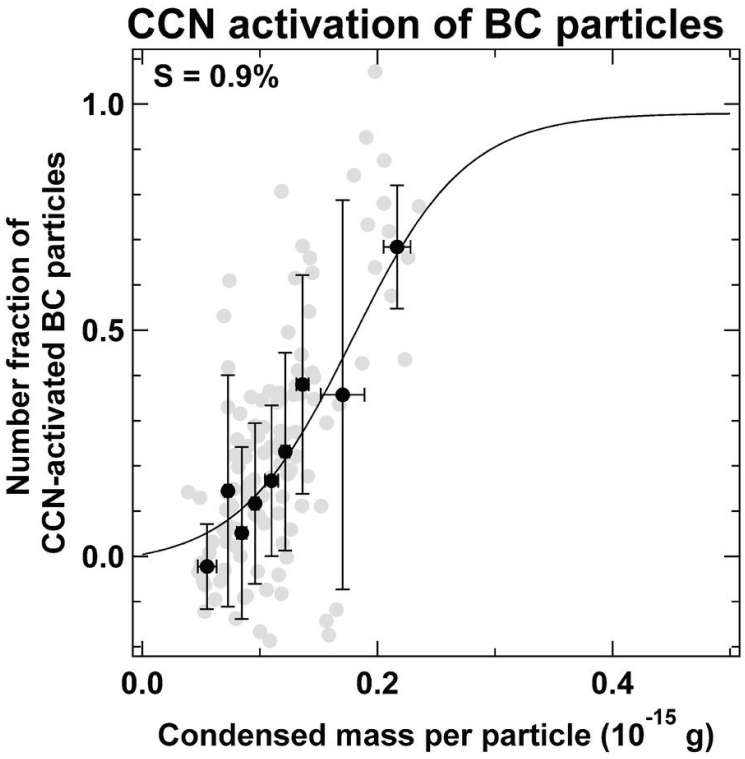


Figure 2.5. The number fraction of CCN-active BC particles versus mass of coating material for supersaturation of 0.9%. The data represent the response of 100-nm BC particles sampled in Tokyo in April 2007. The black points with 1-σ error bars are averages of the individual runs shown as gray data points. The solid curve is a sigmoidal fit to the averaged data points. A sigmoidal function is used because the ordinate should fall in the region between 0 and 1 by definition, although some deviations are apparent likely due to the measurement errors as well as some deviations from the assumptions employed for the calculation. Adapted from Figure 11 of *Kuwata et al.* [2009].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

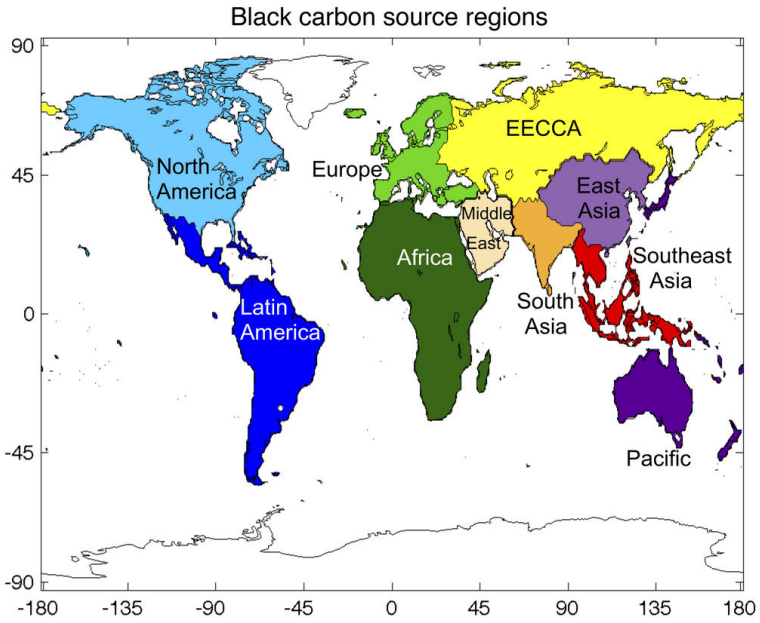


Figure 3.1. Regions (country groups) used for summarizing emissions and concentrations in this assessment. EECCA = Eastern Europe, Caucasus and Central Asia. The regional country groups are listed in Table S.1.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

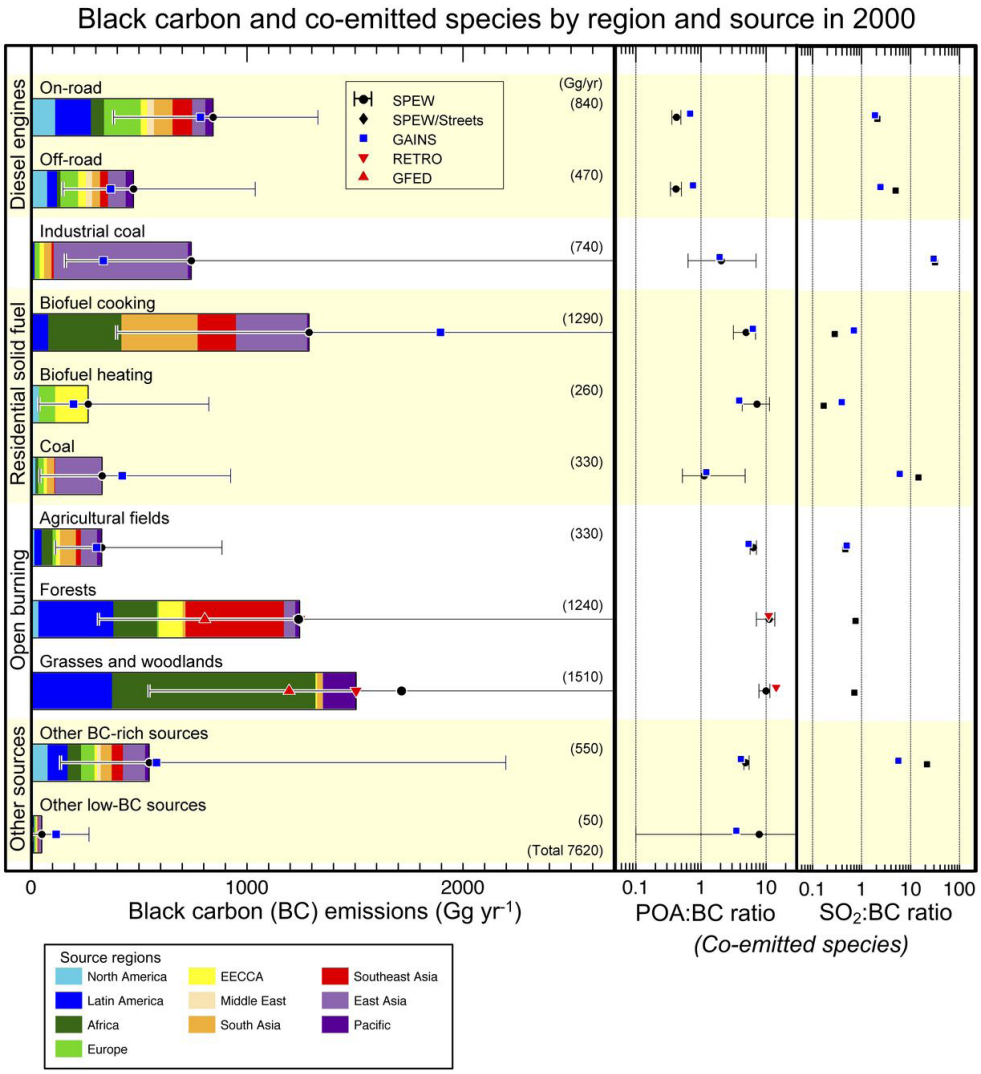


Figure 3.2. Emission rates of BC in the year 2000 by source category, and ratios of co-emitted aerosols (*e.g.,* primary organic aerosol, POA) and aerosol precursors (*e.g.,* SO_2) to BC. For reference, it is often assumed that the ratio of OA to primary organic carbon (OC) varies from 1.1 to 1.4, depending on the source (Section 2.2.2). SPEW emissions are shown as colored bars and are described by *Lamarque et al.* [2010]. GAINS estimates are from *UNEP/WMO* [2011a; b] and RETRO emissions for open burning are described by *Schultz et al.* [2008]. Sulfur emissions from *Streets et al.* [2009] were used for ratios to SPEW. Regions are shown in Figure 3.1.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

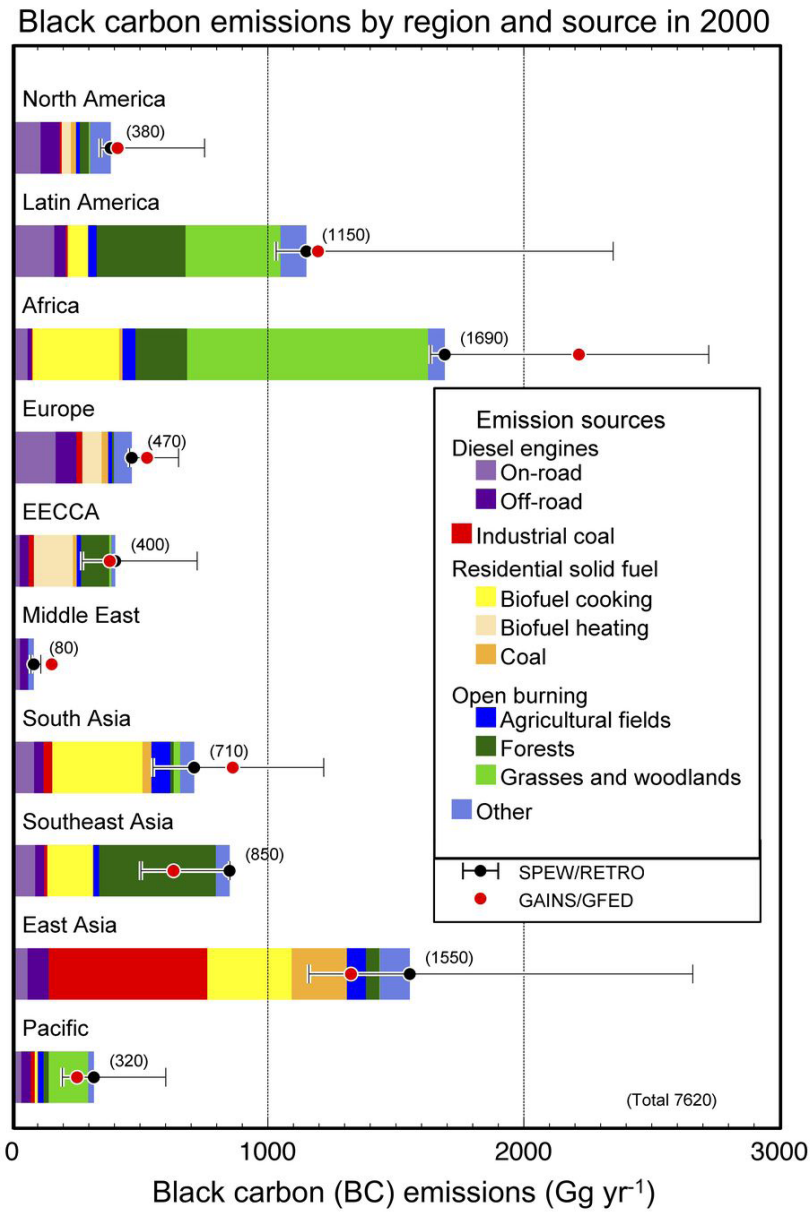


Figure 3.3. Emission rates of BC in the year 2000 by region, indicating major source categories in each region. SPEW, GAINS and RETRO emission data are the same as in Figure 3.2. Regions are shown in Figure 3.1.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

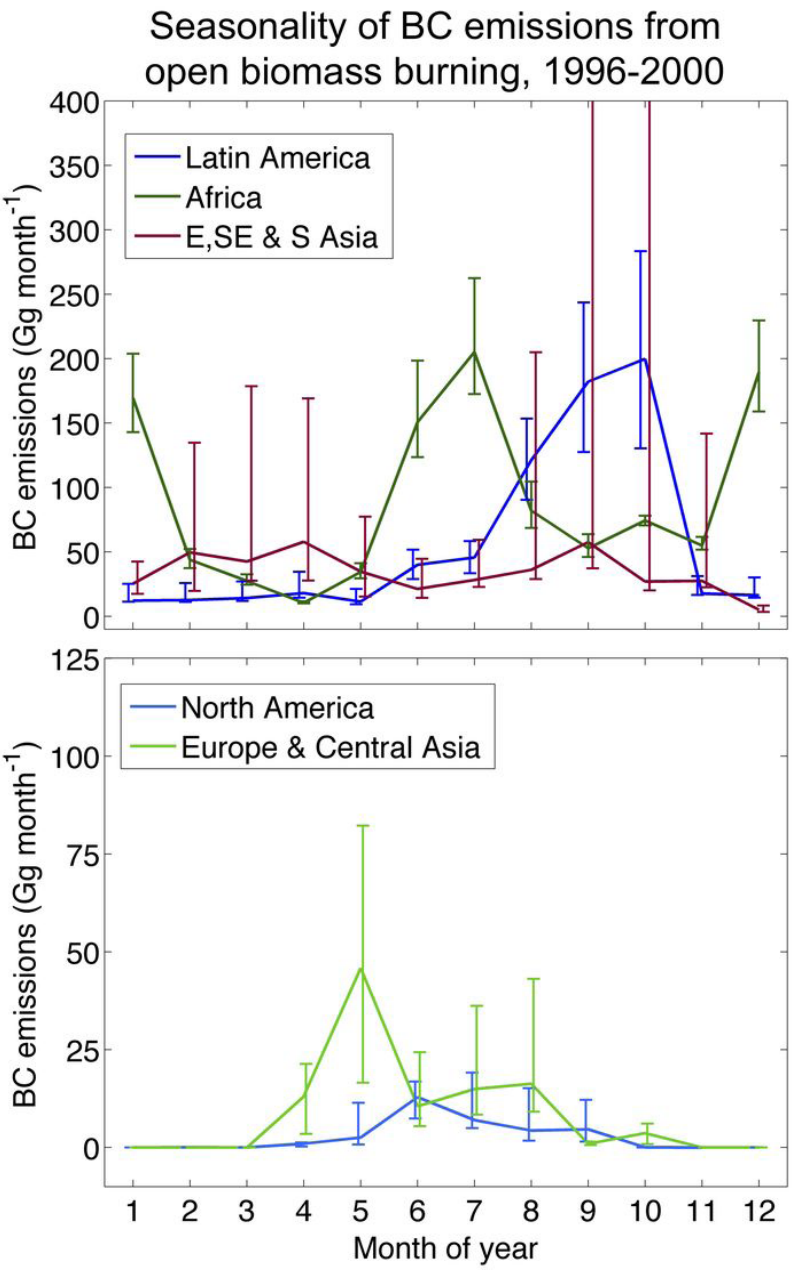


Figure 3.4. Seasonality of BC emissions from forest, grassland and woodland burning. Average monthly emissions estimated by RETRO for the period 1996-2000 are shown [*Schultz et al.*, 2008]. Error bars indicate minima and maxima during each period. Regions correspond to those in Figure 3.1. Africa, which includes the small Middle East emissions, has two burning seasons because the equator bisects it. The group of East, Southeast and South Asia (E, SE & S Asia) includes emissions from Oceania. The very large error bars in that region results from the very high-fire season in 1997. Note the different vertical scales in the two panels.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

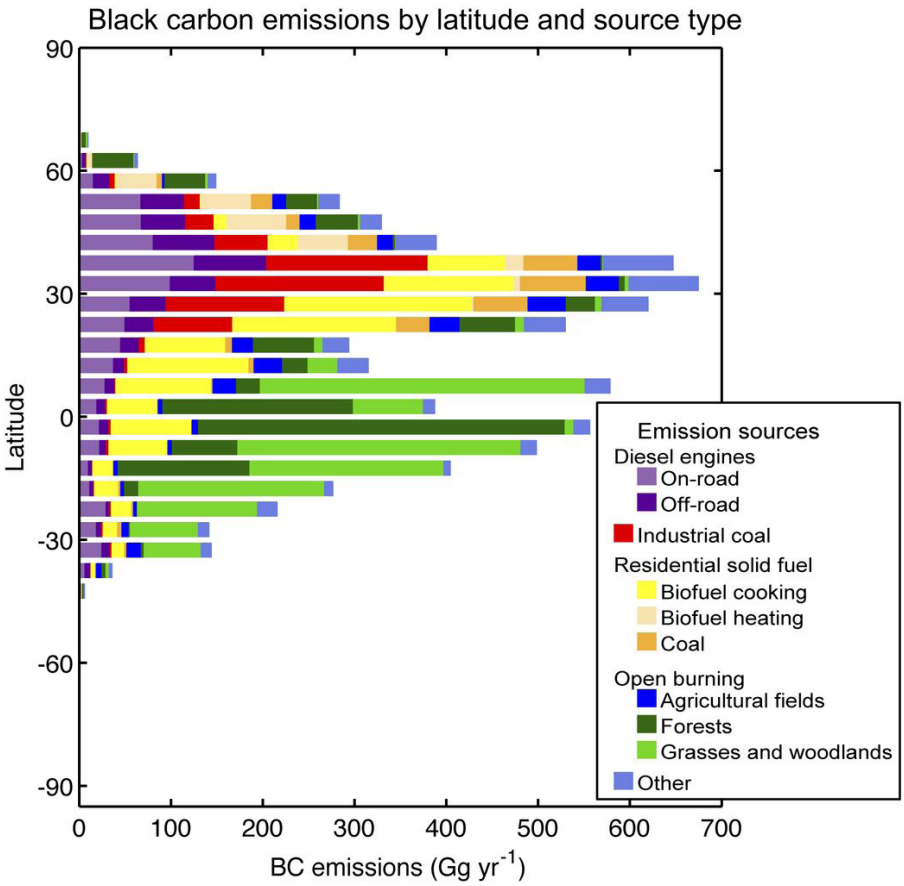


Figure 3.5. Latitude plot of the data shown in Figures 3.2 and 3.3 using 5° latitude bins.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

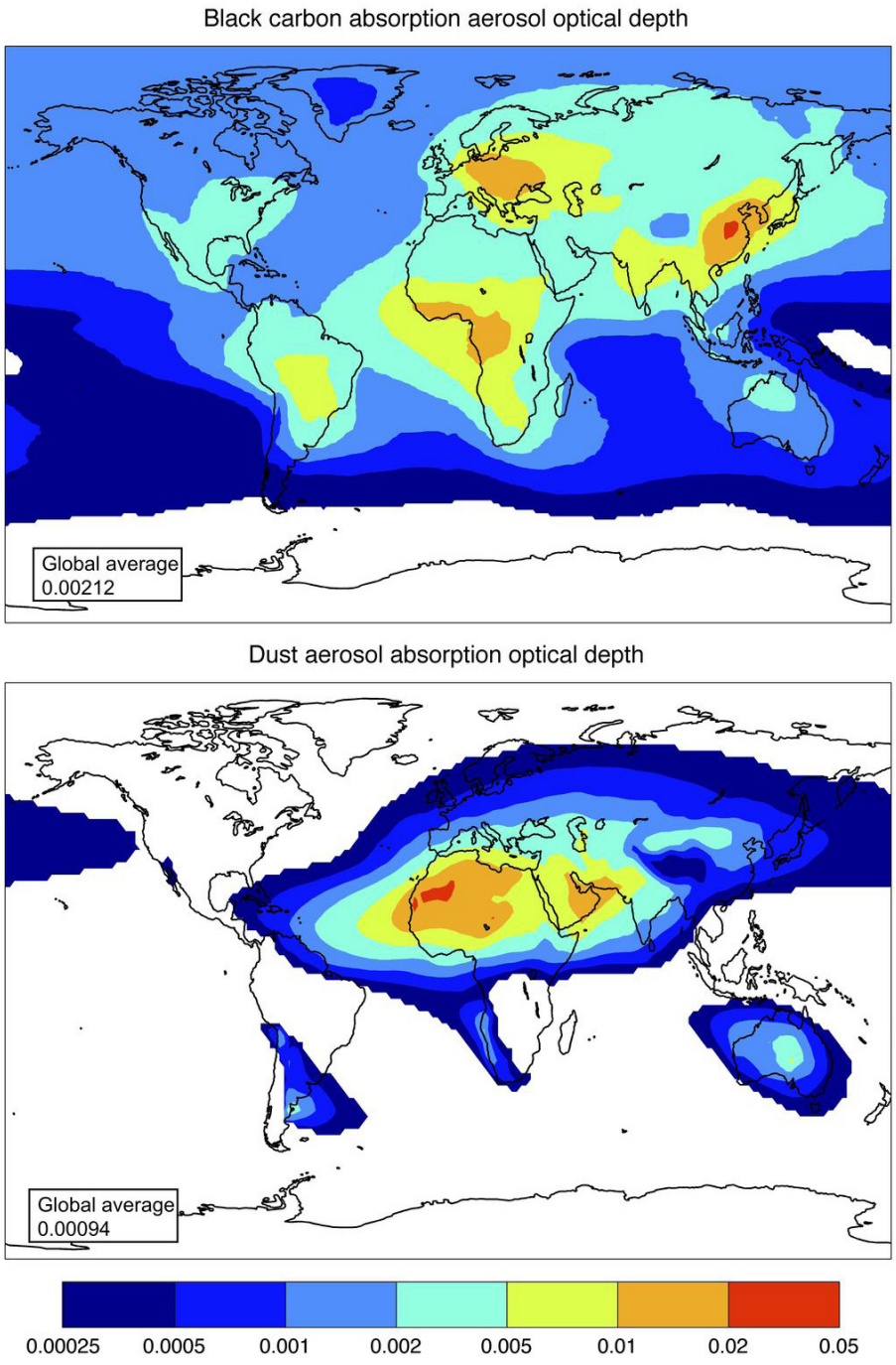


Figure 4.1. Aerosol absorption optical depth (AAOD) at 550 nm attributable to BC and dust. BC-AAOD fields are from the AeroCom median model fields [*Schulz et al.,* 2006] of all-source BC, including AAOD that would have been present before the pre-industrial era. Dust distribution is from *Luo et al.* [2003], with AAOD calculated from particle size in *Mahowald et al.* [2006] and optical properties in *Yoshioka et al.* [2007].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

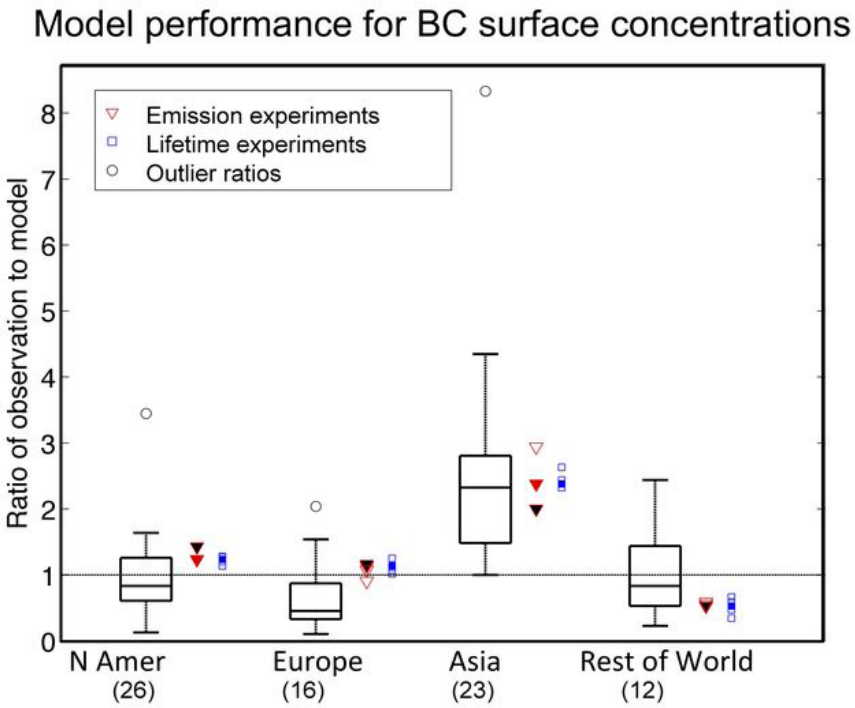


Figure 4.2. Evaluation of model performance and model sensitivities for simulating BC concentrations in surface air for specific regions and the rest of the world. Box plots show ratios between observations and models (*i.e.*, the factor by which modeled values are multiplied to obtain observed values). The middle bar in each box shows the median model value. Box boundaries show 25th and 75th percentiles. Data points outside 1.5 times the interquartile distance from the box are marked as outliers; otherwise, they are included in the whiskers. Symbols show sensitivity experiments using different emission databases (red triangles) and removal rates (blue squares) in a single model (GISS) with the base case shown as filled symbols. For emission experiments, SPEW is shown with red fill and GAINS with black fill; unfilled symbols show results using two other emission databases. The number of surface observations is shown below each region name. Data from *Koch et al.* [2009a].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

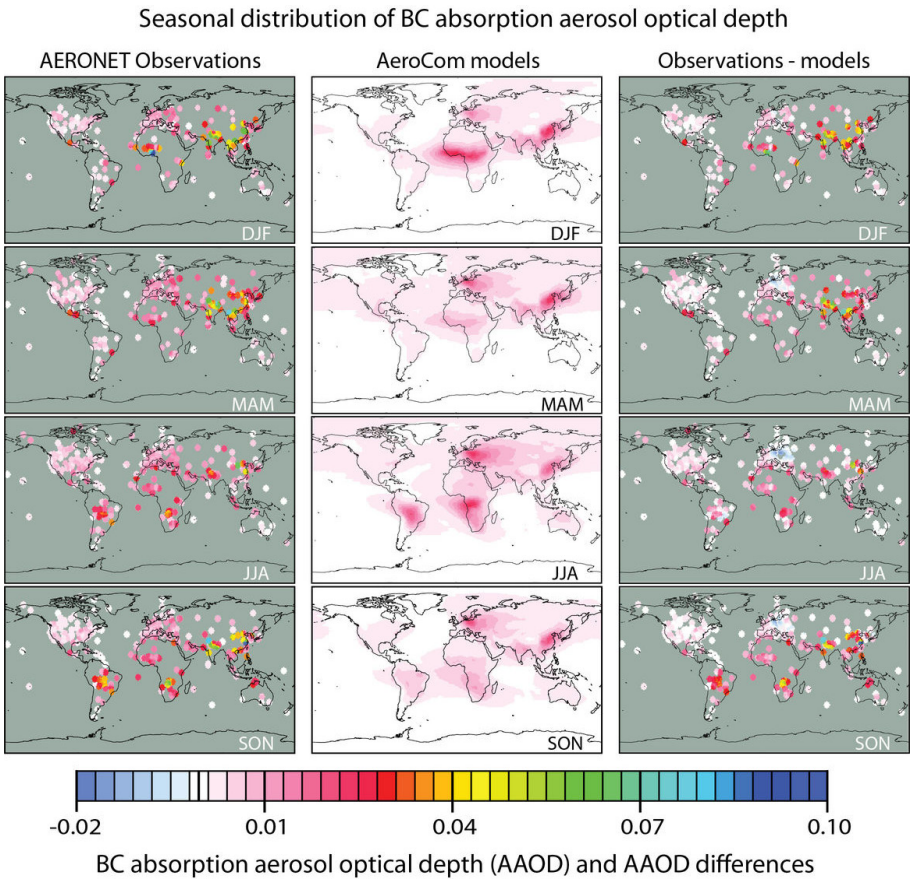


Figure 4.3. Seasonal absorption aerosol optical depth (AAOD) at 550 nm due to BC as inferred from observations and from models. The left-panels show seasonal averages for BC AAOD at AERONET sites, as they were derived from sky-inversion data that were sampled during the last decade (2000-2010). Each symbol represents an AERONET site. The middle panels show seasonal BC-AAOD median maps of AeroCom models (listed in Table 5.1) for year 2000 conditions (see text for methods). The right panel shows differences between the BC-AAOD values inferred from AERONET observations (left column) and AeroCom modeling efforts (middle column) at each location, illustrating deficiencies in global modeling of BC.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

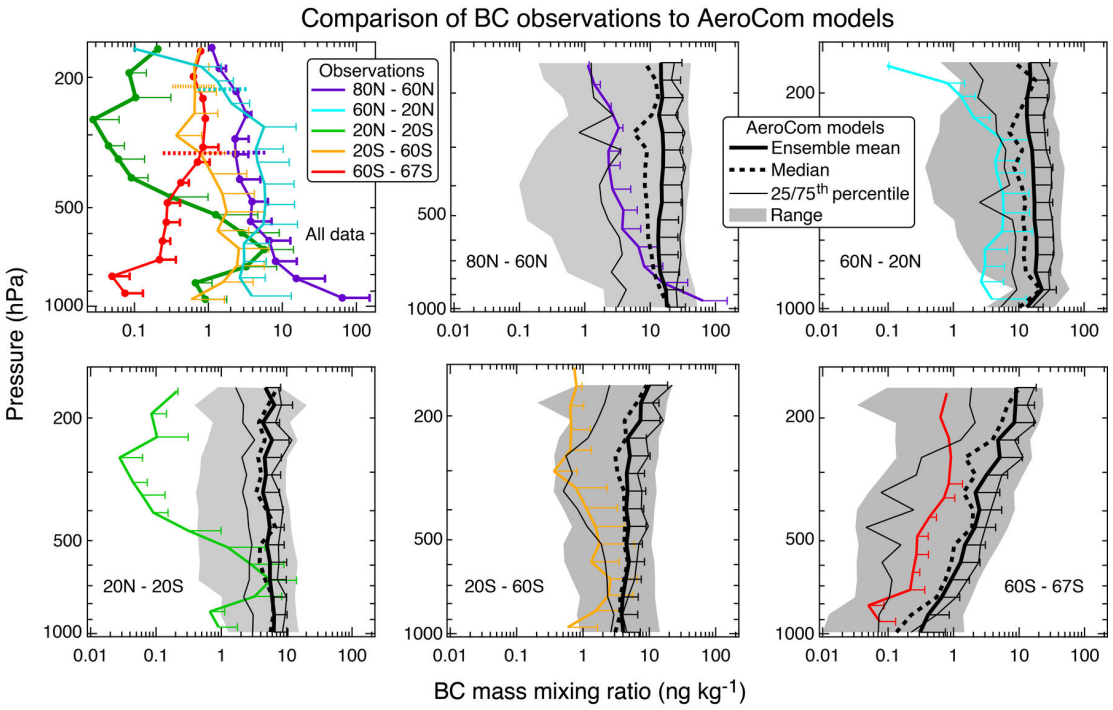


Figure 4.4. Airborne, in situ measurements of BC made in the remote Pacific Ocean between 80°N and 67°S in January 2009 using an SP2 instrument. Upper left panel: average measured BC mass concentrations observed in five latitude bands with whiskers representing atmospheric variability. In the additional panels, colored lines repeat the observed average profiles and include the range of BC mass mixing ratios from the AeroCom model suite. The legend explains lines and shading used to represent model results. The whiskers are numerically symmetric about the average values but are omitted on the left side to simplify the presentation on a log-scale. Adapted from *Schwarz et al.* [2010].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

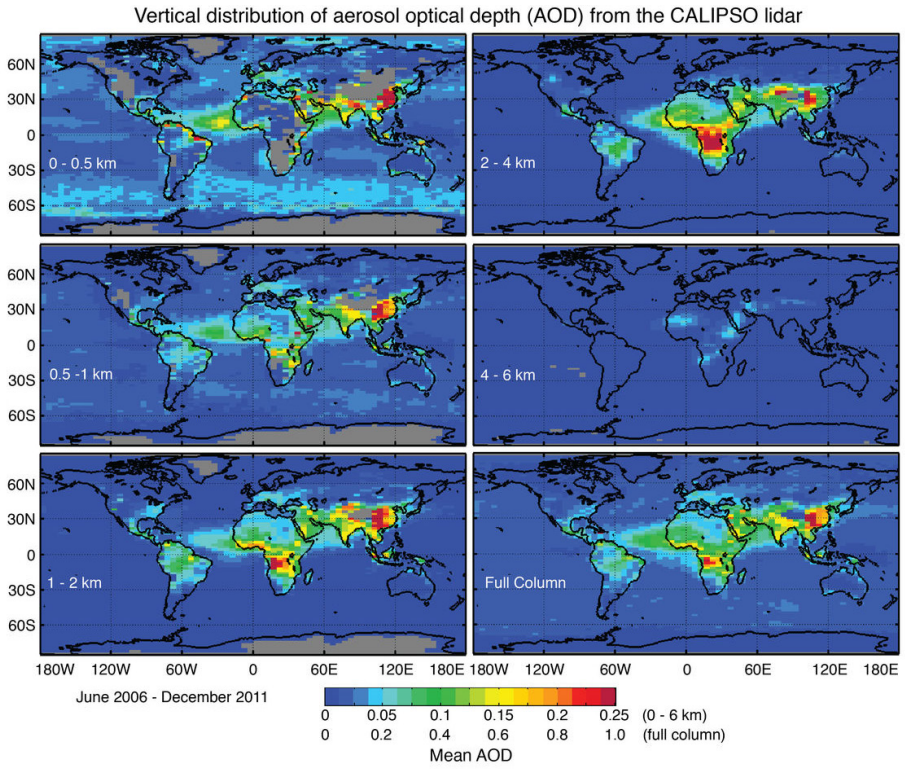


Figure 4.5. Multi-year averages of the global vertical distribution of mid-visible (532 nm), AOD from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) spaceborne lidar on the NASA CALIPSO satellite. The panel colors show average AOD derived from CALIOP observations from June 2006 to December 2011 (Version 3) for specific altitude intervals referenced to sea level (see legends). The color bar has separate scales for the 0 to 6-km and full-column data panels as indicated. The full-column AOD is shown in the bottom right panel. The gray shading indicates 'no observations' usually because of elevated land surfaces. CALIOP statistics were provided by D. Winker of NASA Langley Research Center (Hampton, VA, USA).

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

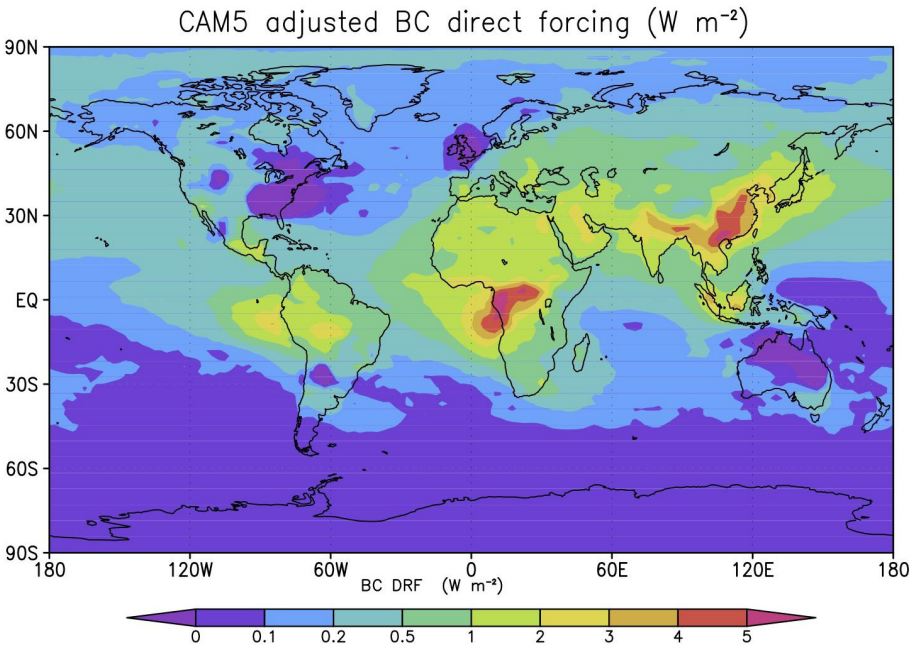


Figure 5.1. Annual mean direct radiative forcing by BC from 1850 to present day, as estimated by the CAM5 AeroCom model and adjusted according to the global annual mean bias of about 1.6, similar to the scaling of BC AAOD derived in the comparison with Aeronet observations (see Table 5.2 and Section 5.7.1). Forcing is negative in regions where biomass or fossil fuel (*e.g.*, coal) emissions were large in 1850. Year 1750 emissions from these regions would be lower, so the total radiative forcing would be more positive. Based on *Liu et al.* [2012] and *Ghan et al.* [2012].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

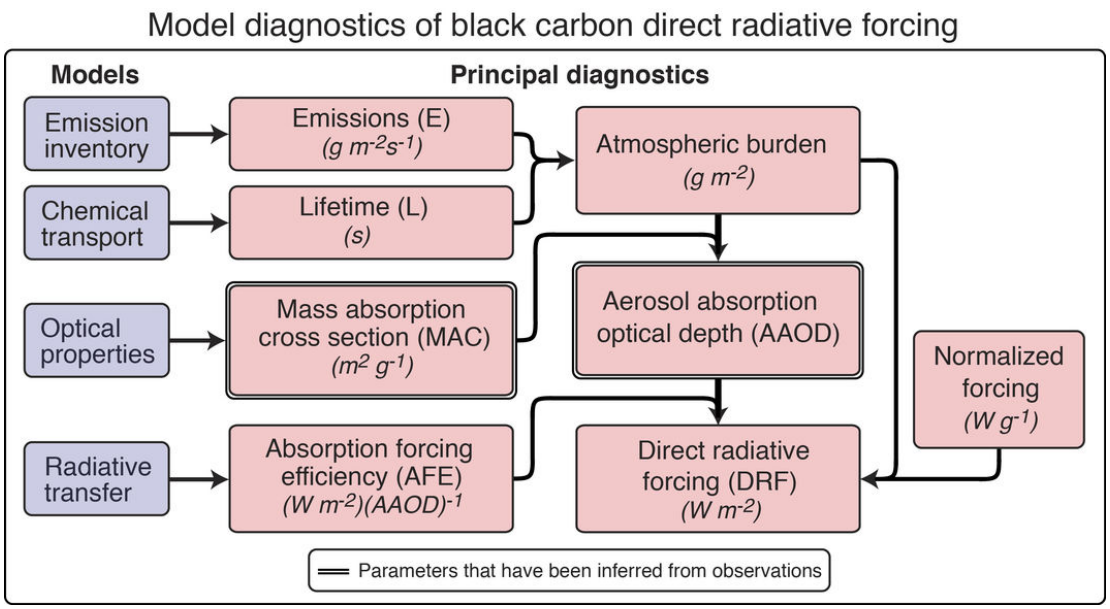


Figure 5.2. Schematic showing the relationships between principal diagnostics of models used to simulate BC direct radiative forcing (DRF) and the role of models in deriving these diagnostics. The arrows show which diagnostics can be multiplied to yield another diagnostic. The schematic expands upon Equation 5.1 which expresses DRF as a product of factors DRF = E L MAC_{BC} AFE. The diagnostics shown within double lines can be directly inferred from observations.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

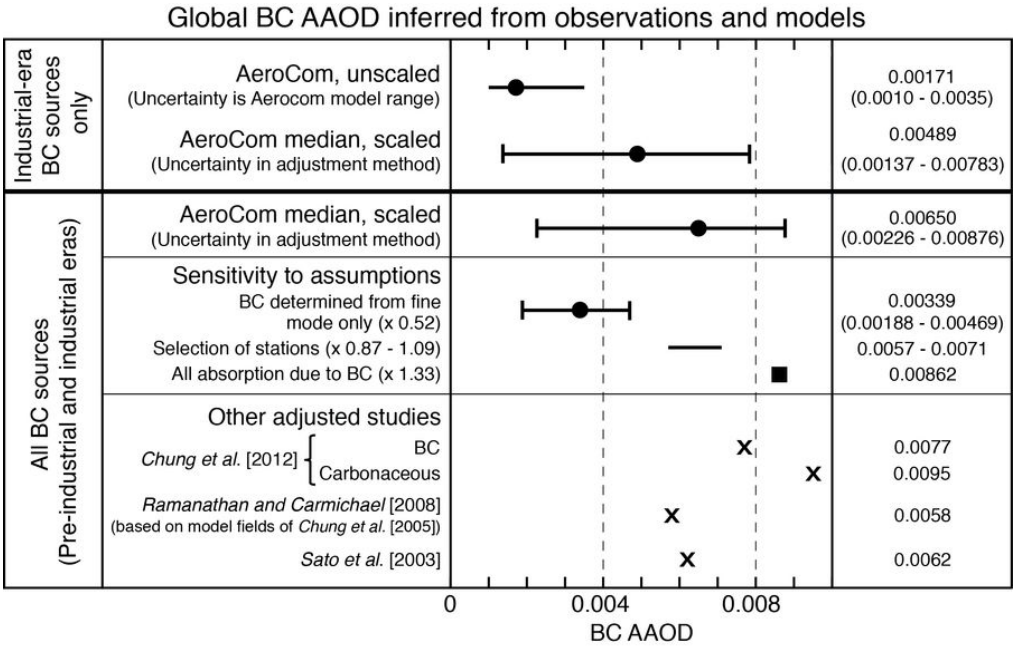


Figure 5.3. Summary of the sensitivity of global BC-AAOD derived from AeroCom models. The scaling of AeroCom BC-AAOD values is based on AERONET observations following the method in Appendix B and discussed in Section 5.4. Separate unscaled and scaled AeroCom model values are shown in Table 5.2. Data points (circles) are AeroCom median values. Ranges are shown with lines and uncertainty with whiskers. Not shown on the figure due to limited scale is an estimate of scaling to average BC AAOD inferred from AERONET version 2.0 averages (0.0143). The sensitivity of scaled all-source BC-AAOD to key assumptions in using the AERONET observations is shown for three cases (see text). Three other model study results are shown at the bottom for comparison. Central estimates, value ranges and uncertainty ranges are shown in the right-hand column.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

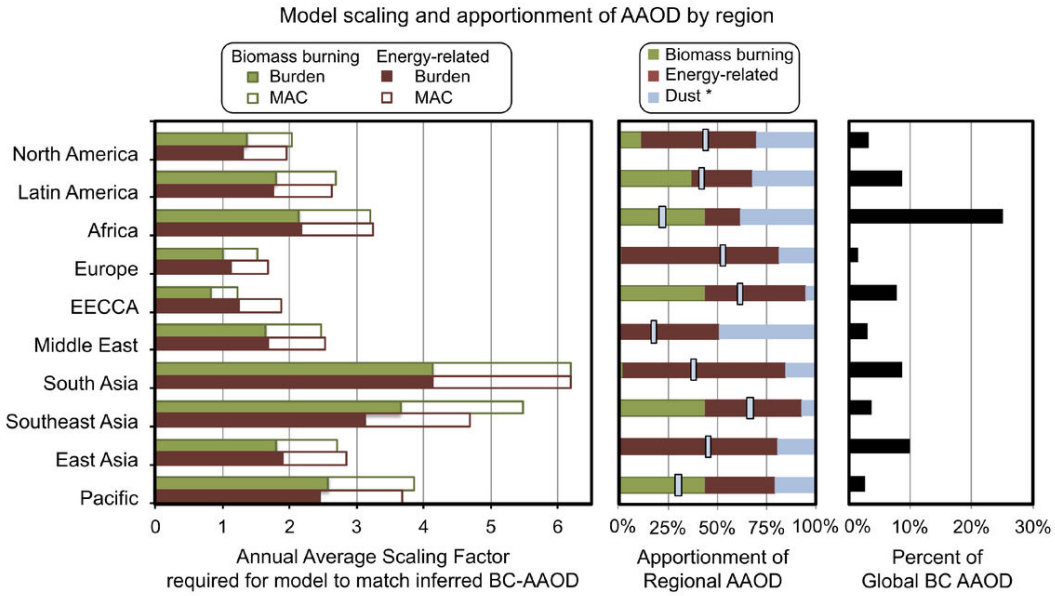


Figure 5.4. Summary of regional BC aerosol absorption optical depth (BC AAOD) scaling and contributions. Left: Summary of regional scaling factors required for AeroCom median model values to match BC AAOD constrained by AERONET observations. The regions are shown in Figure 3.1. Scaling factors are effective annual averages apportioned between open biomass burning and energy related burning. Each factor is an annual average of monthly scaling factors in each region and includes a prescribed MAC_{BC} scaling of 1.5 for all months and regions (open bar), the approximate ratio between the MAC_{BC} of internally and externally mixed BC. The remainder of the scaling is attributed to burden. Center: Estimate of BC AAOD fraction in each region due to energy-related combustion, biomass burning, and dust; the dust contribution is not a true estimate of dust AAOD but of dust AAOD in AERONET. The small blue rectangles indicate where the left boundary of the dust AAOD would lie if BC AAOD were determined by applying AERONET refractive indices to the fine mode of the retrieved size distribution. Right: Contribution of modeled, scaled BC AAOD over land to global total BC AAOD. These percentages do not sum to 100% because BC AAOD over oceans is excluded.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

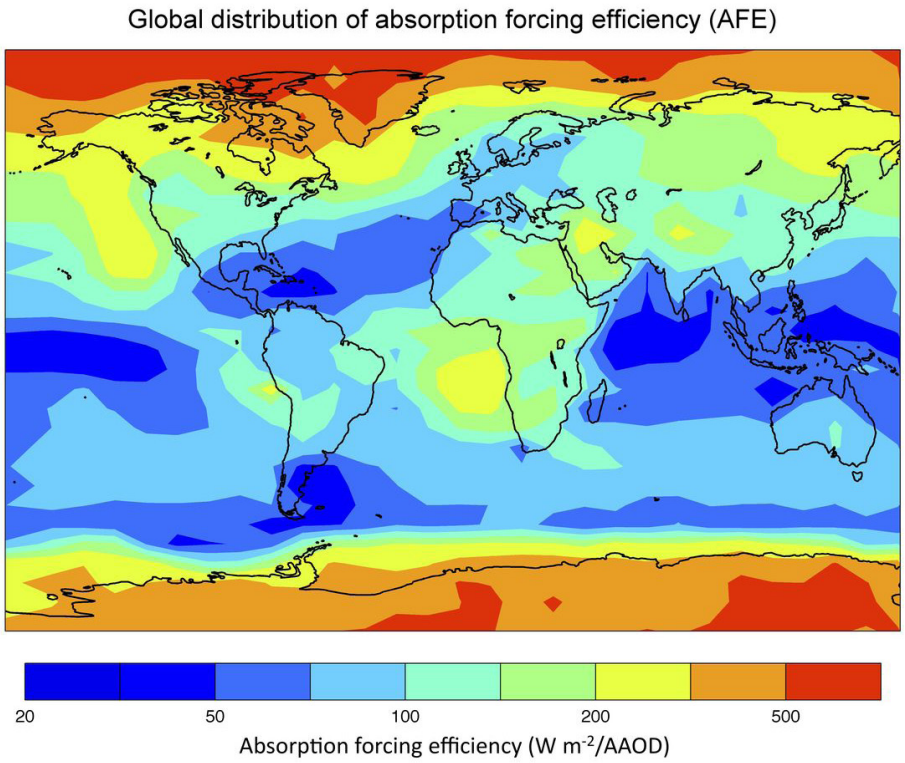


Figure 5.5. Global distribution of absorption forcing efficiency (AFE) defined as direct radiative forcing divided by aerosol absorption optical depth (AAOD). Both forcing and AAOD used are AeroCom median values as described in Section 4.3.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

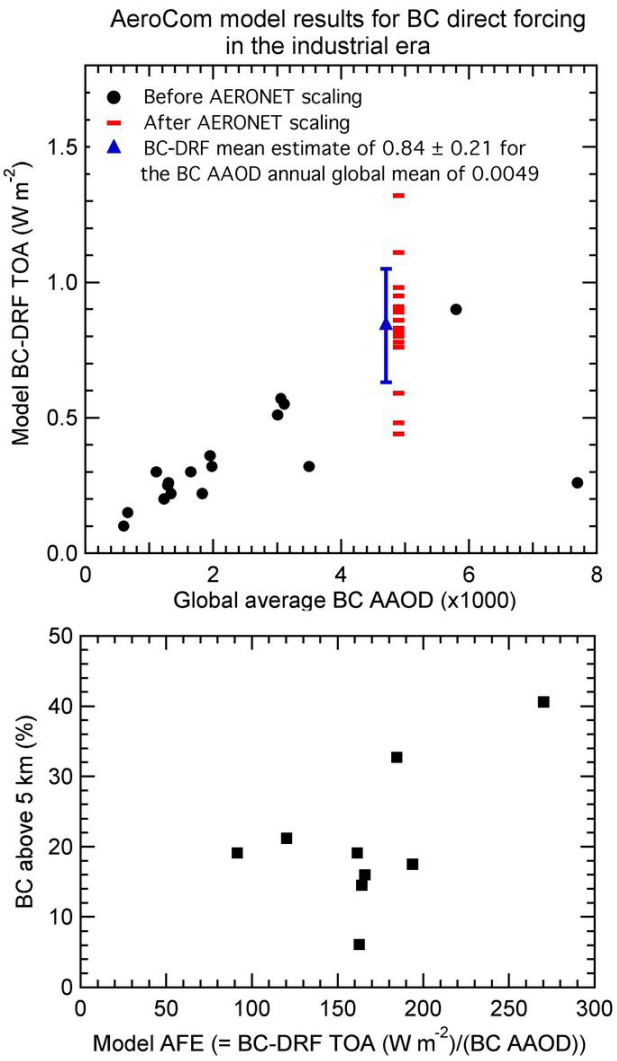


Figure 5.6. AeroCom model results for BC DRF in the industrial era. Top: Unscaled Aerocom BC DRF versus global average BC AAOD in each model (circles) and scaled BC-DRF values (short lines) plotted at the AeroCom median AAOD value (0.0049). BC AAOD is proportional the amount of BC in the atmosphere. Unscaled models with higher BC AAOD generally have higher BC DRF. When BC DRF from each model is scaled to the BC AAOD global mean value of 0.0049, the resulting BC DRF has a mean and standard deviation of 0.84 ± 0.21 W m^{-2} (blue triangle slightly offset for clarity). Bottom: The percentage of BC above 5 km versus absorption forcing efficiency (AFE) in several Aerocom models. Data presented here are also provided in Tables 5.1 and 5.2. The scaling of BC DRF in AeroCom models is discussed in Section 5.7.1. The forcing average shown here is reduced for the best estimate of forcing, as discussed in Section 5.7.2.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

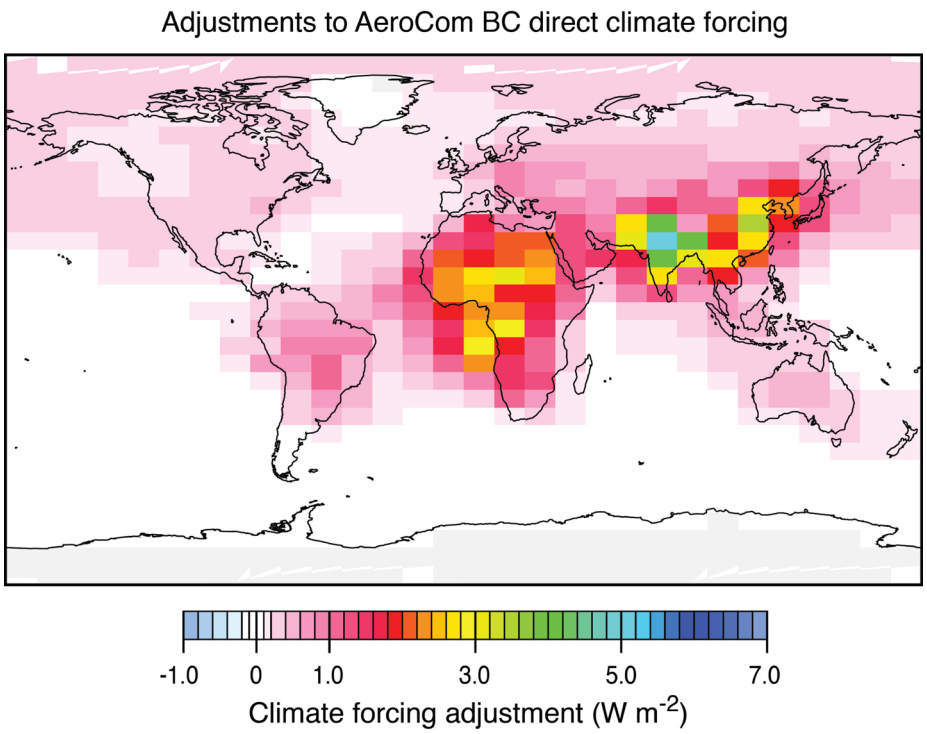


Figure 5.7. Adjustments to the annual mean, direct radiative forcing (W m^{-2}) by BC in the median AeroCom model required for consistency with the AERONET retrieved aerosol absorption optical depth (AAOD).

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

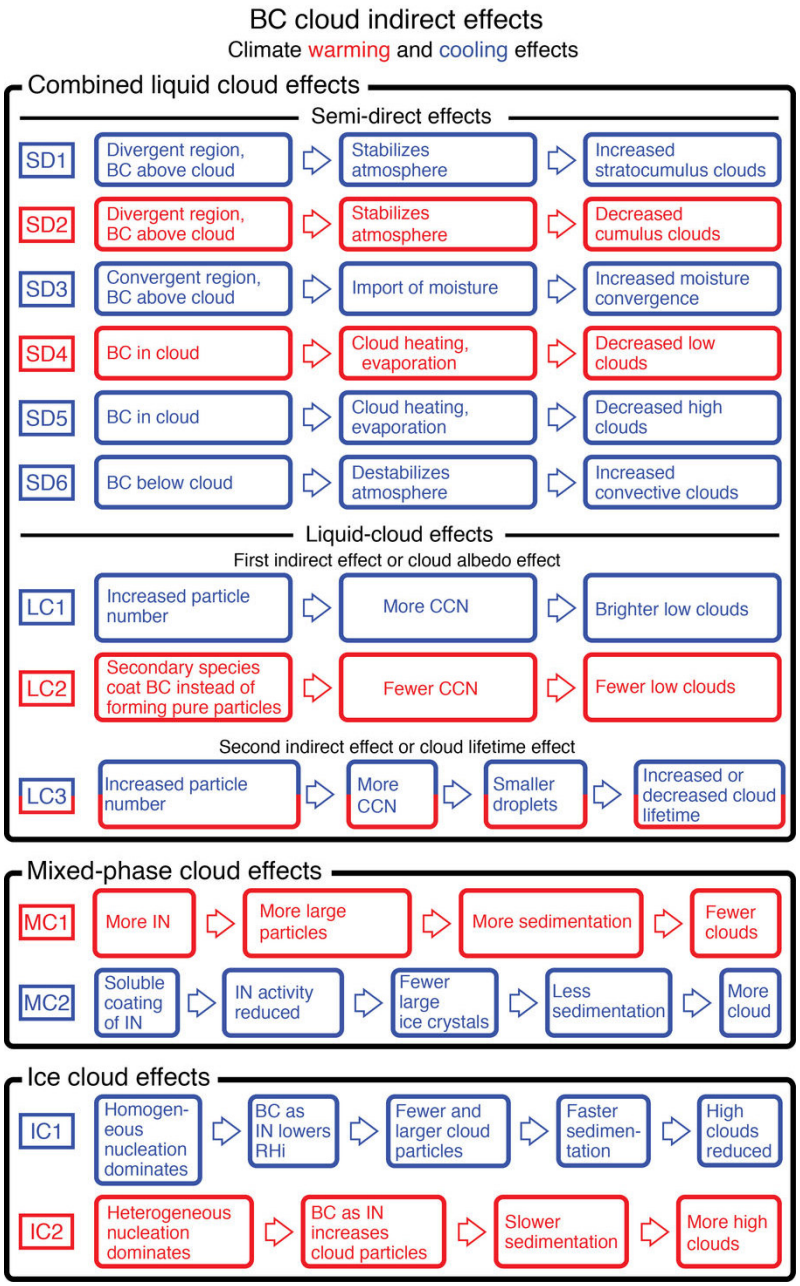


Figure 6.1. Schematic of the causes and effects that lead to cloud effects from BC emissions. Each row begins with an identifying label followed by a cause, namely an atmospheric or microphysical parameter representing a potential perturbation to cloud properties. To the right of each cause are the response(s) to the perturbation. On the far right is the associated effect, namely, the cloud parameter that changes in response to the perturbation. The single color of the components in a row indicates a climate system response of warming (red) or cooling (blue). The split coloring in LC3 indicates that the response can be either warming or cooling (see Section 6.2). Although MC2 is not attributable directly to BC, it is included here because it alters the effects of BC.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

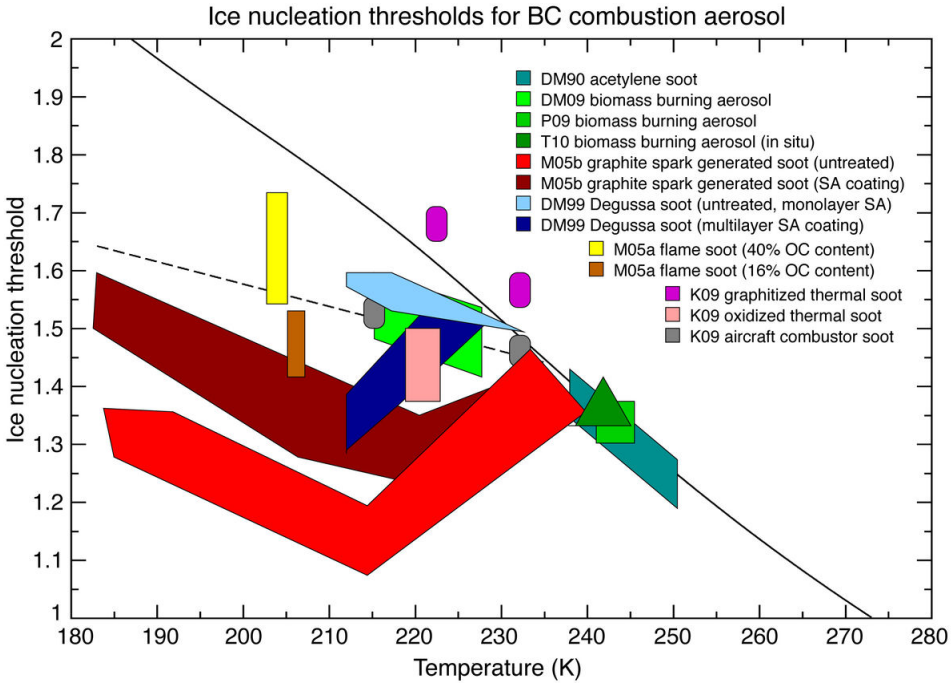


Figure 6.2. Compilation of heterogeneous ice nucleation threshold ranges of combustion aerosol samples from BC sources as a function of temperature. The ice nucleation threshold is the supersaturation with respect to ice at which the aerosol activates. Color-shaded regions show data from *DeMott* [1990] (DM90); *DeMott et al.* [1999] (DM99); *Möhler et al.* [2005a/b] (M05a/b); *Petters et al.* [2009] (P09); *DeMott et al.* [2009a] (DM09); *Köhler et al.* [2009] (K09); and *Twohy et al.* [2010] (T10). The dashed curve represents the equilibrium ice saturation ratio required to freeze an aqueous solution droplet of diameter 500 nm in 1 s [*Koop et al.*, 2000]. The solid curve is the water saturation curve, or the vapor pressure ratio of supercooled liquid water to hexagonal ice [*Murphy and Koop*, 2005]. Figure updated from *Kärcher et al.* [2007].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

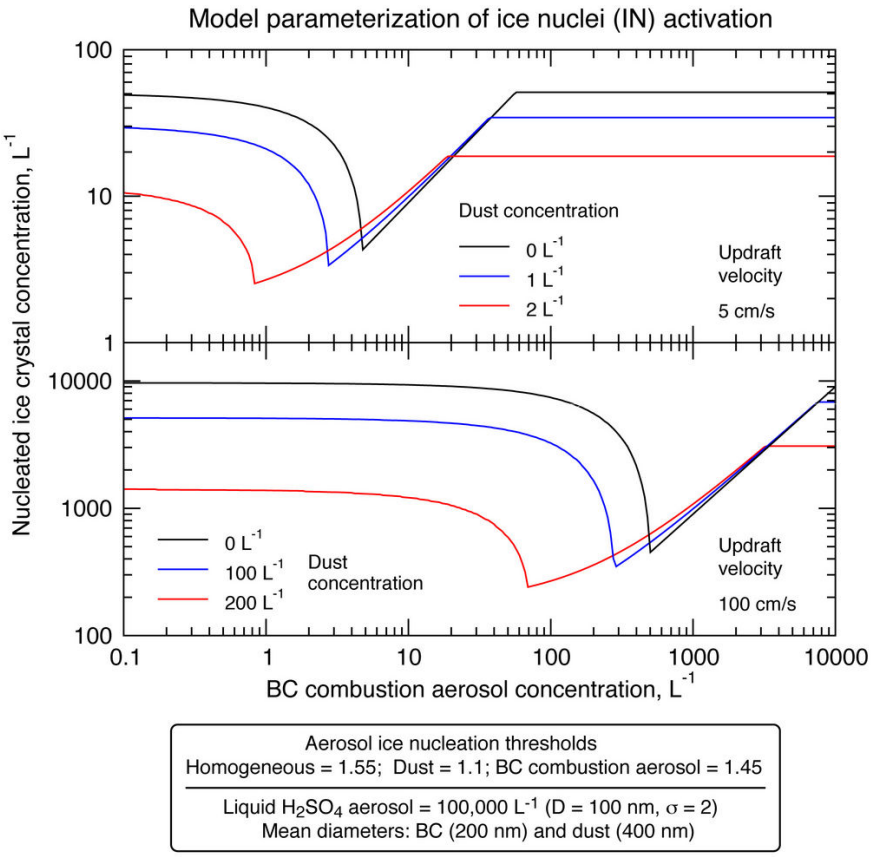


Figure 6.3. Calculated total number concentration of nucleated ice crystals as a function of BC combustion particle number concentration. Ice particle number results from the competition of three particle types (liquid H_2SO_4/H_2O droplets acting as homogeneous freezing nuclei, and dust and BC particles acting as heterogeneous IN) during ice formation in adiabatically rising air parcels (sharp ice nucleation thresholds for the IN given in the legend). Results are shown for an updraft velocity of 5 cm/s (top panel, synoptic-scale vertical winds), and 100 cm/s (bottom panel, strong orographic waves or convective cells). In the simulations, air parcels start rising at 250 hPa and 220 K at ice saturation and contain mineral dust particles with concentrations noted in the legends, a wide range of BC (10^3 L^{-1} = 1 cm^{-3}) concentrations, and a fixed concentration of log-normally distributed aqueous H_2SO_4 particles. Dust and soot particles are assumed to be monodisperse. Adapted from *Kärcher et al.* [2007].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

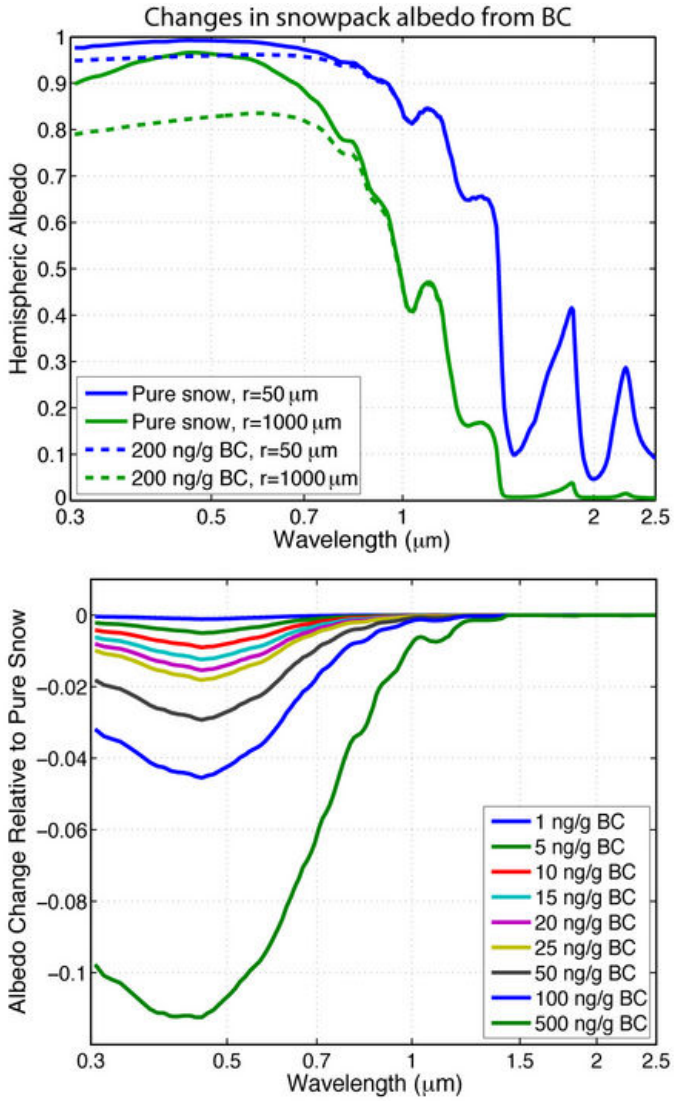


Figure 7.1. Top: Spectrally resolved, hemispheric albedo for snowpack effective grain sizes of radii (r) of 50 and 1000 μm, with and without BC mixing ratios of 200 ng/g, for a semi-infinite snowpack and with diffuse incident solar radiation. Changes in grain size most strongly affect albedo at near infrared wavelengths, whereas BC lowers albedo most strongly at visible and ultraviolet wavelengths. Bottom: the reduction in hemispheric albedo caused by various mixing ratios of BC as a function of wavelength, for a snowpack with effective grain size of 200 μm. BC optical properties are those used by *Flanner et al.* [2007, 2009] for hydrophobic (uncoated) particles, tuned to match recommendations from *Bond and Bergstrom* [2006]. Albedo calculations were made following *Flanner et al.* [2007, 2009].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

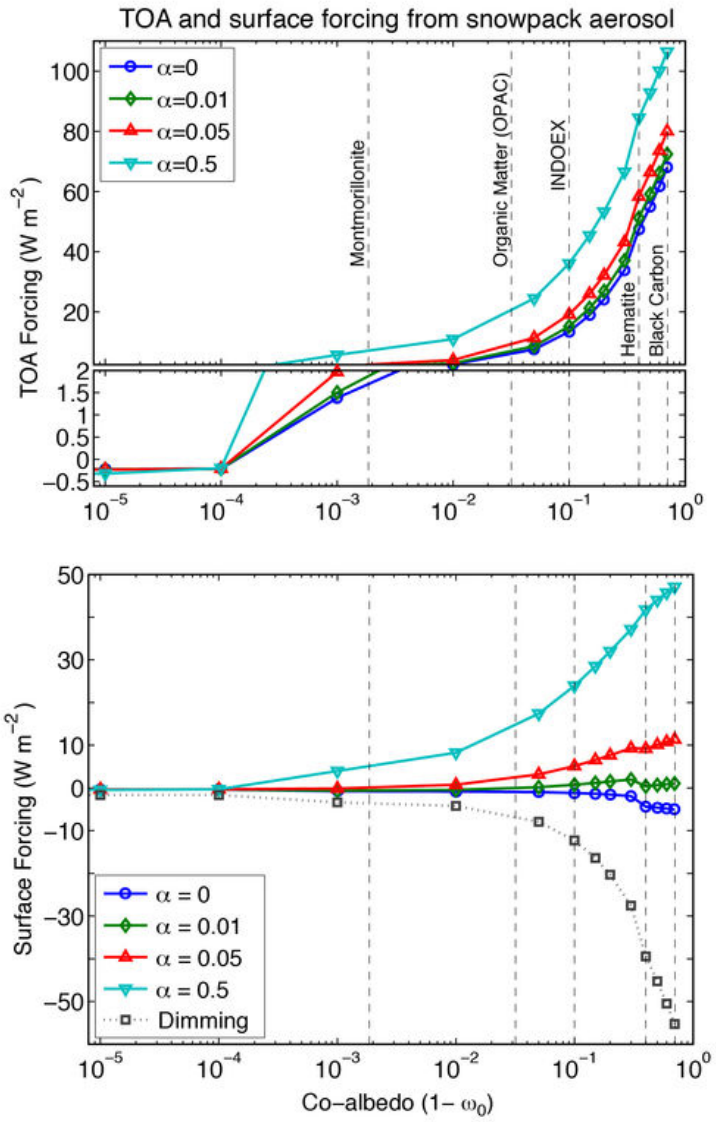


Figure 7.2. Daily-mean (top) top-of-atmosphere and (bottom) surface changes in net solar power (radiative forcing) as a function of single-scattering co-albedo ($1-\omega_o$) for all aerosol at 500 nm. Extinction optical depth of the atmospheric aerosol is fixed at 0.2 and the environment represents a clear-sky atmosphere overlying a snowpack with effective grain radius of 200 μm on 1 April at 45°N. Curves are shown for different values of α, which is the ratio of particle mixing ratio in snow to atmospheric column burden ((kg kg^{-1}) (kg·m^{-2})$^{-1}$). Radiative forcings represent the combined influence of particles in the atmosphere and snow. For reference, the change in downwelling surface insolation ('dimming') is also depicted. Vertical lines depict common co-albedo values of BC and organic matter, and that measured during the Indian Ocean Experiment (INDOEX) [*Ramanathan et al.,* 2001a]. Also shown are co-albedo values of strongly and weakly absorbing components of dust aerosols. The plot illustrates that 1) any mixture of atmospheric BC and organic matter exerts a positive ToA radiative forcing over snowpack, and 2) a small amount of aerosol mixed within the underlying snowpack exerts a darkening effect that exceeds the loss of absorbed energy from surface dimming caused by the atmospheric constituents. Figure from *Flanner et al*. [2009].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

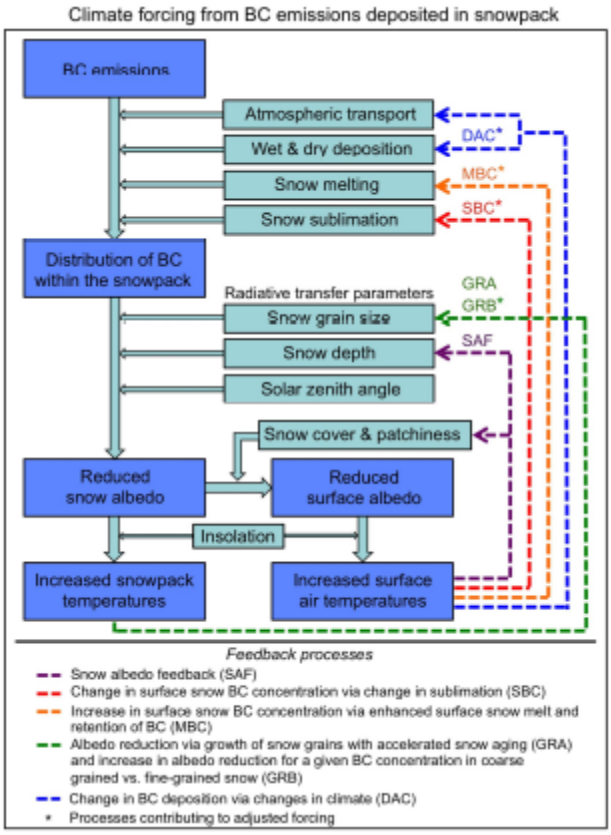


Figure 7.3. Schematic of the parameters and feedbacks that influence climate forcing by BC in surface snow. BC in the snowpack leads to reduced albedo of the snow surface, with the albedo change depending on BC amounts, snow grain size and snow depth. Reduced snowpack albedo reduces regional surface albedo and leads to increased snowpack and surface air temperatures. The temperature changes feed back to snow albedo through changes in snow parameters via several processes, as noted in the legend and discussed in the text. This figure emphasizes feedbacks specific to forcing by BC in snow. Changes in climate of any origin may also affect BC emissions, atmospheric transport, rates of BC deposition to the snowpack and snow accumulation rate.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

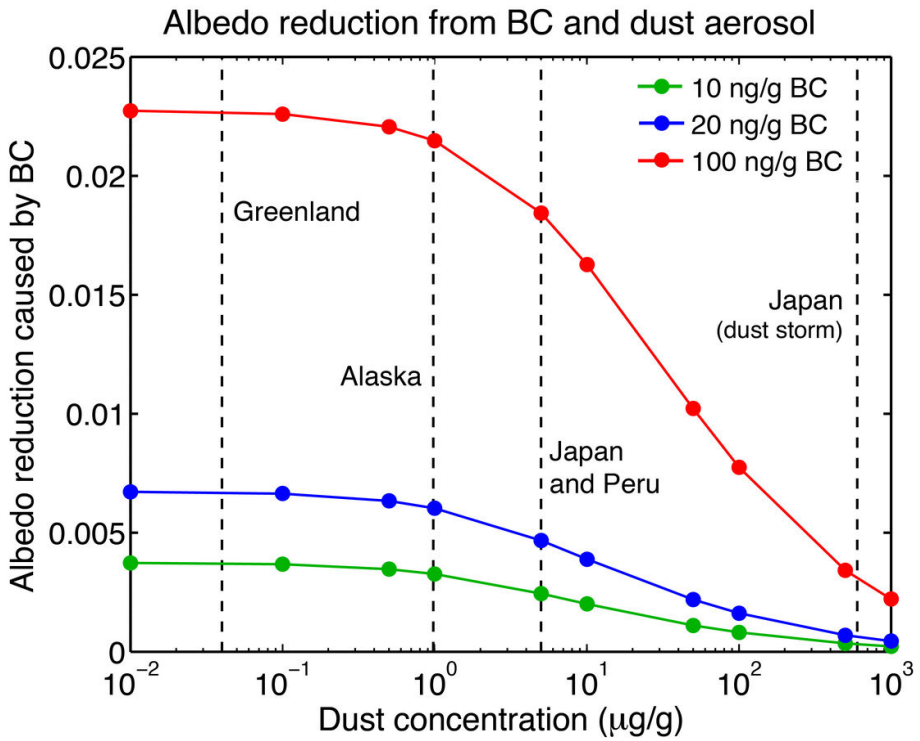


Figure 7.4. Reduction in hemispheric broadband snow albedo (0.3 to 5.0 µm) caused by BC in the presence of varying amounts of dust. The perturbation caused by BC becomes smaller with increasing dust burden. Conditions represent a clear-sky atmosphere with solar zenith angle of 60 degrees and snowpack effective grain radius of 250 µm. Dust optical properties are similar to those listed in *Flanner et al.* [2009] for a particle effective radius of 1300 nm, and albedo calculations follow *Flanner et al.* [2009]. Vertical dashed lines depict, from left to right, dust-in-snow concentrations measured in Greenland (0.03-0.06 µg g^{-1}, *De Angelis et al.* [1997]; *Banta et al*. [2008]), Barrow Alaska (0.98 µg g^{-1}, *Darby et al*. [1974]), Hokkaido, Japan, during pre-melt and Andes, Peru (5 µg g^{-1}, *Thompson et al.* [1979]; *Higuchi and Nagoshi*, [1977]), and Hokkaido, Japan, after a dust storm (600 µg g^{-1}, *Aoki et al*. [2006]).

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

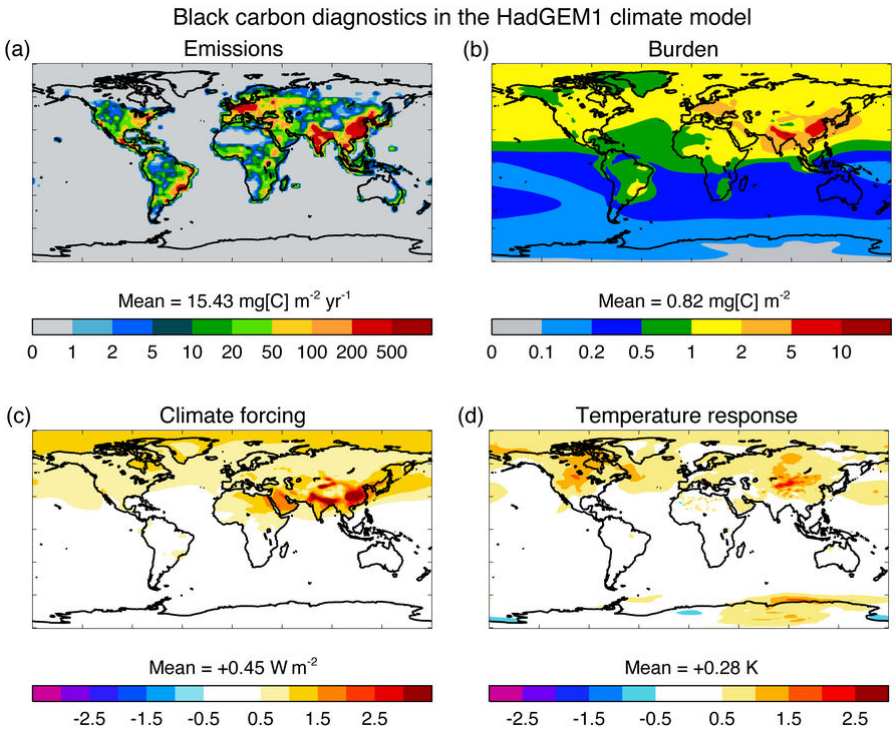


Figure 8.1. (a) Emissions of BC aerosols (mg BC m^{-2} yr^{-1}), (b) burden of BC aerosols (mg BC m^{-2}), (c) direct radiative forcing due to BC aerosols (Wm^{-2}) and (d) equilibrium surface temperature change (K) in response to the BC direct radiative forcing. Adapted from data from the Hadley Centre climate model (HadGEM1) published in *Jones et al.* [2007]. The patterns of burden, radiative forcing and surface temperature response are considered illustrative because the lifetime of BC is known to be too long in this model.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

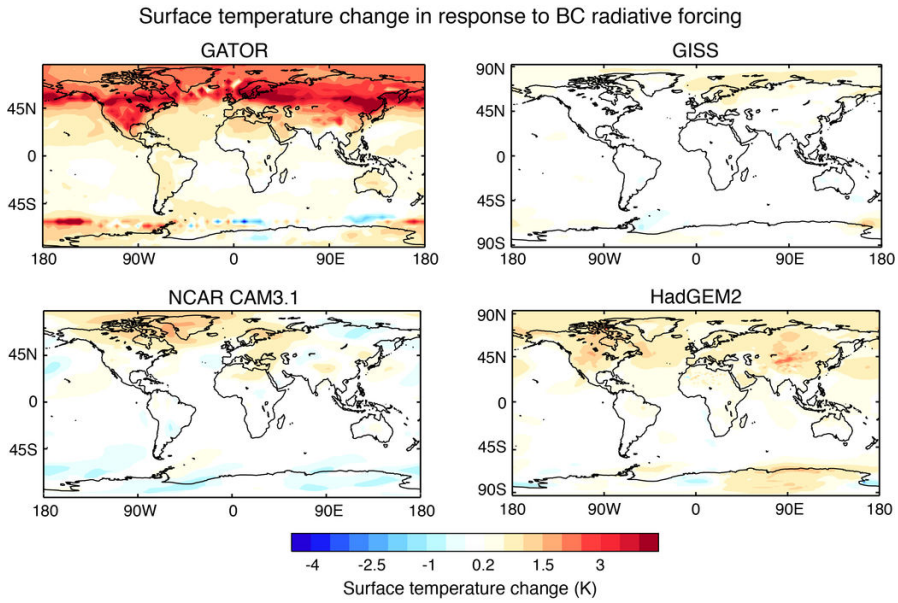


Figure 8.2. Surface temperature change in response to the BC radiative forcing in different climate models. Note that the experiments differ in their BC emissions, inclusion or not of the snow albedo and indirect effects on clouds, and setup. The panels are labeled with the model name. The details of each model and experimental setups are provided in Table 8.3.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

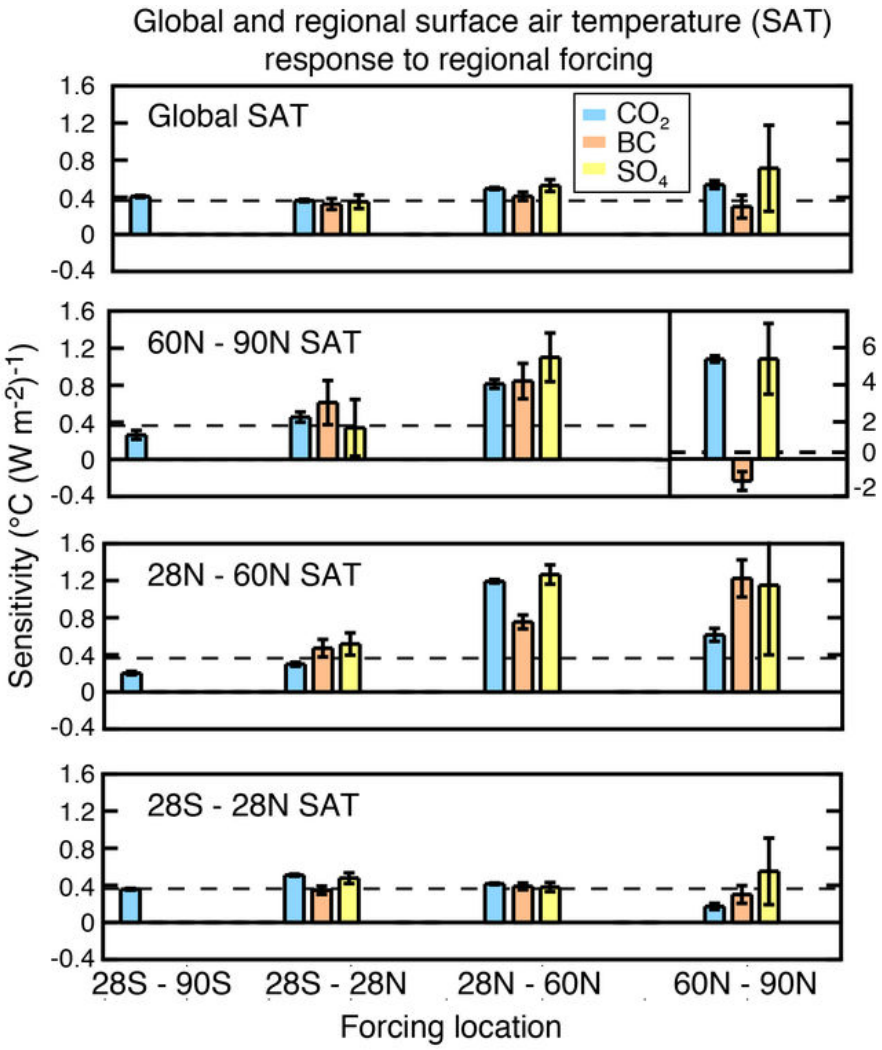


Figure 8.3. Normalized global and regional surface air temperature (SAT) changes (°C $(Wm^{-2})^{-1}$) in response to regional radiative forcings due to CO_2 (blue bars), BC aerosol (no cryosphere) (red bars) and sulfate aerosol (yellow bars). The forcing regions are defined on the horizontal axis as latitudinal bands (Southern Hemisphere mid- and high-latitudes, 28°S-90°S; tropics, 28°S-28°N; Northern Hemisphere mid-latitudes, 28°N-60°N; and Northern Hemisphere high-latitudes, 60°N-90°N). The SAT response regions are labeled in each panel. Adapted from *Shindell and Faluvegi* [2009].

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

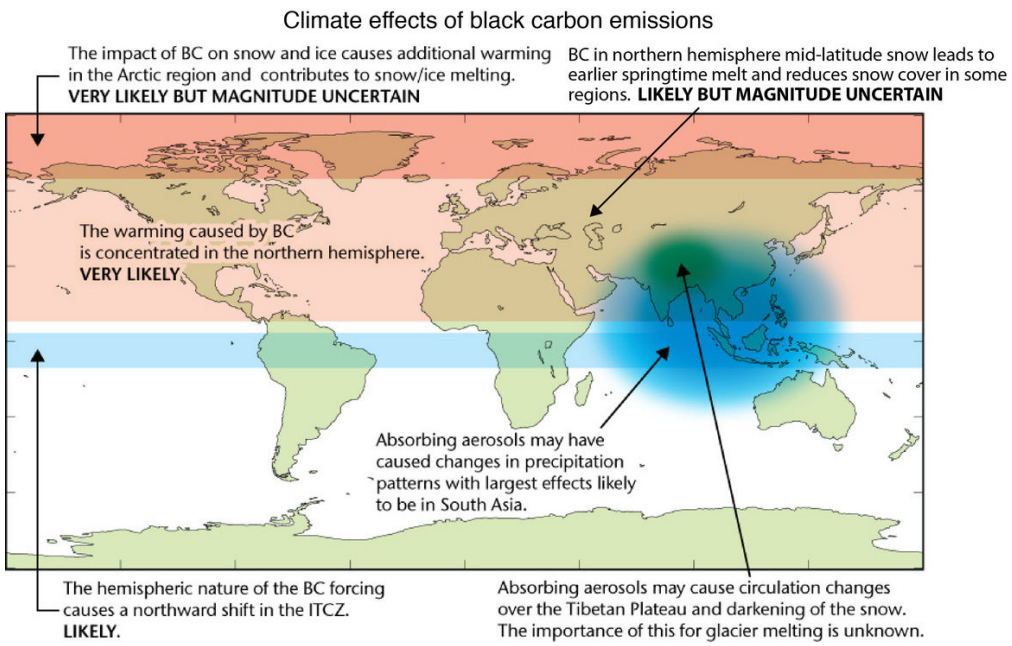


Figure 8.4. Qualitative summary of our current understanding of the global climate impacts of BC emissions.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

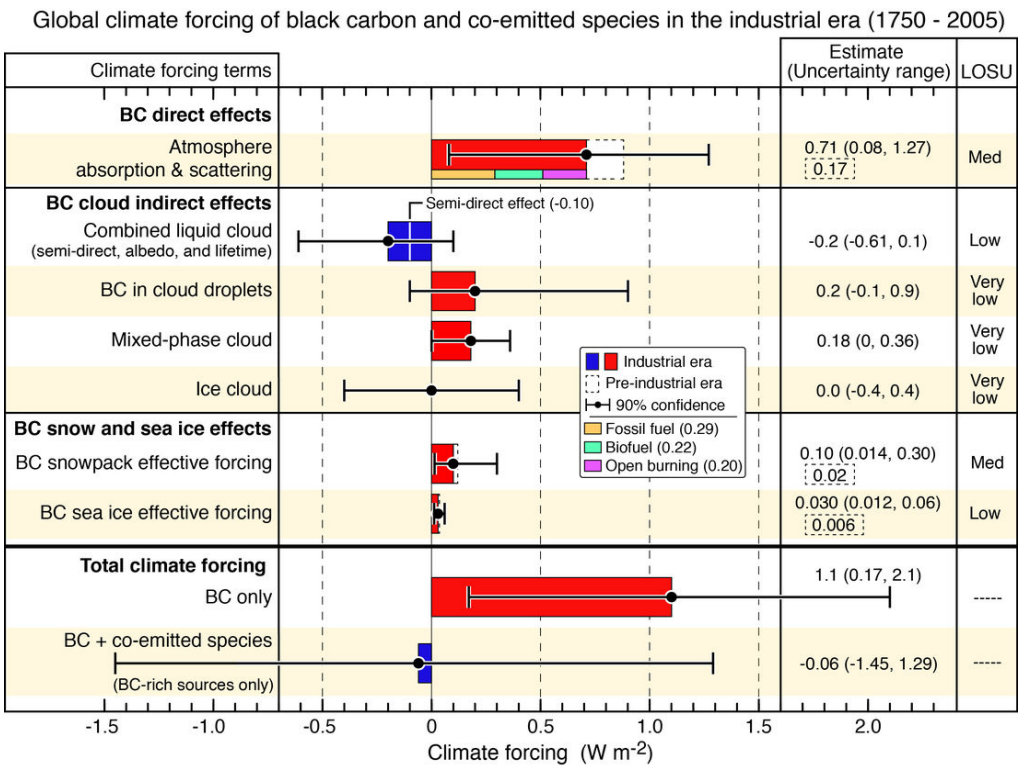


Figure 9.1. Globally averaged climate forcing in units of W m^{-2} from BC emissions in the year 2005 compared to those in 1750 (the industrial era). The bars and whiskers show the best estimates and uncertainties, respectively, of the different climate forcing terms from BC acting alone. The exception is the bottom bar which shows the net climate forcing from BC and its co-emitted species from BC-rich sources. Whiskers represent the assessed 90% uncertainty range (5% to 95%). The three smaller bars immediately below the direct forcing bar and legend display the separate contributions to industrial-era radiative forcing from fossil fuel, biofuel and open burning emissions. The white line on the combined liquid-cloud forcing bar indicates the -0.10 ± 0.2 W m^{-2} contribution from semi-direct effects. The additional direct forcing of +0.17 W m^{-2} shown with the dashed line represents the direct radiative forcing from pre-industrial emissions (*i.e.,* prior to 1750). The combined colored and dashed bar represents our estimate of the all-source (*i.e.,* natural plus anthropogenic) direct radiative forcing, namely a +0.88 W m^{-2} best estimate with a +0.18 to +1.47 W m^{-2} uncertainty range (see Section 5). Likewise, the dashed line on the snow and sea-ice terms correspond to their additional climate forcing prior to 1750 and the combined bars give their all source forcing (see Section 7). For snow and ice effects their adjusted forcing and radiative forcings, respectively, have been scaled by their higher efficacy to give effective forcings as shown. The total climate forcing from all BC effects is shown as 1.1 W m^{-2}. The uncertainty for this bar is assessed using a Monte Carlo method that assumes correlated errors in some of the forcing terms (see text for details). The columns on the right give the numeric value for each climate forcing and its uncertainty; they also present a level of scientific understanding (LOSU) for each forcing term. LOSU follows IPCC practice [*Forster et al.,* 2007] and represents our assessment of confidence in our own evaluation of a given climate forcing (see Table 9.1 and Section 9 for further details). See Figure 10.2 and Section 10 for details of the total climate forcing resulting from co-emissions from BC-rich sources shown in the bottom bar.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

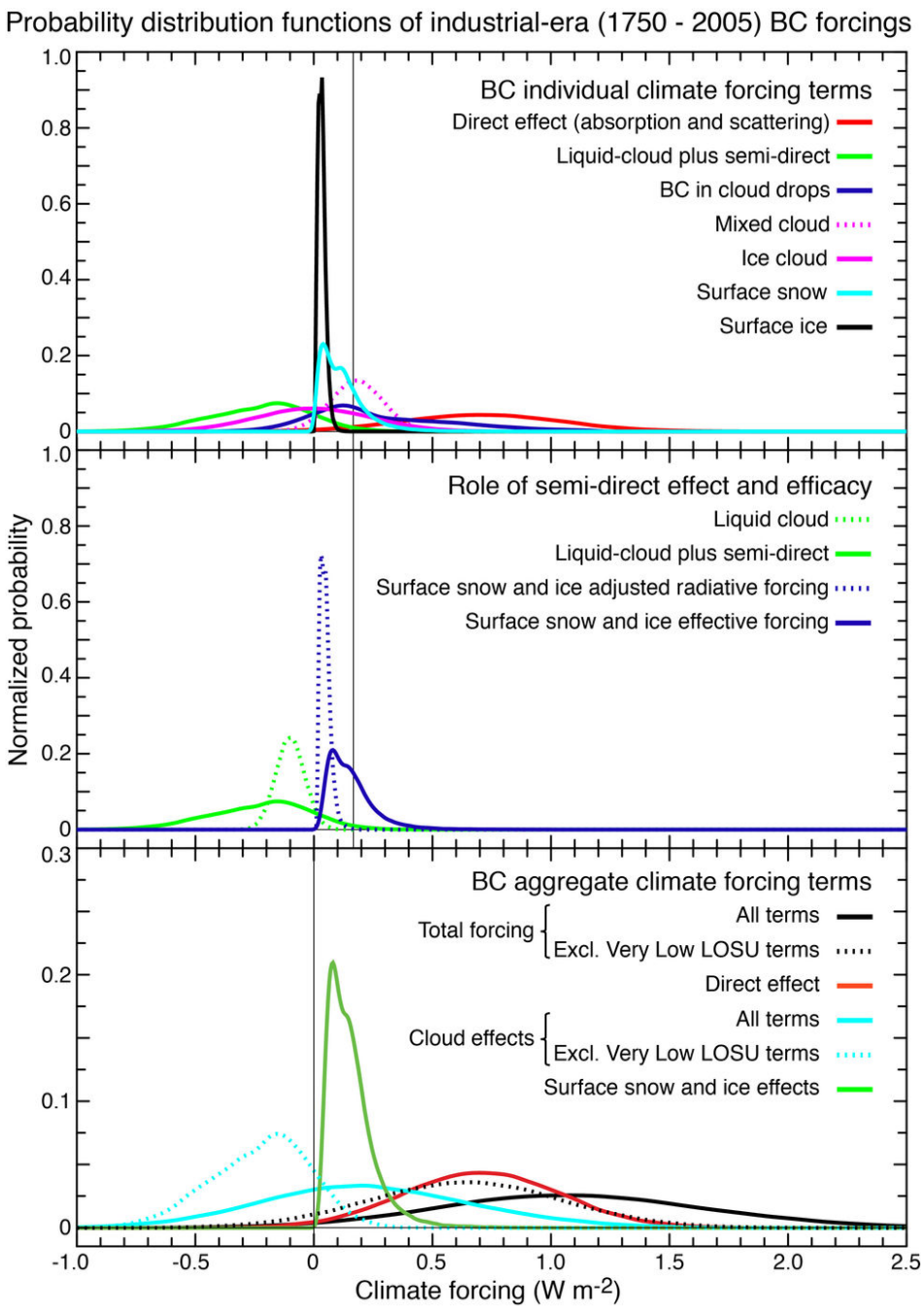


Figure 9.2. Probability distribution functions (PDFs) of industrial-era (1750 - 2005) forcings for BC climate forcing terms. Top: individual PDFs for each climate forcing term. Middle: before and after PDFs showing the role of the semi-direct effect in modifying the liquid cloud climate forcing term and the role of efficacy in modifying the BC-in-snow and BC-in-ice combined forcing term. Bottom: PDFs of the aggregated climate forcing components and the total climate forcing (see text for details). In the bottom panel, aggregated forcings are presented in two ways: with very low LOSU terms included (solid lines) or excluded (dotted lines). Probabilities are normalized to unity for all terms. Note the different vertical scale in the bottom panel.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

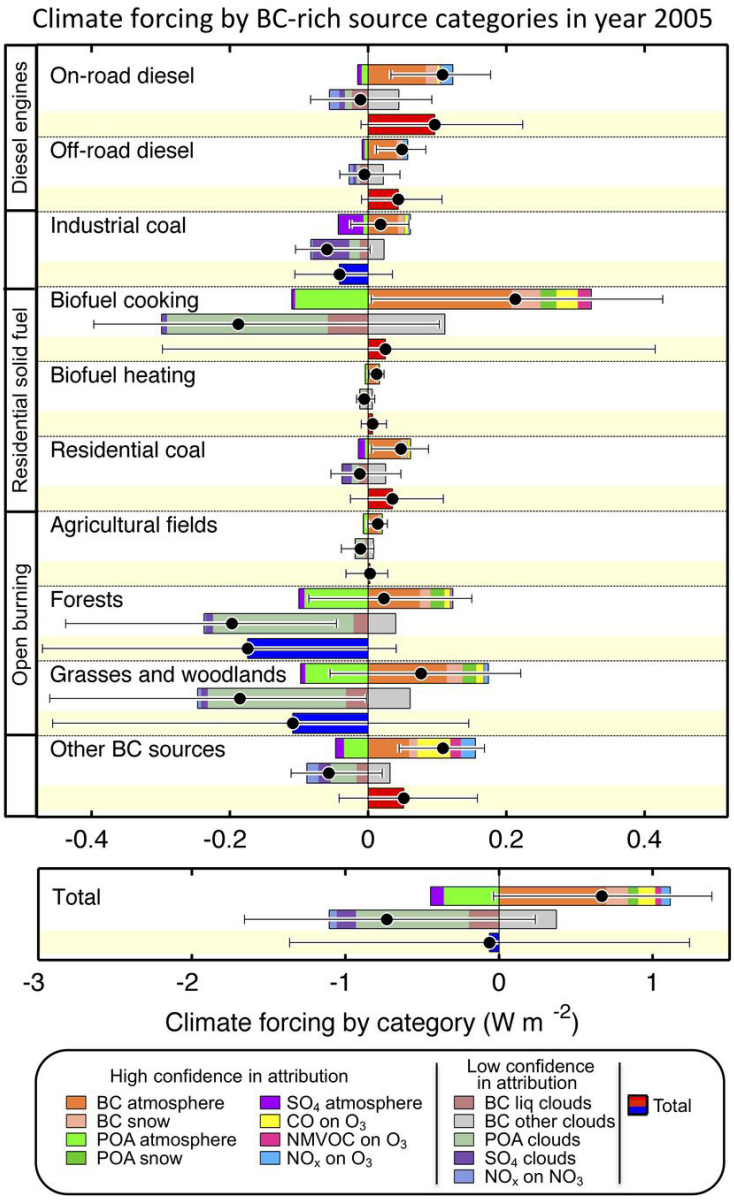


Figure 10.1. Total climate forcing for BC-rich source categories continuously emitting at year-2000 rates scaled to match observations in 2005. Three sets of climate forcings are shown for each source as bars with a best estimate (black circle) and uncertainty range. The top bar contains the components for which attribution to particular species is straightforward: direct forcing by aerosol and most gases, and cryosphere forcing by aerosol (including climate feedback). The second bar shows the components for which there is less confidence in apportionment to individual species and, therefore, to sources. These components include all cloud indirect effects and forcing by nitrate from NO_x. Effects of BC on liquid clouds include the cloud albedo and semi-direct effects. Other BC-cloud forcings represent the effects of cloud absorption, mixed-phase clouds and ice clouds. The bottom bar in each group shows estimated net climate forcing by each emission source, combining all forcings and their uncertainties.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

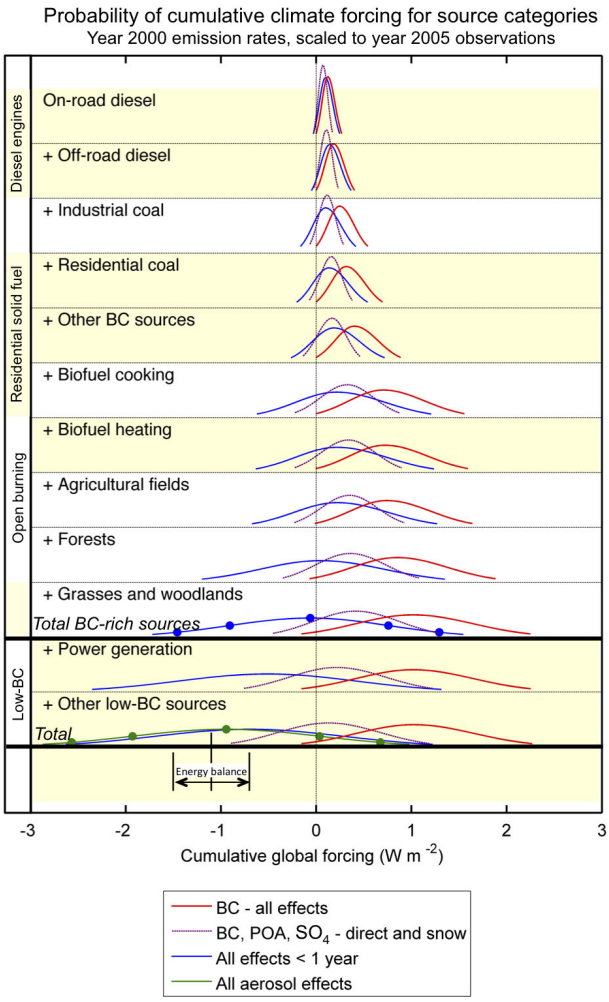


Figure 10.2. Probability density functions for total climate forcing of short-lived species during the first year after emission by the source categories in Figure 10.1. Sources emit continuously at year-2000 levels, scaled to match atmospheric concentrations in 2005. Curves labeled 'BC-all effects' (red lines) show all effects attributable to BC, including cloud effects. Curves labeled 'BC, POA, SO2' (purple lines) show direct and snow effects for the most commonly considered aerosol species and precursors. Total climate forcing (blue lines) is the sum of first-year forcings by all effects due to BC and co-emitted species, including clouds, gaseous species, and nitrate forcing. Progressing from top to bottom, each curve represents forcing by the sum of the labeled category and all categories above it. The total value and its uncertainty from BC-rich sources and co-emitted species are reproduced as the bottom bar in Figure 9.1. The lowest set of curves labeled 'Other low-BC sources' represents the total effect of aerosol sources. The arrow labeled 'energy-balance' represents the central value and one standard deviation of total aerosol forcing from an energy-balance calculation [*Murphy et al.*, 2009]. The curve labeled 'All aerosol effects' (green line) excludes gaseous species but includes all other aerosol effects, so is most directly comparable to the energy-balance inference. All curves have identical vertical scales and are normalized to unity. Blue dots on total curves represent central values, 68% confidence intervals (1 σ), and 90% confidence intervals (1.65 σ). Values outside of 95% confidence intervals are not plotted, so the curves do not meet the zero line.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

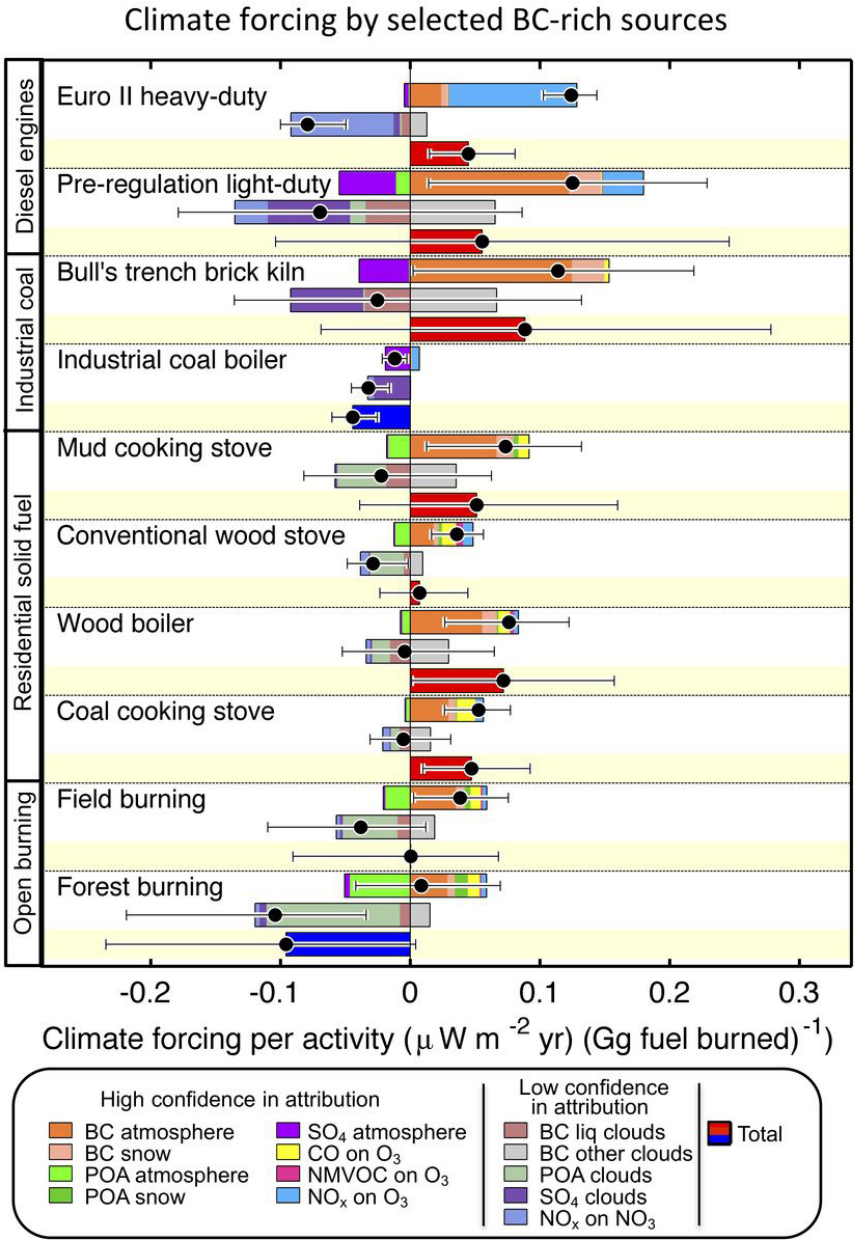


Figure 10.3. Climate forcing during the first year after emission, for selected individual sources that are subsets of the the categories in Figure 10.1. As in Figure 10.1, the three bars for each source correspond to (1) climate-forcing components for which attribution to species and sources can be done with high confidence (direct forcing by gases and aerosols); (2) components for which attribution to individual sources is difficult (cloud changes and nitrate forcing); and (3) total of all components.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

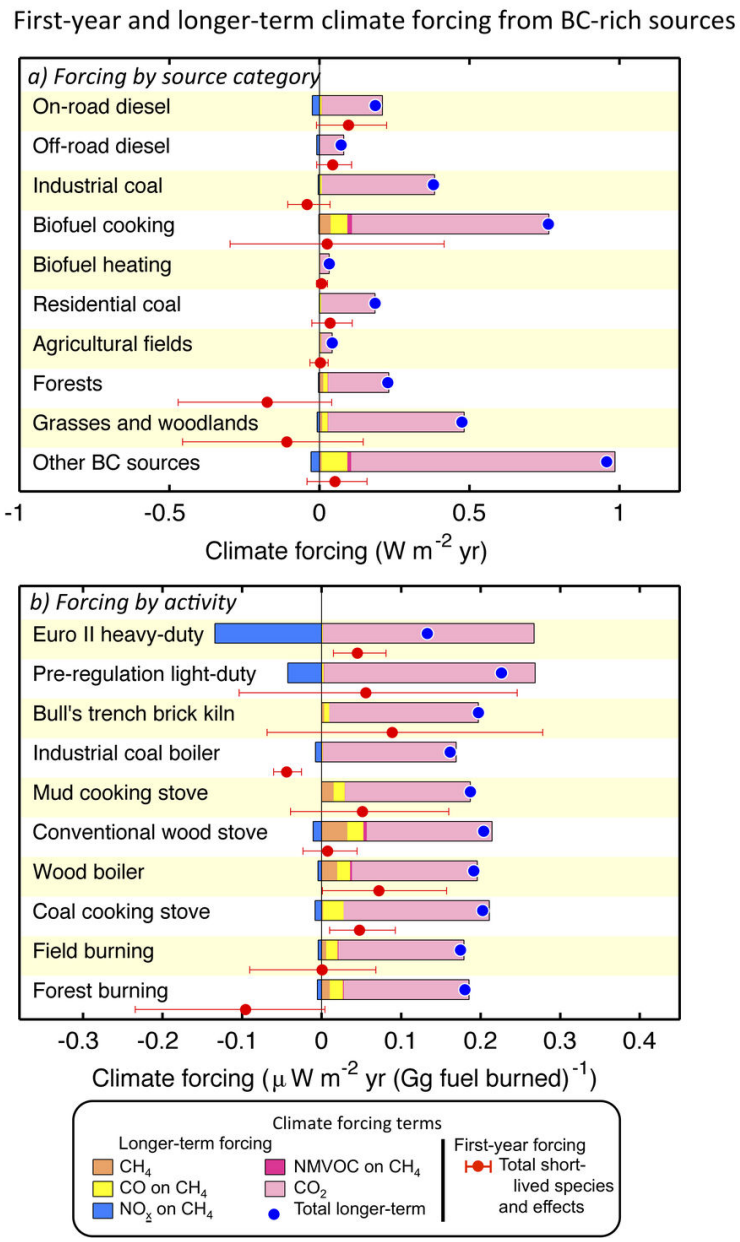


Figure 10.4. First-year and longer-term climate forcing of BC sources. The forcings are shown by category (top panel) and by source activity (bottom panel) corresponding to the categories in Figure 10.1 and 10.3. Totals and individual terms that make up integrated long-term (1-100 year) climate forcings, excluding the first-year forcing, are shown for individual terms and the total forcing with the first-year forcing excluded. The total for the first-year forcing and its uncertainty are also shown in both panels. This figure shows integrated forcing from (a) a single year of emissions (top, 2000 emission rates scaled to match atmospheric observations) or (b) a finite quantity of fuel burned, and does not assume that emissions are sustained.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

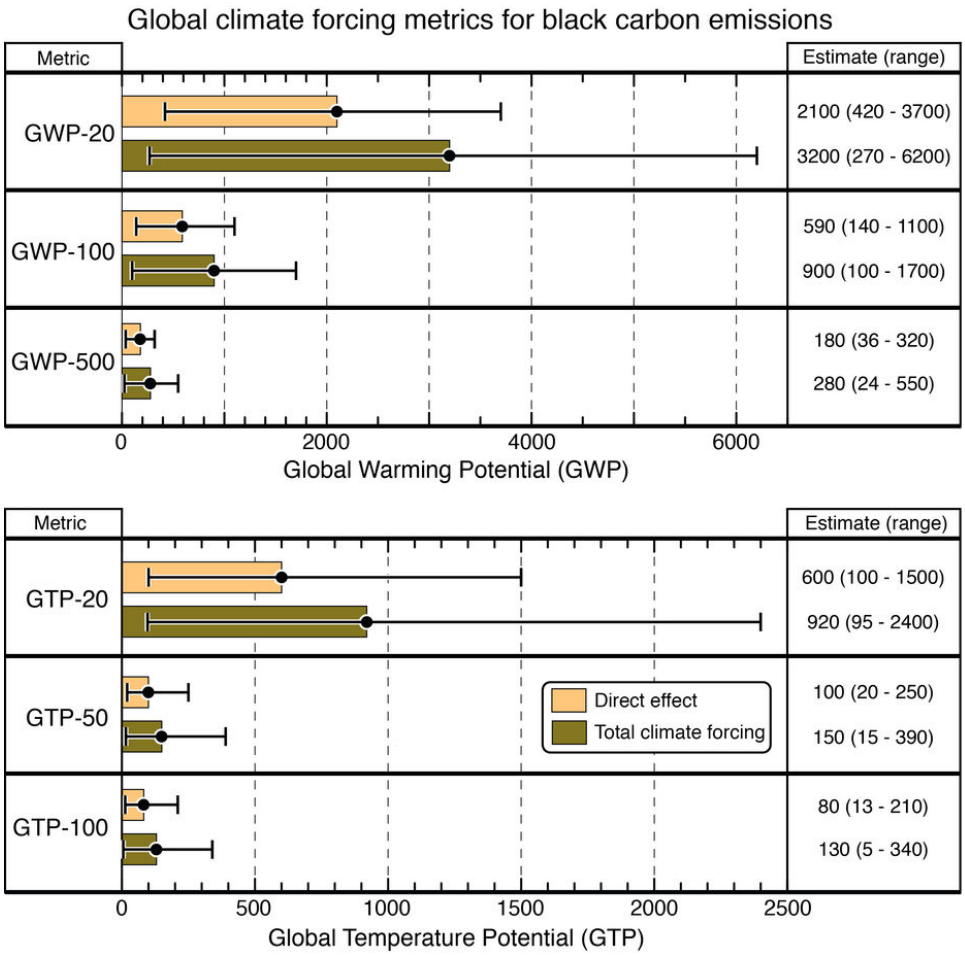


Figure 11.1. GTP and GWP values for several time horizons for BC climate forcing. Values are shown for the BC direct effect and the total climate forcing. The calculations use the industrial-era climate forcing values displayed in Figure 9.1 and an annual BC emission of 8700 Gg yr^{-1}. The whiskers represent the uncertainty range as described in the text.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

Aspects and evolutionary phases of mitigation actions

Program Aspect	*Program phase*			
	I. Nascent	*II. Emerging*	*III. Solidifying*	*IV. Mature*
Scientific Understanding	Recognition	Simple estimation	Detailed quantification	Consensus
Technical Feasibility	Envisioned solution	Successful prototype	Research and development	Production at required scale
Programmatic Feasibility	Experimental interventions	Specialized programs	Pilot programs and scale-up	(Inter)national policies

Figure 12.1. Conceptual framework for evaluating the feasibility of mitigating environmental impacts. The principal aspects are scientific understanding and technical and programmatic feasibility. Each aspect has evolutionary phases that reach maturity in several steps. Different emission sources are generally at different phases in the evolution of knowledge associated with each mitigation aspect. This assessment has primarily focused on the aspect of scientific understanding.

© 2013 American Geophysical Union. All Rights Reserved.

Accepted Article

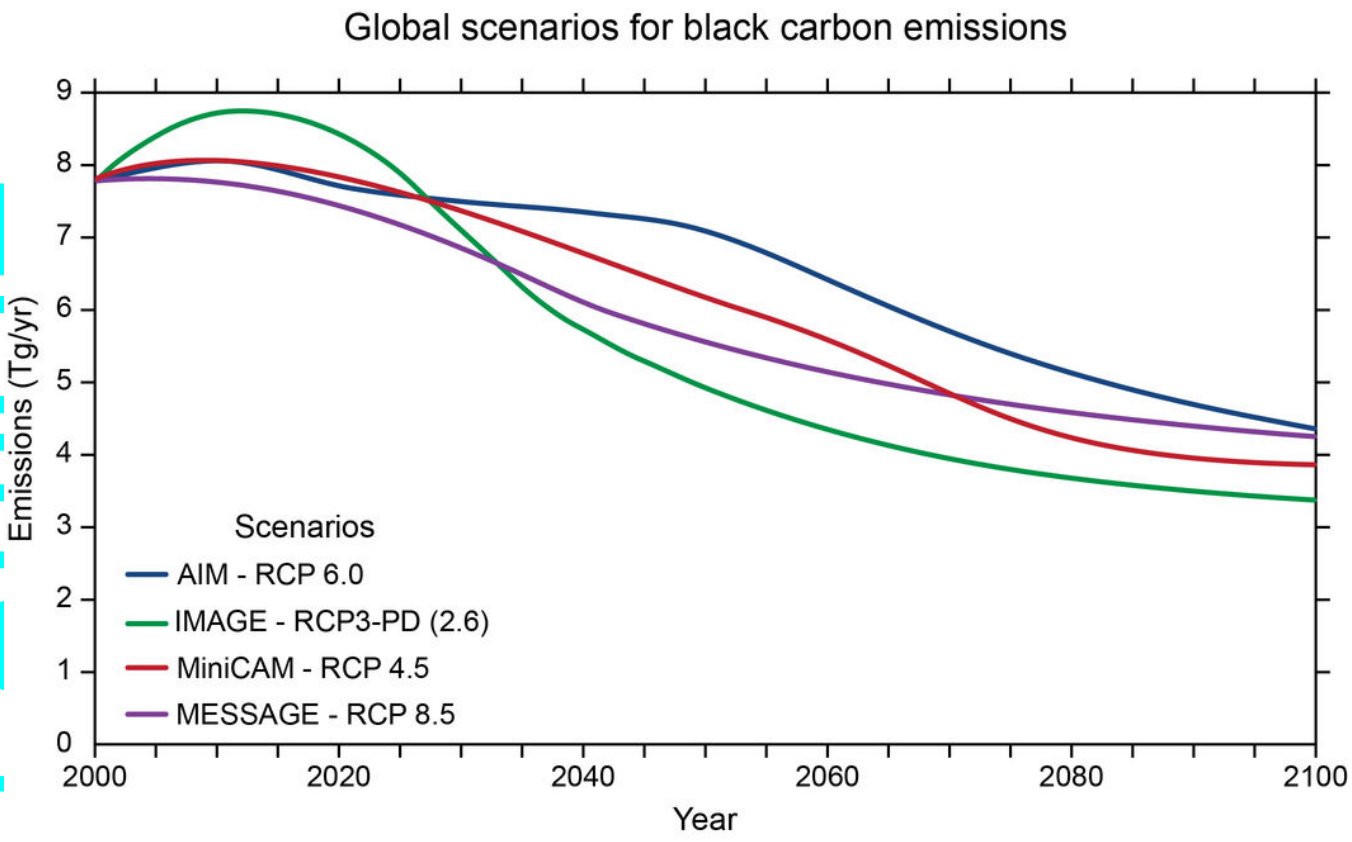


Figure 12.2. Total global BC emission projections from 2000-2100 in the four Representative Concentration Pathway (RCP) scenarios [*Moss et al.,* 2010]. These scenarios are named according to the radiative forcing in 2100, and were developed by four individual modeling groups for use in climate modeling analysis for the IPCC Fifth Assessment Report. Decreasing emissions are a result of expectations of cleaner fuels use and declining emission factors with increasing income.

© 2013 American Geophysical Union. All Rights Reserved.

United States Senate

WASHINGTON, DC 20510

January 3, 2013

The Honorable Ken Salazar
Secretary
Department of the Interior
1849 C Street, N.W.
Washington DC 20240

Dear Secretary Salazar:

We write to you regarding federal coal royalty management. Recent press reports raise troubling questions about whether taxpayers are missing out on millions of dollars in royalties from coal mined on federal and tribal lands, especially in the Powder River Basin of Wyoming and Montana.[1] Because royalties from federal coal are shared with the states in which that coal is mined, affected states may also be losing millions of dollars of revenue.

In addition to our own concerns, as members of Congress, others have weighed in – on a bipartisan basis – including the administrations of both Montana Governor Brian Schweitzer and Wyoming Governor Matt Mead. In a recent interview,[2] Governor Schweitzer said that "we need to collect on the actual value" of coal exported overseas. Wyoming's Department of Audit commented on federal coal royalty collection regulations in 2011 when Office of Natural Resources Revenue ("ONRR") sought comments to update these rules for the first time since 1989.[3] The Mead administration proposed that the regulation's definition of "lessee" include "the lessee and its affiliates, partners, marketing agents, and trade and export associations, and establish royalty value based on the first sale to a buyer who is not included in the definition of 'lessee' and is a bona fide arms-length transaction."

The allegations made in press reports and states' concerns are particularly pertinent as coal exports from federal and tribal lands increase. As companies seek to ship more coal overseas, taxpayers must be confident that the Bureau of Land Management ("BLM") and the ONRR have stringent royalty collection and auditing controls in place as coal markets become increasingly oriented toward international buyers. We know that the Department is reviewing

---

[1] Energy Information Administration, *U.S. Coal and Foreign Coal Distribution by State of Origin*, 2011, http://www.eia.gov/coal/distribution/annual/pdf/o_11foreign.pdf. Coal mines in Montana and Wyoming exported 13.2 million and 4.5 million tons of coal, respectively, in 2011.

[2] Patrick Rucker, "U.S. coal export trade raises alarms for Western states," *Thomson Reuters*, December 20, 2012, http://www.reuters.com/article/2012/12/20/usa-coal-royalty-idUSL1E8NJLAP20121220.

[3] State of Wyoming Department of Audit, Letter to Office of Natural Resources Revenue re: Federal and Indian Coal Valuation (Regulation Identifier Number 1012-AA00), July 26, 2011, http://www.onrr.gov/Laws_R_D/PubComm/PDFDocs/AA00/AA00%20Wyo%20%20Dept%20of%20Audit.pdf.

this matter; we are writing to ask that you provide certain information that may have been generated to date.

The story published December 4, 2012, by *Thomson Reuters*[4] alleges that coal companies may be violating provisions of the Mineral Leasing Act of 1920 (as amended)[5] and applicable regulations[6] that set out royalty payment and valuation requirements for coal produced from federal leases. Based on a review of company financial statements and interviews with royalty experts, the story alleges that coal companies are selling coal to in-house trading affiliates, which in turn sell the coal to buyers on the international market for a premium. The *Reuters* story alleges that coal producers are using this arrangement to report a lower sales price that does not reflect the actual value of coal that is ultimately exported to overseas buyers and sold at a premium.

The *Reuters* article further alleges that U.S. taxpayers could have missed out on millions of dollars in royalties for those exports alone. If this practice is occurring as alleged, and export trends continue to grow, taxpayers, states and tribes could end up losing hundreds of millions of dollars annually. If any violations of the law have occurred, companies should be required to cure any gap in royalty payments and, if misconduct has occurred, civil penalties should be levied.[7] If the Department's regulations are inadequate to ensure that full royalty value is returned, those regulations must be reformed.

Congress made clear when it passed the Federal Coal Leasing Amendments Act that federal coal was meant to "meet the nation's energy needs" and that coal royalties were put in place so that "people ... receive a fair return on their coal, particularly when coal values are increasing rapidly."[8] Accordingly, we request that your Department provide the following information:

1.) Hundreds of millions of tons of coal are mined every year from federal and tribal lands; the ONRR conducts audits and compliance reviews on royalty payments three years after the payments are due:
    a. Please provide a detailed list of any violations of applicable law or regulations – and resulting fines – related to royalty payments for coal mined on federal and tribal lands that occurred during the five most recent audit years.
    b. Please provide a detailed list of any violations of applicable law or regulations – and resulting fines – related to royalty payments for coal mined on federal and tribal lands that occurred in years that are not yet subject to audit or compliance reviews.

---

[4] Patrick Rucker, "Asia coal export boom brings no bonus for U.S. taxpayers," *Thomson Reuters*, December 4, 2012, http://www.reuters.com/article/2012/12/04/us-usa-coal-royalty-idUSBRE8B30IL20121204.
[5] 30 U.S.C. 181-287.
[6] 30 C.F.R. 1206, Subparts F and J.
[7] 30 U.S.C. 1720 (a) provides the Secretary of Interior with authority to levy penalties up to $25,000 per violation per day for violations of federal coal leases.
[8] Committee on Interior and Insular Affairs, Federal Coal Leasing Amendments Act of 1975, S. Rep. No. 94-296, at 16 (1975).

2.) BLM reports that more than 94% of federal coal is produced by mines in Wyoming, Montana, Colorado and Utah; Energy Information Administration data show exports from these states have more than tripled to 21.2 million tons between 2009 and 2011.
    a. What steps will the ONRR take to ensure that federal and tribal coal lessees (royalty payors) are reporting the proper product value for coal sold internationally?
    b. What steps will the ONRR take to ensure that, in a case where the royalty payor sells coal to an affiliated trading entity, the entire consideration received by the royalty payor is reflected in the reported gross proceeds?
3.) The *Reuters* story raised questions about whether sales prices reported to the ONRR reflect the true arms-length value of federally leased coal sold on the international market. What steps will the ONRR take to ensure that, in cases where the royalty payor sells coal to an affiliated trading entity, the reported sales price reflects proper product values, including any premium received in the case of an international sale?
4.) In fiscal year 2012, the ONRR conducted 325 audits and 891 compliance reviews on federal mineral leases that accounted for $3.1 billion in revenue for U.S. taxpayers, equal to nearly one-third federal energy royalties collected in fiscal year 2011. What percentage of these audits and compliance reviews pertained to coal leases, and what amount of under-collection was identified?
5.) The 2009 Omnibus Appropriations Act (P.L. 111-88) codified civil and criminal penalty authority that the ONRR may use against lessees of Federal and Indian coal that violate federal leasing laws.[9]
    a. Has the ONRR used its civil and criminal penalty authority in the past?
    b. Please provide a detailed list of instances when the civil and criminal authority has been used.
    c. How does the ONRR plan to use its civil penalty authority with future violators?
6.) Concerns over royalty collections in the case of exports have only recently come to light; however, more than 118 million tons of coal produced in Utah, Colorado, Wyoming and Montana were exported between fiscal years 2001 and 2011. Does ONRR plan to audit previous fiscal years to ensure that the public received the full royalty payments that they were owed in cases where the coal was exported?
7.) When a royalty underpayment has occurred, it is critical that the Department has the proper tools to recover funds for American taxpayers and affected states.
    a. If underpayment of royalties has occurred, what recourse is available to the Department?
    b. Specifically, does current law and regulation permit remedying such underpayments in a way that accurately reflects the time-value of the money that should have been collected but was not?

[9] 30 U.S.C. 1720 (a).

We know you share our commitment to ensuring that the public receives a fair return on these resources. It would be helpful if the Department could provide the requested information and its plan for addressing this important matter by February 4, 2012. Please contact Peter Gartrell (peter_gartrell@wyden.senate.gov or 202-224-5244) or Colin Hayes (colin_hayes@energy.senate.gov or 202-224-4797) on our staffs with any further questions.

Sincerely,

Sen. Ron Wyden

Sen. Lisa A. Murkowski

Cc: Acting Director Mike Pool, Bureau of Land Management
Director Gregory J. Gould, Office of Natural Resources Revenue
Acting Inspector General Mary Kendall, Department of Interior Office of Inspector General

POTENTIAL LOCAL DIRECT EFFECTS OF INCREASED COAL TRAIN TRAFFIC ON BNSF RAILWAY THROUGH BELLINGHAM

Prepared for
COMMUNITYWISE BELLINGHAM
by

TSM
Transit Safety Management

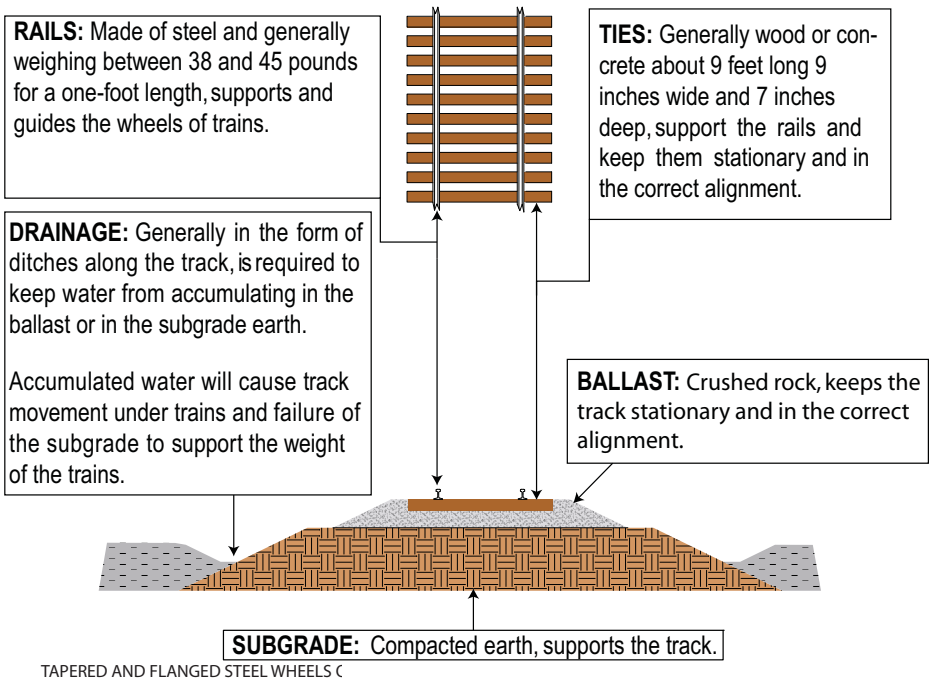
January 17 2012

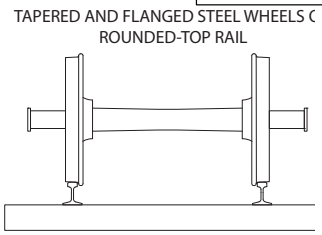
Among land transportation modes, railroads have unique characteristics that affect how they relate to their environment. An understanding of the environmental effect of railroads requires an understanding of these fundamental characteristics. A specific method for the discussion of railroad operation, and specific technical language, has been developed because of the unique nature of the characteristics.

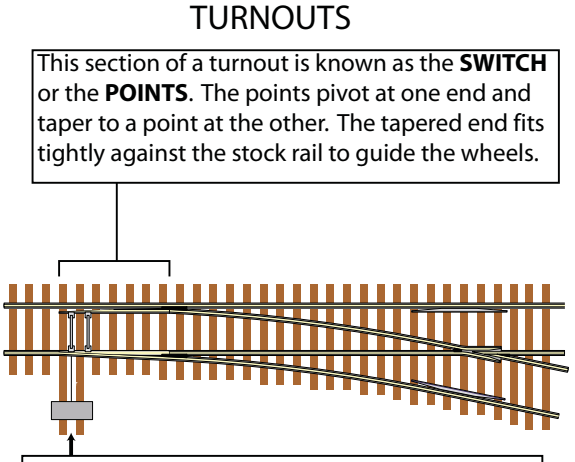
Railroad Characteristics

The most obvious characteristic is the track. A train follows a narrowly defined path. The engineer (operator/driver of a train) does not steer. The locomotives that pull and/or push the train follow the track as do all of the freight or passenger cars in the train. The track allows trains to operate in a space that is not substantially larger than the train. Trains do not require guard rails along curves or jersey barriers between adjacent tracks. Therefore, a railroad can have a relatively modest property requirement.

A train stays on the track because of the shape of the wheels. Wheels are tapered, smaller diameter toward the outside edge, and have a flange that extends below the top of the rail. The flange generally does not touch the rail. Except on sharp curves and when moving through a turnout, the conical shape of the wheels is sufficient to keep the wheels appropriately aligned on the rail.



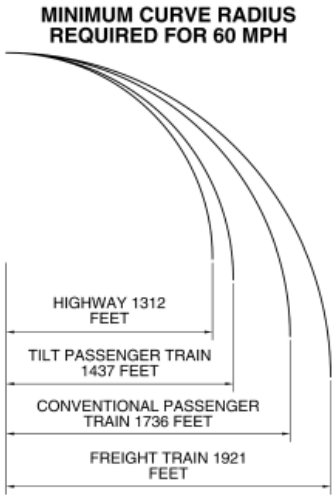


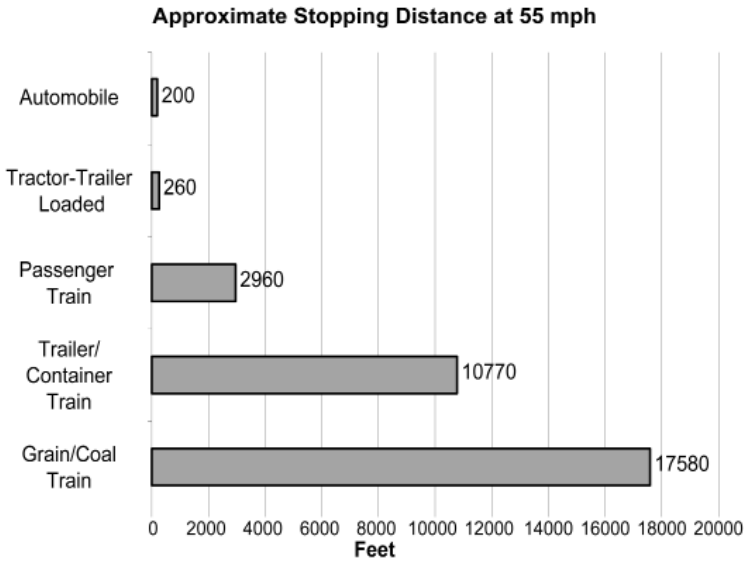


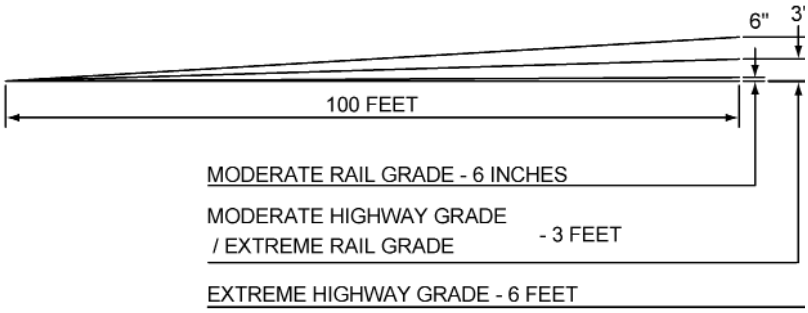
Because the train merely follows the track and the engineer does not steer, a train cannot swerve to avoid an obstruction. Even when there are two or more parallel tracks, a train cannot merely change lanes to avoid another train. Locations at which trains can change tracks, a special configuration called a turnout must be planned in advance and constructed for the purpose.

Tracks used by trains to move along the line at normal speed are main tracks. Trains can move in either direction on a main track. If traffic is relatively light, the railroad may use only a single main track (single track) along all or a portion of a route. A siding is a track constructed parallel to the main track and connected to the main track by turnouts at the ends. A siding is used for one train to leave the main track to allow another train to move by, either meeting (opposing direction) or passing (overtaking in the same direction). A siding must be long enough to accommodate the longest train that will need to leave the main track to yield to another train. Other tracks, generally called industry or yard tracks, are used to store or maintain railroad engines and cars or to provide freight service to business.

The part of the wheel that is in contact with the rail is about the size of a dime. Smooth steel wheels rolling on a steel rail present very little resistance to motion. The small contact area is responsible for only a small amount of friction. The wheel does not deform under the weight or in response to a turn as a rubber tire does. This also limits the resistance to

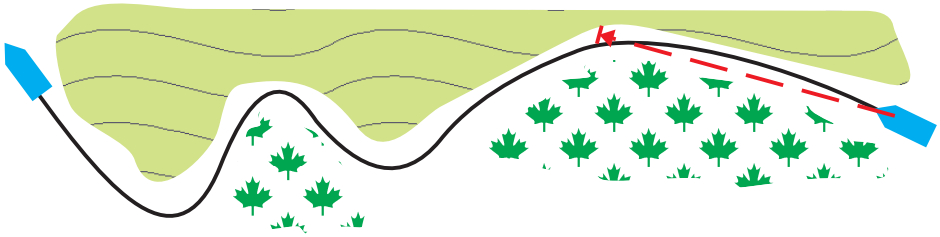




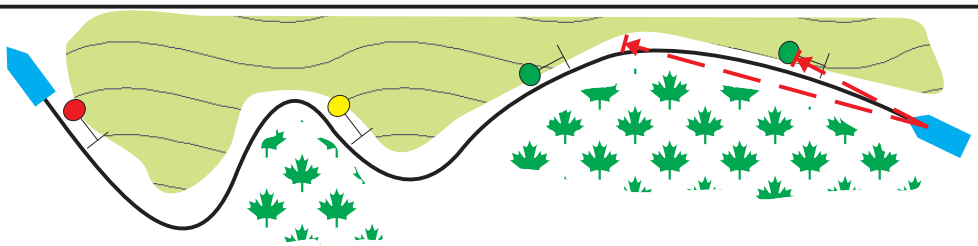


motion. Therefore, the power required to move the lading or passengers is relatively modest. A 40 horsepower Volkswagen Beetle of the 1960s could attain a speed of about 70 mph on a flat road. To attain that speed in the Beetle with steel wheels on steel rails, a large lawnmower engine would suffice. With its original engine, the Beetle could pull 40 other Beetles at about 40 mph with steel wheels on steel rails. It could also pull 13 large SUVs at the same speed. It could pull a 25 ton trailer at close to 60 mph. Modest power requirements provide a great advantage in fuel consumption and the associated emissions. To take advantage of the low friction fixed guideway characteristics of rail vehicles, they are much larger than highway vehicles. The size and weight affects the speed at which they can negotiate curves.

SIGNALS



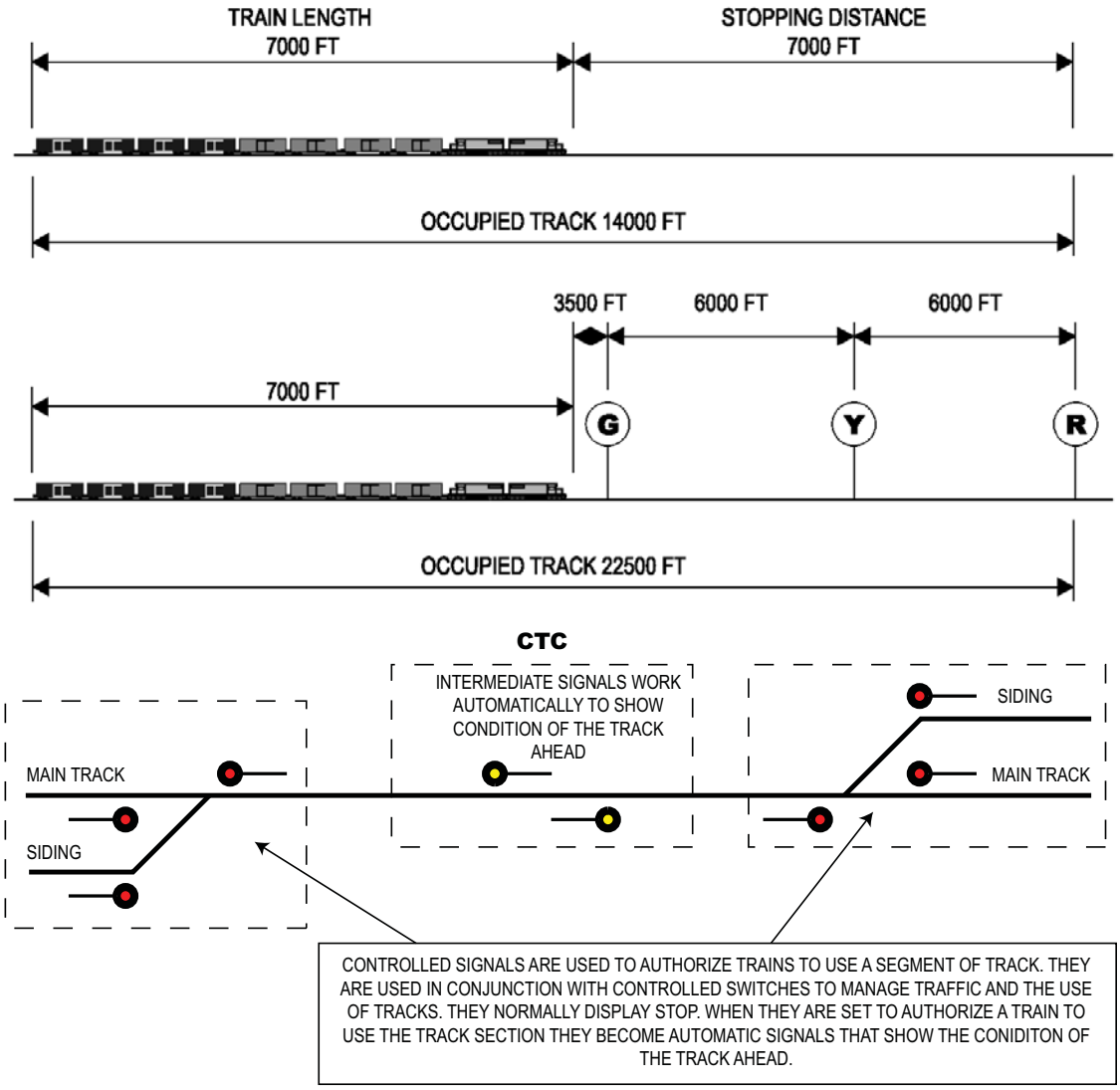
NO SIGNAL SYSTEM: Train speed is limited to the speed at which the train can be stopped within sight distance. To allow increased speed, the engineer must be notified that the track ahead is clear of trains for at least the distance required for stopping at the desired speed.



AUTOMATIC BLOCK SIGNAL SYSTEM: Signals spaced at approximately stopping distance, using electric current in the track to sense the presence of trains, tell the engineer the condition between that signal and the next, extending the engineer's sight distance and allowing increased speed.

The ease of movement on steel rails presents two difficulties. The limited friction makes climbing grades and stopping difficult. Railroad grades must be gentle compared to highway grades. A grade considered moderate for a highway is extreme for a railroad. If the amount of force that the brakes exert on the wheels exceeds the small amount of friction between the wheels and the track, the wheels will

merely slide on the rail. Operating a train is like driving on ice except that the train will not slide off of the desired course. The stopping distance of a train is, at commercially viable speeds, much longer than the engineer's range of vision. A system of detecting the presence of trains (and perhaps other hazards), called a signal system, is needed to virtually extend the engineer's sight distance. Signals along the track, looking similar to traffic signals at intersections but functioning differently, tell the train engineer if the track is occupied at a point ahead that is eyond stopping distance. The signal system electronically divides the track into segments called blocks. There is a signal at the entrance to each block. It indicates the condition of the immediate block (occupied / not occupied) and the condition of one or more blocks beyond the immediate block (proceed-no restriction, prepare to stop at the next signal or second signal, proceed at a speed specified by the signal).



Because the track steers the train, changing tracks at a turnout requires operation of the movable part of the turnout. The movable part may be manually operated, requiring the train to stop, and a crew member to get off and operate the movable part of the turnout. Alternatively, the movable part of the turnout may be operated by a motor, remotely controlled from a distant location. When the turnouts are remotely controlled, typically called Centralized Traffic Control (CTC), signals serve the dual purpose of showing whether the track ahead is clear of other trains and convey authority to occupy the track ahead and may tell the train engineer what route the train will take through the turnout(s) just beyond the signal.

Safety

Railroads, because they are engaged in interstate commerce, are regulated by the US government, specifically the Federal Railroad Administration of the Department of Transportation. The Staggers Act of 1980 deregulated the railaroad industry, but only the economic and business aspect regulated by the Interstate Commerce Commission. Safety regulations and enforcement moved from ICC to FRA.The federal regulations that apply to railroads are found in Title 49 of the Code of Federal Regulations part 200-299. They apply to virtually every aspect of railroad operation. 49 CFR 200-299 is divided into groups that apply to specific subjects:

Part	Subject	Part	Subject	Part	Subject
200	Passenger service rules of practice	222	Use of locomotive horns at public highway - rail grade crossings	237	Bridge safety standards
207	Railroad police officers	223	Safety glazing standards locomotives, passenger cars, and cabooses	238	Passenger equipment safety standards
209	Safety enforcement procedures	224	Reflectoriation of rail freight rolling stock	239	Passenger train emergency preparedness
210	Noise emission	225	Railroad accidents/incidents: reports, classification, and investigation	240	Qualification and certification of locomotive engineers
211	Rules of Practice	227	Occupational noise exposure	241	US location of dispatching of railroads in US
212	State safety participation	228	Hours of service	242	Qualification and certification of conductors
213	Track safety standards	229	Locomotive safety standards	244	Safety integrtion plans governing consilidations, mergers, or acquisitions of control
214	Workplace safety	230	Steam locomotive inspection and maintenance standards	250	Trustees of railroads in reorganization
215	Freight car safety standards	231	Safety appliance standards	256	Financial assistance for passenger terminals
216	Special notice and emergency order procedures	232	Freight brake safety standards	260	Loans and loan guarantees under the rialroad rehabilitation and improvement financing program
217	Operating rules	233	Signal systems reporting	261	Credit assistance for surface transportatoin projects
218	Operating practices	234	Grade crossing signals	262	Capital grnts for rail line relocaton and improvement
219	Control of alcohol and drug use	235	Discontinuance or material modification of a signal system	266	Assistance to states for local rail service
220	Communications	236	Installation, inspection, maintenance, and repair of signal and train control systems	268	Magnetic levitation technology deployment
221	Rear end marking device				

The safety standards are quite detailed. For example, Part 213, Track Safety Standards divides track condition into several classes. a maximum freight train and passenger train speed is assigned to each class. Measurements and condition are specified for track componentswith tolerances specified for each class of track. For some components and conditions, specified measurements are as small as 1/4 inch. The regulations specify the frequency of track inspection and the qualifications of the person inspecting the track. When a defect is found, including any of the specified measurements being out of the tolernce for the track speed limit, train speeds must be reduced by temporary speed restriction to the maximum allowed speed for the class of track that current condition meets. The speed limit may only be restored to the normal speed after the track has been brought back into the standard for that class of track. The regulations also provide a mathematical formula for determining the maximum allowed speed through curves, based upon the sharpness of the curve (radius) and the amount of superelevation (banking). Similarly, the regulations contain detailed specifications for the condition of locomotives, freight cars, and passenger cars. FRA safety inspectors regularly inspect track, signals, cars, and locomotives for compliance with the regulations.

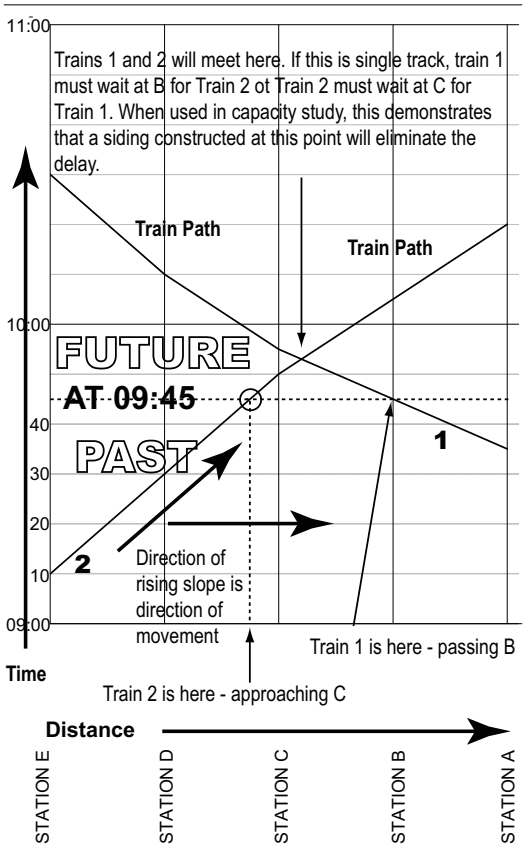
The regulations also specify an extensive set of operating procedures for the use of the locomotive horn at highway grade

crossings, the testing and operation of the air brake system of a train, and general operating practices. The operating practices and rules for each railroad are contained in rulebooks, timetables, and other documents. The practices must be approved by FRA. The regulations provide specific procedures and standards for the certification (licensing) of locomotive engineers and train conductors. Employees are required to pass a biennial examination on the rules and procedures. The regulations require periodic on the job testing by railroad management staff in addition to the biennial written examinations. Testing and examination records must be maintained for periodic review by FRA safety inspectors. FRA inspectors also preiodically perform on the job testing of employees in addition to the testing conducted by railroad management staff.

Railroad cars, freight or passenger, receive a thorough mechanical inspection at each terminal where cars are assembled into trains or trains are broken apart into individual cars for furtherance or delivery. In addition, all employees along the line are required to visually inspect trains as they pass. Electronic detectors spaced periodically along the line inspecting bearings and wheels for defects and detecting objects dragging along the track from the bottomsof cars. when defects are found by electronic detector or visual inspection, the train is notified by radio to stop.

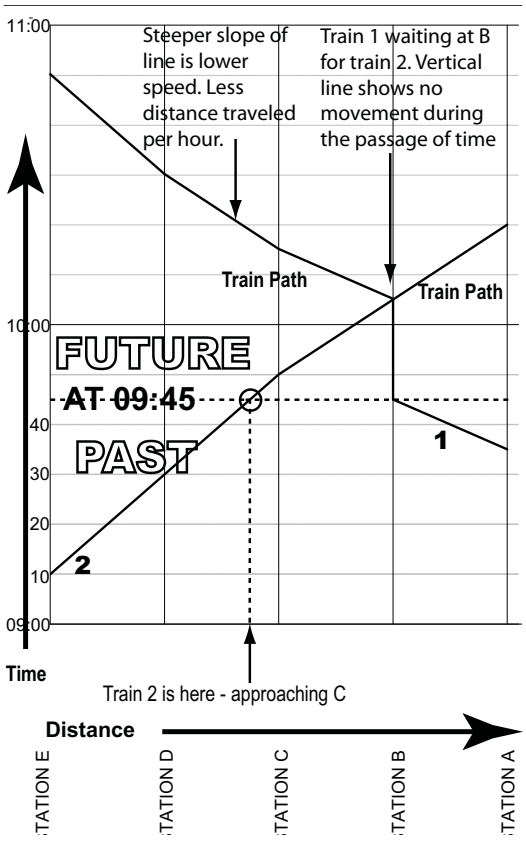
The Language of Railroad Operation.

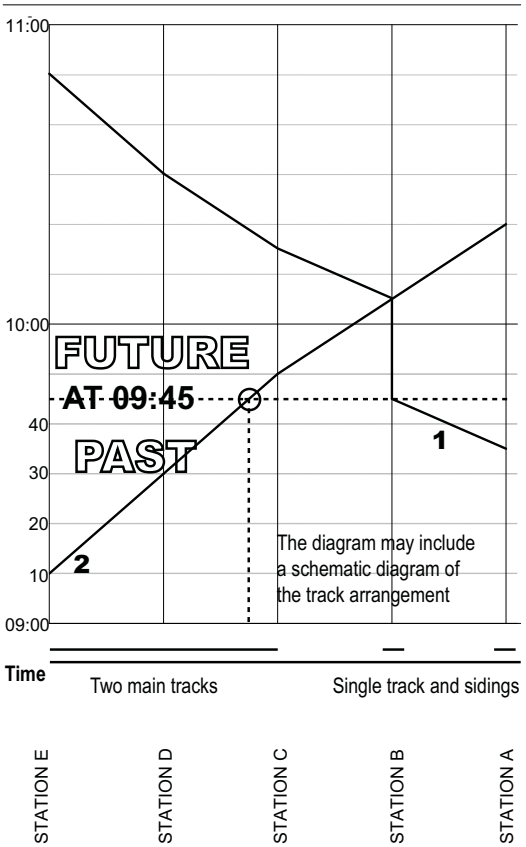
The location of and need for railroad infrastructure is demonstrated using a traffic (stringline) diagram. A stringline diagram is a time-distance chart that demonstrates the location of trains at any point in time. It is necessary to understand and be comfortable with reading stringline diagrams in order to understand railroad infrastructure requirements.



Capacity

Railroad infrastructure requirements are determined in terms of capacity. Capacity is not an absolute quantity. It is dependent upon the speed of the trains, the relative speed of one train to another, the length of the trains, and the specific combination of trains that will be operated (e.g., speed, length, and time sensitivity). At any time, a train must have exclusive occupancy of the track on which is it located as well as the track in front of the train that is within stopping distance. Thus, it may be necessary for a train to have exclusive right to several miles of track at any time. On main lines, the





signal system determines the amount of track ahead of the train that the train must occupy. On a single track line, a train must occupy the segment of line between sidings exclusively as well.

Capacity is generally not uniformly distributed along the line. The distance between signals may vary or the signals may be spaced uniformly but the speed limit varies. Sidings may be located at different intervals or the speed limit may vary between sidings along the line. These factors must be considered in determining the adequacy of the route for proposed traffic. The capacity of the line is generally dictated by the individual segment that trains must occupy for the longest period. On a single track line, that segment is the segment between the two sidings that are the greatest travel time apart. On a line that has two or more main tracks, the capacity is generally determined by the two signals that are separated by the greatest travel time. These are the capacity-limiting segments. The examples will demonstrate single track line capacity because the line between Everett and Bellingham is single track.

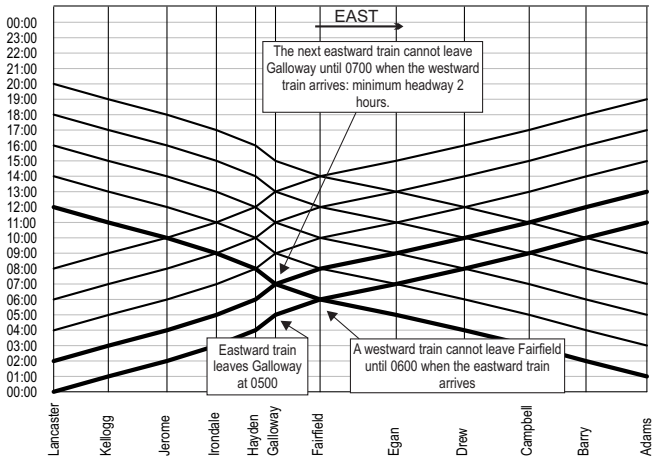
Traffic on the line has reached the capacity of the line when every opportunity to operate a train through the capacity limiting segment has been reached.The minimum time that can be achieved between two trains in the same direction is called minimum headway.

Fleeting, the operation of several trains in one direction on close headway, is generally not an effective means of capacity increase. Fleeting can cause substantial delay to trains in the opposite direction. Fleeting trains in both directions is not an effective means of increasing capacity.

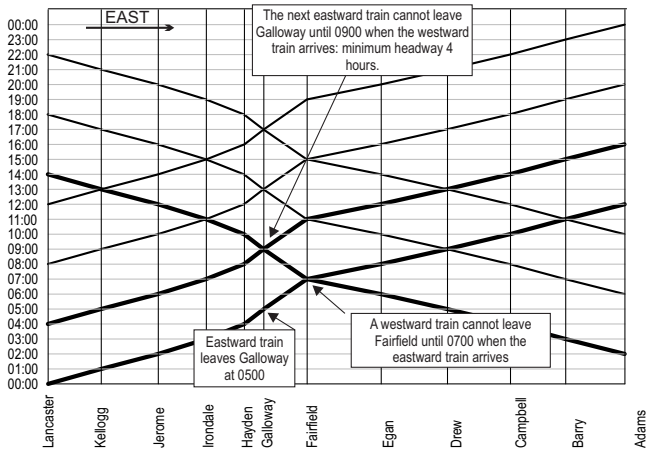
Capacity can be approximated by dividing the length of a day by the travel time through the capacity-limiting segment.Thus, if the travel time through the capacity-limiting segment is 30 minutes (one-half hour) the capacity is 48 trains per day (24 hours divided by 1/2 hour).

Practical and Theoretical Capacity

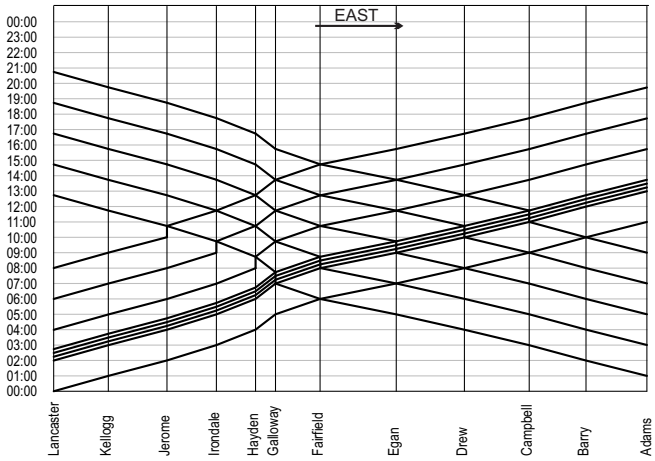
The examples demonstrate theoretical capacity. That is the capacity that can be achieved by using every possible movement opportunity through the capacity-limiting segment. That type of traffic density and the precision that is required to achieve it are not practical in regular operatoin. There will be some variation in even the most precise railroad operation (e.g., Switzerland or Germany). On a continuing basis, a railroad can be expected to perform reliably at about half of the practical cpacity. The unused half of the theoretical capacity is needed for track maintenance and as a buffer when trains do not fit exactly into the full-to-capacity traffic pattern.



In this example, the siding to siding travel time is uniform for the entire length of the line



In tis example, the travel time beteween Fairfield and Galloway is twice the travel time between other sidings. The segment between Fairfield and Galloway is the capacity limiting segment.



Fleeting trains in one direction may provide a small increase in capacity, but it is done at the expense of substantial delays to trains in the opposite direction.

Congestion

Regardless of when it is desirable to operate trains, the infrastructurre will determine when trains can be operated. Congestion occurs when traffic exceeds capacity. Congestion does not end until some time after traffic has been reduced to less than capacity.

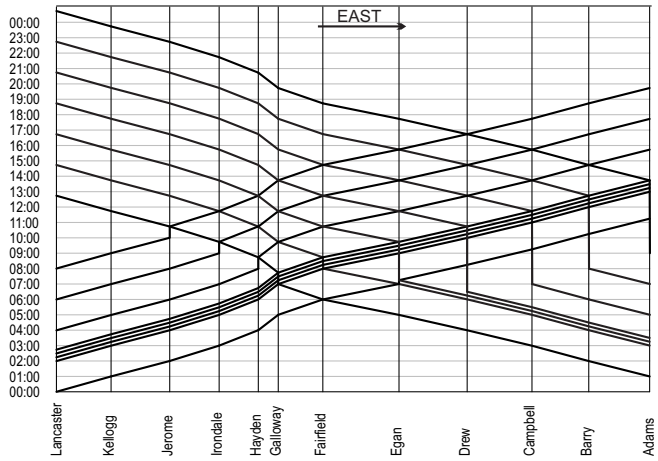
Commercial Capacity

The theory of spacing traffic evanly throughout the day in order to maximize utilization of the infrastructure is often not practical. Railroads are a business competing with other transportation modes for customers. They must provide service when customers need it or customers will shop for an alternative. Rather than configuring traffic to the characteristics of the infrastructure, it may be necessary to configure the characteristics of the infrastructure to the desired traffic. This approach is typically necessary when passenger trains are part of the traffic because of their need to operate at specic times determined by the travel needs of the public. Freight trains can also require special treatment. Bulk commodity trains operate in a conveyor belt-like manner, but trains carrying certain types of manufactured goods and packages for delivery have service requirements similar to those of passenger trains.

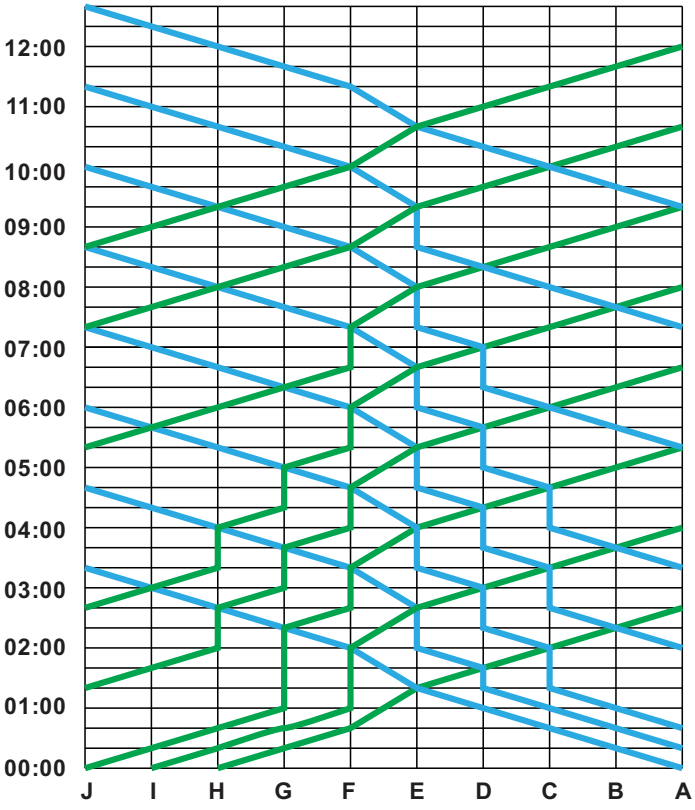
The effect of the pending PTC installations

The purpose of the PTC systems that have been mandated by the US Federal government is collision prevention. Such systems may have some effect on capacity, depending upon their design. The design of the systems is a work in progress. However, the fundamental operation of the system is similar to that of existing systems. The significant difference will be that the system will enforce the speed and stoppng requirements instead of relying solely on the engineers of trains.

PTC systems will probably include a display of the signals in the locomotive cab (commonly called cab signals). Cab signals provide a reliability improvement, but no substantial capacity improvement. Some current systems actually reduce capacity because of their design. The reliability improvement is found in the continuous information about conditions ahead. Wayside signals provide information to the engineer only as they are passed. If the condition ahead changes after the train has passed a signal, the engineer will not know about it until the next signal comes into view. If a train is closing on a slower train ahead, the train will receive a yellow signal (prepare to stop at next signal) when it is one block behind the slower train. If one second after the following train passes the yellow signal, the leading train clears the main track at a turnout, the engineer of the following train must still begin stopping and not discontinue the braking until the next signal, now displaying green, comes into view. A continuously updated cab signal, such as will probably be included in PTC design, will notify the engineer of the following train of the change and the discontinued need to stop immediately. The following train may proceed at normal speed and not experience the delay associated with preparing to stop.



Fleeting trains in both directions may provide a small increase in capacity, but it is done at the expense of greater delays to trains in the opposite direction than result from single direction fleeting.



When trains are operated at a following time of less than minimum headway, congestion occurs. Delays continue until after traffic entering the line has been reduced to less than capacity (less than minimum headway).

PTC systems may include some type of moving block system. These systems do not divide the line into discreet segments (blocks). Electronic systems and radio are used to allow a following train to be as close as stopping distance plus a safety buffer from the train ahead. There is always a possibility that a train may stop suddenly, probably due to a derailment or defective equipment. For that reason, the systems will be designed to not allow the following train to be closer than stopping distance. The systems will not allow many trains to follow within a short distance, making one very long virtual train.

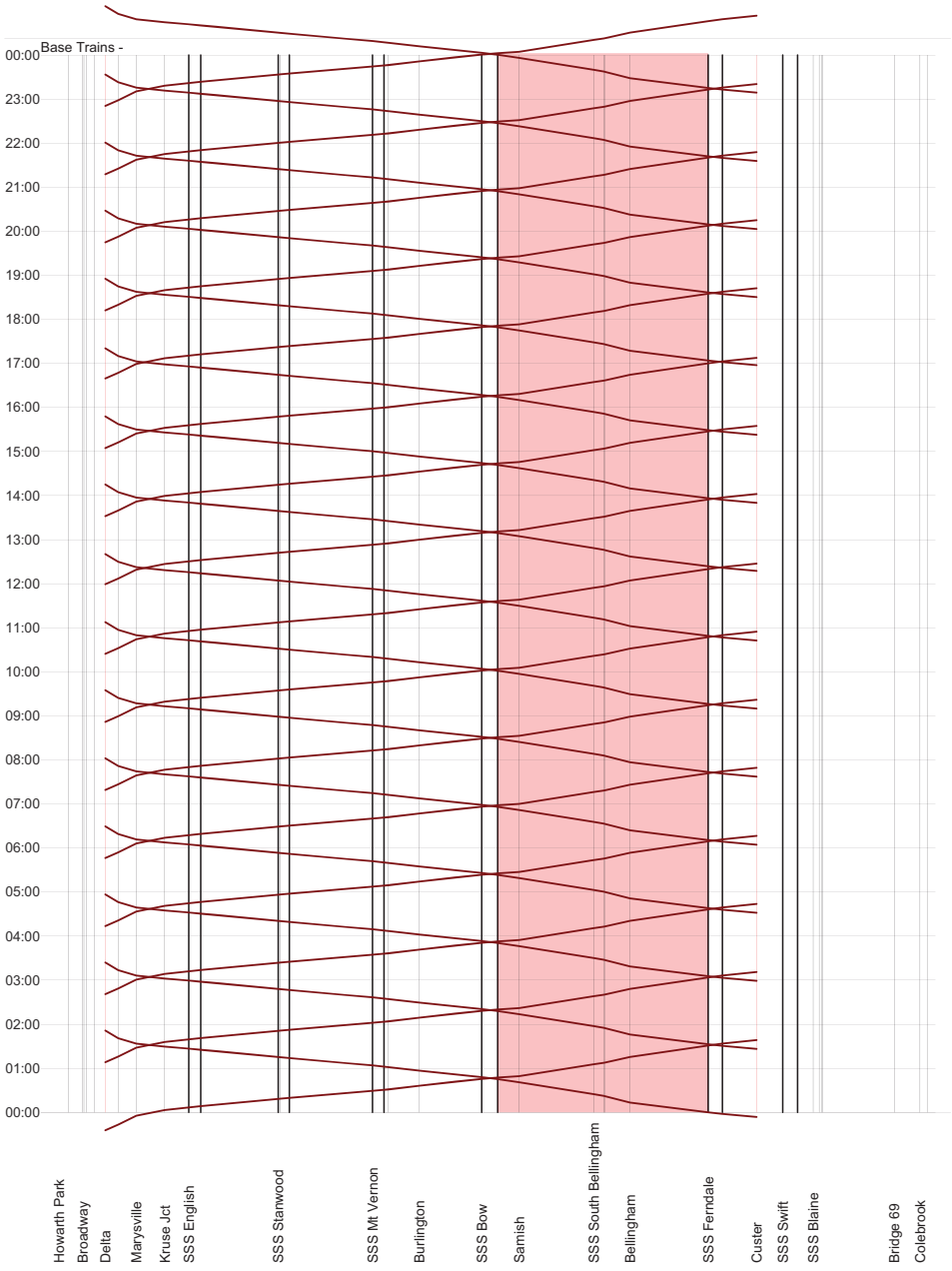
As well, PTC systems do not affect the basic infrastructure limitations on capacity. The distance between sidings on a single track line remain the same. PTC does not materially affect the travel time between sidings. The BNSF line between the Powder River Basin coal mines and the west coast is almost entirely a single track railroad. The supply of trains entering the line that extends between Everett and Custer is limited by the approximately 1,000 miles of single track railroad east of Everett.

Adjusting the infrastructure to the traffic

In general, a single track line should be configured with the travel time between sidings as uniform as possible. This arrangement minimizes delay when traffic is at or near capacity. If traffic is heaviest during a specific period because of commercial requirements, infrastructure is configured for that traffic level. Regardless, uniform travel time between sidings provides the most efficient operation.

The BNSF line between Everett and Custer

The adequacy of the line to accommodate traffic cannot be determined by examining an isolated segment. The line must be examined over a distance that allows consideration of the secondary consequences (e.g., a train that must be held because there is no track available for it at some distant point). That distance typically involves endpoints of junctions or terminals that feed traffic into and accept traffic from the line being examined. For the purpose of the discussion of the BNSF line that extends through Bellingham, we will consider the line between Everett and Custer,

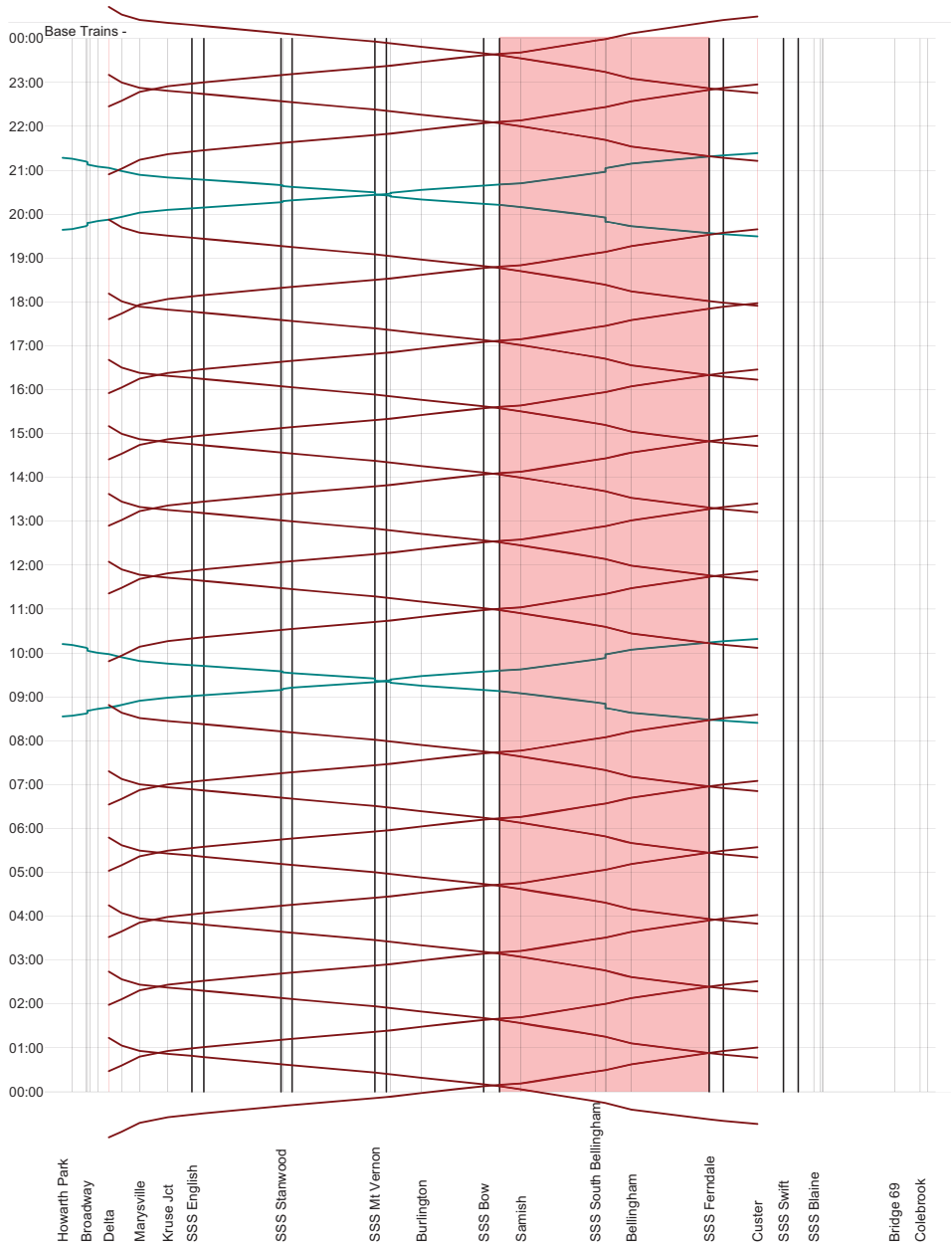


The capacity of the BNSF line between Everett and Custer is limited by the travel time between Bow and Ferndale (shaded). The siding at South Bellingham is not long enough to accommodate a typical freight train. In a day, 31 freight trains can operate through this segment when every movement opoortunity is used (practical capacity 15 trains).

where the proposed coal trains would leave the main line and travel on the branch line to Cherry Point.

Between Everett and Bow, the average speed limit is relatively high, the terrain is relatively flat, and sidings are spaced at intervals of about 15 minutes. Between Bow and Ferndale, the speed limit is relatively low, the steepest (ruling) grade on the line is located between Bellingham and Ferndale, and the siding at South Bellingham is not long enough to accommodate a typical freight train, rendering it useless for providing capacity to the line. The distance between Ferndale and Custer is short, but the capacity affected by coal trains would be limited by the low speed at which trains would leave the main track at Intalco (Custer).

Traffic on the line varies with economic conditions. Typically, there are several daily merchandise (mixture of manufactured goods and raw materials) daily, two daily Amtrak Cascades trains in either direction, and several coal and returning empty trains each week. The coal trains are moving from Wyoming to Roberts Bank BC for export from the West Shore terminal.



When the current Amtrak Cascades trains are added to the diagram, the number of freight train movement opportunities are reduced to 26 (practical capacity 12 freight trains).

Travel time for a freight train through the capacity-limiting segment between Bow and Ferndale is 48 minutes. That generates a theoretical cpacity of 31 trains per day (24 hours / 0.8 hours), which is a practical capacity of 15 trains. Previous to the current economic downturn, normal traffic on the line would regularly reach 12 trains per day, including the four Amtrak trains. Thus, any expected increase in normal traffic, freight or passenger, would require additional infrastructure.

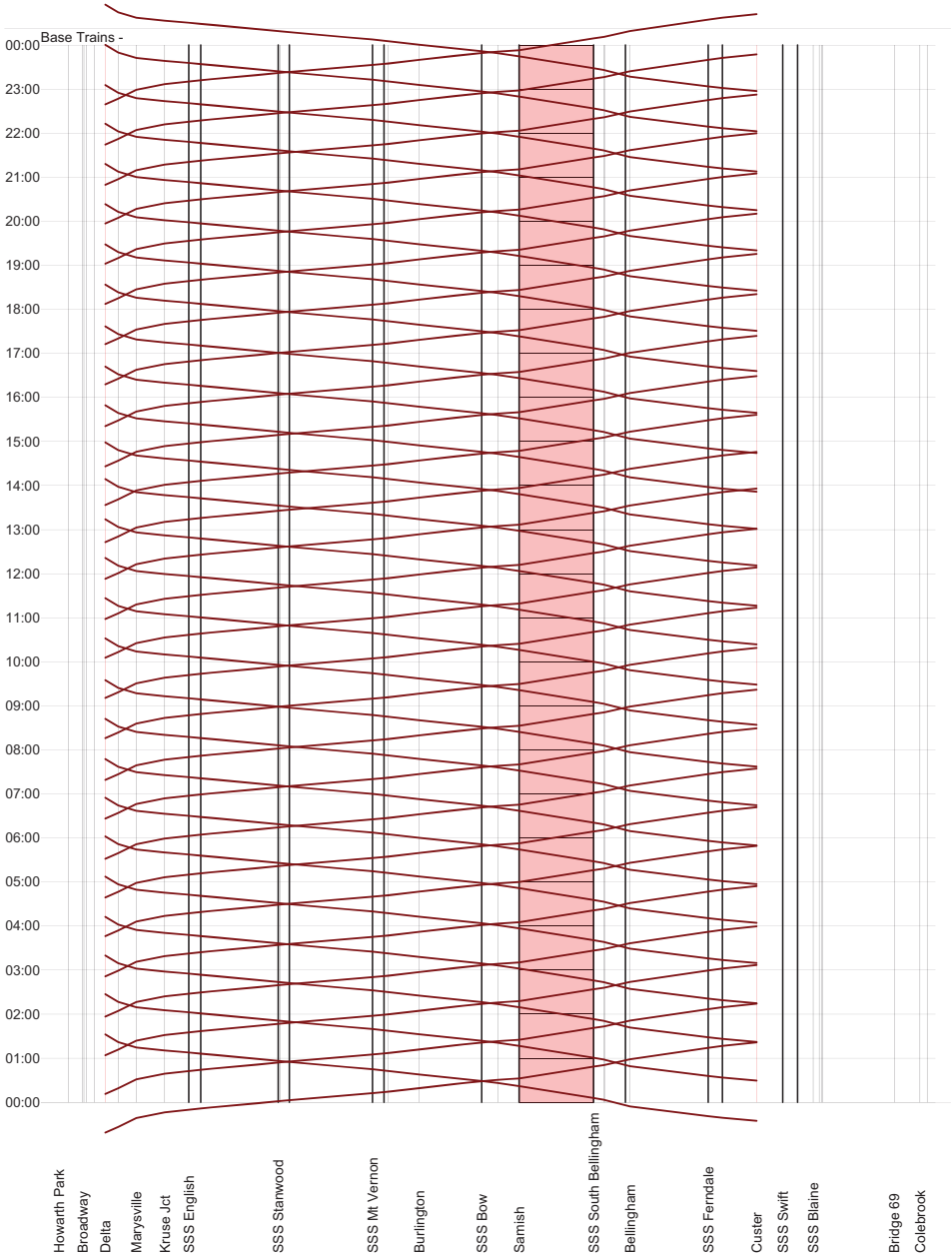
Plans for additional Amtrak Cascades trains

The Washington State Department of Transportation Log Range Plan for Amtrak Cascades (2007) includes two additional Amtrak Cascades trains in either direction between Seattle and Vancouver BC (after substantial infrastructure construction), but there is no currently projected funding for this expansion of the service.

The Long Range Plan describes the additional infrastructure requirements for the first of the two trains (the third daily

train). Between Everett and Custer, the service will require extending the Samish siding to the south and connecting to the siding at Bow, and extending the South Bellingham siding north from its present north end to Central Avenue. The infrastructure requirements for this train in British Columbia are substantial. There is no current plan in Washington or British Columbia to fund the required infrastructure.

The Samish and South Bellingham siding extensions were calculated for those locations for specific reasons. The greatest capacity increase for a project is found in reducing the longest travel time between sidings and simultaneously making inter-siding trvel times as uniform as possible. Construciton that makes the travel time through the capacity limiting segment substantially shorter than those along the rest of the line will move the capacity limitation to another segment. Constructoin that reduces the travel time through the capacity limiting segment to an amount that is still substantially more than the travel time through other segments along the line provides insufficient gain for the expenditure.



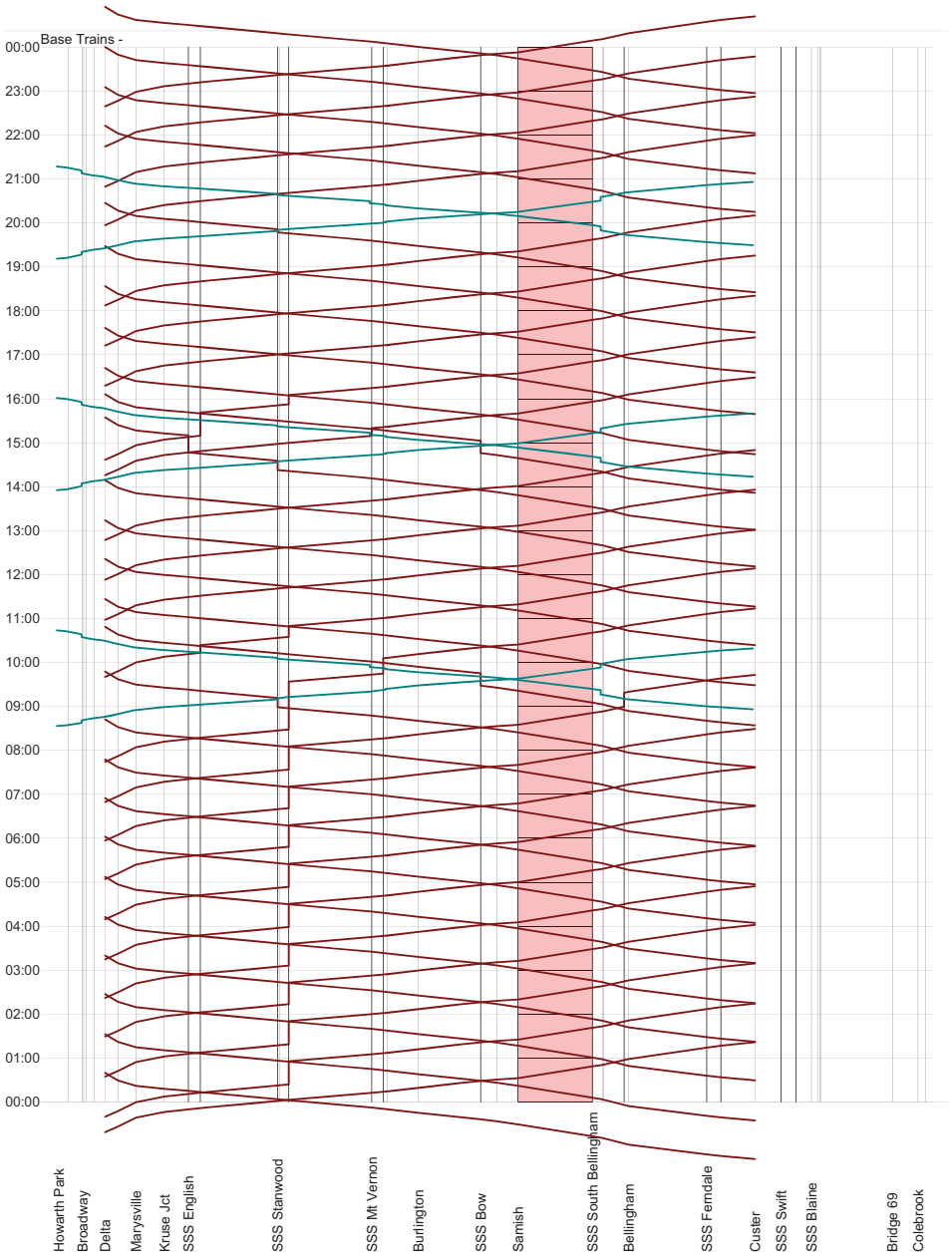
The WSDOT long range plan for Amtrak Cascades includes extending the sidings at Samish and South Bellingham to increase capacity. These locations are necessary in order to increase capacity and maintain approximately uniform travel times between sidings. The capacity limiting segment is now between Samish and South Bellingham. The extension of the Samish and South Bellingham sidings provides a capacity of 53 freight trains per day (Theoretical 25 freight trains per day).

An early plan to address the Bow - Ferndale segment was to construct a new siding north of Bellingham, between the Cliffside Drive and Slater Road crossings. This location provided a very small capacity increase, reducing the Bow - Ferndale travel time by less than ten minutes. That small gain in capacity would have been insufficient, and costly for the benefit. The optimum locatoin for a siding to provide the required capacity would be as close as possible to half way (in travel time) between Bow and Ferndale. That location would have been somewhere south of Chuckanut Bay. It would have been very costly costruction with potentially significant environmental consequences. The resulting inter-siding travel times would have been more than 20 minutes, still the longest inter-siding travel times on the line. The Bow-Ferndale segment would have twice the capacity, but would still limit capacity of the line to less than the other segments.

The solution that was developed for the final plan, extending the Samish and South Bellingham sidings, provided the greatest benefit for the expenditure, would be less costly then a siding south of Chuckanut Bay, and have smaller environmental consequences than a siding south of Chuckanut Bay.

The infrastructure requirements described in the Long Range Plan for the fourth daily round trip are substantial. The plan includes the change from 79 mph maximum speed to 110 mph maximum speed. This change will require a substantial amount of second and third main track between Marysville and Larrabee State Park and between a point near Marine Drive and Alderwood Ave. in Bellingham and the south bank of the Fraser River in Surrey BC. There is likewise no funding plan for this infrastructure.

There is a plan to redevelop the former Georgia Pacific paper mill in Bellingham. Part of the redevelopment plan includes relocating the BNSF main track from its current alignment through the Georgia Pacific property to south of the GP property and south of Cornwall Ave. This realignment would allow a speed increase from the current 20 mph for all trains around the curve through the GP property between Laurel Street and Central Avenue to 60 mph for Amtrak Cascades trains and 40 mph for freight trains. The increased speed reduces the amount of time that trains occupy road crossings and increases capacity by reducing the travel time between the South Bellingham siding and the Ferndale siding.



When the current Amtrak Cascades trains and the one additional Amtrak Cascades train for which the Samish and South Bellingham siding extensions are required are added to the capacity-level freight traffic, 49 freight trains may be operated (24 trains at practical level).

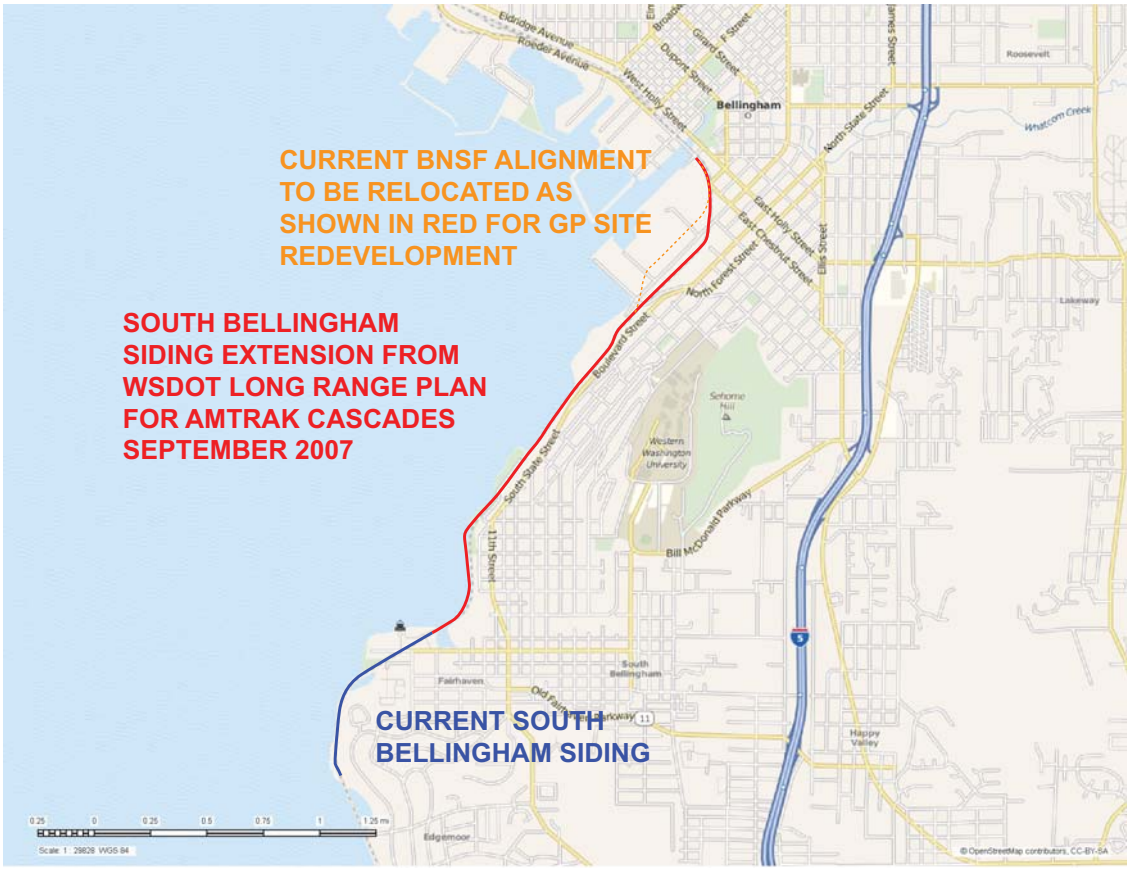
The segment between Bow and Ferndale is the current capacity limiting segment between Everett and Blaine. Extending the Samish and South Bellingham sidings as required for the third daily Amtrak Cascades train and increasing the train speeds as will be provided for in the relocation to the perimeter of the GP property will make travel times between sidings close to uniform between Everett and Blaine, providing a smooth flow of traffic as well as increased capacity.

Coal trains

Railroads are common carriers. That means that they provide service to any party that has something to ship. In the days of regulation, that meant handling any shipment whether it was profitable or not. Regulation ended when such requirements caused the economic collapse of a large part of the railroad industry. Railroads still handle any shipments offered, but with no requirement to handle them at a loss. There remains a small degree of regulation of railroads by Surface Transpor-

tation Board. Shippers who feel that they have been treated unfairly by a railroad may file a complaint with STB for possible corrective action. Railroads have no financial interest in the products they transport.

Freight transport by rail is safer than freight transplort by highway. Freight transport by rail also represents the reduction of damage to roadways by heavily-loaded trucks. Coal trains have characteristics that make them somewhat safer than a conventional freight train. All of the cars in the train are the same size and weight. The effect of braking action is uniform throughout the train. Conventional freight trains are made up of cars of many sizes and weights. The potential for derailment because of the differences in the cars (e.g., heavy cars following light cars or a mixture of long and short cars) requires greater caution in accelerating and braking the train. Coal trains also typically have locomotives at the rear of the train, controlled by radio-based remote control from the engineer of the locomotive at the front of the train. This arrangement facilitates the handling of the train, reducing the stress on the couplings and reducing the chance of mechanical failures. It also improves braking performance.



Railroads do not construct facilities that are not required. They have an extensive process to determine exactly what must

be built, where, and why. The BNSF system consists of about 32,000 miles of track in 27 states and British Columbia. The entire system must compete for the capital improvement funds that are available through normal business revenue. Every prospective project is analyzed and weighed careully against others. Each year, the capital program is the list of the highest return projects among all candidate projects. Projects that do not generate a return of the capital investment in a relatively short time are generally not considered. Unnecessary or poorly conceived projects will not be considered for funding.

The study process expands upon the fundamentals that have been explained in this paper. In addition to development using these principles, simulation is extensively used in a process that establishes a proposed solution as effective and not excessive. BNSF can be expected to support any new business, including the proposed coal trains, with the minimum amount of effective investment.

BNSF has made no public announcement of how it intends to handle the additional traffic, nor what infrastructure must be constructed to support it. It appears likely from examination of the infrastructure proposed in the WSDOT Long Range Plan for Amtrak Cascades, that the infrastrucure solution developed for increased coal train traffic will probably be similar. However, before construction can begin, the project will be subject to the procedures prescribed by the National Environmental Policy Act (NEPA). Projects of the magnitude of the additional infrastructure needed to support the expected coal train traffic will require a detailed statement of purpose and need, extensive research into the potential environmental effects, public discussion, and mitigation plans for environmental impacts that cannot be practically avoided.

Washington State

Amtrak *Cascades* Mid-Range Plan

Washington State Department of Transportation

December 2008

Prepared by the Freight Systems Division
State Rail and Marine Office
Washington State Department of Transportation

For more information, contact:

- Call the WSDOT State Rail and Marine Office at (360) 705-7900 or 1-800-822-2015;
- Write to the WSDOT State Rail and Marine Office at P.O. Box 47407, Olympia, WA 98504-4087;
- Fax your comments to (360) 705-6821; or
- E-mail your comments to rail@wsdot.wa.gov

Persons with disabilities may request this information be prepared and supplied in alternate forms by calling the WSDOT ADA Accommodation Hotline collect 206-389-2839. Persons with vision or hearing impairments may access the WA State Telecommunications Relay Service at TT 1-800-833-6388, Tele-Braille 1-800-833-6385, or Voice 1-800-833-6384, and ask to be connected to 360-705-7097.

Washington State Amtrak *Cascades* Mid-Range Plan

Prepared by

Washington State Department of Transportation
State Rail and Marine Office

December 2008

Washington State Department of Transportation

Washington State Department of Transportation

Table of Contents

Executive Summary vii

Background vii
Plan Purpose viii
Methodology viii
Public Involvement ix
Mid-Range Plan Options ix
Investment in Capital Projects x
Operating Costs, Revenues, and Investment Operations by Option xi
Capacity Increase xii
Reliability Improvement xiii
Ridership Growth xiv
Benefit/Cost Analysis xv
Connectivity xvi
Marketing xvi
Challenges and Opportunities xvii

Chapter 1: Introduction 1-1

Legislative Mandates 1-1
Macro Policy Environment 1-2
Methodology 1-2
Relationship with Other Plans 1-3
Public Involvement 1-4
Organization of this Plan 1-4

Chapter 2: Amtrak *Cascades* Development, Socioeconomic Context, and Mid-Range Plan Options 2-1

Amtrak *Cascades* Development 2-1
Socioeconomic Context 2-3
Mid-Range Plan Options 2-8

Chapter 3: Ridership for Amtrak *Cascades* 3-1

Ridership History 3-1
Ridership Distribution 3-3
Ridership Profile 3-5
Factors that Drive Ridership Growth 3-6
Growth Forecast: Methods and Results 3-6
Growth Analysis: Peak Ridership and Capacity, Time Saving and Reliability Improvement Effect – Discussion and Results 3-7

Chapter 4: Amtrak *Cascades* Needed Infrastructure Improvements: FY2010 to FY2017 4-1
Identifying and Refining Infrastructure Improvements 4-1
Updating Costs to Implement Infrastructure Improvements 4-2
Infrastructure Improvements and Service Capacity 4-3

Chapter 5: Operational Analysis and Costs 5-1
Operational Analysis 5-1
Opportunities to Enhance Reliability and Improve Performance 5-4
Opportunities for Service Enhancements 5-7
Analysis and Estimation of Operating Costs 5-7

Chapter 6: Options for Achieving Additional Amtrak *Cascades* Service 6-1
Options for Achieving Additional Services 6-1
Investment in Capital Projects by Option 6-2
Operating Costs, Revenue, and Investment in Operations by Option 6-3
Total Public Investment by Option 6-5
Growth of Ridership and Capacity by Option 6-7
Economic Impacts 6-13

Chapter 7: Benefit Cost Analysis 7-1
Understanding Public Investment and Benefit 7-1
Benefits and Costs Assessment 7-3
Transportation Cost Analysis 7-11

Chapter 8: Amtrak *Cascades* and Connectivity 8-1
Connections with Other Modes 8-1
Other Issues Impacting the Integration of Transportation 8-7

Chapter 9: Amtrak *Cascades* Marketing 9-1
Introduction 9-1
Goals and Objectives 9-1
Marketing Analysis 9-1
Segments and Target Markets 9-2
Pricing 9-3
Marketing Strategy 9-3
Marketing Action Plan 9-6
Financial Forecast 9-8
Performance Measurements 9-9

Chapter 10: Financing Amtrak *Cascades* Service: The Challenges and Opportunities 10-1

Funding History 10-1
Current Funding Status 10-4
Challenges and Opportunities 10-4

Appendices

Appendix 1: Legislative Mandates A1-1
Appendix 2: Advisory Group Meetings A2-1
Appendix 3: History of Rail Development in Washington State A3-1
Appendix 4: Amtrak *Cascades* Ridership Forecasting A4-1
Appendix 5: Project Cost Estimates A5-1
Appendix 6: Operational Capacity Considerations A6-1
Appendix 7: Peak Ridership and Effective Capacity A7-1
Appendix 8: Societal Benefit Assessment A8-1
Appendix 9: Assessing Environmental Costs A9-1
Appendix 10 Acronyms A10-1
Appendix 11: Bibliography A11-1
Appendix 12: Glossary A12-1
Appendix 13: WSDOT Responses to Stakeholders' Comments or Questions A13-1

List of Exhibits

Exhibit ES-1: Mid-Range Plan Options x
Exhibit ES-2: Capital Investment by Option xi
Exhibit ES-3: Total Operating Costs, Revenue, and Net State Costs for Amtrak *Cascades* Operations Sum of FY2010 – FY2017 ($Millions) xii
Exhibit ES-4: Maximum Annual Seating Capacity by Option Seattle to Portland FY2010-FY2017 xiii
Exhibit ES-5: Reliability Improvement by Option xiii
Exhibit ES-6: Annual Ridership Growth by Option FY2007 vs. FY2017 Vancouver, B.C. to Portland xiv
Exhibit ES-7: Economic Impacts of *Amtrak Cascades Mid-Range Plan* Options: Sum of FY2010 to FY2030* xv
Exhibit ES-8: Estimated Benefit/Cost Ratio by Investment Option xvi
Exhibit 2-1: Amtrak *Cascades* Daily Schedule 2-2
Exhibit 2-2: Population Surrounding Amtrak *Cascades* Service Drive Times to Amtrak Stations 2-4
Exhibit 2-3: Vehicle Miles Traveled Along the I-5 Corridor 2-4
Exhibit 2-4: Greenhouse Gases by Transportation Mode 2-7
Exhibit 3-1: Amtrak *Cascades* Annual Ridership – 1994-2007 3-2
Exhibit 3-2: Station On-Offs – 2007 3-4
Exhibit 3-3: Amtrak *Cascades* On-Offs by Station – 2007 3-5

List of Exhibits (Continued)

Exhibit 3-4: Comparison of Monthly Ridership History, Baseline Forecast, and Alternative Forecast without Gasoline Price Index 3-7
Exhibit 3-5: Peak Ridership vs. Peak Capacity – Option 2 – Minimum Capital Investment 3-9
Exhibit 4-1: Projects and Project Stages that Could Be Implemented to Achieve Additional Service Levels During the Mid-Range Planning Horizon: FY2010 to FY2017 4-4
Exhibit 4-2: Projects with Reliability Benefits 4-5
Exhibit 5-1: Passenger Service On-Time Performance Based on Five Cases of Randomized Freight Service 5-2
Exhibit 5-2: WSDOT Plan's Impact on Freight Service 5-4
Exhibit 5-3: Estimates of Annual Operating Costs and Maintenance Costs (2008 Dollars) 5-10
Exhibit 5-4: Amtrak Cascades Operating Costs for Seattle to Portland Four Daily Round Trips (2008 Dollars) 5-11
Exhibit 5-5: Amtrak *Cascades* Operating Costs for Seattle to Portland Eight Daily Round Trips (2008 Dollars) 5-11
Exhibit 6-1: Capital Investment by Option 6-3
Exhibit 6-2: Total Operating Costs, Revenue, and Net State Costs for Amtrak Cascades Operations FY2010-FY2017 ($ Millions) 6-4
Exhibit 6-3: Dynamics of Total Public Investment Passenger Rail Investment by Option: FY2010 to FY2017 6-5
Exhibit 6-4: Passenger Rail Investment by Year and Option FY2010 to FY2017 ($ Million) 6-7
Exhibit 6-5: Growth of annual Ridership by Option FY2017 vs. FY2007 6-8
Exhibit 6-6: Maximum Annual Seating Capacity by Option Seattle to Portland FY2010 to FY2017 6-8
Exhibit 6-7: Peak Ridership vs. Effective Capacity (Seattle/ Portland): Option 1 – Maintain Current Operation 6-10
Exhibit 6-8: Peak Ridership vs. Effective Capacity (Seattle/ Portland): Option 2 – Minimum Capital Investment 6-11
Exhibit 6-9: Peak Ridership vs. Effective Capacity (Seattle/ Portland): Option 3 – Supply Meets Demand 6-12
Exhibit 6-10: Peak Ridership vs. Effective Capacity (Seattle/ Portland): Option 4 – No Financial Constraint 6-13
Exhibit 6-11: Economic Impacts for Amtrak Cascades Mid-Range Plan Options: FY2010 to FY2030 6-14
Exhibit 7-1: Benefit of Reducing Congestion 7-5
Exhibit 7-2: Comparison of Passenger Safety 7-6
Exhibit 7-3: Emission Rates – Grams per Passenger Mile 7-6

List of Exhibits (Continued)

Exhibit 7-4: Estimated Public Benefits by Investment Option (2008 Dollars, $ Million) 7-7
Exhibit 7-5: Estimated Public Costs for Amtrak *Cascades* Passenger Rail Sum of FY2010 to FY2030 (2008 Dollars, $ Million) 7-9
Exhibit 7-6: Estimated Benefit/Cost Ratio by Investment Option.. 7-10
Exhibit 7-7: Incremental Benefit/Cost Ratio by Investment Options 7-11
Exhibit 7-8: Composition of Cost Per Passenger Mile – Passenger Rail 7-12
Exhibit 7-9: Composition of Cost Per Passenger Mile – Highway 7-14
Exhibit 7-10: Composition of Cost Per Passenger Mile – Air 7-14
Exhibit 7-11: Transportation Costs: Cross Modal Comparison 7-15
Exhibit 8-1: Amtrak *Cascades* Stations in Washington State and Transportation Connections 8-3
Exhibit 8-2: Parking Availability at Amtrak *Cascades* Stations Portland, OR to Vancouver, B.C. 8-9
Exhibit 9-1: Proposed Marketing Budget 9-8
Exhibit 10-1: Amtrak *Cascades* Investment History: 1994-2007..... 10-3

Executive Summary

The Washington State Legislature directed the Washington State Department of Transportation (WSDOT) to develop a mid-range plan for Amtrak *Cascades* that identifies specific steps to achieve additional service beyond current levels. As stated in ESHB 1094, Section 226, WSDOT is required to submit a mid-range plan to the Office of Financial Management and the transportation committees of the legislature by December 31, 2008. The *Amtrak Cascades Mid-Range Plan* fulfills the legislative mandate by identifying and developing options that outline steps to achieve incremental Amtrak *Cascades* services for the next eight years.

Background

Washington State faces both challenges and opportunities resulting from the fundamental changes in our economy and society. Public investment policies embrace solutions that address multiple issues such as economic globalization, population growth, increased roadway congestion, higher fossil fuel prices, global climate changes, and increases in natural and man-made disasters.

Passenger rail, once used as a means to address only mobility problems, is increasingly viewed and used, at both national and regional levels, as an integrated part of robust and resilient multimodal transportation systems. Such robust transportation systems will help policymakers achieve multiple policy ends, including economic viability, societal mobility, environmental sustainability, and public safety.

Amtrak *Cascades* is an intercity passenger rail service between Eugene, Oregon, and Vancouver, British Columbia (B.C.). It is sponsored by the states of Washington and Oregon in partnership with other parties. The service, known as the Amtrak *Cascades*, provides travelers with a viable transportation alternative for their intercity trips.

Rail development in the Pacific Northwest began in 1864, when President Abraham Lincoln signed the Northern Pacific Railroad Charter to build a direct rail connection between the Great Lakes and Puget Sound. Washington State investment in Amtrak intercity passenger rail service began in 1994. After incremental infrastructure enhancements by Washington State and its partners, intercity passenger rail service with Talgo trains began in 1999, and was branded Amtrak *Cascades*.

Amtrak currently operates Amtrak *Cascades* intercity passenger rail service on the Pacific Northwest Rail Corridor (PNWRC), which runs roughly parallel to the I-5 corridor between Vancouver, British Columbia, and Eugene, Oregon. The PNWRC is owned by BNSF Railway (BNSF) in Washington State and by Union Pacific Railroad (UP) in Oregon State. Amtrak *Cascades* offers one daily round trip between Seattle and Vancouver, B.C.; one daily round trip between Portland and Bellingham; two daily round trips between Eugene and Portland; and four daily round trips between Portland and Seattle.

Plan Purpose

In response to a legislative mandate, the *Amtrak Cascades Mid-Range Plan* FY2010 to FY2017 is to provide Washington State policymakers with four strategic investment options for infrastructure development. These plan options incrementally enhance service capacity, improve on-time performance, and increase ridership on the segment between Seattle and Portland over the next eight years.

The mid-range plan:

- Identifies the needs of intercity passenger train services.
- Assesses potential of passenger rail as a strategic multimodal transportation solution.
- Specifies the steps of improving infrastructure to deliver additional intercity passenger services.
- Links capital and operational investment to ridership growth and economic and societal benefits.
- Provides a variety of information to support informed decision-making processes—legislative budgeting and prioritizing.

Methodology

The strategy adopted by WSDOT to develop the mid-range plan is fact-based and demand-driven. WSDOT strengthened its ridership forecast and analytic capacity by developing robust ridership databases and forecast models. WSDOT improved capital project cost estimation through a specific cost study of all historic rail projects.

Based on management directives, the mid-range plan provides policymakers with options that are designed, analyzed, and presented to address socioeconomic policy issues. Results of investment in infrastructure improvements to add additional services are assessed and measured in terms of enhanced capacity, improved reliability, and increased ridership for considering funding additional Amtrak *Cascades* services. Economic impact assessment, benefit/cost analysis, and cross

modal comparison were also performed to assist policymakers in linking the investment of an option to its effects on the economy and society.

Public Involvement

In the development of the mid-range plan, an advisory committee was formed, involving identifiable stakeholders. The advisory committee's role was to help WSDOT assess and evaluate beneficial impacts of rail infrastructure improvement on society, to help WSDOT understand concerns of local communities, and to share information and provide feedback during the mid-range plan development process. Advisory committee stakeholders involved in the development of the mid-range plan include:

- Metropolitan Planning Organizations and Regional Transportation Planning Organizations in the I-5 corridor
- Counties and cities within the study area
- Oregon State
- Province of British Columbia
- Private railroads
- Amtrak
- Washington Public Ports Association
- WSDOT planning units in different modes
- WSDOT regions
- All tribes in Washington State with an interest in the I-5 corridor
- Passenger rail advocacy groups

Two public/advisory committee meetings were held at WSDOT, led by State Rail and Marine Office staff, providing progress reports and opportunities for public comments and discussion. After the public/advisory committee meetings, the draft plan was available for two weeks for public review and comment. Some public comments were incorporated into the final draft and the remainder are included in Appendix 13 with WSDOT's responses.

Mid-Range Plan Options

Options presented in the mid-range plan are designed in the context of the current macroeconomic policymaking environment. The options build on incremental strategies with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. The four options presented in this plan are different approaches to achieve incremental Amtrak *Cascades* services for the next eight years between Portland and Seattle, where the greatest concentration of ridership and the most service improvements are needed (Exhibit ES-1).

Exhibit ES-1: Mid-Range Plan Options

Option 1 □ Maintaining the Current Operation	• Option 1 is an analytical baseline. • No capital investment is needed. • It maintains capacity at four daily round trips between Seattle and Portland. • On-time performance is about 60 percent.
Option 2 □ Incremental Strategy □ Minimizing Capital Investment	• Completes four capital projects already underway by FY2012. • Capital investment is □141 million. • Capacity increases from four to five daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 95 percent.
Option 3 □ Incremental Strategy □ Matching Supply and Demand	• Completes all four projects in Option 2 and five additional new capital projects bye FY2017. • Capital investment is □537 million. • Capacity increases from four to six daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 97 percent.
Option 4 □ No Financial Constraints	• Completes all four projects in Options 2 and 3 and five additional new capital projects by FY2014. • Capital investment is □817 million. • Capacity increases from four to eight daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 92 percent.

Investment in Capital Projects

Exhibit ES-2 shows Amtrak *Cascades* proposed infrastructure improvements and investment. Capital projects are incrementally developed as project groups. Project groups are building blocks that combine a number of projects to deliver an incremental service level. The cost estimates are based on prices during the implementation timeframe of each specific mid-range option.

Exhibit ES-2: Capital Investment by Option

Project Group	Year of Completion	Capital Cost Estimates (Million)				Deliverables
		Option 1: 0	Option 2: 141 Million	Option 3: 578 Million	Option 4: 817 Million	
Project Group A: 141M for Options 2, 3, and 4	Option2,3,and 4: 2012		141.2	141.2	141.2	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.
Project Group B: Option 3 437M; Option 4 334M	Option 3: 2017 Option 4: 2015			437.1	334.2	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.
Project Group C: 341M for Option 4	Option 4: 2015				341.4	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.
A project group is a set of projects or project stages to be implemented collectively to achieve additional service.						
Costs do not include anticipated expenditures prior to July 2009 in 2008 Transportation Supplemental Budget. These projects were currently funded as: Tacoma Bypass of Pt. Defiance 66th St. to Nisqually, 57.1 million; Vancouver Yard Bypass and W 39th St., 59.9 million; King Street Station Track Improvements, 13 million; Cascades Train Sets Overhaul, 4 million. The cost estimates listed in options are additional costs needed to complete these projects starting July 2009.						
Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.						

Source: WSDOT State Rail and Marine Office

Operating Costs, Revenue, and Investment in Operations by Option

Operating costs include the costs to operate Amtrak *Cascades* intercity passenger train services and costs to maintain service equipment. Since each option in the mid-range plan operates at a different level, the operating costs vary. However, Options 3 and 4 operate more efficiently due to economies of scale.

Revenue includes ticket revenues and revenues from services provided on the trains such as food and beverage revenues.

Net state costs in operations is the state's net investment from public funds for Amtrak *Cascades* operation. It is the total operation costs minus revenues from operation. It is a public investment that aims for gaining greater economic and societal benefits.

Exhibit ES-3 shows the sum of operating costs, revenue, and investments in operations for all plan options from FY2010 to FY2017.

Exhibit ES-3: Total Operating Costs, Revenue, and Net State Costs for Amtrak *Cascades* Operations
Sum of FY2010 - FY2017 (Millions)

Plan Options	Operating Costs	Revenue	Net State Costs for Amtrak Cascades Operation
Option 1: Maintaining Current Operation	235.7	118.4	117.3
Option 2: Incremental Strategy 1 - Minimum Capital Investment	360.2	144.4	215.8
Option 3: Incremental Strategy 2 - Supply Meets Demand	366.7	153.0	213.8
Option 4: No Financial Constraints	428.2	157.2	270.9

Include operating costs, Talgo maintenance costs, maintenance costs enhancing reliability, and Amtrak administrative costs. Estimated based on historical data, Amtrak FFY2009 Cost Estimates, and planned activities.

Include revenues from tickets and passenger services. Estimated based on historical revenue data assuming price neutral policy. Total revenue is the product of total forecasted passenger miles and revenue earned per passenger mile, adjusted for inflation.

This is the estimated costs Washington State pays for contracted Amtrak *Cascades* operation.

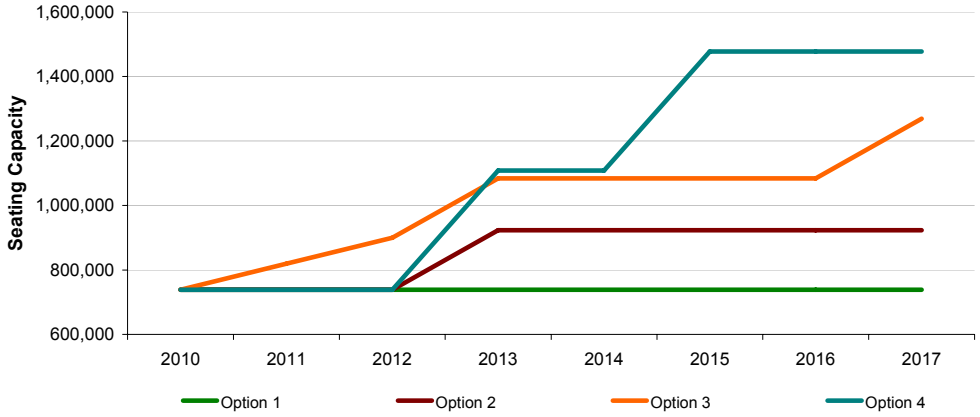
The sixth round trip starts in FY2017, the total operation cost here for Option 3 does not show full effect of the operation at the capacity built.

Source: WSDOT State Rail and Marine Office

Capacity Increase

The capacity growths for plan options are based on capital projects that build capacity for each plan option (Exhibit ES-4). The capacity increase and reliability improvement of capital projects are presented in Chapter 4. Exhibit 6-6 in Chapter 6 provides a dynamic view of capacity changes by option over the time frame of the mid-range plan.

Exhibit ES-4: Maximum Annual Seating Capacity by Option
Seattle to Portland FY2010-FY2017



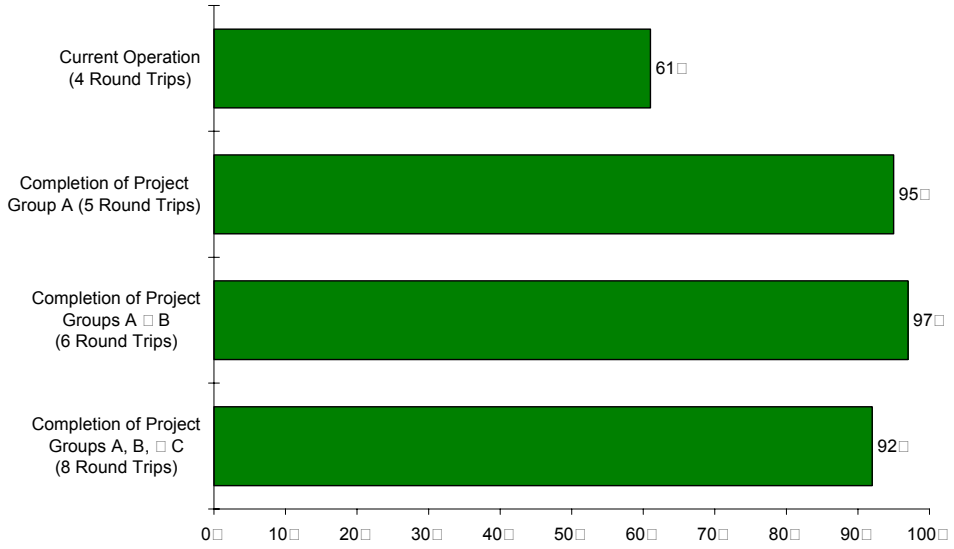
Note: Maximum seating capacity = Seats per train X Trains per day X 365 days

Source: WSDOT State Rail and Marine Office

Reliability Improvement

Operational analysis by the WSDOT State Rail and Marine Office in 2007-2008 reviewed the infrastructure necessary to support each mid-range plan option. The analysis included traffic conditions and growth expectations for Amtrak *Cascades*, Sounder, BNSF, and the UP. The analysis validated the investment in capital projects and their impacts on service capacity and on-time performance (Exhibit ES-5). Please note that on-time performance decreases slightly resulting from the operation of eight round trips.

Exhibit ES-5: Reliability Improvement by Option



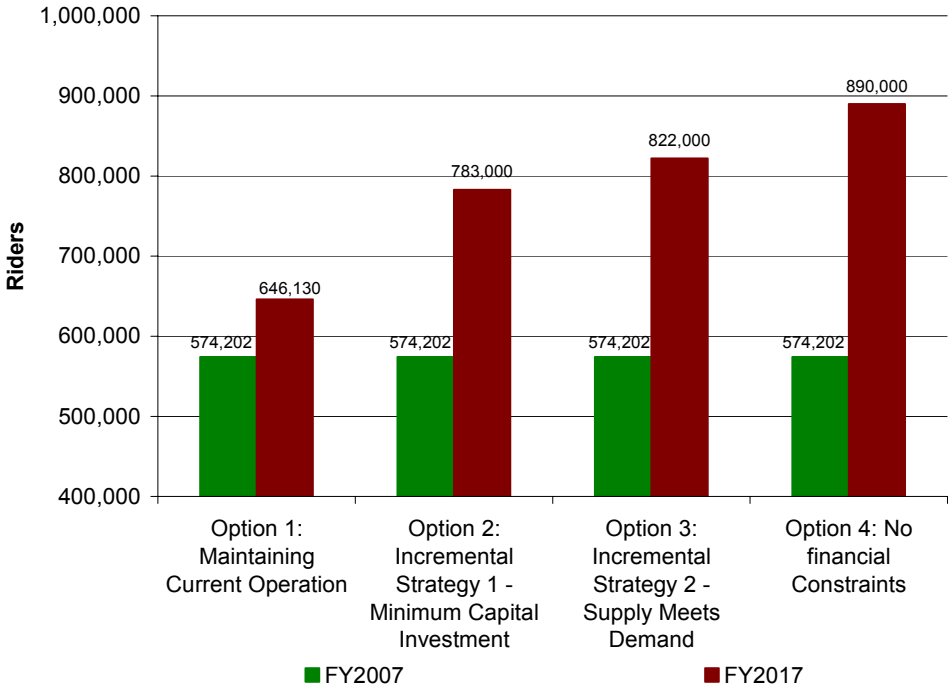
Source: Transit Safety Management

Ridership Growth

The ridership growth for plan options is estimated through two processes. First, the ridership forecast model is developed to forecast long-term growth of ridership based on factors such as population, gas prices and service availability. Second, based on improvement on on-time performance and scheduled time savings resulted from implementation of plan options, additional ridership growth is estimated using demand elasticity of time reduction published for Amtrak passenger trains.

The ridership growth for the mid-range plan options is demonstrated in Exhibit ES-6.

Exhibit ES-6: Annual Ridership Growth by Option
FY2007 vs. FY2017
Vancouver, B.C. to Portland



Source: WSDOT State Rail and Marine Office

Economic Impacts

When public funds are used to invest in Amtrak *Cascades* intercity passenger train services, the investment generates economic impacts that would benefit the state and local communities in general. The magnitudes of economic impacts are dependent on the size of investment and how the funds are invested. WSDOT used the Washington State input-output

economic model, developed using IMPLAN[1], to estimate the ripple effects of the increases in Amtrak *Cascades* services. The IMPLAN model was used to estimate the total economic impacts of mid-range plan options, including the cascading effects of the investments of each option. The economic impacts are assessed in terms of the following two indicators:

- **Employment** represents the jobs created by the investment. Amtrak *Cascades* service directly creates jobs in construction, maintenance, food service, and transportation operations. It also creates jobs indirectly by the affect of the outputs of other industries and government incomes.
- **Value added** is an indicator that reflects the net benefit of the investment. Both labor income (wages and salaries) and business incomes are counted as value added.

Exhibit ES-7 demonstrates economic impacts of the four plan options.

Exhibit ES-7: Economic Impacts of *Amtrak Cascades Mid-Range Plan* Options: Sum of FY2010 to FY2030

Impact	Area	Option 1: Maintaining Current Operation	Option 2: Incremental Strategy 1 - Minimum Capital Investment	Option 3: Incremental Strategy 2 - Supply Meets Demand	Option 4: No Financial Constraints
Support Employment (Job-Year)	Benefits to Local Communities Along I-5 Corridor	4,887	11,725	17,454	23,752
	Statewide Benefits (Include benefits to local communities)	6,202	15,024	22,825	31,138
Value Added (Million, 2008 Dollars)	Benefits to Local Communities Along I-5 Corridor	306.5	746.8	1,139.9	1,555.1
	Statewide Benefits (Include benefits to local communities)	399.7	977.6	1,500.6	2,048.1

Note: Economic impacts are assessed using IMPLAN Input-Output model for Washington State and its local areas.

The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017.

A job-year means that a person is employed as a full-time employee for a year.

Difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the gross domestic product (GDP).

Source: WSDOT State Rail and Marine Office

Benefit Cost Analysis

The benefit/cost analysis looked at investments, benefits, and impacts of the Amtrak *Cascades* projects completed during the mid-range plan period

[1] IMPLAN is a commercial input-output model developed using input-output data from Bureau of Economic Analysis, U.S. Department of Commerce. The model used to estimate economic impacts in this plan is a Washington State specific model.

of FY2010 to FY2017. Because the projects can generate benefits for local communities and Washington State for many years beyond FY2017, the analysis looked at benefits and costs through FY2030. Economic benefits (revenue and value added) and societal benefits (congestion relief, safety improvement, and environmental impact reduction) were analyzed to calculate net benefit, which was used in the benefit/cost analysis. Exhibit ES-8 highlights this analysis.

Exhibit ES-8: Estimated Benefit□Cost Ratio by Investment Option

Plan Option	Sum of FY2010 to FY2030□- □Million (2008 Dollars)			
	Total Cost□□ (□Million)	**Total Benefit□□ (□Million)**	**Net Benefit (□Million)**	**B□C Ratio**
Option 1: Maintaining Current Operation	□310	□625	□315	**2.02**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	□733	□1,853	□1,120	**2.53**
Option 3: Incremental Strategy 2 - Supply Meets Demand	□1,129	□2,744	□1,615	**2.43**
Option 4: No Financial Constraints	□1,536	□3,400	□1,864	**2.21**
Note: Option 1 is the baseline.				
□The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.				
□□Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).				

Source: WSDOT State Rail and Marine Office

Connectivity

Multimodal connectivity at Amtrak *Cascades* train stations includes travel by Sound Transit (Light Rail, Sounder, and Express Bus), marine (Washington State Ferries service, cruise ships), bus (public and private intercity bus services), air, and bicycle. Service improvements to enhance connectivity include integrated fares, travel packages, integrated schedules, passenger information systems, signage, and parking/bicycle storage.

Marketing

Amtrak *Cascades* marketing is operated by the WSDOT State Rail and Marine Office to optimize ridership and service capacity usage. It

promotes the achievement of ridership and revenue targets and builds strong brand awareness (Amtrak *Cascades* as differentiated from Amtrak and other transportation modes). It primarily targets adults ages 25-54 in the Seattle and Portland markets, where potential ridership is most concentrated. Marketing currently operates with a flat budget of $1 million to $1.3 million and is focused on non-business travelers. Depending on the mid-range plan option, Amtrak *Cascades* marketing can be positioned with an industry-standard, ridership-based budget to promote the ease, comfort, and environmental sustainability of train travel as a viable transportation alternative for business and non-business travelers.

Challenges and Opportunities

Mobility, reliability, environmental sustainability, safety, and tourism are important considerations when planning Amtrak *Cascades* intercity passenger rail development. A strategic investment in Amtrak *Cascades* infrastructure development, depending on the mid-range option, can:

- Increase mobility and reduce congestion on the I-5 corridor and at Sea-Tac International Airport.
- Increase reliability and attract business travelers.
- Increase energy efficiency and reduce environmental impacts of other more polluting and energy consuming transportation modes.
- Improve passenger safety and offset the safety of other transportation modes.
- Support and enhance tourism development, one of Washington's top industries.

Policymakers, in considering the *Amtrak Cascades Mid-Range Plan* options, are faced with strategic investment challenges that include the lack of dedicated federal funding, limited multimodal state funding, and uncertain Oregon State and British Columbia funding.

Policymakers are also presented with strategic investment opportunities that can reduce travel time up to 30 minutes, increase reliability (on-time performance) from 60 percent to 90 percent, reduce greenhouse gas emission and fuel consumption, and increase ridership.

Amtrak *Cascades* is experiencing double-digit ridership growth due to higher fuel prices and favorable socioeconomic trends as discussed throughout this plan. The trends are likely to continue beyond the mid- and long-range planning horizons as population and transportation demand increases and resources become scarcer. Strategic investment in Amtrak *Cascades* intercity passenger rail infrastructure development, as an integrated part of the multimodal solution of resilient transportation

systems in Washington State, provides policymakers an opportunity to meet societal needs from a long-term perspective.

To manage the risk of cost escalation, WSDOT plans to develop a better contract management practice. To this end, WSDOT should examine methods of lowering risk to the state including the development of a price agreement with BNSF to run a pre-determined number of round trips at a certain level of performance.

Washington State Department of Transportation

Chapter 1: Introduction

Since 1994 the Washington State Department of Transportation (WSDOT) has partnered with Amtrak, the state of Oregon, the province of British Columbia, the railroads, and others to provide fast, reliable, and more frequent intercity passenger rail service along the 466-mile Pacific Northwest Rail Corridor (PNWRC). As one of 11 federally designated corridors, the PNWRC extends from Eugene, Oregon to Vancouver, British Columbia (B.C.). The service, known as the Amtrak *Cascades*, provides travelers with a viable transportation alternative for their intercity trips.

Following the legislature's directive, WSDOT developed and published the *Long-Range Plan for Amtrak Cascades* (2006). The incremental approach, outlined in the plan, would allow the state of Washington to add faster, more frequent Amtrak *Cascades* service based on market demand, partnership investment, and legislative authorization. In order to ensure that public funds are expended in the most efficient manner, construction projects have been designed and grouped as "building blocks" to deliver incremental services. This strategy would allow projects to be constructed in a logical sequence to meet system performance objectives while providing flexibility for funding.

The Amtrak *Cascades* program is being implemented in stages, using a step-by-step approach for development. Service is added over time, based on available state and federal funding and market demand.

Legislative Mandates

Washington State Legislature has directed WSDOT to develop a mid-range plan for Amtrak *Cascades* that identifies specific steps to achieve additional service beyond current levels. ESHB 1094, Section 226, requires WSDOT to submit a mid-range plan to the Office of Financial Management and the transportation committees of the legislature by December 31, 2008. The *Amtrak Cascades Mid-Range Plan* fulfills the legislative mandate by identifying and developing options that outline steps to achieve incremental Amtrak *Cascades* services for the next eight years. Relevant legislative directives (Appendix 1) were reviewed and implemented as applicable to this mid-range plan.

The purposes of the mid-range plan include:

- Providing policymakers (the Governor and Washington State Legislature) with information, based on benefit and cost analyses, for further development of strategic economic investment policy for Washington State's Amtrak *Cascades* intercity passenger rail program.
- Describing four options to increase intercity passenger rail service along the I-5 corridor based on analysis of supply and demand, and estimating resources needed to implement these options.
- Specifying steps that increase capacity and improve reliability for additional intercity passenger rail services associated with each of the four mid-range plan options.
- Helping policymakers assess the potential of rail as part of an integrated transportation solution that addresses interwoven problems, such as economic development, road congestion, public safety, and environmental impacts.

Macro Policy Environment

Washington State faces both challenges and opportunities resulting from the fundamental changes in our economy and society. Challenges within the macroeconomic policy environment include economic globalization, population growth, increases in I-5 corridor congestion, higher fossil fuel prices, global climate changes, and increases in natural and man-made disasters. Passenger rail, once used as means to address only mobility problems, is increasingly viewed and used as an integrated part of macro solutions to achieve multiple ends. These macro solutions include economic viability, societal mobility, environmental sustainability, public safety, and transportation system redundancy and resiliency.

As directed in RCW 47.82, WSDOT has been monitoring and analyzing socioeconomic and technical conditions that affect intercity passenger rail development. These conditions are directly aligned with state and national policy priorities of transportation, economy, energy, and environment. Several chapters in this plan, specifically Chapter 2, discuss these factors in more detail.

In response to these driving factors, and given our competing needs for limited resources (capital and land), Washington State is increasing its policy efforts to address greenhouse gas emissions, congestion, and health and safety improvements, and to develop a more sustainable economy. WSDOT is seeking policies to increase efficiency, relieve highway congestion, and develop robust and resilient transportation systems.

Methodology

The strategy adopted by WSDOT to develop the mid-range plan is fact-based and demand-driven. WSDOT strengthened its ridership forecast and analytic capacity by developing ridership database and forecast models. WSDOT improved capital project cost estimation through a specific cost study of all historic rail projects.

Based on management directives, the mid-range plan provides policymakers with options that are designed, analyzed, and presented to address socioeconomic policy issues. These are used to integrate transportation solutions, when considering funding additional Amtrak *Cascades* services. Economic impact assessment, benefit/cost analysis, and cross modal comparison were also performed to assist policymakers in linking the investment of an option to its effects on the economy and society.

Options presented in the mid-range plan are designed in the context of the current macroeconomic policymaking environment. The options build on incremental strategies with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. This mid-range plan presents four options for future program development.

Relationship with Other Plans

The mid-range plan is implementing the vision of WSDOT's multimodal plan—the *Washington Transportation Plan*—and the incremental strategy developed in the *Long Range Plan for Amtrak Cascades* under the guidance of the legislature.

The *Washington Transportation Plan* is a 20-year multimodal plan that includes Amtrak *Cascades* development. It establishes guiding principles for investments in current and future facilities through 2026. These investment guidelines are meant to direct funding and resources toward programs and investments that yield the greatest benefits. The mid-range plan is an implementation of the rail section. It states, "as the projects currently underway move forward and the investment priorities are implemented, future planning efforts will build on what we learn about system operations, the pace and challenges of global warming, and the opportunities and limitations of different travel modes such as *rail*, bike, and transit."

The *Long Range Plan for Amtrak Cascades* is a 20-year plan that meets federal requirements for high-speed intercity rail service development through 2023. Based on the long-range plan, the mid-range plan builds for more in-depth planning and economic analysis of projects and investment

opportunities for Amtrak *Cascades* development. It states, "WSDOT will continue to work with the freight railroads, ports, and other partners to ensure the rail system has adequate capacity to meet the demands of its various users. The ability for freight and passenger traffic to coexist on a common infrastructure and continue to grow is important to our regional mobility and economy."

The plans were all developed in coordination with Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Organizations (RTPOs), and other state, regional, tribal, and local stakeholders within their respective planning areas. See the list below for the mid-range plan stakeholder list.

Public Involvement

In the development of the mid-range plan, an advisory committee was formed, involving as many stakeholders as possible. The advisory committee's role was to help WSDOT assess and evaluate beneficial impacts of rail infrastructure improvements on society, to help WSDOT understand concerns of local communities, and to share information and provide feedback during the mid-range plan development process. Advisory committee stakeholders involved in the development of the mid-range plan include:

- MPOs and RTPOs in the I-5 corridor
- Counties and cities within the study area
- Oregon State
- Province of British Columbia
- Private railroads
- Amtrak
- Washington Public Ports Association
- WSDOT planning units in different modes
- WSDOT regions
- All tribes in Washington State with an interest in the I-5 corridor
- Passenger rail advocacy groups

Two public/advisory committee meetings were held at WSDOT, led by State Rail and Marine Office staff, providing progress reports and opportunities for public comments and discussion. After the public/advisory committee meetings, the draft plan was available for two weeks for public review and comment. Some public comments were incorporated into the final draft and the remainder are included in Appendix 13 with WSDOT's responses. The mid-range plan was then submitted to WSDOT executive management for final approval. Appendix

2 provides a complete list of stakeholders and active participants involved in the process.

Organization of this Plan

This chapter introduces the mid-range plan, its legislative mandates, management direction, socioeconomic contexts, and the strategy and methodology WSDOT adopted to develop the plan.

Chapter 2 discusses the macroeconomic environment and its impact on intercity passenger rail infrastructure using historical, current, and future trends and data. This chapter also introduces the mid-range plan options.

Chapter 3 reports the results from ridership and capacity analyses, including models, methods, data sources, and forecasts that were used to develop plan options.

Chapter 4 lists detailed capital projects for "building block" infrastructure improvements, and the costs associated with these projects. The information on the capacity increases and reliability improvements of completing each "building block" for each plan option is included.

Chapter 5 addresses operations and maintenance issues. A simulation analysis provides on-time performance estimates used in the development of the options. Operational cost estimates are also provided, based on historic data and projected costs for each plan option.

Chapter 6 describes the mid-range plan options for achieving additional Amtrak *Cascades* service. It specifies the steps needed for each plan option. It presents detailed information on capital and operation costs, capacity increases and reliability improvements, ridership growth, and economic impacts of investment.

Chapter 7 provides the results of a benefit/cost analysis for all mid-range plan options. It includes assessment of public benefits and costs, discussion of economic and societal impacts, and analysis of full transportation costs.

Chapter 8 is an analysis of the importance of providing easy connections between the different modes of transportation, and how WSDOT is working with other modes to achieve this connectivity.

Chapter 9 is a marketing analysis, including a history of major marketing efforts, marketing goals, trends, updated costs, anticipated impacts, and efforts to measure performance.

Chapter 10 discusses past, present, and future funding challenges and opportunities.

This mid-range plan does not require additional environmental review. The 2006 *Long-Range Plan for Amtrak Cascades* has been determined, jointly by the Federal Railroad Administration and Federal Highway Administration, to sufficiently address the requirements of a Tier 1 Environmental Impact Statement. Individual projects will require a detailed environmental review to determine the need for additional environmental study and documentation. The projects contained in the options either already have completed environmental documentation, are nearing completion of required National Environmental Policy Act (NEPA) documentation, or are categorically excluded from environmental review.

Washington State Department of Transportation

Chapter 2: Amtrak *Cascades* Development, Socioeconomic Context, and Mid-Range Plan Options

Intercity passenger rail benefits society by reducing congestion, pollution, and fuel consumption, while increasing safety by complementing other more heavily used modes of transportation. This plan assesses benefits and costs and evaluates investment strategies related to Amtrak *Cascades* development within its socioeconomic context. This chapter provides an overview of the development Amtrak *Cascades* passenger train service, socioeconomic trends, and macro policy environment.

Amtrak *Cascades* Development

Rail development for the Pacific Northwest began in 1864. At that time President Abraham Lincoln signed the Northern Pacific Railroad Charter to build a direct rail connection between the Great Lakes and Puget Sound. In the mid-1890s passenger rail service reached its peak in ridership when its share of the market was estimated to be about 95 percent. Largely due to interstate highway system development and competition from airlines, passenger rail ridership reached its lowest point in 1970.

Washington State infrastructure investment in intercity passenger rail service began in the late 1980s, when some state funds were expended to improve train stations. The first state-sponsored Amtrak intercity passenger rail service began in 1994. After incremental enhancements by Washington State and its partners, the service was branded Amtrak *Cascades* in 1999, with the introduction of the European-style, custom-built equipment. In 2007 annual ridership reached 676,760 passengers, the highest in the history of the state-sponsored program. Incremental enhancements continue to improve service and ridership. Appendix 3 provides a more detailed history of rail development in Washington State.

Currently, Washington State provides Amtrak *Cascades* intercity passenger service for four daily round trips between Seattle and Portland as shown in Exhibit 2-1. Note that one of the four state-sponsored daily round trips between Seattle and Portland continues on to Bellingham.

Exhibit 2-1: Amtrak *Cascades* Daily Schedule

Amtrak *Cascades* Daily Schedule

Fall 2008

Southbound *Read Down*					Station	Northbound *Read Up*				
517	509	507	513	501		510	500	504	506	516	508
5:45 pm					Vancouver, BC	11:35 am					
7:40			8:35 am		Bellingham	9:44				9:05 pm	
8:12			9:04		Mount Vernon	9:13				8:13	
8:54			9:55		Everett	8:31				7:31	
9:19			10:21		Edmonds	8:07				7:07	
10:05 pm			10:55 am		Seattle	7:40 am				6:40 pm	
	5:30 pm	2:20 pm	11:20 am	7:30 am	Seattle		12:00 pm		3:55 pm	6:20 pm	9:45 pm
	5:45	2:35	11:35	7:45	Tukwila		11:26		3:11	5:46	9:11
	6:15	3:05	12:05 pm	8:15	Tacoma		10:56		2:41	5:16	8:41
	6:54	3:44	12:44	8:54	Olympia Lacey		10:18		2:03	4:38	8:03
	7:13	4:03	1:03	9:16	Centralia		9:57		1:42	4:17	7:42
	7:54	4:44	1:44	9:54	Kelso Longview		9:18		1:03	3:38	7:03
	8:29	5:19	2:19	10:29	Vancouver, WA		8:45		12:30	3:05	6:30
	9:00	5:50 pm	3:00 pm	11:00 am	Portland		8:30 am		12:15 pm	2:50 pm	6:15 pm
	9:10	6:15 pm			Portland		8:05 am	11:35 am			
	9:31	6:36			Oregon City		7:24	10:54			
	10:17	7:22			Salem		6:42	10:12			
	10:46	7:51			Albany		6:13	9:43			
	11:45 pm	8:50 pm			Eugene		5:30 am	9:00 am			

The railroad tracks that span the Pacific Northwest Rail Corridor (PNWRC) are owned by the BNSF Railway (BNSF) in Washington, by the Union Pacific Railroad (UP) between Portland and Eugene, Oregon, by BNSF between the Canadian Border and Fraser River, and by Canadian National Railway from the Fraser River to the Vancouver, B.C. station. Freight and passenger rail traffic run on the same tracks. The Washington State Department of Transportation (WSDOT) partners with federal, state, provincial, tribal, and local jurisdictions; railroads including Amtrak, BNSF, UP, Canadian National Railway (CN), VIA Rail Canada; and others under many agreements to provide Amtrak *Cascades* service.

The state-supported Amtrak *Cascades* service continues to demonstrate record growth in ridership. Ridership of 594,970 in the first three quarters of 2008 increased 16.3 percent over the same period in 2007. High gasoline prices, population growth, and many other factors have contributed to this increase.

Many planning documents have guided Amtrak *Cascades* development over the years. In 1995 WSDOT published *Options for Passenger Rail in the Pacific Northwest* and in December 1997, WSDOT produced the *Pacific Northwest Rail Corridor Operating Plan* for public review.

WSDOT published the *Long-Range Plan for Amtrak Cascades* (2006) that meets the U.S. Department of Transportation's recommended planning framework for high-speed intercity rail service development, a requirement for Washington State to be eligible for federal funding. The long-range plan outlines a 20-year progression of incremental improvements that increase train frequency, reliability, and safety, and reduce travel times.

Socioeconomic Context

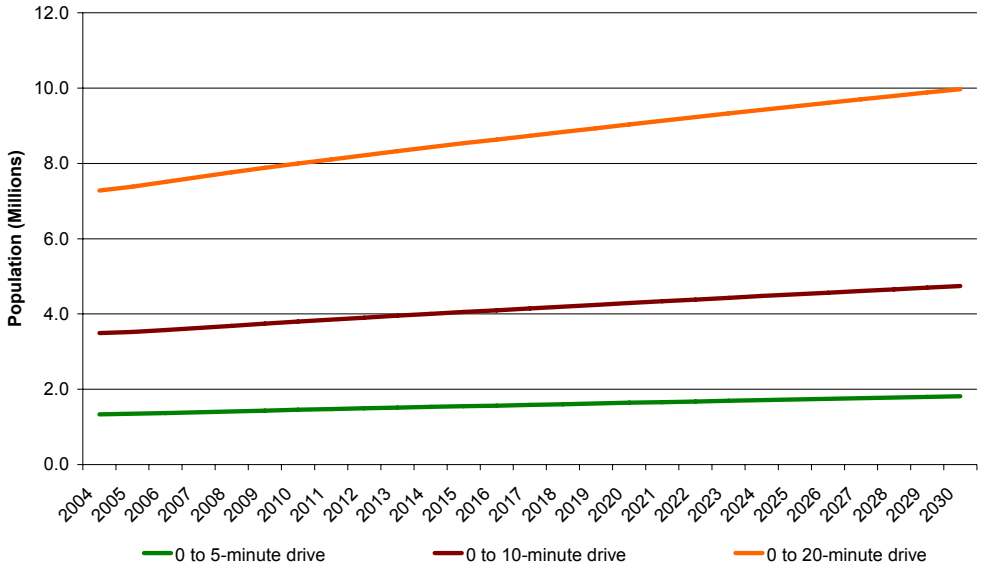
Population/Congestion

Western Washington and the Puget Sound region, anchored by major metropolitan areas, is the densest, most heavily populated area in Washington State. As of 2008 an estimated 3,664,000 people (four out of ten people) reside within 10 driving minutes of Oregon and Washington Amtrak *Cascades* stations.

Exhibit 2-2 shows increasing I-5 corridor population growth from 2004 to 2030, in terms of proximity to nearby Amtrak *Cascades* stations at 5-minute drive, 10-minute drive, and 20-minute drive times. Increasing travel demand on the I-5 corridor impacts mobility, safety, the environment, and energy consumption. Strategies that promote viable

transportation alternatives, such as intercity passenger rail cause mode shifts that can reduce travel demand on the I-5 corridor and improve mobility, safety, environmental sustainability, and the economy.

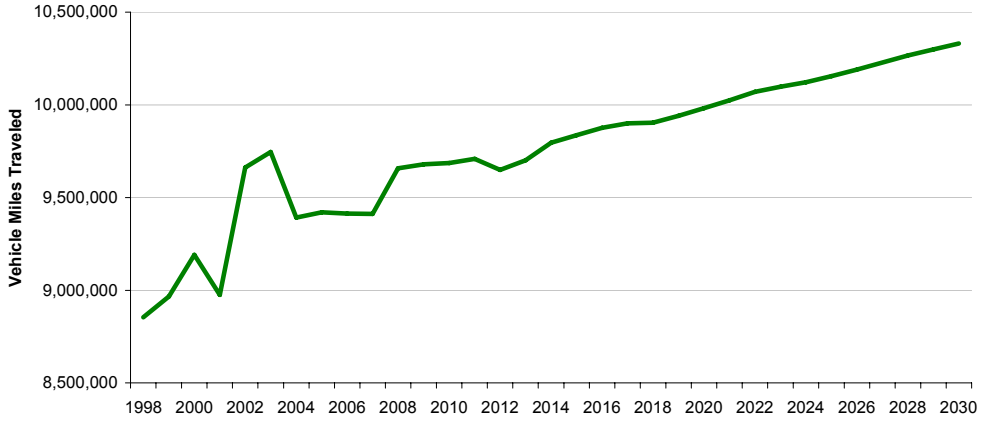
Exhibit 2-2: Population Surrounding Amtrak *Cascades* Services
Vancouver, B.C. to Eugene, OR
Drive Times to Amtrak Stations



Source: Data developed by WSDOT State Rail and Marine Office based on U.S. Census using WSDOT GIS tools.

Exhibit 2-3 shows the increase in I-5 vehicle miles traveled from 1998 to 2030.

Exhibit 2-3: Vehicle Miles Traveled Along the I-5 Corridor



Source: WSDOT Transportation Data Office, and FY2010 to FY2030 projections by State Rail and Marine Office.

With national highway congestions cost estimated at $70 billion annually, states are turning to rail as part of their transportation strategy. Specific

markets, like the Seattle, Portland, and Vancouver, B.C. metropolitan areas, have the most potential to generate public benefits from reduced highway congestion now and in the future. Intercity passenger rail is even more beneficial in regional markets with well-developed *intra*city mass transit systems, because intercity rail is more likely to be more competitive with driving on those routes.

The Amtrak *Cascades*' route goes along the same sections of the I-5 corridor. WSDOT estimates that daily delay along the I-5 corridor is about 300,000 hours and cost about $7 million a day. Amtrak *Cascades* passenger rail can help reduce congestion by diverting traffic away from the crowded I-5 corridor, increasing the serviceability of the overall transportation system.

According to a WSDOT Urban Planning Office model, a 5 percent reduction in I-5 traffic will reduce 70 percent of the delay caused by congestion. Therefore, it doesn't take a huge quantity of travelers switching to intercity passenger rail to generate substantial public benefits by reducing highway congestion.

Intercity passenger rail service could potentially ease air travel congestion (take-off and landing delays) and it could reduce the number of flights between cities. In areas with little to no additional space for runways, airports have fewer options for increasing capacity. In those areas, intercity passenger rail service would be more competitive.

There is an economic advantage for passenger rail in locations where train stations are located in central business districts, especially with convenient access to mass transit.

Safety and Security

On October 16, 2008, President George W. Bush signed into law a 2-part legislation: HR 2095, the Railroad Safety Enhancement Act of 2008, and HR 6003, the Passenger Rail Investment and Improvement Act of 2008. The legislation gives $12.9 billion for intercity passenger rail development over five years, almost double what the U.S. is currently spending. Safety and rail passenger improvements include increased rail safety inspectors, at-grade crossing improvements or eliminations, positive train control technology on rail main lines by 2015, and reporting required on service delays and poor on-time performance for the Amtrak Coast Starlight and Amtrak *Cascades*.

According to the National Safety Council (NSC), the safety of intercity passenger rail travel is comparable to commercial bus and air travel. The 2008 NSC Injury Facts report shows that passenger autos have a 0.81 U.S.

passenger fatalities per 100 million passenger miles ratio (1996-2005 data); buses have a 0.04 ratio; railroad passenger trains have a 0.05 ratio; and airlines have a 0.02 ratio. Passengers may choose to travel by rail to improve their own safety, if they believe passenger rail is safer than other modes.

In addition global development and global warming may cause transportation systems to be more vulnerable to natural and man-made disasters. The ability to respond to and recover from adversity is largely due to society's degree of resiliency. Regions and communities with viable transportation alternatives are better positioned to deal with adversity and successfully recover from emergencies.

A robust intercity passenger rail service is an asset in times of emergency. After the September 11, 2001 attack on the World Trade Center, Amtrak service resumed days before highways were open to the public. Likewise, after I-5 was flooded by the Chehalis River and its tributaries in December 2007, Amtrak *Cascades* service resumed in two days, while I-5 service resumed for public use after four days.

Environment/Energy

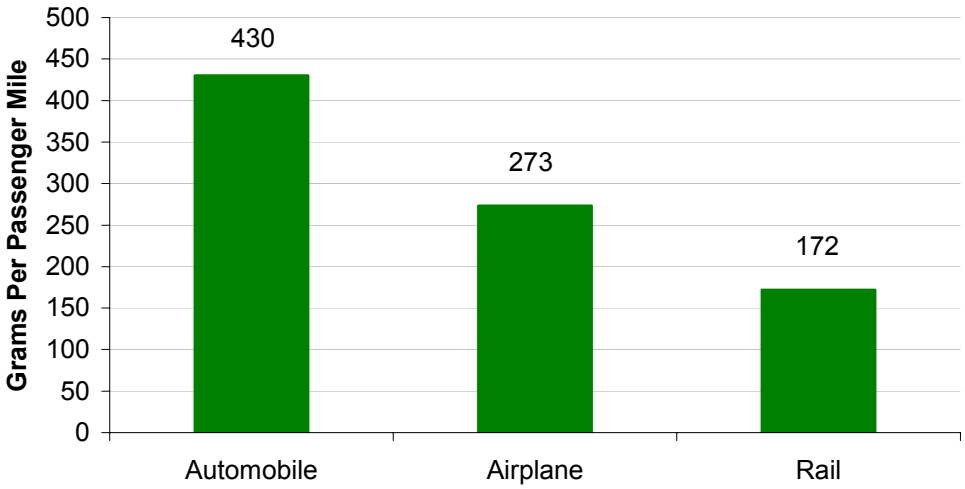
Transportation is the fastest growing source of carbon dioxide (CO_2) in the United States. CO_2 emissions are projected to exceed 175 percent of year 2000 levels by 2025. Personal cars and trucks now account for 40 percent of our nation's oil consumption. Cars and trucks produce about a third of the greenhouse gas emissions in the U.S. Increasing travel demand is expected to cancel out the CO_2 savings from the fuel economy and renewable fuel requirements as specified in the Energy Independence and Security Act of 2007.

The University of California at Berkley recently completed the first comprehensive environmental life-cycle assessment of passenger transportation in the U.S. The assessment includes significant indirect supply chain costs that are harder to measure. It analyzes the real costs of all system components in terms of their energy use and polluting by-products "from cradle to grave."

The University of California study shows that greenhouse gas emissions per passenger mile traveled is less for rail than for cars or airplanes, as indicated in Exhibit 2-4. Rail systems are the best energy and greenhouse gas performers, but they require much larger infrastructure requirements per passenger-mile served. High-speed rail can perform better than automobile and aircraft, but only if ridership is optimized. In the study, intercity passenger rail service similar to Amtrak *Cascades* was not included. Caltrain has a similar type of diesel propulsion system, but

offers a commuter service with shorter distances and more frequent service.

Exhibit 2-4: Greenhouse Gases by Transportation Mode



Source: University of California at Berkeley, Center for Future Urban Transport

Amtrak provides long-distance rail service and intercity passenger rail service throughout the U.S. Current initiatives to increase energy efficiency and reduce fuel consumption include a range of Amtrak programs. With its participation in the Chicago Climate Exchange, Amtrak is committed to cutting diesel emissions by 6 percent by 2010, the largest voluntary reduction commitment in the U.S., and the first commitment made by a national transportation company.

Intercity passenger rail can generate some public benefit by reducing dependency on gasoline and fossil fuels. Another public benefit would be to reduce vulnerability to an energy supply disruption.

Economy

Amtrak *Cascades* investments can increase the economic potential of an area. There are model approaches used around the world to stimulate the economy and improve intercity passenger rail infrastructure and service with established and clearly defined national policy goals, stakeholder roles, and committed funding. In the U.S. where passenger rail is all public sector, Amtrak is taking action to reduce costs, but it is not positioned to address broader goals, roles, and funding issues.

Intercity passenger rail services along designated corridors have a comparative advantage over other transportation modes in terms of financial viability and public benefits. However, currently there isn't a national policy framework for rail and transportation in general. This is a

major finding of the National Surface Transportation Policy and Revenue Study Commission Report of December 2007. The report was developed by an advisory group of 12 delegates, led by the U.S. Department of Transportation Secretary with a vision to create and sustain the pre-eminent surface transportation system in the world. Their recommendation to increase multimodal transportation infrastructure investment will guide future rail policy. The report's call to action states, "…our nation will need to put more emphasis on transit and intercity passenger rail and make them a priority for our country. A cultural shift will need to take place across America to encourage our citizens to take transit or passenger rail when the option is given."

Consumer and Travel Industry Trends

Eco-tourism is growing both in trips to important environmental sites and in ways travelers choose travel alternatives that are more environmentally sustainable. Rail, as part of "green travel," is emerging as the transportation alternative of choice for those who want to benefit local communities, reduce their carbon footprint, and experience the natural scenery in comfort and convenience as they travel.

Global warming is of high concern for 41 percent of Americans and 59 percent believe the affects are apparent now. Approximately 50 percent of Americans changed their summer travel plans due to high gas prices. Almost 25 percent of Americans working in the private sector don't get paid vacations. With soaring gas prices influencing consumer's travel plans, shorter, domestic trips are likely to continue to dominate travel destinations. Amtrak *Cascades* can be a preferred travel alternative for local and regional trips.

In the next five years, America is expected to experience an 80 percent growth in the number of households headed by someone 55+ years old. Their availability to travel, their established and stable income, and their nostalgia for trains is expected to stimulate rail travel, especially if their rail experience is favorable.

Wireless Internet (WiFi), cell phone reception, and electronic media are becoming standard amenities in all sectors of society, particularly among youth and young adults. The availability of convenient, state-of-the-art technology appeals to passengers and is an economic advantage for intercity passenger rail travel.

Mid-Range Plan Options

Washington State is facing both challenges and opportunities resulting from the fundamental changes in our economy and society. The main

factors that shape policy development have been discussed in a previous section. Transportation solutions, once used as a means to address only mobility problems, are increasingly viewed and used as strategies to achieve multiple ends, such as economic viability, societal mobility, and environmental sustainability. The options of the mid-range plan are designed, analyzed, and presented to assist policymakers in determining funding for the Amtrak *Cascades*, to achieve additional services that benefit society and the economy.

Purposes of Mid-Range Plan Options

The purposes of the plan options are identified as:

- Articulating the needs of intercity passenger train services and discussing supply and demand issues for various scenarios.
- Providing alternatives needed by policymakers in developing strategic investment policy, which might help achieve multiple policy ends using transportation solutions.
- Assessing potential of passenger rail as a strategic alternative of long-term transportation solutions, rather than a niche market segment for tourists and intercity travelers.
- Specifying the steps of improving infrastructure to deliver additional intercity passenger services, and link capital and operational investment to ridership growth and economic and societal benefits.
- Providing a variety of information to support informed decision-making processes—legislative budgeting and prioritizing.

Defining Options for Achieving Additional Services

Option 1: Maintaining Current Operation Strategy

This option is designed to maintain current Amtrak *Cascades* operation at four daily round-trip trains between Seattle and Portland and two daily round-trip trains between Seattle and Vancouver, B.C. This option would not have additional capital investment and infrastructure improvements in the mid-range plan period. All previous capital investments for incomplete projects would become sunk costs[1], as no additional investments for completing projects, which increase service capacity and reliability, will

[1] Sunk costs are costs that cannot be recovered once they have been incurred. If there is no additional investment to complete projects that increase service capacity, then the costs of the uncompleted projects are lost or sunk.

occur. Ridership growth will be confined at current capacity levels. The growth opportunity would be to attract additional riders to the non-peak seasons and low ridership days.

This option informs policymakers about the current status of Amtrak *Cascades* services and the outlook of maintaining the current status. It also serves as an analytic baseline for other options.

Option 2: Incremental Strategy 1 □ Minimum Capital Investment

By identifying the cost to deliver the minimum increase of additional service, this option would deliver five daily round-trip trains between Seattle and Portland and maintain two daily round-trip trains between Seattle and Vancouver, B.C. in 2012. This option would complete capital projects that have already been started, and would sustain the capital costs that were already invested into the system to achieve incremental service gains. The increased service would be used to meet the demands that would rise due to improved schedule reliability and rail line capacity.

Option 2 helps decision-making by specifying the investments needed to complete the capital projects for minimum service increase. This option also assesses benefits and costs associated with additional investments that would revive the sunk costs and deliver minimum incremental service.

Option 3: Incremental Strategy 2 □ Supply Meets Demand

By best analyzing and matching supply and demand in a dynamic economy and a changing society, this option assesses both supply and demand and the interactions between them. It provides essential information about ridership growth, cost and revenue, local and state economic impacts, and environmental and social benefits for incremental investments. These investments would achieve additional service levels, where the increased supply (Amtrak *Cascades* service capacity) essentially meets the increased demand (ridership growth).

This option is essential because it supports decision-making by specifying investment levels, where the supply meets the demand, and provides information about a variety of benefits associated with such investments.

Option 4: Rail as a Long-Term Alternative Strategy □ No Financial Constraints

By maximizing engineering feasibility, this option provides information about the maximum capacity that can be built during the mid-range plan horizon, FY2010 to FY2017, given the level of investment necessary to develop such infrastructure improvements. However, this option does

exclude a few reliability improvement projects that are expensive when compared to achieved improvements.

Option 4, which allows eight daily round trips between Seattle and Portland by FY2015, is a viable option in an environment where policymakers might be willing to promote rail as a strategic alternative and part of the solution to highway congestion. It also helps to explore the potential benefits and costs for such a strategic movement to address greenhouse gas reductions, congestion relief, public safety improvements, and transportation resilience to disasters.

Chapter 3: Ridership for Amtrak *Cascades*

Ridership for Amtrak *Cascades* on the Pacific Northwest Rail Corridor (PNWRC) has been increasing. This chapter highlights the changes in ridership in the past, present, and future and includes:

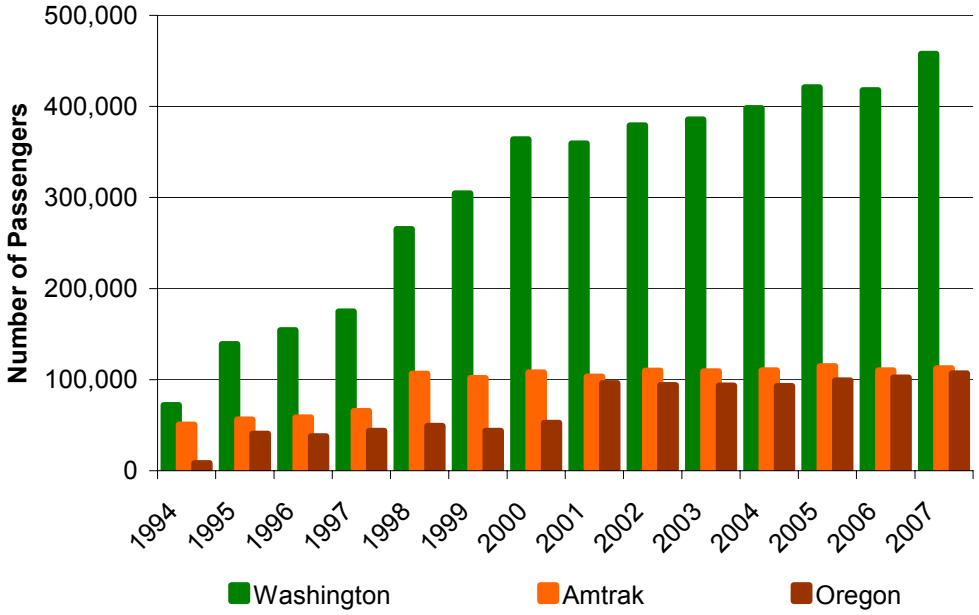
Ridership History

In 1993 Amtrak offered only one daily round trip between Seattle and Portland. Washington State saw the need and demand for more passenger rail service in the PNWRC, and in 1994 expanded service by introducing passenger trains sponsored by Washington State. This new Washington-sponsored train service first leased a train set from Renfe Talgo of America (Talgo) to provide a second daily regional round trip between Seattle and Portland. In 1995 Oregon sponsored a state-funded train and one of two existing Seattle to Portland daily round trips was extended to Eugene, Oregon. Also in 1995, after a 14-year absence, service was restored between Seattle and Vancouver, B.C. In 1996 Washington leased a second Talgo train to support service. The Amtrak *Cascades* brand debuted in 1999 and WSDOT expanded Seattle to Portland service by offering a third daily round trip.

Washington State initiated a new phase for Amtrak *Cascades* in 1999 by replacing leased equipment with custom-built trains purchased from Talgo. Currently there are five train sets in the Amtrak *Cascades* service. Washington State owns three train sets and Amtrak owns two. WSDOT signed a lease/purchase agreement for two train sets with Talgo in 1995, and took delivery in late 1998-early 1999. In 2000 a second daily Seattle to Portland train was extended to Eugene, sponsored by Oregon. A new stop in Tukwila was added in 2001. A fourth daily Seattle to Portland regional round trip started in July 2006, which completed the extent of current Amtrak *Cascades* regional service between Seattle and Portland.

Ridership has risen steadily on the PNWRC from Eugene, OR to Vancouver, B.C., from less than 200,000 annual passengers in 1994 to 676,760 passengers in 2007. Ridership for the three Washington-sponsored trains increased over 500 percent from 1994 to 2007, even though there were service disruptions for approximately three months in 2007. A complete history of the Amtrak *Cascades* annual ridership is shown in Exhibit 3-1.

Exhibit 3-1: Amtrak *Cascades* Annual Ridership 1994-2007



Source: WSDOT State Rail and Marine Office

Annual ridership for 2008 is expected to surpass all previous years in annual growth. Year-to-date ridership through October for Amtrak *Cascades* shows 27.4 percent growth over the same time in 2007. One reason for this growth is the rapid rise in gasoline prices in the last year, prompting consumers to consider train travel rather than driving for their travel needs. More convenient schedules and better connections have also fostered higher growth rates in the last several years.

Since 1994 when Washington began actively supporting Amtrak service, consumers have responded to the increased frequency of daily train service. In every case when or where the supply of passenger train capacity increased, higher ridership has quickly followed. Ridership increases are most pronounced in the Seattle to Portland corridor, now that it has four daily Amtrak *Cascades* regional round trips.

Ridership Distribution

Public use of Amtrak *Cascades* is also measured by station on-offs, which measure passenger volumes per station. This measurement is determined by counting the number of passengers who get on and off trains at each station along the Amtrak *Cascades* corridor. Station volumes can assist planners and businesses in determining local train station activity. This knowledge can support greater connectivity with bus systems and other transportation modes. It can also be of help in land use planning for residential and business expansion.

Station on-offs provide a good measurement of the distribution of ridership along the rail corridor. Amtrak *Cascades* currently has 17 stations, with an additional station scheduled for opening in Stanwood, WA in 2009. Originally, Amtrak *Cascades* had 15 stations in operation in 1995. Tukwila, WA opened in 2001, followed by Oregon City, OR in 2004. Restoration of older stations and building of new stations in more strategic locations led to greater volumes of passengers at stations. For passengers traveling between major cities (i.e. Seattle and Portland), having all trains stop at all stations increases travel time. Future consideration should be given to adding express trains between major cities.

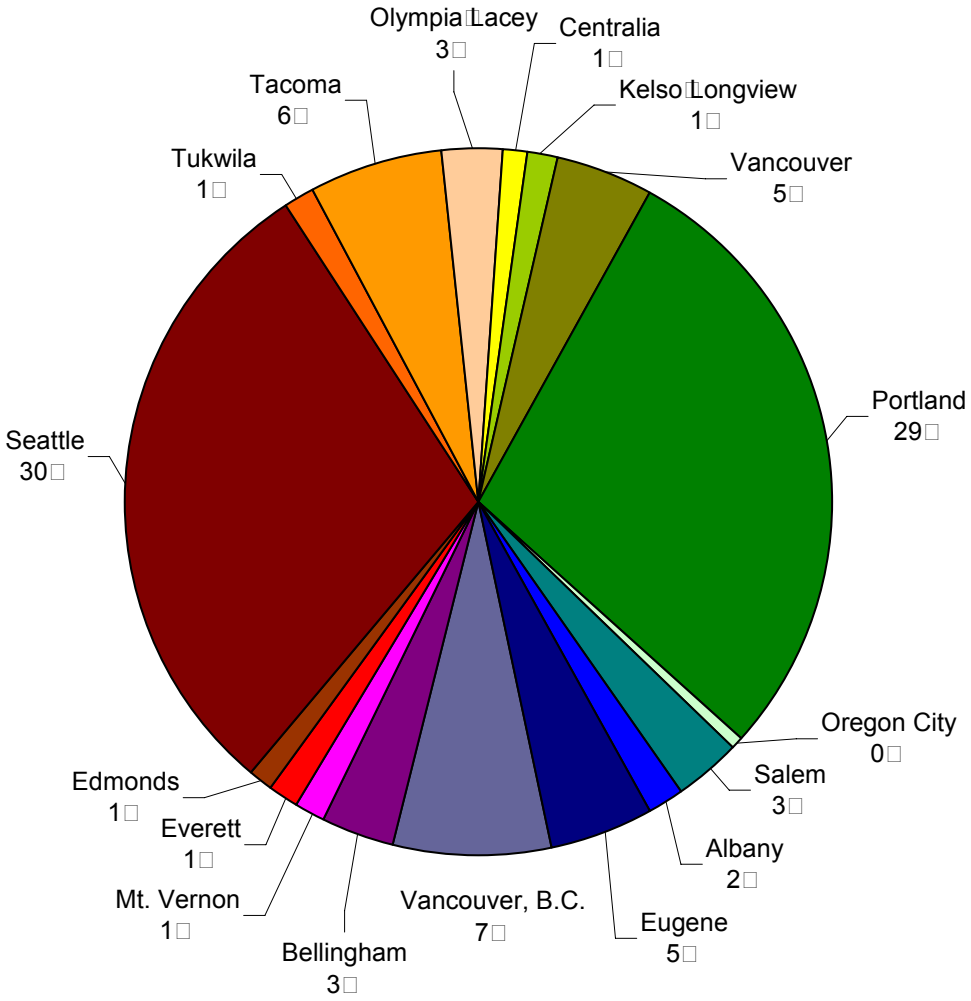
Station locations with 2007 total on-offs are listed from north to south in Exhibit 3-2. Nearly six out of every ten passengers begin or end their train travel at either the Seattle or Portland stations. These two cities serve as hubs for north and south traffic from each station and as beginning or end points for the four daily Seattle to Portland round trips. Exhibit 3-3 illustrates in a pie chart the share of on-offs by station in 2007.

Exhibit 3-2: Station On-Offs 2007

Stations	Number	Percentage
Vancouver, B.C.	***105,960***	***7.2%***
Washington Stations		
Bellingham	51,291	3.5
Mt. Vernon	19,321	1.3
Everett	18,211	1.2
Edmonds	18,200	1.2
Seattle	438,845	29.8
Tukwila	18,884	1.3
Tacoma	87,996	6.0
Olympia Lacey	41,119	2.8
Centralia	17,509	1.2
Kelso Longview	20,314	1.4
Vancouver	66,761	4.5
Total	***798,451***	***54.3%***
Oregon Stations		
Portland	421,658	28.7
Oregon City	7,186	0.5
Salem	42,303	2.9
Albany	24,661	1.7
Eugene	71,040	4.8
Total	***566,848***	***38.5%***
Grand Total	**1,471,259**	**100.0**

Source: WSDOT State Rail and Marine Office

Exhibit 3-3: Amtrak *Cascades* On-Offs by Station – 2007



Ridership Profile

Passenger demographics are important in determining characteristics of current passengers and potential growth of additional passengers. Surveys, periodically conducted by Amtrak, collect national and regional data to provide updated information on Amtrak *Cascades*. Current demographics of riders have been identified for targeting advertising campaigns:

- Adults 25-54.
- Household income $50,000+.
- Slightly skewed female (60 percent).
- Employed (52 percent full time, 12 percent part time).
- Educated (54 percent college graduate, 31 percent some college).
- Travels an average of seven one-way trips along the I-5 corridor per year, for business or leisure.

Approximately 81 percent of passengers are riding Amtrak *Cascades* for leisure. Ridership peaks during Friday, Saturday, and Sunday; and seasonally in the summer months and during the winter holidays. Attracting business travelers, especially those willing to pay higher fare tickets, is essential for increasing demand for current capacity and proposed capacity expansion. Providing frequent and reliable service with flexible timetables is important in attracting business customers.

Factors that Drive Ridership Growth

Ridership has grown over time, in part, because of underlying demographic characteristics of potential rail passengers. Population density and proximity to Amtrak stations is important in determining ridership growth. As of 2008 an estimated 3,664,000 people reside within 10 minutes of Oregon and Washington Amtrak *Cascades* stations. Employment opportunities and income levels of the same nearby populations are also important.

Greater capacity in the number of daily trips between stations is instrumental in increasing demand for passenger rail service. More daily trips expand the daily timetable, attracting more customers who may find an earlier or later travel time more attractive, especially for taking day trips. Business travelers especially respond to more flexibility and choices.

Passengers are sensitive to ticket pricing. Amtrak offers four categories of ticket prices. Similar to airlines, prices rise as the trains fill up. Historically when additional trips were added to the Seattle to Portland segment, ridership responded quickly. More seats were available per day which drove down ticket prices, as more seats were available at a lower price. Saving money can be a great incentive for switching to other travel times.

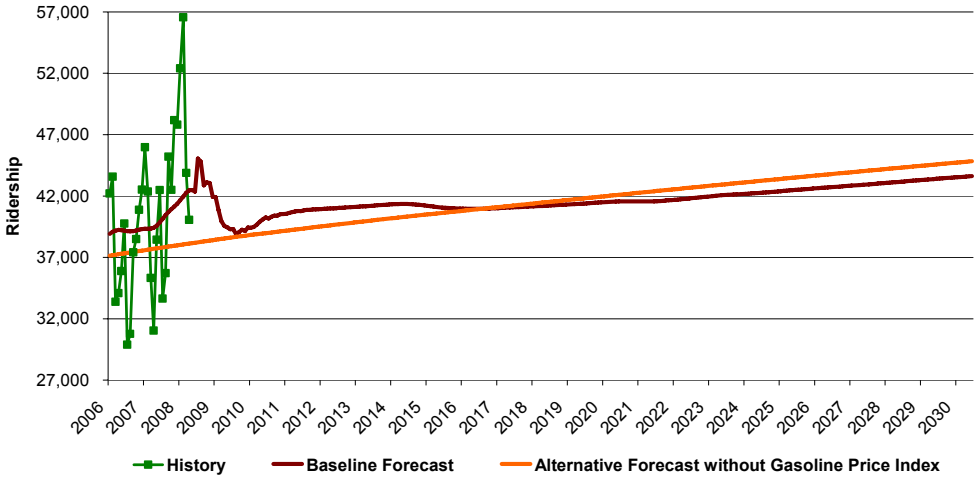
Higher costs for competing transportation modes also increase growth of ridership. Higher gasoline prices for automobile travel have been a big contributing factor for higher ridership, especially this past year. Nationwide, more highways and bridges are charging tolls, which add an additional cost to automobile travel. A new bridge, being planned for the I-5 crossing of the Columbia River between Washington and Oregon, is considering a toll for financing. This has the potential of furthering rail passenger growth between Portland and Seattle by increasing the cost of automobile travel.

Growth Forecast: Methods and Results

Ridership growth on Amtrak *Cascades* trains was forecasted using statistical methods relating ridership to population, capacity increases, and

inflation-adjusted gasoline prices. For more technical information concerning ridership forecasting, please refer to Appendix 4. The Seattle to Portland segment is highlighted here because of the proposed expansion of capacity for this portion of the PNWRC. Monthly ridership from 1996 to October 2008 was available for reference and forecasting. The baseline forecast used monthly ridership, average monthly train occupancy, population based upon driving time from Amtrak stations, inflation-adjusted gasoline prices, and capacity in number of daily round trips. An alternative forecast excluded gasoline prices for comparison. Exhibit 3-4 shows three data series: history starting in January 2006; the baseline forecast; and the alternative forecast. The baseline forecast provides a better fit to actual historical ridership, specifically gasoline prices have increased substantially since 2006. From FY2010 to FY2017, the baseline forecast projects an average of 3 percent higher ridership by including gasoline prices. After FY2017 the alternative forecast projects an average of 2 percent higher forecast.

Exhibit 3-4: Comparison of Monthly Ridership History, Baseline Forecast, and Alternative Forecast without Gasoline Price Index
Seattle to Portland



Stations included are Seattle, Tukwila, Tacoma, Olympia/Lacey, Centralia, Kelso/Longview, Vancouver, and Portland.

Source: WSDOT State Rail and Marine Office

Growth Analysis: Peak Ridership and Capacity, Time Saving and Reliability Improvement Effect □ Discussion and Results

When Amtrak *Cascades* ridership is forecasted in total for the Seattle to Portland corridor, it does not take into consideration peak ridership that occurs when the train is at its fullest along the corridor. For the Seattle to Portland segment, this maximum regularly occurs between Olympia/Lacey and Centralia, whether traveling north or south. During the peak months of

ridership in summer, during the winter holidays, and for weekend days of Friday through Sunday, the Olympia/Lacey to Centralia segment is usually where a train is sold out and passengers are possibly turned away.

An analysis of the distribution of daily ridership in this peak section was conducted for a full year from July 2007 through June 2008 for all four Seattle to Portland daily round trip trains. Nearly 0.5 percent, or 2,348 passengers, was not provided reserved seating as ridership exceeded train capacity for the peak ridership segment between the Olympia/Lacey and Centralia stations. Passengers not securing reserved seating are provided, if possible, overflow seating in the Bistro and Lounge cars. Passengers provided overflow seating are classified as unsupplied marginal demand for the purposes of the following discussion about peak capacity and loading.

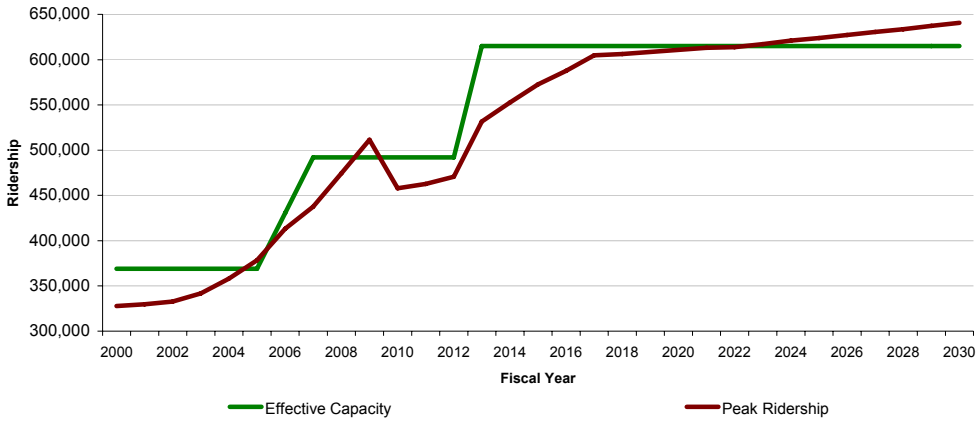
Passengers securing reserved seating, plus the overflow, determine a level of ridership or demand for the peak section. For the year's duration, from July 2007 through June 2008, the peak section demand totaled 474,800 riders. The four Seattle to Portland daily round trips provide a total of 738,760 seats annually. Dividing 474,800 by 738,760 determines an average peak-loading calculation of 64 percent. The difference of 263,960 seats between peak section demand riders and annual total seats reflects lower ridership in non-peak sections: lower ridership during spring and fall seasons and lower ridership levels from Monday through Thursday.

Sensitivity analysis of unsupplied marginal demand levels from 1 percent to 5 percent indicated a range of 5,515 to 27,518 riders. One percent unsupplied demand leading to a peak loading of 67 percent was chosen as a reasonable amount of unsupplied marginal demand. Meeting demand during peak trips is imperative, given the potential lost revenue of high paying passengers and resulting dissatisfied customers.

Ridership can also be responsive to travel time reductions and reliability improvements of adhering to schedules. Option 2 is used as an example for explanation. Option 2 provides for an additional daily round trip (total of five) between Seattle and Portland, starting in July 2012. The Tacoma – Bypass of Point Defiance – 66th St. to Nisqually, included with Options 2 through 4, results in a time savings of 6 minutes per one-way trip. A literature review of elasticity factors cites that train ridership increases 1.58 percent as time decreases by 1 percent. By using the same elasticity factor, expenditures for rail maintenance that improve on-time reliability from the current 61 percent to 95 percent also increases ridership by 18 percent when fully implemented.

Exhibit 3-5 provides a comparison of peak capacity and peak ridership for Option 2. The peak ridership line also incorporates the time and reliability enhancements inherent to Option 2. The chart shows that from 2000 through 2007, peak capacity accommodated the peak ridership levels. Starting in 2008, peak ridership begins to exceed peak capacity with rapidly increasing ridership due to higher gasoline prices and other factors. Both peak capacity and peak ridership rise rapidly from 2012 to 2014, when an additional daily round trip is added and time and reliability enhancements begin to take effect. From 2015 through 2030, peak ridership exceeds peak capacity and demonstrates a need for additional capacity. Options 3 and 4 provide for those additional capacities.

Exhibit 3-5: Peak Ridership vs. Effective Capacity
Option 2 – Minimum Capital Investment
Seattle to Portland



Stations included are Seattle, Tukwila, Tacoma, Olympia/Lacey, Centralia, Kelso/Longview, Vancouver, and Portland.

Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Washington State Department of Transportation

Chapter 4: Amtrak *Cascades* Needed Infrastructure Improvements: FY2010 to FY2017

In 1993 the Washington State Legislature directed the Washington State Department of Transportation (WSDOT) to develop high-quality intercity passenger rail service through the incremental upgrading of the existing BNSF Railway Company's (BNSF) north-south main line. Since that time, WSDOT has been working with railroad companies and other organizations to identify, develop, prioritize, and build infrastructure projects. The 2006 long-range plan identified opportunities to improve existing services between 2004 and 2023. It proposed a set of infrastructure improvement projects that can, depending on the investment strategy "building blocks," enable WSDOT to fulfill the legislature's directive to provide safe, faster, more frequent, and more reliable passenger rail service through an incremental approach.

This chapter outlines major infrastructure improvements that can be implemented during the mid-range plan horizon—FY2010 to FY2017. The infrastructure improvements are designed to achieve additional services, given scenarios of ridership growth and investment goals described in Chapter 6. The economic, societal, and environmental benefits of these services, as well as investment levels to achieve these services, are further assessed in later chapters.

Identifying and Refining Infrastructure Improvements

Since the early 1990s, WSDOT has partnered with Amtrak *Cascades* stakeholders (i.e. BNSF, Amtrak, and others) to increase service—improving safety and building rail line capacity—through phased infrastructure project development. Projects are developed in a very specific order to achieve a range of operational goals—individual projects solve individual problems; groups of projects solve larger operational challenges.

The *Amtrak Cascades Mid-Range Plan* includes operations analysis focused on service goals and strategic investment options between FY2010 and FY2017. By phasing infrastructure projects for incremental implementation, WSDOT provides policymakers with additional flexibility to fund Amtrak *Cascades* services at a desirable level, given a variety of factors that affect state budget and priorities. Meanwhile, WSDOT can better identify solutions, analyzing how to implement projects and maximize public benefit at the given investment level.

Updating Costs to Implement Infrastructure Improvements

With all transportation projects, including rail, cost escalation is a challenge. Transportation projects are huge investments. They often take many years to complete. They contain many uncertainties (i.e. real estate, engineering design, public-private partnerships, societal and environmental challenges). These factors can easily drive cost estimates for transportation projects much higher than originally anticipated.

To better manage cost escalation and deliver transportation projects on time and within budget, WSDOT began use of cost validation processes called Cost Risk Assessment (CRA) and Cost Estimate Validation Process® (CEVP). While the cost validation processes were effective with highway projects, they were marginally effective with rail projects for several reasons:

- Unlike highway projects that have dedicated funding for system inventory and system preservation, rail projects have no dedicated funding sources to develop or manage such systems.

- Unlike highway projects with available historical data, rail projects have limited historical data. Consequently, less information is available for reliable cost estimates and risk analysis processes.

- Highway projects and rail projects have different inflation trends for their major components. Inflation indices that work for highway projects may not produce reliable cost projections for rail projects.

To address cost escalation concerns for rail projects, WSDOT State Rail and Marine Office staff conducted a study based on a set of 1994 to 2008 rail projects (mainly BNSF projects) experiencing cost escalation. The study identified cost escalation drivers and trends. It categorized rail project costs into five cost groups: pre-construction engineering, right of way, track, signal, and earthwork. It found specific indices to analyze inflation trends and quantify inflation effects. It deducted inflation effects, scope-of-work changes, and original cost estimate errors from the cost escalation.

The study found cost escalation for rail projects averaged about 60 percent (ranging from 2 percent to more than 100 percent) depending on cost type, cost categories, initial estimates, and project implementation timeframe. The rail signal system cost inflation index was also systematically understated.

To address the uncertainty of cost escalation and control risks, three cost estimation improvements were developed by the WSDOT State Rail and Marine Office to improve cost estimates:

- A set of rail project specific inflation indices were used to reflect cost inflation between cost estimates and project implementation.

- Cost escalation, due to scope-of-work changes, would be minimized with a developing rail project management system, which includes a database of historical and current information about project location, type, size, economic climate, and other factors.

- Cost escalation, due to estimation errors, was minimized with staff management control of the data and process. A cost item database that represents rail projects will be developed to help validate the cost estimates produced by consultants using their proprietary databases.

Exhibit 4-1 presents cost estimates for rail projects based on the improved methodology described above. Although WSDOT made its best effort to incorporate risk analysis into cost estimation processes, actual costs may still vary, depending on the funding availability, the outcome of environmental analysis for each project, the outlook of the national economy, and the project completion timeline (generally, the longer the timeline, the rougher the cost estimate).

Infrastructure Improvements and Service Capacity

Exhibit 4-1 describes the rail projects that could be implemented, depending on the funding level, to achieve additional service. Each project solves a particular problem (i.e. eliminate a chokepoint, increase safety) and fulfills a specific operational goal. Because operations analysis is based on an incremental approach to project development, if funding is not available to complete all of the listed projects, a sub-set or phase of each project can be implemented and achieve certain passenger service levels associated with that particular investment level.

Exhibit 4-1: Projects and Project Stages that Could Be Implemented to Achieve Additional Service Levels During the Mid-Range Planning Horizon: FY2010 to FY2017

Project Group	Project Name	Year of Completion	Capital Cost Estimates (Million)			
			Option 1: 0	Option 2: 141 Million	Option 3: 578 Million	Option 4: 817 Million
Project Group A: 141M for Options 2, 3, and 4	Tacoma Bypass of Pt. Defiance 66th St. to Nisqually	2012		42.8	42.8	42.8
	Vancouver Yard Bypass and W 39th St.	2012		90.4	90.4	90.4
	King Street Station Track Improvements	2011		2.0	2.0	2.0
	Cascades Train Sets Overhaul	2011		6.0	6.0	6.0
	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.					
Project Group B: Option 3 437M; Option 4 334M	Increase Capacity of Existing Train Sets	2011			48.4	
	Kelso-Martin s Bluff New Siding	Option 3: 2017 Option 4: 2013			83.4	60.2
	Kelso-Martin s Bluff Kelso-Longview Jct. 3rd Main Track	Option 3: 2017 Option 4: 2013			151.0	125.8
	Cascades Two New Train Sets	Option 3: 2016 Option 4: 2012			56.8	50.8
	Blaine to Vancouver, WA Main Line Track Upgrade	Option 3: 2013 Option 4: 2014			97.4	97.4
	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.					
Project Group C: 341M for Option 4	Centralia New Crossover Near China Creek	2011				3.7
	Cascades Two New Train Sets Four Locomotives	2012				69.9
	Kelso-Martin s Bluff Kalama 3rd Main Track	2013				77.8
	Cascades Higher Speed Locomotives	2014				88.4
	Tacoma Reservation to Stewart New 3rd Main Track	2014				101.7
	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.					

A project group is a set of projects or project stages to be implemented collectively to achieve additional service.

Costs do not include anticipated expenditures prior to July 2009. These projects were currently funded as: Tacoma Bypass of Pt. Defiance 66th St. to Nisqually, 59.5 million; Vancouver Yard Bypass and W 39th St., 115 million (include 55 million in 09-11 bienium); King Street Station Track Improvements, 13 million; Cascades Train Sets Overhaul, 4million. The cost estimates listed in the options are additional costs needed to complete these projects starting July 2009.

Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.

Source: WSDOT State Rail and Marine Office.

There are a number of smaller incomplete projects that are underway or are planned to be underway as of this writing. These projects have reliability benefits and in some cases capacity benefits to increase passenger rail service frequency. Some of these projects will be completed prior to the start of this plan's study period, July 1, 2009, and some will carry forward beyond that date. Exhibit 4-2 lists the detail of these projects and their overall costs and anticipated costs to be expended prior to July 1, 2009. These projects are not discussed further in this chapter as

they are planned to be complete, or nearly so, prior to the beginning of the mid-range planning horizon.

Exhibit 4-2: Projects with Reliability Benefits

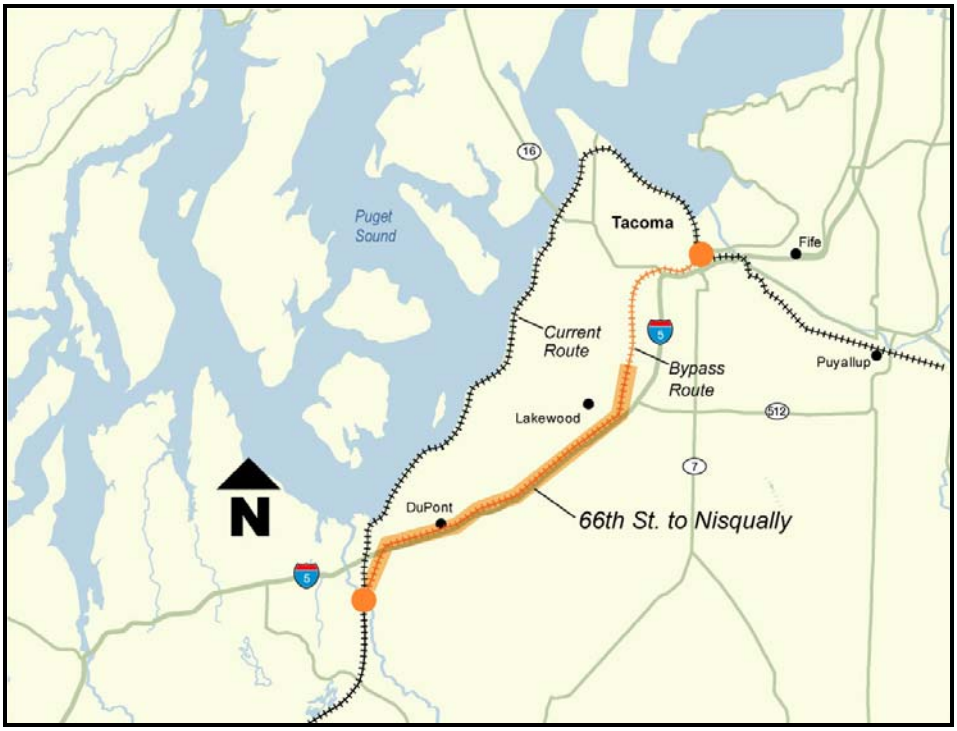
Project Name	Total Budget	Planned Expenditures Prior to July 1, 2009	Planned Expenditures Starting July 1, 2009
Tenino – High Speed Crossovers	$3,875,000	$3,875,000	$0
Mt Vernon – Siding Upgrade	$3,800,000	$3,800,000	$0
Everett – Curve Realignments and Storage Tracks	$14,000,000	$14,000,000	$0
Stanwood – Siding Upgrades	$15,950,000	$15,950,000	$0
Blaine – Customs Facility Siding	$6,000,000	$6,000,000	$0
King Street Station – Track Improvements	$15,000,000	$13,000,000	$2,000,000
Cascades Train Sets – Overhaul	$10,000,000	$4,000,000	$6,000,000
Stanwood – New Station	$5,000,000	$5,000,000	$0

Budgets and planned expenditures are based on the 2008 Supplemental Transportation Budget.

The remainder of this chapter contains information about specific rail projects between Seattle and Portland. Each rail project contains the following information: title, beginning and ending rail milepost (MP) [1], project components, map or photo, cost and funding information, timeframe, and a brief explanation of why it is needed and how it can independently solve a particular problem.

[1] Mileposts or rail mileposts are designations by the railroad indicating the railroad track distance from an established starting point to an ending point.

Tacoma – Bypass of Point Defiance – 66th St. to Nisqually (Rail mileposts 24.7 to 24.2, 11.5 to 0.0, and 9.0 to 0.6)



This project is the first phase of a much larger project listed as Point Defiance Bypass in the long-range plan. Since then, the project has been separated into two phases.

Currently passenger trains must slow down to use the curved tracks along Puget Sound and the single-track tunnels under Point Defiance. The first phase of this project builds a bypass so that passenger trains can avoid those areas. Freight trains would continue to use the existing tracks in the Point Defiance area. This project would increase capacity to allow increases in passenger service, as well as provide reliable Amtrak *Cascades* service by reducing travel time by six minutes and eliminate conflicts with freight trains.

The proposed route of this WSDOT project is the same that Sound Transit would use to extend *Sounder* Commuter Rail service to Lakewood. After both the WSDOT-sponsored and Sound Transit-sponsored projects are completed, Amtrak trains and *Sounder* Commuter Rail would share the route with infrequent freight trains currently serving, Fort Lewis, and other shippers in Lakewood, south Tacoma, and Roy.

This first phase improvement on this bypass route includes a new second track between 66th Street in south Tacoma and Bridgeport Way in Lakewood. It reconstructs the remainder of the existing Sound Transit-

owned track between Lakewood and Nisqually and reconfigures the rail junction at Nisqually on the BNSF's Seattle Subdivision main line. The current cost estimate for this portion of the project is $42.8 million with delivery by 2012 (Exhibit 5A-2, Appendix 5). This project is listed in the 2003 Legislative Transportation Package and the 2005 Transportation Partnership Account, but it would require additional funding beyond the $59.8 million allocated by the state legislature. The design and environmental documentation is complete. The initial work between S. 66th Street and Bridgeport Way is planned to begin construction, along with Sound Transit-funded improvements, in late 2008.

Vancouver – Yard Bypass and W. 39th Street (Rail mileposts 9.9 to 10.4 and 133.3 to 136.5)

This project consists of a single-track bypass of the heavily congested Vancouver rail yard, a siding[2] extension, and associated turnouts from rail MP 133.3 to rail MP 136.5 of the BNSF's Seattle Subdivision and connecting tracks, crossovers[3], and track improvements from rail MP 9.9 to rail MP 10.4 on the BNSF's Fallbridge Subdivision. The bypass separates grain freight traffic from passenger traffic to allow for projected increased traffic in both freight and passenger rail. All the improvements relieve congestion for freight coming from eastern Washington. West 39th Street, which bisects the rail yard, would also be grade separated[4], thus providing a safer crossing for vehicles and pedestrians.

The current estimated construction cost of this project is $150.7 million. This project is listed in the 2003 Legislative Transportation Package. To deliver the project in 2012 it will cost $90.4 million (Exhibit 5A-3, Appendix 5). The design and environmental documentation for this project has been completed, and portions of the rail improvements and the W. 39th Street Bridge are under construction as of this writing.

Add Fifth Seattle to Portland Daily Round Trip

By completing the Vancouver and Tacoma projects described above, the number of daily round trips between Seattle and Portland can be increased from four to five and maintain the two Seattle to Vancouver, B.C. daily round trips.

[2] A siding is an auxiliary track located next to a main line that allows a train to move out of the way of an oncoming train. Sidings are also used to store trains or to add/subtract rail cars.

[3] A crossover is a set of turnouts connecting multiple tracks. A crossover allows a train to move from one track to another.

[4] Grade separated means the crossing lines of rail, auto, or pedestrian traffic are vertically separated from each other (i.e. a roadway that crosses over or under a railroad track).

Increase Capacity of Existing Train Sets

The current fleet of train sets was built from 1996 to 1998 by Renfe Talgo of America (Talgo). Each set has 12 cars and has a relatively fixed consist[5], as it takes a crew of five to seven people up to six hours to add or remove cars for any one train set. Thus, the train set cannot be increased or decreased easily to react to short-term peaks or valleys in ridership. Riders may be turned away during times of peak demand.

In addition each train has one locomotive, usually an Electro-Motive Diesel (EMD) F59 of 3,500-horsepower provided by Amtrak, as well as a cab car.[6] The cab car is required to provide a place for the engineer to operate the train when the powered locomotive is pushing the train instead of pulling. It also provides additional safety in case of a collision. The existing fleet of 12-car train sets is based on the ability of one locomotive to keep to schedule while pulling or pushing the train set and cab car. To move a larger train set and stay on schedule, the cab car needs to be replaced with a second locomotive on each train.

There is a very limited availability of the model of Talgo cars in the current fleet on the used market. This model of train car is no longer in production and has been replaced with a new model that meets current

[5] A consist is the number of cars forming a train set, not including the locomotive or current cab car.
[6] A cab car is an unpowered locomotive.

U.S. rail equipment regulations without modifications. These newer model cars, although similar, are not compatible mechanically with the cars in the current fleet. Further, there is a very limited availability of the model of car in the current fleet on the used market.

This project would purchase a new train set of 14 cars and purchase five new locomotives to supplement the Amtrak-provided fleet of locomotives. The addition of a new type of train set would allow the cars in the existing train sets to be re-arranged to form four train sets consisting of at least 14 cars. This would increase the overall capacity of all trains in the Amtrak *Cascades* service without additional "on the ground" infrastructure improvements.

The cost of the one train set and five locomotives is estimated to be $48.4 million, with delivery by 2012 (Exhibit 5A-4, Appendix 5). As the EMD F59 is no longer in production, the estimate also assumes that locomotives, either of a new design or second-hand from inside the U.S., will be available. While the existing fleet is comprised of equipment from specific manufacturers, the purchase of additional equipment would be a competitive process open to all qualified equipment manufacturers.

Kelso to Martin's Bluff – New Siding (Rail mileposts 105.5 to 110.0)

This project is a phase of a much larger rail improvement project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project consists of adding a Centralized Traffic Controlled[7] arrival and departure track capable of holding up to two full-length trains and associated switches and crossovers on BNSF's Seattle Subdivision. This would allow grain trains inbound for Kalama and empty trains outbound from Kalama to move off the main line, when the Port of Kalama tracks at the two grain terminals are filled with other trains. The project is needed because current congestion on the rail line in this area negatively affects reliability and the ability to add service for additional Amtrak *Cascades* trains. Once this project is completed, service would be more reliable and additional service could be added.

This project can be delivered as early as 2013 at a cost of $60.2 million with Option 4, or 2017 at a cost of $83.4 million with Option 3 (Exhibit 5A-5, Appendix 5). This project is listed in the 2003 Legislative Transportation Package, but would require additional funding beyond the $49 million allocated by the state legislature. Conceptual design and environmental documentation for this project began in 2001. It is anticipated that final design will begin by 2013.

[7] Centralized Traffic Controlled track means the track is dispatcher controlled.

Kelso to Martin's Bluff – Kelso-Longview Jct. – 3rd Main Track (Rail mileposts 96.2 to 102.1)

This project is a phase of a much larger project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project will build on other phases and construct a 4.5-mile third main line track from the passenger station in Kelso to Longview Junction South at the south end of Longview Yard. The Longview Yard is an area of congestion with trains of cars bound for and coming from the Port of Longview and the Weyerhaeuser paper mill. Here cars are switched by BNSF, Union Pacific Railroad (UP), and the Longview Switching Company. The third track would allow passenger and freight trains to move around freight trains leaving or bound for Longview Yard. A new rail bridge over the Coweeman River, as well as two bridges over private access roads, would also be built.

A 5,000-foot storage track in south Kelso would be replaced and converted to main track. This siding would cross Yew Street and Mill Street in Kelso at grade. This project will not require these two grade crossings[8] south of the station to be closed or replaced. They are planned to be replaced in a later phase of the overall project.

[8] A grade crossing is the area along the track where a roadway or pathway crosses on the same grade level.

This project could be delivered as early as 2013 at a cost of $125.8 million with Option 4, or in 2017 at a cost of $151.0 million with Option 3 (Exhibit 5A-6, Appendix 5).

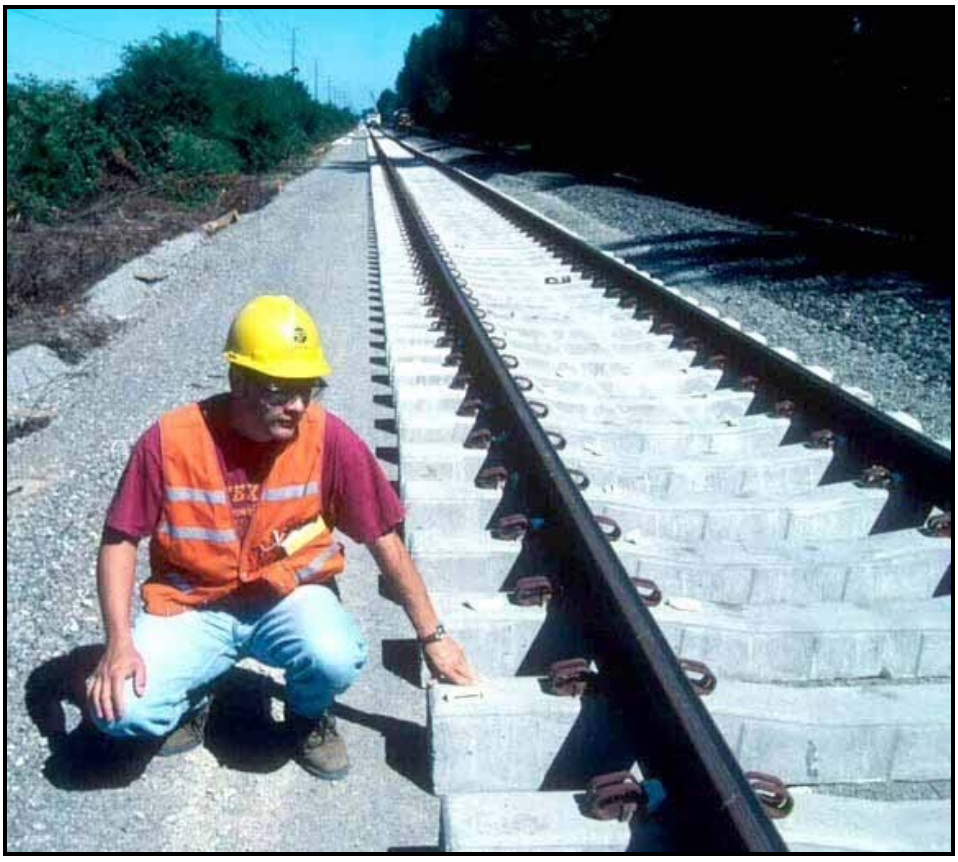
Cascades - Two New Train Sets

In order to increase service capacity between Seattle and Portland, either the service elsewhere would have to be reduced, or more train equipment would be required to supplement the existing fleet of five Talgo-built train sets. While more equipment could be leased from elsewhere in the U.S., it is more conservative to assume that the program would acquire new equipment.

This project would acquire two new train sets for this purpose. It is assumed Amtrak would be able to provide the required locomotives, if WSDOT has not purchased the new high-speed locomotives described later.

The purchase of equipment is difficult to predict as purchasing rail equipment in small quantities, such as two at a time, can increase unit costs substantially. The cost of two new train sets is estimated to be $50.8 million with delivery by 2013 with Option 4 or $56.8 million in 2017 with Option 3 (Exhibit 5A-7, Appendix 5), but could be as much as 25 percent less, if the purchase is associated with a larger order. The estimate assumes a 14-car train set similar to the current fleet, but the equipment purchase would be a competitive process open to all qualified equipment manufacturers.

Blaine to Vancouver, WA – Main Line Track Upgrade



Currently, all the main line tracks that the Amtrak *Cascades* operate on are maintained to Federal Railroad Administration (FRA) "Class IV"[9] standards. Class IV tracks are limited to a maximum speed of 79 mph on straight or nearly straight track. When a track falls out of compliance with the Class IV standard, a "slow order"[10] is imposed by the owning railroad until repairs can be made.

This project will upgrade and maintain all existing main line tracks to FRA "Class V"[11] standards. However, trains would still be limited to 79 mph maximum due to signal limitations. When tracks are brought up and maintained at a higher track standard, then if they fall into disrepair, the Amtrak *Cascades* trains would still be able to operate at 79 mph. This will eliminate nearly all slow orders, thus increasing on-time performance

[9] Class IV is a Federal Railroad Administration (FRA) safety standard focused on track structure, geometry, inspection, and road bed. The Class IV maximum allowable speed for passenger trains is 79 mph.
[10] A slow order is a track condition, usually temporary in nature, that can cancel or severely delay train service (i.e. track damage due to a winter storm, track maintenance in process).
[11] Class V is a higher FRA track safety standard. The maximum allowable speed for passenger trains is 90 mph.

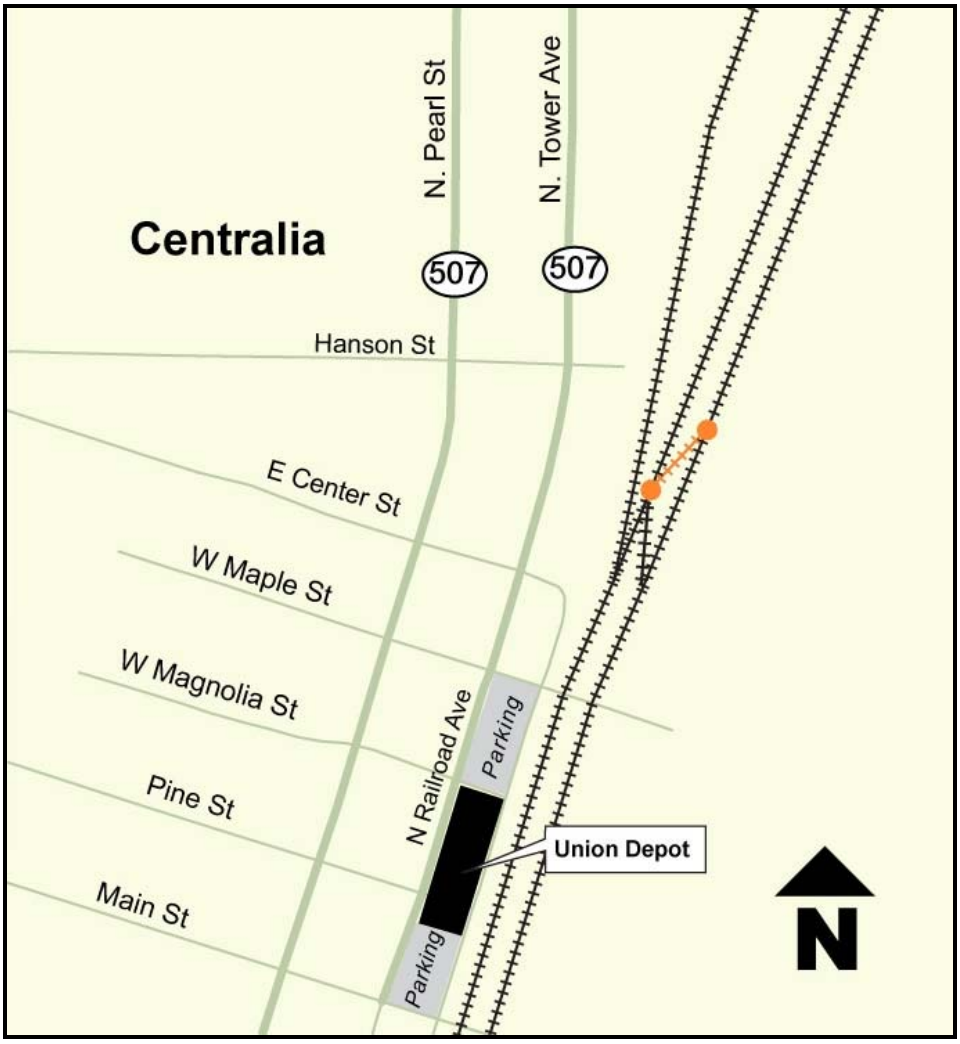
and increasing schedule reliability. A similar project is underway on California's Capital Corridor.

WSDOT estimates it will cost more than $200,000 per track mile. This equates to $97.4 million with delivery in 2014 (Exhibit 5A-8, Appendix 5). In addition, the cost of maintaining the tracks to the higher standard will be higher than today. This will take about four years to implement without severely disrupting existing service. BNSF estimates it will cost between $10,000 and $13,000 (2008 estimates) per track mile annually for ongoing maintenance at the higher track standard.

Six Seattle to Portland and Two Seattle to Vancouver, B.C. Daily Round Trips

By completing the above projects (increasing train capacity, completing the first two phases of Kelso-Martin's Bluff, purchasing two new train sets, and main line track upgrades), the number of daily round trips between Seattle and Portland can be increased to six.

Centralia – New Crossover Near China Creek
(Rail mileposts 53.5 to 53.6)



Construction of this crossover provides flexibility for trains to move between tracks when entering and departing Centralia's Union Depot, ensuring that passengers can exit the train on the west side of the rail line, adjacent to the station. Without this crossover, there would be situations when a passenger train on the east main line would require passengers to cross the west main line, which reduces passenger safety. This project would provide increased capacity, reliability, and safety. The estimated construction cost of this project is $3.7 million with delivery by 2011 (Exhibit 5A-9, Appendix 5).

Cascades - Two New Train Sets & Four Locomotives

As described earlier, in order to add more service between Seattle and Portland, more train equipment would be required to supplement the existing fleet. This project would acquire an additional two new train sets for this purpose. This project would also purchase four additional high-speed locomotives, as described later.

The purchase of rail equipment is difficult to predict because small purchase orders, such as two at a time, can increase unit costs substantially. The cost of two new train sets and four locomotives is estimated to be $69.9 million with delivery by 2013 (Exhibit 5A-10, Appendix 5), but they could cost as much as 25 percent less, if they are part of a larger order. The estimate assumes a 14-car train set similar to the current fleet with a capacity of approximately 300 passengers, but the purchase of the equipment would be a competitive process open to all qualified equipment manufacturers.

Kelso to Martin's Bluff – Kalama 3rd Main Track (rail mileposts 105.8 to 108.9)

This project is a phase of a much larger project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project would build on other phases and construct a 2.9-mile third main track around the congested Port of Kalama area. Here 7,000-foot BNSF and UP grain trains move between the main tracks and one of the largest grain terminals on the west coast. These movements, on and off the main line, create congestion on the main tracks. The third main track would allow passenger and freight trains to move around freight trains that are waiting to enter or are leaving the Port of Kalama.

This project is estimated to cost $77.8 million with delivery by 2014 (Exhibit 5A-11, Appendix 5).

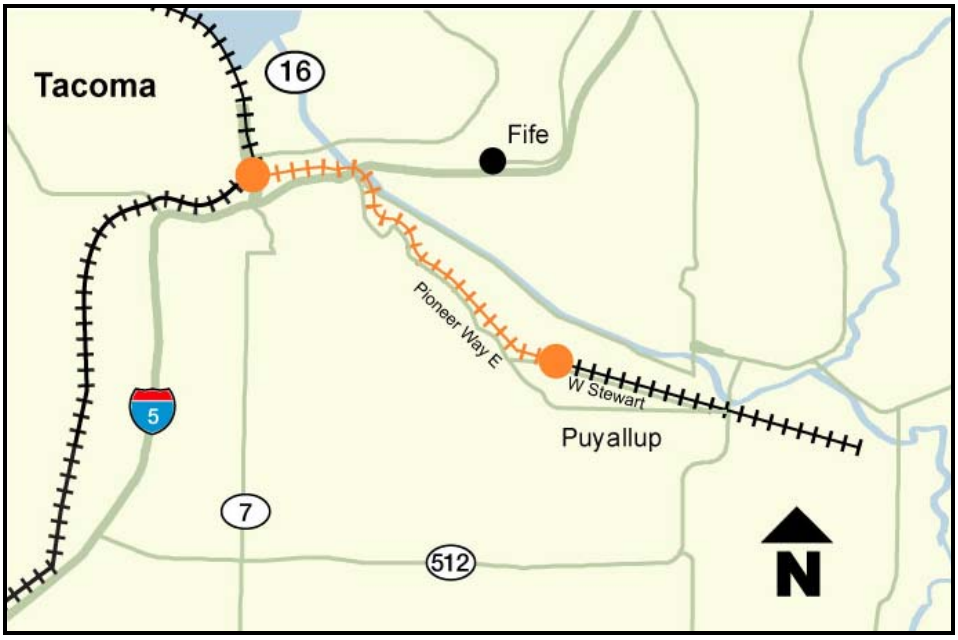
Cascades - Higher Speed Locomotives

As stated earlier, currently each train has one locomotive, usually an EMD F59 of 3,500 horsepower provided by Amtrak and a cab car. This project would purchase 16 new locomotives that are capable of operating consistently and economically with higher speeds (up to 110 mph) and higher acceleration rates than the current F59 locomotive fleet. This project would provide two locomotives per train set plus two reserve locomotives for scheduled maintenance and in case of break-downs.

The estimated cost is $88.4 million with delivery by 2015 (Exhibit 5A-12, Appendix 5), however, as previously stated, the purchase of equipment is difficult to predict since purchasing rail equipment in small quantities, such as two at a time, can increase unit costs substantially. Purchasing the rail equipment as part of a larger order would reduce costs.

For a more detailed discussion of the type of locomotives needed for higher-speed travel, see the 2006 long-range plan, Volume 1; Amtrak *Cascades* Operating and Infrastructure Plan Technical Report, page 4-46.

Tacoma - Reservation to Stewart – New 3rd Main Track (rail mileposts 38.2 to 33.9)



A new main line will be built next to the existing double track. The purpose of this track is to provide a dedicated track for lower speed freight trains that originate, terminate, or stop in Tacoma. The track is needed because freight traffic is predicted to continue to grow in this area over the next 20 years. Without increased capacity additional traffic would result in increased congestion and reduced reliability.

The estimated construction cost of this project is $101.7 million with delivery by 2015 (Exhibit 5A-13, Appendix 5).

Eight Seattle to Portland and Two Seattle to Vancouver, B.C. Daily Round Trips

By completing the above projects (new cross-over in Centralia, two new train sets and higher speed locomotives, the 3rd main track at Kalama, and a new main line in Tacoma), the number of daily round trips between Seattle and Portland can be increased to eight.

Chapter 5: Operational Analysis and Costs

This chapter of the *Amtrak Cascades Mid-Range Plan* reviews the operating environment of Amtrak *Cascades* service in support of mid-range plan options that can allow up to four additional daily Amtrak *Cascades* round trips between Seattle and Portland. Computer simulation modeling was performed throughout 2007-2008 to validate infrastructure requirements necessary for new service, and to identify opportunities to improve the on-time performance and reliability of the service. Appendix 6 provides detailed information regarding the operational analysis and costs described throughout this chapter.

Appendix 6 includes details about the operational analysis, additional reliability projects, service enhancements, and passenger train delays.

Operational Analysis

Operational analysis uses computer simulation modeling to validate Amtrak *Cascades* timetables, track capacity, and service capacity. It looks at proposed infrastructure improvements to increase frequency, improve reliability, and meet on-time performance targets between Seattle and Portland. Operational analysis also helps determine the order of infrastructure and operating projects to be included in Options 2, 3, and 4. Project types include:

- Timetable (schedule) improvements.
- Track capacity improvements.
- Reliability improvements.

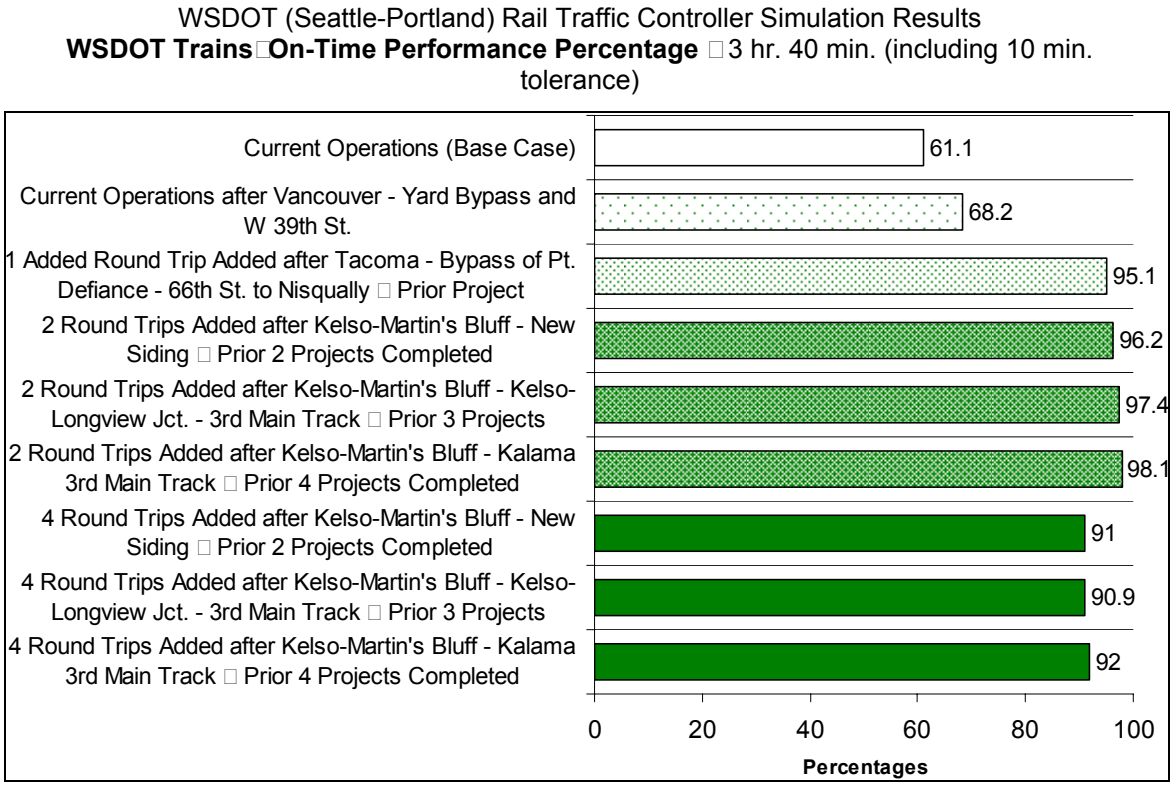
It also examines the feasibility of increasing the frequency (up to four daily round trips) and the fleet (up to four additional trains) for Amtrak *Cascades* service between Seattle and Portland.

The operational analysis for this plan examined four weeks of railroad operation in randomized traffic patterns to represent the current railroad conditions. It analyzed over 2,800 trains in each of 16 simulations. Each simulation began with a base case that was subjected to extensive analysis before proceeding. Each simulation contained many variables, including the differentiations between freight and passenger rail movements. The modeling process ensured that the results represent the infrastructure requirements as accurately as possible.

Modeling results validated and confirmed the previous 2003 operations analysis. The model addressed on-time performance; it didn't address reliability, slow orders, or the "state of good" railroad repair and maintenance.

Exhibit 5-1 shows anticipated on-time performance when a cumulative set of improvements, adding 1, 2, or 4 additional daily Amtrak *Cascades* round trips between Seattle and Portland, is complete.

Exhibit 5-1: Passenger Service On-Time Performance Based on Five Cases of Randomized Freight Service



Source: BNSF Railway Company

The exhibit above shows that the Amtrak *Cascades* has a base case of 61.1 percent on-time performance (a key measure of service reliability), which is relatively consistent with current operations, particularly during peak traffic periods. Completion of the Vancouver – Yard Bypass & W 39th St. Project increases on-time from 61.1 percent to 68.2 percent, but not enough for an additional Amtrak *Cascades* Seattle to Portland daily round trip. Completion of the Tacoma – Bypass of Pt. Defiance Project – 66th St. to Nisqually increases on-time performance and track capacity dramatically, enough to add one additional Seattle to Portland daily round trip to the system and improve on-time performance from 68.2 percent to 95.1 percent.

With the completion of the first two phases of the Kelso-Martin's Bluff Project, an additional Seattle to Portland daily round trip can be implemented with on-time performance in the range of 96 percent to 97 percent.

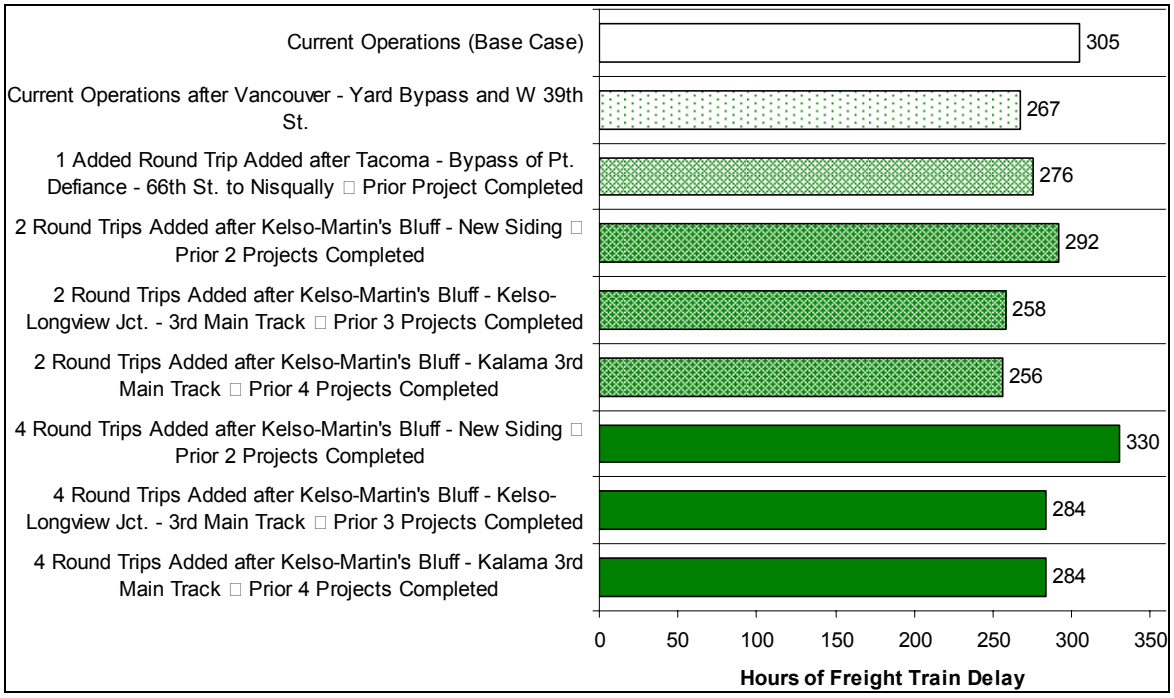
It is important to note that although four daily round trips could be operated, the operation occurs at slightly reduced levels of reliability. This demonstrates that the remaining Kelso-Martin's Bluff – Kalama 3rd Main Track project should be completed and will provide some reliability benefit when the full complement of four additional daily round trips between Seattle and Portland are implemented.

As previously discussed, BNSF is agreeable to allowing additional Amtrak *Cascades* service as long as it will not negatively impact freight service. Impacts to freight service are measured in hours of delay. Current freight train delays, as replicated in the base case, are 304.6 hours per week. It is BNSF's position that intercity passenger rail service expansion can be accommodated as long as their freight business is not adversely impacted.

Exhibit 5-2 shows the relationship between infrastructure improvements, additional Amtrak *Cascades* service, and freight train delay. The modeling confirms that the infrastructure plan can be implemented without negatively impacting freight business.

Exhibit 5-2: WSDOT Plan s Impact on Freight Service

WSDOT (Seattle-Portland) Rail Traffic Controller Simulation Results
Freight Train Delay in hours per week (all main line freight trains)



Source: BNSF Railway Company

Opportunities to Enhance Reliability and Improve Performance

Reliability Improvement

Operational analysis confirms, with a high level of probability, that the incremental infrastructure developments related to Options 2, 3, and 4 would enable additional Amtrak *Cascades* daily round trips between Seattle and Portland, as well as improvement of reliability and overall system performance.

Achieving the 90 percent on-time performance goal in Options 2, 3, and 4 will make Amtrak *Cascades* service punctual and dependable. People who are not satisfied with their service are much more likely to tell others as people who receive a satisfactory rail experience. Amtrak *Cascades* can not achieve broader acceptance unless service is punctual and dependable, regardless of other infrastructure and operating improvements.

Amtrak *Cascades* uses a limited amount of rolling stock (equipment) making multiple trips within the Pacific Northwest Rail Corridor (PNWRC) each day. One delayed train can cause a domino effect of successive delays for passenger and freight trains using the same corridor.

When frequencies (additional daily round trips) are added, operating tolerances become tighter. Amtrak *Cascades* service not only needs the rail line capacity for additional service, but it needs operational changes for much tighter precision and punctuality in the daily operating environment.

Additional Recommended Reliability Improvements

At the request of WSDOT, BNSF ran operational analysis to address three recommended reliability improvements that are currently outside the scope of the mid-range plan. They also have a high potential to increase the capacity for future expansion.

1. **Oregon.** There is a highly congested section of the corridor between the Columbia River and Portland's Union Station. The segment contains several drawbridges and crossing movements of freight traffic to and from port facilities and yard traffic. Four projects have been identified. Two are funded by the state of Oregon and two are unfunded.

2. **Napavine – Winlock to Chehalis 3rd Main Track.** Between Chehalis Junction and Winlock, there is a need for a dedicated main line track, which would allow passenger trains to travel unimpeded by slow moving freight trains traveling on the gradient of Napavine Hill. The dedicated passenger train track would also eliminate sharp curvature, allowing higher travel speeds, which would reduce travel times. This project is unfunded.

3. **Kelso-Martin's Bluff – Longview to Kalama 3rd Main Track.** This project phase adds a third main line track between Kalama and Longview Junction to enhance reliability and achieve an on-time performance of 96 percent or better. This phase is currently unfunded.

Other Reliability Improvements

- **Maintenance Facility.** At the Seattle Maintenance Facility, where trains receive more intensive servicing and maintenance every four days, Amtrak is finalizing plans to reconstruct the facility for current and future needs of Amtrak *Cascades* intercity passenger service, Amtrak long distance service, and Sounder commuter trains.

- **Stations.** Train station access improvements are needed to enhance safety, capacity, wheelchair access, baggage loading, and boarding and de-boarding time.

- **Integrated Scheduling.** Between Seattle, Tacoma, and Nisqually, there are plans to minimize Amtrak *Cascades* and Sound Transit scheduling conflicts. This would allow opportunities to provide rail-to-rail connections and passenger transfers at common stations in Tacoma, Tukwila, and Seattle, where Amtrak *Cascades* and Sound Transit offer complementary services.

Maintenance of Track

The current methods of performing track maintenance during normal daylight hours require "work windows" that limit rail capacity to move freight and passenger trains efficiently through the system. As freight and passenger frequencies increase, the ability to perform track maintenance decreases and the result is slow orders, which can cancel or severely delay train service. Slow orders are placed on a track when conditions exist (i.e. damage to track or crossovers largely due to storm-related events) that restrict the ability for freight and passenger trains to operate at designated track speeds. Slow orders, which are temporary in nature, are problems particularly during construction seasons, when new construction and capitalized maintenance projects are underway.

WSDOT and BNSF are considering additional track maintenance enhancements that limit slow orders, achieve track maintenance goals, accommodate infrastructure growth, and meet the need for absolutely reliable service. Enhancements include:

- **Night maintenance.** Performing maintenance activities at night when traffic is lighter.

- **Alternative methods or equipment.** Multi-function, high-speed track maintenance machines.

- **Capitalized maintenance.** Upgrading from Class IV to Class V track maintenance standards. This is included in Chapter 4 in the project titled "Blaine – Vancouver, WA – Main Line Track Upgrades."

Traffic Management

BNSF is evaluating a "movement planner" program for use throughout their entire system to increase reliability and better manage traffic flow.

Positive Train Control

New rail safety laws require the installation and operation of positive train control, an advanced signal system, by 2015 on rail lines that have mixed

passenger and freight traffic. BNSF is currently testing them on select corridors within their system.

Opportunities for Service Enhancements

In quarterly Amtrak customer satisfaction index surveys, Amtrak *Cascades* service has been ranked in the top five in the nation in customer satisfaction throughout its history. Customers have enjoyed a level of service that is considered better in overall quality than "typical" Amtrak service.

In 2008 Amtrak surveyed existing and potential Amtrak *Cascades* customers. Participants were asked about amenities and improvements to further enhance customer satisfaction. The survey resulted in several recommendations for Coach Class and Business Class travelers. The largest segment of potential new riders is more likely to be business travelers. Their main suggestions are:

- Wireless Internet (WiFi) onboard the passenger coaches.
- WiFi in separate Business Class lounges and in stations.
- Quiet car.
- Business Class amenity upgrades.
- Enhanced passenger information display system.

Analysis and Estimation of Operating Costs

Cost estimation analysis provides detailed and accurate forecasts of Amtrak *Cascades* operating costs for the four strategic investment options discussed in this plan. Operating cost categories, which are defined further in this section, include:

- **Train costs** are direct costs associated with each train. Train costs change with the number of operating trains.

- **System costs** are indirect costs that change with the number of trains, passengers, and train sets. The system cost is allocated equally among the trains.

- **Passenger costs** are individual costs allocated to trains by their ridership. The cost estimation analysis projections do not accurately reflect the relationship of passengers to individual trains, which is an overly complex calculation. The total passenger cost is allocated equally among the trains.

Train Costs

- **Labor and Support for Train and Engine:** Labor costs for engineers, conductors, and other train operating staff.

- **Labor and Support for Onboard Service:** Labor costs for staff involved in dispensing food and beverages on trains to passengers.

- **Fuel:** Costs for locomotive fuel.

- **Commissary Provisions and Management:** Costs for food, beverages, and consumable supplies dispensed on trains to passengers and non-consumable supplies used for customer service on trains.

- **Host Railroad Maintenance-of-Way**: Costs for maintaining track (e.g. track, signals, crossings) and facilities (e.g. stations, other buildings).

- **Host Railroad Performance Payments**: Payments to the railroad for keeping trains on schedule.

- **Insurance**: Purchased property and liability insurance and costs of self-insurance.

System Costs

- **Advertising:** Costs for advertising Amtrak *Cascades* service.

- **General Support:** Expenses not related directly to train operation and the use of resources not dedicated entirely to Amtrak *Cascades* operation (e.g. general counsel, claims services, customer communications, payroll, safety and environmental control, engineering, materials management, human resources, technical training, police and safety services, and procurement/purchasing).

- **Transportation:** Personnel supervising and managing the service and associated costs as well as the costs of buses in lieu of train service and alternative transportation for passengers during service interruptions. Includes itemized categories of yard operations, terminal payments, passenger inconvenience, and transportation supervision and training.

- **Maintenance of Equipment:** Costs of vehicle maintenance.

- **Other Railroad Costs:** Charges by the railroad (BNSF in Washington State and UP in Oregon for the Amtrak *Cascades*) that

are not specific to train operation (e.g. administration, control center functions, avoidable costs).

- **Reservations:** Costs related to managing passenger reservations and the maintenance of information technology systems used for passenger reservations.

- **Other Amtrak Costs:** Includes itemized sub-categories of Amtrak operations and transportation support and amtrak fixed infrastructure maintenance.

Passenger Costs

- **Station Services:** Labor costs for station staff (e.g. ticket agent, janitors) and utility expenses for stations.

- **Commissions:** Fees paid to travel agents and to credit card services.

- **Sales:** Marketing support and the costs of non-station ticketing (e.g. tickets by mail).

The Amtrak *Cascades* cost estimation timeframe is Federal Fiscal Year 2009 (FFY09), which is October 1, 2008 through September 30, 2009. FFY09 cost estimates are split between the partners: Washington at 65 percent, Oregon at 20 percent, and Amtrak at 15 percent. Some cost estimates, such as the cost of Washington State's higher performance Talgo trains, are split differently per agreement with each set of stakeholders.

Analysis results show that cost estimates change based on escalating factors, when capacity changes for additional daily round trips on the Seattle to Portland and Seattle to Vancouver, B.C. segments.

Exhibit 5-3 shows economies of scale.[1] On the Seattle to Portland daily round trip, the "cost per trip" decreases as capacity increases. Factors influencing the "cost per trip" reduction include:

- The cost of adding passenger coaches to existing Talgo train sets.

- The costs of adding locomotives to Talgo train sets that receive an additional passenger coach (a power requirement).

[1] Reduction in cost per round trip resulting from increased round trips, realized through operational efficiencies. Economies of scale can be accomplished because as roundtrip increases, the cost of operate additional roundtrip falls.

- The cost of adding more trains to the fleet.
- The cost of additional Talgo maintenance.
- The cost of enhanced reliability (capitalized maintenance) associated with Options 2, 3, and 4 that eliminate slow orders and improve on-time performance.

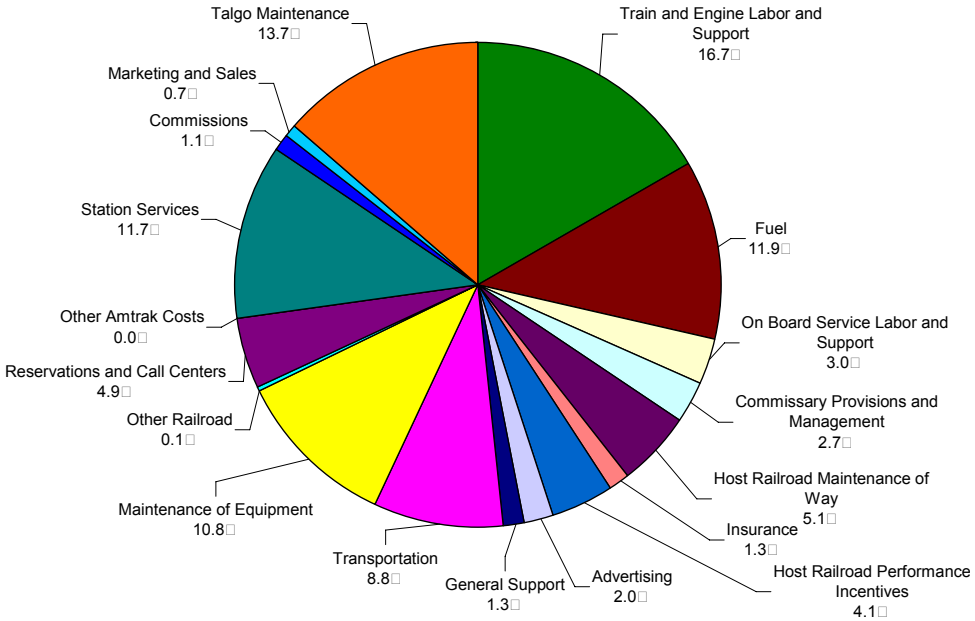
Exhibit 5-3: Estimates of Annual Operating Costs and Maintenance Costs (2008 Dollars)

Daily Round Trips	Amtrak Operating Cost Per Round Trip	Amtrak Operating Cost Per One-Way Trip	Talgo Maintenance Cost Per Round Trip	Talgo Maintenance Cost Per One-Way Trip	Reliability Enhancement Maintenance Cost Per Round Trip	Reliability Enhancement Maintenance Cost Per One-Way Trip
4	5,753,341	2,876,671	913,540	456,770	940,125	470,063
5	5,499,419	2,749,710	899,596	449,798	940,125	470,063
6	5,293,188	2,646,594	890,774	445,387	940,125	470,063
8	4,997,243	2,498,622	873,709	436,854	940,125	470,063

Source: WSDOT State Rail and Marine Office

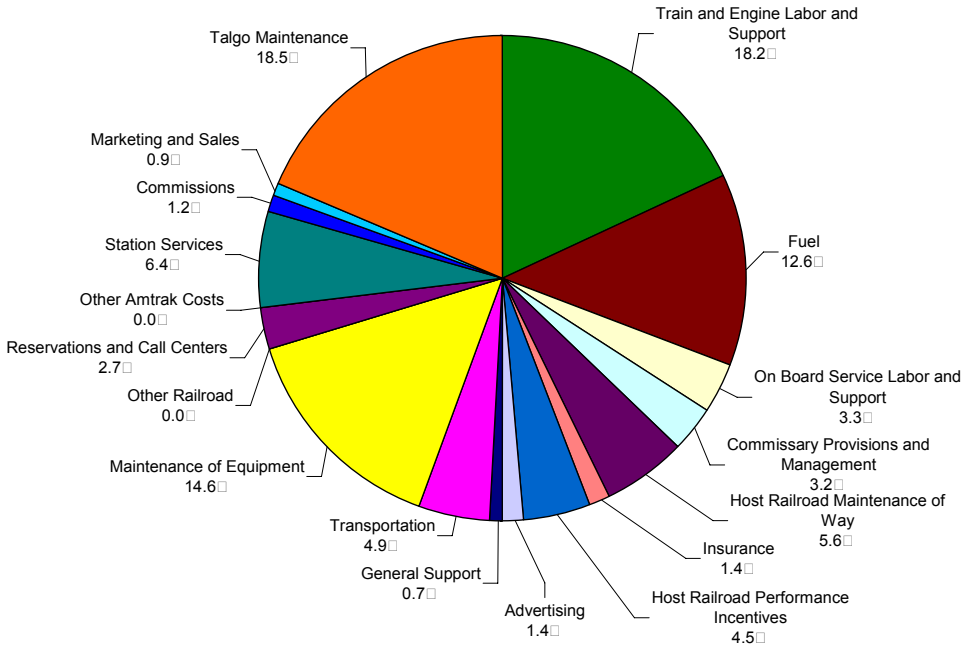
Exhibits 5-4 and 5-5 show analysis results on how Amtrak *Cascades* operating costs change as capacity is added to the Seattle to Portland daily round trip segment as incrementally developed in Options 2, 3, and 4.

Exhibit 5-4: Amtrak *Cascades* Operating Costs for Seattle to Portland Four Daily Round Trips (2008 Dollars)



Source: WSDOT State Rail and Marine Office

Exhibit 5-5: Amtrak *Cascades* Operating Costs for Seattle to Portland Eight Daily Round Trips (2008 Dollars)



Source: WSDOT State Rail and Marine Office

Washington State Department of Transportation

Chapter 6: Options for Achieving Additional Amtrak *Cascades* Service

The analysis in this chapter articulates the needs of intercity passenger train services and discusses supply and demand issues for various scenarios. Comparing the alternatives available to policymakers, the option analysis provides information to help develop strategic investment policies that achieves multiple policy ends using transportation solutions. The option analysis specifies the steps of improving infrastructure to deliver additional intercity passenger services, and link capital and operational investment to ridership growth and economic and societal benefits to support informed decision-making processes—legislative budgeting and prioritizing.

Options for Achieving Additional Services

Options presented in the *Amtrak Cascades Mid-Range Plan* are designed in the context of the current macroeconomic policymaking environment. They build on incremental strategy with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. This mid-range plan presents four options for future program development described in details in Chapter 2. The following is a brief summary of these options.

Option 1 – Maintaining Current Operation Strategy

This option has no additional capital investment and infrastructure improvements in the mid-range planning period. It maintains the current operation level of Amtrak *Cascades* service. All previous capital investments become sunk costs[1], due to no additional investment for completing projects that would increase service capacity.

Options 2 and 3 – Incremental Strategies

These options address specific investment goals based on the supply and demand interactions of our dynamic economy and changing society. They provide essential information about ridership growth, cost and revenue, local and state economic impacts, and environment and social benefits/costs.

[1] Sunk costs are costs that cannot be recovered once they have been incurred. If there is no additional investment to complete projects that increase service capacity, then the costs of the uncompleted projects are lost or sunk.

Option 4 – Rail as a Long-Term Alternative Strategy – No Financial Constraints

This option examines the engineering feasibility of the maximum capacity that can be built, given the availability of investment to develop such infrastructure improvements.

Option 4 is viable in an environment where policymakers are willing to promote rail as a strategic component in integrated transportation solution. In such an environment, rail, while providing transportation service, would help address issues such as greenhouse gas reduction, congestion relief, public safety improvement, and transportation resilience to natural and man-made disasters.

Investment in Capital Projects by Option

Investment options are designed to achieve multiple goals using passenger rail as part of an integrated solution. Investment in capital projects is used to improve infrastructure and acquire additional equipment that is needed to expand the level of operations. The planning period for capital investment is from fiscal year 2010 to fiscal year 2017.

Exhibit 6-1 demonstrates investments in capital projects and shows the capacity and reliability to be achieved by these capital projects.

Exhibit 6-1: Costs of Capital Projects to Achieve Additional Service Level: FY2010 to FY2017

Project Group	Project Name	Year of Completion	Capital Cost Estimates (million)			
			Option 1: 0	Option 2: 141 Million	Option 3: 578 Million	Option 4: 817 Million
Project Group A: 141M for Options 2, 3, and 4	Tacoma Bypass of Pt. Defiance 66th St. to Nisqually	Option 2, 3, and 4: 2012		141.2	141.2	141.2
	Vancouver Yard Bypass and W 39th St.					
	King Street Station Track Improvements					
	Cascades Train Sets Overhaul					
	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.					
Project Group B: Option 3 437M; Option 4 334M	Increase Capacity of Existing Train Sets	Option 3: 2017 Option 4: 2015			437.1	334.2
	Kelso-Martin's Bluff Stage 1 New Siding					
	Kelso-Martin's Bluff Stage 2 Kelso-Longview Jct. 3rd Main Track					
	Cascades Two New Train Sets					
	Blaine to Vancouver, WA Main Line Track Upgrade					
	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.					
Project Group C: 341M for Option 4	Centralia New Crossover Near China Creek	Option 4: 2015				341.4
	Cascades Two New Train Sets Four Locomotives					
	Kelso-Martin's Bluff Stage 3 Kalama 3rd Main Track					
	Cascades Higher Speed Locomotives					
	Tacoma Reservation to Stewart New 3rd Main Track					
	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.					

A project group is a set of projects or project stages to be implemented collectively to achieve additional service.

Costs do not include anticipated expenditures prior to July 2009 in 2008 Transportation Supplemental Budget. These projects were currently funded as: Tacoma Bypass of Pt. Defiance 66th St. to Nisqually, 57.1 million; Vancouver Yard Bypass and W 39th St., 59.9 million; King Street Station Track Improvements, 13 million; Cascades Train Sets Overhaul, 4 million. The cost estimates listed in options are additional costs needed to complete these project starting July 2009.

Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.

Source: WSDOT State Rail and Marine Office

Operating Costs, Revenue, and Investment in Operations by Option

Operating Costs

Operating costs include the costs to operate Amtrak *Cascades* intercity passenger train services and costs to maintain service equipment. Since

each option in the mid-range plan operates at a different level, the operating costs vary. However, Options 3 and 4 operate more efficiently due to economies of scale.

Revenue

Revenue includes ticket revenues and revenues from services provided on the trains such as food and beverage revenues.

Investment in Operations

Investment in operations is the state's net investment of public funds to maintain the operation. It is the total operation costs minus revenues from operation. It is a public investment that aims for gaining greater economic and societal benefits.

Exhibit 6-2 shows the sum of operating costs, revenue, and investments in operations for all plan options from FY2010 to FY2017.

Exhibit 6-2: Total Operating Costs, Revenue, and Net State Costs for Amtrak *Cascades* Operations FY2010 - FY2017 (Millions)

Plan Options	Operating Costs	Revenue	Net State Costs for Amtrak *Cascades* Operation
Option 1: Maintaining Current Operation	235.7	118.4	117.3
Option 2: Incremental Strategy 1 - Minimum Capital Investment	360.2	144.4	215.8
Option 3: Incremental Strategy 2 - Supply Meets Demand	366.7	153.0	213.8
Option 4: No Financial Constraints	428.2	157.2	270.9

Include operating costs, Talgo maintenance costs, maintenance costs enhancing reliability, and Amtrak administrative costs. Estimated based on historical data, Amtrak FFY2009 Cost Estimates, and planned activities.

Include revenues from tickets and passenger services. Estimated based on historical revenue data assuming price neutral policy. Total revenue is the product of total forecasted passenger miles and revenue earned per passenger mile, adjusted for inflati

This is the estimated costs Washington State pays for contracted Amtrak Cascades operation.

The sixth round trip starts in FY2017, the total operation cost here for option 3 does not show full effect of the operation at the capacity built.

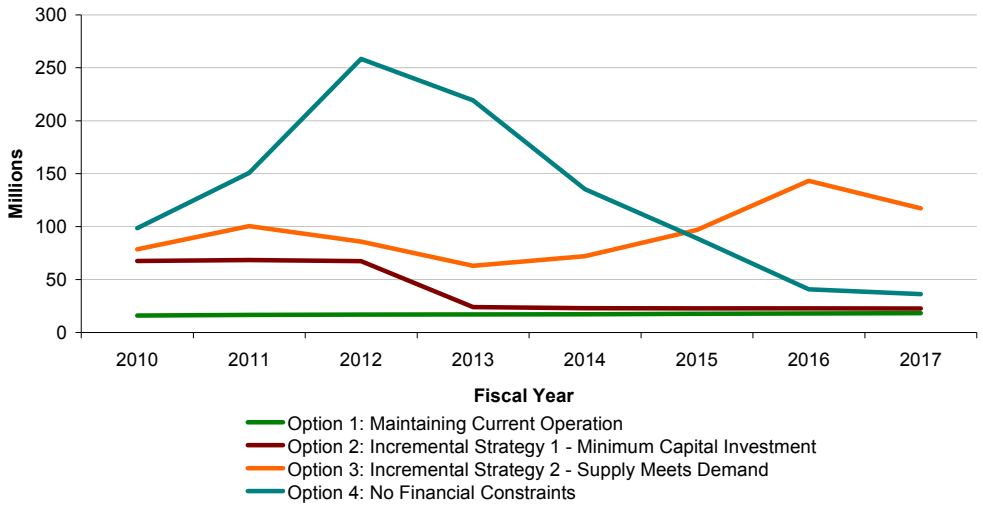
Source: WSDOT State Rail and Marine Office

Total Public Investment by Option

Total public investment includes both capital investments and operational costs. It reflects public costs for a specific option of Amtrak *Cascades* intercity passenger train service.

Exhibit 6-3 shows the total investment (sum of capital projects and operations) over time for the four options. The chart only reflects capital investments during the mid-range planning period of FY2010 to FY2017.

Exhibit 6-3: Dynamics of Total Public Investment
Passenger Rail Investment by Option: FY2010 to FY2017



Source: WSDOT State Rail and Marine Office

Operation Investments

Annual operation investments for FY2010 to FY2017 are present in all incremental strategy options, from around $14 million to $48 million, per year depending on capacity development level of each option.

Capital Investments

The timing of capital investments depend on each option's construction schedule. Depending on the option, estimated project completion dates are 2011, 2013, 2015, and 2017.

Option 1 has no investment in capital projects, since this option only invests in operations. Its line in Exhibit 6-3 is relatively flat.

Option 2 would invest and build capacity of five daily round-trip trains between Seattle and Portland at $141 million as soon as possible to complete ongoing projects that increase reliability/on-time performance

and capacity. The investment improves reliability (on-time performance) from approximately 60 percent currently to above 90 percent.

Option 3 would invest in capital project investments and train sets gradually, based on the market demand. For a total capital of roughly $578 million, this option gradually increases equipment and capacity to 14 cars per train in 2011, five daily round trips between Seattle and Portland in 2013, and six daily round trips between Seattle and Portland to meet demand in 2017. The investment improves reliability (on-time performance) from roughly 60 percent currently to above 90 percent.

Option 4 would invest in even more capital projects to build capacity to eight daily round trips between Seattle and Portland in the shortest time based on engineering feasibility. A total capital of roughly $816 million would be invested by 2015. The reliability would be improved to above 90 percent.

In the "supply meets demand" financially constrained strategy of Option 3, the capital investment is over a longer period of time than the "no financial constraints" strategy of Option 4. This is because Option 3 is designed to meet the growth of demand for a policy neutral scenario, while Option 4 is designed for policies that stimulate demand of train services.

Exhibit 6-4 lays out the annualized investment details for all four options. It shows the distribution of investments between capital projects and operation. The operation investments are the total operating costs minus revenues. It is the public costs for Amtrak *Cascades* services.

Exhibit 6-4: Passenger Rail Investment by Year and Option
FY2010 to FY2017 (□ Million)

Year	Option 1: Maintaining Current Operation			Option 2: Incremental Strategy 1 - Minimum Capital Investment			Option 3: Incremental Strategy 2 - Supply Meets Demand			Option 4: No Financial Constraints		
	Net State Costs for Amtrak *Cascades* Operation□	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment
2010	□13.6	□0.0	**□13.6**	□14.7	□48.4	**□63.1**	□14.7	□72.2	**□86.9**	□14.7	□92.6	**□107.3**
2011	□13.6	□0.0	**□13.6**	□15.3	□48.4	**□63.7**	□15.3	□107.1	**□122.5**	□15.3	□157.9	**□173.2**
2012	□14.2	□0.0	**□14.2**	□17.4	□44.4	**□61.8**	□16.2	□77.0	**□93.2**	□17.4	□249.2	**□266.6**
2013	□14.5	□0.0	**□14.5**	□34.0	□0.0	**□34.0**	□32.7	□39.0	**□71.6**	□40.6	□196.8	**□237.5**
2014	□14.9	□0.0	**□14.9**	□33.8	□0.0	**□33.8**	□32.4	□26.6	**□59.0**	□38.4	□85.2	**□123.5**
2015	□15.2	□0.0	**□15.2**	□33.6	□0.0	**□33.6**	□32.1	□47.4	**□79.5**	□49.0	□35.0	**□84.0**
2016	□15.5	□0.0	**□15.5**	□33.6	□0.0	**□33.6**	□32.0	□116.1	**□148.2**	□47.7	□0.0	**□47.7**
2017	□15.8	□0.0	**□15.8**	□33.5	□0.0	**□33.5**	□38.3	□92.8	**□131.1**	□47.9	□0.0	**□47.9**
Total Cost	**□117.3**	**□0.0**	**□117.3**	**□215.8**	**□141.2**	**□357.0**	**□213.8**	**□578.1**	**□791.9**	**□270.9**	**□816.7**	**□1,087.6**

□This is the estimated costs Washington State pays for contracted Amtrak *Cascades* operation.

Source: WSDOT State Rail and Marine Office

Growth of Ridership and Capacity by Option

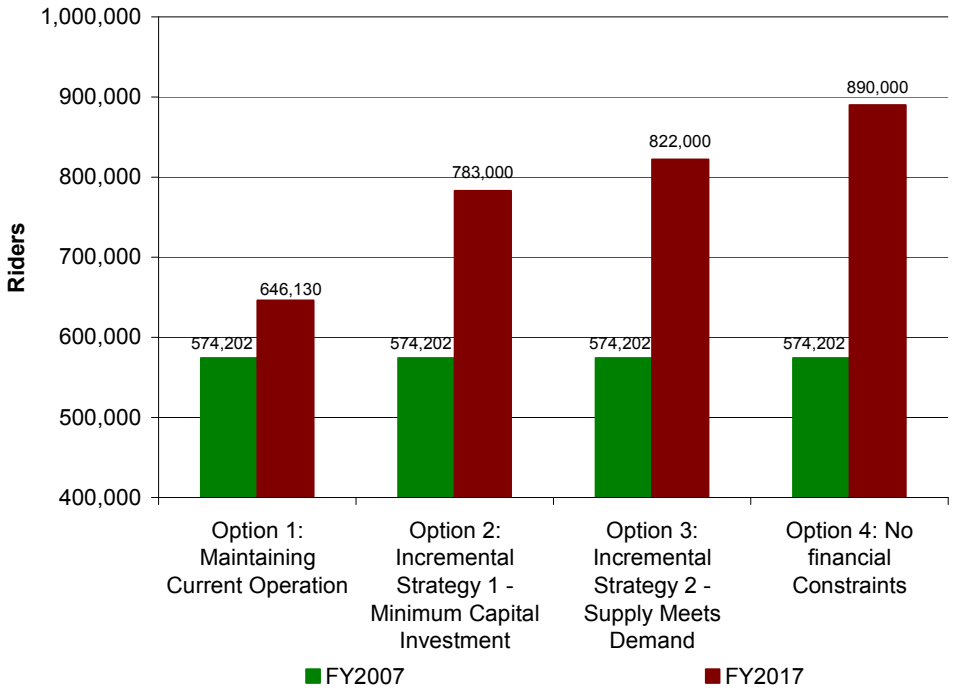
Ridership Growth - Demand

The ridership growth for plan options is estimated through two processes. First, the ridership forecast model is developed to forecast long term growth of ridership based on factors such as population, gas prices, and service availability (Chapter 3 and Appendix 4).

Second, based on improvement on on-time performance and scheduled time savings resulting from implementation of plan options, additional ridership growth is estimated using demand elasticity of time reduction published for Amtrak passenger trains.

The total ridership growth for options is demonstrated in Exhibit 6-5.

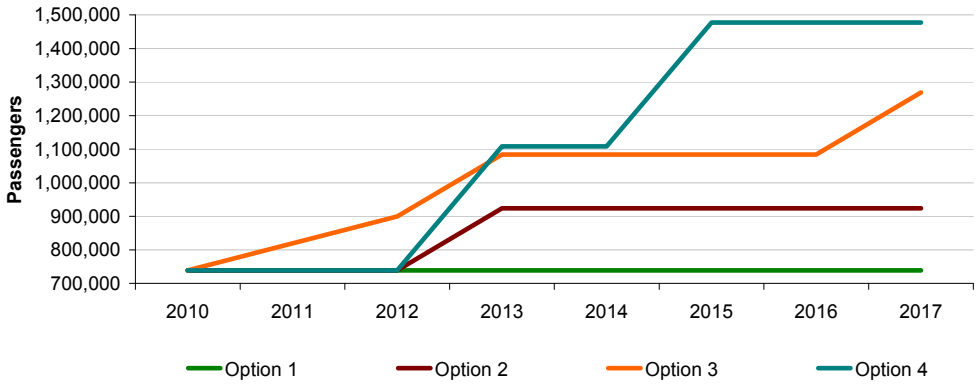
Exhibit 6-5: Annual Ridership Growth by Option
FY2007 vs. FY2017
Vancouver, B.C. to Portland



Capacity Growth – Supply

The capacity growth for plan options is based on capital projects that build capacity for each plan option. The capacity increase and reliability improvement of capital projects are presented in Chapter 4. Exhibit 6-6 provides a dynamic view of capacity changes by option over the time frame of the mid-range plan.

Exhibit 6-6: Maximum Annual Seating Capacity by Option
Seattle to Portland FY2010 to FY2017



Demand and Supply Analysis

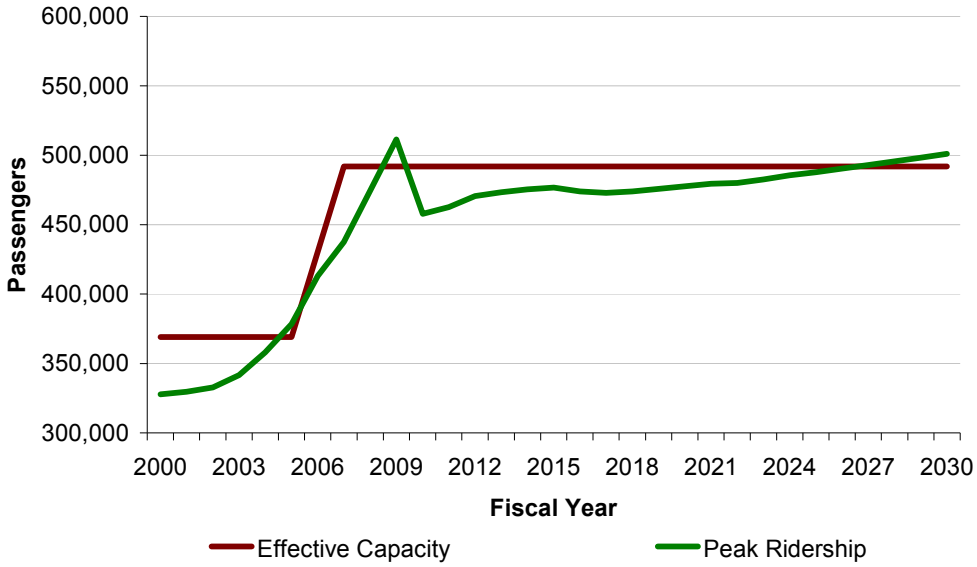
The demand of Amtrak *Cascades* intercity passenger rail service, like utilities such as electricity, is seasonal. While electricity production usually has scalability that allows the electric company to adjust production for peaks and valleys, passenger rail has little flexibility to adjust due to the fixed schedule. The big gap between peak and valley demands makes capacity use and development much more challenging. If WSDOT builds sufficient supply to meet the peak demand, the average capacity use will be low due to the valley in demand. If WSDOT limits the capacity growth, peak demand will not be met. Therefore, there is a trade-off between economic efficiency and policy to meet the societal demand. This is a policy issue similar to policies to regulate and subsidize electrical industries, where economic efficiency does not guarantee sufficient supply. However, the efficiency can be improved through attracting riders in non-peak time through both service improvement and marketing.

Appendix 7 discussed effective or peak capacity and peak ridership—supply and demand indicators. The supply and demand analysis, which is based on peak demand and effective capacity defined, provides information on how growth of the Amtrak *Cascades* service is related to ridership growth.

The following charts demonstrate the relationship between supply and demand for the four policy options of Amtrak *Cascades* investment.

Option 1 – Maintain Current Operations Strategy: Ridership would exceed the capacity in FY2008, and could exceed the capacity for the future by any factor that cause ridership jumps since there is little room to meet the additional growth of ridership (Exhibit 6-7).

Exhibit 6-7: Peak Ridership vs. Effective Capacity (Seattle–Portland): Option 1 - Maintain Current Operation

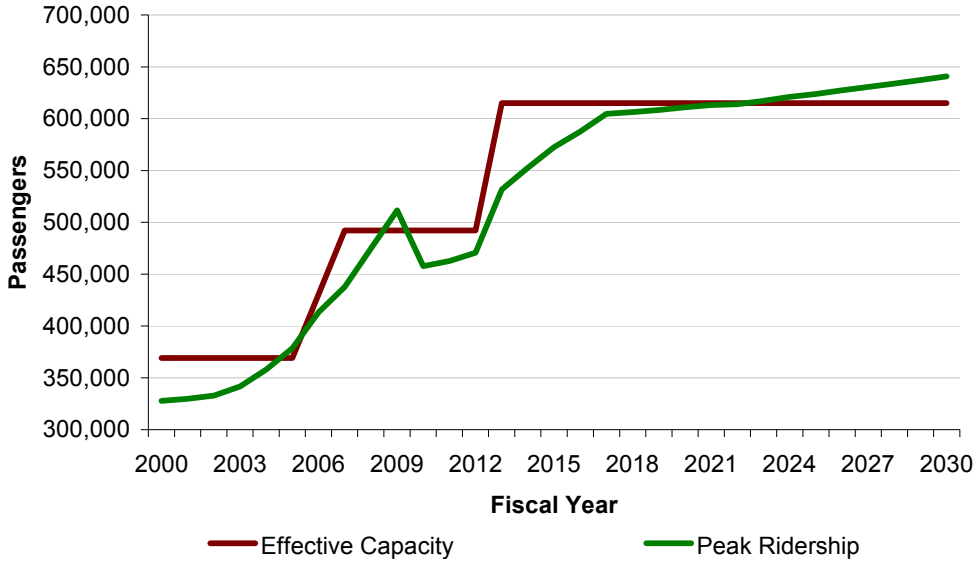


Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 2 – Minimum Capital Investments: Peak ridership would exceed seating capacity in FY2008 and could exceed the capacity for the future by any factor that causes ridership jumps until FY2013, when the minimum capital investments would increase service levels to five daily round-trip trains between Seattle and Portland. The improved reliability and increased capacity resulting from completion of capital investments and operational improvements would continue to drive up ridership. The demand indicated by ridership would exceed supply in about ten years (Exhibit 6-8).

Exhibit 6-8: Peak Ridership vs. Effective Capacity (Seattle–Portland): Option 2 - Minimum Capital Investment



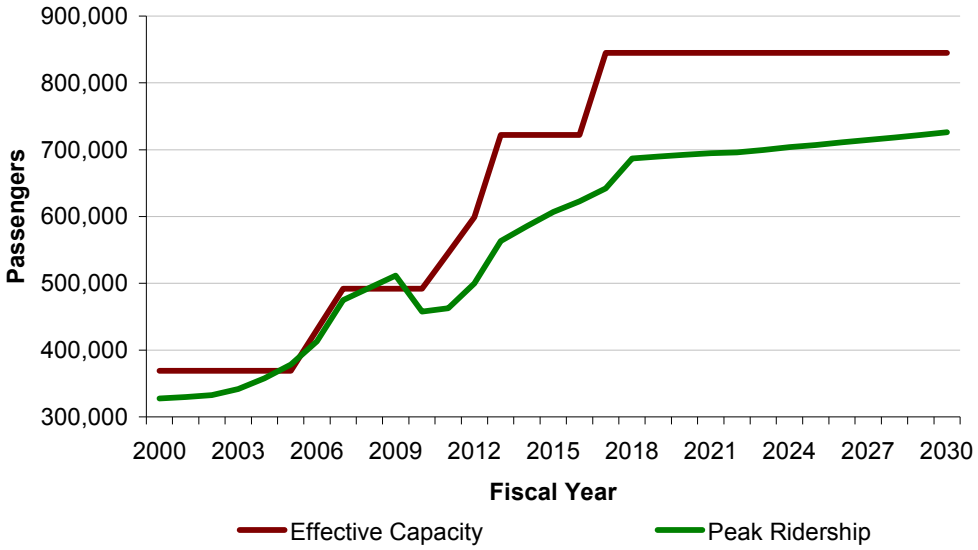
Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 3 – Supply Meets Demand: Peak ridership would exceed capacity in FY2008. Capacity would stay above ridership in FY2009 and could exceed capacity at any time. The investment in a new train set would add two additional cars to each train set and the longer trains would increase service levels for additional riders in FY2011.

The capital investment would deliver a fifth daily round-trip train between Seattle and Portland in FY2013. Ridership would continue to increase due to reliability improvements and other factors. The capital investments would deliver a sixth daily round-trip train between Seattle and Portland in FY2017, to ensure that sufficient seating capacity is available to meet the ridership growth. Since higher frequency and reliability improvements could trigger the demand for business riders, the ample capacity could be filled by such a demand. Since the increase in such a demand was not estimated by the ridership model due to lack of data, ridership indicated by the demand curve may be understated (Exhibit 6-9).

Exhibit 6-9: Peak Ridership vs. Effective Capacity (Seattle–Portland): Option 3 - Supply Meets Demand

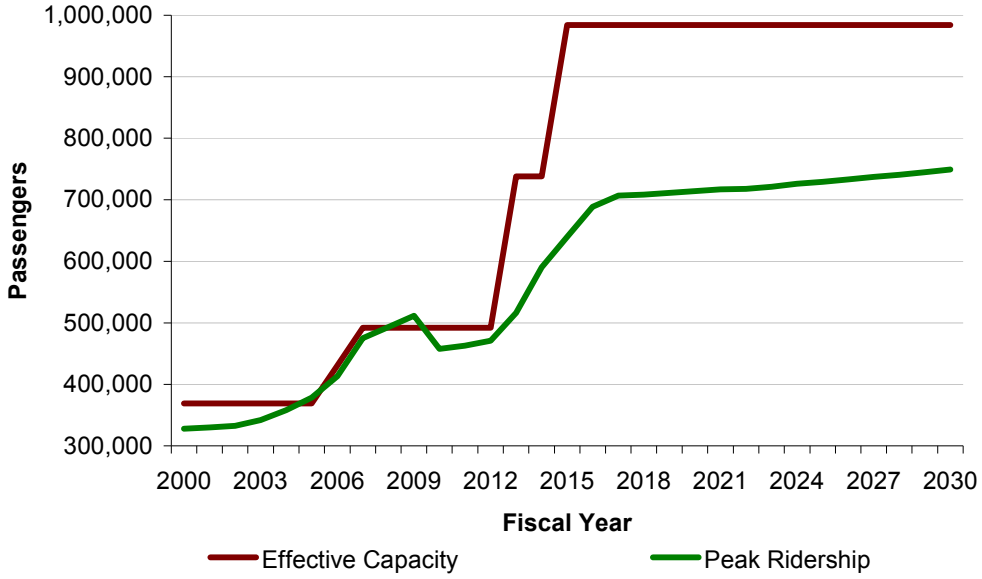


Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 4 – No Financial Constraints: Peak ridership would exceed the capacity in FY2008. Capacity would stay above the capacity in FY2009. In this option, rail service would be used as a strategic solution to address multiple issues related to transportation. Ample capacity would be built for policies that encourage the use of passenger rail services. Investments in capital projects are only subject to engineering feasibility during this period. The invested capital projects would deliver two additional daily round-trip trains between Seattle and Portland in FY2013, and another two daily round-trip trains in FY2015, for a total of eight daily round trips between Seattle and Portland. The improved reliability, the higher capacity, and frequency would attract additional riders to Amtrak *Cascades* service. This option also opens other incentive policies, such as a modified fare structure, that could increase rail ridership substantially. The ample capacity could be used for any promotional policies that view passenger rail as part of a solution to address multiple issues (Exhibit 6-10).

Exhibit 6-10: Peak Ridership vs. Effective Capacity (Seattle–Portland): Option 4 - No Financial Constraint



Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Economic Impacts

When public funds are used to invest in Amtrak *Cascades* intercity passenger train services, the investment generates economic impacts that affect the state's economy, employment, people's income, business' profits, and taxes to governments. These economic impacts would benefit the state and local communities in general. The magnitudes of economic impacts are dependent on the size of investment and how the funds are invested.

WSDOT used the Washington State input-output economic model, developed using IMPLAN[2], to estimate the ripple effects of the increases in Amtrak *Cascades* services. The IMPLAN model was used to estimate the total economic impacts of mid-range plan options, including the cascading effects of the investments of each option (direct, indirect, and

[2] IMPLAN is a commercial input-output model developed using input-output data from Bureau of Economic Analysis, U.S. Department of Commerce. The model used to estimate economic impacts in this plan is a Washington State specific model.

induced impacts). The economic impacts are assessed in terms of the following two indicators:

- **Employment** represents the jobs created by the investment. Amtrak *Cascades* service directly creates jobs in construction, maintenance, food service, and transportation operations. It also creates jobs indirectly by the affect of the outputs of other industries and government incomes.

- **Value added** is an indicator that reflects the net benefit of the investment. Both labor income (wages and salaries) and business incomes are counted as value added.

Exhibit 6-11 demonstrates economic impacts of the four plan options.

Exhibit 6-11: Economic Impacts of *Amtrak Cascades Mid-Range Plan* Options: Sum of FY2010 to FY2030

Impact	Area	Option 1: Maintaining Current Operation	Option 2: Incremental Strategy 1 - Minimum Capital Investment	Option 3: Incremental Strategy 2 - Supply Meets Demand	Option 4: No Financial Constraints
Support Employment (Job-Year)	Benefits to Local Communities Along I-5 Corridor	4,887	11,725	17,454	23,752
	Statewide Benefits (Include benefits to local communities)	6,202	15,024	22,825	31,138
Value Added (Million, 2008 Dollars)	Benefits to Local Communities Along I-5 Corridor	306.5	746.8	1,139.9	1,555.1
	Statewide Benefits (Include benefits to local communities)	399.7	977.6	1,500.6	2,048.1

Note: Economic impacts are assessed using IMPLAN Input-Output model for Washington State and its local areas.

The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017.

A job-year means that a person is employed as a full time employee for a year.

Difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the gross domestic product (GDP).

Source: WSDOT State Rail and Marine Office

Chapter 7: Benefit Cost Analysis

Studies show that passenger rail has many benefits. With its fuel efficiency, safety records, and lower environmental impacts, passenger rail has resurfaced as an attractive candidate that can be included in policy options aimed at solving economic, social, and environmental problems with integrated solutions.

The common public benefits associated with passenger rail include stimulating the state's economy, supporting local communities and businesses with jobs and revenues, reducing congestion, improving public safety, offering a transportation choice, reducing environmental pollution, and saving energy.

This chapter will assess benefits and costs associated with the four plan options that provide various Amtrak *Cascades* service levels. The impacts of these options on the state budget, the state's economy, local communities, highway congestion, public safety, and the environment will be evaluated to determine the likely effects of these policy options. This chapter includes three sections:

- Understanding Public Investment and Benefit
- Benefits and Costs Assessment
- Transportation Cost Analysis

Understanding Public Investment and Benefit

Investment analysis in the public sector is very different from private sector analysis. There are several principles that must be understood in analyzing public investment and public benefits.

Discounting

Discounting addresses the problem of translating values from one time period to another. The larger the discount rate, the more weight that is placed on benefits and costs in the near-term over benefits and costs in the future. Unlike the private sector, long-term benefits, such as environmental quality, are important public policymaking criteria. Consequently, public investment analysis usually uses a relatively lower discount rate than the private sector.

Leveraging

Public projects usually involve multiple sources of investment and partnership. While the analysis of such an investment assesses the efficiency of total investment, public investment analysis also assesses the effectiveness of public investment only. In other words, a measure of the effectiveness of public investment is how much additional investment a public investment can bring into a specific project. This measure is called leveraging.

Distributional Benefits

Many public investment projects provide distributional benefits to the public by transferring public resources to where they are needed most. Such a transfer payment is not a traditionally defined benefit. It could be measured as a public benefit, if it helps reach the goal of public policy to benefit the targeted public group.

With/Without Principle

Many public investment projects provide benefits to the public by mitigating negative impacts. While such investment does not create positive value, it reduces the negative value. The difference between the larger negative value and the smaller negative value is defined as a benefit based on the with/without principle. For example, with an investment in Amtrak *Cascades* capacity, more people would ride trains instead of driving cars. This results in less emissions, due to the fact that rail has a lower emission level per passenger mile compared to auto. The difference of the higher emission (auto) and lower emission (rail) will be defined as a benefit of the investment in Amtrak *Cascades*. Without such an investment project, societal loss due to higher emissions would be much larger. The reduced societal loss would be the benefit of the investment project. Also, as more people choose to ride the train, the emission per passenger would decrease.

Public Benefits and Public Costs

Based on the above discussion about the characteristics of public investment analysis, the benefit/cost analyses performed and presented in this chapter will be based on an assessment of public benefits and public costs.

Period of Analysis

Although the capital investment projects for this plan are implemented from FY2010 to FY2017, the benefits of the plan options are assessed for a longer period: FY2010 to FY2030. The reason for using a longer period for benefit/cost analysis is to demonstrate the benefits of capital projects.

Although projects will be completed in the mid-range plan period, their benefits last for many years.

Benefits and Costs Assessment

This section is a summary of the benefit/cost analyses for the plan options. Appendix 8 will provide the detailed analysis and methodology.

Public Benefit Assessment

Public benefits of statewide rail investment are those benefits directly or indirectly received by the public due to the specified investment. There are three categories of benefits from public investment:

- **Taxes** are generated from investment. These taxes are direct incomes from the public investment and can be spent and reinvested for public benefit.

- **Economic impacts** resulting from the investment, such as the employment and personal incomes, are generated from the investment projects.

- **External impacts**, such as greenhouse gas emissions and accidents, are reduced.

There are multiple benefits associated with passenger rail from all three types of public benefits described above. The magnitude of benefits received by the people of Washington State depends on how passenger rail will be integrated into the policies that embrace integrated solutions for interconnected problems. In general passenger rail has been identified by many studies to have the following benefits:

- ***Tourism Market:*** Passenger rail is one of the major ways for tourists to access Washington State's bountiful cultural and amenity resources, natural beauties, and historical heritages.

- ***Supports Local Communities:*** Passenger rail construction projects bring jobs and revenue to local communities and businesses.

- ***Generate Government Incomes for Public Programs:*** While rail, like highways, is a publicly funded infrastructure improvement and operation, it supports growth of many businesses in various industries that pay business taxes to governments.

- ***Congestion Relief:*** Passenger rail helps solve congestion problems. As the economy and population continue to grow, the

congestion problems on the I-5 corridor will increase. The potential of passenger rail as part of the solution for congestion is promising.

- ***Public Safety:*** Passenger rail transportation has a strong safety record with a national accident fatality rate of 0.08 per 100 million passenger miles, about 1/10 that of motor vehicles. Replacing motor vehicle drivers with passenger rail riders will help improve public safety.

- ***Energy Benefit:*** Passenger rail is much more efficient than airplanes and motor vehicles. Increasing passenger rail services will reduce the growth of other energy inefficient modes and help tackle the energy dependence problems.

- ***Pollution Reduction:*** The level of released toxic substances and greenhouse gas emissions for passenger rail is lower than auto. Replacing motor vehicle users with rail riders will help reduce environmental pollution.

- ***Transportation Choice:*** Passenger rail provides the public another transportation option, especially for the mobility-impaired and the non-driving public.

Public benefits of the mid-range plan options are measured in terms of the following indicators:

Economic Benefits

- ***Revenue:*** Revenue from Amtrak *Cascades* operations, in this analysis, is not counted as an economic benefit. It actually offsets the state's investment in Amtrak *Cascades* infrastructure improvement, operation, and maintenance. In other words, public investments (costs) would be larger without Amtrak *Cascades* service revenue.

- ***Value Added:*** Value added includes personal income from employment, profits for businesses, and taxes paid to governments. Amtrak *Cascades* train services support industries such as tourism, transportation, construction, and maintenance. The value added to the economy resulting from direct and secondary impacts of Amtrak *Cascades* services is measured as economic benefits using IMPLAN—an Input-Output model that measures economic impacts. Other indicators of economic impacts of the plan options, such as economic output, jobs created, and taxes, were presented in Chapter 6 and not used as a measure of net benefits.

Societal Benefits

Societal benefits measured in these plan options include congestion benefits, safety benefits, and environmental benefits. The methodology used to assess these benefits is described in Appendix 7.

- ***Congestion Relief:*** Congestion on the I-5 corridor continues to increase. By diverting traffic away from the I-5 corridor, incremental services of Amtrak *Cascades* can help relieve the congestion of I-5. Amtrak *Cascades* currently accounts for less than one percent of traffic volume along the I-5 corridor. However, as Exhibit 7-1 demonstrates, a small fraction of I-5 traffic reduction could lead to tremendous improvement in reducing delay hours that are costs to travelers. In addition, the potential return on investment is very promising, if rail is considered a strategic alternative for transportation resilience to natural and man-made disasters.

Exhibit 7-1: Benefit of Reducing Congestion

I-5 Interstate Highway Average Daily Traffic Reduction and Hours of Delay				
	Traffic Reduction □			
	0□	-5□	-10□	-20□
Hours of Delay	302,000	90,000	64,000	30,000
Reduced Hours of Delay Due to Traffic Reduction	-	212,000	238,000	272,000
□ **Delay Reduction from Today**	0	-70□	-79□	-90□

Source: WSDOT Urban Planning Office

- ***Safety Improvement:*** The societal costs of motor vehicle collisions on Washington State highways were estimated at $2.5 billion in 2007. Passenger rail transportation has a strong safety record. The national fatality rate is only one tenth of that of highway travel (Exhibit 7-2).

Exhibit 7-2: Comparison of Passenger Safety

Fatality and Injury: Highway vs. Rail			
	Fatality Per Million Passenger Mile	**Injury Per Million Passenger Mile**	**Sum**
Rail	0.0005	0.0590	0.06
Highway	0.0119	0.7689	0.78
Rail to Highway Ratio	0.0387	0.0768	0.08

Source: USDOT Bureau of Transportation Statistics

It is clearly evident that passenger rail travel benefits public safety and is in the public interest. Work remains to further improve rail safety, including rail crossings and trespassing. If more passengers use rail instead of auto, the societal cost of motor vehicle collisions for roadways will be reduced. Since passenger rail has lower fatality and injury rates, passenger safety improves. Reduced societal costs will be assessed as public benefits of using passenger rail.

- ***Health Benefit of Environmental Pollution Reduction:*** Passenger rail has lower emission rates for many greenhouse gases and toxic substances. Exhibit 7-3 provides a comparison of emission rates for three modes.

Exhibit 7-3: Emission Rates Grams per Passenger Mile

	Automobile	**Airplane**	**Rail**
Carbon Dioxide (CO_2)	430	273	172
Volatile Organic Compounds (VOC)	2.68	0.15	0.16
Carbon Monoxide (CO)	16.40	0.46	0.60
Nitrogen Oxides (NO_X)	0.90	0.21	0.90
Particulate Matter (PM)	0.01	Not Applicable	0.08
Road Dust	0.88	Not Applicable	Not Applicable
Sulfur Oxides (SO_X)	0.03	Not Available	0.05

Source: Compiled by WSDOT State Rail and Marine Office based on multiple sources.

If more travelers use passenger rail instead of motor vehicles, the total emission rates of pollutants would be much lower. The social

costs caused by pollution would be reduced. Such reduction in social costs will be measured as environmental benefits of using passenger rail. The environmental benefits assessed in this plan are mostly health impacts caused by pollutants.

The environmental impacts of global warming, resulting from greenhouse gases, could cost society billions of dollars. Such societal costs have not been well studied and documented. WSDOT was not able to assess them in this chapter. Therefore, the environmental benefits assessed by this chapter might understate the real benefits, which could be substantially higher.

Total Public Benefits

Total public benefits include both economic benefits and societal benefits. Many public benefits are intangible; they are therefore not included in the assessment.

Exhibit 7-4 provides an overview of public benefits for the four plan options. Detailed benefit assessment is provided in Appendix 8. In general, the magnitude of benefits is correlated to investment size. However, the efficiency criteria presented later in this chapter will provide information on which options are more efficient.

Exhibit 7-4: Estimated Public Benefits by Investment Option (2008 Dollars, □ Million)

Plan Option	Economic Benefit	Societal Benefits			Sum
	Value Added	Congestion Relief Benefit	Safety Benefit	Environmental Benefit	
Option 1: Maintaining Current Operation	□399.7	□0.0	□67.2	□158.0	**□625**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	□977.6	□598.3	□81.1	□196.3	**□1,853**
Option 3: Incremental Strategy 2 - Supply Meets Demand	□1,500.6	□939.9	□87.7	□215.4	**□2,744**
Option 4: No Financial Constraints	□2,048.1	□1,041.0	□89.6	□221.0	**□3,400**
Note: Option 1 is the baseline.					
□The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.					

Source: Benefits estimated by WSDOT State Rail and Marine Office based on multiple data sources. See Appendix 8 for details.

Public Cost Assessment

Based on the above discussion about the characteristics of public investment analysis, WSDOT assessed public costs of the mid-range plan options by two categories: cost of capital projects and cost of operation and maintenance.

Cost of Capital Projects

Cost of capital projects includes costs for projects to increase capacity and improve reliability, and equipment investment for locomotives and cars. WSDOT estimated the capital costs based on cost estimates provided by external consultants in the long-range plan and the recent study on historical costs of rail projects. Costs of capital projects planned for implementation between FY2010 and FY2017 are listed in Chapter 4. An annual summary of capital cost estimates for each plan option is presented in Chapter 6, Exhibit 6-1.

Costs of Operation and Maintenance

Costs of operation and maintenance include both operating costs for Amtrak *Cascades* passenger train services and maintenance costs of train equipment owned by the state of Washington. Chapter 5 discussed the estimation process and economies of scale for operating costs and maintenance costs among plan options, from FY2010 to FY2030.

Public Costs for Amtrak Cascades Program

Total public costs the for Amtrak *Cascades* program include all costs for capital projects and state support for operation and maintenance of Amtrak *Cascades* services. State support is the total program costs minus operational revenue received from tickets, food, and other services. Revenue is estimated based on a revenue neutral policy, which means that revenue estimates reflect no change in price except adjustments for inflation and change in operation costs.

While WSDOT estimates revenue based on revenue neutral policy (no price increase), it is noted that increased ridership, higher capacity and frequency, and improved reliability provide an opportunity to raise prices and increase revenues for the program. Therefore, the revenues estimated for this plan options are conservative (see Exhibit 7-5).

Exhibit 7-5: Estimated Public Costs for Amtrak *Cascades* Passenger Rail Sum of FY2010 to FY2030 (2008 Dollars, □ Million)

Options	Service Level	Costs of Subsidize Operation and Maintenance	Capital Investment	Administrative and Marketing Costs	Total Cost
Option 1: Maintaining Current Operation	Four round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	□280	□0	□29	□310
Option 2: Incremental Strategy 1 - Minimum Capital Investment	Five round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	□563	□133	□37	□733
Option 3: Incremental Strategy 2 - Supply Meets Demand	Six round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	□573	□516	□40	□1,129
Option 4: No Financial Constraints	Eight round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	□746	□749	□41	□1,536
Note: Option 1 is the baseline.					
□□Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both costs are discounted to present value (2008 dollars).					

Source: WSDOT State Rail and Marine Office

Benefit/Cost Ratio and Net Benefit

As noted in an earlier section, a benefit/cost ratio is used to measure economic efficiency for each option, as investment size usually dictates the magnitude of benefits. A net benefit measure is used to measure the size of the benefits with no linkage to how much is invested.

Exhibit 7-6 demonstrates the total benefit/cost ratio for public investment options outlined in the mid-range plan. All options involve capital project investments to achieve higher benefit/cost ratios. This is because the capital projects increase capacity and improve reliability to meet the increased demand of ridership growth. Such gain in capacity and improvement in reliability allow much higher service levels to serve more riders, while improving program efficiency by economies of scale.

Exhibit 7-6: Estimated Benefit□Cost Ratio by Investment Option

Plan Option	Sum of FY2010 to FY2030 - □Million (2008 Dollars)			
	Total Cost (□Million)	Total Benefit (□Million)	Net Benefit (□Million)	B□C Ratio
Option 1: Maintaining Current Operation	□310	□625	□315	**2.02**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	□733	□1,853	□1,120	**2.53**
Option 3: Incremental Strategy 2 - Supply Meets Demand	□1,129	□2,744	□1,615	**2.43**
Option 4: No Financial Constraints	□1,536	□3,400	□1,864	**2.21**
Note: Option 1 is the baseline.				
□The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.				
□□Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).				

Source: WSDOT State Rail and Marine Office

Exhibit 7-7 shows the incremental benefit/cost ratios for Options 2, 3, and 4. Option 1 is used as a baseline for the analysis. The results indicate incremental investments generate higher benefit/cost ratios. This indicates that additional public investments will improve current efficiency of the Amtrak *Cascades* program.

Exhibit 7-7: Incremental Benefit□Cost Ratio by Investment Options

Plan Option	Sum of FY2010 to FY2030 - □ Million (2008 Dollars)		
	Incremental Investment□□	Incremental Benefit	Incremental Investment B□C Ratio
Option 1: Maintaining Current Operation	**Baseline**	**Baseline**	**Baseline**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	□423	□1,228	2.90
Option 3: Incremental Strategy 2 - Supply Meets Demand	□819	□2,119	2.59
Option 4: No Financial Constraints	□1,226	□2,775	2.26
Note: Option 1 is the baseline.			
□The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.			
□□Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).			

Source: WSDOT State Rail and Marine Office

Transportation Cost Analysis

For an individual to travel from one place to another, different types of costs are incurred based on their mode of travel. This section discusses the cost composition of three modes (rail, highway, and air), the methods to assess these costs, and comparison of the full costs to travel for these modes. Detailed information and methods about environmental costs will be described in Appendix 9.

Costs of Passenger Rail Travel

User Costs

User costs for passenger rail modes are the price of the tickets to ride the train. These costs are calculated based on historical data from operation of the Amtrak *Cascades* program.

System Utilization Costs

There are two types of system utilization costs. The first type is the public capital investments necessary to develop and maintain infrastructure improvements. These types of costs are estimated based on life-cycle

analysis methods. Life cycles used in this analysis are 25 years and 50 years depending on the types of capital projects. The second type of system utilization costs is the net costs the state pays to operate and maintain the systems that are not recovered from the service revenue. These costs are estimated using reported data from prior operation costs.

Safety Costs

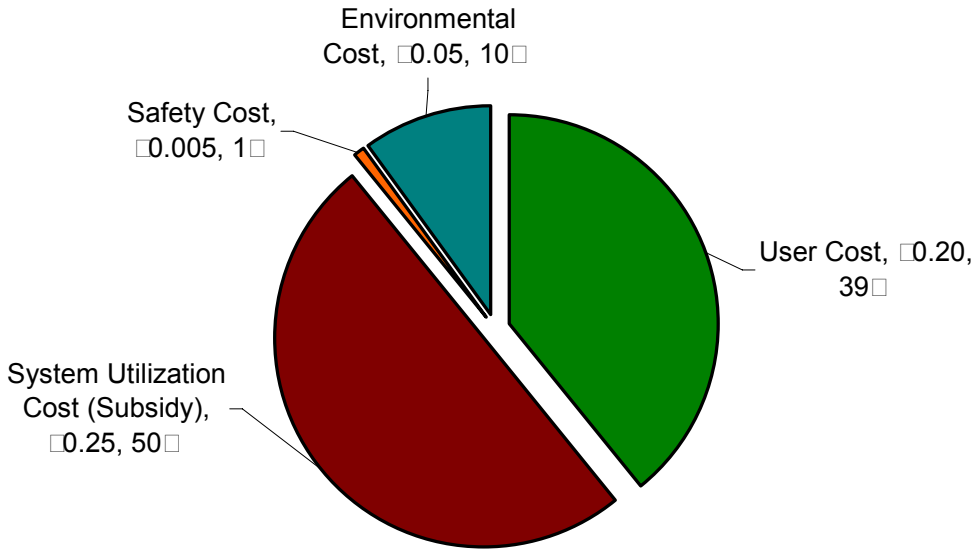
These are societal costs of collision-caused deaths and injuries. Rail has a much smaller probability to have accidents that cause passenger deaths and injuries. Data from the Bureau of Transportation Statistics are used to assess the probabilities of death and injury for both rail and highway travel. Then highway safety costs are used to estimate the safety costs for rail based on comparison of the probabilities.

Environmental Pollution Costs

Environmental costs are determined based on emission levels of locomotives and their costs to society. The data used for the assessment are published government data and research findings. These data sources include both rail and highway modes (Appendix 9).

Exhibit 7-8 describes the full rail transportation costs in 2008 dollars. The full cost per mile for rail transportation is $0.51.

Exhibit 7-8: Composition of Cost Per Passenger Mile □ Passenger Rail
Full Cost Per Mile: □0.51 (2008)



Source: WSDOT State Rail and Marine Office

Costs of Highway Travel

User Costs

User costs for the highway mode include car depreciation, insurance, fuel cost, and maintenance of the car. There are various ways to calculate highway user costs per mile. The costs published by the Internal Revenue Service are used and adjusted for Washington State. Taxes and fees that are assessed to fund highway system operations and improvements are excluded from the user costs to avoid double counting.

System Utilization Costs

System utilization costs are public costs to develop and maintain highway systems. Although travelers use the system essentially free of charge (tolling is an exception), highway system utilization costs are actually a part of user costs. This is because highway systems are mostly funded by special taxes and fees such as motor fuel taxes and vehicle license fees. These costs are assessed using historical data, WSDOT expenditures—excluding non-highway modes—and historical data on vehicle miles traveled.

Safety Costs

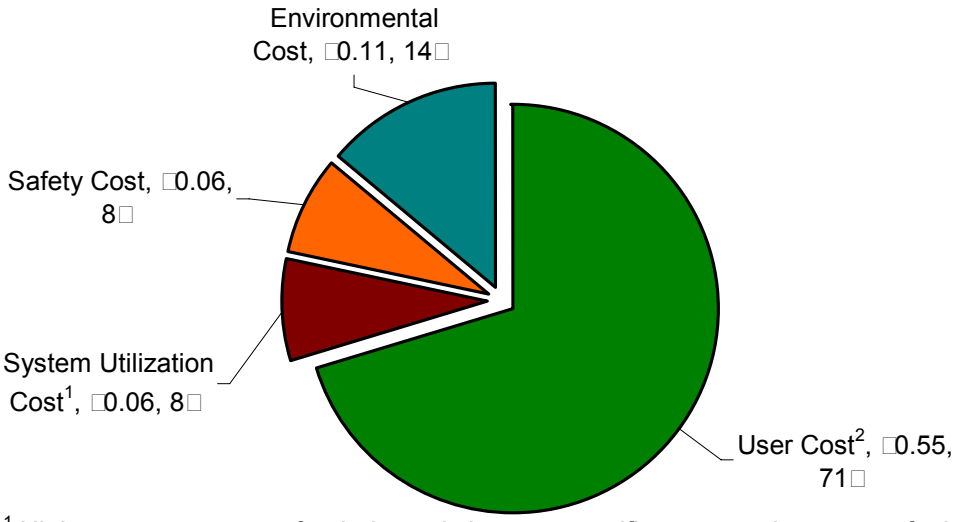
These are societal costs of collision-caused deaths and injuries. WSDOT Transportation Data Office estimates the annual cost to the state based on total deaths and injuries occurred. Safety costs per mile are developed using the annual cost and miles traveled on state highways.

Environmental Pollution Costs

Environmental pollution costs are assessed based on emission levels of motor vehicles and their costs to society. The data used for the assessment are published government data and research findings (Appendix 9).

Exhibit 7-9 describes the full highway transportation costs in 2008 dollars. The full cost per mile for highway transportation is $0.78.

Exhibit 7-9: Composition of Cost Per Passenger Mile – Highway
Full Cost Per Mile: $0.78 (2008)



[1] Highways systems are funded mostly by user specific taxes such as motor fuel taxes and vehicle license fees.
[2] Special user taxes and fees paid by users such as motor fuel tax and license fee are excluded.

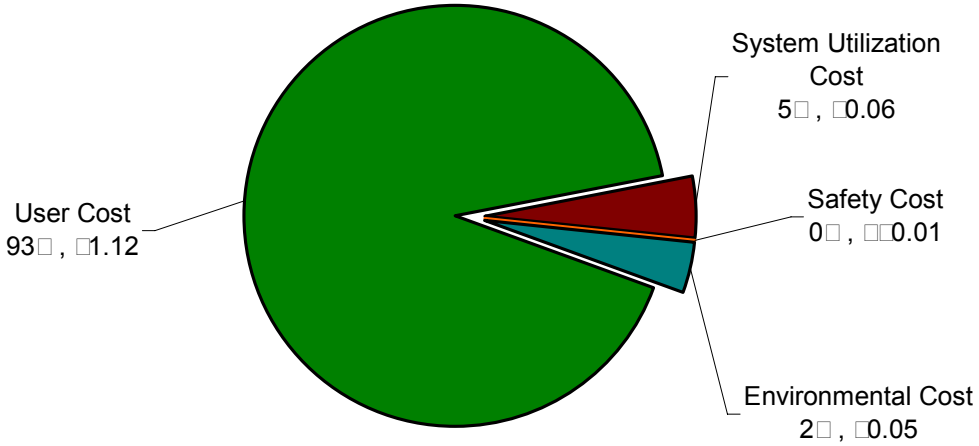
Source: WSDOT State Rail and Marine Office

Costs of Air Travel

The composition of costs of air travel and definitions are similar to rail travel. These data are adopted from Berk and Associates (2006).

Exhibit 7-10 describes full air transportation costs in 2008 dollars. The full cost per mile for air travel is $1.23.

Exhibit 7-10: Composition of Cost Per Passenger Mile – Air
Full Cost Per Mile: $1.23 (2008)



Source: WSDOT State Rail and Marine Office

Cross Modal Comparison

Exhibit 7-11 compares full costs of transportation for highway, rail, and air for 2008. Please note WSDOT used Option 3 as an example of rail system utilization costs because Option 3 has heavy capital and operation investments for increasing capacity and improving reliability.

Exhibit 7-11: Transportation Costs: Cross Modal Comparison

Esitmated Transportation Cost by Mode (¢ Passenger Mile)				
Year	**Cost Type**	**Rail**	**Highway Motor Vehicle**	**Air**
2008	User Costs	¢0.20	¢0.55	¢1.12
	System Utilization Costs	¢0.26	¢0.06	¢0.06
	Environmental Costs	¢0.05	¢0.11	¢0.05
	Safety Costs	¢0.00	¢0.06	¢0.00
	Other Costs	N/A	N/A	N/A
	Total Costs	**¢0.51**	**¢0.78**	**¢1.23**
User costs: Rail user costs are the ticket price based on historical operations data. Highway user costs are car depreciation, insurance, fuel, and car maintenance. Special user taxes and fees paid by users such as motor fuel tax and license fees are excluded from highway user costs to avoid double counting.				
System utilization costs: Rail systems are mostly funded by public investments (subsidies besides what is recovered from service revenue). Highway systems are mostly funded by specific user taxes, such as motor fuel taxes and vehicle license fees.				
Cost such as flexibility is not assessed because lack of data.				

Source: WSDOT State Rail and Marine Office

Chapter 8: Amtrak *Cascades* and Connectivity

Connectivity is an important aspect of the *Amtrak Cascades Mid-Range Plan*. Nobody starts their journey at the train station; travelers reach the station by another mode or, in some cases, a combination of modes. Therefore, if a mode does not exist or is unknown by a potential passenger, ridership would suffer. The more seamless the transfer, the more the likelihood that people will make use of it.

This chapter examines the importance of providing easy connections between modes of transportation, with special focus on the Amtrak *Cascades* passenger service.

This chapter has two main but complimentary areas of focus—station location and transportation mode. This chapter and exhibits describe what exists, what could exist, and shows these by each Amtrak station.

Other issues that can influence traveler choice were examined. They include communication of the alternatives, clarity of the message and pricing, and through-ticketing opportunities.

Connections with Other Modes

Public Transportation

Vancouver, B.C.

Translink, the regional transportation authority in the greater Vancouver, B.C. area, provides extensive transit services throughout the region. SkyTrain's 30.8 miles of track, making it the longest automated light rapid transit system in the world, operates on multiple routes with stations at key locations. The Main Street Skytrain Station is located adjacent to the Pacific Central Station served by Amtrak *Cascades*, providing an effective connection to and from the trains. Depending upon time of day, Skytrain locations are served every four to twelve minutes.

The Skytrain Waterfront Station, in the heart of downtown Vancouver, provides access to cruise terminals, and links with West Coast Express commuter trains and the Vancouver SeaBus. In 2009 the station will link with the new Canada Line, connecting downtown Vancouver with the Vancouver International Airport.

Translink also provides extensive bus service throughout the region with routes that stop at Pacific Central Station. Greyhound Canada Thruway connections also depart from Pacific Central Station.

Translink has implemented an extensive "trip planner" to assist individuals in determining schedules and the most effective methods of reaching their destinations.

Washington State

Most communities served by Amtrak *Cascades* are also served by local/regional transit agencies. In some cases stations—like Centennial Station in Olympia/Lacey and Skagit Station in Mount Vernon—are owned and operated by local transit agencies as multimodal facilities. Although some public transit agencies have coordinated schedules to coincide with Amtrak *Cascades* arrivals and departures, there are opportunities to improve these connections. Exhibit 8-1 lists Amtrak *Cascades* stations within Washington State and types of transportation connections that are available. Individual station stops throughout the corridor are highlighted on the Amtrak *Cascades* Web site (www.amtrakcascades.com/RoutesAndDestinations.aspx), where additional information on available connecting services is provided.

Exhibit 8-1: Amtrak *Cascades* Stations in Washington State and Transportation Connections

Station	Transportation Connections
Fairhaven Station, Bellingham	• Whatcom Transportation Authority • Greyhound • San Juan Island Commuter • Alaska Marine Highway System • Taxi
Skagit Station, Mt. Vernon	• Skagit Transit • Greyhound • Taxi
Everett Station, Everett	• Everett Transit • Sound Transit • Community Transit • Greyhound • Northwestern Trailways • Taxi
Edmonds Station, Edmonds	• Community Transit • Sound Transit • Washington State Ferries • Taxi
King Street Station, Seattle	• King County Metro • Sound Transit • Greyhound • Northwestern Trailways • Washington State Ferries • Victoria Clipper • Community Transit • Taxi
Tukwila Station, Tukwila	• Seattle Express • Sound Transit • Metro Transit • Taxi
Tacoma Amtrak Station, Tacoma	• Pierce Transit • Sound Transit • Tacoma Link Light Rail • Greyhound • Washington State Ferries • Northwestern Trailways • Taxi
Centennial Station, Olympia–Lacey	• Intercity Transit • Taxi
Union Depot, Centralia	• Twin Transit • Taxi
Kelso Multimodal Transportation Center, Kelso	• CUBS (Community Urban Bus Services) • Taxi
Vancouver Station, Vancouver	• C-TRAN (Clark County Transportation Benefit Area) • Taxi

Portland, OR Area

Tri-Met, the public transit agency in greater Portland, provides MAX light rail throughout Portland and surrounding suburbs, as well as extensive bus service. The north end of the Portland Transit Mall is located at Portland Union Station. Additional construction is underway at the station and will provide dedicated bus and MAX lanes that will extend to points throughout the Portland area. Currently, MAX service is located several blocks from Union Station. MAX service connects with neighboring suburbs, the Portland Exposition Center, and Portland International Airport. The system further integrates with the Portland Streetcar and Westside Express Service commuter rail that will open in early 2009.

Tri-Met, like Translink, provides an extensive "trip planner" to allow passengers to determine routing, schedules, and options to coordinate their trips.

Sound Transit: Light Rail, Sounder, and ST Express Bus

Sound Transit, the regional transportation authority in the Central Puget Sound, is developing a network of commuter rail, light rail, and express bus services in the region.

Sounder Commuter Rail currently operates between Tacoma, Seattle, and Everett during peak commuting hours. Sounder and Amtrak *Cascades* use the same route, and both serve stations at Everett, Edmonds, Seattle, Tukwila, and Tacoma. Sounder provides additional intermediate stops along the route. Sound Transit and WSDOT are exploring opportunities to provide for coordinated ticketing, which would allow persons to travel between sites (i.e. Auburn to Portland via Sounder and Amtrak *Cascades*) that are uniquely served by one or the other, similar to coordination of services in Europe. Between Seattle and Everett, the "Rail Plus" program allows Sounder travelers to ride Amtrak *Cascades* using their Sounder monthly pass and vice versa. Sounder operating schedules are already coordinated with Amtrak *Cascades* to eliminate operational conflicts.

Sound Transit will be operating light rail in Seattle in 2009. The International District light rail station at the Metro Bus Tunnel is one block from King Street Station. Construction is underway to provide a light rail link to Sea-Tac International Airport.

In Tacoma, Sounder, Tacoma Link Light Rail, and ST Express Bus services operate from the Tacoma Dome Station at Freighthouse Square. Amtrak *Cascades* will be moving to that facility upon completion of the Tacoma—Bypass of Point Defiance – 66th St. to Nisqually project, described on page 4-7.

Washington State Ferries

Washington State Ferries operate a ferry service from several places in the Puget Sound. Edmonds and Seattle are located near Amtrak *Cascades* stations. Amtrak is not mentioned on the Washington State Ferries Web site, although it indicates connections by road, local transit, and Sound Transit Sounder trains.

Edmonds Ferry Terminal is the closest, with a 5-minute walk connecting the train station and the ferry terminal. The Seattle ferry terminal (Coleman Dock) is within walking distance of Seattle's King Street Station. A regular connection runs on Metro Transit Service 99 (Waterfront Streetcar) from the ferry terminal to within a block of King Street Station and vice versa.

Amtrak Thruway Motorcoach

Thruway motorcoach service provides coordinated train/bus service with connections at Amtrak stations as well as through integrated fares and ticketing.

Amtrak has contracted with Olympic Trailways to provide "thruway" bus service between Seattle and Vancouver, B.C. This service meets up with Amtrak long-distance and Amtrak *Cascades* trains in Seattle.

Since May 2008, WSDOT has sponsored a round-trip thruway bus connection with trains 500 and 509 in Seattle that provides service to Everett, Mount Vernon, and Bellingham. This bus provides direct connections and ticketing with Amtrak *Cascades* and provides for a southbound link to Amtrak's Empire Builder, which travels east to Chicago via Spokane and Minneapolis.

Oregon's Department of Transportation sponsors multiple daily round-trip thruway bus connections to Amtrak trains that serve Portland Union Station.

Intercity Bus

There are a variety of intercity bus providers (i.e. Greyhound, etc.) that parallel the Amtrak *Cascades* route. Greyhound Canada serves Pacific Central Station in Vancouver. In Portland, the Greyhound terminal is one block from Union Station. Greyhound serves most Amtrak stations throughout the route. These bus companies do not have coordinated ticketing/interline connections with Amtrak at this time, but they do provide information on Amtrak service to potential customers who are not well served by existing bus schedules.

The initial phase of WSDOT's Travel Options (intercity travel planner) is anticipated to be in place by January 2009. Amtrak *Cascades* schedules are integrated in the travel planner to be proposed as travel options.

Sea-Tac International Airport

Tukwila station is less than five miles from Sea-Tac International Airport. In the future a more direct shuttle bus connection between the two facilities should be explored, as a more seamless connection between the airport and the train station could attract more riders.

Bellingham Cruise Terminal

The Bellingham Cruise Terminal, located adjacent to Bellingham's Fairhaven Station (Amtrak *Cascades*), provides cruise ship and ferry connections to southeast Alaska, Victoria, B.C., and the San Juan Islands.

Rental Cars

Amtrak has explored providing rental car satellites at train stations on the Amtrak *Cascades* route. Currently, rental cars are available at Union Station in Portland and Vancouver's Pacific Central Station.

Car Sharing Services

Another option that is open to visitors to a different city is the use of car sharing. There are a number of car sharing services, such as *Zipcar* and *Car Sharing US*. The service operates when a user pays a subscription fee and then makes use of the service of a car. Not all locations offer this service, but it is possible for it to be available in Seattle, Portland, and other locations.

Taxi

Taxis are available at the stations shown in Exhibit 8-1, but it is important to note that they are limited to particular areas. Edmonds and Centralia have limited taxi service. The current Amtrak *Cascades* timetable does not indicate if taxi service is available at stations, or what hours they operate if they are available. Adding an entry on this aspect may influence some people to travel by train.

Bike

There are two ways that bike riders could build ridership numbers. One concerns the "on the ground" facilities at stations (racks and lockers) and dedicated bike lanes to and from stations. The other is the ability to transport bicycles onboard the trains. Both of these impact whether bike users will take the train.

Cruise Ships

Passengers who use the cruise ship service are usually one-way passengers. They either travel to Seattle or Vancouver, B.C. to catch a cruise ship, which then takes them back to a different port, or they arrive in Seattle or Vancouver, B.C. having boarded in a different port.

They are very unlikely to be local residents of the Vancouver, B.C. or Seattle area. The vast majority of cruise ship passengers is on an inclusive tour package that includes bus or shuttle transfers between the train station and the docks.

Amtrak often works cooperatively with cruise ship lines to develop "packages" that include travel by rail as part of the trip. As an example, coordinated travel between Amtrak *Cascades*, Victoria Clipper, and other major cruise lines provide for coordinated travel for thousands of passengers annually on Amtrak *Cascades* to Vancouver, B.C.

Other Issues Impacting the Integration of Transportation

Integrated Fares/Travel Packages

Many passengers, who use the Amtrak *Cascades* service to connect with cruise ships, are taking advantage of an integrated fare that was put together by the tour operator. However in addition to these fares, there are many other avenues that could be explored. WSDOT needs to work with the Washington State Ferries and local transit agencies to explore what opportunities exist for integrated fares.

Travel Planners

Also mentioned, as part of the marketing of the Amtrak *Cascades* service, is the ability for these trains to be shown alongside other services in timetables and journey planners that operate in the corridor. WSDOT should pursue connections with these other agencies and organizations that produce these documents, and work with them to obtain maximum visibility for the service.

Integrated Schedules

An issue that has been raised by passengers in the past has been the lack of integration between services that are operated by different organizations. While it is never possible to cater for late running services, it should be possible to ensure that buses, ferries, and trains make every effort to coordinate their timetables to ensure that passengers, who are not using only the one mode, are able to make reasonable connections.

WSDOT could improve coordination of schedules and, where it is practical, show these connections in published literature.

Passenger Information Systems

One aspect of travel, which is gaining in importance as technology becomes more readily available, is access to real-time information systems on train arrival and departure times. Passengers are becoming accustomed to finding out how flights are performing from the Internet. This avoids arrival at the terminal too early for services that are running late. As the timetable develops and reaches multiple journeys each day, it will become even more important that real-time running information be available over the Internet and cell phones.

Signs Including Pictograms

Some parts of the state enjoy a far greater degree of tourism, and thus non-English speaking people could be users of the Amtrak *Cascades* services. WSDOT knows that tourism is an important aspect of the service. The Amtrak *Cascades* service must cater to the non-English speaker, and one way to accomplish that is to use internationally recognized pictograms for signage on the stations throughout the network.

WSDOT found several examples where there are a few signs from different modes of transportation. Signs from I-5 to Amtrak *Cascades* stations were good, but signs for pedestrians from ferry terminals, transit centers, and bus stops are rarely found. A full survey of locations that could benefit from better signage should be performed and submitted for future funding consideration.

Parking

An inventory of parking availability appears in Exhibit 8-2. Some locations have insufficient parking at this time. WSDOT should determine how to add to the pool of parking spaces. In addition WSDOT noted that at locations such as Tacoma, when the service moves to Freighthouse Square in the future, parking will become a major issue. WSDOT will need to work with Sound Transit to explore options for expanding parking availability at this location.

Exhibit 8-2: Parking Availability at Amtrak *Cascades* Stations
Portland, OR to Vancouver, B.C.

Station	Free at Station	On-Street Parking	Pay Lots	Disabled	Bikes	Other
Union Station Portland, OR	0	45 □ 1 motorcycle	177 □ 1.25□hr or □6.50□day	9	5	There is a 411-stall Smart Park two blocks north at □1.25□hour or □6.00□day, limit 24 hours. It also has motorcycle parking.
Vancouver Station Vancouver, WA	30 □2 hr. max. 60 □long term	0	0	3	0	None
Kelso Multimodal Transportation Center Kelso, WA	15 □7AM to 9PM, no overnight 45 □1 week max	16	0	2	8 □ lockers	None
Union Depot Centralia, WA	72	15 □street parking within two blocks	0	1	16	None
Centennial Station Olympia□Lacey, WA	126	0	0	6	5 □ lockers	None
Tacoma Amtrak Station Tacoma, WA	80	0	0	0	0	2,400 spaces at Tacoma Dome Station, 3 blocks west
Tukwila Station Tukwila, WA	250	0	0	0	0	None
King Street Station Seattle, WA	0	Metered □1.50□day	Day only □9□day	0	0	Several other garages within 3 blocks, day□overnight □20□day
Edmonds Station Edmonds, WA	6 pickup □dropoff only	0	210 □12□day	0	0	None
Everett Station Everett, WA	25 □8 rideshare	0	0	0	6	4 Park □ Ride lots with 750 stalls adjacent to station
Skagit Station Mt. Vernon, WA	90	13 free, 2 hr. limit	0	4	8	None
Fairhaven Station Bellingham, WA	18	0	160 □6□day, □30□week	0	8	None
Pacific Central Station Vancouver, B.C.	0	19 □2 Canadian, 2 hr. max.	21 □1 Canadian, 1 hr. max.	0	0	37 Free, 2 hr limit within 1 block; 20 long-term within 3 blocks northwest, □12□day Canadian

An outcome of the two Advisory Committee meetings included different options to improve connectivity. Although there wasn't enough time to examine or test these options, WSDOT will need to explore them further in the future.

Washington State Department of Transportation

Chapter 9: Amtrak *Cascades* Marketing

Introduction

Marketing and advertising efforts for Amtrak *Cascades* is a cooperative effort shared by Amtrak and the Washington State Department of Transportation (WSDOT). A comprehensive advertising campaign has been employed annually focusing on brand building and awareness to reach a mass media target market. In addition to media advertising, Amtrak employs two regional field marketing representatives to develop and implement grassroots marketing in designated markets serving the Amtrak *Cascades* route.

Looking ahead to the next eight years, the marketing plan is focused on the following key elements:

- The travel experience—delivery of service, frequency/schedule, ease of travel.
- Customer satisfaction—onboard customer service, amenities offered, consistency.
- Execution and attention to detail.

Goals and Objectives

1. To support the achievement of ridership and revenue targets.
2. To establish strong brand awareness for Amtrak *Cascades.*
3. To differentiate Amtrak *Cascades* from other transportation options in this market and position it as the preferred method of intercity travel.
4. To establish Amtrak *Cascades* as the preferred choice for business travel in the I-5 corridor.

Marketing Analysis

Market Size

In Washington State about 2.4 million people live within a 10-minute drive of an Amtrak *Cascades* train station as of 2008. Population growth in this area is expected to climb to over 3 million by FY2030.

Current Ridership

Total ridership on Amtrak *Cascades* has risen from 94,000 in 1993 to over 676,000 in 2007. In the history of the service, ridership has risen steadily with losses sustained in only one year.

Rising gas prices, on-going construction projects along the I-5 corridor, and growing concerns about the quality of the environment have helped to drive consumers to consider alternative transportation options. These conditions have contributed to substantial growth in ridership in 2008.

Current Travel Options

Multimodal travel options include personal vehicles, public and private transit, aviation, marine, and rail. The current primary mode of travel is the automobile.

The main thoroughfare available to consumers traveling within the PNWRC is Interstate 5 (I-5). On average, people are making roughly seven
one-way trips on I-5 during a given year. Seattle, Tacoma, and Portland remain the most popular destinations, and more than twice as many trips are for leisure, as opposed to business. Travel times for Amtrak *Cascades* are very competitive with private vehicles and transit alternatives due to the congestion on I-5.

Air travel is accommodated by a choice of domestic and international carriers, operating out of Seattle-Tacoma International, King County International/Boeing Field (Seattle), Portland International, and Vancouver (Canada) International. Amtrak *Cascades* will compete directly with air travel in the I-5 corridor that it serves. Air travel may provide faster flight plan times, but once airport access, check-in, security, and baggage claim wait times are factored in, the total travel time by Amtrak *Cascades* is relatively comparable.

Travel by Amtrak *Cascades* also allows customers to take advantage of onboard amenities and facilities and make more productive use of their travel time.

Segments and Target Markets

The Amtrak *Cascades* market comprises a mix of local residents and visitors, traveling for a variety of purposes including intercity travel, vacation/recreation, business travel, and personal business.

The business traveler is a “golden egg” in that they represent the potential for significant revenue and ridership increases. In order to capitalize on this segment, significant improvements in service, frequency, and on-time performance will need to be made to accommodate the business traveler’s needs.

Demographics

Current demographics (advertising target):

- Adults 25-54.
- Household income (HHI) $50,000+.
- Slightly skewed female.
- Employed (52 percent full time, 12 percent part time).
- Educated (54 percent college graduate, 31 percent some college).
- Travels an average of seven one-way trips along the I-5 corridor per year, for business or leisure.

Pricing

Current pricing for Amtrak *Cascades* ranges from as low as $10 one-way to/from neighboring cities, to as high as $114 for one-way travel on the entire route between Vancouver, BC and Eugene, OR.

Amtrak *Cascades* service between Seattle and Portland is as low as $28 one-way. Comparable one-way air travel between Seattle and Portland (depending on airline restrictions and policies) ranges from $95 to $150, inclusive of all taxes and fees. For travel by automobile, the estimated cost between Seattle and Portland is $0.61 per mile. This makes the comparable cost of traveling the 173 miles between Seattle and Portland by automobile roughly at $106 (one-way).

Marketing Strategy

Opportunities and Challenges

Strengths

- Convenience.
- Alternative to driving a car on already congested roads.
- High levels of customer service and access to amenities.
- Traditional allure of passenger rail services.
- High level of public support.

Weaknesses

- Dependence on the host railroad (Amtrak does not own railroad).
- Service reliability (on-time performance).
- Speed of service/travel time.
- Frequency/schedule.
- Perception of cost, relative to automobile use.
- Dependency on other services for trip connections/completion.

Threats

- Continuing challenges with on-time performance (rail line capacity—congestion from increased freight rail traffic).
- Equipment maintenance and malfunctions.
- Harsh weather conditions resulting in mudslides and flooding.
- Limited political support/funding.
- Volatile gas prices:
  - Reduce discretionary spending.
  - Increase Amtrak's fuel costs, creating pressure for fare increases.

Opportunities

- Volatile gas prices help increase awareness and consideration of alternative travel.
- Development of partnership and alliances with other transportation service providers, attractions, and the travel industry to deliver a seamless, integrated customer travel experience.
- Unique Pacific Northwest brand.
- Promotion of "green" travel.

Branding and Positioning

Amtrak *Cascades* is a unique Northwest brand. Awareness of train travel is fairly significant and Amtrak is well known. However, there is still confusion among consumers regarding the difference between Amtrak and Amtrak *Cascades*. Most consumers assume that Amtrak and Amtrak *Cascades* are one and the same. It is important to establish Amtrak *Cascades* as its own independent identity from Amtrak (similar to Amtrak's *Coast Starlight* and *Empire Builder*) and highlight the Northwest appeal and branding.

More than just a convenient way to travel, trains are also energy efficient. Amtrak *Cascades* intercity passenger rail can move more people for each energy dollar, minimize damage to the environment, and increase the safety of our transportation system. Highlighting Amtrak *Cascades*' energy efficiency will be an effective way to reach out to the consumer's consciousness and desire to choose travel options that reduce carbon emissions.

Advertising and Promotion

An annual marketing and advertising plan is executed through the advertising agency under contract by Amtrak and WSDOT. The advertising budget is funded cooperatively by Amtrak and WSDOT.

Media Strategy

The current media strategy is a broad-based reach campaign to educate the total target market about Amtrak *Cascades*. Primary target markets are focused on Seattle and Portland, with secondary targets in Tacoma, Bellingham, and Eugene. Vancouver, B.C. is a primary target as well, but the media strategy has been put on hold due to the fluctuation between U.S. and Canadian currencies and the uncertainty of the second train service.

Current time frame for advertising campaigns remain focused on the spring season (March – May) and the fall season (September – November). These time frames are considered the "shoulder" seasons between the "peak" seasons of the summer and holiday travel periods. Ridership is usually lower during these times and the need to fill seats is greater.

Promotions

Currently, promotions are executed at two levels: grassroots marketing and regional promotions. Amtrak employs two field marketing representatives who work assigned markets, executing grassroots marketing and promotions, and drive trial (sampling) through cooperative marketing efforts with travel and tour operators. Regional promotions, with properties such as professional sports, state and regional tourism bureaus, and hotel chains, are executed through the advertising agency jointly employed by Amtrak and WSDOT.

Promotions allow Amtrak *Cascades* to:

- Drive immediate train ridership in low—or moderate—use periods, or on specific routes with low ridership.
- Stimulate trial (sampling), which could lead to repeat ridership.
- Generate awareness and exposure when no advertising is running.
- Generate awareness and exposure in markets not included in the media buy.
- Extend marketing budget.
- Reward repeat ridership with consumer loyalty/rewards program (Amtrak Guest Rewards).

Customer Service

Customer service is the cornerstone to the success of any service-based business. It is crucial that customer service needs on Amtrak *Cascades* are addressed on a consistent and proactive basis.

Service Reliability □ Passenger Guarantee

Service and travel reliability will be paramount to the ongoing success of Amtrak *Cascades*. No other single factor is more critical to the current and future success of Amtrak *Cascades* than on-time performance. In order to continue to be a viable transportation option and to become a preferred method of intercity travel, on-time performance will have to be improved to a level of consistency.

Real-Time Information

In an increasingly wired and wireless society, there is growing expectation that service providers will have the capability to assemble and disseminate real-time schedule information. Amtrak *Cascades* must be able to deliver real-time service information (delays, cancellations, etc.) using the latest technology.

Enhanced Amenity Package

There are a wide range of amenities that could be considered both onboard the trains and at stations that will enhance the customer experience. For business travelers, wireless Internet capability is critical. Vacationing families could choose from a variety of onboard entertainment options (games, movies, and designated play areas) to keep their children occupied for the duration of their trip.

Marketing Action Plan

Option 1: Maintaining Current Operation Strategy

Option 1 investment strategy would maintain the current advertising and promotion levels with a flat budget. In this option, the advertising and promotions budget would continue to be invested strategically with the expectation of diminished returns on our investment due to the annual increase in media costs that cannot be met by our current budget.

Options 2 and 3: Incremental Investment Strategies

Options 2 and 3 investment strategy would require a significant increase in the advertising and promotion budget. With the proposed budget increase, the advertising plan could reach more consumers and develop more targeted campaigns aimed at the business traveler to meet the added service. This would make a significant impact in media reach, brand awareness, and driving demand.

Option 4: Rail as a Long-Term Alternative Strategy – No Financial Constraints

Option 4 investment strategy would require a comparable budget for advertising and promotion as Options 2 and 3. This would continue to reach the mass market while investing in targeted media aimed at the business traveler.

Build Usage and Market Share

- Retain core ridership constituencies through effective service delivery and customer communications.
- Build loyalty and ridership frequency among occasional riders through service improvements, appropriate fare media, and promotional efforts.
- Attract new riders from population segments with viable ridership potential, through targeted promotional programs.

Price

- **Pricing objectives** – pricing should be managed along with market demand (what the market will bear) and operational costs.
- **Sales promotion** – promotional pricing should be used as an incentive to drive trial (sampling) and promote brand awareness.

Promotion and Public Relations

- Maintain an ongoing image campaign to educate the general public about Amtrak *Cascades*.
- Use aggressive public relations efforts to maximize positive media coverage and news media support.
- Leverage brand awareness by developing cooperative promotion opportunities.

Advertising

A combination of radio, outdoor, online, and newspaper are used to provide message continuity throughout the advertising campaigns.

Financial Forecast

Option 1: Maintaining Current Operation Strategy

Option 1 investment strategy would maintain the current advertising and promotion levels with a flat budget. The current advertising and promotion budget is $600,000 annually and has not changed since the inception of the service. In this option, the current budget would remain static while

media costs will continue to increase annually, which will result in diminishing returns on our advertising investment.

Options 2 and 3: Incremental Investment Strategies

Options 2 and 3 investment strategies would require a significant increase in the advertising and promotion budget. In order to effectively reach our consumers, raise awareness levels of the service expansion, and develop demand for the service, the advertising investment must be seriously considered. As Exhibit 9-1 shows, the amount of advertising investment is significantly larger in Options 2, 3, and 4 as compared to Option 1. This is because the advertising investment has not changed in the last 14 years, although media costs have risen at approximately 7 percent annually. In order to meet the rising costs of today's (and future) advertising opportunities and drive demand, the budget must grow with the service.

Option 4: Rail as a Long-Term Alternative Strategy – No Financial Constraints

Option 4 investment strategy would require a comparable budget for advertising and promotion as Options 2 and 3.

Exhibit 9-1: Proposed Marketing Budget

FY	Option 1	Option 2	Option 3	Option 4
2010	□600,000	□915,000	□915,000	□915,000
2011	□600,000	□940,000	□940,000	□940,000
2012	□600,000	□989,000	□1,054,000	□949,000
2013	□600,000	□1,032,000	□1,095,000	□1,078,000
2014	□600,000	□1,038,000	□1,100,000	□1,109,000
2015	□600,000	□1,035,000	□1,097,000	□1,228,000
2016	□600,000	□1,030,000	□1,091,000	□1,221,000
2017	□600,000	□1,030,000	□1,151,000	□1,222,000

Performance Measurements

- Reviewing monthly ridership and revenue reports can help determine if the marketing message is effective.
- Market research using focus groups, surveys, and advertising awareness research will help gain insight to the effectiveness of our campaigns.
- Obtain feedback from customers using comment cards and on-board surveys to gather information about key attributes such as service reliability, personal safety, employee presentation and

helpfulness, condition of equipment and facilities, and quality and availability of customer information.

- Operating statistics such as on-time performance and customer service ratings are important performance indicators related to the execution of the advertising strategy and marketing promotions, and the effectiveness of customer service delivery.

Washington State Department of Transportation

Chapter 10: Financing Amtrak *Cascades* Service: The Challenges and Opportunities

The 2006 long-range plan identified various construction projects for infrastructure improvements, equipment requirements, capital investments, and operating expenditures for providing and expanding Amtrak *Cascades* services. The *Amtrak Cascades Mid-Range Plan* outlines the implementation options and steps for each option to achieve additional services over the next eight years. Capital and operating investments that improve capacity and service are developed for the four mid-range plan options. The benefits and costs of these options are assessed.

The options analyzed in the mid-range plan provide information for policymakers to consider in how Amtrak *Cascades* service can be funded. The implementation of improved Amtrak *Cascades* service will depend on funding availability.

This chapter discusses how the Amtrak *Cascades* was funded in the past and what the challenges and opportunities are to fund Amtrak *Cascades* services in the future. This chapter includes three sections:

Funding History

The states of Washington and Oregon, Amtrak, Sound Transit, the Province of British Columbia, the federal governments of the United States (U.S.) and Canada, railroads, other participating organizations and agencies, and passengers that use the service are all direct or indirect sources of funding to the Amtrak *Cascades*.

Since Washington State began providing public funds for intercity passenger rail service in April 1994, it has been assumed that major capital construction projects, which are needed to support expanded Amtrak *Cascades* service, would be funded in the following manner:

- Projects necessary to provide faster, more frequent Amtrak *Cascades* service, between downtown Portland, OR and the Columbia River, would be funded by the state of Oregon, with potential funding coming from the U.S. federal government and Amtrak.

- Projects necessary to provide faster, more frequent Amtrak *Cascades* service, between the Columbia River and the Canadian

border, would be funded by the state of Washington, with potential funding coming from the U.S. federal government and Amtrak.

- Projects needed to improve Amtrak *Cascades* service in British Columbia would be funded by the Province of British Columbia, the Canadian federal government, and regional transportation agencies.

- Train sets and locomotives would be funded by the states of Washington and Oregon, with additional funds provided by the U.S. federal government and Amtrak.

- Projects necessary for increased Sounder commuter rail service in the Central Puget Sound would be funded by Sound Transit and the federal government.

Funding of the Amtrak *Cascades* program and related projects is listed by funding entity in Exhibit 10-1:

Exhibit 10-1: Amtrak *Cascades* Investment History: 1994-2007

Capital Investments
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Funding Source	Types of Projects	Amount
BNSF Railway Company	Track and signal work to support reintroduction of rail service between Seattle and Vancouver, B.C.	9.4 million
State of Washington (WSDOT and the Washington State Transportation Improvement Board)	Traffic control and safety systems; rail replacement and track relocations; crossovers; siding extensions; storage tracks; train sets; station restorations and improvements.	124.4 million
Amtrak	Track relocation; train sets; locomotives; Seattle Maintenance Facility; station improvements.	62.0 million
Federal Funds (non-Amtrak, Federal Transit Administration, and Federal Railroad Administration)	Station renovations and improvements; crossing signals and closures.	44.1 million
Sound Transit and the Federal Transit Administration	Capacity improvements between Everett and Tacoma that benefit commuter, intercity passenger, and freight services.	284.3 million
	Capacity improvements between Tacoma and Lakewood that benefit commuter and intercity passenger service.	165.7 million
Oregon (Union Station to the Columbia River)	Traffic control system; track adjustments; improvements at Portland's Union Station.	13.7 million
Local/Other	Station improvements.	13.6 million
Total Capital Investment		**717.2 million**

Operating Subsidies
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Funding Source	Amount
State of Washington	176.0 million
Amtrak	91.4 million
Total Operating Funds	**267.4 million**

Total Capital and Operating Investments for Amtrak *Cascades*
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Total	**984.6 million**
Washington State Share of Total	**300.4 million**

Source: WSDOT State Rail and Marine Office

Current Funding Status

The primary source of funding for the Amtrak *Cascades* capital and operating programs are state funds. These funds, which are generated from non-fuel tax revenues such as licenses, permits and fees, rental car tax, vehicle weight tax, and a portion of the sales tax on new and used vehicles, are deposited in the Statewide Multimodal Account. The state constitution restricts the use of motor vehicle fuel tax revenues exclusively to highway related expenditures.

The Washington State Legislature provided up to $29 million in the 2007-2009 biennial budget for Amtrak operations of Amtrak *Cascades* and for the maintenance of Talgo train sets attributable to state-supported services.

The state legislature has provided direction on capital investments with an approved project list and 10-year spending plan for rail capital investment. Currently programmed passenger rail investments are $360.4 million through 2025. The approved project list provides funding for several major projects, including the Vancouver – Rail Bypass and W. 39th St. Bridge, the Tacoma – Bypass of Point Defiance Phase 1, and a $49 million phase of the Kelso-Martin's Bluff project, as discussed earlier in this mid-range plan.

Limited federal funds have been available for intercity passenger rail development. The Pacific Northwest Rail Corridor (PNWRC), between Vancouver, B.C. and Eugene, OR, is one of 11 regional corridors identified by the USDOT for high-speed rail development. The corridor is one of the original five corridors designated in 1992. An average of $690,000 per year has been made available through the federal "High-Speed Rail Grade Crossing and Hazard Elimination" program. In September 2008, the Federal Railroad Administration announced the award of a $6 million grant to WSDOT for intercity passenger rail capital assistance. This grant will be used to partner with Sound Transit to help fund the Tacoma – Bypass of Point Defiance project.

Challenges and Opportunities

The mid-range plan focuses on infrastructure and operating improvements in the "highest transportation demand" segment of the PNWRC, Seattle to Portland, a segment that is traditionally funded by the state of Washington.

Challenges

- **Limited Multimodal Funding:** The Statewide Multimodal Fund, the primary source of state funding that is available for investment in the Amtrak *Cascades* program, also provides funding for transit, the Washington State Ferries system, bike, pedestrian, and some

highway activities. The amount of funds available is tied to vehicle registrations, various fees, and a percentage of the sales tax on new and used vehicles. The recent economic recession, witnessed by unprecedented volatility of capital market, may adversely impact the overall funding available for multimodal activities. Meanwhile, policies to heavily invest in infrastructure, which are often used by governments to stimulate the economy in prolonged economic recession or depression, could create emerging opportunities in passenger rail funding given its multiple benefits to society. In addition, there will be tremendous competition for available funds due to budget shortfalls and increased costs. Policymakers will be challenged to prioritize the limited resources. This mid-range plan attempts to provide comprehensive information through both quantitative and qualitative analyses to help policymakers make informed decisions.

- **No Dedicated Federal Funding:** Historically, there has not been a dedicated multi-year source of federal funding to provide a partnership similar to other modes of surface transportation.

- **Capital Funding in Oregon and Canada:** The availability of capital funding for improvements south of the Columbia River and north of the U.S./Canadian border is uncertain. Each of those entities needs to participate in rail capacity and reliability projects, if there is to be Amtrak *Cascades* service expansion, as described in the long-range plan.

Opportunities

Future Capital Funding Opportunities

After many years of deliberation, in October 2008, the US Congress passed the Rail Safety and Investment Act of 2008. This legislation provides, for the first time, a multi-year federal matching program with the states to fund intercity rail passenger capital projects. The legislation authorizes $1.9 billion in federal grants over five years. This 80 percent federal and 20 percent state program will allow WSDOT the opportunity to use state funds as leverage for federal funds for rail capital projects (infrastructure and equipment) in a manner that is similar to how other modes of surface transportation have been supported at the federal level. This program, if and when funds are actually appropriated, would need to be an essential component for the future development of Amtrak *Cascades*.

Provisions in the legislation allow states like Washington to use state investments as a 20 percent match for federal funds, up to a maximum of

$15 million per year, applying for up to $60 million in federal capital funds annually—prior to expending "new" state capital funds. The ability to use state funds as a match will be an important factor to consider when policymakers make determinations on future program funding levels.

Funding for Future Amtrak *Cascades* Operations

Ticket-buying passengers, the states of Washington and Oregon, and Amtrak currently fund the operating costs for Amtrak *Cascades* service in the PNWRC. It is assumed that any proposed increases in service as provided for in this mid-range plan, which focuses on enhanced Seattle to Portland service, would be funded by ticket buying passengers and by the state of Washington. Projected additional operating costs for each of the options presented in this plan are described in Chapter 6.

One of the major challenges is how to capture the opportunity of strong ridership growth to make the program more self-funded. Currently the farebox recovery ratio is about 50 percent—with strong ridership growth this year, it could reach a higher level. A 50 percent farebox recovery is considered very good for publicly-funded transportation. Policymakers need to determine the appropriate balance of farebox and public costs. It is possible that policymakers could view the many benefits of rail transportation as worthy of an appropriate level of public support. There are several factors that could drive a long-term growth of ridership.

- **High Energy Prices:** Rising fuel costs and the environmental advantages of rail passenger service have contributed to strong ridership growth. As Washington State and other entities in the region attempt to reduce greenhouse gas emissions and make environmentally responsible infrastructure choices, intercity passenger rail development as a method of travel should receive stronger consideration in the future. The mid-range plan options provide information on environmental impacts of multimodal investments for consideration.

- **Reliability Improvements:** There is tremendous opportunity to improve Amtrak *Cascades* service reliability through targeted investments in capital and in enhanced maintenance as discussed in this report. On-time performance can be expected to improve from the current 60+ percent to more than 90 percent in the next several years with investments outlined in this plan.

- **Reduced Travel Times:** Mid-range plan options for investment can reduce scheduled travel times in the range of 4 to 30 minutes due to infrastructure and reliability improvements, boosting

ridership by providing a more attractive and dependable rail transportation option in our region.

- **High Frequency of Train Service:** Higher frequency of train services, along with higher reliability (on-time performance and time savings) could trigger significant growth as business travelers start to use reliable train service. The mid-range plan did not forecast such growth due to lack of data. However, experiences in other corridors show this is a likely scenario as Amtrak *Cascades* operates at a service level of eight daily round trips.

Higher ridership could create a strong opportunity for the program to reduce net public costs.

- Higher ridership could increase occupancy that in turn decreases cost per passenger mile. If ticket prices hold, the lower costs mean lower public costs.

- If higher ridership is met by higher levels of service, economy of scale of running train services could also lead to lower costs per passenger mile.

This plan uses conservative estimates in analyzing ridership and farebox recovery. Actions proposed in the plan could lead to further improvements of revenue and cost performance.

- **Marketing Concepts:** For the first time, the mid-range plan includes marketing concepts that lay out actions to expand market reach to targeted customers. With the right marketing concepts, ridership fluctuation caused by seasonality could be improved and the average occupancy rate could be higher. Consequently, state support could be lowered. An investment in marketing could be fruitful in support of infrastructure and operation improvements. More people seek alternative transportation choices for many reasons, including concerns about high energy prices, congestion, and the environment.

- **Increased Ticket Prices:** Higher prices could lead to higher revenue, if the demand is not price sensitive for such a price increase. As the cost of using other modes (auto and airplane) increases sharply due to the fuel price hikes, people might select less expensive modes, such as rail and bus. This creates an opportunity for price increases. A study is proposed in the operation plan to further explore such an opportunity.

- **Improve Revenue Opportunity:** Revenues could be increased by improvements to onboard service quality, improving existing amenities such as the food and beverage service.

March 16, 2011

Commissioner Peter Goldmark
Washington Department of Natural Resources
P.O. Box 47000
1111 Washington Street SE
Olympia, WA 98504-7000
cpl@dnr.wa.gov

Via U.S. Mail and Email

RE: Millennium Bulk Logistics' Proposed Aquatic Lands Sublease Transfer; Information on Millennium's "Business Reputation"

Dear Commissioner Goldmark,

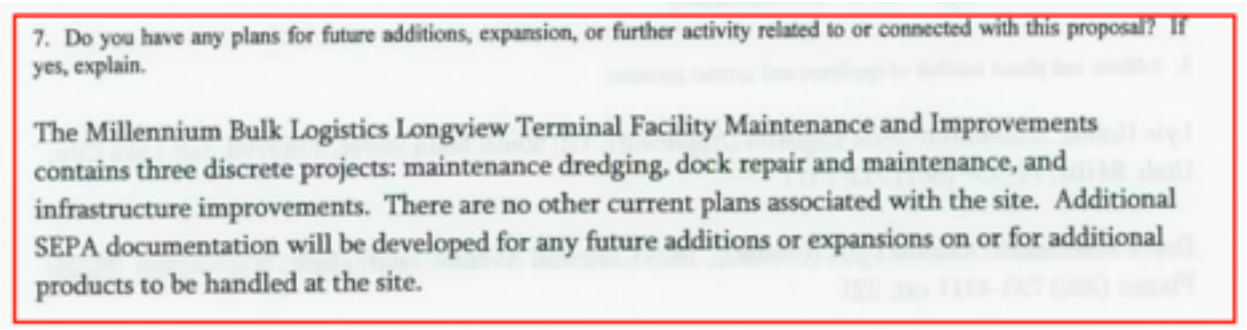
On behalf of Climate Solutions, Columbia Riverkeeper, Sierra Club, and Washington Environmental Council (collectively "the Coalition"), I am writing to provide useful information on Millennium Bulk Logistics' (Millennium) "business reputation," which is one of the factors that the Department of Natural Resources (DNR) may consider in evaluating Millennium and Northwest West Alloys Inc.'s (Northwest Alloys) aquatic lands sublease transfer request. *See* Aquatic Lands Lease No. 20-B09222 at § 9.1(a) (describing factors DNR may consider in making a decision on a sublease transfer, including the proposed transferee's "business reputation.").

As you're aware, DNR is currently evaluating this highly controversial sublease transfer that would allow Washington's first large-scale coal export terminal. As proposed in its application to Cowlitz County, Millennium would operate a 5 million ton per year (mty) coal export terminal on the banks of the Columbia River. Through internal company documents we now know that Millennium did not disclose the truth in its State Environmental Policy Act (SEPA) filings and, in fact, plans to operate a terminal that would export 25 mty in the short term and at least 80 mty in the long term.

Millennium's misrepresentation to County and State officials had harsh consequences. Yesterday, Millennium announced that it was pulling its Shoreline Permit and re-starting the permit process, including SEPA compliance. Millennium's deceitful business practices to date have direct bearing on DNR's evaluation of the proposed sublease transfer to Millennium.

By way of background, last year the Coalition challenged Cowlitz County's Shoreline Substantial Development Permit approval and SEPA determination for Millennium's proposed coal export terminal in Longview. Through discovery, we uncovered internal company documents that clearly demonstrate Millennium's attempts to evade SEPA review by hiding its true plans from County and State officials. These documents provide important insight into how Millennium operates its business and interacts with state officials.

As reported in the Longview Daily News, the New York Times and The Wall Street Journal, among other newspapers, Millennium's environmental review has been marred by misrepresentations and a lack of material disclosure. The nation's eyes are on the State of Washington and are eager to see how our state addresses this deception. Specifically, when asked in the SEPA checklist for this project whether Millennium had "any plans for future additions, expansion, or further activity related to or connected with" its permit application, the company answered in the negative. An excerpt of Millennium's SEPA application states:



7. Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.

The Millennium Bulk Logistics Longview Terminal Facility Maintenance and Improvements contains three discrete projects: maintenance dredging, dock repair and maintenance, and infrastructure improvements. There are no other current plans associated with the site. Additional SEPA documentation will be developed for any future additions or expansions on or for additional products to be handled at the site.

SEPA Checklist at 2. This statement, signed by a Millennium project manager as being "true and complete to the best of my knowledge," was at best a major misrepresentation about the scope of the project.

Peter Goldmark, Commissioner

A memo from Millennium's CEO sent that same month to its parent company's board of directors lays a deliberate strategy to expand the project immediately upon receipt of the permits from Cowlitz County. See Attachment A. That letter describes a piecemealing strategy to segment review of the first part of Phase I—separating the first 5 mty from the much larger 25 mty. The memo also outlines a political strategy of waiting two months between issuance of its current shoreline permit before seeking permits for the expansion in order to avoid harm to Millennium's "good reputation."

In addition to piecemealing the first phase of the project, Millennium has made quite clear to its investors that its ultimate objective is to build a facility that will handle not just 25 million tons of coal per year, but ultimately 60 million tons of coal per year – **twelve times the current permit level**. See Attachment B. Such a facility would be the largest coal export terminal on the west coast of North America, and would be double the size of the existing Westshore export terminal near Vancouver, B.C. Millennium has been saying one thing to its investors while it is leaving public officials and Longview residents in the dark.

In the February 14, 2011, New York Times story, Millennium's CEO, Joe Cannon, claimed that the company has "no plans to pursue" the second half of Phase I of the project. Millennium's documents and decision to pull the Shoreline permit tell a different story. Millennium has already invested millions of dollars in engineering and permitting for the expansion. Before the Coalition's SEPA appeal, Millennium had a precise permitting schedule and strategy to complete in-water work during 2011. In fact, emails show that Millennium continued to work towards an October 2011 start date for construction on the expansion even after this appeal was filed.

Most troublesome, the documents reveal a deliberate pattern of deception to withhold this information from Cowlitz County, the State, and the public. A November 5, 2010 email from Lyle Hobbs, Project Manager, to the project team demonstrates clear plans to expand the project while intending to keep the true project size hidden from the State, the County, and the community. The email also demonstrates Millennium's intent to complete the current permitting path based on false information. An excerpt of the email states:

> I do not feel we should engage with the River Pilots at this time regarding Berth 2 locations. We are at too sensitive a juncture to raise the plans to build a second berth. The community is small, and the risk to the current permit path is too large.

Berth 2 refers to an undisclosed new ship berth. Ambre has actually spent at least $2.8 million on consultants engineering the new expansion. Another email suggests that several additional stages of the expansion can be completed "without having to complete a full EIS" and

recommends that "any expansion plans beyond Stage 3 should not be made of available to any party."[1]

In an undated document titled "Project Platinum," Millennium's pet name for its mega expansion plans, Millennium describes its near-term plans to expand to 20 mty and then later to 60 mty. The document states:

- Ambre is proposing to redevelop the private "Platinum" port site on the US West coast into a multi product port with an emphasis on coal terminal facilities
- In the short to medium term Ambre will develop a 20Mtpa coal terminal. This will be the largest coal terminal on the US West coast and second only to the 21Mtpa capacity at Westshore in Vancouver, Canada on the North American west coast
- In the longer term Ambre plans to develop a 60Mtpa coal terminal which will be the largest coal terminal on the North American west coast.

A July 19, 2010 email from Jeff Torkington, Vice President of Ambre, Millennium's parent company, demonstrates a clear intent to keep expansion secret based on a calculated political decision. An excerpt of the email states:

- Any expansion plans beyond your Stage 3 should not be made available to any outside party.
- The port should be referred to as a bulk materials handling port and not as "primarily a coal port". This is to mitigate the political risk involved in this project. Hence the change in document name.
- The import component of this project will be used to help sell the economic benefit to the State and County and hence is very important in gaining political support.
- Finally, we are developing this project under the banner of "Millennium Bulk Logistics" and not AE.

An October 28, 2010 memo from Jeff Torkington to the Ambre directors demonstrates actual intent to obtain permits based on deception and then discloses a strategy to wait two months before telling state agencies that Ambre misled them:

The Stage 1 New project is targeting an annual coal throughput of 20 million tonnes per annum (Mtpa) which requires either a dual berth, single travelling ship loader or a two quadrant ship loaders configuration (a single quadrant ship loader can achieve up to 15 Mtpa loading a panama sized vessel).

…

If Stage 1 New is introduced to the agencies without the appropriate consultation period then Millennium will be perceived as having deceived the agencies with its hidden during Phase 1 Existing permitting phase and Millenniums good reputation would be lost over night. It is recommended that a period of at least two months expire after the granting of the Phase 1 Existing permits before Millennium approaches the agencies regarding an expansion project.

[1]In internal company emails, Millennium refers "Phase I New," which described the coal export expansion to at least 25 mty. "Phase I Existing" refers to Millennium's application to Cowlitz County, which describes its plans for a 5 mty coal export terminal.

The same memo by Mr. Torkington discusses how Ambre received permits for the smaller 5 mty project without conducting an Environmental Impact Statement.

Environmental Impact Study Requirements

Phase 1 Existing SEPA determination resulted in the Cowlitz County finding of a Mitigated Determination of Non Significance (MDNS) rather than the requirement to conduct a full Environmental Impact Study (EIS). The MDNS finding, based primarily on conducting maintenance only on the in-water structures, allowed the permit process to progress due to the less onerous environmental impact studies required.

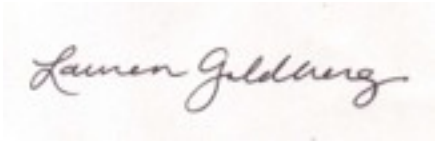
The Phase 1 New project will result in the requirement for an EIS based on the substantial new in-water work required.

Deliberate manipulation of a project's scope to avoid environmental review is a violation of SEPA. This strategy also reveals that Millennium is not an entity to be trusted—its efforts to brand itself as an honest and transparent partner to the community and to state agencies is a public relations ploy with no substance.

Since these internal documents became public, Millennium has further demonstrated its company ethos. On February 15, 2011, the Longview Daily News reported, "[o]f the documents' released to the public, Cannon said, 'I would really like to un-ring this bell. I would. ... (But) I don't think we've been disingenuous. I think we've been as open as we can be.'" Millennium's response is puzzling. Millennium failed to admit its mistakes and apologize to the County and State officials. We urge DNR to consider the veracity of Millennium's statements after reviewing the documents described above and submitted today.

With a proprietary interest at stake, DNR must carefully consider Millennium's business reputation before it entrusts state-owned aquatic lands to the care of a company with a demonstrated record of misrepresentation and deceit. DNR-Northwest Alloys Aquatic Lands Lease No. 20-B09222 at § 9.1(a). We appreciate DNR's careful consideration of the proposed sublease transfer and hope that the new information on Millennium's business practices will assist DNR in reaching its ultimate decision.

Sincerely,



Lauren Goldberg
Staff Attorney, Columbia Riverkeeper

Peter Goldmark, Commissioner

On behalf of Climate Solutions, Columbia Riverkeeper, Sierra Club, and Washington Environmental Council

Enc.
cc: *(Letter via email only)*

Governor Chris Gregoire
Jay Manning, Chief of Staff
Governor's Office
(jay.manning@gov.wa.gov)

Keith Phillips
Governor's Office
(keith.phillips@gov.wa.gov)

Alan Bogner
Office of Regulatory Assistance
(alan.bogner@ora.wa.gov)

Ted Sturdevant, Director
Department of Ecology
(tstu461@ecy.wa.gov)

Josh Baldi
Department of Ecology
(jbal461@ecy.wa.gov)

Janice Adair
Washington Department of Ecology
(jada461@ecy.wa.gov)

Sally Toteff
Southwest Region
Washington Department of Ecology
(sally.toteff@ecy.wa.gov)

Kim Wigfield
Washington Department of Ecology
(kim.wigfield@ecy.wa.gov)

Judy Schweiters

Peter Goldmark, Commissioner

Washington Department of Ecology
(judith.schweiters@ecy.wa.gov)

Rogers Weed
Washington Department of Commerce, Director
(rogersw@cted.wa.gov)

Tony Usibelli
Washington Department of Commerce
(tonyu@cted.wa.gov)

Phil Anderson, Director
Washington Department of Fish & Wildlife
(director@dfw.wa.gov)

Dave Howe
Washington Department of Fish & Wildlife
(david.howe@dfw.wa.gov)

Steve West
Washington Department of Fish & Wildlife
(steve.west@dfw.wa.gov)

Brian Larsen
Washington Department of Natural Resources
(brian.larsen@dnr.wa.gov)

Denise Wilhem
Washington Department of Natural Resources
(denise.wilhelm@dnr.wa.gov)

Bridget Moran
Washington Department of Natural Resources
(bridget.moran@dnr.wa.gov)

Edie Gilliss
Washington Department of Natural Resources
(edie.gilliss@dnr.wa.gov)

Heath Packard
Washington Department of Natural Resources

(heath.packard@dnr.wa.gov)

Siri Nelson
U.S. Army Corps of Engineers
(siri.c.nelson@usace.army.mil)

David Marten
U.S. Army Corps of Engineers
(david.j.martin@usace.army.mil)

Danette Guy
U.S. Army Corps of Engineers
(danette.l.guy@usace.army.mil)

Dan Guy
National Marine Fisheries Service
(dan.guy@noaa.gov)

Steve Landino
National Marine Fisheries Service
(steven.landino@noaa.gov)

Mike Wojtowicz, Director
Department of Building & Planning
Cowlitz County
(wojtowiczm@co.cowlitz.wa.us)

Chris Bischoff
Cowlitz Co. Environmental Health Manager
(bischoffc@co.cowlitz.wa.us)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to NMFS No.:
NWR-2012-9480

December 27, 2012

Shawn Zinszer
Chief, Regulatory Branch
Portland District, Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Request for Additional Information to Initiate Endangered Species Act Section 7 Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Coyote Island Terminals Construction of a New Coal Exportation Dock Facility in the Columbia River (6th field HUC 170701010904), Morrow County, Oregon (Corps No.: NWP-2012-56)

Dear Mr. Zinszer:

This letter acknowledges National Marine Fisheries Service's (NMFS) receipt of your November 23, 2012 letter, requesting formal consultation under section 7 of the Endangered Species Act (ESA) and section 305 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The request concerns the possible effects of the proposed issuance of Corps of Engineers (Corps) permits under section 10 of the Rivers and Harbors Act. The applicant, Coyote Island Terminal LLC, proposes to construct a new barge loading dock and upland coal receiving and storage facility. The project is located in the Port of Morrow at Columbia River mile 271, near the City of Boardman, Oregon. The facility would allow for the loading of coal that would be barged down the Columbia River and transshipped at an existing dock structure at the Port of St. Helens, Oregon. The intent of this letter is to obtain additional information to begin the consultation process.

The Corps has determined that 13 ecologically significant units (ESUs) of salmonids, 7 species of marine mammals, 4 species of sea turtles, the southern distinct population segment (DPS) of green sturgeon and the southern DPS of eulachon listed under the Endangered Species Act (ESA) may be affected by the proposed project as outlined in Table 1. The Corps also believes that the proposed action may adversely affect essential fish habitat (EFH) for salmonids, coastal pelagic species, and Pacific Coast groundfish.

Table 1. ESA listed species considered in the Corps request for consultation for the Coyote Island Terminal project at the Port of Morrow, Morrow County, Oregon

Species	**ESU/DPS[1]**
Steelhead (*Oncorhynchus mykiss)*	Upper Columbia River DPS
	Middle Columbia River DPS
	Lower Columbia River DPS
	Upper Willamette River DPS
	Snake River Basin DPS
Chinook salmon (*O. tshawytscha*)	Upper Columbia River spring run ESU
	Lower Columbia River ESU
	Snake River fall run ESU
	Snake River spring/summer ESU
	Upper Willamette River ESU
Chum salmon (*O. keta*)	Columbia River ESU
Coho salmon (*O. kisutch*)	Lower Columbia River ESU
Sockeye salmon (*O. nerka*)	Snake River ESU
Green sturgeon (*Acipenser medirostris*)	Southern DPS
Eulachon (*Thaleichthys pacificus*)	Southern DPS
Steller sea lion (*Eumetopias jubatus*)	Eastern DPS
Killer whale (*Orcinus orca*)	Southern resident DPS
Humpback whale (*Megaptera novaeangliae*)	
Fin whale (*Balaenoptera physalus*)	
Sei whale (*B. borealis*)	
Blue whale *(B. musculus*)	
Sperm whale *(Physeter catodon*)	
Leatherback turtle (*Dermachelys coriacea*)	
Green turtle (*Chelonia mydas*)	
Loggerhead turtle (*Caretta caretta*)	North Pacific Ocean DPS
Olive ridley turtle (*Lepidochelys olivacea*)	

Due to the public controversy surrounding this project and the potential for substantial impacts to NMFS' trust species, we recommend that the Corps prepare a draft environmental impact statement (EIS) for the project instead of the environmental assessment that we understand is currently proposed. An EIS would provide a platform to more thoroughly evaluate the effects of the proposed action as well as to consider less damaging alternatives. It would also provide an opportunity for the Corps to do a comparative analysis of the relative effects of several other coal transshipping projects being proposed at various sites in the Pacific Northwest. Such a comparative analysis should be structured to determine whether a project at one of one of the other sites would result in fewer impacts to NMFS trust species than the proposed action at the Port of Morrow.

If the Corps decides to prepare an EIS, it would be appropriate to postpone the ESA and MSA consultation process until after a preferred alternative is selected at the FEIS stage In the event that the Corps decides to proceed with the current NEPA approach and not prepare an EIS, the NMFS has identified additional information necessary to initiate this consultation as outlined in

[1] ESU = Ecologically significant unit. DPS = distinct population segment

the regulations governing interagency consultations for ESA at 50 CFR section 402.14(c) (initiation of formal consultation) and for EFH at 50 CFR 600.920(g) (EFH assessments).

To complete the initiation package, please provide the following:

- The BA provides no information on a stormwater plan for the 23 acres of newly created impervious surface for the coal storage facility in the uplands at the Port of Morrow. Please provide a description of how and to what extent stormwater will be treated on site and where any discharges may be located.
- The reasons that existing facilities cannot be used for coal loading should be discussed. For example, there is a loading facility immediately east of the proposed project site. Describe what alternatives (if any) are available in the surrounding area that would suffice in lieu of construction of a new facility.
- Details are needed on the water depth(s) where permanent piles will be driven and what will be covered by over water structures.
- Specify the location and number of derelict pilings proposed for removal as mitigation for the new facility. Also discuss the methods that will be used to remove the piles.
- A planting plan for areas disturbed by construction at the Port of Morrow should be provided.
- A more in-depth analysis of the contaminants at the sites where vessels will be disturbing contaminated sediment (through prop wash) and the contaminant effects on species is needed.
- Please provide information on what measures will be implemented to mitigate impacts from shoreline erosion and juvenile fish wake strandings resulting from the increase in barge and vessel traffic due to the proposed action throughout the Columbia River action area.
- The BA acknowledges an increased risk of ship strikes from additional vessel and barge traffic could result in take of marine mammals and turtles, so the determination of not likely to adversely affect marine mammals and turtles is not valid. A Marine Mammal Protection Act permit may be needed. We are coordinating with NMFS marine mammal experts on this issue. Further information may be necessary.
- Effects to NMFS trust resources, such as potential marine mammal strikes from increased shipping traffic, should be analyzed at least out to the edge of the Exclusive Economic Zone (EEZ), not just to the mouth of the Columbia River.
- Effects on species and critical habitat from invasive species in ballast water and on the hulls of ocean going vessels coming from Asia should be analyzed, as well as effects from water withdrawals and return from these vessels.
- The BA acknowledges that transportation of the coal by rail to the Port of Morrow could be considered an interrelated and interdependent action, but provides no description or analysis of the effects. This should be provided. A discussion as to the extent of coal dust lost during transportation, the fate of that dust, what streams containing NMFS trust resources could be impacted and the extent of that impact needs to be provided.
- Methyl mercury has been identified as one of the threats to listed Lake Ozette sockeye salmon. Burning of coal in Asia has been linked to the increase in methyl mercury in the atmosphere. The project's contribution to the deposition of methyl mercury in Lake Ozette should be analyzed.

- There is no analysis in the BA of the effects of burning the coal in Asia (acid deposition, global climate change). Global climate change and resultant impacts to ESA listed salmonids has been shown and is a growing concern. An analysis of the extent to which the increase of coal being exported to Asia with subsequent burning affects climate change is necessary.
- The BA indicates that construction of the upland portion of the site will begin in May 2013. The applicant should be made aware of the potential problem of irretrievable and irreversible commitment of resources prior to issuance of a permit if construction is completed before a permit is issued.
- As part of our Tribal Trust responsibilities, NMFS will also be consulting with Tribal representatives regarding this project. Columbia River Tribes may have additional concerns not identified in this letter

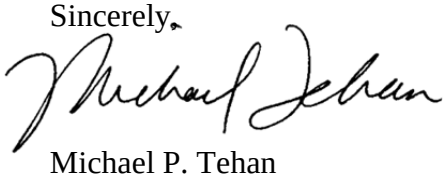
The NMFS requests the above information to evaluate fully the potential adverse effects from the proposed action. If desired, NMFS is available to discuss conservation measures that may minimize adverse effects to listed species and could be adopted as part of the proposed action.

Until these information needs are addressed, consultation will not proceed. Consultation on the proposed action will resume upon receipt of the requested information if it is determined that the information is sufficient to complete consultation. If the additional information necessary to evaluate the effects of the proposed action on ESA-listed species and EFH is unavailable, the Corps has two options: (1) With your agreement, the consultation may be discontinued until sufficient information is available for a complete analysis; or (2) the NMFS can complete its analysis with the available information, giving the benefit of the doubt to the species. The consequence of completing consultation while giving the benefit of the doubt to the species depends on the significance of the missing data. Moreover, if additional data become available that differs from what was considered during consultation, re-initiation of consultation might be necessary.

We will notify you when we receive this additional information. Our notification letter will also outline the dates within which consultation should be completed.

If you have questions regarding this letter, or how to continue with the consultation process, please contact Ben Meyer, Chief, Willamette/Lower Columbia Habitat Branch of the Oregon State Habitat Office, at 503-230-5425.

Sincerely,



Michael P. Tehan
Assistant Regional Administrator
Habitat Conservation Division

Columbia Riverkeeper
111 Third Street
Hood River, OR 97031
Phone: (541) 387-3030
www.columbiariverkeeper.org

June 17, 2013

Cowlitz Wahkiakum Council of Governments
c/o Melissa Taylor, Acting Director
Administration Annex
207 4th Avenue North
Kelso, WA 98626

City of Longview
c/o Bob Gregory, City Manager
Longview City Hall
Executive Office
P.O. Box 128
Longview, WA 98632

RE: SR 432 Rail Realignment and Highway Improvement Project

Dear Ms. Taylor and Mr. Gregory:

We understand that the City of Longview (City) and Cowlitz Wahkiakum Council of Governments (CWCOG) plan to complete a documented categorical exclusion for the SR 432 Rail Realignment and Highway Improvement Project (SR 432 Project). Columbia Riverkeeper, Sierra Club, Landowners & Citizens for a Safe Community, and Greenpeace are writing to urge you to reconsider this decision. Trying to shove the SR 432 Project into a documented categorical exclusion is akin to housing an elephant in a dog kennel. It simply won't fit. Documented categorical exclusions are reserved for a narrow set of circumstances—none of which resemble the major undertaking and environmental impacts associated with the SR 432 Project. The project's impacts clearly warrant full disclosure and analysis in an Environmental Impact Statement (EIS). We therefore ask that you reconsider the decision to forego preparing an EIS before more taxpayer dollars are expended on a process that is inappropriate and unlawful given the nature and scale of the SR 432 Project.

The SR 432 Project is a major undertaking that will impact thousands of residents in Longview and Cowlitz County. And the public is best served by understanding how increased rail traffic and new traffic patterns will impact their health, the economy, and shape the future of Cowlitz County. An Environmental Impact Statement is the vehicle for the public to understand these impacts. It is also the vehicle for the public to engage in a meaningfully discourse with

federal, state, and local agencies that can inform the ultimate decisions on how the SR 432 Project proceeds. In contrast, a documented categorical exclusion is an end-run around this government disclosure and public engagement process.

The SR 432 Project and Increased Rail and Road Traffic

The SR 432 Project calls for overhauling highway and rail access routes on SR 432 and the rail lines in the vicinity of Barlow Point on the west to 3rd Avenue/Industrial Way on the east. The estimated price tag: $200 million. According to CWCOG, one of the purposes of the project is to accommodate growth for rail shipments along the SR 432 Corridor, which are projected to increase 40% by 2030.[1]

One of the primary purposes of the SR 432 Project is increasing unit train capacity for the Port of Longview, the Mint Farm Industrial Park, and the proposed Millennium Bulk Terminals coal export terminal. The impacts of these rail improvements alone warrant an EIS. For example, the Millennium project would result in an additional sixteen (16) train trips per day to and from the proposed coal export terminal.

Among other impacts, increased rail traffic is associated with increased diesel emissions and toxic coal dust. Numerous studies have documented the link between fine particles in the air and increased risk of emergency room visits, hospital admissions, asthma attacks, cardiovascular disease, respiratory disease, adverse birth outcomes, and premature death. We are particularly concerned about the impacts of diesel particulate matter, which is associated with:

- impaired pulmonary development in adolescents;
- increased cardiopulmonary mortality and all-cause mortality;
- measurable pulmonary inflammation;
- increased severity and frequency of asthma attacks, ER visits, and hospital admissions in children;
- increased rates of myocardial infarction (heart attack) in adults; and
- increased risk of ischemic stroke.

According to Burlington Northern Santa Fe and coal dust proceedings before the Surface Transportation Board, rail cars lose huge volumes of coal dust during transportation, an average of 500 pounds of coal per rail car. Each train is composed of 120 cars or more. Threats associated with acute and chronic exposure to coal dust include:

- chronic bronchitis;
- emphysema;
- pulmonary fibrosis and
- environmental contamination through the leaching of toxic heavy metals.

The impact of diesel pollution and toxic coal dust are only a small subset of the serious environmental impacts that must be disclosed in an EIS.

[1] *SR 434 Rail Realignment and Highway Improvements Project* Power Point Presentation, Cowlitz Wahkiakum Council of Governments Longview City Council Workshop (Oct. 6, 2011).

Satisfying the Requirements of the National Environmental Policy Act

The CWCOG and City are in the early stages of evaluating the SR 432 Project under the National Environmental Policy Act (NEPA). NEPA requires federal agencies, in this case the Federal Highway Administration (FHWA), to consider the environmental impacts of any "major federal action significantly affecting the quality of the human environment." 42 U.S.C. § 4332(2)(C). The agency may first prepare an EA to determine whether the effects will be significant. If the EA establishes that the action may have significant environmental impacts, the agency must prepare an EIS. In many cases, an EA is not necessary based on the intensity and nature of a project's impacts and the agency will proceed directly to an EIS.

As much as NEPA focuses on environmental protection, its purpose to protect and promote health is also clear. *See* 42 U.S.C. §§ 4321, 4331; 40 CFR § 1502.16(g). Court decisions and NEPA's implementing rules leave no room for doubt: NEPA is about more than protecting pristine natural areas. NEPA applies equally to urban areas where federal actions can result in significant environmental impacts including degraded air quality, induced growth, impacts to public safety, or other effects on quality of life.

Under the FHWA's NEPA regulations, the FHWA may use a categorical exclusion for actions in limited circumstances. Specifically, a categorical exclusion is permissible for actions that "do not involve significant environmental impacts" and do not induce significant impacts to planned growth or land use for the area; do not require the relocation of a significant number of people; do not have a significant impact on any natural, cultural, recreational, historic or other resource; do not involve significant air, noise, or water quality impacts; do not have significant impacts on travel patterns; or do not otherwise, either individually or cumulatively, haven any significant environmental impacts. *See* 23 CFR § 771.117(a).

A so-called "documented categorical exclusion" is available for certain types of actions that comply with the overarching definition of a categorical exclusion in 40 CFR § 1508.4 and 23 CFR § 771.117(a). Examples of actions that are appropriate for a documented categorical exclusion include construction of new truck weigh stations or rest areas, transportation corridor fringe parking facilities, resurfacing highways, and highway safety improvement projects (*i.e.*, installing ramp metering control devices and lighting). *See* 23 C.F.R. §§ 771.117(d)(1)-(12). None of these actions even come close to resembling the series of projects that comprise the SR 432 Rail Realignment and Highway Improvements Project.

The CWCOG and the City have the benefit of learning from a similar, though much smaller, infrastructure improvement project that attempted to go the route of a documented categorical exclusion—but failed. In the late 1990s, the Washington State Department of Transportation (WSDOT) proposed a two-stage fully directional interchange construction project between Seattle and Tacoma. *West v. Secretary of the Dept. of Transp.*, 206 F.3d 920 (9th Cir. 2000). Stage 1 involved construction of a new interchange at milepost 118 to allow access from I-5 to the main road serving Weyerhaeuser's Northwest Landing Development in DuPont. Stage 2 called for upgrading the new Stage 1 interchange, rerouting additional connectors and reconstructing an existing interchange. The final project price tag: $18.6 million.

The agencies in *West* prepared a documented categorical exclusion instead of an Environmental Assessment or Environmental Impact Statement. And the Ninth Circuit Court of Appeals rejected that decision. Specifically, the court held that an interchange designed to have a substantial effect on traffic patterns does not qualify for a documented categorical exclusion. *Id.* at 922, n. 10. The court noted that the FHWA's regulations intend a very different scale of project to escape the more detailed environmental review under NEPA.

Held side by side, the SR 432 Project is orders of magnitude more substantial in scope and intensity (and cost) that the transportation project in *West*. Given the Ninth Circuit's reasoning in *West* and the plain language of the FHWA's NEPA implementing regulations, a documented categorical exclusion is clearly not appropriate for the SR 432 Project. For similar reasons, the CWCOG and County should revisit: (1) the decision not to analyze the SR 432 project as part of the Millennium NEPA/SEPA process, and (2) the decision not to prepare an EIS under the State Environmental Policy Act (SEPA).

We request the opportunity to discuss our concerns early in the decision-making process. Please contact Columbia Riverkeeper's Staff Attorney, Lauren Goldberg, at (541) 965-0985 to arrange a meeting. Thank you in advance for considering our organizations' input on this important decision.

Sincerely,

Brett VandenHeuvel
Executive Director
Columbia Riverkeeper

Jessica Yarnall Loarie
Associate Attorney
Sierra Club

Gayle Kiser
Landowners & Citizens
for a Safe Community

Kelly Mitchell
Climate and Energy Campaigner
Greenpeace

cc:

Federal Highway Administration
Cowlitz County
Weyerhaeuser
Port of Longview
Washington State Department of Transportation

SHORELINES HEARINGS BOARD
STATE OF WASHINGTON

CLIMATE SOLUTIONS; COLUMBIA RIVERKEEPER; SIERRA CLUB; and WASHINGTON ENVIRONMENTAL COUNCIL, Petitioners, STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY, Intervenor, v. COWLITZ COUNTY and MILLENNIUM BULK LOGISTICS, INC. Respondents.	SHB No. 10-023 DECLARATION OF JUSTIN BRANT

I, JUSTIN BRANT, declare under penalty of perjury under the laws of the state of Washington that the following is true and correct:

1. I am over the age of 18, am competent to testify in a court of law, and voluntarily provide this statement from my own personal knowledge and recollection.

2. I currently work as a Climate Change Technical Analyst in the Climate Policy Group at the Department of Ecology (Ecology). My duties for Ecology include developing and analyzing state policies to reduce greenhouse gas emissions. I am the state lead on technical issues related to greenhouse gas emissions quantification and projecting greenhouse gas

ATTORNEY GENERAL OF WASHINGTON
Ecology Division
PO Box 40117
Olympia, WA 98504-0117
(360) 586-6770

emissions reductions from proposed and implemented state policies. I also review environmental documents for greenhouse gas impacts. I have held this position for two and a half years.

3. Prior to joining Ecology's Climate Policy Group, I worked as a consultant helping industrial clients with environmental compliance issues. This included quantifying greenhouse gas emissions from a number of sources and ensuring compliance with air quality and other environmental regulations. I also have significant experience quantifying greenhouse gas emissions from business operations, communities, government operations, and forests.

4. I am familiar with Millennium's proposal to expand terminal operations at the Port of Longview for the purpose of exporting coal overseas. I was asked to review Cowlitz County's draft Mitigated Determination of Non-Significance (MDNS) to determine whether greenhouse gases had adequately been considered. I also reviewed the environmental checklist that Millennium provided to the County. Attached as Exhibit 1 is a true and correct copy of the MDNS. Attached as Exhibit 2 is a true and correct copy of the environmental checklist.

5. The draft MDNS required Millennium to develop a baseline greenhouse gas emissions estimate for the Scope 1 and Scope 2 emissions[1] from activities under the organizational and operational control of Millennium. Ex. 1, ¶10.d. This was problematic insofar as the County was poised to issue a MDNS (which is appropriate when there are no significant impacts) but Millennium had not yet been required to disclose the greenhouse gas emissions associated with its project. Under the circumstances, the MDNS seemed premature.

6. The draft MDNS was also problematic in that it very narrowly described the scope of greenhouse gas emissions that needed to be analyzed to include only Scope 1 and 2 emissions within Millennium's control. However, greenhouse gas emissions can be caused by

[1] Greenhouse gas reporting methodologies generally divide emissions into three categories or Scopes. Scope 1 emissions consist of emissions from resources owned by the reporting entity such as fossil fuels burned in owned stationary and mobile sources. Scope 2 emissions consist of emissions generated to produce electricity or steam purchased for use at a facility. Scope 3 emissions include all other sources of greenhouse gas emissions not directly owned by the entity such as employee commuting and emissions from leased facilities.

ATTORNEY GENERAL OF WASHINGTON
Ecology Division
PO Box 40117
Olympia, WA 98504-0117
(360) 586-6770

a project even if those emissions are not within the project proponent's control. In the case of Millennium, at a minimum, it seemed apparent that there would be fairly significant transportation emissions associated with transporting coal to and from the site.

7. In Ecology's comment letter on the project, I recommended that the greenhouse gas emissions estimate be completed before the environmental determination is made because the estimate is necessary in order to evaluate and mitigate significant impacts of the project. Laschever Decl., Ex. E. I also recommended that transportation emissions be assessed as part of the transportation analysis included in section B.14 of the environmental checklist. *Id.* This is the portion of the checklist that analyzes rail and vessel transportation as well as employee commute and truck traffic. Ex. 2 at 28-29. I included my direct telephone number in the letter. Nobody from the County or Millennium contacted me with questions about my comments.

8. On November 11, 2010, the County issued its final environmental determination, a modified MDNS (MMDNS). The County had partially incorporated my recommendation by requiring Millennium to provide a limited greenhouse gas emissions estimate. The County partially incorporated my recommendation to include transportation emissions by requiring disclosure of emissions associated with employee commute, limited truck traffic, and a short stretch (six miles) of rail travel. Laschever Decl., Ex. A. However, Millennium had not been required to disclose full rail or vessel emissions, which appear to be a significant source of greenhouse gas emissions associated with the project.

9. The project consultants provided a memo to the County which stated that vessel and rail emissions were excluded to avoid "the issue of 'emission double-counting' which is highlighted as a concern in both the EPA and WBCSD/WRI [World Resources Institute] guidance documents." Laschever Decl., Ex. B. Without having more information about what the consultants meant by that, it appears that they may have misunderstood when double

ATTORNEY GENERAL OF WASHINGTON
Ecology Division
PO Box 40117
Olympia, WA 98504-0117
(360) 586-6770

counting is of concern which may be based on a misunderstanding of the applicability of the EPA Climate Leaders and WRI quantification protocols to environmental review.

10. The EPA Climate Leaders protocol lays out the greenhouse gas quantification methodology for entities who voluntarily report their emissions to the Climate Leaders program. This methodology provides an overview of greenhouse gas emissions quantification and is a well-recognized source of generic greenhouse gas emissions factors for activities within the United States. The sources of emissions that this methodology requires for reporting are only applicable to entities participating in the Climate Leaders program.

11. Similarly the WRI quantification protocol lays out a methodology for voluntary disclosure of emissions from business operations. The protocol is a good source of quantification methods for various sources, but the sources of emissions that are either required or voluntary are only applicable for entity-wide voluntary reporting of greenhouse gas emissions.

12. The WRI in particular has developed excellent tools for calculating greenhouse gas emissions from various sources. However, neither WRI nor EPA's guidance are particularly useful in determining the scope of greenhouse gas emissions that need to be considered as part of the environmental review process. Within the context of environmental review, double counting is not an issue unless a lead agency requires mitigation for emissions that have already been mitigated through another source (such as cap and trade regulation or traditional clean air act regulation). To my knowledge, greenhouse gas emissions from rail and vessel travel are largely unregulated. Therefore, double counting does not appear to be a concern in the present case.

13. Related to this litigation, I was asked to calculate greenhouse gas emissions associated with rail transport to and from the Millennium site. There are a few good tools out there for calculating rail emissions. From Millennium's limited emissions estimate, it appears that the project consultants used EPA Climate Leaders Guidance. Using the same tool, I

ATTORNEY GENERAL OF WASHINGTON
Ecology Division
PO Box 40117
Olympia, WA 98504-0117
(360) 586-6770

calculated that in-state rail emissions associated with the project are 72,258 annual metric tons of carbon dioxide equivalent.[2] Out-of-state rail emissions (from Montana to Longview) are 233,717 annual metric tons. To help describe the scale of this, 75,000 annual metric tons of carbon dioxide equivalent equates to putting about 13, 636 new cars on the road annually.

14. In performing my calculations, I determined which routes the trains would likely transit by reviewing BNSF route maps for coal transport. I chose the starting destination of Decker Montana because of the coal mines located in Decker. However, there are other locations in the Powder River Basin where coal could travel from. I assumed that the trains would enter Washington State at Spokane, travel south along the length of the state, west to Vancouver, and then north to Longview. Based on Millennium's permit application materials, I assumed that 1.2 125-car trains would arrive at the terminal every day, and that 1.2 125-car trains would leave the terminal. I included round trip emissions because I assumed that the departing trains would not be transporting commodity to Montana since the departing trains will consist of coal cars.

15. Millennium disclosed no greenhouse gas emissions associated with vessels. However, relevant emissions could include not only time spent actually transporting the product, but also emissions associated with the time the vessel spends in Port and factors that are unique to the Columbia River, such as time spent crossing the Colombia River Bar (sometimes referred to as the "graveyard of the Pacific" due to the ships and lives that have been lost trying to cross it).

DATED this __31__ day of January, 2011, in Seattle, Washington.

JUSTIN BRANT

[2] Carbon dioxide equivalent is a metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential. RCW 70.235.010(1).

ATTORNEY GENERAL OF WASHINGTON
Ecology Division
PO Box 40117
Olympia, WA 98504-0117
(360) 586-6770

BST Associates

6475 NE 183rd St
Kenmore, WA 98028
(425) 486-7722 (425) 486-2977 fax
bstassoc@seanet.com

September 30, 2010

Mr. Mark Larsen
Anchor QEA
1423 Third Avenue, Suite 300
Seattle, Washington 98101-2177

Re: Impact of the Proposed Terminal at Chinook Ventures on the Capacity of the Columbia River System

Dear Mr. Larsen:

BST Associates was retained to analyze the impact that development of a coal terminal in Longview, Washington would have on congestion in the Columbia River Shipping Channel.

We have evaluated this issue and find that the proposed development will likely have only a minor impact on the Columbia River System. The additional ship calls at the mouth of the bar and in the river channel will modestly increase the number of calls from existing levels. Improvements being undertaken by the U.S. Army Corps of Engineers will mitigate impacts on the anchorages.

The following letter presents the conclusions of this analysis.

Very Truly Yours,

Paul Sorensen,

Principal

Impact of the Proposed Terminal at Chinook Ventures on the Capacity of the Columbia River System

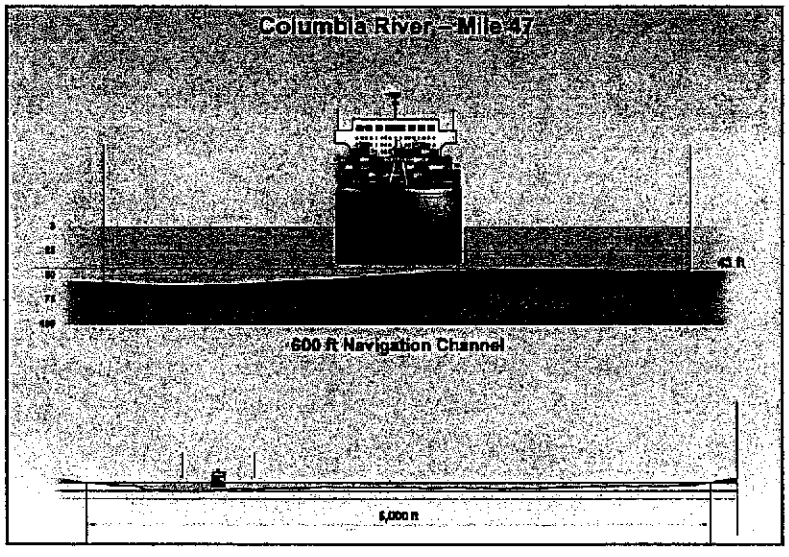
Proposed Terminal

The proposed terminal would be located at the Chinook Ventures property in Longview, at Columbia River mile 63. At full development, the facility will accommodate approximately around 5.0 million tons of coal exports with approximately 100 full outbound loads. The facility would also handle approximately 14 barges per year of cement imports.

Description of the Columbia River Channel

The Columbia River navigation channel begins at the Columbia River bar and continues five miles upriver at a depth of 55 feet and a width of 2,640 feet. After this point, the channel maintains a depth of 43 feet and a width of 600 feet for 106.55 miles to the Ports of Vancouver and Portland. (See Figure 1)

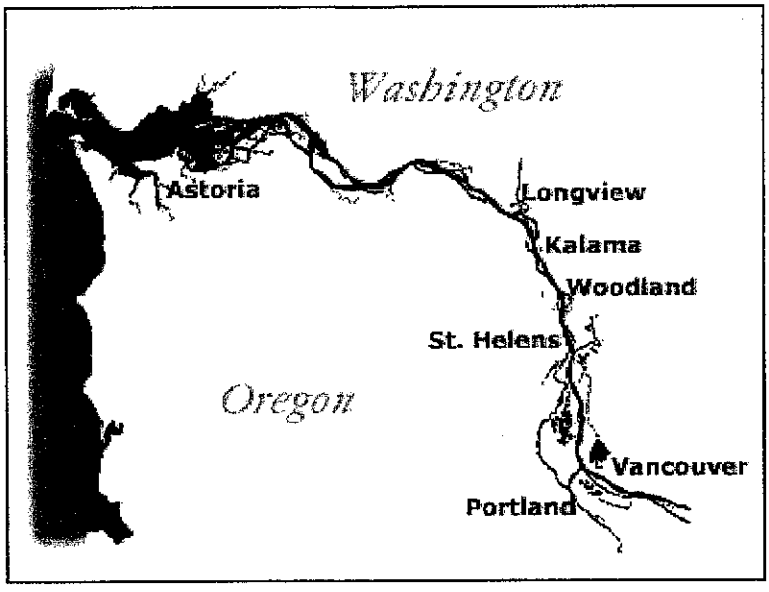
Figure 1: Cross Section of the Lower Columbia River Channel



As shown in Figure 2, the main ports in the Columbia River are located at:

- River Mile 12 (Port of Astoria)
- River Mile 65 (Port of Longview)
- River Mile 75 (Port of Kalama)
- River Mile 105 (Port of Vancouver)
- Willamette River (with access to Port of Portland terminals up to Willamette River Mile 12

Figure 2: Map of Lower Columbia River Port System



Recent Trends in Ship & Port Traffic

Vessel Traffic

This section summarizes recent trends in vessel traffic.

Overall Traffic Trends

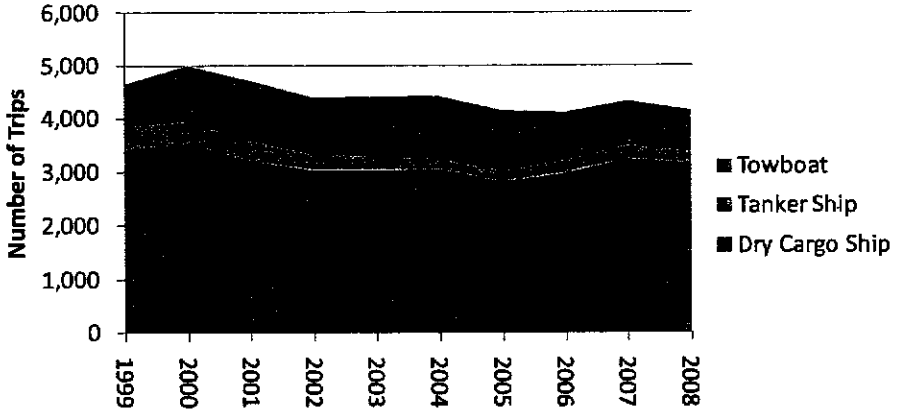
Cargo is carried into and out of the Columbia River in both ships and barges. The Corps of Engineers reports the number of cargo vessels that cross the Columbia River Bar, by type of vessel, including dry cargo ships, tanker ships, dry cargo barges, tanker barges, and towboats. Analysis of these statistics shows that a growing majority of the cargo vessels crossing the bar are dry cargo ships.

As shown in Figure 3, the number of cargo vessel trips decreased over the most recent decade (1999 through 2008, the last year of available data). From a peak of more than 5,000 cargo vessel crossings in 2000, the number dropped to approximately 4,150 in 2005, 2006, and 2008. Note that these trends intentionally omit the number of barges that crossed the bar; since barges are necessarily pulled by towboats, barge transits are included in towboat transits.

Because dry cargo ships account for the majority of cargo traffic on the Lower Columbia River, they have the most impact on channel congestion.

The number of dry cargo ships crossing the Columbia River Bar dropped approximately 10% between 1999 and 2008. Between 1999 and 2001 the number averaged 3,390 per year, but between 2004 and 2008 this dropped to 3,050. However, the share of total crossings accounted for by dry cargo ships grew from an average of less than 70% from 2001 through 2005 to nearly 76% in 2008.

Figure 3: Columbia River Crossing Trends by Type of Cargo Vessel



Columbia River Bar

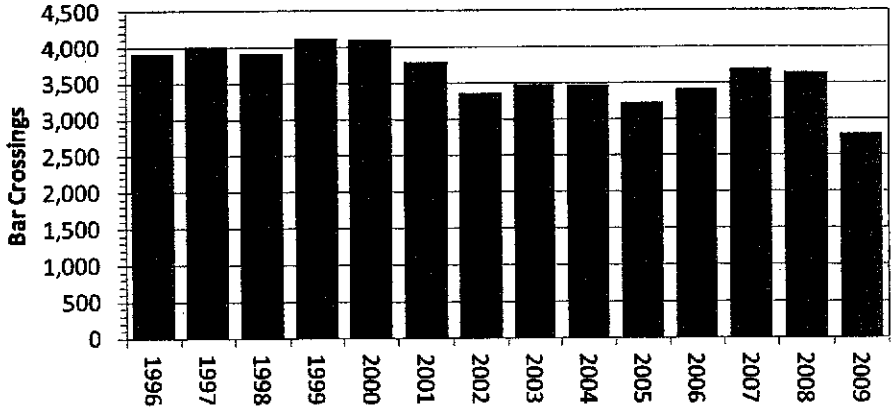
Pilotage across the Columbia River Bar and up or down the river is compulsory for U.S. vessels sailing under registry and for all foreign vessels, except foreign recreational or fishing vessels not more than 100 feet in length or 250 gross tons international. Pilotage is provided by the Columbia River Bar Pilots for the river entrance, from the open sea in at least 30 fathoms of water to the easternmost wharf at Astoria, Oregon.

Columbia River Bar Pilots board inbound vessels in the vicinity of the CR Buoy (Columbia River Entrance Buoy), and navigate ships beyond the Astoria-Megler Bridge, where vessels are turned over to a Columbia River Pilot.

According to data provided by the Oregon Pilot Commission, the number of vessel transits guided by bar pilots has not increased in more than a decade. In fact, between 2002 and 2008 the number of piloted transits averaged less than 3,500 per year, compared with an average of 4,000 per year between 1996 and 2000. These trends are consistent with those reported in the Corps of Engineers vessel trips data. In 2009, the number of transits dropped substantially, to less than 2,800, as a result of economic conditions.

The proposed terminal in Longview is projected to serve approximately 100 vessels per year. These 100 vessels represent 200 transits of the Columbia River Bar. These 200 transits represent a 7.1% increase over the depressed 2009 level, and 4.9% of the 1999 peak level.

Figure 4: Columbia River Piloted Bar Crossings



Source: Oregon Pilot Commission

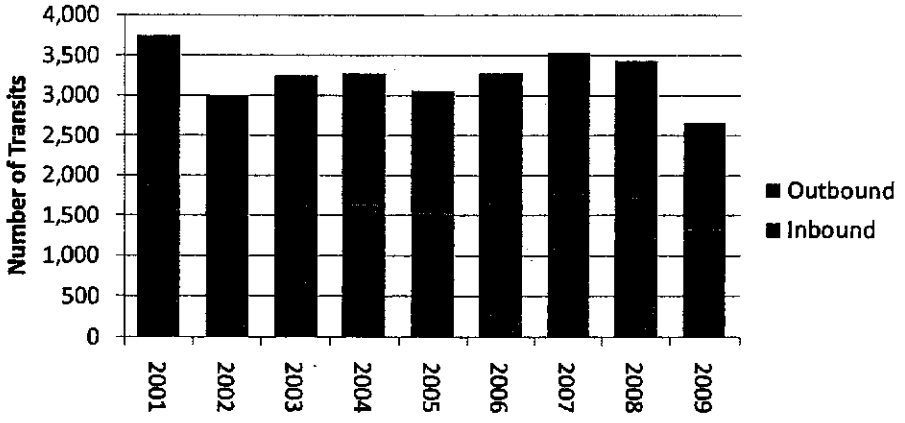
Columbia River Channel

The river pilots cover 105 nautical miles of the Columbia River from Astoria to the ports of Longview, Kalama, Vancouver and Portland. They also cover 13 miles of the Willamette River from its mouth to the seawall in downtown Portland. Between Astoria and the seawall in downtown Portland there are over 90 course changes, and the longest straight stretch of river is only about 2 miles in length.

Inbound vessels destined for all points upriver are boarded by a river pilot above the Astoria-Megler Bridge where they take over from the Columbia River Bar Pilots. A typical inbound transit will take between six and seven hours from when the river pilot boards in Astoria to when the ship arrives at the mouth of the Willamette River.

The trend in river channel pilots is similar to that of the bar pilots. With the exception of docks in Astoria, all other cargo terminals on the river require a ship to use a river pilot. The 200 vessel transits that the proposed facility may generate represent an increase of 5.3% to 7.5% over current traffic levels. (See Figure 5)

Figure 5: Columbia River Piloted Channel Transits



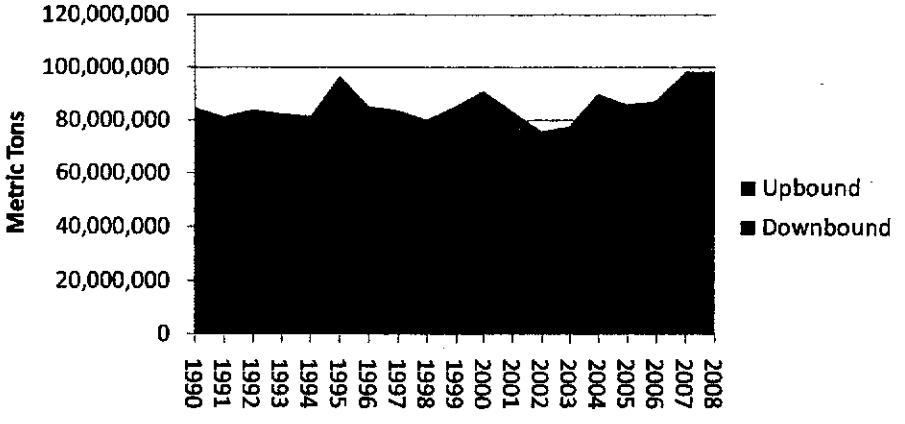
Source: Oregon Pilot Commission

Cargo Volume Trends

This section summarizes recent trends in cargo volumes on the Columbia River.

Over the past two decades the volume of cargo moving through the entrance to the Columbia River has grown by nearly 20%, and much of this growth was seen in the most recent years. (See Figure 6).

Figure 6: Cargo Volume at Columbia River Entrance



Source: U.S. Army Corps of Engineers Waterborne Commerce Statistics

Between 1990 and 1994 the annual volume of cargo averaged approximately 83 million metric tons, before jumping to 97 million tons during the record corn season in 1995. After 1995 the volume dropped back to 80 million in 1998, and then jumped back to 91 million in 2000. Following another decline in 2001 and 2002 the volume of cargo grew during most of the years between 2002 and 2008. The volumes of cargo moved through the Columbia River entrance in both 2007 and 2008 were the highest in the past two decades. U.S. Army Corps of Engineers Waterborne Commerce Statistics data is not yet available at the port level for 2009.

Downbound, or export, cargo has typically accounted for 75% to 80% of the total volume moved. With the exception of 1995, the years between 1990 and 2002 generally saw a decline in export volumes, due in large part to the shrinking forest products industry. Between 2002 and 2008, however, the volume of exports grew by more than 40%, largely due to increasing volumes of grain.

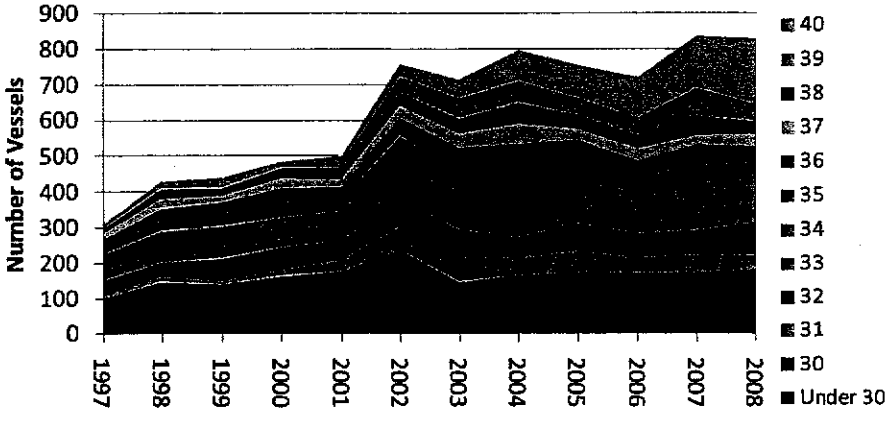
In contrast to downbound movements, inbound movements grew throughout the 1990's. This growth was especially strong from 1997 through 2000, when inbound volume grew from 19.5 million metric tons to 31.8 million metric tons. The recession of 2001-2002 quickly reversed this trend, and by 2003 inbound volume had dropped to 21.1 million metric tons. In both 2006 and 2007 inbound volume grew back to more than 27 million metric tons, but then dropped again due to the current recession.

Trends in Ship Size

The growth in cargo volume over the past decade has not been accompanied by a growth in ship movements, which indicates that the average load per ship has grown. There are several reasons for this, including: 1) the same ships now carry larger loads, and 2) larger ships are being used. Both of these are trends are explored below.

First, it is likely that the same ships are now carrying larger loads, due to the deepening of the Columbia River Channel. This project to deepen the channel from 40 feet to 43 feet began in 2005, and is now essentially complete. Even though the project has taken several years to complete, shippers began to take advantage of the work done to date as early as 2005. As illustrated in Figure 7, the number of outbound bulk vessels sailing with a draft of 40 feet grew substantially between 2005 and 2008, the last year for which data is available.

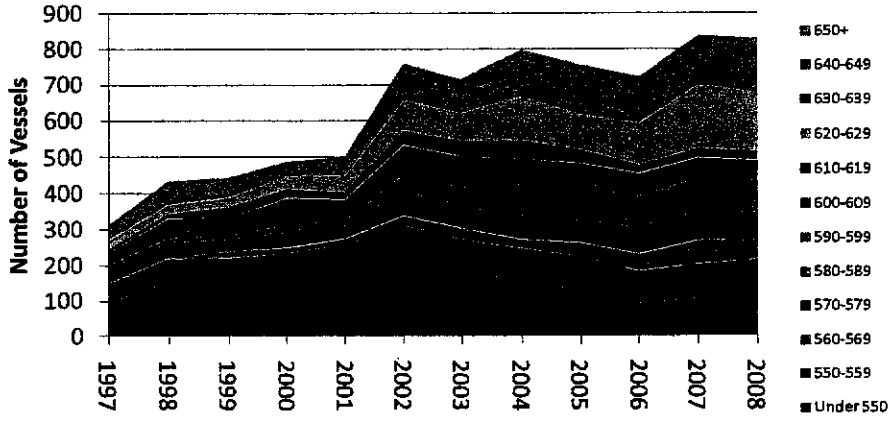
Figure 7: Outbound Draft (feet) of Bulk Vessels on Columbia River



Source: US Army Corps of Engineers Vessel Entrances and Clearances

Second, it is also clear that vessels are getting larger. As illustrated in Figure 8, bulk vessels 600 feet or longer accounted for just one-third of outbound ships in 1997, a proportion that held steady through 2001. In 2002 the number of bulk vessels 600 feet or longer began to grow, and by 2007 and 2008 this type of ship accounted for 46% of outbound bulk ships.

Figure 8: Length (feet) of Outbound Bulk Vessels on Columbia River



Source: US Army Corps of Engineers Vessel Entrances and Clearances, Clarkson Data

Impact Assessment

Areas of Potential Congestion

Based on conversations with maritime industry personnel, there appear to be three areas in which congestion could potentially occur:

- In the river channel,
- Crossing the Columbia River Bar, and
- At anchorages.

The potential for each of these is discussed below.

Impact on Congestion at Columbia River Bar.

Between 1996 and 2009 the Columbia Bar Pilots handled an average of between 7.6 and 11.3 vessels per day. With the addition of the 200 vessels from the proposed terminal, this would increase to between 8.2 and 11.8 vessels per day, or slightly more than one-half vessel per day.

A typical transit of the bar takes 1.5 hours. The bar pilots typically have eight pilots available at any time, so one pilot can handle multiple transits in a day. The addition of one-half vessel per day is well within the capacity of the bar pilots.

The existing number of transits also does not constrain the channel over the bar. Even at the potential level of 11.8 ships per day, each ship would have two hours to transit the channel. Since the channel is not limited to a single vessel at a time, the anticipated level of traffic is not an issue.

Impact on Congestion in the Columbia River Channel.

Between 2001 and 2009 the Columbia River Pilots handled an average of between 7.3 and 10.3 vessels per day. With the addition of the 200 vessels from the proposed terminal, this would increase to between 7.9 and 10.8 vessels per day, or an increase of slightly more than one-half vessel per day.

There are currently 42 river pilots, and there a typically 20 available on any day. With an average transit time of six to eight hours, pilots typically handle one move per day. The projected level of 10.8 vessels per day is well within the capacity of the river pilots.

In terms of physical constraints, the Port of Longview is 66 river miles from the Columbia River Bar, and approximately 50 miles from Astoria. With an average of less than six upbound and six downbound transits per day, there is little congestion in the channel.

This conclusion was confirmed in conversation with personnel from the U.S. Coast Guard, who stated that there is no limit to the number ships that can use the channel. We interpret this to mean that the potential increase in the number of ships associated with this project will not create a constraint to the system.

Impact at Anchorages

According to conversations with the Columbia River pilots, the primary areas with the potential to see congestion are at the designated anchorages, which are placed in selected stretches of river by the Coast

Guard for anchorage. The majority of these anchorage areas do not provide buoys for tying the stern of vessels, and ship personnel must be vigilant to set anchor keeping in mind the potential for the vessel to swing into other vessels, the shoreline, and shallow water. Table 1 presents a list designated anchorages, arranged from Astoria upriver to Vancouver.

Table 1: Capacity of Designated Anchorages

Designated Anchorage	River Mile Range	Length of Area (Miles)	Normal Capacity
Astoria North Anchorage	14.0 – 17.8	2.5	6
Astoria South Anchorage	15.0 – 18.2	2.75	4
Longview Anchorage	64.0 – 66.0	1.5	5
Cottonwood Island Anchorage	66.7 – 71.2	4.5	13
Kalama Anchorage	73.2 – 76.2	3.0	6
Woodland Anchorage	83.6 – 84.3	0.75	3
Henrici Bar Anchorage	91.6 – 93.9	2.3	8
Lower Vancouver Anchorage	96.2 – 101.0	4.0	14
Kelley Point Anchorage	101.6 – 102.0	0.5	1
Upper Vancouver Anchorage	102.6 – 105.2	2.6	7
Total			67

Source: Columbia River Anchorage Guidelines

The two anchorages closest to Longview are the Longview Anchorage and the Cottonwood Island Anchorage. The Longview Anchorage is 1.5 miles long, and is located downstream of the Longview Bridge. The Cottonwood Island Anchorage is located upstream of the bridge, and extends for 4.5 miles. Under normal conditions the combined capacity of the two anchorages is 18 vessels. Both of these anchorages are normally limited to vessels less than 650 in length.

Anchoring guidelines for both the Longview and Cottonwood Island anchorage state that vessels are normally anchored facing upstream, but can be expected to swing on the tide during low water conditions and on the wind in slack water conditions.

Vessels that are not operated on fixed schedules often arrive at port before there is room to tie up at a terminal, in which case they must drop anchor to await their turn at the terminal. Most of the cargoes handled at terminals in the Longview area (including Longview, Kalama, and St. Helens) handle bulk and neo-bulk terminals such as grain, gypsum, logs, steel, wind turbine components, and others. The ships that handle these types of cargoes are typically not operated on fixed schedules, and as a result they must often wait at anchor.

The new grain terminal under construction at the Port of Longview is likely to increase the usage of the local anchorages. This new terminal is currently projected to export as much as 8 million tons of grain per year. At a projected average load of 40,000 tons, the number of ships calling at the terminal could average 200 per year. This number of ships makes it likely that one or more will be at anchorage while another is loading.

The ships calling at the proposed coal terminal will supply long-term contracts, and are anticipated to run on relatively regular schedules. This should limit the number of times and the amount of time vessels

must anchor. However, the terminal will likely generate some increase in the usage of the designated anchorages.

The Corps of Engineers is currently assessing the need for additional mooring buoys on the Columbia River, especially in the Longview area. These mooring buoys allow ships to tie off at the stern, preventing them from swinging at anchor. This decreases the amount of room need to tie up a ship. These buoys typically cost $0.5 million each to install, with the cost split between the Corps of Engineers and local sponsors. The addition of several buoys in the Longview area will likely mitigate the increased demand for moorage generated by the new Longview grain terminal and the proposed coal terminal.

Conclusion

The additional vessel traffic generated by the proposed coal terminal should not cause congestion in the Columbia River Channel or at the Columbia River Bar. The proposed terminal may increase the demand for anchorage in the Longview area, but this increased demand for anchorage should be mitigated with the installation of mooring buoys.

THIS IS THE BEST

COPY THAT CAN

BE OBTAINED AS

THE ORIGINAL IS

OF A POOR

QUALITY

DOCUMENT IMAGED AS PRESENTED

WARNING: Once printed, this document is an uncontrolled copy

Australian Securities & Investments Commission

AUSTRALIAN SECURITIES & INVESTMENTS COMMISSION
028629780

Form 388
Corporations Act 2001
294, 294B, 295, 298-301, 307, 308, 319, 321, 322
Corporations Regulations
1.0.08, 2M.3.01, 2M.3.03

PAID

Copy of financial statements and reports

If there is insufficient space in any section of the form, you may photocopy the relevant page(s) and submit as part of this lodgement

Company/scheme details

Company/scheme name
AMBRE ENERGY LIMITED

ACN/~~ARSN/FIN/ABN~~
114 812 074

Lodgement details

An image of this form will be available as part of the public register.

Who should ASIC contact if there is a query about this form?

ASIC registered agent number (if applicable)

Firm/organisation
AMBRE ENERGY LIMITED

Contact name/position description
NEIL McGREGOR / COMPANY SECRETARY

Telephone number (during business hours)
(07) 3089 9191

Email address (optional)
n.mcgregor@ambreenergy.com

Postal address
GPO Box 3288 ,

Suburb/City
BRISBANE

State/Territory
QLD

Postcode
4001

Australian Securities and Investments Commission
RCVD
14 OCT 2013
BRISBANE
Service Centre

1 Reason for lodgement of statement and reports

Tick appropriate box.

- [x] A public company or a disclosing entity which is not a registered scheme or prescribed interest undertaking (A)

See Guide for definition of Tier 2 public company limited by guarantee

- [ ] A Tier 2 public company limited by guarantee (L)
- [ ] A registered scheme (B)
- [ ] Amendment of financial statements or directors' report (company) (C)
- [ ] Amendment of financial statements or directors' report (registered scheme) (D)

See Guide for definition of large proprietary company

- [ ] A large proprietary company that is not a disclosing entity (H)

See Guide for definition of small proprietary company

- [ ] A small proprietary company that is controlled by a foreign company for all or part of the period and where the company's profit or loss for the period is not covered by the statements lodged with ASIC by a registered foreign company, company, registered scheme, or disclosing entity (I)
- [ ] A small proprietary company, or a small company limited by guarantee that is requested by ASIC to prepare and lodge statements and reports (J)
- [ ] A prescribed interest undertaking that is a disclosing entity (K)

Dates on which financial year begins and ends

Financial year begins
0 1 / 0 7 / 1 2
[D D] [M M] [Y Y]

to

Financial year ends
3 1 / 1 2 / 1 2
[D D] [M M] [Y Y]

2 Details of large proprietary company

See Guide for definition of large and small proprietary companies.

If the company is a large proprietary company that is not a disclosing entity, please complete the following information as at the end of the financial year for which the financial statements relate:

A What is the consolidated revenue of the large proprietary company and the entities that it controls?

B What is the value of the consolidated gross assets of the large proprietary company and the entities that it controls?

C How many employees are employed by the large proprietary company and the entities that it controls?

D How many members does the large proprietary company have?

3 Auditor's or reviewer's report

Tick one box and complete relevant section(s)

Were the financial statements audited or reviewed?

- [x] Audited - complete **B** only
- [ ] Reviewed - complete **A** and **B**
  - [ ] No
    - If no, is there a class or other order exemption current for audit/review relief?
      - [ ] Yes
      - [ ] No

A. Reviewed

Is the reviewer a registered company auditor, or member of The Institute of Chartered Accountants in Australia, CPA Australia Limited, or Institute of Public Accountants and holds a practising certificate issued by one of those bodies?

- [ ] Yes
- [ ] No

B. Audited or Reviewed

Is the opinion/conclusion in the report:

Modified? (The opinion/conclusion in the report is qualified, adverse or disclaimed)

- [ ] Yes
- [x] No

Does the report contain an Emphasis of Matter and/or Other Matter paragraph?

- [x] Yes
- [ ] No

4 Details of current auditor or auditors

Notes:

- Registered schemes must advise ASIC of the appointment of an auditor on a Form 5137 *Appointment of scheme auditor* within 14 days of the appointment of the auditor.
- A public company limited by guarantee may, in some circumstances, have their accounts reviewed. These companies are still required to have an auditor and these details must be provided.

Auditor registration number *(for individual auditor or authorised audit company)*

Family name

Given name

or

Company name

ACN/ABN

or

Firm name (if applicable)

GRANT THORNTON AUDIT PTY LTD

Office, unit, level

LEVEL 17

Street number and Street name

383 KENT ST

Suburb/City

SYDNEY

State/Territory

NSW

Postcode

2000

Country (if not Australia)

Date of appointment

18/11/09

[D D] [M M] [Y Y]

A company may have two appointed auditors, provided that both auditors were appointed on the same date. Otherwise, an appointed auditor must resign, be removed or otherwise ceased before a subsequent appointment may be made.

Auditor registration number *(for individual auditor or authorised audit company)*

Family name

Given name

or

Company name

ACN/ABN

or

Firm name (if applicable)

Office, unit, level

Street number and Street name

Suburb/City

State/Territory

Postcode

Country (if not Australia

5 Statements and reports to be attached to this form

Financial statements for the year (as required by s295(2) and accounting standards)

- Statement of comprehensive income, may also include a separate income statement for the year
- Statement of financial position as at the end of the year
- Statement of cash flows for the year
- Statement of changes in equity.

OR

If required by accounting standards — the consolidated statements of comprehensive income/income statement, financial position, cash flows and changes in equity.

Notes to financial statements (see s295(3))

- Disclosures required by the regulations
- Notes required by the accounting standards
- Any other information necessary to give a true and fair view (see s297).

The signed directors' declaration about the statements and notes (see s295(4)).

The signed directors' report for the year, including the copy of the auditor's or reviewer's independence declaration (see s298 to s300A).

Signed auditor's report or, where applicable, reviewer's report (see s301, s307 to s308).

Concise report (if any) (see s319).

Signature

See Guide for details of signatory.

I certify that the attached documents marked (A) are a true copy of the original reports required to be lodged under s319 of the *Corporations Act 2001*.

Name

NEIL M'GREGOR

Signature

Capacity

☐ Director

☑ Company secretary

Date signed

14 / 10 / 13

[D D] / [M M] / [Y Y]

Lodgement

Send completed and signed forms to:
Australian Securities and Investments Commission,
PO Box 4000, Gippsland Mail Centre VIC 3841.

Or lodge the form electronically by:

- visiting the ASIC website www.asic.gov.au
- using Standard Business Reporting enabled software. See www.sbr.gov.au for more details.

For more information

Web www.asic.gov.au
Need help? www.asic.gov.au/question
Telephone 1300 300 630

AMBRE ENERGY LIMITED
ACN 114812074

ANNEXURE A

THIS IS ANNEXURE A OF 84 PAGES REFERRED TO IN FORM 388 - COPY OF FINANCIAL STATEMENTS AND REPORTS.

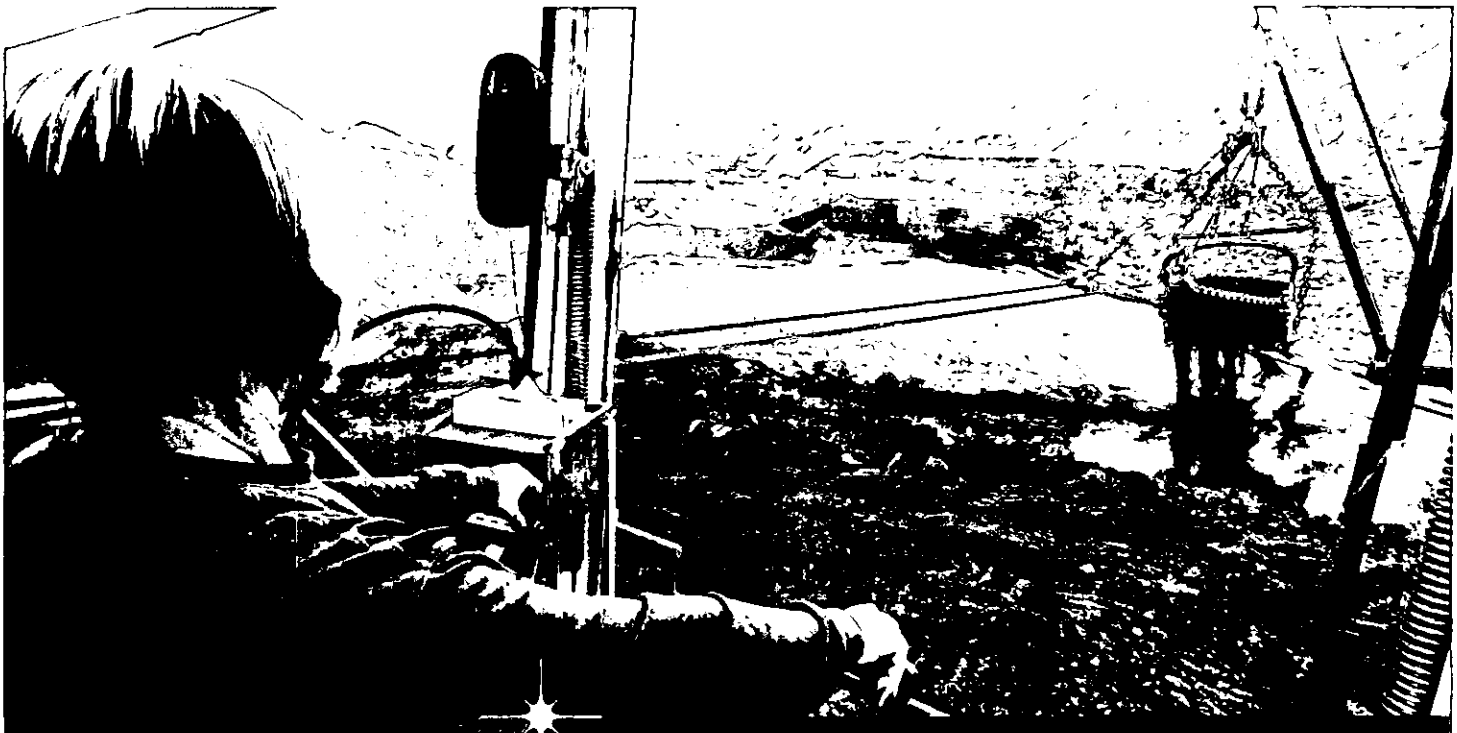
NEIL McGREGOR
COMPANY SECRETARY
14 OCTOBER 2013

directors' and financial report

for the period 1 July 2012 to 31 December 2012

Amber LPG LP No1

amber energy



About Ambre Energy

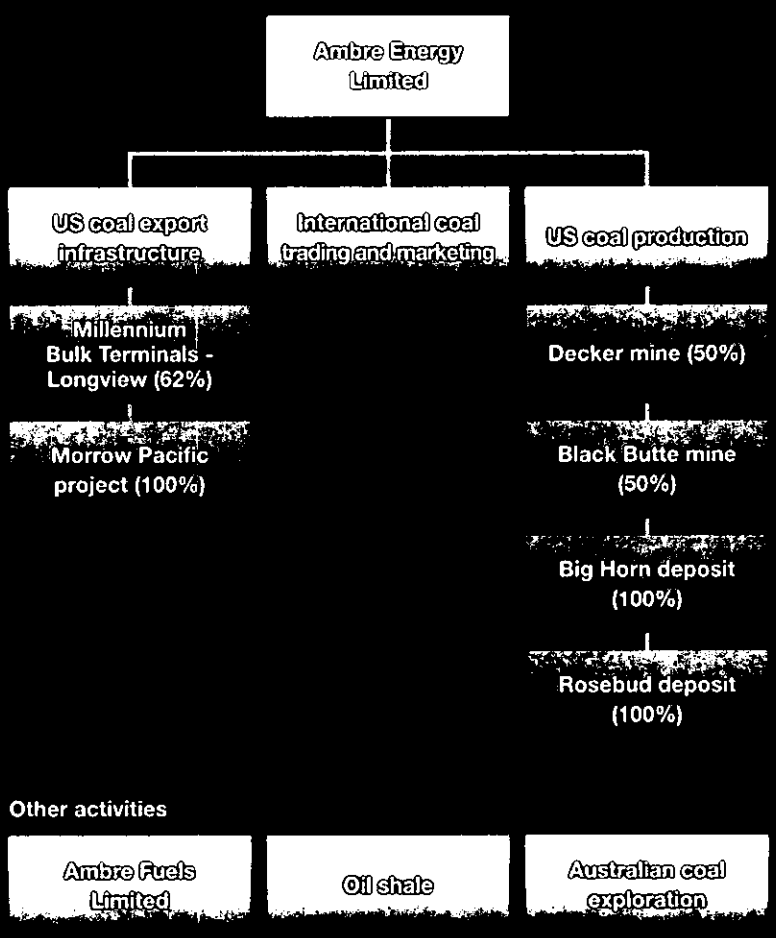
Ambre Energy Limited is an unlisted public company headquartered in Brisbane, Australia with coal export infrastructure developments and mining assets located in the USA.

The company's jointly owned western US coal mines currently produce more than 3 million metric tons of thermal coal per year, with output sold domestically to power utilities.

Ambre is planning to extend the scale of its coal mining operations and commence the export of coal to power utilities located in Asia through its own port facilities in the US Pacific Northwest: Millennium Bulk Terminals (MBT) in Washington State (62% owned by Ambre), and the Morrow Pacific project (MPP) at Port of Morrow and Port Westward in Oregon (100% owned by Ambre).

The company is also planning to demerge its Ambre Fuels subsidiary to allow both Ambre Fuels and its parent Ambre Energy to focus on their respective core business.

Ambre Energy business structure



CONTENTS

Directors' report **4**

Auditor's independence declaration **19**

Financial report **20**

Consolidated statement of comprehensive income 21

Consolidated statement of financial position 22

Consolidated statement of cash flows 23

Consolidated statement of changes in equity 24

Notes to the financial statements 25

Directors' declaration **78**

Independent auditor's report **79**

Corporate directory **84**

DIRECTORS' REPORT

Ambre Energy Limited, in December 2012, changed its financial year end from 30 June to 31 December. Due to the change of year end, Ambre Energy is required to report on the six month period 1 July 2012 to 31 December 2012 (the period). The annual report subsequent to this report will account for the year 1 January 2013 to 31 December 2013.

The annual report for the financial year ended 30 June 2012 was signed on behalf of directors on 12 December 2012. Consequently, certain information in this report overlaps with information in the annual report for the financial year ended 30 June 2012.

The directors of Ambre Energy Limited present their report together with the financial statements of the consolidated group, being Ambre Energy Limited (the parent) and its controlled entities (the group), for the period 1 July 2012 to 31 December 2012.

Directors

The following persons were directors of the parent entity during the whole of the period and up to the date of this report, unless otherwise noted:

Terry O'Reilly BCom, MBA, MApplied Finance, CPA, FAICD, FAIM
Chairman
Appointed: 23 January 2012
Chairman of Nomination and Remuneration Committee
Member of Audit and Risk Management Committee

Terry O'Reilly has extensive board, chief executive and senior executive experience after working principally in the resources, energy and manufacturing sectors in Australia and internationally.

Terry has served as managing director of: Conzinc Asia, based in Singapore; Pacific Coal, based in Brisbane; and Coal and Allied Industries, based in Sydney. He has also served on the boards of the Port Waratah and Dalrymple Bay coal terminals.

With a commerce degree and MBA from Melbourne University, and a Masters in Applied Finance from Macquarie University, Terry is a Certified Practicing Accountant, a Fellow of the Australian Institute of Company Directors and a Fellow of the Australian Institute of Management.

Terry has served as Chairman of the Australian Coal Association, Queensland Coal Operators, the NSW Minerals Council and the World Coal Institute Promotions Committee, and was President of the Australia Philippines Business Council.

On the board of Macarthur Coal from October 2008 to October 2011, he served on the Audit and Special Projects committees and as Chairman of the Nomination and Remuneration Committee. Terry is a non-executive director with Thomas & Coffey Limited and Bandanna Energy Limited.

Edek Choros MSc (Geol), BE (Mining)
Chief Executive Officer and Managing Director
Appointed: 17 June 2005

Edek Choros founded Ambre Energy in June 2005. With more than 25 years of geological and engineering experience, Edek has demonstrated an innate ability to identify and develop new project opportunities.

Before forming Ambre Energy, Edek established and sold the Millennium Coal Project in Queensland's Bowen Basin. His experience developing innovative and profitable ventures ensures Ambre Energy continues to attract investment and international interest.

Edek gained his qualifications as a geologist and mining engineer in Krakow, Poland before moving to Australia in 1989. He worked for the Electricity Trust of South Australia and as a private consultant in the coal mining industry before establishing Millennium Coal.

Michael Mewing BEc

Executive Director, Coal Business Development and Marketing

Appointed: 14 April 2008

Michael Mewing joined the board of Ambre Energy in April 2008 as Non-Executive Chairman and assumed a full-time executive role in September 2008.

Michael was President of Ambre Energy's US subsidiary, Ambre Energy North America, from December 2008 to December 2010 and is now an executive director based in Brisbane. His primary responsibilities include strategic development and coal trading and marketing.

Instrumental in progressing Ambre Energy's US acquisition and development program, Michael joined Ambre Energy with 30 years of experience in the international energy field, working in New South Wales, Queensland, Japan, Indonesia and the USA. He has held commercial, marketing and business development roles with BP Oil, BP Coal, Rio Tinto, PT Berau Coal and Millennium Coal.

Michael van Baarle BCom, LLB

Executive Director, Corporate Development

Appointed: 10 April 2006

Michael van Baarle has been an executive director of Ambre Energy Limited since 2006, shortly after the company's inception. In that time, he has assisted with business and corporate development, which has seen Ambre grow from a small coal exploration and technology business starting out in Brisbane to a global resources group that employs and manages over 300 personnel.

Michael's role has included raising capital in Australia and internationally, attending to the legal and corporate requirements involved in various acquisitions, including US technology and mining companies and port assets, managing communication with shareholders and other stakeholders, and overseeing corporate development generally. Prior to this time, Michael was a solicitor for 20 years, mainly in private practice in Brisbane. He is a graduate of the University of Queensland with degrees in law and commerce.

David Usasz BCom, FCA

Non-Executive Director

Appointed: 1 February 2009

Chairman of Audit and Risk Management Committee

Member of Nomination and Remuneration Committee

David Usasz is an expert in financial and strategic affairs with 31 years of service at PricewaterhouseCoopers, including 20 years as a partner. Throughout his career, David has advised businesses in both government and the private sector on management issues around success and growth.

David gained extensive experience in corporate finance with a focus on tax and mergers and acquisitions. Three years working in Hong Kong, coupled with extensive travel to Japan, Taiwan, Jakarta and Singapore, gives David a strong understanding of Asian markets and investors.

David is currently a non-executive director of the publicly listed corporation Cromwell Group and of Queensland owned corporation Queensland Investment Corporation Limited. He was Chairman of Queensland Mining Corporation (2007-2013) and director of unlisted company URBIS Pty Ltd (2008–2013).

David's diversified interests and networks are boosted by former directorship of the Australian Rugby Union Limited (2005–2007) and honorary positions held with the Princess Alexandra Hospital Research Foundation and the Australia Taiwan Business Council.

Jayson Newitt BSc, MBA

Non-Executive Director

Appointed: 1 December 2010

Member of Nomination and Remuneration Committee

Jayson Newitt holds a Bachelor of Science from Brigham Young University and received a Master of Business Administration degree from the Marriott School of Management (BYU).

Jayson is co-founder and managing director of Ritchie Opportunity Fund I, a private equity and investment fund with investment allocations in energy, manufacturing and healthcare, based in Salt Lake City, Utah. He is also a principal of The Ritchie Group, a private equity company with investments and projects across a diversified industry base, across two countries and across nine US states.

Jayson has substantial experience in project management, real estate, healthcare and private equity projects as a manager, limited partner, investor and board member.

Dr Ross Bhappu BSc, MSc, PhD (Mineral Econ.)

Non-Executive Director

Appointed: 16 November 2011

Member of Audit and Risk Management Committee

Since 2005, Ross has been a partner with Resource Capital Funds, a series of private equity funds investing in the mining and minerals industry. From 2001 until 2005, he was vice-president/principal of Resource Capital Funds.

Since 2010, Ross has served as Chairman of the board of Molycorp Inc. and since 2008 has been on the board of directors of EMED Mining Public Ltd, a copper mining company. He has been a director of Traxys SA, a metal trading and distribution company, since 2007.

From July 2002 until November 2007, Ross served on the board of directors of copper mining company Constellation Copper Corporation, and from November 2005 until September 2006 on the board of gold mining company Anglo Asian Mining.

Ross has experience in constructing and operating complex mining and processing operations, as well as mining-related merger and acquisition activities. He has worked for Newmont Mining Corporation, GTN Copper Corporation and Cyprus Minerals Company.

Company Secretary

Neil McGregor BMus, MMus, MBA

Appointed: 15 March 2012

Neil McGregor joined Ambre Energy in August 2008. He has held the position of Company Secretary for Ambre Fuels Limited since September 2011 and was appointed as Company Secretary and GM Corporate Communications for Ambre Energy Limited in March 2012. Neil holds a Masters of Business Administration and is currently studying for a Graduate Diploma in Applied Corporate Governance. Prior to joining Ambre Energy, Neil was Director of Bands/Head of Woodwind at a Brisbane private school and enjoyed an active performance schedule as a professional clarinettist with symphony orchestras in Australia, New Zealand and the USA for 14 years.

PRINCIPAL ACTIVITIES

Ambre Energy is engaged in the following principal activities:

Export infrastructure

a) Jointly with partner Arch Coal, Inc., operating and rehabilitating a bulk commodities terminal, Millennium Bulk Terminals-Longview, on the Columbia River in Washington State, USA, and developing an expansion of the terminal to handle up to 44 million metric tons of coal per year for delivery into the international seaborne market

b) Developing a proposed coal barging and transloading project known as the Morrow Pacific project on the Columbia River in Oregon, USA, with the capacity to handle up to 8 million metric tons of coal per year for delivery into the international seaborne market

International coal marketing and trading

a) Developing an international coal marketing business to sell US coal into the seaborne market, principally to service North Asian power utilities in South Korea, Japan and Taiwan

Coal mining

a) Operating the Decker coal mine in south-east Montana, USA, on behalf of itself and joint venture partner, Cloud Peak Energy, and selling the coal to domestic US power utilities

b) Operating the Black Butte coal mine in south-west Wyoming, USA on behalf of itself and joint venture partner, Anadarko Petroleum, and selling the coal to domestic US power utilities

Alternative fuels

a) Developing processing facilities in the USA for the production of liquid fuels and chemicals from coal.

REVIEW OF OPERATIONS AND ASSETS

The following review of operations and assets provides further detail on the separate businesses in the Ambre Energy group.

Principal activities

US bulk commodities terminal operation and coal export infrastructure development

Ambre Energy's infrastructure business is responsible for operating and implementing expansion projects at the jointly-owned Millennium Bulk Terminals (Washington State, USA), and the wholly-owned Morrow Pacific project (Oregon, USA).

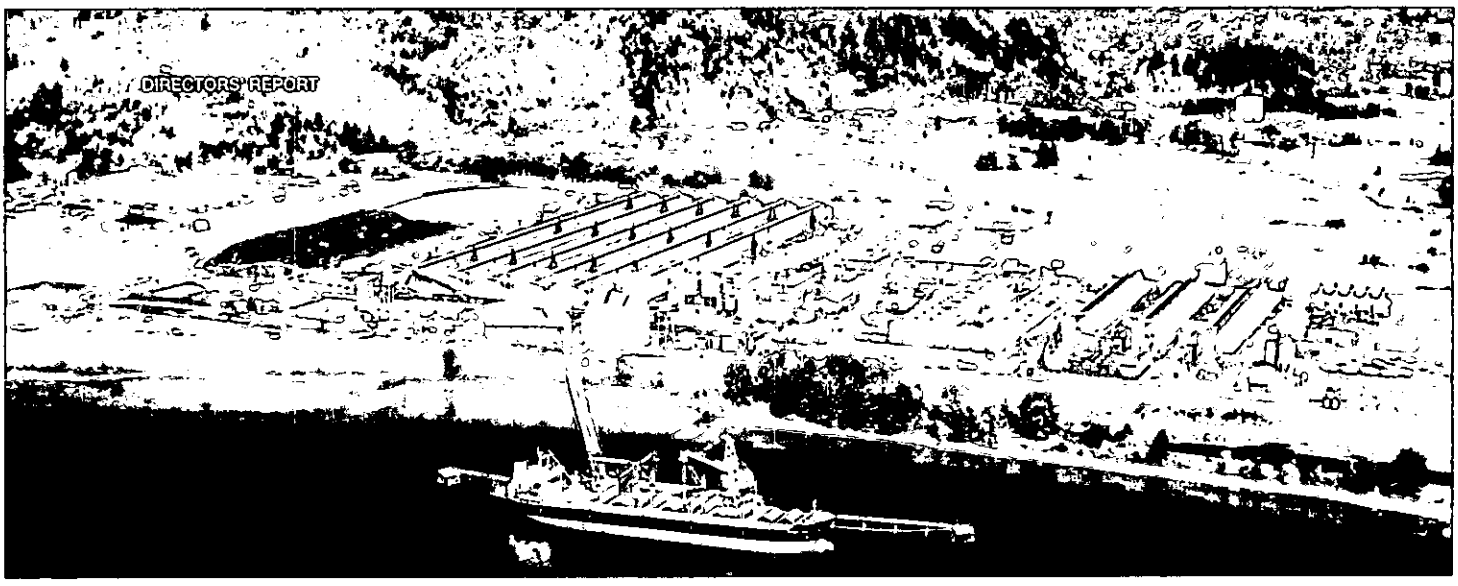
Millennium Bulk Terminals-Longview

Millennium Bulk Terminals-Longview (MBTL) is a bulk materials port on the Columbia River in Washington State, USA.

Ambre Energy owns 62 per cent of MBTL, with the remaining 38 per cent owned by Arch Coal, Inc. The site operated as an aluminum smelter from 1941 through 2000. Since 1968, the dock has been used to import alumina and materials for smelting.

A significant works program to maintain and upgrade the existing facilities is underway, including clean-up projects related to decades of aluminum smelting. The works have improved the safety and condition of the site for staff while addressing government requirements and community expectations. On 16 February 2012, Barlow Point Land Company, LLC, a State of Washington limited liability company wholly owned by MBTL, acquired the 20 acre Barlow Point property adjacent to the site for future environmental mitigation.

Since the company commenced operations in January 2011, MBTL has registered one loss time injury and no environmental citations. MBTL annually handles approximately 300,000 to 350,000 metric tons of alumina for Alcoa and 100,000 metric tons of coal for the neighbouring Weyerhaeuser paper mill. The company employed an average of 35 people on site during the reporting period, led by Chief Executive Officer, Ken Miller.



MBTL submitted permit applications on 23 February 2012 seeking approval to build a coal export facility at its Longview site. A contractor assigned to complete the Environmental Impact Statement for the proposed facility was appointed in March 2013. If approved, the US$450 million first stage will result in a coal export terminal with approximately 25 million metric tons per annum (Mtpa) capacity. The second stage, projected to cost US$200 million, will take total export capacity to approximately 44Mtpa.

The proposed new terminal facilities will include a rail yard to house trains arriving from western US coal mines, and two new docks to create a modern and efficient port capable of receiving, stockpiling, blending and loading coal for export. At full build-out, two vessels per day are anticipated to depart for offshore markets.

Morrow Pacific project

The Morrow Pacific project is a proposed coal barging and transshipping operation involving two industrial sites on the Columbia River, in Oregon, USA.

At the publicly owned Port of Morrow located 272 miles up the Columbia River near Boardman, Oregon, a wholly owned Ambre Energy subsidiary will construct the Coyote Island Terminal. The terminal will be capable of unloading coal from incoming trains using the Port of Morrow's existing rail loop. The coal will be stored in covered warehouses before being barged 219 miles downriver to a second site at Port Westward.

This site is an existing dock at the Port Westward Industrial Park, also located on the Oregon side of the Columbia River and approximately 50 miles from the Pacific Ocean. It is capable of receiving ocean-going vessels up to Panamax class. The coal in the barges arriving from Coyote Island Terminal will be transloaded directly onto ships berthed at the Port Westward dock. The ships will be loaded via a state-of-the-art, fully enclosed, floating transloading facility.

The Union Pacific transcontinental rail line, also historically used by BNSF Railway, provides the Port of Morrow with a rail link to coal mines in Montana, Wyoming, Colorado and Utah, including Ambre Energy's co-owned mining operations at Decker and Black Butte.

Permits to build a barge loading terminal at the Port of Morrow were lodged in February 2012 and in May 2012, the United States Army Corps of Engineers (USACE) completed a 60 day comment period. In August 2012, Anderson Perry & Associates, Inc., a civil engineering, surveying and natural resource firm completed an Environmental Review (ER) of the Morrow Pacific project. The ER looks at the potential environmental, economic and social impact that the project would have regionally. The ER was submitted to USACE as part of the permitting process.

In September 2012, USACE determined that the project at the Port of Morrow would be subject to an Environmental Assessment. In May 2013, Oregon's Department of Environmental Quality issued draft air, stormwater and process water permits, followed by a public comment period which closed on 12 August 2013. These permits, if granted, would allow construction to begin on the Coyote Island Terminal.

Initially, Ambre Energy anticipates shipping 3.5 million metric tons of coal per year from 2015 to countries such as South Korea, Japan and Taiwan. Full operational and permitted capacity is expected to be 8 million metric tons annually, subject to necessary approvals.

International coal marketing and trading

Ambre Energy's international coal marketing and trading business is aiming to source, market and sell high quality US thermal coal to customers predominantly in the Asia-Pacific market.

Total coal demand from Asia until 2030 is forecast to grow at 6.7 per cent per year – 1.3 billion additional metric tons of coal. The US is currently a minor supplier of thermal coal into the Pacific export market, accounting for only 8 million of Asia's 650 million metric tons of thermal coal demand.

As export facilities are commissioned on the US north-west coast, western US coal producers will increase their share of the Asian market. Ambre Energy believes its port developments, the Morrow Pacific project and Millennium Bulk Terminals-Longview, will be among the first projects to be permitted and developed.

Ambre Energy's international coal marketing and trading business will optimise sales from its current operations and underpin the potential development of the company's new projects. The marketing business will also seek to buy coal from other western US producers and export through Ambre Energy's wholly and jointly owned export infrastructure, once commissioned. The primary markets will be South Korea, Japan and Taiwan – the markets geographically closest to the US west coast.

New sales will build on Ambre Energy's current 10-year coal supply agreements with two South Korean companies: Korea South East Power Co. Ltd (KOSEP) and Korea Southern Power Co. Ltd (KOSPO). In May 2012, KOSEP entered into an agreement to purchase up to three million metric tons of coal each year from Ambre Energy for 10 years and in June 2012, KOSPO agreed to purchase up to two million metric tons from Ambre Energy for 10 years. The agreements with KOSEP and KOSPO will commence from commissioning of Ambre Energy's first US coal export terminal.

Within the US, Ambre Energy's marketing focuses on expanding sales to current and new customers for its jointly held Decker and Black Butte mines.

US thermal coal production

In November 2011, through the purchase of a US company, KCP, Inc., Ambre Energy assumed the operation of, and acquired a 50 per cent ownership interest in, the Decker coal mine in Montana and the Black Butte coal mine in Wyoming, USA. The company also secured interests in two reclaimed Wyoming mines with significant remaining coal resources, Big Horn and Rosebud.

Ambre Energy's thermal coal production business fulfills operating and marketing responsibilities for the Decker and Black Butte mines, and is also responsible for investigating the viability of redeveloping the Big Horn and Rosebud deposits.

Decker coal mine

The Decker coal mine is in the northern Powder River Basin. Located within Montana's Big Horn County, the mine is divided into two areas – East Decker and West Decker – each with its own rail loadout facilities. The mine is serviced by BNSF Railway.

Since operations began in the 1970s, Decker has produced approximately 300 million metric tons of coal. Decker coal has the highest calorific value in the Powder River Basin (PRB) at 5000 Kcal/kg NAR, making it attractive for the export market as well as offering domestic users a quality premium to other PRB coals. Decker mine also has the shortest railing distance to Canadian and prospective US Pacific Northwest ports of all PRB mines.

Ambre Energy has operated the Decker mine since acquiring its 50% interest on 14 November 2011. In the period 1 July 2012 to 31 December 2012:

+ Decker had one lost time injury and zero significant environmental citations
+ Decker sold approximately 1.6 million metric tons of coal into the US domestic market, thereby achieving total sales for 2012 of 2.6 million metric tons
+ A new geological model for the Decker resource was completed, which has resulted in an improved mine plan and a better understanding of the extent of the resource
+ Ambre Energy was sued (on 9 July 2012) by its joint venture partner (a subsidiary of Cloud Peak Energy) in connection with, inter alia, the future plans for Decker mine, and Ambre Energy counterclaimed. As set out below, there was a subsequent agreement between the parties to resolve the dispute
+ Ambre Energy and Cloud Peak Energy (CPE) entered into a series of agreements on 5 December 2012 (through respective subsidiaries) whereby the parties would discontinue their lawsuits against each other, and Ambre Energy would purchase CPE's indirect 50% joint venture share in the Decker Coal Company and related assets, including entitlement to certain royalties payable by Decker.

On 28 August 2013, Ambre Energy and CPE announced jointly that the potential transaction related to the agreements reached in December 2012 has not been completed and is not expected to be completed in the foreseeable future. The timing of any potential closing is uncertain and will depend on Ambre Energy's ability to replace CPE's outstanding reclamation and lease bonds for the Decker Mine. The companies continue to be in discussions and have jointly dismissed the previously disclosed Decker litigation without prejudice to allow time for their ongoing discussions and evaluations. For further information, see Note 34 (a) in the financial statements.

Black Butte coal mine

Black Butte coal mine is in the Green River Basin in Sweetwater County, south-west Wyoming, USA. The mine is a 50/50 joint venture between Ambre Energy and Anadarko Petroleum Corporation (APC). As with the Decker mine, Ambre Energy operates the mine and is responsible for marketing.

Ambre Energy has operated the Black Butte mine since acquiring its 50% interest on 14 November 2011. During the period, one loss time injury and one citation has occurred.

The mine, a combination of dragline and truck and shovel stripping, is serviced by Union Pacific Railroad and the existing rail loop can support throughput of 14.5 million metric tons per annum. The mine targets production of approximately 3.6 million metric tons of coal each year and in the period 1 July 2012 to 31 December 2012, the mine sold approximately 1.2 metric tons, thereby achieving total sales for 2012 of 2.6 million metric tons. An average of 186 people were employed during the period.

Along with supplying the existing domestic market, Ambre Energy is working towards exporting coal from Black Butte to the international market.

Rosebud deposit

Rosebud coal mine – located north of Hanna, in the Hanna Basin, Carbon County, Wyoming – opened in 1955 and operated until the early 1990s. The mine produced approximately 2.7 million metric tons per year at the height of its productivity in the 1970s. Today, the mine is nearly fully reclaimed and no coal production occurs.

As with the Big Horn deposit, there are significant remaining resources available at Rosebud. Developing these deposits is a potential future option for Ambre Energy.

Big Horn deposit

Located in the Northern Powder River Basin in Sheridan County, Wyoming, a mine operated at the Big Horn site from 1944 until 2000, producing up to 4.1 million metric tons of coal per year at its peak.

While the Big Horn deposit is not currently being mined, it has significant remaining resources.

Additional Ambre Energy group activities

Ambre Fuels Limited

Ambre Fuels Limited, a wholly-owned subsidiary of Ambre Energy, is developing projects and technologies in Australia and the USA to convert coal into transport fuels. An independent board directs Ambre Fuels Limited.

Ambre Fuels has investigated sites in Queensland, Wyoming, Montana, Colorado and Texas to identify the location of the company's first coal-to-liquids project, while working with US research partners to investigate alternative methods for fuel production. At this stage, Wyoming is the most prospective location for the first project.

In Australia, while Ambre Fuels continues to maintain coal exploration permit EPC935 near Pittsworth, Queensland, there are no longer any immediate prospects for developing a project within the permit area. This will be reviewed periodically.

It is Ambre Energy's intention to demerge Ambre Fuels Limited and its subsidiaries from the Ambre Energy group at the earliest opportunity, subject to approval from shareholders and secured creditors. The demerger will provide the necessary independence for Ambre Fuels Limited to pursue its strategy to develop coal-to-liquids projects in North America and will allow Ambre Energy to dedicate its resources to the company's US coal export business.

Research and development

During the financial period, Ambre Fuels pursued the development and application of the following technologies:

+ Coal gasification to produce liquid fuels such as methanol, unleaded petrol, LPG and next-generation fuels such as DME
+ Catalyst for syngas conversion
+ Converting biomass and municipal waste to alternate fuels
+ Co-firing biomass and coal
+ Lignin-to-fuels conversion technologies
+ Coal liquefaction (dissolving coal).

Oil shale

Ambre Energy is the largest private owner of oil shale leases in Utah, USA, with 38,000 acres across 18 mineral leases and in-place resources of 8.7 billion metric tons containing 5.5 billion in-situ barrels of oil.

Approximately 1 billion in-situ barrels of this oil are contained in shale resources occurring at less than 500ft of cover, with the majority of near-surface resources well placed for surface mining techniques[1].

Australian coal exploration

Ambre Energy holds coal exploration permits in Queensland, located roughly between Millmerran, Pittsworth and Warwick.

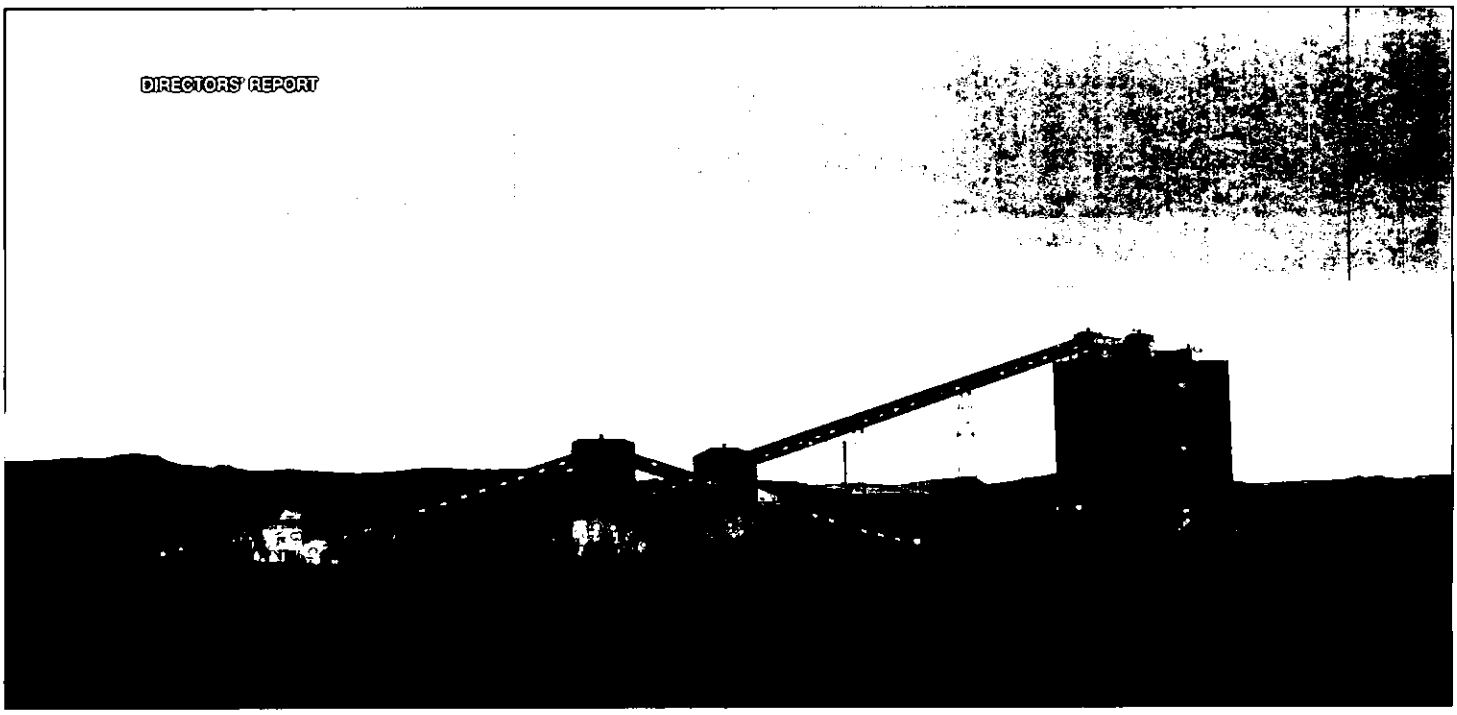
These exploration permits are located within the region currently under review as part of the Queensland Government's statutory regional planning process.

Due to uncertainty and in accordance with Australian accounting standards, Ambre Energy's coal exploration tenements were written down to zero value.

Operating results (Corporate and financial position)

The net accounting loss for the group for the period was $30,741,000 (Jun 2012: $62,759,000). Cash flow (negative) from operations was $17,644,000 (Jun 2012: $26,366,000).

1 Ambre Energy Oil Shale Resource Determination Report, Norwest Corporation, August 2011



SIGNIFICANT CHANGES IN THE STATE OF AFFAIRS

During the reporting period, the following significant changes in the state of affairs occurred:

+ Prior to the period, permit applications were lodged seeking approval to build a coal storage and barge loading terminal at the Port of Morrow, Oregon, as part of the Morrow Pacific project. In August 2012, Ambre Energy subsidiary Coyote Island Terminal, LLC (CIT) submitted an Environmental Review to USACE which investigates the potential environmental, economic and social impact that the coal barging terminal would have on the Port of Morrow region. In September 2012, CIT was informed that USACE will move forward with an Environmental Assessment of works proposed at the Port of Morrow.

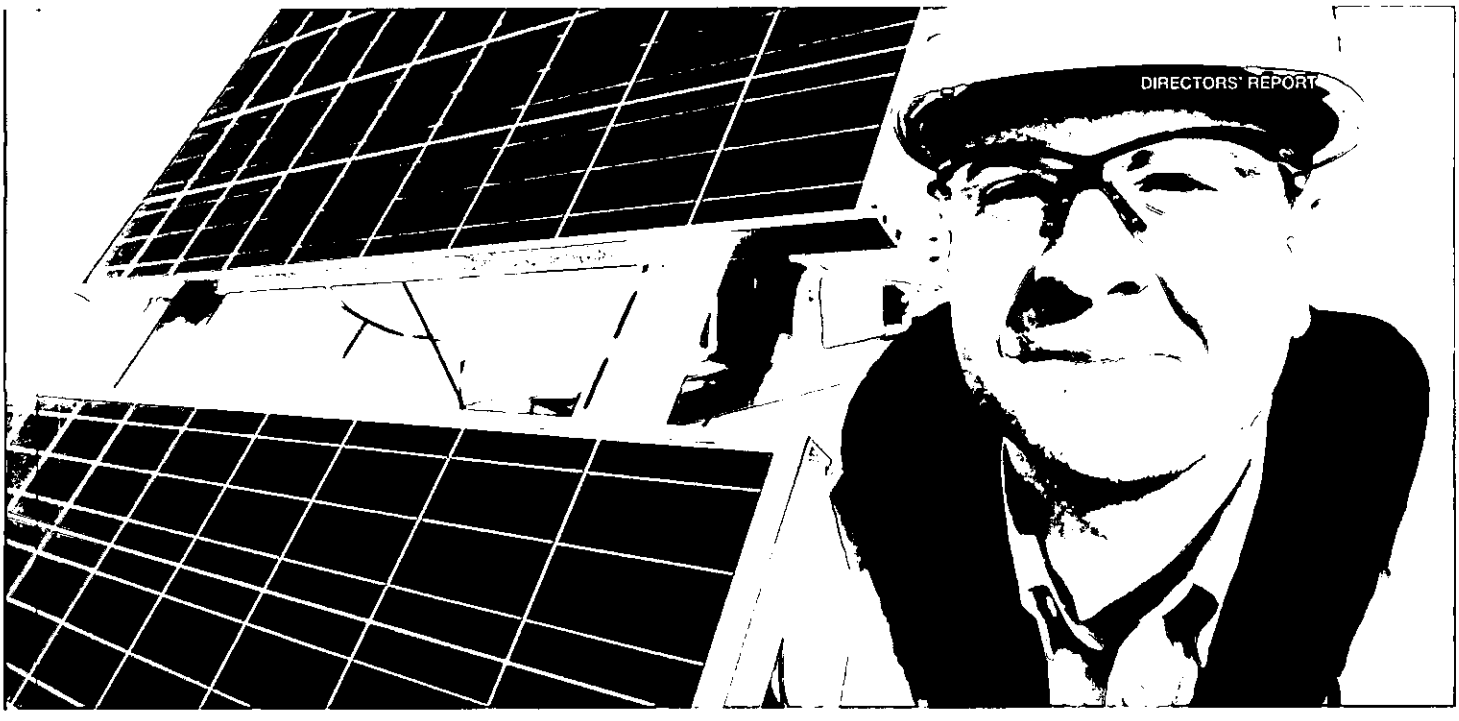
+ Ambre Fuels Limited was informed by the Queensland Government in August 2012 that its Australian coal-to-liquids project, ambreCTL, would not be declared a significant project for which an environmental impact statement is required. The Queensland Government announced its intentions to undertake a regional planning process to resolve land use conflicts such as those arising between agricultural and mining activities.

+ On 9 July 2012, the 50% joint venture owner of the Decker Mine, Western Minerals LLC, filed a Complaint and Jury Demand with the US District Court in Billings, Montana. The defendants named in the Complaint were KCP, Inc., Ambre Energy North America, Inc. (AENA) and Ambre Energy Limited. KCP and AENA filed an Answer and Counterclaim on 30 July 2012, which Counterclaim also added Cloud Peak Energy, Inc. (CPE) as a defendant. Western Minerals and CPE filed a Response and Jury Demand to Counterclaims and Third Party Claims on 10 September 2012.

+ On 5 December 2012, a subsidiary of Ambre Energy Limited entered into an agreement with a CPE subsidiary to purchase CPE's indirect 50% joint venture share in the Decker Coal Company and related assets, including entitlement to certain royalties payable by Decker. The terms of this agreement included a settlement of the previously disclosed Decker litigation.

+ On 5 December 2012, the board of directors resolved to change the financial year end for the Ambre Energy group to 31 December. Therefore, this financial period is for the six months ending 31 December 2012.

+ On 10 December 2012, Ambre and Resource Capital Fund V L.P. (RCF) agreed to amend, restate, modify, extend and continue their existing loan agreement. Under the amended agreement RCF made available to Ambre Energy North America, Inc. an additional $25 million senior, secured, non-revolving, convertible loan, of which $5 million was drawn down in the period and the remaining $20 million was drawn down between 1 January 2013 and 4 April 2013.



EVENTS ARISING AFTER BALANCE SHEET DATE

The following events occurred after the end of the financial period:

+ On 20 March 2013, the company's Managing Director elected to cancel 30 million options over Ambre Energy Limited shares. Refer to note 34 (c) in the financial statements for further information.
+ Subsequent to the loan agreement executed by Ambre Energy and RCF on 10 December 2012, Ambre Energy and RCF entered into a second amended and restated loan agreement on 20 August 2013 to provide an additional financing facility to Ambre Energy. For further information on these agreements see note 11 (b) i. ii, and note 34 (b).
+ Ambre Energy entered into agreements with KOSEP and KOSPO to restructure the repayment terms of convertible notes held by the Korean power companies, which were originally due for repayment in May and June 2013 respectively. For further information see note 34 (f), (g).
+ On 28 August 2013, Ambre Energy and CPE announced jointly that the potential transaction related to agreements reached in December 2012 whereby Ambre Energy was to purchase CPE's 50% interest in Decker mine has not been completed and is not expected to be completed in the foreseeable future. Nevertheless, the parties agreed to dismiss the Decker litigation without prejudice.

Otherwise, there has not been any matter or circumstance that has significantly affected, or may significantly affect, the operations of the group, the results of those operations, or the state of affairs of the group in future financial periods, other than those matters disclosed on pages 76 and 77 of the financial report.

LIKELY DEVELOPMENTS

Likely developments include:

+ progress on permitting for the Morrow Pacific project and the Environmental Impact Statement for Millennium Bulk Terminals
+ a demerger of the alternative fuels division from the group, subject to approval from Ambre Energy shareholders and secured creditors
+ restructuring of the board of directors and changes to the company's staffing requirements to reflect Ambre Energy's increased focus on its North American export infrastructure and mining business.

DIRECTORS' MEETINGS

The number of meetings of the company's board of directors held during the period 1 July 2012 to 31 December 2012, and the number of meetings attended by each director was as follows:

		Meetings of directors		Meetings of committees			
				Audit and Risk Management Committee		Nomination and Remuneration Committee	
		Total – 4		Total – 1		Total – 1	
		Number Attended	Number eligible to attend	Number Attended	Number eligible to attend	Number Attended	Number eligible to attend
T O'Reilly	Non-Executive	4	4	1	1	1	1
E Choros	Executive	3	4	0	0	0	0
M Mewing	Executive	4	4	0	0	0	0
SMJ van Baarle	Executive	4	4	0	0	0	0
D Usasz	Non-Executive	4	4	1	1	1	1
J Newitt	Non-Executive	4	4	0	0	1	1
R Bhappu	Non-Executive	3	4	0	1	0	0

DIVIDENDS

The directors declare that no amount has been paid or declared by way of a dividend since the start of the financial year. The directors do not recommend the payment of a dividend in respect of the financial year.

SHARE OPTIONS

Share options granted to directors and executives

No options were granted to directors and executives over unissued ordinary shares in Ambre Energy Limited during the period.

UNISSUED SHARES UNDER OPTION

Unissued ordinary shares in Ambre Energy Limited under option at the date of this report are:

Date options granted	Number of ordinary shares under option	Exercise Price of option	Expiry date of options
6 November 2008	200,000	0.48	31 December 2013
1 February 2009	450,000	0.48	31 December 2013
1 February 2009	500,000	0.48	31 December 2013
1 February 2009	600,000	0.48	31 December 2013
1 February 2009	400,000	0.48	31 December 2013
7 May 2009	100,000	0.48	31 May 2014
7 May 2009	200,000	0.48	31 December 2014
7 May 2009	1,000,000	0.48	31 May 2014
7 May 2009	100,000	0.48	31 May 2014
7 May 2009	200,000	0.48	31 May 2014
27 January 2010	400,000	0.48	31 December 2013
1 February 2010	100,000	0.48	31 December 2013
1 March 2010	500,000	0.48	31 December 2015
1 March 2010	600,000	0.48	31 December 2016
15 March 2010	200,000	0.48	31 December 2014
20 April 2010	1,000,000	0.60	31 December 2015
20 April 2010	1,000,000	0.60	31 December 2014
20 April 2010	600,000	0.60	31 December 2015
30 April 2010	200,000	0.60	31 December 2015
30 April 2010	500,000	0.60	31 December 2015
30 April 2010	50,000	0.48	31 December 2014
30 April 2010	200,000	0.48	31 December 2015
30 April 2010	50,000	0.48	31 December 2014
30 April 2010	100,000	0.48	31 December 2014
30 April 2010	100,000	0.48	31 December 2014
30 April 2010	600,000	0.48	31 December 2015
30 April 2010	500,000	0.60	31 December 2015
3 May 2010	1,000,000	0.48	31 December 2015
10 May 2010	500,000	0.48	31 December 2015
20 May 2010	1,000,000	0.60	31 December 2015
1 July 2010	100,000	0.48	31 December 2015
1 July 2010	1,000,000	0.48	31 December 2015
1 July 2010	100,000	0.48	31 December 2015
1 October 2010	1,000,000	0.48	31 December 2015
21 October 2010	100,000	0.60	31 December 2015
22 October 2010	100,000	0.60	31 December 2015
1 November 2010	200,000	0.60	31 December 2015
22 November 2010	600,000	0.60	31 December 2015
1 December 2010	300,000	0.60	31 December 2015
1 May 2011	250,000	1.00	31 Decemebr 2015
11 May 2011	500,000	1.25	31 December 2015
16 June 2011	50,000	1.00	31 December 2015
16 June 2011	500,000	1.00	31 December 2015
16 June 2011	200,000	1.25	31 December 2015
18 July 2011	100,000	1.25	31 December 2015
18 July 2011	200,000	1.25	31 December 2015
8 August 2011	400,000	1.10	31 December 2015
16 August 2011	100,000	1.10	31 December 2015
1 October 2011	200,000	1.10	31 December 2015
1 October 2011	100,000	1.10	31 December 2015
1 October 2011	300,000	1.10	31 December 2015
24 October 2011	200,000	1.10	31 December 2015
1 November 2011	500,000	1.25	31 December 2015
14 November 2011	6,250,000	1.00	14 November 2014
16 November 2011	200,000	1.10	31 December 2015
16 November 2011	1,000,000	1.25	31 December 2015
16 November 2011	2,000,000	1.25	31 December 2015

Date options granted	Number of ordinary shares under option	Exercise Price of option	Expiry date of options
16 November 2011	4,000,000	1.10	31 December 2015
16 November 2011	4,000,000	1.25	31 December 2015
16 November 2011	500,000	1.10	31 December 2015
16 November 2011	200,000	1.10	31 December 2015
16 November 2011	4,000,000	1.25	31 December 2015
25 November 2011	200,000	1.25	31 December 2015
5 December 2011	200,000	1.10	31 December 2015
31 December 2011	6,250,000	1.00	31 December 2014
23 January 2012	1,600,000	1.80	31 December 2016
7 March 2012	100,000	1.80	31 December 2015
1 April 2012	12,500,000	1.00	1 April 2015
27 April 2012	100,000	1.50	31 December 2016
27 April 2012	100,000	1.50	31 December 2016
27 April 2012	500,000	1.50	31 December 2016
27 April 2012	250,000	1.50	31 December 2016
30 April 2012	100,000	1.25	31 December 2015
14 May 2012	500,000	1.80	31 December 2016
28 May 2012	100,000	1.50	31 December 2016
28 May 2012	400,000	1.50	31 December 2016
28 May 2012	100,000	1.50	31 December 2016
28 May 2012	50,000	1.50	31 December 2016
28 May 2012	100,000	1.50	31 December 2016
28 May 2012	100,000	1.50	31 December 2016
5 June 2012	12,500	1.80	31 December 2016
6 June 2012	200,000	1.50	31 December 2016
1 November 2012	500,000	1.50	31 December 2016
23 January 2013	100,000	1.50	31 December 2016
25 January 2013	400,000	1.50	31 December 2016
Total	**66,662,500**		

SHARES ISSUED DURING OR SINCE THE END OF THE PERIOD AS A RESULT OF EXERCISE

During or since the end of the period, Ambre Energy Limited issued ordinary shares as a result of the exercise or net (cashless) exercise of options as follows:

Date options granted	Number of ordinary shares under option	Price per share	Number of ordinary shares issued as a result of exercise
26 June 2008	100,000	0	68,000
26 June 2008	100,000	0	68,000
26 June 2008	100,000	0	68,000
26 June 2008	100,000	0	68,000
30 June 2008	136,765	0	93,000
1 September 2008	191,176	0	130,000
1 September 2008	225,000	0	153,000
4 September 2008	125,000	0	85,000
30 September 2008	800,000	0	544,000
1 October 2008	750,000	0	510,000
28 January 2009	100,000	0	68,000
26 June 2008	100,000	0.48	100,000
30 June 2008	100,000	0.48	100,000
30 June 2008	100,000	0.48	100,000
1 September 2008	275,000	0.48	275,000
Total	**3,302,941**		**Total** **2,430,000**

Under the parent entity's employee share option plan, option holders are entitled, as an alternative to exercising their options through payment of the exercise price, to exchange their options for a lesser number of shares based on the prevailing value of the company's shares (commonly referred to as "cashless exercise"). During the period, 2,727,941 options were exchanged for 1,855,000 ordinary shares by way of cashless exercise. No consideration was paid to the company for these share issues.

ENVIRONMENTAL LEGISLATION

The group's operations are subject to various environmental laws and regulations under the relevant government's legislation. Full compliance with these laws and regulations is regarded as a minimum standard for all operations to achieve.

Instances of environmental non–compliance by an operation are identified either by external compliance audits or inspections by relevant government authorities.

There have been no significant breaches by the group during the period.

INDEMNIFICATIONS OF OFFICERS AND AUDITORS

During the period the company's parent entity, Ambre Energy Limited, paid a premium in respect of a contract insuring the directors of the company (as named above), the company secretary, and all executive officers of the company and of any related body corporate against a liability incurred as a director, secretary or executive officer to the extent permitted by the Corporations Act 2001. The contract of insurance prohibits disclosure of the nature of the liability and the amount of the premium.

Directors' Deeds

Ambre Energy Limited entered into a Deed of Indemnity, Insurance and Access (Directors' Deeds) with current directors of the parent. These Deeds formalise the arrangements between the company and the directors as to indemnities, insurance and access to board records. Under each Deed the company indemnifies the director to the extent permitted by law against any liability (including liability for legal defence costs) incurred by the director as an officer of the company or any operating company or while acting at the request of the company or any operating company as an officer of a non-controlled entity.

PROCEEDINGS ON BEHALF OF A COMPANY

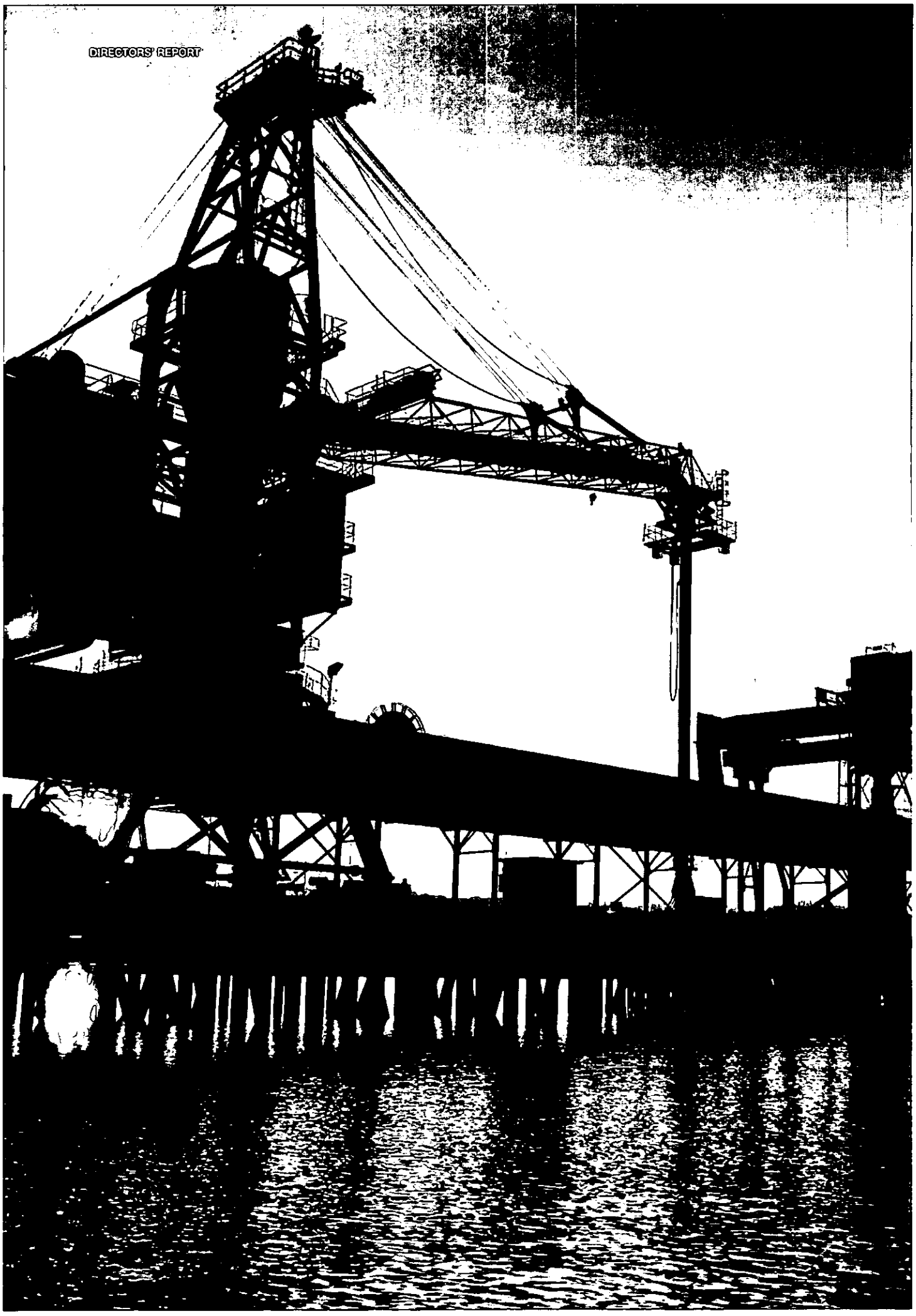
No person has applied to the Court under section 237 of the Corporations Act 2001 for leave to bring proceedings on behalf of the Company, or to intervene in any proceedings to which the Company is a party, for the purpose of taking responsibility on behalf of the Company for all or part of those proceedings.

AUDITOR'S INDEPENDENCE DECLARATION

The auditor's independence declaration for the period 1 July 2012 to 31 December 2012 has been received and can be found on page 19 of the annual report.

The report is made in accordance with a resolution of the directors.

Edward (Edek) Choros
Director
10 October 2013



AUDITOR'S INDEPENDENCE DECLARATION

Grant Thornton Audit Pty Ltd
ABN 91 130 913 594

Level 18
145 Ann Street
Brisbane Queensland 4000
GPO Box 1008
Brisbane Queensland 4001

T + 61 7 3222 0200
F + 61 7 3222 0444
E info@au.gt.com
W www.grantthornton.com.au

Auditor's Independence Declaration
To the Directors of Ambre Energy Limited

In accordance with the requirements of section 307C of the Corporations Act 2001, as lead auditor for the audit of Ambre Energy Limited for the 6 months period ended 31 December 2012, I declare that, to the best of my knowledge and belief, there have been:

a no contraventions of the auditor independence requirements of the Corporations Act 2001 in relation to the audit; and

b no contraventions of any applicable code of professional conduct in relation to the audit.

Grant Thornton

GRANT THORNTON AUDIT PTY LTD
Chartered Accountants

D J Carroll
Partner - Audit & Assurance

Brisbane, 10 October 2013

Grant Thornton Australia Limited ABN 41 127 556 389

'Grant Thornton' refers to the brand under which the Grant Thornton member firms provide assurance, tax and advisory services to their clients and/or refers to one or more member firms, as the context requires. Grant Thornton Australia Ltd is a member firm of Grant Thornton International Ltd (GTIL). GTIL and the member firms are not a worldwide partnership. GTIL and each member firm is a separate legal entity. Services are delivered by the member firms. GTIL does not provide services to clients. GTIL and its member firms are not agents of, and do not obligate one another and are not liable for one another's acts or omissions to the Australian context only, the use of the term 'Grant Thornton' may refer to Grant Thornton Australia Limited ABN 41 127 556 389 and its Australian subsidiaries and related entities. GTIL is not an Australian related entity to Grant Thornton Australia Limited.

Liability limited by a scheme approved under Professional Standards Legislation. Liability is limited in those States where current scheme applies.

FINANCIAL REPORT

Consolidated statement of comprehensive income.....21

Consolidated statement of financial position.....22

Consolidated statement of cash flows.....23

Consolidated statement of changes in equity.....24

Notes to the financial statements.....25

AMBRE ENERGY LIMITED
ACN 114 812 074
CONSOLIDATED STATEMENT OF COMPREHENSIVE INCOME
FOR THE PERIOD ENDED 31 DECEMBER 2012

	Note	6 mth Dec 2012 $'000	12 mth Jun 2012 $'000
Revenue from operations	5	3,363	4,630
Other income	6	1,531	232
Share of gains/(losses) from joint ventures	4(a)	(5,582)	(10,105)
Share of gains/(losses) from associates		(5)	(47)
Gain on business combination	3	-	5,768
Depreciation and amortisation expense		(766)	(2,158)
Employee benefits expense	23(a)	(6,084)	(10,908)
Foreign exchange gains/(losses)		(45)	29
Impairment expense	7	(163)	(10,857)
Finance costs	7	(8,135)	(11,395)
Consultants and professional expense		(5,847)	(10,940)
Insurance expense		(285)	(559)
Loss on disposal of fixed assets		(23)	(216)
Lease expense		(569)	(1,009)
Research and development expense		(302)	(1,167)
Recruitment and relocation expense		(311)	(509)
Repairs and maintenance expense		(215)	(1,218)
Share based payments expense	20(c)	(5,136)	(8,992)
Travel expense		(630)	(1,756)
Other expenses		(2,798)	(4,189)
Profit/(loss) before income tax		(32,002)	(65,367)
Income tax (benefit)/ expense	8(a)	-	1
Profit/(loss) for the period		(32,002)	(65,367)
Attributable to members of the parent entity		(30,741)	(62,759)
Loss attributable to non-controlling interest		(1,261)	(2,607)
Other comprehensive income:			
Items that will not be reclassified subsequently to profit or loss:			
Actuarial gains (loss) on pension and retirement benefit schemes		(1,917)	(655)
Share of other comprehensive income from equity accounted investees		119	(1,725)
Items that may be reclassified subsequently to profit or loss:			
Exchange differences on translation of foreign controlled entities		(635)	(4,699)
Other comprehensive income for the period, net of income tax		(2,433)	(7,079)
Total comprehensive income for the period		(34,435)	(72,446)
Attributable to members of the parent entity		(33,169)	(69,782)
Attributable to non-controlling interest		(1,266)	(2,664)
Earning per share		$	$
Basic and diluted earnings per share attributable to members of the parent entity:	24	(0.08)	(0.17)

The accompanying notes form part of these financial statements

AMBRE ENERGY LIMITED
ACN 114 812 074
CONSOLIDATED STATEMENT OF FINANCIAL POSITION AS AT 31 DECEMBER 2012

	Note	Dec 2012 $'000	Jun 2012 $'000
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	9	2,887	20,300
Trade and other receivables	10	2,131	2,697
Other current assets	15	3,442	2,391
TOTAL CURRENT ASSETS		8,460	25,388
NON-CURRENT ASSETS			
Investments in equity accounted investees	4	34,522	36,914
Other financial assets	11(a)	59,973	64,750
Property, plant and equipment	12	29,105	21,809
Intangible assets	13	25,021	20,566
Exploration and evaluation assets	14	19,588	19,163
Other non-current assets	15	535	541
TOTAL NON-CURRENT ASSETS		168,744	163,743
TOTAL ASSETS		177,204	189,131
CURRENT LIABILITIES			
Trade and other payables	16	5,969	5,847
Other financial liabilities	11	20,919	43,796
Employee entitlements	17	396	383
Provisions	18	460	1,296
TOTAL CURRENT LIABILITIES		27,744	51,322
NON-CURRENT LIABILITIES			
Employee entitlements	17	197	155
Other financial liabilities	11	32,851	-
Share of net liabilities of joint ventures	4	30,906	28,537
Provisions	18	11,543	10,125
TOTAL NON-CURRENT LIABILITIES		75,497	38,817
TOTAL LIABILITIES		103,241	90,139
NET ASSETS		73,963	98,992
EQUITY			
Issued capital	20	178,518	176,443
Reserves	22	17,627	17,550
Retained earnings		(153,132)	(124,016)
Parent interest		43,013	69,977
Non-controlling interest		30,950	29,015
TOTAL EQUITY		73,963	98,992

The accompanying notes form part of these financial statements

AMBRE ENERGY LIMITED
ACN 114 812 074
CONSOLIDATED STATEMENT OF CASHFLOWS FOR THE PERIOD ENDED 31 DECEMBER 2012

	Note	6 mth Dec 2012 $'000	12 mth Jun 2012 $'000
CASH FLOWS FROM OPERATING ACTIVITIES			
Receipts from customers		3,023	3,976
Payments to suppliers and employees		(20,183)	(30,312)
Income tax offset received		-	571
Interest received		82	251
Interest paid		(566)	(852)
Net cash provided by (used in) operating activities	33(a)	(17,644)	(26,366)
CASH FLOWS FROM INVESTING ACTIVITIES			
Payment for acquisition of subsidiary, net of cash acquired	3	(540)	(4,047)
Payments for investment in associate		(75)	(110)
Joint venture partnership distributions received		1,454	4,171
Joint venture partnership contributions paid		(1,926)	(5,986)
Proceeds from sale of non-current assets		892	(720)
Purchase of property, plant and equipment		(7,689)	(8,099)
Purchase of other intangible assets	13(a)	(4,908)	(9,226)
Loans to related parties		52	(686)
Purchase of exploration and evaluation assets	14	(72)	(542)
Purchase of financial assets		3,570	(66,008)
Net cash provided by (used in) investing activities		(9,242)	(91,253)
CASH FLOWS FROM FINANCING ACTIVITIES			
Proceeds from issue of shares		1,028	88,850
Share issue transaction costs		-	(3,350)
Proceeds from borrowings		4,861	24,948
Proceeds from issue of redeemable convertible notes		-	18,955
Repayment of redeemable convertible notes		-	(10,000)
Finance lease payments		(69)	-
Transactions with non-controlling interests	21(b)	3,810	7,529
Net cash provided by (used in) financing activities		9,630	126,932
Net movement in cash held		(17,256)	9,313
Cash at beginning of financial period		20,300	10,980
Effect of exchange rates on cash holdings in foreign currencies		(157)	7
Cash at end of financial period	9	2,887	20,300

The accompanying notes form part of these financial statements.

AMBRE ENERGY LIMITED
ACN 114 812 074
CONSOLIDATED STATEMENT OF CHANGES IN EQUITY FOR THE PERIOD ENDED 31 DECEMBER 2012

	Share capital $'000	Retained earnings $'000	Foreign currency translation reserve $'000	Option reserve $'000	Other reserves $'000	Convertible notes $'000	Non-controlling interest $'000	Total $'000
Balance at 1 July 2011	89,497	(69,618)	(4,866)	16,497	-	671	22,817	54,998
Profit/ (Loss) attributable to members of parent entity	-	(62,759)	-	-	-	-	-	(62,759)
Profit/ (Loss) attributable to non-controlling interests	-	-	-	-	-	-	(2,607)	(2,607)
Other comprehensive income for the year	-	-	167	-	-	-	1,276	1,443
Shares issued during the year	89,454	-	-	-	-	-	-	89,454
Transaction costs	(3,350)	-	-	-	-	-	-	(3,350)
Transactions with non-controlling interests	-	-	-	-	-	-	7,529	7,529
Options issued during the year	-	-	-	8,992	-	-	-	8,992
Other finance costs	-	-	-	7,672	-	-	-	7,672
Actuarial gains/(losses) on pension and retirement benefit schemes	-	-	-	-	(655)	-	-	(655)
Share of other comprehensive income from equity accounted investees	-	-	-	-	(1,725)	-	-	(1,725)
Transfers from option reserve	829	7,703	-	(8,532)	-	-	-	-
Transfer from equity convertible notes	13	658	-	-	-	(671)	-	-
Balance at 30 June 2012	176,443	(124,016)	(4,699)	24,629	(2,380)	-	29,015	98,992
Balance at 1 July 2012	176,443	(124,016)	(4,699)	24,629	(2,380)	-	29,015	98,992
Profit/ (Loss) attributable to members of parent entity	-	(30,741)	-	-	-	-	-	(30,741)
Profit/ (Loss) attributable to non-controlling interests	-	-	-	-	-	-	(1,261)	(1,261)
Other comprehensive income for the period	-	-	(630)	-	41	-	(614)	(1,203)
Shares issued during the period	1,028	-	-	-	-	-	-	1,028
Transaction costs	-	-	-	-	-	-	-	-
Transactions with non-controlling interests	-	-	-	-	-	-	3,810	3,810
Options issued during the period	-	-	-	5,136	-	-	-	5,136
Other finance costs	-	-	-	-	-	-	-	-
Actuarial gains/(losses) on pension and retirement benefit schemes	-	-	-	-	(1,917)	-	-	(1,917)
Share of other comprehensive income from equity accounted investees	-	-	-	-	119	-	-	119
Transfers from option reserve	1,047	1,625	-	(2,672)	-	-	-	-
Transfer from equity convertible notes	-	-	-	-	-	-	-	-
Balance at 31 December 2012	178,518	(153,132)	(5,329)	27,093	(4,137)	-	30,950	73,963

The accompanying notes form part of these financial statements

Note 1: Statement of significant accounting policies

The consolidated financial statements of Ambre Energy Limited and its controlled entities for the six month financial period ended 31 December 2012 comprises Ambre Energy Limited and its controlled entities (together referred to as the "group"). Ambre Energy Limited (the "parent") is an unlisted public company incorporated in and domiciled in Australia.

The financial year end of the group was changed from 30 June to 31 December during the period to better align the reporting period with Ambre's global business cycles. The comparative figures for the Statement of Comprehensive Income, Statement of Cashflows and Statement of Changes in Equity and related notes are for the 12 months to 30 June 2012. The results for the financial period ended 31 December 2012 are therefore not directly comparable with the results for 30 June 2012.

Basis of preparation

The consolidated financial statements are general purpose financial statements that have been prepared in accordance with Australian Accounting Standards (including Australian Accounting Interpretations) of the Australian Accounting Standards Board ("AASB") and the Corporations Act 2001. The group is a for profit entity for financial reporting purposes under Australian Accounting Standards.

Australian Accounting Standards set out accounting policies that the AASB has concluded would result in financial statements containing relevant and reliable information about transactions, events and conditions. Compliance with Australian Accounting Standards ensures that the financial statements and notes also comply with International Financial Reporting Standards.

The consolidated financial statements, except for cashflow information, have been prepared on an accruals basis and are based on historical costs modified by the revaluation of selected non-current assets, financial assets and financial liabilities for which the fair value basis of accounting has been applied.

The parent entity has applied the relief available to it under Australian Securities and Investment Commission Class Order CO 98/100 and presents all monetary amounts in thousands of Australian dollars.

The group has early adopted AASB 10 Consolidated Financial Statements, AASB 11 Joint Arrangements, AASB 12 Disclosure of Interests in Other Entities, AASB 128 Investments in Associates and Joint Ventures, AASB 127 Separate Financial Statements and AASB 2011-7 Amendments to Australian Accounting Standards arising from the Consolidated and Joint Arrangements Standards from July 2011, because the new accounting policies provide more reliable and relevant information for users to assess the composition of the group and the amounts, timing and uncertainty of future cash flows. In accordance with the transition provisions, comparative figures have been restated where applicable.

The following is a summary of the material accounting policies adopted by the group in preparation of the financial statements. The accounting policies have been consistently applied, unless otherwise stated.

Accounting policies

(a) Principles of consolidation

A controlled entity is any entity which Ambre Energy Limited has control over. Ambre Energy Limited has such control when it is exposed, or has rights, to variable returns from its involvement with the entity and has the ability to affect those returns through its power over the entity.

Note 1: Statement of significant accounting policies (cont'd)

(a) Principles of consolidation (cont'd)

A list of controlled entities is contained in Note 21 to the financial statements. All controlled entities now have a 31 December financial year end.

As at the reporting date, the assets and liabilities of all controlled entities have been incorporated into the consolidated financial statements as well as their results for the period then ended. Where controlled entities have entered (left) the group during the period, their operating results have been included (excluded) from the date control was obtained (ceased).

Non-controlling interests, being the equity in a subsidiary not attributable, directly or indirectly, to a parent, are shown separately within the Equity section of the Statement of Financial Position and the Statement of Comprehensive Income. The non-controlling interests in the net assets comprise their interests at the date of the original business combination and their share of changes in equity since that date.

All inter-company balances and transactions between entities in the group, including any unrealised profits and losses are eliminated in preparing the financial statements.

Accounting policies of subsidiaries have been changed where necessary to ensure consistencies with those policies applied by the parent entity.

(b) Business combinations

Business combinations occur where an acquirer obtains control over one or more businesses.

A business combination is accounted for by applying the acquisition method unless it is a combination involving entities or businesses under common control, when assets and liabilities are transferred at book value. The acquisition method requires that for each business combination one of the combining entities must be identified as the acquirer. The business combination will be accounted for as at the acquisition date, which is the date that control over the acquiree is obtained by the parent entity. At this date, the parent shall recognise in the accounts and subject to certain limited exceptions, the fair value of the identifiable assets acquired and liabilities assumed.

In addition, contingent liabilities of the acquiree will be recognised where a present obligation has been incurred and its fair value can be reliably measured. The acquisition may result in the recognition of goodwill or a gain from a bargain purchase. All transaction costs incurred in relation to the business combination are expensed to the Statement of Comprehensive Income.

(c) Income tax

The income tax expense (revenue) for the period comprises current income tax expense (income) and deferred tax expense (income).

Current income tax expense charged to the profit or loss is the tax payable on taxable income. Current tax liabilities (assets) are therefore measured at the amounts expected to be paid to (recovered from) the relevant taxation authority.

Deferred income tax expense reflects movements in deferred tax asset and deferred tax liability balances during the period as well unused tax losses.

Note 1: Statement of significant accounting policies (cont'd)

(c) Income tax (cont'd)

Current and deferred income tax expense (income) is charged or credited directly to equity instead of the profit or loss when the tax relates to items that are credited or charged directly to equity.

Deferred tax assets and liabilities are ascertained based on temporary differences arising between the tax bases of assets and liabilities and their carrying amounts in the financial statements. Deferred tax assets also result where amounts have been fully expensed but future tax deductions are available. No deferred income tax will be recognised from the initial recognition of an asset or liability, excluding a business combination, where there is no effect on accounting or taxable profit or loss.

Deferred tax assets and liabilities are calculated at the tax rates that are expected to apply to the period when the asset is realised or the liability is settled, based on tax rates enacted or substantively enacted at reporting date. Their measurement also reflects the manner in which management expects to recover or settle the carrying amount of the related asset or liability.

Deferred tax assets relating to temporary differences and unused tax losses are recognised only to the extent that it is probable that future taxable profit will be available against which the benefits of the deferred tax asset can be utilised.

Where temporary differences exist in relation to investments in subsidiaries, branches, associates, and joint ventures, deferred tax assets and liabilities are not recognised where the timing of the reversal of the temporary difference can be controlled and it is not probable that the reversal will occur in the foreseeable future.

Current tax assets and liabilities are offset where a legally enforceable right of set-off exists and it is intended that net settlement or simultaneous realisation and settlement of the respective asset and liability will occur. Deferred tax assets and liabilities are offset where a legally enforceable right of set-off exists, the deferred tax assets and liabilities relate to income taxes levied by the same taxation authority on either the same taxable entity or different taxable entities where it is intended that net settlement or simultaneous realisation and settlement of the respective asset and liability will occur in future periods in which significant amounts of deferred tax assets or liabilities are expected to be recovered or settled.

Tax consolidation

Ambre Energy Limited and its wholly-owned Australian subsidiaries have formed an income tax consolidated group under the tax consolidation regime. Each entity in the group recognises its own current and deferred tax liabilities, except for any deferred tax assets resulting from unused tax losses and tax credits, which are immediately assumed by the parent entity. The current tax liability of each group entity is then subsequently assumed by the parent entity. The group notified the Australian Taxation Office that it had formed an income tax consolidated group to apply from 20 October 2006.

There are no tax sharing arrangements in place between members of the income tax consolidated group at the date of this report.

(d) Property, plant and equipment

Each class of property, plant and equipment is carried at cost less, where applicable, accumulated depreciation and impairment losses.

Note 1: Statement of significant accounting policies (cont'd)

(d) Property, plant and equipment (cont'd)

Property

Freehold land and buildings are shown at their fair value (being the amount for which an asset could be exchanged between knowledgeable willing parties in an arm's length transaction), based on periodic, but at least triennial, valuations by external independent valuers, less subsequent depreciation for buildings.

Increases in the carrying amount arising on revaluation of land and buildings are credited to a revaluation reserve in equity. Decreases that offset previous increases of the same asset are charged against fair value reserves directly in equity; all other decreases are charged to the Statement of Comprehensive Income. Each year the difference between depreciation based on the revalued carrying amount of the asset charged to the Statement of Comprehensive Income and depreciation based on the asset's original cost is transferred from the revaluation reserve to retained earnings.

Any accumulated depreciation at the date of revaluation is eliminated against the gross carrying amount of the asset and the net amount is restated to the revalued amount of the asset.

Plant and equipment

Plant and equipment are measured on the cost basis less accumulated depreciation and any accumulated impairment losses.

The carrying amount of plant and equipment is reviewed annually by directors to ensure it is not in excess of the recoverable amount from these assets. The recoverable amount is assessed on the basis of the expected net cash flows that will be received from the asset's employment and subsequent disposal. The expected net cash flows have been discounted to their present values in determining recoverable amounts. A formal assessment of recoverable amounts are made when impairment indicators are present (see Note 1(h)).

The cost of fixed assets constructed within the group includes the cost of materials, direct labour, borrowing costs and an appropriate proportion of fixed and variable overheads.

Subsequent costs are included in the asset's carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the group and the cost of the item can be measured reliably. All other repairs and maintenance are charged to the Statement of Comprehensive Income during the financial period in which they are incurred.

Depreciation

The depreciable amount of all fixed assets, including buildings and capitalised lease assets but excluding freehold land, is depreciated on a straight-line basis over their useful lives to the consolidated group commencing from the time the asset is held ready for use. Leasehold improvements are depreciated over the shorter of either the unexpired period of the lease or the estimated useful lives of the improvements.

The depreciation rates used for each class of depreciable assets are:

Class of fixed asset	Depreciation rate
Buildings	2-100%
Plant and equipment	2-100%
Leasehold improvements	5-20%

Note 1: Statement of significant accounting policies (cont'd)

(d) Property, plant and equipment (cont'd)

The assets' residual values and useful lives are reviewed, and adjusted if appropriate, at each balance date.

An asset's carrying amount is written down immediately to its recoverable amount if the asset's carrying amount is greater than its estimated recoverable amount.

Gains and losses on disposal are determined by comparing proceeds with the carrying amount. These gains and losses are included in the Statement of Comprehensive Income.

When revalued assets are sold, amounts included in the revaluation reserve relating to that asset are transferred to retained earnings.

(e) Exploration and development expenditure

Exploration, evaluation and development expenditure incurred is capitalised in respect of each identifiable area of interest. These costs are only capitalised to the extent that they are expected to be recouped through the successful development of the area or where activities in the area have not yet reached a stage that permits reasonable assessment of the existence of economically recoverable reserves.

Accumulated costs in relation to an abandoned area are written off in full against profit in the period in which the decision to abandon the area is made.

When production commences, the accumulated costs for the relevant area of interest are amortised over the life of the area according to the rate of depletion of the economically recoverable reserves.

A regular review is undertaken of each area of interest to determine the appropriateness of continuing to carry forward costs in relation to that area of interest.

Costs of site restoration are provided over the life of the facility from when exploration commences and are included in the costs of that stage. Site restoration costs include the dismantling and removal of mining plant, equipment and building structures, waste removal, and rehabilitation of the site in accordance with clauses of the mining permits. Such costs have been determined using estimates of future costs, current legal requirements and technology on an undiscounted basis.

Any changes in the estimates for the costs are accounted on a prospective basis. In determining the costs of site restoration, there is uncertainty regarding the nature and extent of the restoration due to community expectations and future legislation. Accordingly the costs have been determined on the basis that the restoration will be completed within one year of abandoning the site.

Note 1: Statement of significant accounting policies (cont'd)

(f) Leases

Leases of fixed assets where substantially all the risks and benefits incidental to the ownership of the asset, but not the legal ownership that is transferred to entities in the group are classified as finance leases.

Finance leases are capitalised by recording an asset and liability at the lower of the amounts equal to the fair value of the leased property or the present value of the minimum lease payments, including any guaranteed residual values. Lease payments are allocated between the reduction of the lease liability and the lease interest expense for the period.

Leased assets are depreciated on a straight line basis over the shorter of their estimated useful lives or the lease term.

Lease payments for operating leases, where substantially all the risks and benefits remain with the lessor, are charged as expenses in the periods in which they are incurred. Lease incentives under operating leases are recognised as a liability and amortised on a straight line basis over the life of the lease term.

(g) Financial Instruments

Initial recognition and measurement

Financial assets and financial liabilities are recognised when the entity becomes a party to the contractual provisions to the instrument. For financial assets, this is equivalent to the date that the company commits itself to either the purchase or sale of the asset (i.e. trade date accounting is adopted).

Financial instruments are initially measured at fair value plus transaction costs, except where the instrument is classified 'at fair value through profit or loss', in which case transaction costs are expensed to profit or loss immediately.

Classification and subsequent measurement

Financial instruments are subsequently measured at either of fair value, amortised cost using the effective interest rate method, or cost. Fair value represents the amount for which an asset could be exchanged or a liability settled, between knowledgeable, willing parties. Where available, quoted prices in an active market are used to determine fair value. In other circumstances, valuation techniques are adopted.

Amortised cost is calculated as:

a) the amount at which the financial asset or financial liability is measured at initial recognition;
b) less principal repayments;
c) plus or minus the cumulative amortisation of the difference, if any, between the amount initially recognised and the maturity amount calculated using the effective interest method; and
d) less any reduction for impairment.

The effective interest method is used to allocate interest income or interest expense over the relevant period and is equivalent to the rate that exactly discounts estimated future cash payments or receipts (including fees, transaction costs and other premiums or discounts) through the expected life (or when this cannot be reliably predicted, the contractual term) of the financial instrument to the net carrying amount of the financial asset or financial liability. Revisions to expected future net cash flows will necessitate an adjustment to the carrying value with a consequential recognition of an income or expense in profit or loss.

Note 1: Statement of significant accounting policies (cont'd)

(g) Financial instruments (cont'd)

Fair value is determined based on current bid prices for all quoted investments. Valuation techniques are applied to determine the fair value for all unlisted securities, including recent arm's length transactions, reference to similar instruments and option pricing models.

The group does not designate any interests in subsidiaries, associates or joint venture entities as being subject to the requirements of accounting standards specifically applicable to financial instruments.

Financial assets at fair value through profit or loss

Financial assets are classified at 'fair value through profit or loss' when they are either held for trading for the purpose of short-term profit taking, derivatives not held for hedging purposes, or when they are designated as such to avoid an accounting mismatch or to enable performance evaluation where a group of financial assets is managed by key management personnel on a fair value basis in accordance with a documented risk management or investment strategy. Such assets are subsequently measured at fair value with changes in carrying value being included in profit or loss.

Loans and receivables

Loans and receivables are non-derivative financial assets with fixed or determinable payments that are not quoted in an active market and are subsequently measured at amortised cost.

Loans and receivables are included in current assets, except for those which are not expected to mature within 12 months after the end of the reporting period.

Held-to-maturity investments

Held-to-maturity investments are non-derivative financial assets that have fixed maturities and fixed or determinable payments, and it is the group's intention to hold these investments to maturity. They are subsequently measured at amortised cost.

Available-for-sale financial assets

Available-for-sale financial assets are non-derivative financial assets that are either not suitable to be classified into other categories of financial assets due to their nature, or they are designated as such by management. They comprise investments in the equity of other entities where there is neither a fixed maturity nor fixed or determinable payments.

They are subsequently measured at fair value with changes in fair value (with any remeasurements other than impairment losses and foreign exchange gains and losses) recognised in other comprehensive income. When the financial asset is derecognised the cumulative gain or loss pertaining to that asset previously recognised in other comprehensive is reclassified into the profit and loss.

Available-for-sale financial assets are classified as noncurrent assets when they are expected to be sold after 12 months from the end of the reporting period. All other available -for-sale financial assets are classified as current assets.

Financial liabilities

Non-derivative financial liabilities (excluding financial guarantees) are subsequently measured at amortised cost.

Note 1: Statement of significant accounting policies (cont'd)

(g) Financial instruments (cont'd)

Derivative instruments

The group designates certain derivatives as either:

- hedges of the fair value of recognised assets or liabilities or a firm commitment (fair value hedge); or
- hedges of highly probable forecast transactions (cash flow hedges).

At the inception of the transaction the relationship between hedging instruments and hedged items, as well as the group's risk management objective and strategy for undertaking various hedge transactions is documented.

Assessments, both at hedge inception and on an ongoing basis, of whether the derivatives that are used in hedging transactions have been and will continue to be highly effective in offsetting changes in fair values or cash flows of hedged items, are also documented.

(i) Fair value hedge

Changes in the fair value of derivatives that are designated and qualify as fair value hedges are recorded in the Statement of Comprehensive Income, together with any changes in the fair value of hedged assets or liabilities that are attributable to the hedged risk.

(ii) Cash flow hedge

The effective portion of changes in the fair value of derivatives that are designated and qualify as cash flow hedges is deferred to a hedge reserve in equity. The gain or loss relating to the ineffective portion is recognised immediately in the Statement of Comprehensive Income.

Amounts accumulated in the hedge reserve in equity are transferred to the Statement of Comprehensive Income in the periods when the hedged item will affect profit or loss.

Impairment

At each reporting date, the Group assesses whether there is objective evidence that a financial asset has been impaired. A financial asset or a group of financial assets is deemed to be impaired if, and only if, there is objective evidence of impairment as a result of one or more events (a 'loss event') having occurred, which has an impact on the estimated future cash flows of the financial asset(s).

In the case of available-for-sale financial assets, a prolonged decline in the market value of the instrument is considered to constitute a loss event. Impairment losses are recognised in profit or loss immediately. Also, any cumulative decline in fair value previously recognised in other comprehensive income is reclassified to profit and loss at this point.

In the case of financial assets carried at amortised cost, loss events may include: indications that the debtors or a group of debtors are experiencing significant financial difficulty, default or delinquency in interest or principal payments; indications that they will enter bankruptcy or other financial reorganisation; and changes in arrears or economic conditions that correlate with the defaults.

Note 1: Statement of significant accounting policies (cont'd)

(g) Financial instruments (cont'd)

For financial assets carried at amortised cost (including loans and receivables), a separate allowance is used to reduce the carrying amount of financial assets impaired by credit losses. After having taken all possible measures of recovery, if management establishes that the carrying amount cannot be recovered by any means, at that point the written-off amounts are charged to the allowance account or the carrying amount of impaired financial assets is reduced directly if no impairment amount was previously recognised in the allowance account.

When the terms of financial assets that would otherwise have been past due or impaired have been renegotiated, the Group recognises the impairment for such financial assets by taking into account the original terms as if the terms have not been renegotiated so that the loss events that occurred are duly considered.

Financial guarantees

Where material, financial guarantees issued, which require the issuer to make specified payments to reimburse the holder for a loss it incurs because a specified debtor fails to make payment when due, are recognised as a financial liability at fair value on initial recognition.

The guarantee is subsequently measured at the higher of the best estimate of the obligation and the amount initially recognised less, when appropriate, cumulative amortisation in accordance with AASB 118: Revenue. Where the entity gives guarantees in exchange for a fee, revenue is recognised under AASB 118.

The fair value of financial guarantee contracts has been assessed using a probability weighted discounted cash flow approach. The probability has been based on:

- the likelihood of the guaranteed party defaulting in a next reporting period;
- the proportion of the exposure that is not expected to be recovered due to the guaranteed party defaulting; and
- the maximum loss exposed if the guaranteed party were to default.

Derecognition

Financial assets are derecognised where the contractual rights to receipt of cash flows expires or the asset is transferred to another party whereby the entity no longer has any significant continuing involvement in the risks and benefits associated with the asset. Financial liabilities are derecognised where the related obligations are discharged, cancelled or expired. The difference between the carrying value of the financial liability extinguished or transferred to another party and the fair value of consideration paid, including the transfer of non-cash assets or liabilities assumed, is recognised in profit or loss.

(h) Impairment of assets

At the end of each reporting period, the group assesses whether there is an indication that an asset may be impaired. This assessment includes the consideration of external and internal sources of information including dividends received from subsidiaries, associates or jointly controlled entities deemed to be out of pre-acquisition profits. If such an indication exists, an impairment test is carried out on the asset by comparing the recoverable amount of the asset, being the higher of the asset's fair value less cost to sell and value in use, to the asset's carrying value. Any excess of the asset's carrying value over its recoverable amount is expensed to the Statement of Comprehensive Income.

Note 1: Statement of significant accounting policies (cont'd)

(h) Impairment of assets (cont'd)

Where it is not possible to estimate the recoverable amount of an individual asset, the group estimates the recoverable amount of the cash-generating unit to which the asset belongs.

Impairment testing is performed at each reporting date for goodwill and intangible assets with indefinite lives.

(i) Intangible assets other than goodwill

Patents

Patents are recorded at cost less accumulated amortisation and impairment. Amortisation is charged on a straight line basis over their estimated useful lives. The estimated useful life and amortisation method is reviewed at the end of each annual reporting period, with any changes being recognised as a change in accounting estimate.

Research and development costs

Expenditure on the research activities is recognised as an expense in the period in which it is incurred. Development costs are capitalised only when technical feasibility studies identify that the project will deliver future economic benefits and these benefits can be measured reliably. Development costs have a finite life and are amortised on a systematic basis matched to the future economic benefits over the useful life of the project.

Acquisition costs of operating lease

On 11 January 2011 the group acquired a ground lease on the site commonly known as the Former Reynolds Aluminium Smelter Facility in Longview, Washington, USA. Significant costs were incurred to obtain this lease. These costs have been capitalised as an intangible asset as they relate to payments made to a former tenant to buy out the lease agreement and will be amortised over the remaining term of the lease.

(j) Foreign currency transactions and balances

The individual financial statements of each group entity are presented in the currency of the primary economic environment in which the entity operates (its functional currency). For the purpose of the consolidated financial statements, the results and financial position of each entity are expressed in Australian dollars, which is the functional currency of Ambre Energy Limited and the presentation currency for the consolidated financial statements.

Foreign currency transactions are translated into functional currency using the exchange rates prevailing at the date of the transaction. Foreign currency monetary items are translated at the year-end exchange rate. Non-monetary items measured at historical cost continue to be carried at the exchange rate at the date of the transaction. Non-monetary items measured at fair value are reported at the exchange rate at the date when fair values were determined.

Exchange differences arising on the translation of monetary items are recognised in the Statement of Comprehensive Income, except where deferred in equity as a qualifying cash flow or net investment hedge.

Exchange differences arising on the translation of non-monetary items are recognised directly in equity to the extent that the gain or loss is directly recognised in equity, otherwise the exchange difference is recognised in the Statement of Comprehensive Income.

Note 1: Statement of significant accounting policies (cont'd)

(j) Foreign currency transactions and balances (cont'd)

The financial results and position of foreign operations whose functional currency is different from the group's presentation currency are translated as follows:

i. assets and liabilities are translated at year-end exchange rates prevailing at that reporting date;
ii. income and expenses are translated at average exchange rates for the period where this approximates the rate at the date of the transaction; and
iii. retained earnings are translated at the exchange rates prevailing at the date of the transaction.

Exchange differences arising on translation of foreign operations are transferred directly to the group's foreign currency translation reserve in the Statement of Financial Position. These differences are recognised in the Statement of Comprehensive Income in the period in which the operation is disposed.

(k) Employee benefits

Provision is made for the group's liability for employee benefits arising from services rendered by employees to balance date. Employee benefits that are expected to be settled within one year have been measured at the amounts expected to be paid when the liability is settled. Employee benefits payable later than one year have been measured at the present value of the estimated future cash outflows to be made for those benefits. In determining the liability, consideration is given to employee wage increases and the probability that the employee may satisfy vesting requirements. Those cashflows are discounted using market yields on national government bonds with terms to maturity that match the expected timing of cashflows.

Equity settled compensation

The group operates equity-settled share-based payment employee share and option schemes. The fair value of the equity to which employees become entitled is measured at grant date and recognised as an expense over the vesting period, with a corresponding increase to an equity account. The fair value of options is ascertained using a Black–Scholes and or a binomial option pricing model which incorporates all market vesting conditions. The number of shares and options expected to vest is reviewed and adjusted at each reporting date such that the amount recognised for services received as consideration for the equity instruments granted shall be based on the number of equity instruments that eventually vest.

Defined Benefit Plans

The group has assumed the retirement benefit obligations of two defined benefit plans on the acquisition of the coal assets of Level 3 on 14 November 2011 (see Note 19).

The liability or asset recognised on the Statement of Financial Position in respect of defined benefit plans is the present value of the defined benefit obligation at the end of the reporting period less the fair value of plan assets, together with adjustments for unrecognised past service costs. The defined benefit obligation was calculated on 31 December 2012 (and 30 June 2012) using the unit credit method by independent actuaries.

The present value of the defined benefit obligation is determined by discounting the estimated future cash outflows using interest rates based on high quality corporate bonds that are denominated in the currency in which the benefit will be paid.

Actuarial gains and losses arising from experience adjustments and changes in actuarial assumptions are recognised in the period in which they occur, directly in other comprehensive income.

Note 1: Statement of significant accounting policies (cont'd)

(l) Provisions

Provisions are recognised in the Statement of Financial Position when the group has a legal or constructive obligation as a result of a past event, and it is probable that an outflow of economic benefits will be required to settle the obligation, and that outflow can be reliably measured.

Provisions are measured using the best estimate of the amounts required to settle the obligation at the end of the period.

(m) Cash and cash equivalents

Cash comprises cash on hand and demand deposits. Cash equivalents are short term, highly liquid investments that are readily convertible to known amounts of cash (within 3 months) and are subject to an insignificant risk of changes in value.

(n) Revenue and other income

Revenue is measured at the fair value of consideration received or receivable, net of the amount of goods and services tax.

Interest revenue is recognised as it accrues, taking into account the effective yield on the financial asset.

Revenues have been received for the unloading, handling, storage and trucking of bulk materials. Revenue is recognised when the unloading of alumina is complete at the site. Other revenue from the rendering of services is recognised upon the delivery of the service to the customers. The exception to this is income relating to storage and trucking of coal and rental of land which is invoiced monthly. The source of these revenues is the port facility at Longview, WA, USA.

All revenue is stated net of the amount of goods and services tax ("GST") or appropriate USA taxes.

(o) Trade and other payables

Trade and other payables represent the liabilities for goods and services received by the group that remain unpaid at the end of the financial period. The balance is recognised as current liability with the amounts normally paid within 30 days of recognition of the liability.

(p) Trade and other receivables

Trade receivables are initially recognised at fair value less any provision for impairment. Collectability is reviewed on an ongoing basis. Debtors which are known to be uncollectable are written off by reducing the carrying amount directly. A provision for impairment for trade receivables is raised when there is objective evidence that the group will not be able to collect all amounts due according to the original terms of the receivables. The amount of the impairment is the difference between the carrying amount and the present value of estimated future cash flows, discounted at the original effective interest rate. Cash flows relating to short term receivables are not discounted if the effect of discounting is immaterial.

Note 1: Statement of significant accounting policies (cont'd)

(q) Goods and services tax

Revenue, expenses and assets are recognised net of the amount of GST, except where an amount of GST incurred is not recoverable from the Australian Taxation Office ("ATO"). In these circumstances the GST is recognised as part of the cost of acquisition of an asset or as part of an item of expense.

Receivables and payables are stated with the amount of GST included. The net amount of GST recoverable from, or payable to, the ATO, is included as a current asset or liability in the Statement of Financial Position.

Cash flows are included in the Statement of Cash Flows on a gross basis. The GST components of cash flows arising from investing and financing activities which are recoverable from, or payable to, the ATO are classified as operating cash flows.

(r) Operating segments

In identifying its operating segments, management follows the group's service lines, which represent the main products and services provided by the group.

The three segments identified by management are the three divisions of operation being the Coal, Alternative Fuels and Infrastructure.

The activities of each are as follows:

- Coal – operation and management of thermal coal mines, coal exploration and development of coal resources, development and acquisition of coal mines.
- Alternative fuels – the development and use of alternative fuel technologies including coal to liquids project development and other research and development.
- Infrastructure – the operation of a bulk materials terminal and the development and eventual operation of port facilities for the shipping of coal in the USA.

Note that not all inter-segment transfers are carried out at arm's length prices. However, the inter-segment transfers are infrequent and insignificant.

Unless otherwise stated, all amounts reported to the Board being the chief decision makers with respect to operating segments are determined in accordance with accounting policies which are consistent with those reported in the annual financial statements of the group.

(s) Comparative figures

When required by Accounting Standards, comparative figures have been adjusted to conform to changes in presentation for the current financial period. Where the group has retrospectively applied an accounting policy, made retrospective statement of items in the financial statements or reclassified items in the financial statements an additional statement of financial performance as at the beginning of the earliest comparative period will be disclosed.

Note 1: Statement of significant accounting policies (cont'd)

(t) New accounting standards for application in future periods

The following standards, amendments to standards and interpretations have been identified as those which may impact the group in the period of initial application. They are available for early adoption at 31 December 2012, but have not been applied in preparing these financial statements:

- *AASB 9: Financial Instruments and AASB 2010-7 (applicable for annual reporting periods commencing on or after 1 January 2015):* these standards are applicable retrospectively and amend the classification and measurement of financial assets. The group has not yet determined the potential impact on the financial statements.

- *AASB 13 Fair Value Measurement*: does not affect which items are required to be fair-valued, but clarifies the definition of fair value and provides related guidance and enhanced disclosures about fair value measurements. It is applicable for annual periods beginning on or after 1 January 2013. The group's management have yet to assess the impact of this new standard.

- *AASB 124 Related Party Disclosure amendments:* AASB 2011-4 makes amendments to AASB 124 to remove individual key management personnel disclosure requirements, to achieve consistency with the international equivalent (which includes requirements to disclose aggregate (rather than individual) amounts of KMP compensation), and remove duplication of the Corporations Act 2011. The amendments are applicable for annual periods beginning on or after 1 July 2013. The group's management have yet to assess the impact of these amendments.

- *AASB Interpretation 20 Stripping cost in the Production Phase of a Surface Mine*: clarifies that the costs of removing waste materials (overburden) to gain access to mineral ore deposits during the production phase of a mine must be capitalised as inventories under *AASB 102 Inventories* if the benefits from stripping activity is realised in the form of inventory produced. Otherwise, if stripping activity provides improved access to the ore, stripping costs must be capitalised as a non-current, stripping activity asset if certain recognition criteria are met (as an addition to, or enhancement of, an existing asset). The interpretation is applicable for annual periods beginning on or after 1 January 2013. The group's management are currently assessing the impact of these amendments.

(u) Critical accounting estimates and judgments

The directors evaluate estimates and judgements incorporated into the financial statements based on historical knowledge and best available current information. Estimates assume a reasonable expectation of future events and are based on current trend and economic data, obtained both externally and within the group.

Key judgements

i. Mineral leases and capitalised exploration costs
Included in the financial statements are mineral leases and capitalised exploration costs (see Note 14). The initial value of these assets has been determined by the directors after assessing the value of similar assets and the expected value (discounted) upon successful commercialisation of these assets. The directors believe that the amounts are recoverable with no further impairment expense needed in this period.

ii. Impairment – Investment in Thermosolv, LLC.
The directors have determined that the Group's $163,000 investment in Thermosolv, LLC, an associate of the Group which is fully dedicated to the research and development of alternative fuel technology, be fully impaired for the period.

Note 1: Statement of significant accounting policies (cont'd)

(u) Critical accounting estimates and judgments (cont'd)

iii. Impairment – Loans by the parent to other entities in the group.
The directors of the parent have determined that $3,596,000 of loans to other entities in the group are unrecoverable and accordingly have resolved to reduce the carrying amounts of the pertinent assets for this impairment. While this adjustment has no effect on the consolidated financial statements of the Group it does affect the parent entity disclosures shown in Note 32.

iv. Reclamation liabilities.
Included in the investment in equity accounted investees balance of $3,616,000 (see Note 4) are the majority of the group's reclamation obligations arising from its participation in the joint ventures of Decker Coal Company and Black Butte Coal Company. As the group equity accounts for its interests in these joint ventures in its financial statements its share of the estimated reclamation liabilities of $103.99 million ($USD107.98 million) are included in this amount. The provision for reclamation liabilities have been determined by the directors as the best estimates of the expenditure required to settle the present obligation at the end of the reporting period.

(v) Early adoption of standards

The group has elected to early adopt AASB 10 Consolidated Financial Statements, AASB 11 Joint Arrangements, AASB 12 Disclosure of Interests in Other Entities, AASB 128 Investments in Associates and Joint Ventures, AASB 127 Separate Financial Statements and AASB 2011-7 Amendments to Australian Accounting Standards arising from the Consolidated and Joint Arrangements Standards from July 2011, because the new accounting policies provide more reliable and relevant information for users to assess the composition of the group and the amounts, timing and uncertainty of future cash flows. In accordance with the transition provisions, comparative figures have been restated where applicable. The following is a brief summary of these standards.

- *AASB 10: Consolidated Financial Statements:* supersedes the consolidation requirements in AASB 127 Consolidated and Separate Financial Statements and Interpretation 112 Consolidation – Special Purpose Entities. It revised the definition of control together with accompanying guidance to identify an interest in a subsidiary. However, the requirements and mechanics of consolidation and the accounting for any non-controlling interests and changes in control remain the same.

- *AASB 11 Joint Arrangements:* supersedes AASB 131 Interests in Joint Ventures adopted. It aligns more closely the accounting by the investors with their rights and obligations relating to the joint arrangement. It introduces two accounting categories (joint operations and joint ventures) whose applicability is determined based on the substance of the joint arrangement. In addition, AASB 131's option of using proportionate consolidation for joint ventures has been eliminated. AASB 11 now requires the use of the equity accounting method of joint ventures, which is currently used for investments in associates. See Note 1(w) for accounting treatment for joint ventures.

- *AASB 12 Disclosure of Interests in Other Entities:* integrates and makes consistent the disclosure requirements for various types of investments, including unconsolidated structured entities. It introduces new disclosure requirements about the risks to which an entity is exposed from its involvement with structured entities.

- *AASB 127 Separate Financial Statements* replaces AASB 127 Consolidated and Separate Statements and now deals only with separate financial statements. AASB 128 Investments in Associates and Joint Ventures replaces AASB 128 Investments in Associates and brings investments in joint ventures into its scope. However, AASB 128's equity accounting methodology remains unchanged.

Note 1: Statement of significant accounting policies (cont'd)

(v) Early adoption of standards (cont'd)

The group has also adopted the following standards, amendment to standards and interpretations.

- Amendments to AASB 119 Employee Benefits (IAS 19) has been early adopted the effect of which is that for employee defined benefit plans:
  - Eliminating the 'corridor method', requiring entities to recognise all gains and losses arising in the reporting period in other comprehensive income.
  - Streamline the presentation of changes in plan assets and liabilities.
  - Enhance the disclosure requirements, including information about the characteristics.

See Note 1(k) for details on the group's treatment of defined benefit plans.

(w) Investments in joint ventures

The group acquired interests in joint ventures in the prior period ending 30 June 2012 (see Note 4) and decided to early adopt AASB 11 Joint Arrangements which classifies the newly acquired interests in coal mining assets (amongst other interests) as interests in joint venture entities and are therefore required to be treated as equity accounted investments.

The interest in an investee is accounted for using the equity method after initially being recognised at cost. Under the equity method the group's share of the investees' post-acquisition profits or losses is recognised in the profit or loss, and its share of post-acquisition other comprehensive income is recognised in other comprehensive income. The cumulative post-acquisition movements are adjusted against the carrying amount of the investment. Drawings or dividends from investees are recognised as a reduction in the carrying amount of the investment.

Unrealised gains on transactions between the group and its investees are eliminated to the extent of the group's interest in the investees. Unrealised losses are also eliminated unless the transaction provides evidence of an impairment of the asset transferred.

(x) Investments in associates

Associates are companies over which the Group has significant influence through holding directly or indirectly 20% or more of the voting power of the company. The group has a significant but non-controlling interest in an associated entity and is therefore required to treat such an interest as an equity accounted investee.

The group has acquired a significant but non-controlling interest in an associated entity in the period ended 30 June 2012 (see Note 4) and is therefore required to be treated as an equity accounted investee.

The interest in an investee is accounted for using the equity method after initially being recognised at cost. Under the equity method the group's share of the investees' post-acquisition profits or losses is recognised in the profit or loss, and its share of post-acquisition other comprehensive income is recognised in other comprehensive income.

The cumulative post-acquisition movements are adjusted against the carrying amount of the investment. Drawings or dividends from investees are recognised as a reduction in the carrying amount of the investment.

Unrealised gains on transactions between the group and its investees are eliminated to the extent of the group's interest in the investees. Unrealised losses are also eliminated unless the transaction provides evidence of an impairment of the asset transferred.

Note 1: Statement of significant accounting policies (cont'd)

(y) Borrowing costs

Borrowing costs directly attributable to the acquisition, construction or production of assets that necessarily take a substantial period of time to prepare for their intended use or sale, are added to the cost of those assets, until such time as the assets are substantially ready for their intended use or sale.

All other borrowing costs are recognised in the profit or loss in the period in which they are incurred.

(z) Going concern

Notwithstanding the current and prior year period losses, the financial statements have been prepared on a going concern basis. The Board acknowledges that without further funding the group will deplete its cash reserves within 12 months of the date of this report.

The group successfully secured funding in the year ending 30 June 2012 totalling $132.8 million after acquiring interests in revenue and cash producing assets (see Note 3). During the period an additional $USD25 million loan facility was arranged (see Note 11(b)(i)). At the end of the reporting period the group had $USD20 million remaining for draw down under this facility. At the date of this report the group has drawn down the remaining $USD20 million available under this facility.

Subsequent to period end the group obtained further financing of up to $USD20 million as described under Note 11(b)(ii). Further the group has agreed to the repayment of 25% of the outstanding principal and interest accrued under existing convertible notes with the repayment date for the remaining 75% extended until 31 December 2015 (see Note 11(b)(iii),(iv)).

The Board has assessed the resources available to the group and, subject to raising further funds, believes that the company will be able to pay its debts as and when they fall due. Consequently, these financial statements are prepared on a going concern basis.

Note 2: Segment Information

Management has chosen to organise the group by division around three different activities and are the operating segments used for the purposes of this note.

The operating segments and their respective type of products and services are as follows:

Coal operations, exploration, development and acquisition (Coal)
- Operational management of jointly owned coal mines in the USA.
- Coal exploration and development of coal resources.
- Development and operation of coal mines.
- Acquisition of coal mines.

Infrastructure
Infrastructure entails the acquisition, development and eventual operation of port facilities primarily for the exporting of coal from the United States of America.

Alternative fuels
The development and use of alternative fuel technologies including:
- The development of coal to liquids fuel projects.
- The development of oil shale resources.
- Research and development activities.

Segment earnings are described as Earnings before interest, tax, depreciation and amortisation (EBITDA).

Segment result	Coal Dec 2012 $'000	Infrastructure Dec 2012 $'000	Alternative fuels Dec 2012 $'000	Total Dec 2012 $'000
EBITDA (loss)	(12,735)	(7,632)	(1,799)	(22,166)
Depreciation and amortisation	(170)	(461)	(78)	(709)
Head office expense				(2,481)
Other finance costs				(2,889)
Interest expense				(3,757)
Profit/(loss) after income taxation				(32,002)
Assets and liabilities				
Segment assets	103,067	50,265	22,495	175,827
Unsegmented assets				1,377
Total assets of the group				177,204
Segment liabilities	60,335	20,929	179	81,443
Unsegmented liabilities				21,798
Total liabilities of the group				103,241
Revenues from external customers	2,547	718	17	3,281
Interest revenue	-	-	3	3
Unsegmented interest revenue				79
Total interest revenue				82
Total revenue				3,363

Note 2: Segment information (cont'd)

Segment result	Coal Jun 2012 $'000	Infrastructure Jun 2012 $'000	Alternative Fuels Jun 2012 $'000	Total Jun 2012 $'000
EBITDA (loss)	(14,868)	(12,336)	(4,350)	(31,554)
Impairment expense			(10,857)	(10,857)
Depreciation and amortisation	(148)	(780)	(1,118)	(2,046)
Head office expense				(11,341)
Other finance costs				(7,672)
Interest expense				(1,896)
Taxation expense/ (benefit)				(1)
Profit/(loss) after income taxation				(65,367)
Assets and liabilities				
Segment assets	107,291	42,493	22,428	172,212
Unsegmented assets				16,919
Total assets of the group				189,131
Segment liabilities	65,003	4,221	254	69,478
Unsegmented liabilities				20,661
Total liabilities of the group				90,139
Revenues from external customers	2,899	1,624	88	4,611
Interest revenue	3	4	5	12
Unsegmented interest revenue				239
Total interest revenue				251
Total revenue				4,862

The Group's revenues from external customers and its non-current assets (other than financial instruments, investments accounted for using the equity method, deferred tax assets and post-employment benefits assets) are divided into the following geographical areas:

	Dec 2012		Jun 2012	
	$'000 Revenue	$'000 Non-current assets	$'000 Revenue	$'000 Non-current assets
United States of America	3,350	71,316	4,542	59,022
Australia	13	2,933	88	3,057
Total	3,363	74,249	4,630	62,079

The group has provided port facilities in the infrastructure segment to two customers who accounted for 47% and 44% (Jun 2012: 51% and 42%) of external revenue for this segment.

Note 3: Business combinations

a. On 10 November 2011, the Parent, through a newly created controlled entity, AE Wind River, LLC entered into an agreement with Level 3 Holdings, Inc. ("Level 3") to purchase all of the common stock of Level 3's coal mining operations holding company, Eldorado Coal Inc., a Delaware corporation ("Eldorado Coal"). The transaction closed on 14 November 2011 and post-closing conditions were satisfied on 28 November 2011.

Details of this business combination were disclosed in note 3 of the prior year financial report (June 2012) and note 25 of the 2011 financial report, 'Events after the reporting period'.

		Dec 2012 $'000	Jun 2012 $'000
ASSETS			
Cash and cash equivalents		-	294
Trade and other receivables		-	444
Interests in joint ventures		-	18,093
Property, plant and equipment		-	1,577
Other assets		-	88
Total assets		-	20,496
LIABILITIES			
Trade and other payables		-	20
Provisions		-	9,827
Total liabilities		-	9,847
Identifiable net assets acquired		-	10,649
Gain from bargain purchase		-	(5,768)
Net consideration paid			4,881
Working capital adjustment paid	3(i)	540	(540)
Cash and cash equivalents acquired		-	(294)
Net cash consideration paid in the period		540	4,047

(i) Working capital adjustment

Eldorado coal was purchased for a provisional consideration of $4,341,000. There was an element of consideration payable relating to an adjustment to final working capital calculations at the date of transaction close. The amount of this working capital adjustment was agreed upon in the prior period by the parties to the transaction as $540,000 (US$550,000). This additional consideration was paid in the current period.

Note 4: Joint arrangements and associates

	Note	Dec 2012 $'000	Jun 2012 $'000
Equity accounted investees			
Interests in joint ventures	4(a)	34,522	36,805
Investments in associates	4(e)	-	109
		34,522	36,914
Share of net liabilities of joint ventures	4(a,d(i))	(30,906)	(28,537)

Interests in joint ventures

Set out below are the joint ventures of the group as at 31 December 2012 which, in the opinion of the directors, are material to the group. The country of incorporation or registration is also their principal place of business, and the proportion of ownership interest is the same as the proportion of voting rights held.

Name of Entity	Place of business/ country of registration	% of ownership interest Dec 2012	% of ownership interest Jun 2012	Nature of relationship	Measurement method
Black Butte Coal Company (& R-K Leasing Company)	USA	50	50	Joint Venture (i)	Equity method
Decker Coal Company	USA	50	50	Joint Venture (ii)	Equity method
Montana Royalty Company, Ltd	USA	50	50	Joint Venture (iii)	Equity method

The group's share of loss from its joint ventures for the period was $5,582,000 (Jun 2012:$10,105,000). During the period ended 31 December 2012 the group has received $USD1,000,000 in distributions from the Black Butte Coal Company and made contributions of $USD2,000,000 to the Decker Coal Company in respect of its interests. The joint ventures were acquired on 14 November 2011 (see Note 3).

(i) Black Butte Coal Company operates the Black Butte Coal mine in Wyoming, USA.

(ii) Decker Coal Company operates the Decker coal mine in Montana, USA.

(iii) Montana Royalty Company, Ltd holds property located near the Decker coal mine.

On 5 December 2012 a conditional agreement was reached between Western Minerals, LLC, and the Ambre Energy group for Ambre to purchase Western Minerals' 50 per cent interest in the Decker Coal Company and related interests. However, the group has not been able to complete this purchase (see Note 34a).

Commitments and contingent liabilities - joint ventures

	Dec 2012 $'000	Jun 2012 $'000
b. Commitments- joint ventures		
Share of approved capital expenditure commitments of joint ventures payable, if called:		
Not later than one year	-	3,243

c. Contingent liabilities - joint ventures

The share of the groups contingent liabilities in respect of reclamation obligations of the joint ventures is disclosed under Note 29.

Note 4: Joint arrangements and associates (cont'd)

d. Summarised financial information for joint ventures and associates

The tables below provide summary financial information for those joint ventures that are material to the group. The information disclosed reflects the amounts presented in the Australian Accounting Standards financial statements of the relevant joint ventures and not Ambre Energy Limited's share of those amounts. They have been amended to reflect adjustments made by the entity on acquisition and when using the equity method, including fair value adjustments and modifications for differences in accounting policy.

Summarised balance sheet	Note	Black Butte Coal Company		Decker Coal Company		Montana Royalty Company, Ltd	
		Dec 2012 $'000	Jun 2012 $'000	Dec 2012 $'000	Jun 2012 $'000	Dec 2012 $'000	Jun 2012 $'000
Current assets							
Cash and cash equivalents		3,980	1,809	4,793	4,562	247	254
Other current assets		12,347	16,771	11,257	11,619	-	-
Total current assets		16,327	18,580	16,050	16,181	247	254
Non-current assets		152,726	156,737	79,228	80,654	636	669
Current liabilities							
Financial liabilities (excluding trade payables)		-	-	-	-	43	111
Other current liabilities		18,006	17,623	7,636	17,909	1	-
Total current liabilities		18,006	17,623	7,636	17,909	44	111
Non-current liabilities							
Financial liabilities (excluding trade payables)		-	-	-	-	1,861	1,896
Other non-current liabilities		81,983	83,096	148,431	134,916	-	-
Total non-current liabilities		81,983	83,096	148,431	134,916	1,861	1,896
Net assets		69,064	74,598	(60,790)	(55,990)	(1,022)	(1,084)
Reconciliation to carrying amounts:							
Opening net assets:		74,598	85,959	(55,990)	(52,755)	(1,084)	(1,021)
Profit/(loss) for the period		(1,332)	293	(9,836)	(17,410)	42	(63)
Other comprehensive income/ (loss)		97	(1,287)	141	(2,184)	-	-
Contributions/ (distributions)		(2,908)	(10,367)	3,852	16,359	-	-
Net exchange difference on translation into the presentation currency		(1,391)	-	1,043	-	20	-
Closing net assets		69,064	74,598	(60,790)	(55,990)	(1,022)	(1,084)
Group's share in %		49.99%	49%	50%	50%	50%	50%
Group's share in $		34,522	36,805	(30,395)	(27,995)	(511)	(542)
Goodwill		-	-	-	-	-	-
Carrying amount		34,522	36,805	(30,395)	(27,995)	(511)	(542)

Note 4: Joint arrangements and associates (cont'd)

i The group's share in net assets for the Decker Coal Company and Montana Royalty Company, Ltd represents obligations to contribute funds for future mine reclamation and other commitments. Accordingly $30,906,000 has been disclosed as a non-current liability named share of net liabilities of joint ventures on the Statement of Financial Position.

	Note	Black Butte Coal Company		Decker Coal Company		Montana Royalty Company, Ltd	
		Dec 2012	Jun 2012	Dec 2012	Jun 2012	Dec 2012	Jun 2012
Summarised statement of comprehensive income		**$'000**	**$'000**	**$'000**	**$'000**	**$'000**	**$'000**
Revenue		42,175	63,677	25,345	24,760	115	15
Interest income		-	1	-	-	-	-
Depreciation and amortisation		(8,652)	(5,912)	(1,479)	(6,225)	(21)	(21)
Interest expense		(1)	(24)	(1)	(8)	(47)	(56)
Income tax expense		-	-	-	-	-	-
Profit/(loss) for the period		(1,332)	293	(9,836)	(17,410)	42	(63)
Other comprehensive income/(loss)		97	(1,287)	141	(2,184)	-	-
Total comprehensive income/(loss)		(1,235)	(994)	(9,695)	(19,594)	42	(63)

e. Individually immaterial associates

In addition to the interests in joint ventures discussed above, the group also has an interest in an individual immaterial associate that is accounted for using the equity method.

	Dec 2012	Jun 2012
	$'000	**$'000**
Investment in associate	163	109
Less provision for impairment	(163)	-
Carrying amount of individually immaterial associate	-	109
Amount of the group's share of:		
Profit/(loss) from continuing operations	(5)	(47)
Other comprehensive income/(loss)	-	-
Total comprehensive income/(loss)	(5)	(47)

Note 5: Revenue

	Note	Dec 2012 $'000	Jun 2012 $'000
Sales revenue			
Services		906	1,583
Management fee income - related party		2,335	2,888
Other revenue			
Interest		82	251
Rent and sub-lease rentals		40	(92)
		3,363	4,630

Note 6: Other Income

Government grants	6(a)	86	84
Fair value gains (losses) on:			
Embedded derivative liability		1,407	-
Other income		38	148
		1,531	232

(a) Government grants

Research and development grants of $86,000 (Jun 2012: $84,000) were recognised as other income during the financial period. There are no unfulfilled conditions or other contingencies attaching to these grants.

Note 7: Expenses

	6 mth Dec 2012 $'000	12 mth Jun 2012 $'000
Profit/(loss) before income tax includes the following specific expenses:		
Net loss on expiry of held to maturity financial assets	-	109
Finance costs		
Interest and finance charges paid/payable for financial liabilities	4,592	1,303
Provisions - unwinding of discount	2,054	593
Share based payment expense for financial liabilities	-	7,672
Premiums paid for the provision of surety bonds to the States of Montana & Wyoming, USA for coal mine reclamation obligations	1,489	1,827
Finance costs expensed	8,135	11,395
Impairment losses		
Investment in associate (4(e))	163	-
Impairment of other assets		
Other assets	-	80
Land and buildings	-	1,112
Capitalised exploration costs	-	7,639
Patents	-	2,026
	163	10,857

Note 8: Income tax expense

	Dec 2012 $'000	Jun 2012 $'000
a. The components of tax expense/(benefit) comprise:		
Current tax	-	-
Over provision for income tax benefit from prior year	-	1
Deferred tax	-	-
	-	1
The prima facie tax on profit from ordinary activities before income tax is reconciled to the income tax as follows:		
Profit from continuing operations before income tax expense	(32,002)	(65,366)
Tax at the Australian tax rate of 30% (Jun 2012: 30%)	(9,601)	(19,609)
Tax effect of amounts which are not deductible (taxable) in calculating taxable income:		
- Entertainment	21	9
- Gifts and donations	6	1
- Gain on business combination	-	(1,729)
- Finance costs	-	2,301
- Share option expense	1,541	2,698
- Travel	-	6
- Other non deductible expenses	42	556
	(7,991)	(15,767)
Effect of different tax rates of subsidiaries operating in other taxation jurisdictions.	(1,869)	(2,700)
(Under)/over provision in prior period	163	1
- Deferred tax assets not brought to account	9,697	18,467
Less:		
Tax effect of:		
- Tax concessions (research and development)	-	-
Income tax expense/ (benefit) attributable to entity	-	1
Weighted average effective tax rates	0.0%	0.0%

Where applicable, grants and tax concessions are accrued in the year in which they are receivable.

Potential deferred tax assets attributable to unused tax losses and unrecognized temporary differences carried forward:	45,542	35,845

Unused tax losses and unrecognised temporary differences relate to the Australian tax consolidated group and three USA tax groups.

Of the three USA tax groups, the tax group headed by AE Oil Shale, Inc. has restrictions on the utilisation of losses within the group.
The unused restricted losses of this USA tax group are as follows:

- group headed by AE Oil Shale, Inc.	4,729	4,819

The unused losses of each subsidiary within this USA tax group may only be utilised against taxable profits of the same subsidiary. The potential tax benefit of restricted unused tax losses of the USA tax group are as follows:

- group headed by AE Oil Shale, Inc.	1,764	1,798

Note 9: Cash and cash equivalents

	Note	Dec 2012 $'000	Jun 2012 $'000
Cash at bank and in hand		2,887	20,300

(a) The group's exposure to interest rate risk is discussed in Note 31. The maximum exposure to credit risk at the end of the reporting period is the carrying amount of each class of cash and cash equivalents mentioned above.

Note 10: Trade and other receivables

Current assets			
Trade receivables	10(a)	1,050	1,330
GST receivable		90	173
Other receivables		-	805
Corporate relocation program	10(b)	329	389
Amounts receivable from related parties		662	-
		2,131	2,697

(a) Trade receivables
All amounts are short-term. The net carrying value of trade receivables is considered a reasonable approximation of fair value.

The group's trade and other receivables have been reviewed for indicators of impairment. No trade receivables were found to be impaired and no allowance for credit losses has been recorded. Trade receivables are non-interest bearing and generally paid within 14 days.

(b) Corporate relocation program
A controlled entity provides assistance with the relocation expenses of USA based senior employees through an external residential brokerage relocation service provider. Amounts totalling $329,000 are recoverable from the relocation service provider for advances and relocation expenses paid by the controlled entity (see Note 30(b)).

Note 11: Financial assets and liabilities

The carrying amounts presented in the Statement of Financial Position relate to the following categories of assets and liabilities:

	Note	Dec 2012 $'000	Jun 2012 $'000
Financial assets			
Current:			
Loans and receivables			
- Cash and cash equivalents		2,887	20,300
- Trade and other receivables		2,131	2,697
		5,018	22,997
Non-current:			
- Other assets		472	477
- Restricted cash	11(a)	59,973	64,750
		60,445	65,227
Financial liabilities			
Measured at amortised cost:			
Current:			
- Borrowings	11(b)	18,282	39,983
- Trade and other payables		5,969	5,847
- Lease liabilities	25	184	-
- Share application funds		46	-
Measured at fair value through profit or loss:			
Current:			
- Borrowings	11(b)	2,407	3,813
		26,888	49,643
Measured at amortised cost:			
Non-current:			
- Borrowings	11(b)	32,130	-
- Lease liabilities	25	721	-
		32,851	-

11a. Restricted cash

- Deposits not at call:		
Opening collateral provided	64,750	69,370
Additions (reductions) during the period	(3,570)	(4,555)
Net exchange difference arising on translation of a foreign subsidiary into the presentation currency	(1,207)	(65)
	59,973	64,750

As at reporting date the group has outstanding collateral of $59.97m (USD $62.28m) to Zurich of North America ("Zurich") via a restricted cash holding with the Bank of New York Mellon. Zurich has provided surety bonds required by the States of Wyoming and Montana (the "States") for the groups share of financial assurance in relation to the mining operations acquired in the States (see Note 3). Additionally the parent and certain controlled entities have unconditionally indemnified Zurich against all losses in connection with the issued bonds, excluding any amount paid or payable to a reinsurer or co-surety provider. During the period the restricted cash holding was reduced by USD $3.71 million due to surety bonding refunds received.

Note 11: Financial assets and liabilities (cont'd)

11b. Borrowings	Note	Dec 2012 $'000	Jun 2012 $'000
Secured			
Financial liabilities measured at amortised cost (unless otherwise indicated)			
Current			
- Short term loan	(i)	-	24,534
- Unsecured redeemable convertible notes	(iii,iv)	18,282	15,449
- embedded derivative liability (at fair value through profit or loss)	(iii,iv)	2,407	3,813
Non- current			
- Secured loan	(i,ii)	32,130	-
		52,819	43,796

(i) Ambre Energy shareholder and financier, Resource Capital Fund V L.P. ("RCF") provided ongoing funding to the group during the reporting period as recorded in the following amendments to the original short-term bridge loan agreement (the "Loan") between RCF and Ambre Energy North America, Inc. ("AENA") dated 14 November 2011:

Amendment dated 26 October 2012
- The term of the Loan, originally 12 months, was extended by 60 days.
- The amount of the Loan, originally $USD25 million and fully drawn, was increased by a further $USD5 million advanced to AENA on 1 November 2012.

Amendment dated 10 December 2012 (entitled First Amended and Restated Loan Agreement)
- The term of the Loan was extended for a further 4 years, and now matures on 8 January 2017.
- The amount of the Loan was increased to $USD50 million, to be drawn down in tranches.
- The interest rate for the Loan was increased from 5% to 12% per annum, with interest to be capitalised monthly rather than paid during the course of the Loan.
- An establishment fee of $USD3 million was capitalised as part of the principal of the Loan and is included under finance costs in the Statement of Comprehensive Income.
- A Makewhole Amount was added to the principal and interest, so that the total amount of the Loan repayable on maturity or on default is $USD110 million, regardless of the outstanding principal and interest accrued at time of repayment.
- The Loan was made convertible to ordinary shares in the parent on or after a liquidity event, subject to shareholder approval

- An additional obligation was imposed on the group to obtain by 31 July 2013 all permits necessary to commence development and operation of the Morrow Pacific Project (the "Morrow Deadline"), unless this deadline was extended by RCF.

(ii) After the reporting period, the following advances were made to AENA under the Loan:
- $USD5 million on 8 January 2013
- $USD5 million on 5 March 2013

and thereafter RCF provided additional funding to the group as recorded in the following further amendments to the Loan:

Amendment dated 4 April 2013
- Certain conditions of the Loan were relaxed to allow the final draw down under the Loan of $USD10 million to be advanced to AENA on 4 April 2013.
- In exchange, RCF was granted 250,000 new ordinary shares in the parent.

Amendment dated 20 August 2013 (entitled Second Amended and Restated Loan Agreement)
- In exchange for receiving 50 million new ordinary shares in the parent (the "Establishment Fee"), RCF will:
  - provide a letter of credit facility for up to $USD20 million for the purpose of releasing restricted cash held by Zurich as collateral for reclamation bonds; and
  - extend the Morrow Deadline from 31 July 2013 to 31 December 2015, subject to shareholder approval.
- RCF may now convert the Loan at any time to the greater of 220 million shares in the parent or 32.4% of the fully diluted capital of the parent at the conversion date, adjusted to exclude shares issued or issuable after 1 July 2013 for $0.50 or more
- RCF will allow the convertible noteholders, KOSEP and KOSPO, to take security over the assets of subsidiary Ambre Energy North America Inc, ranking pari passu with the security held by RCF over those assets. That concession was instrumental in obtaining the agreement of the convertible noteholders to extend the repayment date of the convertible notes (see notes 34(f) and 34(g)).

Note 11: Financial assets and liabilities (cont'd)

- The parent must seek shareholder approval to allow RCF to increase its voting power up to 55% ("the Shareholder Approval"). Furthermore:
  - The parent has issued 12.5 million new ordinary shares to RCF as part payment of the Establishment Fee, with the balance of 37.5 million ordinary shares to be issued to RCF subject to the Shareholder Approval.
  - RCF has provided an initial letter of credit for $USD10 million but is not obliged to provide letters of credit totalling more than $USD15 million before the Shareholder Approval.
  - The Morrow Deadline is extended until 10 business days after the shareholder meeting, and will not be further extended to 31 December 2015 unless RCF is given the Shareholder Approval.

(iii) 12.655 million redeemable convertible notes at $1 per note were issued to the Korea South East Power Co., Limited (KOSEP) on 31 May 2012 with an initial repayment date of 31 May 2013. The interest on the notes was 5% per annum until 15 July 2012 and 10% per annum thereafter. Note that the interest rate was changed after the end of the reporting period to 14% per annum, to take effect from 10 December 2012 (see Note 34(e)). Conversion of the notes to issued shares is at the discretion of the holder. The parent provides security (to the effect of a fixed and floating charge) over all its assets in relation to the above arrangement.

Subsequent to reporting date and further to the interest rate amendment (see Note 34(e)) the terms of the convertible notes including the repayment date, conversion rights and security provided were renegotiated with 25% of the notes to be repaid following the satisfaction of certain conditions to the agreement (see note 34(f)) and the balance to be repaid by 31 December 2015.

The KOSEP convertible notes are considered to be a hybrid financial instrument with an amortised financial liability component and an embedded derivative liability component that are disclosed separately. The value of the embedded derivative liability at reporting date was $1,557,000 (initial recognition was $2,546,000 with the balance of $10,108,000 recognised as a financial liability). The amortised cost of the financial liability at reporting date was $12,291,000.

(iv) 4.2 million redeemable convertible notes at $1.50 per note were issued to the Korea Southern Power Co., Limited (KOSPO) on 28 June 2012 with an initial repayment date of 28 June 2013. The interest on the notes was 5% per annum until the 15 July 2012 and 10% per annum thereafter. Note that the interest rate was changed after the end of the reporting period to 14% per annum, to take effect from 10 December 2012 (see Note 34(e)). Conversion of the notes to issued shares is at the discretion of the holder. The parent provides security (to the effect of a fixed and floating charge) over all its assets in relation to the above arrangement.

Subsequent to reporting date and further to the interest rate amendment (see Note 34(e)) the terms of the convertible notes including repayment date, conversion rights and security provided were renegotiated with 25% of the notes to be repaid following the satisfaction of certain conditions to the agreement (see note 34(g)) and the balance to be repaid by 31 December 2015.

The KOSPO convertible notes are considered to be a hybrid financial instrument with an amortised financial liability component and an embedded derivative liability component that are disclosed separately. The value of the embedded derivative liability at reporting date was $850,000 (initial recognition was $1,267,000 with the balance of $5,033,000 recognised as a financial liability). The amortised cost of the financial liability at reporting date was $5,991,000.

Note 12: Property, plant and equipment

	Dec 2012 $'000	Jun 2012 $'000
Land and buildings		
Freehold land		
At cost	5,092	5,190
Accumulated depreciation	(16)	(9)
Less impairment	(1,112)	(1,112)
Total land	3,964	4,069
Buildings		
At cost	873	870
Accumulated depreciation	(460)	(408)
Total buildings	413	462
Total land and buildings	4,377	4,531
Plant and equipment		
At cost	31,199	23,280
Accumulated depreciation	(6,526)	(6,065)
	24,673	17,215
Leasehold improvements		
At cost	114	110
Accumulated amortisation	(59)	(47)
Total leasehold improvements	55	63
Total plant and equipment	24,728	17,278
Total property, plant and equipment	29,105	21,809

a. Movements in carrying amounts

Movement in the carrying amounts for each class of property, plant and equipment between the beginning and the end of the current period.

		Freehold land	Buildings	Leasehold improvements	Plant and equipment	Total
		$'000	$'000	$'000	$'000	$'000
Balance at 1 July 2011		3,141	405	47	12,269	15,862
Additions		877	24	34	7,164	8,099
Acquisition of subsidiary		1,159	155	-	263	1,577
Disposals		0	0	-	(1,464)	(1,464)
Impairment		(1,112)	-	-	-	(1,112)
Net exchange difference arising on translation of a foreign subsidiary into the presentation currency		13	2	2	614	631
Depreciation and amortisation expense		(9)	(124)	(20)	(1,631)	(1,784)
Balance at 30 June 2012		4,069	462	63	17,215	21,809
Balance at 1 July 2012		4,069	462	63	17,215	21,809
Additions	12(b)	0	0	6	8,452	8,458
Disposals		(61)	-	-	(48)	(109)
Net exchange difference arising on translation of a foreign subsidiary into the presentation currency		(37)	2	(2)	(320)	(357)
Depreciation and amortisation expense		(7)	(51)	(12)	(626)	(696)
Balance at 31 December 2012		3,964	413	55	24,673	29,105

b. Leased assets

Plant and equipment includes the following amounts where the group is a lessee under a finance lease:

	Dec 2012 $'000	Jun 2012 $'000
Leasehold equipment		
At cost	965	-
Accumulated depreciation	(80)	-
Net book value	885	-

Note 12: Property, plant and equipment (cont'd)

b. Leased assets (cont'd)

During the period the group acquired leased assets of $965,000 through a financial lease. This amount less an amount of $196,000 for a non-cash item adjustment are not included in the purchase of property plant and equipment amount of $7,689,000 per the Statement of Cashflows.

Note 13: Intangible assets

	Dec 2012	Jun 2012
	$'000	$'000
Patents		
At cost	2,956	2,956
Accumulated amortisation	(930)	(930)
Less provision for impairment	(2,026)	(2,026)
Net carrying value	-	-
Capitalised development costs - coal terminal		
At cost	16,878	12,197
Accumulated amortisation	-	-
Net carrying value	16,878	12,197
Acquisition costs for long-term operating lease		
At cost	8,419	8,579
Accumulated amortisation	(276)	(210)
Net carrying value	8,143	8,369
Total intangible assets	25,021	20,566

a. Movements in carrying amounts

Movement in the carrying amounts for each class of intangible between the beginning and the end of the current period.

	Note	Patents	Capitalised development costs	Acquisition cost for operating lease	Total
		$'000	$'000	$'000	$'000
Balance at 1 July 2011		2,076	2,841	8,078	12,995
Development costs capitalised	13(b)	-	9,226	-	9,226
Amortisation charge		(164)	-	(210)	(374)
Impairment		(2,026)	-	-	(2,026)
Net exchange difference arising on translation of a foreign subsidiary into		114	130	501	745
Balance at 30 June 2012		-	12,197	8,369	20,566
Balance at 1 July 2012		-	12,197	8,369	20,566
Development costs capitalised	13(b)	-	4,908	-	4,908
Amortisation charge		-	-	(70)	(70)
Impairment		-	-	-	-
Net exchange difference arising on translation of a foreign subsidiary into		-	(227)	(156)	(383)
Balance at 31 December 2012		-	16,878	8,143	25,021

b. $4,908,000 (Jun 2012: $9,226,000) has been spent on the development of coal terminal facilities in the USA in the period.

Note 14: Exploration and evaluation assets

	Note	Dec 2012 $'000	Jun 2012 $'000
Mineral leases & exploration expenditure capitalised			
- Exploration and evaluation phases - Felton, Queensland, Australia	14(a)	-	-
- Exploration and evaluation phases - Utah, United States of America	14(b)	19,531	19,039
- Coal exploration and evaluation phases - United States of America	14(c)	57	124
Total exploration expenditure		19,588	19,163

a. Movements in carrying amounts

Opening balance	-	7,310
Exploration expenditure capitalised	-	329
Less impairment	-	(7,639)
Closing balance	-	-

b. Movements in carrying amounts

Opening balance	19,039	17,936
Exploration expenditure capitalised	72	89
Net exchange difference arising on translation of a foreign subsidiary into the presentation currency	420	1,014
Closing balance	19,531	19,039

c Movements in carrying amounts

Opening balance	124	-
Exploration expensed	(67)	-
Exploration expenditure capitalised	-	124
Closing balance	57	124

Note 15: Other assets

		Dec 2012 $'000	Jun 2012 $'000
CURRENT			
Deposits paid		170	124
Escrowed funds	15(b)	362	409
Prepayments		2,853	1,821
Other		57	37
		3,442	2,391
NON-CURRENT			
Deposits paid		63	64
Note receivable	30(b)	299	304
Cash backed bank guarantees	15(a)	173	173
		535	541

a. Restricted cash deposited with a bank as security under an office lease.

b. Escrowed funds is in relation to potential liabilities arising under an asset purchase agreement.

Note 16: Trade and other payables

The carrying amounts may be analysed as follows:	Dec 2012 $'000	Jun 2012 $'000
CURRENT		
Unsecured liabilities		
Trade payables	3,964	3,344
Amounts payable to related parties	-	108
Sundry payables and accrued expenses	2,005	2,395
	5,969	5,847

Note 17: Employee entitlements

	Short-term employee benefits $'000	Long-term employee benefits $'000
Opening balance at 1 July 2012	383	155
Additional provisions	286	42
Amounts used	(269)	-
Net exchange difference arising on translation of a foreign subsidiary into the presentation currency	(4)	-
Balance at 31 December 2012	396	197

Analysis of total employee entitlements

	Dec 2012 $'000	Jun 2012 $'000
Current	396	383
Non-current	197	155
	593	538

Provision for short-term employee benefits

A provision has been recognised for employee entitlements relating to annual leave. The measurement and recognition criteria relating to employee benefits has been included in Note 1 to this report.

Provision for long-term employee benefits

A provision has been recognised for employee entitlements relating to long service leave. In calculating the present value of future cash flows in respect of long service leave, the probability of long service leave being taken is based on historical data. The measurement and recognition criteria relating to employee benefits has been included in Note 1 to this report.

Note 18: Provisions

The carrying amounts may be analysed as follows:

	Note	Carrying amount at 1 July 2012	Additional provisions	Amounts used	Foreign exchange movem't	Carrying amount at 31 Dec 2012
		$'000	$'000	$'000	$'000	$'000
Provision for asset retirement obligations	18(a)	1,001	-	(369)	100	732
Asset purchase adjustments - Chinook		200	-	(200)	-	-
Asset purchase adjustments - Eldorado		540	-	(540)	-	-
Repairs and claims	18(c)	409		(39)	(8)	362
Provision for pension and retirement benefits	18(b)	8,967	2,266	(463)	(227)	10,543
Black lung reserves		74	2	(7)	(2)	67
Other		230	84	(11)	(4)	299
Total		11,421	2,352	(1,629)	(141)	12,003

	Dec 2012	Jun 2012
	$'000	$'000
Current	460	1,296
Non-current	11,543	10,125
	12,003	11,421

a. Provisions for asset retirement obligations relate to final amounts required to reclaim land and buildings at a former 100% owned coal mining operation, Big Horn Coal Mine which is in the final stages of reclamation.
b. Provisions for pension and retirement benefits liabilities refer to post-employment defined benefit pension plans as well as a plan for other post employment benefits at Big Horn Coal Company. The plans for Big Horn contain only inactive participants (see Note 19).
c. The provisions for repair and claims arises from the 2011 asset purchase agreement with Chinook Ventures, Inc. The group's management expects to settle the remaining claims in the 2013 financial year.

Note 19: Accrued pension and retirement benefits liability

Two plans being the Big Horn Coal Company Pension Plan (Pension Plan) and Big Horn Coal Company Retiree Medical and Life (Medical and Life) are the sole responsibility of the group and are disclosed as follows.

The Big Horn Coal Company is no longer active and consequently has no employees. Accordingly all members are former employees, surviving spouses or qualified dependants of former employees.

Big Horn Coal Company Pension Plan

The defined benefit obligation for Pension Plan for the period ending 31 December 2012:

	Dec 2012	Jun 2012
	$'000	$'000
Opening defined benefit obligation	2,485	2,381
Current service cost	30	38
Interest cost	44	62
Change in actuarial assumptions	34	141
Experience adjustments on plan liabilities	53	(17)
Benefits paid	(169)	(112)
Foreign exchange movement	(46)	(8)
Closing defined benefit obligation	2,431	2,485

For determination of the Pension Plan obligation and expense, the following actuarial assumptions were used.

	Dec 2012	Jun 2012
Discount rate	3.65%	3.80%
Expected long term rate of return on plan assets	8.00%	8.00%

The mortality table used is ' Fully Generational RP-2000 Combined Healthy Blue Collar - using Projection Scale AA'.

The assets held for this Pension Plan's defined benefit obligations can be reconciled for the period as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Opening fair value of plan assets	1,633	1,650
Actual return on plan assets	100	101
Plan contributions	164	-
Benefits paid out of plan assets	(169)	(112)
Foreign exchange movement	(30)	(6)
Closing fair value of plan assets	1,698	1,633

The Pension Plan's defined benefit obligation and its assets may be reconciled to the amounts presented on the face of the statement of financial position for the reporting period under review as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Defined benefit obligations	(2,431)	(2,485)
Fair value of planned assets	1,698	1,633
Shortfall / pension cost	(733)	(852)

Note 19: Accrued pension and retirement benefits liability (cont'd)

Total expenses resulting from the Pension Plan can be analysed as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Service cost	(30)	(39)
Interest cost	(44)	(63)
Expected return on plan assets	65	78
	(9)	(24)

The expected employer contribution for next year is $193,000 (June 2012 $270,000)

Big Horn Coal Company Retiree Medical and Life

The defined benefit obligation for Medical and Life for the period ending 31 December 2012:

	Dec 2012	Jun 2012
	$'000	$'000
Opening defined benefit obligation	8,115	7,721
Current service cost	-	-
Interest cost	238	213
Actuarial loss or (gain)	1,866	552
Benefits paid	(276)	(361)
Retiree drug subsidy received	18	16
Foreign exchange movement	(151)	(26)
Closing defined benefit obligation	9,810	8,115

For determination of the defined benefit obligation, the following actuarial assumptions were used:

	Dec 2012	Jun 2012
Discount rate	3.75%	3.85%
Health care cost trend: Initial	9.50%	7.50%
Health care cost trend: Ultimate	5.00%	5.00%
Year ultimate reached	2022	2020

The assets held for Medical and Life's defined benefit obligations can be reconciled from the date of assumption to the reporting date as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Opening fair value of plan assets	-	-
Employer contribution	276	361
Benefits paid	(276)	(361)
Closing fair value of plan assets	-	-

Medical and Life's defined benefit obligation and its assets may be reconciled to the amounts presented on the face of the statement of financial position for the reporting period under review as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Defined benefit obligations	(9,810)	(8,115)
Fair value of planned assets	-	-
Shortfall / pension cost	(9,810)	(8,115)

Total expenses resulting from this defined benefit plan can be analysed as follows:

	Dec 2012	Jun 2012
	$'000	$'000
Service cost	-	-
Interest cost	(238)	(213)
Expected return on plan assets	-	-
	(238)	(213)

The expected contribution for next year is $539,000 (June 2012: $534,000).

Note 20: Issued capital

Effective 1 July 1998 the Corporations Law abolished the concepts of authorised share capital and par value. Accordingly the parent entity has no authorised capital and its shares have no par value.

	Note	Dec 2012	Jun 2012
		No.	No.
Ordinary shares - issued	20(a)	408,793,740	405,835,907
		$'000	$'000
Ordinary shares - fully paid		182,967	180,892
Issue costs		(4,449)	(4,449)
Issued capital		178,518	176,443

a. Ordinary shares		No.	No.
At the beginning of the reporting period		405,835,907	318,216,983
Shares issued on equity settled transactions		-	21,997,757
Shares issued on exercise of options	20(c)	2,062,000	5,000,000
Shares issued on conversion of convertible notes and interest	20(b)	-	60,142,000
Shares issued in lieu of interest payments on loans outstanding		895,833	479,167
At the end of the reporting period		408,793,740	405,835,907

At the shareholders meetings, each ordinary share is entitled to one vote if a poll is called, otherwise each shareholder has one vote on a show of hands.

b. Redeemable convertible notes	Dec 2012 No.	Jun 2012 No.
At the beginning of the reporting period	16,855,000	12,642,000
Notes issued	-	76,855,000
Notes redeemed	-	(12,500,000)
Conversion into ordinary shares	-	(60,142,000)
At the end of the reporting period	16,855,000	16,855,000

c. Options

Share options and weighted average exercise prices are as follows for the reporting period presented:

	Note	Dec 2012		Jun 2012	
		Number of options	Weighted average exercise price $	Number of options	Weighted average exercise price $
Outstanding at the beginning of the period		106,070,000	1.36	83,420,000	0.32
Granted		500,000	1.50	78,850,000	1.64
Forfeited		(350,000)	1.20	(20,800,000)	0.21
Exercised	20c(i)	(3,302,941)	0.48	(5,000,000)	0.26
Expired		(5,967,059)	0.48	(30,400,000)	0.20
Outstanding at the end of the period		96,950,000	1.45	106,070,000	1.36
Exercisable at reporting period end		59,909,999	1.13	59,992,500	1.02

The options outstanding at 31 December 2012 had a weighted average exercise price of $1.45 and a weighted average remaining contractual life of 3.03 years. Exercise prices range from $0.48 to $2.47 in respect of options outstanding at 31 December 2012.

Note 20: Issued capital (cont'd)

c. Options (cont'd)

The fair values of options granted were determined using a variation of the binomial option pricing model that takes into account factors specific to the share option incentive plans, such as the vesting period.

The following principal assumptions were used in the valuations of options issued this period:

Exercise price	$1.50
Life of the option	4 years
Underlying share price	$1.50
Expected share price volatility	44.2%
Risk free interest rate	2.68%

Due to the company's low trading volumes over recent times, it is the view of the company's management that the future expected volatility is better represented by an average volatility of similar companies listed on the Australian Securities Exchange. An analysis of similar listed companies provided a volatility of 44.2%.

Share based employee remuneration of $5,068,000 has been included in share based payments expense of $5,136,000. The group employee share option plans (Australian & USA) are the basis for the share based employee remuneration as well as a employee share option scheme in a subsidiary, Ambre Fuels Limited.

The share based expense that relates to the subsidiary employee share scheme is $629 for the period. Note that the only shareholder of this subsidiary is Ambre Energy Limited.

(i) Under the parent entity's employee share option plan, option holders are entitled, as an alternative to exercising their options through payment of the exercise price, to exchange their options for a lesser number of shares based on the prevailing value of the company's shares (commonly referred to as "cashless exercise"). During the period, 2,727,941 options were exchanged for 1,855,000 ordinary shares by way of cashless exercise. No consideration was paid to the company for these share issues.

(ii) Subsequent to the reporting period, on 20 March 2013, the CEO & Managing Director Mr E Choros elected to cancel 30.0 million options granted in May 2012 to Mr Choros's related entities. Following the cancellation of these options total options outstanding at the date of this report are 67,450,000.

Note 21: Subsidiaries and transactions with non-controlling interests

a. Interest in subsidiaries

Set out below are the group's principal subsidiaries at 31 December 2012. Unless otherwise stated, the subsidiaries as listed below have share capital consisting solely of ordinary shares, which are held directly by the group, and the proportion of ownership interests held equals to the voting rights held by the group. The country of incorporation or registration is also their principal place of business.

Name of entity	Note	Place of business/ country of incorporation	Ownership interest held by the group(%)		Principal activities
			Dec 2012	Jun 2012	
Ambre Energy (Felton) Pty Ltd		Aust	100	100	Coal exploration
Ambre Energy Exploration Pty Ltd		Aust	100	100	Coal exploration
Ambre Fuels Limited (formerly Ambre CTL Limited)		Aust	100	100	CTL project development
Ambre EOR Pty Ltd		Aust	100	100	CTL project development
Ambre Pipelines Pty Ltd		Aust	100	100	CTL project development
AE Minerals Pty Ltd		Aust	100	100	AUS corporate
AE Oil Shale, Inc.		USA	100	100	Oil shale resource development
Ambre Energy Partners, Inc.		USA	100	100	Oil shale development
Ambre Energy Technology, LLC		USA	100	100	Oil shale development
AE Alternative Fuels, LLC		USA	100	100	R & D activities
AE Fuels North America, LLC		USA	100	100	CTL project development
Ambre Energy North America, Inc.		USA	100	100	USA corporate
AE Coal, LLC		USA	100	100	Coal operations management
AE Infrastructure, LLC		USA	100	100	Coal terminal development
Millennium Bulk Terminals-Longview, LLC	21(b)	USA	62	62	Bulk materials terminal operation and development
AE Coal Marketing, LLC		USA	100	100	Marketing
Coyote Island Terminal, LLC		USA	100	100	Coal terminal development
Gulf States Bulk Terminal, LLC		USA	100	100	Coal terminal development
Barlow Point Land Company, LLC		USA	62	62	Bulk materials terminal operation
Pacific Transloading, LLC		USA	100	100	Coal terminal development
AE Wind River, LLC		USA	100	100	USA corporate
Eldorado Coal, Inc.		USA	100	100	USA corporate
KCP, Inc.		USA	100	100	Coal operations management
KCP Properties, Inc.		USA	100	100	Coal operations assets holdings
Big Horn Coal Company		USA	100	100	Reclaimed coal property
Rosebud Coal Sales Company		USA	100	100	Reclaimed coal property

b. During the period the non-controlling interest in Millennium Bulk Terminals-Longview, LLC contributed $3,810,000 (USD$3,956,000) being its ownership interests (38%) share of capital contributions required to fund operational and capital expenditure for the period (Jun 2012: $7,529,000).

Note 22: Reserves

a. Foreign currency translation reserve

The foreign currency translation reserve records exchange differences arising on translation of a foreign controlled subsidiary.

b. Option reserve

The option reserve records items recognised as expenses on valuation of share options.

c. Other reserves

Other reserves includes share of other comprehensive income from equity accounted investees and actuarial gains or losses from defined employee pension and retirement schemes.

Note 23: Employee remuneration

a. Employee benefits expense	Dec 2012 $'000	Jun 2012 $'000
Wages and salaries	5,262	9,651
Annual leave	230	279
Long service leave	7	56
Personal leave	34	28
Superannuation contribution	197	294
Workers compensation	-	40
Other employee expenses	354	560
	6,084	10,908

b. Share based payments

See Note 20(c) for detail on share based payments to employees.

Note 24: Earnings per share

Both basic and diluted earnings per share have been calculated using the total income attributable to members of the parent entity (after tax) as the numerator.

The weighted average number of shares used in the calculation of basic earnings per share and diluted earnings per share is as follows:

Amounts in shares:	Dec 2012 No.	Jun 2012 No.
Weighted average number of ordinary shares used in basic earnings per share	406,286,881	366,060,350
Effect of share options and convertible notes on issue	-	-
Weighted average number of ordinary shares used in diluted earnings per share	406,286,881	366,060,350

Note that issued convertible notes and issued company share options are considered to be antidilutive and therefore were excluded from the diluted weighted average number of ordinary shares calculation.

Note 25: Leasing commitments

	Dec 2012 $'000	Jun 2012 $'000
a. Operating lease commitments		
Non-cancellable operating leases contracted for but not recognised in the financial statements:		
Minimum lease payments due		
- Not later than 12 months	1,118	1,140
- One year or later and not later than five years	3,770	3,151
- Later than five years	-	-
	4,888	4,291

The operating lease commitments include two significant non-cancellable office property leases in Australia and the United States of America. All leases allow for subletting. Also included in operating lease commitments is a non-cancellable lease for land in Corpus Christi Texas that was entered into during the last period that is a subject site for the development of a coal port facility. The lease has 5 end on end options with each option providing a renewal at the discretion of the group for a further term of 5 years.

b. Ground lease

Millennium Bulk Terminals-Longview, LLC (MBTL), a controlled entity entered into a ground lease on the site commonly known as the Former Reynolds Aluminium Smelter Facility in Longview, Washington, USA, on 11 January 2011 for an initial term of sixty years with Northwest Alloys, Inc. (Lessor). Annual rental commitments do not commence until 1 January 2014 and will equate to the provision of alumina and other bulk material handling and/or offloading services provided to the lessor not exceeding set limits. Due to the contingent nature of the rent, there are no minimum lease payments relating to the ground lease included in the minimum lease payments due shown above. The rent free period ending on 31 December, 2013 recognises the expenditure requirements of MBTL relating to specified work obligations include the demolition, removal and disposal of substantial existing structures on the leased site to be completed by 31 December 2013.

The ground lease agreement provides an option for the group to purchase the leased site within 12 months of specified environmental remediation and other specified work being completed. As consideration for this option the group has agreed to perform certain work obligations under the lease. The most notable obligation is the performance of environmental remediation work up to a maximum expenditure of $USD20 million over a 4 year period commencing no later than 31 December 2013. In the prior period MBTL commenced remediation work and at current period end expenditure since commencement totalled $USD1,888,000 (Jun 2012: $USD1,094,000).

In addition a letter of credit was provided by the non controlling interest in MBTL to the Lessor for $USD10 million. There is no obligation to MBTL by the group unless the group defaults on the ground lease obligations.

Note 25: Leasing commitments (cont'd)

c. Finance leases

The group leases information technology hardware and software with a carrying amount of $885,000 under finance lease that will expire 4 years and 8 months from period end. Under the terms of the lease the group has the option to purchase this equipment for $1 at the expiry of the lease.

	Dec 2012 $'000	Jun 2012 $'000
Commitments in relation to the finance leases are payable as follows:		
- Not later than 12 months	208	-
- One year or later and not later than five years	761	-
- Later than five years	-	-
Minimum lease payments	969	
Future finance charges	64	-
Recognised as a liability	905	-
Representing lease liabilities		
Current	184	-
Non-current	721	-
	905	-
The present value of finance lease liabilities is as follows:		
- Not later than 12 months	205	-
- One year or later and not later than five years	700	-
- Later than five years	-	-
Minimum lease payments	905	-

Note 26: Capital commitments

a. Financial guarantees

Related party guarantees provided by the parent entity:

The parent entity has provided a guarantee to a third party in relation to the performance and obligations of the controlled entity, Ambre Energy North America, Inc., in respect to a property lease rental. The guarantee is for the term of the lease and represents a financial commitment of $USD1,110,000 as at 31 December 2012 (see note 25a).

The parent entity provided another guarantee to a third party in relation to the performance and obligations of the controlled entity, Ambre Energy North America, Inc., in respect of information and technology hardware and software lease. The guarantee is for the full amount of lease payments and represents a financial commitment of $USD988,000 (see note 25c).

In addition, a cash backed guarantee of $173,000 (see Note 15) is held as security for performance and obligations of the parent entity in respect to a property lease rental.

Exploration expenditure commitments

The group has certain statutory obligations to undertake a minimum level of exploration activity in order to maintain rights of tenure to its exploration licenses. These obligations may vary from time to time in accordance with the type of tenements held and are expected to be fulfilled in the normal course of operations of the group to avoid forfeiture of any tenement.

	Dec 2012 $'000	Jun 2012 $'000
Exploration commitments payable:		
- Not later than 12 months	170	170
- One year or later and not later than five years	240	240
Tenement & Mineral Lease rental payable:		
- Not later than 12 months	67	63
- One year or later and not later than five years	170	189
- Later than five years	154	173
	801	835

c. Pilot plant site commitments

Fees payable on pilot plant site, Utah, United States:		
- Not later than 12 months	3	4
- One year or later and not later than five years	14	14
- Later than five years	53	56
	70	74

d. Research and development commitments

	Dec 2012 $'000	Jun 2012 $'000
Research and development expense commitments payable:		
- Not later than 12 months	229	364
- One year or later and not later than five years	-	93
	229	457

The group has committed to pay the salaries and share of overhead of two research staff and half the full time equivalent of a key person for Jantra Fuels and Chemicals, LLC as part of a commercial arrangement for research and development activities The group has further committed to provide for the expense of basic utility, equipment, consumables, analysis and insurance for the laboratory. The commitments end 31 October 2013.

Note 26: Capital commitments (cont'd)

d. Research and development commitments (cont'd)

On 16 August 2011, the group entered into an agreement with the Western Research Institute (a body affiliated with the University of Wyoming) to develop a dimethyl ether reactor. Costs are to be shared with the group's contribution predominantly being in-kind. The project is expected to be completed before 1 February 2014. At period end the group's remaining commitment is estimated to be $587,000. As the group's commitment is predominantly the provision of in-kind contributions, its financial commitment has not been included in the amounts disclosed above in this note.

e. Commitments to associates

The group has an associate company, Thermosolv LLC which is dedicated to a specific research and development activity. USD$250,000 in cash and in kind has been committed by a subsidiary of the group in the event that certain government grant money becomes available to Thermosolv, LLC. At period end $236,000 of cash and in kind contributions have been applied to this commitment.

f. Millennium Bulk Terminals-Longview, LLC (MBTL) capital calls

To meet the future capital and operational needs of MBTL, a controlled entity, its board of directors may from time to time require by written notice that the members make additional capital contributions. Capital calls shall be made to the members in proportion to their respective percentage membership interests at the date of notification. At period end the group had a 62% membership interest in MBTL and made $USD6,454,000 of capital contributions during the period (Jun 2012:$USD12,643,000).

Note 27: Dividends

No dividends were paid or declared during the current or prior period.

Franking credits

	Dec 2012 $'000	Jun 2012 $'000
The amount of the franking credits available for subsequent reporting periods are:		
- Balance at the end of the reporting period (Parent)	3	3

Note 28: Auditors' remuneration

Remuneration of the auditor of the parent for:

	Dec 2012 $'000	Jun 2012 $'000
- Audit of the financial report	92	109
- Review of half year financial statements	-	150
	92	259
- Taxation compliance	-	24
- Corporate advice services	-	40
	-	64
Assurance services provided by overseas network firm:		
- Review of half year financial statements	-	42
- Audit of the financial report	87	-
	87	42

Note 29: Contingent liability

a. Reclamation liabilities

The group is required to provide financial assurance for reclamation obligations in relation to its coal mining operations to the States of Montana and Wyoming (the States).The group has arrangements with Zurich of North America (Zurich), in which Zurich provided surety bonds to the States as financial assurance for the mine reclamation liabilities acquired. The surety bonds given to these States on the group's behalf collectively amount to approximately $138.9 million ($USD144.2 million).

The group has provided collateral of $USD66.75 million to Zurich in the form of a restricted cash holding of $USD62.28m (see Note 11) and an irrevocable letter of credit of $USD4.47m provided by U.S. Bank in favour of Zurich. Additionally the parent and certain controlled entities have unconditionally indemnified Zurich against all losses in connection with the issued bonds, excluding any amount paid or payable to a re-insurer or co-surety provider.

The majority of the group's reclamation obligations arise from its participation in the joint ventures of Decker Coal Company and Black Butte Coal Company. As the group equity accounts for its interests in these joint ventures in its financial statements (see Note 4), its share of the estimated reclamation liabilities are $103.99 million ($USD107.98 million) and are reflected in the investment in equity accounted investees balance of $3,616,000 (see Note 4).

If the group were to default on it's reclamation obligations at reporting date, the group will have under provided for this outcome by some $34.9 million in its financial statements being $138.9 million ($USD144.2 million) less $103.99 million ($USD107.98 million) currently provided for the reclamation liability. As, it is not probable that an outflow of resources embodying economic benefits will be required to settle the obligation, the group discloses the $34.9 million under provision as a contingent liability.

Claims

i) As disclosed in Note 22 of the 2011 annual financial statements, various legal claims were brought against the parent and controlled entities, Ambre Energy North America, Inc. and Millennium Bulk Logistics, Inc. by M.M. Dillon & Co. Group, LLC (M.M. Dillon) during that year. These claims arise out of M.M. Dillon's non-exclusive agency relationship with Millennium Bulk Logistics, Inc. pursuant to a letter agreement dated 28 September 2010. M.M. Dillon's complaint was filed in the Supreme Court of New York, Kings County.

M.M Dillon are alleging damages of over USD$4.0 million in breach of the agreement. The parties attempted to resolve the case through mediation in July 2012 but were not successful. Management do not believe that the parent and controlled entities have any liability and are vigorously defending the claims. Further detailed information on these contingencies is omitted so as not to seriously prejudice the group's position in the related disputes.

ii) On 9 July 2012 an action was filed by Western Minerals LLC in the United States District Court of Montana. The action names KCP, Inc. ("KCP"), Ambre Energy North America, Inc. and Ambre Energy Limited as defendants. The complaint alleged breaches of contract and fiduciary duty by KCP and sought unspecified damages and to remove KCP as manager of the Decker Coal Company. KCP and Ambre Energy North America filed an answer to the complaint denying any breach by KCP or wrong-doing by Ambre Energy North America which included a counterclaim against Western Minerals LLC and Cloud Peak Energy, Inc. ("CPE"). Subsequent to reporting period, on 27 August 2013 the parties jointly dismissed the litigation without prejudice (see Note 34(a)).

Note 30: Related party transactions

Transactions between related parties are on normal commercial terms and conditions no more favourable than those available to other parties unless otherwise stated.

Details of transactions between the group and its related parties are as follows:

a. **Loans with wholly owned subsidiaries**
Loans made between the parent entity and wholly owned subsidiaries are non interest bearing with no set repayment terms and conditions.

b. **Loans with senior employees**
A controlled entity provides assistance with the relocation expenses of USA based senior employees through an external residential brokerage relocation service provider. Amounts totalling $329,000 are recoverable for advances and relocation expenses paid by the controlled entity (see Note 10(b)).

Further assistance was provided to two senior employees for the cost of relocation. An advance of USD$300,000 by way of promissory note was provided to one senior employee. No interest is payable on the note with 500,000 options to purchase shares in the group provided as security by the employee. The loan is repayable on the earlier of the exercise of the options or 31 December 2014. The other employee was provided with a no interest loan of $USD20,000. At period end $USD10,000 was outstanding (see Note 15).

c. **Interest of key management personnel (KMP)**
The total remuneration paid to KMP of the group during the period is as follows:

	Dec 2012 $'000	Jun 2012 $'000
- Short-term employee benefits	1,333	2,953
- Share-based payment	-	18,003
	1,333	20,956

d. **Management of joint venture mines**

	Dec 2012 $'000	Jun 2012 $'000
- Management fee income	2,335	2,888

Note 31: Financial risk management

The group's financial instruments consist mainly of deposits with banks, short-term investments, accounts receivable and payable and redeemable convertible notes.

	Floating interest rate		Non-interest bearing	
Financial assets:	**Dec 2012 $'000**	**Jun 2012 $'000**	**Dec 2012 $'000**	**Jun 2012 $'000**
- Cash and cash equivalents	2,887	20,300	-	-
- Receivables	-	-	1,140	2,308
- Amounts receivable from related	-	-	991	389
- Other assets	173	173	299	304
- Financial assets	-	-	59,973	64,750
Total financial assets	3,060	20,473	62,403	67,751

	Fixed interest rate		Non-interest bearing	
Financial liabilities:	**Dec 2012 $'000**	**Jun 2012 $'000**	**Dec 2012 $'000**	**Jun 2012 $'000**
Financial liabilities at amortised cost				
- Trade and other payables	-	-	5,969	5,739
- Redeemable convertible notes	18,282	15,449	-	-
- Term loan	-	24,534	-	-
- Secured loan	32,130	-	-	-
- Finance lease	905	-	-	-
- Amounts payable to related	-	-	-	108
Total financial liabilities	51,317	39,983	5,969	5,847

Financial risk management policies

The Audit and Risk Committee (ARC) has been delegated responsibility by the Board of Directors for, amongst other issues, monitoring and managing financial risk exposures of the group. The ARC reviews the effectiveness of internal controls relating to currency risk, financing risk and interest rate risk. Minutes of the ARC are reviewed by the Board.

The ARC's overall risk management strategy seeks to assist the group in meeting its financial targets, while minimising potential adverse effects on financial performance. Its functions include the review of the use of hedging derivative instruments, and future cash flow requirements.

Specific financial risk exposures and management

The main risks the group is exposed to through its financial instruments are interest rate risk, foreign currency risk, liquidity risk and credit risk.

a. Interest rate risk

Exposure to interest rate risk arises on financial assets and financial liabilities recognised at reporting date whereby a future change in interest rates will affect future cash flows or the fair value of fixed rate financial instruments. The group is also exposed to earnings volatility on floating rate instruments.

Note 31: Financial risk management (cont'd)

b. Liquidity risk

Liquidity risk arises from the possibility that the group might encounter difficulty in settling its debts or otherwise meeting its obligations related to financial liabilities. The group manages this risk through the following mechanisms:

- preparing forward looking cash flow analysis in relation to its operational, investing and financing activities
- obtaining funding from a variety of sources
- maintaining a reputable credit profile
- managing credit risk related to financial assets
- investing only in surplus cash with major financial institutions

Financial assets pledged as collateral:

An amount of $173,000 has been pledged as security for contract guarantees and their realisation into cash may be restricted subject to the terms and conditions of the contract. See Note 15(a) for further details.

The group has provided $59,973,000 in collateral to Zurich by way of restricted cash holding with the Bank of New York Mellon (see Note 11(a)) and $USD4,470,000 to U.S. Bank as collateral for a letter of credit in favour of Zurich.

As at 31 December 2012, the Group's non-derivative financial liabilities have contractual maturities (including interest payments where applicable) as summarised below:

	Current		Non-current	
	Within 6 months	6 to 12 months	1 to 5 years	Later than 5 years
- Trade and other payables	5,969	-	-	-
- Redeemable convertible	18,282	-	-	-
- Finance lease	92	92	721	-
- Secured loan	-	-	32,130	-
Total	24,343	92	32,851	-

This compares to the maturity of the Group's non-derivative financial liabilities in the previous reporting period as follows:

	Current		Non-current	
	Within 6 months	6 to 12 months	1 to 5 years	Later than 5 years
- Trade and other payables	5,739	-	-	-
- Redeemable convertible	-	15,449	-	-
- Term loan	24,534	-	-	-
- Secured loan	-	-	-	-
- Amounts payable to related	100	8	-	-
Total	30,373	15,457	-	-

Note 31: Financial risk management (cont'd)

c. Foreign exchange risk

Exposure to foreign exchange risk may result in the fair value or future cash flows of a financial instrument fluctuating due to movement in foreign exchange rates of currencies in which the group holds financial instruments which are other than the AUD functional currency of the group.
With instruments being held by overseas operations, fluctuations in US Dollar may impact on the group's financial results unless those exposures are appropriately hedged.

The following table shows the foreign currency risk on financial assets and liabilities of the group's operations denominated in currencies other than the functional currency of the operations.

Net financial assets/(liabilities) in AUD

Functional currency of the group	Dec 2012 $'000	Jun 2012 $'000
AUD	(17,758)	(2,771)
USD	26,840	45,165
Total	9,082	42,394

d. Credit risk

The maximum exposure to credit risk, at balance date to recognised financial assets, is the carrying amount, net of any provisions for impairment of those assets, as disclosed in the Statement of Financial Position and notes to the financial statements.

There are no material amounts of collateral held as security at balance date.
The group does not have any material credit risk exposure to any single receivable or group of receivables under financial instruments entered into by the group. Credit risk related to balances with banks and other financial institutions is managed by the ARC. The following table provides information regarding credit risk relating to cash and money market securities based on Standard & Poor's counter party credit ratings.

	Dec 2012 $'000	Jun 2012 $'000
Cash and cash equivalents excluding cash on hand		
- A-1+ rated	841	16,006
- A-1 rated	2,044	4,292
	2,885	20,298
- AA- rated (see Note 15(a))	173	173
Restricted cash holding		
- AA- rated	59,973	64,750

e. Net fair values

The net fair values of assets and liabilities are carried at their approximate carrying value. No financial assets and financial liabilities are readily traded on organised markets in standardised form

f. Sensitivity analysis

The following table illustrates sensitivities to the group's exposures to changes in exchange rates. The table indicates the impact on how profit and equity values reported at balance date would have been affected by changes in the relevant risk variable that management considers to be reasonably possible. These sensitivities assume that the movement in a particular variable is independent of other variables.

	Profit $'000	Equity $'000
Period ended 31 Dec 2012		
- +/- 10% in $AUD/$USD	+/-2,551	+/-2,551
Period ended 30 June 2012		
- +/- 10% in $AUD/$USD	+/-3,322	+/-3,322

Note 32: Parent entity disclosures

The following information has been extracted from the books and records of the parent and has been prepared in accordance with accounting standards.

	Dec 2012 $'000	Jun 2012 $'000
Financial position of parent entity at reporting date		
Current assets	111,784	113,532
Total assets	131,455	133,153
Current liabilities	21,505	20,510
Total liabilities	21,702	20,665
Total equity of the parent entity comprising of:		
Share capital	178,519	176,443
Share-based payment reserve	27,090	24,627
Retained earnings	(95,856)	(88,582)
Total equity	109,753	112,488
Result of the parent entity		
Profit/(loss) for the period	(8,899)	(60,154)
Total comprehensive income	(8,899)	(60,154)
Parent entity commitments for operating leases		
Non-cancellable operating leases contracted for but not capitalised in the financial statements		
Payable - minimum lease payments		
- Not later than 12 months	386	461
- One year or later and not later than five years	671	867
	1,057	1,328

Impairments

The directors of the parent have determined that $3,596,000 of loans to other entities in the group are unrecoverable and accordingly have resolved to reduce the carrying amounts of the pertinent assets for this impairment.

Guarantees

The company has provided bank guarantees totalling $172,920 (Jun 2012: $172,920) in respect of the company's Brisbane head office. These amounts are secured by bank deposits to the value of $172,920 (Jun 2012: $172,920)

Refer to Note 26(a) for details of other guarantees provided by the company.

Contingent liabilities and contingent assets

The company does not believe it has any material contingent liabilities or contingent assets other than those disclosed under note 29.

Research and development commitments

On 16 August 2011, the parent entered into an agreement with the Western Research Institute (a body affiliated with the University of Wyoming) to develop a dimethyl ether reactor. Costs are to be shared with the parent's contribution predominantly being in-kind. The project is expected to be completed before 1 February 2014. At year end the group's remaining commitment is estimated to $587,000. Additionally the parent has agreed to commit to expenditure of $229,000 to support research and development activities to be undertaken by Jantra Fuels and Chemicals, LLC refer to Note 26(d)).

Note 33: Cash flow information

		6 mth Dec 2012 $'000	12 mth Jun 2012 $'000
a.	**Reconciliation of cash flow from operations with profit after income tax**		
	Profit/(loss) after income tax	(32,002)	(65,367)
	Cash flows excluded from profit attributable to operating activities		
	Non-cash flows in profit		
	Amortisation	70	394
	Depreciation	696	1,764
	Impairment	163	10,857
	Share based payments	5,136	16,664
	Non-cash retirement benefits expense	143	312
	Gain on business combination	-	(5,768)
	Share of loss/(gain) of joint venture partnerships and associates	5,587	10,152
	Net loss on disposal of property, plant & equipment	23	216
	Net loss/(gain) on disposal of other assets	67	109
	Finance costs capitalised	2,889	-
	Exchange differences	(358)	425
	Provision accretion	(250)	-
	Fair value adjustment of embedded derivative liability	(1,407)	-
	Amortisation of lease incentive	84	
	Other equity settled transactions	-	504
	Changes in assets and liabilities, net of the effects of purchase and disposal of subsidiaries		
	(Increase)/decrease in trade and other receivables	(383)	(634)
	(Increase)/decrease in other assets	(1,053)	(1,315)
	Increase/(decrease) in trade and other payables	223	4,251
	Increase/(decrease) in current tax assets	-	571
	Increase/(decrease) in financial liabilities	3,192	565
	Increase/(decrease) in provisions	(464)	(66)
	Cashflow from operations	(17,644)	(26,366)

b. Credit facilities

The group has no unused credit facilities other than the facility disclosed in note 11b(i) and a $20,000 overdraft all available at period end.

c. Non-cash financing and investing activities

i) Share issues:

Non cash equity movement represented by:

- During the period 895,833 shares (Jun 2012: 479,167) were issued at $1.00 per share for total consideration of $895,833 (Jun 2012: $479,167) in payment for interest expense under the bridge loan facility (see Note 11(b)(i)).
- During the period 1,855,000 ordinary shares were issued in exchange for 2,727,941 options. No cash consideration was paid in the exchange (See note 20c(i)).

Note 34: Events occurring after the reporting period

a. Ongoing discussions regarding purchase of 50% joint venture share in Decker Coal Company

As reported under Note 34 in the June 2012 Annual Report, on 5 December 2012, Cloud Peak Energy, Inc. ("CPE"), Ambre Energy and the relevant subsidiaries entered into a series of agreements including:

(i) the sale to Ambre subsidiaries of CPE's indirect 50% joint venture share in the Decker Coal Company and CPE's right to certain production royalties payable by Decker Coal Company;
(ii) the assumption by Ambre subsidiaries of all liabilities of Decker Coal Company and replacement of CPE's reclamation bonds for Decker being $70.7 million;

(iii) the granting of an option to CPE to take up to 5 million tonnes per year of Ambre's throughput capacity at the proposed new coal export facility at Millennium Bulk Terminals-Longview, at commercial terminal handling rates;

This potential transaction has not been completed and is not expected to be completed in the foreseeable future and is dependent on the group's ability to replace CPE's outstanding reclamation and lease bonds for the Decker mine. The group and CPE continue to be in discussions and have jointly dismissed the previously disclosed Decker litigation without prejudice to allow time for their ongoing discussions and evaluations (see Note 29(b)(ii)).

b. Financing

Subsequent to reporting date the group requested and received drawdowns under the secured loan facility provided by major shareholder and financier Resource Capital Fund V L.P. ("RCF") totaling USD $20 million (see Note 11) to fund project development and other costs and expenses of the group. The total available funds under this facility have been drawn down at the date of this report. The final tranche of USD $10 million was advanced on the basis of an amendment to the RCF facility which relaxed certain conditions precedent to the advance of this final tranche, but also imposed some additional obligations on the group (see Note 11(b)(i)).

Further to this a second amended and restated loan agreement was executed on 20 August 2013 resulting in RCF providing a USD$20 million letter of credit facility and an extension of the Morrow Pacific permit deadline to the 31 December 2015 in exchange for the issue of 50 million new shares. See Note 11(b)(ii) for further detail of the significant changes in the terms to the original RCF agreement.

c. Option cancellations

On 20 March 2013, the CEO & Managing Director Mr E Choros elected to cancel 30.0 million options granted in May 2012 to Mr Choros' related entities. Following the cancellation of these options total options outstanding at the date of this report are 66,662,500.

d. Demerger of Ambre Fuels Limited and its subsidiaries

The directors will be seeking shareholder approval to demerge Ambre Fuels Limited and its subsidiaries from the remainder of group. Ambre Fuels Limited conducts an Alternative Fuels business which looks to develop projects to produce liquid fuels and chemicals from coal. Subsequent to period end the directors have formed the view that it is not in the best interests of the group to try to develop the Alternative Fuels business in conjunction with the development and operation of the coal export infrastructure and mining businesses. The outcome of the demerger will be that the shareholders in Ambre Energy Limited will be allotted the shares in the demerged Ambre Fuels Limited in proportion to their shareholding in Ambre Energy Limited.

e. Convertible notes initial amendment

Following an application by the parent entity to KOSEP and KOSPO for their approval for Ambre Energy North America, Inc. to increase the loan amount under the RCF facility (see Note 11(b)(i)), the parent entity agreed with KOSEP and KOSPO in March 2013 to increase the interest payable under their convertible notes from 10% per annum to 14% per annum to take effect on and from 10 December 2012.

Note 34: Events occurring after the reporting period (cont'd)

f. Repayment of and further changes to KOSEP convertible notes

Further to note 34(e) the terms of the KOSEP convertible notes referred to in note 11(b)(iii) were renegotiated on 31 July 2013 so that 25% of the principal and interest accrued on the convertible notes are to be repaid following the satisfaction of certain conditions to the agreement. The redemption date for the 75% remaining convertible notes has been extended to 31 December 2015. Note that the original redemption date for all KOSEP issued convertible notes was 31 May 2013.

The interest rate was increased to 16% from 1 June 2013 to the date of repayment for the convertible notes, with the interest calculated on the outstanding principal and interest accrued as at 31 May 2013 on a compounding basis. From 1 August 2013 interest is to compound quarterly on the 75% remaining convertible notes with the interest rate continuing to be 16% until the agreed changes to the security interests provided by the group to KOSEP are in place. From thereon the interest rate will become 12%. Furthermore 50% of the interest accruing from any quarter will be repayable on the last day of that quarter.

The security interests provided by the group to KOSEP will further extend to include those provided to RCF for their loan with respect to AE Minerals Pty Ltd, Ambre Energy North America, Inc. and its subsidiaries. KOSEP will rank equally with RCF with respect to these security interests.

The remaining convertible notes now have a conversion price being the lower of $0.50 per share, the conversion price applicable to RCF's loan (see note 11(b)(ii)) or 90% of the market price per share upon an initial public offering. The RCF conversion price will only be applicable where KOSEP converts its convertible notes within 30 days after RCF has converted its loan to shares.

The group may redeem the remaining convertible notes without KOSEP's consent prior to 31 December 2013 without penalty but thereafter must have KOSEP's consent to redeem. KOSEP may request redemption prior to the 31 December 2015 in the case that project financing is secured for the Morrow Pacific project.

g. Repayment of and further changes to KOSPO convertible notes

Further to note 34(e) the terms of the KOSPO convertible notes referred to in note 11(b)(iv) were renegotiated on 27 September 2013 so that 25% of the principal and interest accrued on the convertible notes are to be repaid following the satisfaction of certain conditions to the agreement. The redemption date for the 75% remaining convertible notes has been extended to 31 December 2015. Note that the original redemption date for all KOSPO issued convertible notes was 28 June 2013.

The interest rate was increased to 16% from 28 June 2013 to the date of repayment for the convertible notes, with interest calculated on the outstanding principal and interest accrued as at 28 June 2013. From 28 September 2013 interest will compound quarterly on the 75% remaining convertible notes with the interest rate continuing to be 16% until the agreed changes to the security interests provided by the group to KOSPO are in place. From thereon the interest rate will become 12%. Furthermore 50% of the interest accruing from any quarter will be payable on the last day of that quarter.

The security interests provided by the group to KOSPO will further extend to be the same as those provided to RCF for their loan with respect to AE Minerals Pty Ltd, Ambre Energy North America, Inc. and its subsidiaries. KOSPO as well as KOSEP will rank equally with RCF with respect to these security interests.

The remaining convertible notes now have a conversion price being the lower of $0.50 per share, the conversion price applicable to RCF's loan (see note 11(b)(ii)) or 90% of the market price per share upon an initial public offering. The RCF conversion price will only be applicable where KOSPO converts its convertible notes within 30 days after RCF has converted its loan to shares.

The group may redeem the remaining convertible notes without KOSPO's consent prior to 31 December 2013 without penalty but thereafter must have KOSPO's consent to redeem. KOSPO may request redemption prior to the 31 December 2015 in the case that project financing is secured for the Morrow Pacific project.

Other than the above matters, no other matters or circumstances have arisen since the end of the financial period which significantly affected or may significantly affect the operations of the Company, the results of those operations, or the state of affairs of the Company in future financial years.

The financial report was authorised for issue on 10 October 2013 by the board of directors.

DIRECTORS' DECLARATION

for the period 1 July 2012 to 31 December 2012

The directors of the Company declare that:

1. the consolidated financial statements and notes of Ambre Energy Limited are in accordance with the Corporations Act 2001 and

   a) comply with the Australian Accounting Standards which as stated in note 1 to the financial statements, constitutes compliance with the international financial reporting standards (IFRS); and

   b) give a true and fair view of the financial position as at 31 December 2012 and of the performance for the period ended on that date of the company and consolidated group; and

2. in the directors' opinion there are reasonable grounds to believe that Ambre Energy Limited will be able to pay its debts as and when they become due and payable, having regard to the disclosure made in note 1 (z).

This declaration is made in accordance with a resolution of the board of directors.

E. Choros

Edward (Edek) Choros
Director
Brisbane, 10 October 2013

INDEPENDENT AUDITOR'S REPORT

Grant Thornton Audit Pty Ltd
ABN 91 130 913 594

Level 18
145 Ann Street
Brisbane Queensland 4000
GPO Box 1008
Brisbane Queensland 4001

T + 61 7 3222 0200
F + 61 7 3222 0444
E info@au.gt.com
W www.grantthornton.com.au

Independent Auditor's Report
To the Members of Ambre Energy Limited

We have audited the accompanying financial report of Ambre Energy Limited (the "Company"), which comprises the consolidated statement of financial position as at 31 December 2012, the consolidated statement of comprehensive income, consolidated statement of changes in equity and consolidated statement of cash flows for the 6 month period then ended, notes comprising a summary of significant accounting policies and other explanatory information and the directors' declaration of the consolidated entity comprising the Company and the entities it controlled at period end or from time to time during the financial period.

Directors' responsibility for the financial report

The Directors of the Company are responsible for the preparation of the financial report that gives a true and fair view in accordance with Australian Accounting Standards and the Corporations Act 2001 and for such internal control as the Directors determine is necessary to enable the preparation of the financial report that gives a true and fair view and is free from material misstatement, whether due to fraud or error. The Directors also state, in the notes to the financial report, in accordance with Accounting Standard AASB 101 Presentation of Financial Statements, the financial statements comply with International Financial Reporting Standards.

Auditor's responsibility

Our responsibility is to express an opinion on the financial report based on our audit. We conducted our audit in accordance with Australian Auditing Standards. Those standards require us to comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance whether the financial report is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial report.

Grant Thornton Australia Limited ABN 41 127 556 389

'Grant Thornton' refers to the brand under which the Grant Thornton member firms provide assurance, tax and advisory services to their clients and/or refers to one or more member firms, as the context requires. Grant Thornton Australia Ltd is a member firm of Grant Thornton International Ltd (GTIL). GTIL and the member firms are not a worldwide partnership. GTIL and each member firm is a separate legal entity. Services are delivered by the member firms. GTIL does not provide services to clients. GTIL and its member firms are not agents of, and do not obligate one another and are not liable for one another's acts or omissions in the Australian context only, the use of the term 'Grant Thornton' may refer to Grant Thornton Australia Limited ABN 41 127 556 389 and its Australian subsidiaries and related entities. GTIL is not an Australian related entity to Grant Thornton Australia Limited.

Liability limited by a scheme approved under Professional Standards Legislation. Liability is limited in those States where current scheme applies.

Grant Thornton

The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial report, whether due to fraud or error.

In making those risk assessments, the auditor considers internal control relevant to the Company's preparation of the financial report that gives a true and fair view in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Company's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made by the Directors, as well as evaluating the overall presentation of the financial report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Independence
In conducting our audit, we have complied with the independence requirements of the Corporations Act 2001.

Auditor's opinion
In our opinion:

a the financial report of Ambre Energy Limited is in accordance with the Corporations Act 2001, including:

   i giving a true and fair view of the consolidated entity's financial position as at 31 December 2012 and of its performance for the 6 month period ended on that date; and

   ii complying with Australian Accounting Standards and the Corporations Regulations 2001; and

b the financial report also complies with International Financial Reporting Standards as disclosed in the notes to the financial statements.

Material uncertainty regarding the recoverability of mineral leases and going concern
Without qualifying our opinion, the financial report includes mineral leases ($19,531,000 – refer notes 1 (u) and 14) which are valued by the directors using fair value methodologies. The ultimate recovery of the asset balance by the consolidated entity is dependent upon accessing sufficient equity and/or debt funding to successfully commercialise the mineral leases, or by selling the leases.

The consolidated entity has recorded a loss of $32,002,000 for the six month period, and current liabilities exceed current assets by $19,284,000 at period end.

Grant Thornton

As detailed in Note 1(z), the Board has forecast that without further funding the consolidated entity will deplete its current cash reserves within twelve months. The consolidated entity is currently in discussions to secure the necessary further funding to complete planned capital expenditure and for working capital requirements.

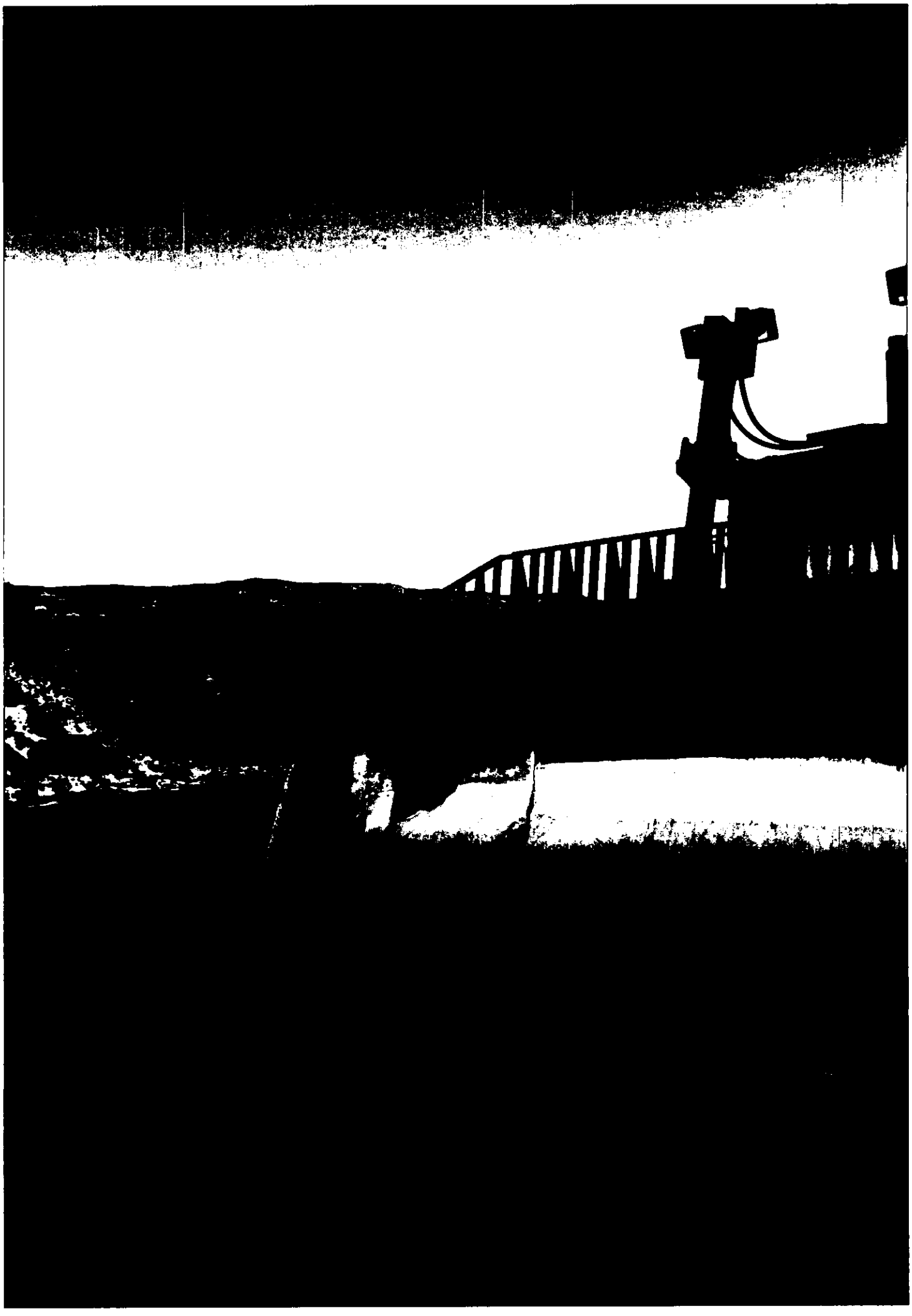
If the planned funding or alternative sources of capital are not obtained, there exists a material uncertainty whether Ambre Energy Limited and its controlled entities would be able to continue as a going concern and therefore may be forced to realise its assets and extinguish its liabilities other than in the normal course of business and at the amounts stated in the financial report.

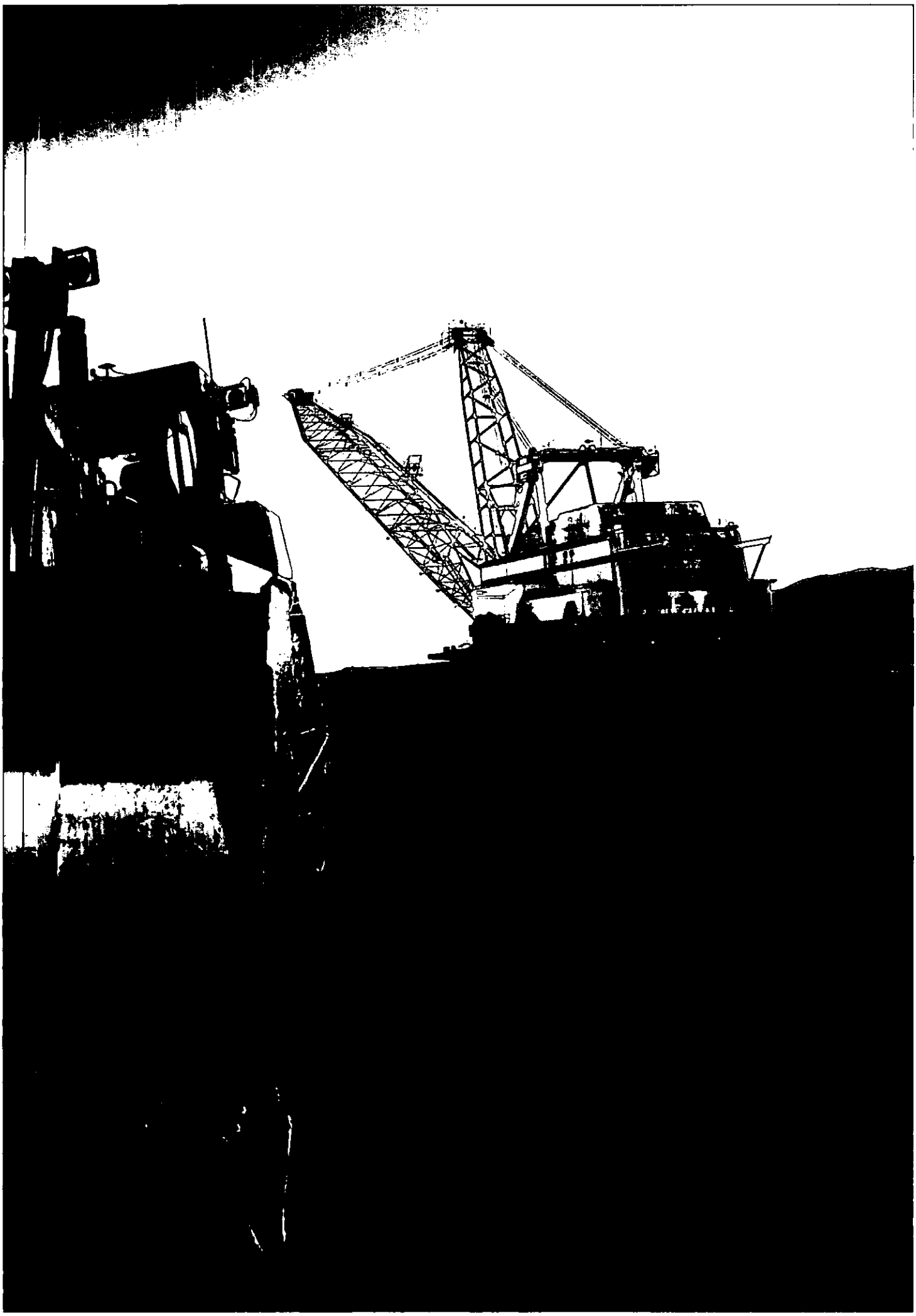
Grant Thornton

GRANT THORNTON AUDIT PTY LTD
Chartered Accountants

D J Carroll
Partner - Audit & Assurance

Brisbane, 10 October 2013





CORPORATE DIRECTORY

Ambre Energy Limited
ACN 114 812 074

Directors

Terry O'Reilly
David Usasz
Edek Choros
Michael Mewing
Michael van Baarle
Jayson Newitt
Ross Bhappu

Company Secretary

Neil McGregor

Principal registered office of Australia

Level 27 AMP Place, 10 Eagle Street
Brisbane QLD 4000, Australia

TEL +61 (0)7 3009 9180
FAX +61 (0)7 3009 9181
EMAIL info@ambreenergy.com
WEB www.ambreenergy.com

Principal registered office in the United States

Ambre Energy North America, Inc.
170 South Main Street, Suite 700
Salt Lake City, UT 84101

TEL +1 801 539 3788
FAX +1 801 539 3789

Share registry

Computershare Investor Services Pty Limited
GPO Box 2975
Melbourne Victoria 3001

TEL (within Australia) 1300 850 505
(outside Australia) +61 3 9415 4000
FAX +61 3 9473 2500
WEB www.computershare.com.au

Auditor

Grant Thornton Audit Pty Ltd

Sightline INSTITUTE

Ambre Energy: *Caveat Investor*

A money-losing energy startup takes a big risk on coal exports

Clark Williams-Derry
February 2013

Executive Summary

The decline of US coal demand has sparked renewed interest in exporting American coal to Asia. One of the highest-profile players in the coal export arena is an Australian firm called Ambre Energy, which is planning two controversial export terminal projects on the Columbia River in Washington and Oregon.

But the coal export debate has largely overlooked a curious fact: Ambre Energy barely qualifies as a coal company. The company's annual reports reveal that the Australian-based venture has never made a profit, and has virtually no track record in mining or selling coal, either in the US or abroad. Worse, an in-depth look at the company's financial statements, as well as public records of other companies that have done business with Ambre, reveals a firm with deeply troubled finances, including:

Minuscule revenues. the firm has collected only $6.6 million in worldwide revenues over the past 7 years.

Massive losses. Ambre has accumulated $124 million in losses on its balance sheets.

Failed Australian venture. The firm recently admitted that it lost $10.9 million on a failed coal project in Australia.

Huge liabilities. The company is on the hook for hundreds of millions of dollars for mine reclamation and site cleanup, retiree medical and pension benefits, and costs arising from a recent legal settlement.

Troubled assets. Ambre may see little value from some of its assets, including a $65 million bond cash holding dedicated for mine reclamation, and $19 million in shale oil development costs.

High borrowing costs. The company has taken out multi-million dollar loans with annual interest rates of at least 10 percent, and a "balloon" loan charging 12 percent interest.

Massive capital needs. Ambre needs to raise about $1 billion to bring its coal export plans to fruition.

Potential investors in Ambre, as well as the communities and businesses hoping to benefit from the firm's business, would be wise to consider Ambre's finances and troubled history before committing money or other resources to the company's export ventures.

Introduction

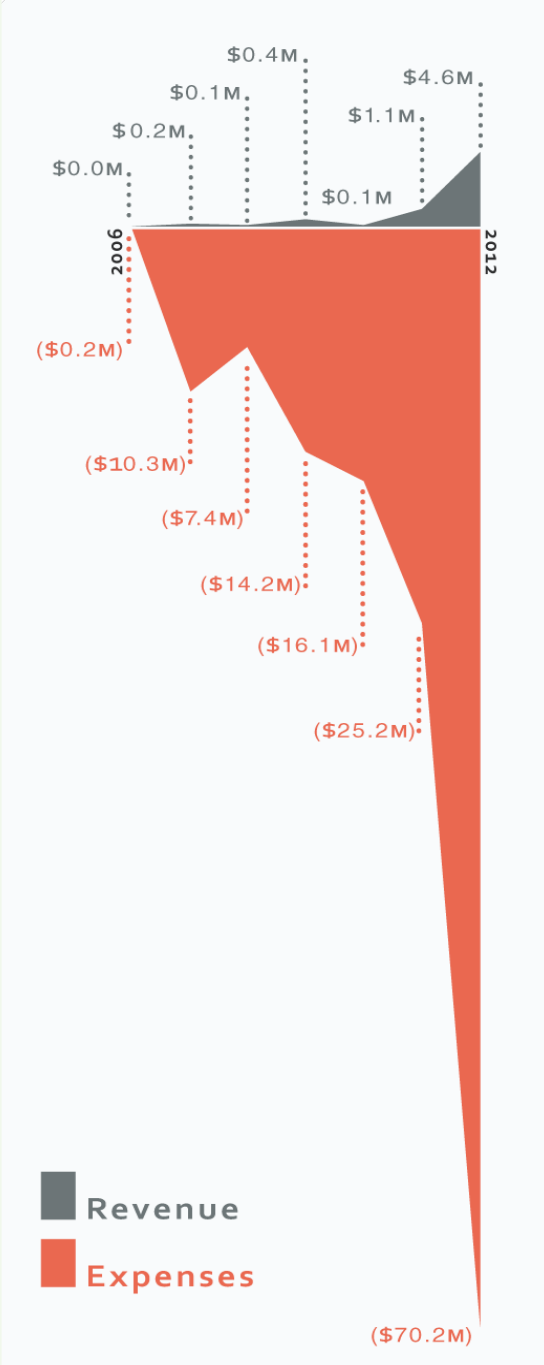
America is turning away from coal. Domestic demand for the mineral has fallen substantially since 2008, as electricity generators have spurned the fossil fuel in favor of cleaner burning natural gas.[1] In desperation, many US coal producers have shifted their gaze towards Asian energy markets, and some have initiated plans to export their product to China, Japan, and Korea through ports in the Pacific Northwest.

One of the highest flyers in the Northwest's coal export game is little-known **Ambre Energy.** The Australian-based company's proposal to ship coal by rail from Montana and Wyoming to terminals on the Columbia River, and then on to Asia, has earned the ire of tribes and citizens' groups; piqued the interest of regulators; and filled the business press with stories of lawsuits and deceptions—as well as talk of handsome profits to be made from the coal trade.

Yet the Northwest's coal export debate has largely overlooked a curious fact: *Ambre Energy barely qualifies as a coal company.* The company's annual reports reveal that the firm has virtually no track record in mining or selling coal, either in the US or abroad.

Worse, a look at Ambre's financial statements reveals a sea of red ink. The company has never made a profit. It has accumulated Aus$124 million dollars◆ of losses over 7 years, while bringing in less than Aus$7 million in total revenues.[2] In FY2012 alone, Ambre's expenses exceeded its income by more than Aus$65 million. (See Figure 1.) More than half a decade after it was founded, the company remains

Figure 1. Ambre Energy has suffered accelerating losses.



Note: All figures in Australian dollars, compiled from data in Ambre Energy, Ltd. annual reports. "Revenue" represents operating revenue, and "Expenses" represents the net of all other categories of ordinary income and expenses. See Appendix 1 for details.

◆ This report uses the symbol "Aus$" to refer to values denominated in Australian dollars, and the symbol "$" to refer to values denominated in U.S. dollars. Over the past several years, the Australian dollar has traded close to parity with the U.S. dollar: for example, Aus$124 million currently equals about $131 million in US dollars. For simplicity, readers can think of Australian and US dollars as roughly equal.

little more than a high-risk startup struggling to establish a toehold in the coal business—suggesting that Ambre's vision of lucrative coal exports may stem not from savvy experience but from equal measures of hope and hype.

A Short History of Failure

Ambre Energy was founded in June 2005 by an industrialist named Edek Choros, who had made his fortune developing an Australian coal mine, dubbed the "Millennium mine," which he promptly sold to a rival company.[3] With Ambre, Choros hoped to develop the technology to convert Australia's abundant deposits of dirt-cheap, low-quality coal into a substitute for oil. The company's promotional literature touted the growing specter of Peak Oil—the theory that global oil production would soon decline—and hinted at the financial promise of processing low-quality coal for use as an alternative to increasingly scarce petroleum.

Headquartered in Australia, the new company applied in September 2005 to patent its so-called Hybrid Energy System, "designed to convert coal into char, gas and hydrocarbon liquids through retorting."[4] Eleven months later Ambre entered into a joint venture to develop and commercialize its coal-to-liquids technology, and had begun eyeing a large deposit of low-quality, high-ash coal in rural Queensland, Australia, to use as a feedstock.[5] The company pursued its coal-to-liquids strategy for years—testing its technology, assaying coal deposits, pursuing regulatory approvals from the Queensland government, and looking for technical and financial partners to bring its speculative vision to life. These startup activities didn't come cheap. In the 2007 fiscal year alone, Ambre spent Aus$10.6 million but earned less than Aus$160,000 in total revenues.[6]

Ambre's spending spree proved fruitless.

Ambre's spending spree proved fruitless. As revealed in Ambre's FY 2008 annual report, a University of Utah research team, sponsored by Ambre itself, determined that the Hybrid Energy System "was not the most efficient system" for creating an oil substitute[7]—a discovery that helped render Ambre's patent and its associated research and development investments essentially worthless.[8] All the while, the red ink kept flowing. The company and its subsidiaries notched a net loss of more than Aus$7.2 million in the fiscal year that ended in June 2008, while collecting less than Aus$142,000 in revenues.[9]

When the global financial crisis struck in late 2008, it took the steam out of both global capital markets and worldwide petroleum demand—a double jolt that revealed the inherent riskiness of Ambre's capital-intensive coal-to-liquids bets.

From Coal-to-Liquids to Coal-to-Asia

Ambre had little left to lose in the financial collapse. Its proprietary technology had proven unworkable. It had no customers or revenue to speak of, and its profit and loss statements showed mostly red ink. Yet ironically, the company found itself in a position to view the global economic downturn not as a crisis but as an opportunity: a rare chance to buy distressed coal assets at bargain prices. And like many of its more established competitors, Ambre came to believe that exporting coal to Asia—particularly China, where coal consumption continued to rise despite the global recession—

offered a shot at a payoff that could save the troubled company. So Ambre shifted course, beginning a search for cheap coal mines within shipping distance of Asia. Over the next two years, the company's public statements increasingly touted the promise of coal exports, while deemphasizing its coal-to-liquids ventures.

The company soon settled on a strategy: Ambre would aim to export US coal to Asian markets via shipping terminals on the Columbia River. Like its coal-to-liquids efforts, Ambre's coal-to-Asia plan was a high-stakes gamble. The fledgling venture would face massive startup costs, regulatory hurdles, deep-pocketed US rivals, volatile Asian markets, and host of coal-rich Pacific Rim competitors who were eyeing the very same export markets.

For the fiscal years 2006 through 2012, the company accrued losses of Aus$124 million on its balance sheets, while garnering just Aus$6.6 million in revenue worldwide.

Undeterred by the long odds, Ambre launched its coal-to-Asia plan in the summer of 2010 by by forming a subsidiary dedicated to developing the site of a former aluminum smelter on the banks of the Columbia River in Longview, Washington into a coal terminal. Ambre planned to use the site to move coal from trains onto ocean-going vessels bound for Asia. Ambre executed a purchase agreement for the site in August 2010, filed permit applications two weeks later, and acquired a lease on the site in January 2011. Then in May 2011, the company entered into a lease option agreement at Oregon's Port of Morrow, also along the Columbia, for a similar coal transshipment project. And in November of 2011 Ambre purchased a 50 percent stake in two operating US coal mines, one in Wyoming and another in Montana.[10]

With the acquisition of those mines, more than six years after Choros founded the enterprise, Ambre Energy had finally become a coal company—at least on paper.

But it was a costly achievement. For the fiscal years 2006 through 2012, the company accrued losses of Aus$124 million on its balance sheets,[11] while garnering just Aus$6.6 million in revenue worldwide. In each of the last three years the company's Australian auditors warned of impending financial collapse, noting that at the end of the 2012 Fiscal Year:

> [Ambre Energy] has recorded a loss of $65,397,000 for the year…[T]he Board has forecast that without further funding the consolidated entity will deplete its current cash reserves within twelve months.
>
> If this planned funding or alternative sources of capital are not obtained, there exists significant uncertainty whether Ambre Energy Limited and its controlled entities would be able to continue as a going concern and therefore may be forced to realise its assets and extinguish its liabilities other than in the normal course of business and at the amounts stated in the financial report.[12]

Ambre has managed to stave off bankruptcy so far. But virtually all of Ambre's bets in the coal trade have met with trouble.

Money-Losing Mines

In November 2011, Ambre purchased a 50 percent interest in two mines—the Decker mine in Montana and the Black Butte mine in Wyoming—from a company called Level 3 Communications. Level 3's primary business is selling internet bandwidth; its coal interests lingered as a legacy investment by a former incarnation of the company.[13] Level 3 was triply interested in shedding its coal holdings: first, because coal mining was a distraction from its core business;[14] second, because coal profits were waning and one of its two active mines was losing money; and third, because it was legally on the hook for mine cleanup and reclamation after the mines ceased production—liabilities that, according to Level 3's financial statements, amounted to $105 million at the beginning of 2011.[15]

Level 3's coal business suffered from two other vulnerabilities. First, each of its two operating coal mines was serviced by a single railroad—unlike many of its major coal-producing competitors, who could seek lower shipping costs by picking and choosing among two or more rail lines. Second, Level 3's coal was expensive to mine, with production costs "as much as four and five times greater than… certain competitors," according to the company's financial statements.[16]

Level 3 proved so eager to rid itself of its coal holdings that it let Ambre purchase them for less than Aus$5 million.[17] Still, Ambre compensated Level 3 handsomely for the mines; in addition to the up-front payments, the Australian company also assumed Level 3's massive long-term liabilities for cleaning up and reclaiming the mines after production ceased, as well as pension and medical obligations for retirees who had worked at Level 3's mines. As a result, and even though little money changed hands during the transaction, Level 3's financial statements showed a $72 million dollar gain from the sale, mostly from shifting liabilities off their balance sheet and onto Ambre's.

Ambre' acquisition also brought the company an immediate risk of short term losses in the mining business. Level 3's coal revenues had fallen dramatically over the previous decade. Its pre-tax earnings on its coal business declined from roughly $20 million in 2002 to essentially nothing in 2009, rebounding to a scant $4 million in 2010.[18] The Decker mine was especially troubled: Decker coal sales fell from 7 million tons in 2007 to about 3 million in 2010 and 2011.[19] Independent analysts, as well as Level 3 itself, believed that the mine was nearing the end of its financially viable life.[20] According to internal financial documents, the Decker mine lost $21 million in 2011 alone, and the company projected an $11.9 million loss in 2012.[21] Prior to Ambre's purchase, the mine's managers had apparently planned to cut its losses and close Decker at the end of 2013, when its one remaining coal production contract expired.[22]

Ambre soon found itself embroiled in a lawsuit over the Decker mine.

To make matters worse, Ambre soon found itself embroiled in a lawsuit over the Decker mine. The suit, filed by Cloud Peak Energy (which owned the other 50 percent stake in Decker) accused Ambre of violating the terms of its agreements to shutter the mine, while squeezing its partner out of management decisions, claiming that Ambre was:

> ...significantly abusing its obligations and responsibilities as day-to-day Manager, unilaterally acting outside the approved budget and underlying mine plan, engaging in a campaign of public and other unauthorized communications to pursue the Ambre Entities' unapproved agenda for Decker, and engaging in various self-dealing transactions among the Ambre Entities and their affiliates.[23]

The lawsuit further accused Ambre of "raising the expectations in the local community regarding jobs and economic development where such expectations may not be justified," while complaining of a "loosely defined export redevelopment proposal lacking basic information and transparency…built upon a foundation of self-dealing among the Ambre entities."[24]

Ambre countersued Cloud Peak soon thereafter. The company resolved both lawsuits in December 2012, when Ambre agreed to buy all of Cloud Peak's interests in the Decker mine. But the agreement came at a premium: Ambre agreed either to pay Cloud Peak Aus$57 million in cash if it could raise the money by March 31, 2013, or else to issue a promissory note for Aus$64 million to be paid at a later date. (Considering that Ambre paid a mere $5 million for the first 50 percent of the Decker mine together with a stake in the better-performing Black Butte mine, the settlement seems exorbitant.) More expensive still, Ambre agreed to assume Cloud Peak's cleanup liabilities for the Decker mine, which includes posting a $70.7 million reclamation bond.[25]

> ***"A small-time Queensland resources company…at risk of financial collapse."***

But as steep as these costs have been, they may prove a minor nuisance compared with Decker's other financial challenges. Ambre's year-end financial statements for June 2012 show that the Decker mine's liabilities outweighed its assets by Aus$55 million, and that the mine lost Aus$17 million during the fiscal year.[26] In November of 2012, the mine announced plans to lay off many as 75 of its 162 workers. Ambre gave few details, but attributed the layoffs to "ongoing expense management activities"—a hint that the mine continues to hemorrhage money.[27]

Boxed Out in Queensland

Although Ambre had turned much of its attention to its US coal export plans by 2011, it hadn't completely abandoned hopes to mine and process low-value coal in Queensland, Australia.

But the project had run into fierce local opposition. The coal deposit that Ambre hoped to mine lay in a fertile agricultural area, and the region's farmers increasingly spoke out against the project, arguing that Ambre's plans would harm both their livelihoods and their quality of life. In March 2012, Ambre's opponents gained a key ally, as the newly-elected premier of Queensland announced his opposition to the mine.[28] Still, Ambre continued to move the project forward, ultimately angering the community so much that farmers rallied against the company. The episode prompted an article in T*he Australian*, that country's largest newspaper, which described Ambre as "A small-time Queensland resources company…at risk of financial collapse."[29]

Soon afterwards, Queensland's premier made his position official, stating in a public letter: "To be absolutely clear, no company, whatever it chooses to call itself, has a right to develop a mining operation in the Felton Valley, and companies will not be able to secure such a right under the Government."[30] Ambre's opponents say that the premier's opposition settled the matter: "as far as we are concerned," stated one community leader, "we have won the battle." In statements to the press, however, Ambre said it hadn't given up hope, and would consider re-petitioning the government at a later date.[31] Yet Ambre's 2012 annual report shows that the company has completely written off its Queensland coal mining assets and claimed a loss of Aus$10.9 million on the debacle.[32]

Shipping Terminals: Deceptions, Delays, and Disappointments

Ambre has touted its coal terminal plans as a key selling point to potential investors; the company hopes to position itself as a "vertically integrated" venture that owns both coal and the facilities to export it. But Ambre's coal terminal plans have faced mounting problems—including high costs, permitting delays, fierce public opposition, and evidence of systematic deceptions about the scale of its ambitions.

Ambre took its first foray into the coal terminal business by signing a lease-and-purchase agreement at a former aluminum smelter along the Columbia River in Cowlitz County, Washington; the agreement had been planned since the summer of 2010, and was executed in January 2011 after months of delay. A review of Ambre's financial statements suggests that the company avoided paying cash up front for the terminal lease, but instead committed to long-term cleanup expenses—including demolishing, removing, and disposing of existing structures on the Longview site.[33] Dubbing the site the "Millennium Bulk Terminals-Longview" (a name that hearkens back to Edek Choros's original Millennium coal mine), Ambre told county regulators that the site would handle alumina and cement as well as coal, in amounts totaling 5.7 million tons per year.

> ***Millennium Bulk Terminal has been dogged by reversals, delays, and revelations of massive costs.***

But after the county approved the plan, a legal challenge uncovered evidence that Ambre executives had actually been aiming to export up to 80 million tons of coal per year[34]—fifteen times as much as the company had admitted to in public. An internal email from a project executive urged that the company postpone announcing its expansion plans for at least two months after the project's initial approval, warning that if it acted sooner, "Millennium will be perceived as having deceived the agencies" and the company's "good reputation would be lost overnight." The revelation of these emails, and of the scope of Ambre's undisclosed plans, damaged the company's relationship both with local officials and with the surrounding community.

Since then, the Millennium Bulk Terminal has been dogged by reversals, delays, and revelations of massive costs. In March 2011, Ambre pulled its initial permit application for the coal terminal.[35] Just over a week later, it said that it would re-launch a new application.[36] The following February it did so, aiming for a facility that could handle up to 44 million tons of coal per year—nearly 8 times as much as the amount the company indicated in its initial application. Ambre stated that the new facility would cost $600 million, including cleanup and construction costs.[37] Adding to Millennium's woes, in July the US Army Corps of Engineers declared that the new project would require Ambre to prepare a full Environmental Impact Statement—potentially delaying the project for years.

Because of these delays, another Ambre terminal project has moved forward much faster than Millennium. Shortly after Ambre signed its lease agreement at Longview, the company secured a site at Oregon's Port of Morrow, also on the Columbia River, which has access to both of the rail lines that run near Ambre's two operating coal mines

Ambre has announced intentions to ship up to 8 million tons of coal to Asia via Morrow. But for the international coal trade, Morrow has a key disadvantage: it is too far upstream on the Columbia to

service ocean-going ships. To make use of its terminal at Morrow, Ambre plans to barge the coal downstream to yet another port on the Columbia: Port Westward, to the northwest of Portland. It's a costly plan with significant logistical challenges. Ambre has announced its intention to build a small fleet of covered barges—at a cost of $75 million[38]—to ferry coal downstream. Transferring the coal at two separate facilities on the Columbia would increase labor and handling costs, as well as increasing the costs of constructing the terminals themselves.

Ambre has had one small piece of luck: the US Army Corps of Engineers has not yet decided whether it will require Ambre to prepare a full Environmental Impact Statement for its Morrow project. For now, Ambre is proceeding with a more limited Environmental Assessment, while the Corps of Engineers decides whether the project requires a protracted and costly Environmental Impact Statement. The option of requiring an EIS for the Morrow project remains very much alive, however, and the overwhelming majority of the roughly 30,000 public comments on the project urged the Corps to require Ambre to prepare a full Environmental Impact Statement.[39]

Ambre's plans face further regulatory and public relations challenges. In November of 2012, the Oregon Department of State Lands postponed action on a proposed permit for the Morrow facility, citing a failure to properly notify the Yakama Nation about the project. And the Port of Morrow plans have generated growing opposition in nearby communities. Ambre had hoped to commence coal shipments at Morrow sometime in 2013, but the company recently announced that it likely would be forced to delay coal shipments until 2014.[40]

In an ostensible piece of good news for the project, the company announced in mid-2012 that two Korean power companies, Korea South East Power Co. Ltd. and Korea Southern Power Co. Ltd., had agreed to purchase up to 5 million tons of coal per year from Ambre for 10 years, as soon the company was ready to start shipments.[41] Yet it's not clear that this announcement means much. Ambre's documents describe the value of this agreement as "[Aus]$3.5 billion at market prices at the date of signing." This suggests that the two Korean companies are simply willing to buy coal from Ambre at prevailing market rates—not that Ambre will get a guaranteed price, let alone a price premium, for its coal. Regardless, the heart of the agreement was that the two Korean companies extended a one-year loan to Ambre, totaling about Aus$19 million, through a complex financial instrument. The loan carries interest rates of up to 10 percent per year, a strikingly high rate at a time when interest rates are near record lows. By comparison "junk" bonds—the riskiest of rated securities—currently yield less than 6 percent.[42] Indeed, the terms of this loan, lurking beneath what seemed to be good news for Ambre, make the Korean agreements look more like a sign of weakness than of strength.

The loan carries interest rates of up to 10 percent per year, a strikingly high rate at a time when interest rates are near record lows.

Ambre's Financial Lifeline

The past several years have seen Ambre post massive losses, lose virtually all hope of developing its Australian mining project, enter into a contentious lawsuit with its mining partner that ended in a costly settlement, assume hundreds of millions of dollars of long-term cleanup and pension obligations,

stumble over new regulatory hurdles, take on high-interest loans, and postpone its most promising export project. These troubles, along with broader challenges in the financial markets, forced Ambre to postpone an initial public offering that it had hoped would raise at least Aus$100 million in desperately needed capital.

All of which raises a question: how has this troubled company managed to keep itself afloat?

The answer is a deep-pocketed financier who now sits on Ambre's board: Ross Bhappu, a principal at mining-focused, Denver-based venture capital firm Resource Capital Funds (RCF). A review of Ambre's financial statements suggests that an infusion of cash from Resource Capital Funds may have saved Ambre from bankruptcy at the end of 2011—and allowed the company to pursue its risky coal export ventures. Dr. Bhappu's venture capital fund put up the Aus$60 million in capital, plus a separate $25 million loan, that allowed Ambre to take possession of Level 3's coal mines in November 2011. A month later, RCF injected an additional Aus$10 million into Ambre, after another investor pulled its money out of the company.[43] And in December 2012, Bhappu's firm expanded its earlier Aus$25 million loan to a line of credit totaling $50 million—$30 million of which Ambre had used by late December 2012. This line of credit carries an interest rate of 12 percent per year, with interest payments deferred and added to the principal each month. [44]

> ***What looked like a can't-miss investment—one that yielded a payday for those who sold stock at the peak—has yielded a bitter disappointment for value-seeking "buy and hold" investors.***

Curious footnotes in Ambre's last two financial reports underscore both Ambre's shaky financial footing, and Bhappu's influence on the company. As of late 2011, Edek Choros—Ambre's founder, CEO, and managing director—owned options that gave him the right to buy 50 million unissued shares of Ambre by year end, at just Aus$0.20 per share. Around the same time that Resource Capital Funds was considering its investment in Ambre, Choros agreed to cancel 20 million of those options. In their place, Ambre issued options with a much higher exercise price—Aus$1.10 to Aus$1.25—to other executives of the firm. Then, on December 31, 2011, Choros allowed his remaining 30 million stock options to expire, unexercised. It was a striking move, given that the options would have allowed Choros to purchase a significant stake in the company for just Aus$6 million. Ambre's board subsequently granted Choros 30 million new options, but at the much higher exercise price of Aus$2.47 per share—more than 12 times as high as the strike price of his previous options.

The explanation for these odd transactions remains a matter of speculation. Perhaps Choros didn't think his Ambre options were actually worth a paltry 20 cents per share. Perhaps he lacked the cash to exercise them himself, and couldn't find another investor willing to pay $6 million for a substantial stake in Ambre. Or perhaps Resource Capital Fund simply refused to put its money into the firm unless Choros renounced his stock options—which, if exercised, would have substantially diluted the value of RCF's investment. (As a condition of investing in Ambre, RCF did insist on anti-dilution rights that guarantee that the venture capital firm can receive additional shares in Ambre at no cost whenever Ambre issues new shares below a set share price.)[45] Regardless of the reasons, the fact that Ambre was either unable or unwilling to raise money from the sale of 30 million low-priced stock options highlights Ambre's dependence on the investment by Bhappu's Resource Capital Fund.

Bhappu is best known for another risky investment that paid off handsomely: his investment in Molycorp, a rare-earth minerals mining company. After helping bring Molycorp public, Bhappu quickly turned an initial $110 million investment into stock shares that, as of early 2011, were valued on paper at $1.2 billion. Bhappu's prescience was heralded in Forbes magazine piece (titled *"Best. Private Equity Deal. Ever (Maybe)."*). This praise came just a few months before Molycorps' share price peaked at more than $74 per share.[46] Bhappu looked like a wizard, and his venture capital fund attracted new investors eager to partake of his magic.

As of January 2013, though, Molycorp's shares have fallen below $9 per share, erasing most of those early gains. In early November, 2012, the US Securities and Exchange Commission launched an investigation into the company's public disclosure records, creating further uncertainty and turmoil for the company. The stock fell again in early 2013, after the company warned of weak earnings in the coming year. What looked like a can't-miss investment—one that yielded a payday for those who sold stock at the peak—has yielded a bitter disappointment for value-seeking "buy and hold" investors.

In some ways, Molycorp's tumble was predictable: even the laudatory Forbes article suggested that rare-earth minerals had become "an investment fad, some would argue a bubble." Bhappu's wizardry, some would argue, was in getting the timing right—that is, guiding an initial public offering to take advantage of a short-lived investment fad—rather than in fostering long-term value. One could be forgiven for believing that Dr. Bhappu is hoping for a repeat performance with Ambre: a chance to reap quick financial rewards from a startup company in an overhyped industry, either by bringing Ambre public or by selling it to another, larger firm.

Conclusion: *Caveat Investor*

Despite Ambre's confident public statements about its coal export plans, a careful review of its financial statements and history reveals a company on shaky financial footing: a risky endeavor with few assets, little revenue, massive liabilities, and little chance of profits soon.

Minuscule revenues. Since 2005, Ambre has taken in only Aus$6.6 million in total revenue.

Massive losses. Ambre has accumulated losses of at least $124 million dollars over its history. The firm lost $65.4 million in fiscal year 2012 alone.

Limited, encumbered, and troubled assets. At the end of the 2012 fiscal year, Ambre's balance sheet listed nearly $99 million in net assets—which might seem like a substantial sum. Yet the plus side of the company's balance sheet is dominated by a single $65 million bond, held in trust for the exclusive purpose of reclaiming Ambre's mines. Ambre also counts $19 million of development costs for oil shale leases as "assets," even though its auditor has warned the company may never see a penny from those leases unless it can finance and develop a system to extract and process oil shale at a profit—a decades-old pipe dream for the US petroleum industry.[47] Ambre's balance sheet further lists more than $20 million in "intangible assets," which represents the development and acquisition costs for its coal terminal projects—which will likely be worth far less than $20 million if Ambre's export plans fail to meet with regulatory approval.

Money-losing coal mines. Each of Ambre's two mines operated at a loss in fiscal year 2012, after considering amortization and depreciation costs. Recent losses at the Decker mine exceeded $17 million.

Regulatory uncertainty. The Corps of Engineers has already required Ambre to prepare a time-consuming Environmental Impact Statement for the larger of its two proposed coal export projects. The agency may still require the same for Ambre's smaller project. And according to recent news reports, Ambre now faces regulatory scrutiny for its plan to avoid paying high royalties to the US government by having one of its own subsidiaries purchase coal at the company's own mines at a low price, and then re-sell that coal at a higher price in Asia.[48]

Huge long-term liabilities. Ambre has had more success in accumulating liabilities than in generating profits. The company is responsible for over $40 million in reclamation costs for its ownership stake in the Black Butte mine; roughly $135 million in reclamation costs for the Decker mine; and as much as $46 million of additional "contingent liabilities" for reclamation at the two sites. Also, under the terms of a recent legal settlement Ambre must also pay rival Cloud Peak Energy at least $57 million for the purchase of the remaining 50 percent stake in the money-hemorrhaging Decker mine. Ambre has an additional $9.6 million in obligations for pension and retirement benefits for employees of a defunct coal mine that the company purchased in 2011, as well as millions of additional dollars in obligations for its own employees, for non-cancellable lease commitments, and for cleaning up the Millennium Bulk Terminals site in Longview, Washington.

Diluted shares. Ambre has already issued 406 million shares of stock. Given that Ambre estimates its total equity at less than Aus$100 million, each of these shares is worth less than 25 cents. In addition, Ambre has issued share purchase options for an additional 106 million shares. Any new investor in Ambre would face a substantial risk that their invested capital would be diluted among the existing shareholders.

High borrowing costs. Ambre's 2012 financial report reveals that it is paying 10 percent interest rates to investors from Korea, and 12 percent to Resource Capital Funds—strikingly high interest rates in today's low-interest environment.

Nearly $1 billion in capital needs. To get its Morrow-Pacific project underway, Ambre will need to invest roughly $242 million to build coal barges and to prepare the two coal transfer sites on the Columbia River.[49] Ambre states that its proposed Longview, Washington export terminal will require an additional $600 million investment. The company's acquisition of the Decker mine will require the company to pay at least $57 million to a rival coal company, plus an additional $70.7 million to post a mining reclamation bond. All told, Ambre will need to secure nearly $1 billion in new capital to move its business plan towards completion.

There are still more reasons to be wary of Ambre. The company's complicated business structure, which includes 26 subsidiaries, raises questions about transparency. Its high borrowing costs, coupled

with actions by some investors to withdraw money from the company, suggest that those most familiar with Ambre's finances consider it a shaky venture. To the extent that the company has any track record at all, it is a record of failure, punctuated by a complete write-off of its Australian coal mining assets. And even if the company can obtain both the cash it needs to survive in the short term and the much larger amount of capital it needs to fully pursue its export plans, it still has no guarantee of making a profit, given the volatility of international coal markets and the fierce competition the company will face from more established competitors.

As of February 2013, Ambre still appears to be searching for the capital it needs to fulfill its coal export ambitions. Perhaps the company's most potent asset in that search is found not in its balance sheet or income statements, but in the story it tells about itself: a tale of ready profits from exporting US coal to Asia. Now, it's up to potential investors to decide if the lure of that story is enticing enough to take a risk on a company with shaky finances, a troubled history, and a cloudy future.

To that question, one can only say: *Caveat investor*.

About the Author

Clark Williams-Derry directs research and communications for Sightline Institute. His research and writing over a 20 year career has spanned climate and energy policy, sustainable transportation, sprawl and smart growth, voting theory, agricultural policy, and wetlands preservation.

Sightline Institute is a not-for-profit research and communications center—a think tank—based in Seattle. Sightline's mission is to make the Northwest a global model of sustainability—strong communities, a green economy, and a healthy environment.

Design and layout by Nicole Bernard. Chart and tables designed and produced by Devin Porter, Good Measures. Thanks to Sightline staff Anna Fahey, Eric de Place, Jennifer Langston, Serena Larkin, and Alan Durning, as well as Ross Macfarlane of Climate Solutions, Jan Hasselman of Earthjustice, and Julian Carmona of the Sierra Club, for helpful comments on drafts.

Appendix 1. Ambre Energy, Ltd. consolidated income statements for Fiscal Years 2006 through 2012.

	2006	2007	2008	2009	2010	2011	2012
ORDINARY INCOME / (EXPENSES)							
Revenue		156,753	141,696	426,516	117,681	1,090,462	4,630,000
Other income		53		64,477			232,000
Share of gains/(losses) from joint ventures							(10,105,000)
Share of gains/(losses) from associates							(47,000)
Gain on business combination							5,768,000
Depreciation and amortisation expense		(701,408)	(1,204,389)	(1,524,361)	(1,527,784)	(1,554,874)	(2,158,000)
Employee benefits expense	(33,345)	(508,917)	(1,555,747)	(3,925,081)	(4,275,486)	(6,685,350)	(10,908,000)
Foreign exchange gains/(losses)		(346,684)	(65,491)	543,963	(57,351)	(121,524)	29,000
Impairment expense							(10,857,000)
Finance costs					(224,413)	(1,459,433)	(11,395,000)
Consultants and professional expense		(634,009)	(737,407)	(1,452,932)	(2,341,423)	(6,940,935)	(10,940,000)
Insurance expenses						(343,114)	(559,000)
Loss on disposal of fixed assets							(216,000)
Loss on disposal of financial assets			(131,108)		(69,583)		
Office property lease expense				(377,022)	(552,083)	(591,651)	(1,009,000)
Research and development expense	(180,000)	(366,235)	(2,665,776)	(2,928,720)	(2,127,099)	(2,063,036)	(1,167,000)
Recruitment and relocation expense						(279,602)	(509,000)
Repairs and maintenance expense						(366,313)	(1,218,000)
Share based payments expense		(7,455,162)	(827,100)	(2,932,174)	(3,362,504)	(1,920,380)	(8,992,000)
Travel expenses			(334,810)	(571,170)	(618,707)	(1,018,740)	(1,756,000)
Loss of minority interest prior to acquisition			673,305				
Other expense	(33,344)	(716,851)	(556,575)	(1,067,441)	(1,404,171)	(2,465,793)	(4,189,000)
PROFIT/(LOSS) BEFORE INCOME TAX	(246,689)	(10,572,460)	(7,263,402)	(13,743,945)	(16,442,923)	(24,720,283)	(65,366,000)
Income tax (benefit)/expense	(67,500)	(344,942)			(447,551)	(572,439)	1,000
PROFIT/(LOSS) FOR THE YEAR	(179,189)	(10,227,518)	(7,263,402)	(13,743,945)	(15,995,372)	(24,147,844)	(65,367,000)
Attributable to members of the parent entity	(179,189)	(9,387,674)	(7,193,978)	(13,743,945)	(15,995,372)	(23,129,390)	(62,759,000)
Loss attributable to minority equity interest (also "non-controlling")		(839,844)	(69,424)	(4,567)		(1,018,454)	(2,607,000)
OTHER COMPREHENSIVE INCOME / (EXPENSES)							
Actuarial gains (loss) on pension and retirement benefit schemes							(655,000)
Share of other comprehensive income from equity accounted investees							(1,725,000)
Exchange differences on translation of foreign operations					(1,452,816)	(4,865,705)	(4,699,000)
TOTAL COMPREHENSIVE INCOME FOR THE YEAR	(179,189)	(10,227,518)	(7,263,402)	(13,793,378)	(17,448,188)	(29,013,549)	(72,446,000)
Profit/ (loss) attributable to members of the parent entity	(179,189)	(9,387,674)	(7,193,978)	(13,793,378)	(17,448,188)	(28,020,002)	(69,782,000)
Attributable to non-controlling interest				(4,567)		(933,547)	(2,664,000)

Notes: *All figures compiled by Sightline Institute from Ambre Energy, Ltd. annual reports for Fiscal Years 2007 through 2012, available at* http://www.ambreenergy.com/reports-and-presentation_1. *Headings, text and some numbers may differ from the original presentations to provide for consistent comparisons among years and to correct minor errors in Ambre's own publications. All figures denominated in Australian dollars.*

Appendix 2. Ambre Energy, Ltd. consolidated income statements for Fiscal Years 2006 through 2012.

	2006	2007	2008	2009	2010	2011	2012
CURRENT ASSETS							
Cash and cash equivalents	1	3,982,145	12,180,297	4,297,221	2,909,037	10,980,040	20,300,000
Trade and other receivables	19,999	74,004	101,226	80,019	141,163	487,901	2,697,000
Financial assets	66,689	1,029,652					
Current tax assets	69,104	414,535			447,551	572,439	
Other current assets		12,226	33,611	54,737	171,896	1,038,554	2,391,000
TOTAL CURRENT ASSETS	155,793	5,512,562	12,315,124	4,431,977	3,669,647	13,078,934	25,388,000
NON-CURRENT ASSETS							
Investments in equity accounted investees							36,914,000
Financial assets		1,574,320			131,088	154,015	64,750,000
Property , plant and equipment		4,742,063	3,835,707	4,705,181	3,571,086	15,862,499	21,809,000
Intangible assets		3,463,614	2,881,477	3,258,232	2,796,600	12,994,949	20,566,000
Exploration and evaluation assets				30,111,826	29,451,258	25,246,016	19,163,000
Other non-current assets		3,875,682	23,570,490	249,192	243,569	229,507	541,000
TOTAL NON-CURRENT ASSETS		13,655,679	30,287,674	38,324,431	36,193,601	54,486,986	163,743,000
TOTAL ASSETS	155,793	19,168,241	42,602,808	42,756,408	39,863,248	67,565,920	189,131,000
CURRENT LIABILITIES							
Trade and other payables	315,982	442,225	1,989,327	573,291	665,481	1,631,871	5,847,000
Other financial liabilities					4,871,741	9,843,101	43,796,000
Employee entitlements					143,311	267,284	383,000
Short-term provisions		11,586	1,516,762	110,294		759,601	1,296,000
TOTAL CURRENT LIABILITIES	315,982	453,811	3,506,089	683,585	5,680,533	12,501,857	51,322,000
NON-CURRENT LIABILITIES							
Other financial liabilities					83,444		
Employee entitlements				17,882	17,366	65,812	155,000
Share of net liabilities of joint ventures							28,537,000
Other long-term provisions							10,125,000
TOTAL NON-CURRENT LIABILITIES				17,882	100,810	65,812	38,817,000
TOTAL LIABILITIES	315,982	453,811	3,506,089	701,467	5,781,343	12,567,669	90,139,000
NET ASSETS	(160,189)	18,714,430	39,096,719	42,054,941	34,081,905	54,998,251	98,922,000
EQUITY							
Issued capital	12,000	9,994,200	48,449,019	58,747,769	64,497,625	89,496,566	176,443,000
Convertible notes					362,792	670,814	
Reserves		6,771,349	5,565,453	13,800,391	15,710,079	11,631,615	17,550,000
Retained earnings	(172,189)	(9,559,863)	(16,753,841)	(30,493,219)	(46,488,591)	(69,617,981)	(124,016,000)
Parent interest	(160,189)	7,205,686	37,260,631	42,054,941	34,081,905		69,977,000
Minority equity interest		11,508,744	1,836,088			22,817,237	29,015,000
TOTAL EQUITY	(160,189)	18,714,430	39,096,719	42,054,941	34,081,905	54,998,251	98,992,000

Notes: *All figures compiled by Sightline Institute from Ambre Energy, Ltd. annual reports for Fiscal Years 2007 through 2012, available at* http://www.ambreenergy.com/reports-and-presentation_1. *Headings, text and some numbers may differ from the original presentations to provide for consistent comparisons among years. All figures denominated in Australian dollars.*

Notes and Sources

1. US Energy Information Administration, Annual Energy Review, "Table 2.1f: Electric Power Sector Energy Consumption, 1949-2011," September 2012, http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0201f; and US Energy Information Administration, Quarterly Coal Report (3rd Quarter of 2012), "Table 32: US Coal Consumption by End-Use Sector, 2006-2012," December 20, 2012, http://www.eia.gov/coal/production/quarterly/pdf/t32p01p1.pdf.
2. Compiled from Ambre Energy Annual reports for FY 2007 through FY 2012, at http://www.ambreenergy.com/reports-and-presentation_1.
3. Paddy Manning, "Gillard fiddles while the country burns," Sydney Morning Herald, July 10, 2010, http://www.smh.com.au/business/gillard-fiddles-while-the-country-burns-20100709-10405.html; Peabody Energy Corporation, Securities and Exchange Commission Form 10-K for the Fiscal Year Ended December 31, 2006, http://www.sec.gov/Archives/edgar/data/1064728/000095013707003006/c12536e10vk.htm; Tony Haggerty, "Presentation to the Sydney Mining Club," Excel Coal Limited, April 6, 2006, http://www.sydneyminingclub.org/presentations/2006/april/Excel-Coal.pdf.
4. Ambre Energy, Ltd., "Timeline," http://www.ambreenergy.com/timeline.
5. Ambre Energy, Ltd., "Timeline," http://www.ambreenergy.com/timeline.
6. Ambre Energy, "Ambre Energy Limited 2007 Annual Report," p. 18, http://www.ambreenergy.com/FileLibrary/annualreport2007full.pdf.
7. Ambre Energy, "Ambre Energy Limited 2008 Annual Report," p. 12, http://www.ambreenergy.com/FileLibrary/ae_ar_08_web.pdf.
8. Ambre's 2012 annual report showed a complete writeoff of "patents for technology that are unlikely to be exploited by the group." Ambre Energy, "Ambre Energy Limited 2012 Annual Report," pp. 38 and 48, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
9. Ambre Energy, "Ambre Energy Limited 2008 Annual Report," p. 31, http://www.ambreenergy.com/FileLibrary/ae_ar_08_web.pdf.
10. Ambre Energy, "Ambre Energy Limited 2011 Annual Report," pp. 18, 19, and 92, http://www.ambreenergy.com/FileLibrary/annualreport2011_ae_webversion_final.pdf.
11. This figure refers to "Retained earnings" on Ambre's 2012 balance sheet. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 22, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
12. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," pp. 77-78, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
13. Level 3 Communications, "Why Level 3 Had and Sold a Coal Mine Business," November 30, 2011, http://blog.level3.com/culture/why-level-3-had-and-sold-a-coal-mine-business/.
14. Level 3 Communications, "Why Level 3 Had and Sold a Coal Mine Business," November 30, 2011, http://blog.level3.com/culture/why-level-3-had-and-sold-a-coal-mine-business/.
15. Level 3 Communications, Inc. (2012), Securities and Exchange Commission Form 10-K for the fiscal year ended December 31, 2011, http://lvlt.client.shareholder.com/secfiling.cfm?filingID=794323-12-3.
16. Level 3 Communications, Inc. (2011), Securities and Exchange Commission Form 10-K for the fiscal year ended December 31, 2010, http://lvlt.client.shareholder.com/secfiling.cfm?filingID=1047469-11-1410.
17. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 43, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
18. Level 3 Communications, Inc. Securities and Exchange Commission Form 10-K for the 2004 through 2011 fiscal years, http://lvlt.client.shareholder.com/sec.cfm?DocType=Annual.
19. Western Minerals LLC vs. KCP, Inc.; Ambre Energy North America, Inc.; Ambre Energy Limited. No. CV-12-85-BLG-RFC-CSO. United States District Court for the District of Montana. July 8, 2012. Paragraph 82. http://media.oregonlive.com/environment_impact/other/CloudPeakSuit.pdf; "Decker Mine Production," CoalDiver.org, http://coaldiver.org/mine/DECKER-MINE.

20. John T. Boyd Company, "Powder River Basin Coal Resource and Cost Study," September 2011, http://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/PSCo-ERP-2011/8-Roberts-Exhibit-No-MWR-1.pdf.
21. Associated Press, "Montana's Decker Coal Mine to lay off 75 workers," The Missoulian, November 17, 2012, http://missoulian.com/news/state-and-regional/article_3e92aa2c-30b7-11e2-93e4-0019bb2963f4.html.
22. Western Minerals LLC vs. KCP, Inc.; Ambre Energy North America, Inc.; Ambre Energy Limited. No. CV-12-85-BLG-RFC-CSO. United States District Court for the District of Montana. July 8, 2012. Paragraph 68. http://media.oregonlive.com/environment_impact/other/CloudPeakSuit.pdf. See also, Cloud Peak Energy, inc., November 28, 2009 prospectus for 30,600,000 shares of common stock, p 158, http://www.sec.gov/Archives/edgar/data/1441849/000104746909010369/a2195588z424b4.htm.
23. Western Minerals LLC vs. KCP, Inc.; Ambre Energy North America, Inc.; Ambre Energy Limited. No. CV-12-85-BLG-RFC-CSO. United States District Court for the District of Montana, July 8, 2012. Paragraph 16. http://media.oregonlive.com/environment_impact/other/CloudPeakSuit.pdf.
24. Western Minerals LLC vs. KCP, Inc.; Ambre Energy North America, Inc.; Ambre Energy Limited. No. CV-12-85-BLG-RFC-CSO. United States District Court for the District of Montana. July 8, 2012. Paragraphs. 75 and 142. http://media.oregonlive.com/environment_impact/other/CloudPeakSuit.pdf.
25. Anthony Klan, "Ambre gest $60m mine after legal settlement," The Australian, December 7 2012, http://www.theaustralian.com.au/business/ambre-gets-60m-mine-after-legal-settlement/story-e6frg8zx-1226531654302.
26. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 46, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
27. Associated Press, "Montana's Decker Coal Mine to lay off 75 workers," The Missoulian, November 17, 2012, http://missoulian.com/news/state-and-regional/article_3e92aa2c-30b7-11e2-93e4-0019bb2963f4.html.
28. Anthony Klan, "Miner Ambre Energy in financial trouble as Queensland rejects its coalmine project," The Australian, April 2, 2012, http://www.theaustralian.com.au/business/mining-energy/miner-ambre-energy-in-financial-trouble-as-queensland-rejects-its-coalmine-project/story-e6frg9e6-1226315904534.
29. Anthony Klan, "Angry Queensland farmers boycott Ambre Energy's coalmine study," The Australian, July 31, 2012, http://www.theaustralian.com.au/business/mining-energy/angry-queensland-farmers-boycott-ambre-energys-coalmine-push/story-e6frg9e6-1226438928521.
30. Campbell Newman, Queensland Government, letter dated August 21, 2012, http://www.fof.org.au/uploads/media/Premier_Newman_s_letter.pdf.
31. Anthony Klan, "Angry Queensland farmers boycott Ambre Energy's coalmine study," The Australian, July 31, 2012, http://www.theaustralian.com.au/business/mining-energy/angry-queensland-farmers-boycott-ambre-energys-coalmine-push/story-e6frg9e6-1226438928521.
32. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 14, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
33. Ambre Energy, "Ambre Energy Limited 2011 Annual Report," p 88, http://www.ambreenergy.com/FileLibrary/annualreport2011_ae_webversion_final.pdf.
34. Erik Olson, "Millennium internal e-mail reveals goal of 80 million tons in annual coal exports," The Daily News (Longview, Washington), February 24, 2011, http://tdn.com/news/local/article_8a86fa28-4072-11e0-b60d-001cc4c002e0.html.
35. Scott Learn, "Millennium Bulk Terminals says it won't pursue exporting coal out of Longview -- for now ," The Oregonian, March 7, 2011, http://www.oregonlive.com/environment/index.ssf/2011/03/millennium_bulk_terminals_says.html.
36. Erik Olson, "Millenium to restart coal terminal permit process," The Daily News (Longview, Washington), March 15, 2011, http://tdn.com/news/local/millenium-to-restart-coal-terminal-permit-process/article_abb5534c-4f5f-11e0-b8ef-001cc4c03286.html.
37. Ambre Energy, Ltd., "Millennium Bulk Terminal submits permits to revitalise brownfield port facility," http://www.ambreenergy.com/millennium-bulk-terminal-submits-permits-to-r.

38. Christina Williams, "Morrow Pacific coal project ready to pay $75M for barges," Sustainable Business Oregon, July 23, 2012, http://www.sustainablebusinessoregon.com/articles/2012/07/morrow-pacific-coal-project-ready-to.html.
39. Beth Doglio, Climate Solutions, personal communication, January 21, 2013.
40. Erik Siemers, "Morrow Pacific: Only thing delayed is expectations," Sustainable Business Oregon, September 14, 2012, http://sustainablebusinessoregon.com/articles/2012/09/morrow-pacific-only-thing-delayed-is.html.
41. Tim Boreham, "Green light for Ambre's $200m listing," The Australian, April 30, 2012, http://www.theaustralian.com.au/business/green-light-for-ambres-200m-listing/story-e6frg8zx-1226342068562.
42. Patrick McGee, "'Junk'-Bond Yields Break Below 6% for the First Time," The Wall Street Journal, January 4, 2013, http://online.wsj.com/article/SB10001424127887323374504578221842362822994.html.
43. Patrick McGee, "'Junk'-Bond Yields Break Below 6% for the First Time," The Wall Street Journal, January 4, 2013, http://online.wsj.com/article/SB10001424127887323374504578221842362822994.html.
44. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 73, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
45. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 60, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
46. Nathan Vardi, "Best. Private Equity Deal. Ever (Maybe)." Forbes Magazine, January 26, 2011, http://www.forbes.com/forbes/2011/0214/focus-bhappu-schwarzman-rubenstein-molycorp-best-equity-deal.html.
47. Ambre Energy, "Ambre Energy Limited 2012 Annual Report," p. 77, http://www.ambreenergy.com/FileLibrary/ambre_energy_limited_annual_report_30_june_2012_lr.pdf.
48. Scott Learn, "Scrutiny rises for royalties paid on US coal exports to Asia," The Oregonian, January 16, 2013, http://www.oregonlive.com/business/index.ssf/2013/01/scrutiny_rises_for_royalties_p.html.
49. ECONorthwest, "The Economic Impacts of Proposed Coal Barging Operations," May 2012, http://morrowpacific.com/wp-content/uploads/2012/06/Ambre_Econ_Impact_Study_Final.pdf.

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT. CORPS OF ENGINEERS
P O BOX 2946
PORTLAND, OREGON 97208-2946

REPLY TO
ATTENTION OF

Operations Division
Regulatory Branch
Corps No. NWP-2006-160

Mr. Tim Wetherall
Port of Arlington
P.O. Box 279
Arlington, Oregon 97812

Dear Mr. Wetherall:

This letter refers to the Department of the Army permit application the Port of Arlington (Port) submitted for authorization to construct a barge dock, trestle, and steel pile dolphins and fender piles, to off-load containerized garbage for transport to the local landfill. The project is located in the Columbia River, River Mile 252.6, Section 26, Township 4 North, Range 22 East, near Arlington, Gilliam County, Oregon. The application was assigned number NWP-2006-160.

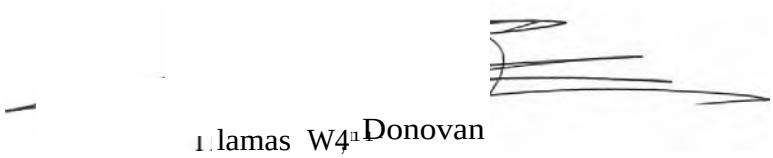
My decision to issue a permit, issue with conditions, or deny a permit is based on an evaluation of the probable impacts, including the cumulative impacts of the proposed project and its intended use on the public aquatic resource. During this review the benefits which may reasonably be expected to accrue from the proposal are balanced against reasonably foreseeable detriments. During the review of the Port's proposal the information provided by the Port and its agents was thoroughly evaluated by my staff, as was the material submitted by the Federal and state agencies, the Tribes and the interested public. After considering all of the relevant public interest factors, I have determined the project as proposed would adversely impact treaty fishing rights and is, therefore, contrary to the public interest. For that reason, it is my decision to deny the permit request xvith prejudice. Should this issue be resolved at any time in the future, the Port could submit another application for a Department of the Army permit. The review and this effect are discussed in greater detail in the Environmental Assessment and Statement of Findings (Enclosure 1).

On April 3, 2007, I suspended the Letter of Permission (LOP) that authorized construction of the barge dock. That letter also stated additional review was required to determine whether to reinstate, modify, or revoke the permit. It is my decision to formally revoke the LOP based on that review.

The Port and/or its authorized agent may appeal a permit denial under the U.S. Army Corps of Engineers' Administrative Appeal Process. The administrative appeal process may be initiated by completing the Notification of Administrative Appeal Options and Process and Request for Appeal (Enclosure 2). The point of contact for appeal is Mr. David W. Gesl, U.S. Army Corps of Engineers Northwestern Division, 1125 NW Couch St, Suite 500, PO Box 2870, Portland, Oregon 97208. The appeal must be received by Mr. Gesl, the Review Officer, within 60 days of this Notification of Appeal Process.

I have not come to this decision easily. It is only after careful review of the facts surrounding this project that I have reached this decision. The Corps understands the financial and economic consequences of this decision and is committed to continuing to work with all affected parties on a mutually acceptable solution.

A copy of this letter is being furnished to Mr. Gene Leverton, 3144 NE 17 th. Portland. Oregon 97212.



lamas W4n Donovan
Colonel, Corps of Engineers
District Commander

Enclosures

DEPARTMENT OF THE ARMY ENVIRONMENTAL ASSESSMENT AND STATEMENT OF FINDINGS

Applicant: Port of Arlington

Application Number: NWP-2006-160

1. Introduction: This is a Department of the Army (DA) permit decision document for a permit action being reviewed by the Portland District of the U.S. Army Corps of Engineers (Corps). This document constitutes the Environmental Assessment, Section 404(b)(1) Evaluation and Determination, Statement of Findings, and Public Interest Determination for the proposed project described below. Review was conducted according to the procedures at 33 CFR Part 320 and 325, including Appendices B and C. This document also addresses the Environmental Protection Agency's Section 404(b)(1) Guidelines published at 40 CFR Part 230.

1.1. Authority.

(X) Section 10 of the Rivers and Harbors Act of 1899.
(X) Section 404 of the Clean Water Act.
( ) Section 103 of the Marine Protection, Research and Sanctuaries Act.

1.2. Permit Decision. As District Engineer, my decision is to deny an individual Department of the Army permit for the proposed project.

1.3. Background. On June 26, 2006, a complete application was received from the Port of Arlington (Port) for the construction of a dock and mooring dolphins for the off-loading of barges. The proposed work included the construction of a barge dock on piling with fender piles along the waterward edge of the dock, ten mooring dolphins, a trestle and footing to connect the dock to the shoreline. A public notice was issued on November 29, 2006 soliciting conunents on the proposed issuance of a Letter of Permission (LOP) for the project under Section 10. Inadvertently, this public notice did not propose authorization for the discharge of fill material for the footing required under Section 404. On February 21, 2007, an LOP was issued to the Port of Arlington authorizing the construction of the dock, fender piles, dolphins, and trestle under Section 10. When we discovered the LOP did not authorize the discharge of fill material for the footing under Section 404, a second public notice was issued on February 23, 2007 soliciting comments on the proposed issuance of an Individual Permit for the complete project under Section 10 and Section 404.

On April 3, 2007, the LOP was suspended based on cultural resource and treaty fishing site concerns at the site pending a decision on the Individual Permit for the complete project. A total of 43 piles consisting 31 single piles and 12 piles to construct dolphins were driven at the site as authorized under the LOP prior to suspension of the LOP. Since then, there has been no further construction or work at the site. This Decision Document contains our evaluation of the Port's application for a permit for the complete project under both Section 10 and Section 404.

2. Proposed Project.

2.1. Location. The project is located along the Columbia River, River Mile 252.6 approximately 1/4 mile downstream from the mouth of Willow Creek, Section 26, Township 4 North, Range 22 East, near Arlington, Gilliam County, Oregon.

2.2. Project description. The Corps permitted the following work on February 21, 2007:

> The project involves construction of a barge dock, trestle, and steel pile dolphins and fender piles. Ten new mooring dolphins made up of approximately five, 24-inch diameter steel piles connected by a steel plate, or cast-in-place concrete cap will be installed. The new dolphins Will be driven using an impact hammer via barge mounted equipment, and if necessary, the rock may be drilled and grouted for additional support. Upon installation, some piles will then be filled with sand or concrete. Up to twelve, 24-inch diameter temporary piles may be installed for each dolphin. To protect the proposed dock, approximately 15 new fender piles will be installed. The fender piles will be either untreated wood or steel, driven with a vibratory hammer.
>
> The new dock will measure 40 feet wide by 80 feet long approximately parallel to the shore. The new dock surface will be concrete with pre-cast concrete deck panels. Approximately thirty-five, 24-inch diameter steel piles will be driven to support the new dock. The dock will be accessed by a 30-foot wide by 75-foot long trestle. Approximately sixteen, 24-inch diameter steel piles will support the trestle, which will be aligned roughly perpendicular to the shore.

The purpose of the additional public notice was to re-authorize the above work with the addition of the following fill under Individual Permit:

> To support the trestle approximately 650 cubic yards of rock will be placed below ordinary high water to create a footing along the shoreline.
>
> There have been no project changes since the Individual Permit Public Notice was issued.

2.3. Existing conditions. The site is located along the left descending (south) bank of the Columbia River, River Mile 252.6 of the John Day Pool (also known as Lake Umatilla) approximately 1500 feet west of the mouth of Willow Creek.

The upland portion of the site consists of an abandoned rock quarry previously used by the Port of Arlington and for the construction of the Union Pacific Railroad (approximately 7 acres). It is sparsely vegetated, and encompasses the abandoned pit area, and has very steep shoreline access, with the exception of a small 'beach' area immediately west of the dock construction site.

The river portion of the site, where the dock is to be constructed consists of open water area adjacent to the shoreline. The depth of the river at the project location is approximately 25 feet. There are no islands, shoals, or rapids in the vicinity of the project site. The water surface elevation at this location remains relatively constant as it is managed based on hydropower , fish passage, and flood control needs.

The site does not contain any wetlands or other waters and provides very little wildlife habitat. It is bound on the south by the Union Pacific railroad line and Interstate 84.

To date, a total of 43 piles have been driven at the site as authorized under the Letter of Permission (LOP) February 21, 2007. A total of 31 single piles, and a total of 12 grouped piles to create dolphins were installed.

The Corps suspended the LOP based on cultural resource and treaty fishing right concerns at the site on April 3, 2007. Since the time of the suspension there have been no further construction or work at the site.

2.4. Jurisdiction. A Jurisdictional Determination form, dated July 18, 2006 is located in the project file.

2.5. Project Purpose. The purpose of the proposed project is to accommodate waterway bulk and container deliveries to the regional landfill complex near Arlington, Oregon.

3. Public Notification Issues.

3.1 Public Notice Information. A complete application was received on June 26, 2006. A Public Notice describing the project was originally issued on November 29, 2006 (for the Letter of Permission) A second public notice was issued February 23, 2007 (for the total project and Individual permit). Both notices were sent to all interested parties, including appropriate Federal and state agencies and Native American Tribes. Comments received on this action are summarized below, followed by the applicant's response to the comments and the Corps' response.

3.2. Comments to the Public Notice.

3.2.1. Federal Agencies. No comments received.

3.2.1.1. Environmental Protection Agency (EPA). No comments received.

3.2.1.2. U.S. Fish and Wildlife Service (**FWS**). No comments received.

3.2.1.3. National Marine Fisheries Service (**NMFS**). The Corps initiated formal consultation for potential impacts to species listed under the Endangered Species Act (ESA) with the NMFS July 25, 2006. NMFS issued a Biological Opinion (BiOp) with special conditions January 31, 2007, which this office received on February 2, 2007. All terms and conditions of this BiOp were included as terms and conditions of the LOP.

3.2.2. State and Local Agencies.

3.2.2.1. Oregon Department of Fish and Wildlife (**ODFW**). No comments received.

3.2.2.2. State Historic Preservation Officer (**SHPO**). SHPO did not provide comments to the Corps in response to the first public notice or at any time prior to issuance of the Letter of Permission. The Corps contacted SHPO after concerns were raised by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) about cultural resources within the site. The Corps received comments from SHPO on March 9, 2007, after the Letter of Permission had been issued and the Individual Permit public notice had been sent. These comments indicated that there was a known site in the area and a cultural resources survey was recommended.

When asked why SHPO had not commented previously, they told the Corps they had submitted a similar comment letter to DSL in response to their public notice. This letter was dated August 3, 2006 and also stated that there was a known site in the area and that a survey was recommended. This information was neither sent directly to nor copied to the Corps.

3.2.3. Organizations. No comments received.

3.2.4. Individuals. No comments received.

3.2.5. Native American Tribes. Catherine Dickson representing the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) contacted the Corps' Archeologist (Michael Martin) on May 11, 2006 to obtain information regarding the proposed project. Michael Martin contacted the Regulatory Branch (Karla Ellis) to request that the CTUIR receive a copy of the application and any subsequent Public Notices. Michael Martin identified a known site in the vicinity of the project, and indicated that cultural resource survey work had been conducted. In July, 2006 Catherine Dickson contacted Michael Martin by phone to request a copy of the cultural resources survey conducted for the site, referenced as Martin (1999) and Gilsen (1999) and also requested the opportunity to comment when the application was filed. In August 2006, Karla Ellis received the cited report directly via hard-copy from Michael Martin. The same day, this copy was provided by e-mail to Catherine Dickson.

On November 29, 2006, the Corps issued a Public Notice for the Letter of Permission. A hard copy of the notice was sent to directly to Catherine Dickson. The application for the project was also sent to Ms. Dickson, as requested. No comments were received; specifically no comments were received from SHPO (see Section 3.2.2.2 above), the CTUIR, or Catherine Dickson.

On February 21, 2007, the Corps issued the Letter of Permission for barge dock construction. On February 21, 2007, the Corps received calls from Catherine Dickson stating all requested information had not been received. Upon receiving notification on February 21, 2007 that the CTUIR did not have the requested information, the Corps emailed Catherine Dickson to determine what information was outstanding. She referred to the conversation in July stating she needed the report by Martin and Gilsen.

On February 26, 2007, the Corps emailed the requested report to Catherine Dickson, which was the same report the Corps sent to her in August 2006. On March 2, 2007, Karla Ellis emailed Catherine Dickson to confirm that the information had been received. On March 5, 2005, the Corps received a response stating that while the information had been received, she would need several days to review. On March 6, 2007 the Corps received an email from Catherine Dickson, specifically requesting the map that should have been with the report that identified a known site. During this time, we received a report from the Port that pile driving was occurring.

On March 19, 2007, the Corps received the first letter from the CTUIR. In summation, the letter requested formal consultation with the CTUIR, expressed concern about the project, requested the map to support the above-mentioned report, stated the area was known to contain cultural resources, that it was a treaty reserved fishing site, and traditional cultural property. It also went

on to state that the notifications of the project by the Corps to the Tribe were insufficient means to initiate government-to-government consultation.

Coordination was started internally with Barbara Creel (Corps Tribal Liaison), Shawn Zinszer (Regulatory Section Chief), and Larry Evans (Regulatory Branch Chief).

On March 22, 2007, the Corps located the map the Tribe had requested and transmitted it to the Tribe. Also on this day, we began coordination with Mr. Audie Huber of the CTUIR. He requested the application and other project information, public notices, consultations, etc., which were provided electronically.

On March 23, 2007, the Corps notified the Port of the cultural resources issues, and clearly stated that the permit for the fill portion of the work would not be forthcoming until the issue was resolved in full.

On March 24, 2007, the CTUIR requested an extension to the comment period for the Individual Permit public notice.

On March 26, 2007, the CTUIR sent a request to the Corps asking for a stop work order at the Arlington site to allow sufficient time to review and comment on the project. On March 28, 2008, the Corps confirmed with the Port that work had voluntarily ceased for a period of one week. On March 29, 2007, the Corps responded to the CTUIR's letters received on March 19 and 26, 2007. This letter requested a meeting with the CTUIR to discuss the identified concerns and also notified them that the Port had been made aware of the concerns. During this time, the Corps attempted to obtain information regarding the treaty fishing right claim and was unable to identify this area on any map or other resource available to the District.

On March 30, 2007, the Corps received a letter from the CTUIR. The stated purpose of the letter was threefold:

1) to inform the Corps and Port of Arlington staff about the nature of federally protected Indian treaty reserved usual and accustomed fishing sites;
2) to reiterate the CTUIR's request that work stop immediately on the construction project (NWP-2006-160); and
3) to provide notice that should construction not stop immediately, and remain stopped pending satisfactory resolution of the concerns stated in their letter, the CTUIR would be prepared to file a complaint in the United States District Court for the District of Oregon and seek a Temporary Restraining Order and Preliminary Injunction prohibiting further work and the issuance of any further permits or other permission that would allow work to continue on the site.

Further, the letter went on to state that the Corps failed to engage in government-to-government consultation with the CTUIR prior to issuing the permit, which violated the Corps' "trust and fiduciary obligations" to the CTUIR. During this time the Corps arranged to meet directly with the CTUIR.

On April 3, 2007, the Corps sent a letter to the CTUIR thanking the Tribe for the opportunity to meet and notifying them that based on those discussions and new information the Corps would be suspending the permit effective immediately.

On April 3, 2007 the Corps issued a letter to the Port officially suspending the permit.

On April 4, 2007 the CTUIR contacted the Governor's office regarding this project.

On April 10, 2007, the Corps received a letter from the CTUIR stating that approximately 90 steel piles had been driven "on and in the middle of the Tribe's usual and accustomed fishing site and reiterated the importance of the traditional cultural property. The letter went on to outline steps to help resolve the issue as follows:

1) Define the Undertaking. The CTUIR requested that the Corps enter into full consultation with the CTUIR.
2) Assess Impacts from Construction to Date. The CTUIR requested that the Corps conduct a survey.
3) Review Section 10 and Section 404 Permits. The CTUIR requested 30 days to review both actions.
4) Conduct NEPA Review. The CTUIR requested that the Corps revise the NEPA document.
5) Collaborative Resolution Development. The CTUIR stated that they and the Corps needed to enter into discussion with the Port and Gilliam County collectively.
6) Collaborative Media Relations. The CTUIR requested that any release be coordinated with them.
7) Improve Tribal/ACOE Relationships and Communication.

On April 17, 2007, the Corps sent a response to the April 10, 2008 the CTUIR letter acknowledging receipt and identifying next steps. This letter reiterated the importance of 7 next steps listed above.

On May 4, 2007, the Corps sent a letter to the CTUIR defining the Area of Potential Effect (APE) as required under 36 CFR 800.4 and 33 CFR 325, Appendix C.

On May 11, 2007, the CTUIR provided comments back on the APE. They also suggested contacting the Confederated Tribes of the Warm Springs (CTWS), Yakama, and Nez Perce Tribes. At this suggestion, the Corps provided the APE letter to CTWS, Yakama, and Nez Perce Tribes.

On May 16, 2007, the Corps received a letter from the CTUIR asserting that an Environmental Assessment (EA) was not sufficient and did not adequately address the impacts of the project. For this reason the CTUIR requested that the Corps complete an Environmental Impact Statement (EIS).

On June 6, 2007, the Corps sent a letter to the CTUIR, the CTWS, Yakama Nations and the Nez Perce Tribe clarifying the APE as requested by the CTUIR.

On June 11, 2007, the Corps sent letter to the CTUIR in response to their letter dated May 16, 2007. This letter stated that while the Corps understood the request, an EIS was not warranted at this time.

On July 2, 2007, the Corps received an email from the CTWS requesting additional information on the project. The Corps sent the requested information to the CTWS on July 23, 2007 and again on August 8, 2007. On September 7, 2007 CTWS stated they had not received the requested information. The Corps again sent it on September 7, 2007. No comments have been received to date from the CTWS.

On July 5, 2007, the Corps received a letter from the CTUIR stating that it was dissatisfied with the APE. To address these concerns the Corps held a conference call. In attendance were SHPO, Corps Regulatory, and the CTUIR. On July 9, 2007, the Corps received a letter from the CTUIR that expressed frustration that the May 4, 2007 APE letter did not address their concerns. No action was requested.

On July 16, 2007, the Corps received a letter from the CTUIR discussing a request by the Port to remove gravel from the quarry site while negotiations for the larger project took place. The CTUIR did not oppose this proposal provided material outside of the quarry was not removed.

On July 24, 2007, the Corps sent the CTUIR a letter to clarify that the APE would be defined as it was in the May 4, 2007 letter to the CTUIR. The Corps stated that the APE would be defined as 8 acres, not 50 acres as requested.

On July 27, 2007, the Corps received a letter from the CTUIR that responded to the Corps' June 11, 2007 letter regarding the EA and EIS. The Tribe reiterated their request for an EIS. This letter further stated that if the matter could not be resolved it would be taken to the Federal Court system.

On August 10, 2007, the Corps sent a letter to the CTUIR in response to the CTUIR's July 27, 2007 letter. The Corps requested documentation from the Tribe that the project site is a treaty-reserved usual and accustomed fishing site and information on what impact the project would have on the asserted treaty fishing site. Specifically, declarations or affidavits from tribal members were requested.

On August 22, 2007, the Corps sent a letter to the CTUIR requesting that they participate as a consulting party for the Section 106 determination. On September 4, 2007 the Corps also enlisted the services of David Ellis of Willamette Cultural Resources Associates to conduct a cultural resources survey. On September 4, 2007 the Corps issued a similar letter to CTWS, the Nez Perce Tribe and the Yakama Nation requesting their participation in the Section 106 survey. On September 7, 2007, the Corps received a copy of a letter from the CTUIR to the Advisory Council on Historic Properties (ACHP). This letter requested the ACHP's participation in the NHPA compliance in this project. On September 17, 2007, the Corps received a request from the ACHP for all pertinent project information so that they might respond to the CTUIR's request. On November 19, 2007 the Corps provided all relevant project info via letter to the ACHP.

On November 2, 2007, the Corps received a letter from the CTUIR, which was also addressed to the Port of Arlington and Gilliam County that stated no mitigation was possible for the construction and operation of the barge dock. Further, CTUIR stated that the barge dock could not co-exist with the tribal fishing at the site and that this is a significant fishing site to the Tribe.

On November 19, 2007 the Corps responded to the CTUIR's letter and requested a meeting to discuss options.

On November 23, 2007, the Corps received a bid from the CTUIR to conduct the Section 106 Cultural resources survey for the Tribe's asserted traditional cultural property.

On November 27, 2007, the Corps received signed affidavits from two Tribal members, Robert Brigham and Leo Stewart, describing the current and historical fishing done by tribal members at this site and near the mouth of Willow Creek and the impact the pilings have had and the impact the completed barge dock would have on the their ability to fish.

On December 5, 2007, the Corps received a letter from the CTUIR reiterating their statements in their November 2, 2007 letter that the dock could not coexist with the fishing on the site and summarizing their meetings with various branches of the state, federal and county government. They also stated that the "pilings already driven into one of our usual and accustomed fishing areas must be removed, as the construction impermissibly and unavoidably interferes with the exercise of' treaty fishing rights. They also committed to providing additional affidavits and record materials related to the historical identification of the site as a usual and accustomed fishing site by December 14, 2007.

On December 19, 2007, the Corps received additional signed affidavits from Tribal members describing current and historical fishing done by tribal members at this site and near the mouth of Willow Creek and the impact the pilings have had and the impact the completed barge dock would have on the their ability to fish. Included where affidavits from Donald Sampson, Robert Brigham (who had previously provided an affidavit in November, this affidavit focused on how the pilings interfered with his ability to fish at the site and the damage he allegedly incurred to his nets when attempting to fish the site after partial construction), and Kat Brigham.

On January 15, 2008, David Ellis of Willamette Cultural Resources Associates transmitted to the Corps his report on the archaeological and historical survey he conducted on the site. This report found an isolate not Tribal in nature and did not encounter any cultural resources at the project site. An Isolated Find in Oregon is defined as one (1) to nine (9) artifacts discovered in a location that appears to reflect a single event, loci, or activity, as per the Oregon Parks and Recreation Department Heritage Program. While visibility was a problem for the in-water portion, there was no evidence that the project to-date had impacted any cultural resources. There are no known cultural resources in the project area, as per Willamette Cultural Resources Associates.

On January 31, 2008, the Corps received a letter from the CTUIR's attorney (Brent Hall) that included some of the documentation of the project site as a usual and accustomed treaty fishing site.

On February 4, 2008, the Corps received a letter from the CTUIR to the Port reiterating their position that no mitigation was possible, that the CTUIR is opposed to the project at the Willow Creek site, and that the CTUIR will "vigorously oppose the Project in the Willow Creek location in federal court if necessary."

On February 11, 2008, the Corps sent a letter to the CTUIR requesting formal Government to Government consultation with the Tribe.

On February 29, 2008. the Corps received the Traditional Cultural Properties portion of the cultural resources survey from the CTUIR. The document provides information that satisfies National Register Criteria A for Significance (Property is associated with the events that have made a significant contribution to the broad pattern of our history). Furthermore, the CTUIR determined the nomination form "to be adequately documented and technically and professionally cor-ect and sufficient." The CTUIR indicated they would recommend acceptance of the nomination for "as meeting the documentation standards for registering properties in the National Register of Historic Places and meeting the procedural and professional requirements set forth in 36 CFR Part 60."

On March 10, 2008 the Corps sent a letter to the Port of Arlington providing opportunity to comment on the usual and accustomed fishing site assertion made by the CTUIR. The Corps provided documentation provided by the CTUIR and requested any comments by March 21, 2008.

On March 19, 2008, SHPO provided concurrence that the project will have no effect on any known archaeological resources.

On March 20, 2008 the Port of Arlington sent a letter in response to the usual and accustomed fishing site assertion by the CTUIR. The letter surmises the Port is not equipped or qualified to make a determination on the fishing site assertion. The letter also raises concerns about how usual and accustomed sites are defined and what this means for development of its waterfront.

The Corps has not evaluated whether any other alternative locations would also impact usual and accustomed fishing stations. Any other location would require a similar fact specific analysis. While the Corps appreciates the issues raised in the Port's letter, it is the Corps' opinion that the project as proposed impermissibly impacts a treaty-reserved usual and accustomed fishing station.

3.3. Public Hearing (33CFR Part 327). Public hearings are held if the Corps determines additional information from such a hearing is needed to make a final permit decision. Generally, public hearings are held if comments to the public notice raise substantial issues which cannot be resolved informally. Public hearings are conducted on an as needed basis at the discretion of the District Engineer. No public hearing was requested or held for this project.

4. Compliance With Other Federal and State Laws. (e.g., **ESA,WQC, CZM, EFH,** Executive Order

4.1. Water Quality Certification. Oregon Department of Environmental Quality (**DEQ**). On February 20, 2008, DEQ issued a letter stating that they needed additional information from the Port. The letter also stated that if they did not hear back from the Port by February 22, 2008 DEQ would deny WQC. DEQ has not issued Water Quality Certification (WQC) for this project. lithe WQC is denied, the applicant understands that DEQ will re-open review of the file when the additional information is received.

The full letter is located in the project file, however the following outlines the additional info needs from DEQ:

1) Clarification of work that has taken place.
2) Clarify if the existing quarry has an NPDES permit.
3) Fluvial geomorphological analysis of the barge dock site.
4) Clarification of construction materials.
5) Work area isolation from cement.
6) Clarify how silt curtains will contain sediment in this site.
7) Revegetation plan.
8) Mitigation plan.
9) Post-Construction Stormwater Management Plan
10) Operations Plan for the site (spill containment, invasive species management, etc.)

4.2. State and/or Local Authorizations (if issued).

4.2.1 Oregon Department of State Lands (**DSL**). DSL issued a Removal/Fill Permit on August 22, 2006. A renewal of the permit was issued on August 22, 2007. However, DSL then placed it on hold until the requirements of the Corps could be met. Once the Port has resolved the issues with the Corps, DSL will take the permit "off of hold status."

4.2.2 Oregon Water Resources Department (**WRD**). Not applicable.

4.3. Endangered Species Act. The Corps initiated formal consultation for potential impacts to ESA-listed species with the NMFS July 25, 2006. NMFS issued a Biological Opinion (BiOp) with special conditions January 31, 2007, which this office received on February 2, 2007. All terms and conditions of this BiOp were included as terms and conditions of the LOP authorization. All terms and conditions of the BiOp would be terms and conditions of an Individual Permit, if issued, as the original BiOp covered the entire project.

4.4. Essential Fish Habitat (**EFH**).

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), requires Federal agencies to consult with NMFS on activities that may adversely affect EFH. We prepared an EFH assessment and consulted on EFH along with our ESA consultation discussed in Section 4.3 above. We proposed conservation recommendations to avoid, minimize or otherwise offset adverse modification of EFH. We anticipate that implementation of the conservation measures contained in the consultation and other considerations outlined previously will avoid, minimize or otherwise offset potential adverse effects to EFH in the proposed action area. All terms and conditions of the BiOp would be terms and conditions of an Individual Permit, if issued, as the original BiOp covered the entire project.

4.5. Executive Orders. Not applicable.

4.6. Coastal Zone Management Consistency Determination. Oregon Department of Land Conservation and Development (DLCD). Not applicable. The project is not located within the coastal zone.

5. Alternatives. [33 CFR Part 320.4 (a)(2)(ii) and 40 CFR Part 230.10(a)] Section 404(b)(1) of the Clean Water Act prohibits the discharge of dredged or fill material into waters of the United States unless the proposed discharge is the least environmentally damaging practicable alternative capable of achieving the project purpose. Alternatives were evaluated pursuant to 40 CFR 230.10. The NEPA and implementing regulations at 40 CFR 1502.14 require that a range of reasonable alternatives including the no action alternative be evaluated. Under NEPA, the no action alternative and action alternatives that meet the project purpose and need of the preferred alternative are considered to be reasonable alternatives. These alternatives under NEPA do not need to be available to the applicant. Though we evaluate these alternatives, the alternatives selected should be available to the applicant at the time of our permit decision. Following is a detailed discussion of alternatives to the proposed project that meet the project purpose and need. Each alternative discussed addresses logistics, technology, cost and environmental consequences and is followed by a statement indicating whether or not we consider the alternative to be practicable. Alternatives to the proposed project are evaluated throughout this document unless they are considered not practicable, do not meet the project purpose, are not the least environmentally damaging or are not available.

5.1. No Action. Under the No Action alternative, the Corps would not issue a Department of the Army permit. In this case, the applicant began work under a LOP and installed a total of 43 pilings. For this case, the no action alternative also includes removing structures already placed by the applicant. Removal of the existing structures would result in a minor and temporary impact to the waterway during construction. There would be no long-term impacts to the environment resulting from piling removal.

The site could then presumably be developed to support non-water dependant uses.

5.2. Other Project Designs.

5.2.1. Smaller Project Designs. As a portion of the project has already been completed, smaller project designs were not considered. Originally, before issuance of the LOP the Port designed the current project to ensure there was minimal impact on the environment, minimal financial impact, and that it was logistically feasible. This alternative was considered to be the least environmentally damaging practicable alternative.

5.2.2. Larger Project Designs. Larger project designs were originally considered by the Port. The larger design involved blasting into the cliff-face along the Columbia River to avoid dredging and dock construction. While this alternative would not require dock construction, it would have included significantly more environmental impact than the current design. Dredging in the river would have resulted in disturbance and blasting into

the cliff-face would have resulted in an unquantifiable amount of rock and debris entering the waterway uncontrolled. A larger project would not be the least environmentally damaging practicable alternative.

5.2.3. Different Project Designs. Due to constraints at the site, and the existing conditions alternative designs beyond blasting of the cliff-face were not considered and would not be feasibly logistically. See below for different designs that were considered at alternative sites.

5.3. Other Sites Available to the Applicant. The Port investigated several others locations before settling on the current site. The following was provided by the Port **at** the Corps' request.

Site 1- Known as the Downtown Site: In the fall of 2001, a conditional use permit process was initiated through the City of Arlington. This permit would have allowed construction of a barge dock downtown to handle waste products, and possibly rock. Two parcels were available- one of about 3 acres on the west side and one acre on the east. With public pressure to reduce visual impacts, the Port chose the east side location. Although there was only one acre of land on the east side of a man-made peninsula, and 5 acres underwater, the Port owned it and the location was closest to the landfill complex. A Citizen Advisory Panel was formed, and met three times and two Town Hall meetings were held to openly discuss the project. In April 2002, the Corps held an onsite pre-application meeting was held with representatives from the Corps, NMFS, ()DFW, USFWS, and DEQ. The location on the east side of the peninsula would involve large amounts of fill in water that is 60-80 feet deep. The agencies encouraged the Port to find an alternate site because of the potential environmental impacts. Combining this information with the resistance expressed in the public meetings, the Port commission withdrew its proposal to build a dock downtown.

The major public objections were noise and truck traffic that would be generated by the dock. Truck traffic would need to transit the downtown park area. Visual impacts from downtown were a concern, as was the perception of possible cross-contamination with the existing grain elevator tenant who seasonally uses open storage. City of Arlington zoning ordinance prohibits potential conflicts with existing tenants.

Site 2- A nearby site, a bout 'A mile east of the peninsula, was briefly considered as well. It was called the old depot site because it was formerly a railroad depot. Obstacles included that the only access was on railroad right-of-way, it required transit of the downtown park, there were less than a few acres on two levels, it was owned by the Corps of Engineers and the Union Pacific Railroad, and would have required significant amounts of fill material in the river. The applicant rejected this site due to the above-listed concerns.

Site 3- Blalock Canyon: This river access point is 10 miles west of Arlington. Although there is an existing freeway interchange, there is only a narrow strip of land along the water. It is owned by the Corps of Engineers, and Union Pacific Railroad has main line track and right-of-way consuming most of the land. The largest possible site north of the rail track is about 3 acres, but there is no way to safely cross the track. A rail crossing bridge would occupy most of the available land. The applicant rejected this site due to size constraints and safety concerns.

Site 4- Willow Creek Site: The site is 10 miles east of Arlington. The Port bought 56 acres from the Corps in 1967. The land is north of the Union Pacific rail line, and about '/2 miles west of where Willow Creek enters the Columbia River. The site includes basalt quarry, originally developed to relocate rail lines and highways because of the John Day Dam construction. One result of the 2001 attempt to locate the barge dock downtown was strong public endorsement of the Willow Creek site as ideal for this purpose. It is owned by the Port, has good highway access, is away from downtown, properly zoned, the landfill transit route avoids the city park, and it is a zoned quarry that could supply barges with back-haul rock.

Any alternate location within the Willow Creek property would need to consider the potentially eligible historic property and if found eligible, how to resolve the adverse effects from the project because the Tribe may have concerns about that stretch of the river, not just the specific location already isolated for the proposed barge facility.

In 2002, the Port and county began planning for the barge dock at Willow Creek. Studies were completed on how best to cross the rail track. A right-of-way easement was negotiated with Union Pacific Railroad, **land** was purchased from the Oregon Department of Transportation south of the rail track for access, and a new bridge was designed and built with County funds. This bridge was completed in August 2006. It gave, for the first time, safe access to the Port's Willow Creek site.

The analysis and review of the four above-mentioned sites resulted in the selection of the Willow Creek site. It is my determination that this alternative resulted in the least environmentally damaging alternative, was feasible based on logistics and technology and cost, and met the project purpose.

5.4. Other Sites Not Available to the Applicant. The above-mentioned sites were the only locations within a reasonable distance to the landfill that the Port would have access to, or the ability to purchase. For this reason, additional sites not investigated.

6. Environmental Impact Assessment. [33 CFR Part 320.3 and 320.4]. The following paragraphs describe the potential beneficial and detrimental direct impacts of the activity on various public interest factors considering the parameters that are necessary to ensure minimal

adverse effects. Direct impacts are the potential short and long team effects of discharges on the chemical, physical, and biological components of the aquatic environment. Direct impacts are caused by the action and occur at the same time and place. The extent to which each factor is discussed is based on the value of the resource, the controversy surrounding it, the level of concern expressed by the commenting public, and the potential impact to the factor. Indirect and cumulative impacts of the proposed work are discussed at the end of this section.

6.1. Substrate. The installation of piling and the addition of fill will alter the substrate in the project area. However, it is anticipated that the piles will have a minimal impact as their footprint is limited **in size, and the fill** in considered to be a small quantity (650 cy). To off set impacts to the substrate and shoreline from the fill, the applicant has proposed shoreline re-vegetation and mitigation west of the project site.

6.2. Currents, circulation or drainage patterns. The barge dock would impact flow in the project area. However this impact is expected to be extremely limited in nature as the installation of the piles are sufficiently far enough apart to allow unimpeded water flow and access.

6.3. **Suspended Particulates and Turbidity.** Turbidity will increase as **a** result of this project. However, the impacts are expected to be limited in duration and size. Pile driving will be done with a vibratory hammer and proper erosion and sediment controls will be employed during fill portions of the project. The turbidity is expected to be limited to a short timeframe during construction and **there** will be no long-term impacts on turbidity resulting from the project.

6.4. Water Quality (temperature, salinity patterns). The barge dock shall be constructed at sufficient height that it will not affect the temperature of the River either at the project site, or as a whole. Any additional water quality concerns are addressed in Section 6.3 above.

The offloading of garbage at the site would not impact water quality. Garbage shipments would be in containerized forms and would not be at risk of spilling or dumping into the river.

6.5. Flood Control, Storm, Wave and Erosion Buffers. No impacts expected. The new structure is not expected to have any impacts on the above-mentioned factors. The dock would not impede any flowage restrictions that may apply for the area, nor would it impact any buffers. The project was designed so that it would have the minimal amount of impact **on** the River and shoreline.

6.6. Erosion and accretion patterns. Construction of the barge dock is not expected to have any impact on the above-mentioned factors. If constructed, the dock would not appreciably alter normal flowage patterns in the area.

6.7. Aquifer recharge. Not applicable.

6.8. Baseflow. Not applicable.

6.9. Mixing Zone (for projects that involve the discharge of dredged material) (consider the depth of water at the disposal site, current velocity, direction and variability of the disposal site, degree of turbulence, water column stratification, discharge vessel speed and direction, rate of discharge, dredged material characteristics, and number of discharges per unit of time). The project would require the discharge of 650 cubic yards of rock fill to support the access ramp. The fill is not expected to create a significant amount of turbidity, nor is it expected to result in any long-term impacts.

6.10. Special Aquatic Sites. There are no special aquatic sites that would be impacted by the proposed project.

6.11. Habitat for Fish and Other Aquatic Organisms. As stated in the Biological Assessment, riparian vegetation is sparse to non-existent and the shoreline is rip-rapped and hardened by native basalt from the Willow Creek Quarry site. Water temperatures in the action area during the summer and early fall are higher than those of properly functioning conditions for the listed salmonids that are likely to occur in the area. There are areas of steep bluffs outside of the proposed project site and two small crescent shaped beach areas to either side of the promontory where the new access ramp to the dock would be constructed.

Habitat elements conducive to juvenile rearing, such as large woody debris, shallow water habitat, and riparian vegetation are rare or absent. In general, there is no suitable spawning habitat in the project area along the Columbia River at the project site due to the sandy substrates or larger angular quarried substrates from the former quarry and submerged rail bed.

Constructing the proposed project will have a permanent impact of creating approximately 5,450 square feet of overwater structure in the John Day pool of the middle Columbia River. Benthic habitat is likely to be affected for a portion underneath the structure, though the height of the structure above the average water elevation will allow light to penetrate under most of the structure at some time throughout the day. As aquatic invertebrates are an important source of prey for salmonids, the loss of their habitat through burial or displacement may temporarily reduce foraging opportunities for listed juvenile salmonids. However, aquatic invertebrates can re-colonize disturbed locations quickly and adapt to new features in their environment. Additionally, the proposed project will add vertical attachment points that may

enhance some communities of invertebrates. Shading in the John Day pool is nearly absent and the structure itself is likely to provide some minimal benefit in the form of increased shading. In fact, shading may create areas for predatory fish to gather, potentially impacting listed salmonids.

6.12. Wildlife habitat. The upland portion of the project site is very sparsely vegetated and does not support any major populations of wildlife. There appears to be no documented wildlife use in the area, and therefore the project is not expected to have any impact on wildlife species.

6.13 Threatened and Endangered Species. See Section 4.3 above.

6.14. Biological availability of possible contaminants in dredged or fill material, considering hydrography in relation to known or anticipated sources of contaminants; results of previous testing of material from the vicinity of the project; known significant sources of persistent pesticides form land run-off or percolation; spill records for petroleum products or designated (Section 311 of the CWA) hazardous substances; other public records of significant introduction of contaminants from industries, municipalities or other sources. The project does not involve any dredging or alteration of the substrate. While the project will result in minor impacts during pile driving activities, the discharge from displacement during that activity is considered to be minimal. The fill is not known to be a carrier of contaminants and sediment testing is not required.

6.15. Existing and Potential Water Supplies. The project site does not support water supplies of any kind. No impact.

6.16. Recreational and Commercial Fisheries. The project site is not known to support any type of commercial or recreational fishery.

For information on treaty-reserved usual and accustomed fishing sites, please see Section 6.33.1 below.

6.17. Other Water Related Recreation. No other water recreation is known to take place in this location.

6.18. Aesthetics of Aquatic Ecosystem. The project site is located in a relatively undeveloped, semi-natural area. The addition of a man-made structure would detract from the natural viewscape of the area. There are no residences in the vicinity, but the area is visible to passing motorists using Interstate 84 along the south shore of the river and State Highway 14 along the north shore.

For information on historic properties, please see Section 6.26 below.

6.19. Parks, National Seashores, Wild and Scenic Rivers, Wilderness Areas, Research Sites, etc. Not applicable.

6.20. Traffic/Transportation Patterns. In 2006 the Port constructed an on and off-ramp from 1-84 for the quarry site. The purpose of this construction was to allow access to the quarry site as well as to facilitate barge dock construction upon deciding on this site (see Section 5 above). Truck traffic would increase on Interstate 84, however as this highway is currently used for this type of commercial transport, this effect is expected to be minimal.

6.21. Energy Consumption or Generation. The proposed project will not have any impact on energy consumption. While power may be needed to operate the dock and attendant features, this impact is expected to be minimal.

6.22. Navigation. The Columbia River currently supports navigation and heavy barge traffic along this segment. The project will be constructed in such as manner as to not impact shipping or navigation on the main-stem Columbia.
According to the applicant 1-5 barges are expected to visit the site per week, over the 49 week operation timeframe for the year. There are two weeks out of the year that the locks are closed during the month of March for inspection and maintenance. This number equates to a minimum of 49 barge deliveries to a maximum of 245 barges per year. The River currently supports barge traffic that supplies grain and other commodities to points well east of the project site (Boardman, etc.) and the addition of a maximum of 245 barges per year is not expected to significantly impact traffic along the Columbia River.

6.23. **Safety.** The Columbia River currently supports navigation and heavy barge traffic along this segment and the amount of barge traffic expected will not impact safety of the river. The new off ramp will allow vehicular traffic within the proximity of the project site, however, this traffic is expected to be directly related with barge dock operation, and will not impact the general public.

6.24. Air Quality. There are no adverse impacts expected to result from this project. While barge traffic will occur in an area where none previously existed, use of this site is not anticipated to be heavy enough to result in impacts to air quality.

6.25. Noise. There will be an increase in noise at the site. Currently, the site is an abandoned rock quarry. For this reason there is no known on-going operation or pedestrian use at the site. Construction of the barge dock would bring vehicular traffic (trucks, passenger vehicles for workers, back hoes and other off-loading machinery), and barge traffic. The noise level of the operation of this site is anticipated to be commensurate with operations at any other off-loading facility. While noise levels will change, it is not anticipated that operations will adversely the ambient noise levels. Additionally, there are no residences in the project vicinity, and therefore, the project will not result in increased noise impacts to people.

6.26. Historic Properties (National Historic Preservation Act). The area was surveyed and reviewed for the presence of historic properties eligible for inclusion on the National Register as well as the possible effects to those properties. Two survey were undertaken. The first survey focused on archaeological resources. The report, dated January 8, 2008, was conducted by Willamette Cultural Resource Associates (Willamette CRA), and is known as Willamette CRA Report 07-02. According to the report, there are no historic properties located within the project area of potential effect, nor are there any archeological sites eligible for listing on the National Register of Historic Places. The second survey focused on traditional cultural properties. This survey was done by CTUIR. The Corps believes the results of the survey demonstrates that there is a traditional cultural property which is eligible for inclusion in the National Register under criterion A because of its association with events that have made a significant contribution to the broad patterns of our history. However, the Corps has not yet received the Oregon SHPO's concurrence.

6.27. **Land Use Classification. The** project location was previously zoned properly to allow completion of the project without zoning changes. There will no change to land-use classifications.

6.28. **Economics.** The Port won a 1.9 million dollar Connect Oregon Grant (Grant) to build the in-water portion of the dock (fill, ramp, dock, and dolphins). The Grant is based on a local investment of 1.5 million dollars. Investments have included a new site access bridge, roadwork, utilities and dock engineering. The Port goes on to state: "The $1.9 million Grant is the largest received in Gilliam County, and tremendously important for economic vitality."

6.29. Prime and Unique Farmland (7 CFR Part 658). The project site is not used as farmland.

6.30. Food and Fiber Production. The project site does not support food and fiber production.

6.31. Mineral Needs. The project site previously consisted of a rock quarry. However, the site was used to extract basalt, not minerals. There are no mineral mining operations associated with the project site.

6.32. Consideration of private property. The Port owns the project site and holds a right-of-way lease for the overpass portion of the road at the interchange with I-84. The project will not impact any adjacent private property.

6.33. Tribal and Cultural Resources. Evidence presented by the Tribe supports a finding that there is a treaty fishing site at the project location and that the project would have more than a *de minimis* impact on their right of access to their treaty fishing site. Further, as noted in 6.26 above, the location falls within an area the Corps believes contains eligible historic properties which may be adversely affected by the project.

6.33.1 Treaty Fishing Sites. The CTUIR is a signatory to the Treaty with the Walla Walla Cayuses, and Umatilla Tribes and Bands of Indians, June 9, 1855, 12 Stat 945. Article I of this treaty provides in pertinent part:

> Provided, also, That the exclusive right of taking fish in the streams running through and bordering said reservation is hereby secured to said Indians, and at all other usual and accustomed stations in common with citizens of the United States, and of erecting suitable buildings for curing the same .. .

"Usual and accustomed" fishing places have been defined as all sites where tribal members customarily fished at or before the time the treaty was signed regardless of the distance from the Tribe's usual home or whether other Tribes also fished in the same waters. *E.g., United States v. Washington,* 520 F.2d 676, 689 (9th Cir. 1975); *United States v. Washington,* 730 F.2d 1314, 1318 (9th Cir. 1984). The words "usual and accustomed," as contemplated by the treaty, have been defined as "closely synonymous words" which "indicate the exclusion of unfamiliar locations and those used infrequently or at long intervals and extraordinary occasions." *Northwest Sea Farms, Inc. v. US. Army Corps of Engineers,* 931 F. Supp. 1515, 1521 (W.D. Wash. 1996) (citing *U.S. v. Washington,* 384 F. Supp. 312, 332 (W.D. Wash. 1974); *see also U.S. v. McGowan,* 62 F.2d 955 (9th Cir. 1933).

Due to the scarce documentation of Indian fishing locations in and around 1855, federal courts do not follow stringent proof standards because to do so would likely preclude a finding of a usual and accustomed fishing station; therefore, there is a lower evidentiary standard of proof to support a finding of a usual and accustomed fishing station. *See U.S. v. Washington,* 730 F.2d at 1316-1317; *U.S. v. Lumm Indian Tribe,* 841 F.2d 317, 318 (9th Cir. 1988). In finding that a particular site is a "usual and accustomed" fishing site, federal

courts have relied on anthropological reports, testimony of tribal elders, and current fishing use of the site. *See U.S. v. Washington,* 384 F. Supp. at 350; *See U.S. v. Washington,* 459 F. Supp. 1020, 1059 (W.D. Wash. 1978). More specifically, the Oregon federal district court has relied on the manner of fishing used by the Indians at the time of the treaty. *Confederated Tribes of the Umatilla Indian Reservation v. Alexander,* 440 F. Supp. 553, 554 (D. Or. 1977).

The CTUIR provided the Corps an anthropological report by Robert B. Lane and Barbara Lane [1] dated April 1979 which documents the traditional fisheries of the Walla Walla, Cayuse and Umatilla. In the Lane and Lane report, two usual and accustomed places sites were identified of particular relevance to this project area. The first was identified as the location at the "Columbia River about mouth of Willow Creek[.]" Lane at 122. The second was identified as the location at the "Columbia River just downstream from Willow Creek." *Id.* According to Lane and Lane, both sites were mentioned by Lewis and Clark in their journals or noted by them on their sketch maps.

As the manner of fishing used by the Indians at the time of the treaty, Lane and Lane notes that traditionally, the most important fisheries to the Cayuse, Umatilla and Walla Walla were on the main stem rivers, Columbia and Snake, as well as the mouths of tributaries. Lane at 83. The project site's proximity on the Columbia and near the mouth of Willow Creek is consistent with manner of fishing by the Tribe at treaty times. Rapids and falls provided an obvious fishing place where dip nets, harpoons and spears were used. *Id.* In calmer stretches of water, nets were used. *Id.* at 84. Fishing could also take place from canoes with harpoons, seine nets, or dip nets. *Id.*

There was a mobile character to the manner of fishing by Indians at the time of the treaty. According to the findings of fact issued by the Indian Claims Commission in 1964:

> The Indians were familiar with the various places where the salmon could be found in greatest abundance probably beginning with the Columbia River as far down stream as The Dalles and Celilo Falls where their fishing began, and *as the fish moved up stream the Indians followed to the headwaters of the tributary streams,* principally the Walla Walla and Umatilla Rivers[.]
> Claims of villages out on headwaters of streams in the Blue Mountain and other areas where the summer groups went on their gathering, hunting, and fishing activities are not realistic. These areas were actually camping areas rather than villages…There is no evidence in the record that dwellings of any kind existed in any of these areas on

[1] Barbara Lane was the anthropologist expert witness relied on heavily by Judge Boldt in the early *U.S. v. Washington* line of cases. See *U.S. v. Washington,* 384 F. Supp. at 350 and *U.S. v. Washington* 459 F. Supp. at 1059.

> anything resembling a permanent basis; in fact no dwellings even in the Indian version of a dwelling are mentioned in the evidence. The only places where lodges are described are in the areas where these Indians lived throughout the winter season in one sense were their permanent villages. *Their life during the summer season seemed to be one round of camp spots after another.*

Confederated Tribes of the Umatilla Indian Reservation v. U.S., 14 Ind. Cl. Comm. 14, 27-28 (1964) (emphasis added). According to testimony by Dr. Verne Ray, during the middle of the nineteenth century, the Umatilla occupied both banks of the Columbia River from the vicinity of Rock Creek, Washington (approximately river mile 229 on the Columbia or approximately 27 miles west of the project location) to a few miles below the mouth of the Walla Walla River. He noted that Umatilla families sometimes camped as far west as the John Day River (approximately river mile 217 or approximately 39 miles west of the project location). 14 Ind. Cl. Comm. at 40. The Indian Claims Commission delineated the western boundary of the lands the CTUIR ceded to the United States as Willow Creek, from its headwaters down to the Columbia River. 14 Ind. Cl. Comm. at 132.

In an affidavit, CTUIR tribal member Robert Brigham states that he earns his living fishing on the Columbia River, including sites downstream from the mouth of Willow Creek. Brigham Affidavit (August 29, 2007) at ¶ 1. His knowledge of the fishing sites near Willow Creek goes back 40 years. *Id.* at ¶ 2. His father began fishing these sites in the mid-1960s prior to the construction and inundation by the John Day Dam. *Id.* at ¶3. His father would tie off at the bluff before the area was flooded and fished with various other tribal members. *Id.* He asserts that since 1980 he has been the primary fisherman on the site and that the site is registered to him by the Umatilla Tribes. *Id.* at ¶4 . He no longer ties his nets "off to the shore" but rather, weighs them down and the net locations are in the same general area each season. *Id.* at ¶ 7.

Leo Stewart, an enrolled member of the CTUIR, submitted an affidavit asserting his fishing use of the area downstream from the mouth of Willow Creek, which includes the location of the Port of Arlington barge dock construction. Stewart Affidavit at ¶ 2. From 1985 to 1997, he and his brother-in-law, Robert Brigham, would set their nets off the bluff because it was "very deep and [they] could tie off on the shore." *Id.* at ¶ 4. Prior to that time, he also fished the sites downstream from the mouth of Willow Creek when tribal members Walt Farrow and Marvin Reed fished on the site immediately below the bluff *Id* at ¶ 5. He states that the area downstream from the mouth of Willow Creek "is recognized by tribal fishermen as an historic tribal fishing site" and "was and is fished every year by tribal fishermen, many of whom I talk to." *Id.* at ¶ 8.

Donald Sampson, enrolled member and Executive Director of the CTUIR, also submitted an affidavit attesting to his fishing history at sites around the mouth of Willow Creek, including the location of the barge dock. Sampson Affidavit at 2. He fished around the mouth of Willow Creek in 1979 and 1980. *Id.* at ¶3 . He recalls that while fishing, fishermen would "pass[] down the knowledge of our ancestors about how to fish these sites on the Columbia River, including Willow Creek[.]" *Id.* at ¶ 6. His brother continued to fish the site with Percy Brigham from 1980 to 1982. *Id.* at ¶ 8.

Given the lower standard of evidentiary proof for usual and accustomed fishing sites, it is my conclusion that the following evidence supports a finding that the site is a usual and accustomed station[s] of the CTUIR:

- the anthropological report that identifies usual and accustomed fishing sites at the mouth of Willow Creek and just downstream of Willow Creek;
- the mobile character and manner of traditional Indian fishing on the Columbia River;
- the fact that Willow Creek was delineated as the western boundary of the Tribe's ceded territory;
- the recent history of fishing in the area as attested to by tribal members.

Whether a site is a considered a usual and accustomed fishing station is not whether the interference by a proposed project is substantial. The standard for interference is a determination that an action *will have an effect* on the treaty fishing right. That standard has been met even if the site is not the most productive fishing areas or primary fishing site used by the Tribe. *See Northwest Sea Farms v. United States,* 931 F. Supp. 1515 (W.D. Wash. 1996). The standard has also been met even if the project would only eliminate a portion of the usual and accustomed fishing site. *See Muckleshoot Indian Tribe v. Hall,* 698 F. Supp. 1504 (W.D. Wash. 1988). The following two federal cases in the northwest involving the Corps permit regulatory program are noteworthy:

- In *Northwest Sea Farms v. United States,* the Corps denied the plaintiff a Section 10 permit under the Rivers and Harbors Act because it would conflict with the Lummi Nation's fishing rights at one of its usual and accustomed fishing places. 931 F. Supp. 1515 (W.D. Wash. 1996). The applicant argued that its project would not affect or would have only a *de minimis* effect upon Lummi Nation fishing and further argued that the area was not a productive fishing area and also not a fishing site used by the Lummi Nation primarily. The court disagreed and found that the record for the denial of the permit supported the Corps' conclusion that the Tribe's right to access would be affected by the project and therefore, the project would interfere with treaty fishing rights. The court upheld the Corps' decision.

- In *Muckleshoot Indian Tribe v. Hall,* the Corps issued a permit for construction of a 1200 slip marina. The Tribe sought an injunction to enjoin the construction because it would eliminate a portion of one of the usual and accustomed fishing areas in Elliot Bay and thus interfere with their treaty right to fish at the marina site. The defendants argued that the marina would not preclude "meaningful use" of the fishing area because the project would only occupy a "fraction of one percent of the Tribes' usual and accustomed Puget Sound fishing areas." 698 F. Supp. at 1515. The court found that the construction would eliminate a portion of the usual and accustomed fishing ground and deny the Tribes' access. "No case has been presented to this Court holding that it is permissible to take a small portion of a tribal usual and accustomed fishing ground, as opposed to a large portion, without an act of Congress or to permit limitation of access of a tribal fishing place for a purpose other than conservation." *Id.* The court granted the motion for preliminary injunction and enjoined the Corps from taking any action to permit or allow any activities relating to construction of the marina.

In several letters from the CTUIR and in affidavits of those tribal members who have on prior occasions or currently fish the site, the Tribe asserts that the installed pilings have already had an effect on their ability to fish at the site. One tribal member asserts that his nets were damaged when he tried to fish in the vicinity of the pilings and that the pilings are located on the exact location that he normally fishes. *See* Brigham Affidavit (December 6, 2007).

Federal courts have consistently found that taking of access or taking of fishing grounds or stations must be specifically authorized by Congress. *E.g., Umatilla,* 440 F. Supp at 556; *Muckleshoot,* 698 F. Supp at 1512; *Northwest Sea Farms,* 931 F. Supp. at 1520. More specifically, it has been held that the "treaty right is a *property right* which may not be abrogated without specific and express Congressional authority." *Muckleshoot,* 698 F. Supp. at 1512 (citing *Menominee Tribe,* 391 U.S. 404, 411 n. 12 (1968)) (emphasis added). No court has permitted the taking of treaty fishing grounds without an act of Congress, other than allowing some fishing limitation by States for purposes of conservation. See *Muckleshoot,* 698 F. Supp. at 1512 (summarizing cases). In *Muckleshoot,* the court found that the Corps did not have the ability "to qualify or limit the Tribes' geographical treaty fishing right (or to allow this to occur through permits) by eliminating a portion of an Indian fishing ground for a purpose other than conservation." 698 F. Supp. at 1514. In *_Northwest Sea Farms,* the court held that "[i]n carrying out its fiduciary duty, it is the government's, and subsequently the Corps', responsibility to ensure that Indian treaty rights are given full effect." 931 F. Supp. at 1520. Further, the court found that "[i]t is this fiduciary duty, rather than any express regulatory provision, which mandates that the Corps take treaty rights into consideration." *Id.*

I conclude that the evidence presented by the CTUIR supports a finding that the project currently would have more than a *de minimis* impact on their right of access to their usual and accustomed fishing site and if fully constructed, will continue to have an impact on its treaty fishing right in this location.

6.33.2 Traditional Cultural Properties. As noted in 6.26 and 6.33 above, the additional cultural resource surveys done also indicate that there may be effects to National Register eligible historic properties.

6.34. Secondary and Cumulative Impacts.

6.34.1. Secondary Impacts. Secondary impacts are the effects on an aquatic ecosystem that are associated with a discharge of dredged or fill material, but do not result from the actual placement of the dredged or fill material. Secondary effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable.

The project would result in a secondary impact by increasing barge transport to the project site as well as traffic in the project area as well as the area that intersects with 1-84. Currently ships do not visit this area and the project would allow for docking and off-loading at the site. Additionally, the project site does not currently experience the volume of traffic that is expected to result from construction and operation of the facility. These impacts are not expected to be negative.

The project will also result in a secondary impact, by affecting a usual and accustomed treaty fishing site of the CTUIR. See Section 6.33.1 above for more information. It is expected that the project would result in adverse impacts to the treaty fishing site. The significance of the effect of the project on these Trust resources and the Corps' fiduciary duty to the tribes to ensure that their treaty rights are given full effect absent an express abrogation from Congress dictates that the Corps cannot issue a permit.

6.34.2. Cumulative Impacts. Cumulative impacts are the changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the impact of a particular discharge may constitute a minor change by itself, the cumulative effect of numerous separate actions can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems. Cumulative effects attributable to the discharge of dredged or fill material in waters of the United States should be predicted to the extent reasonable and practicable.

This project is not expected to have any cumulative impacts. The project site has over time been subject to several different uses, all commercial or industrial in nature. The installation of the dock and use of the site will not result in any cumulative impacts.

7. Compliance with 404 (b)(1) Guidelines of the Clean Water Act [40 CFR 230.11. The following evaluates how the project complies with these guidelines. A check in a block denoted by an asterisk indicates that the project does not comply with the guidelines.

7.1. Alternatives Test.

- Are there practicable alternatives available which do not involve a discharge of dredged **or** fill material into waters of the United States or that would involve discharges at other locations within these waters?
  Yes* No X

- For proposed discharges into special aquatic sites, has the applicant clearly demonstrated that there are no practicable alternative sites available?
  Yes X No* N/A X

7.2. Special Restrictions.

- Will this discharge violate state water quality standards?
  Yes* No X

- Will this discharge violate toxic effluent standards (under Section 307 of the Act)?
  Yes* No X

- Will this discharge jeopardize endangered or threatened species or their critical habitat?
  Yes* No X

- Will this discharge violate requirements imposed by the Department of Commerce to protect marine sanctuaries?
  Yes* No N/A X

7.3. Significant Degradation. Would this discharge contribute to significant degradation of waters of the United States through adverse impacts to:

- Human health or welfare, through pollution **of** municipal **water** supplies, fish , shellfish, wildlife and special aquatic sites?
  Yes* No X

- Life stages of aquatic life and other wildlife?
  Yes* No X

- Diversity, productivity and stability of the aquatic ecosystem, such as loss of fish or wildlife habitat or loss of the capacity of wetlands to assimilate nutrients, purify water or reduce wave energy?
  Yes* No X

- Recreational, aesthetic, and economic values:
  Yes* No X

7.4. Evaluation of the information in Section 6 above indicates that the proposed discharge material meets testing exclusion criteria for the following reasons:

(X) Based on the above information, the material is not a carrier of contaminants.

( ) The levels of contaminants are substantially similar at the extraction and disposal sites and the discharge is not likely to result in degradation of the disposal site and pollutants will not be transported to less contaminated areas.

( ) Acceptable constraints are available and will be implemented to reduce contamination to acceptable levels within the disposal site and prevent contaminants from being transported beyond the boundaries of the disposal site.

7.5. Minimization of Impacts. Will the applicant take all appropriate and practicable steps to minimize potential adverse impacts of the discharge on the aquatic ecosystem?
Yes X No* ___

8. Mitigation. To compensate for the impacts of construction to waters of the United States, the permit, if issued, would require enhancement of approximately 3,500 square feet of degraded shoreline immediately adjacent to the project site. It is my opinion the mitigation proposed would adequately offset the impacts of the proposed project.

9. Special Conditions. Special conditions were not developed because the project would interfere with treaty fishing rights; therefore, the project would have an adverse impact on the public interest.

10. Determinations.

10.1. Finding of No Significant Impact (FONSI) (33 CFR Part 325). Having reviewed the information provided by the applicant, all interested parties and the assessment of environmental impacts contained in Section 6 of this document, I find that the denial of this permit will not have a significant impact on the quality of the human environment. Therefore, an Environmental Impact Statement is not required.

10.2. 404(b)(1) Guidelines (40 CFR 230.12) Determination.

(X) The discharge complies with the guidelines.

( ) The discharge complies with the guidelines, with the inclusion of the appropriate and practicable conditions listed above (in Section 9) to minimize pollution or adverse effects to the affected ecosystem.

( ) The discharge fails to comply with the requirements of these guidelines because:

There is a practicable alternative to the proposed discharge that would have less adverse effect on the aquatic ecosystem and that alternative does not have other significant adverse environmental consequences.

The proposed discharge will result in significant degradation of the aquatic ecosystem under 40 CFR 230.10(b) or (c).

The discharge does not include all appropriate and practicable measures to minimize potential harm to the aquatic ecosystem, namely...

There is not sufficient information to make a reasonable judgment as to whether the proposed discharge will comply with the guidelines.

10.3. Public Hearing Determination. No public hearing was requested or held for this project.

10.4. Clean Air Act Determination. The proposed project has been analyzed for conformity applicability pursuant to regulations implementing Section 176(c) of the Clean Air Act. I have determined that the activities proposed under this permit will not exceed de minimis levels of direct emissions of a criteria pollutant or its precursors and are exempt by 40 CFR Part 93.153. Any later indirect emissions are generally not within the Corps' continuing program responsibility and generally cannot be practicably controlled by the Corps. For these reasons a conformity determination is not required for this project.

10.5. Public Interest Determination. I find that issuance of a Department of the Army permit as prescribed by regulations published in 33 CFR Parts 320 to 330, and 40 CFR Part 230 is contrary to the public interest because issuance would interfere with CTUIR' s treaty fishing right of access at their usual and accustomed fishing place.

11. Findings. It is my decision to deny this permit application with prejudice because of unresolved impacts to treaty fishing rights. The Corps has a fiduciary responsibility to the tribes to ensure that their treaty rights are given full effect absent an express abrogation from Congress. Should these issues be resolved at any time in the future, the applicant could submit another application for another department of the Army permit. However, I also remain concerned regarding possible impacts to potentially eligible historic properties as defined by the National Historic Preservation Act. This issue must also be resolved during any future consideration of work at this site.

In compliance with the requirements of Executive Order 12630 and the Attorney General's Guidelines for the Evaluation of Risk and Avoidance of Unanticipated Takings, I have reviewed and considered the Takings Implication Assessment (TIA) prepared for this permit application and have concluded that the denial of this permit does not indicate a takings implication.

PREPARED BY:

Ms. Karla G. Ellis
Project Manager, Team Leader

REVIEWED BY:

awrence C. Evans
Chi Regulatory Branch

APPROVED BY:

Thomas E. O Donovan
Colonel, Corps of Engineers
District Commander

NOTIFICATION OF ADMINISTRATIVE APPEAL OPTIONS AND PROCESS AND REQUEST FOR APPEAL

Applicant: Port of Arlington c/o Timothy Wetherall , File Number: 200600160		Date: 4/4/08
Attached is:		See Section below
	INITIAL PROFFERED PERMIT (Standard Permit or Letter of permission)	A
	PROFFERED PERMIT (Standard Permit or Letter of permission)	B
X	PERMIT DENIAL	C
	APPROVED JURISDICTIONAL DETERMINATION	D
	PRELIMINARY JURISDICTIONAL DETERMINATION	E

SECTION I - The following identifies your rights and options regarding an administrative appeal of the above decision. Additional information may be found at http://usace.army.mil/inet/functions/cw/cecwo/reg or Corps regulations at 33 CFR Part 331.

A: INITIAL PROFFERED PERMIT: You may accept or object to the permit.

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Permit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.

- OBJECT: If you object to the permit (Standard or LOP) because of certain terms and conditions therein, you may request that the permit be modified accordingly. You must complete Section II of this form and return the form to the district engineer. Your objections must be received by the district engineer within 60 days of the date of this notice, or you will forfeit your right to appeal the permit in the future. Upon receipt of your letter, the district engineer will evaluate your objections and may: (a) modify the permit to address all of your concerns, (b) modify the permit to address some of your objections, or (c) not modify the permit having determined that the permit should be issued as previously written. After evaluating your objections, the district engineer will send you a proffered permit for your reconsideration, as indicated in Section B below.

B: PROFFERED PERMIT: You may accept or appeal the permit

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Pennit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.

- APPEAL: If you choose to decline the proffered permit (Standard or LOP) because of certain terms and conditions therein, you may appeal the declined permit under the Corps of Engineers Administrative Appeal Process by completing Section 11 of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

C: PERMIT DENIAL: You may appeal the denial of a permit under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

D: APPROVED JURISDICTIONAL DETERMINATION: You may accept or appeal the approved JD or provide new information.

- ACCEPT: You do not need to notify the Corps to accept an approved JD. Failure to notify the Corps within 60 days of the date of this notice, means that you accept the approved JD in its entirety, and waive all rights to appeal the approved JD,

- APPEAL: If you disagree with the approved JD, you may appeal the approved JD under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice, Also, see Section II.

E: PRELIMINARY JURISDICTIONAL DETERMINATION: You do not need to respond to the Corps regarding the preliminary JD. The Preliminary JD is not appealable. If you wish, you may request an approved JD (which may be appealed), by contacting the Corps district for further instruction. Also you may provide new information for further consideration by the Corps to reevaluate the JD.

SECTION II - REQUEST FOR APPEAL or OBJECTIONS TO AN INITIAL PROFFERED PERMIT

REASONS FOR APPEAL OR OBJECTIONS: (Describe your reasons for appealing the decision or your objections to an initial proffered permit in clear concise statements. You may attach additional information to this form to clarify where your reasons or objections are addressed in the administrative record. If you believe you have additional information pertinent to an approved jurisdictional determination {see Part D} with which you disagree, that new information should first be sent to the Portland District for reconsideration. Following the District's reconsideration, the approved jurisdictional determination can still be appealed as noted in Part D)

ADDITIONAL INFORMATION: The appeal is limited to a review of the administrative record, the Corps memorandum for the record of the appeal conference or meeting, and any supplemental information that the review officer has determined is needed to clarify the administrative record. Neither the appellant nor the Corps may add new information or analyses to the record. However, you may provide additional information to clarify the location of information that is already in the administrative record.

POINT OF CONTACT FOR QUESTIONS OR INFORMATION:

if you have questions regarding this decision and/or the appeal process you may contact: U.S. Army Corps of Engineers Portland District Office CENWP-OP-GP (ATTN: Michael Turaski) Post Office Box 2946 Portland, Oregon 97208-2946	If you decide to appeal an action under Parts B, C or D above, send a copy of each page to: Division Engineer Attention: Karen Kochenbach Regulatory Program Manager P.O. Box 2870 Portland, OR 97208-2870 Telephone: 503-808-3888

RIGHT OF ENTRY: Your signature below grants the right of entry to Corps of Engineers personnel, and any government consultants, to conduct investigations of the project site during the course of the appeal process. You will be provided a 15 day notice of any site investigation, and will have the opportunity to participate in all site investigations.

	Date:	Telephone number:
Signature of appellant or agent.		

the Morrow Pacific project

A pathway to jobs. An investment in rural counties.

August 5th, 2013

Charles P. Redon
Resource Coordinator, Wetlands and Waterways Conservation Division
Department of State Lands, Oregon
775 Summer St NE
Salem, OR 97301-1279

Re: *Coyote Island Terminal permit application No. 49123-RF*

Dear Mr. Redon:

We mutually agreed to extend the decision making timeline for the Coyote Island Terminal (CIT) permit to September 1st, 2013. The extension was based on the information request in your April 11, 2013 letter. In the letter, you request a number of items. We have provided additional information on a number of points including alternatives analysis and mitigation as well as a timeline for forthcoming documentation. Some of the requested items are primarily within the jurisdiction of the federal government permitting process. Nevertheless, this letter provides responses to the Department of State Lands' (DSL) questions based on the best available information.

1. **Cultural Resources: We understand that Section 106 consultation is required through the Corps permit process. The Department requests information related to the outcome of that consultation to ensure and changes to the project are addressed in our permit decision.**

   Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires Federal agencies to take into account the effects of their undertakings on historic properties. With the input of the State Historic Preservation Office (SHPO), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and US Army Corps of Engineers (USACE), we prepared an in-depth cultural resource survey plan for the entire CIT lease hold, including the underwater portion. This plan was implemented from the fall of 2012 through the spring of 2013. The findings and recommendations of these surveys are documented in two reports which can be made available to DSL upon request. The reports **do not** suggest a modification of the site design presented to DSL in the original permit, biological assessment, or environmental review. USACE initiated the section 106 process with tribes and other interested parties in early July. We anticipate completion of this process in the fall of 2013.

2. **Tribal Fishing Treaty Rights related to the construction of the dock at the Port of Morrow: We understand that the Corps will be working with you and the Tribes to resolve the treaty related concerns. While we understand we do not have the trust responsibility assigned to the Federal Government, it is an important fisheries issue that another government entity has raised.**

Protection of Treaty Fishing Rights falls within the USACE Tribal Trust Responsibility. USACE requested affidavits of fishing rights from the four treaty tribes. Only one of the tribes responded. We are actively engaged in conversations with this tribe and are working to provide appropriate mitigation. We do not anticipate modifications to the dock design as submitted to DSL.

3. **Adverse effects to water resources: There were many comments related to adverse effects to water resources, with a focus on aquatic life and habitat, particularly fish. We understand that ESA consultation is required by the Corps. The Department requests all information related to the outcome of that consultation as it pertains to the construction of the dock at the Port of Morrow. This would include, but not be limited to, any Biological Opinion and any National Environmental Policy Act documents.**

As we stated in previous letters to DSL, this request is outside the normal operating parameters of DSL. We provided information to DSL in the Environmental Review and the Biological Assessment which provides detailed information to thoroughly evaluate the impacts of dock construction. Pages 3-187 through 3-197 of the Environmental Review document the water quality baseline and anticipated impacts from the construction and operation of the dock and associated infrastructure. This analysis in the Environmental Review document is based on NMFS guidance and generally accepted standards for conducting impacts analysis. The section concludes that "Implementation of the mitigation measures outlined above, along with mitigation measures inherent to project design, limit any potential adverse impacts that may result from project construction and operation." In addition, the Biological Assessment evaluates the impact of the dock construction and operation and concludes that the majority of impacts will be temporary and are greatly diminished by the inclusion of best management practices such as vibratory hammers and bubble curtains. Finally, the dock has been designed with elements to reduce impacts to shallow water habitat and predation. For example, the dock has been significantly elevated and designed with grated surfaces.

DSL has permitted numerous similar docks, such as the Tidewater ethanol dock, just upstream of the proposed dock location. ESA and water quality impacts of the proposed dock will be similar to this dock and others permitted on the Columbia River. If DSL finds that the detailed information

provided is inadequate, please provide examples of permits where this documentation has been required in the permitting decision so that we can model our responses on DSL's information needs.

4. **Work at Port Westward: We understand that an analysis is being conducted to determine what work needs to be done at Port Westward to accommodate a throughput of 8 million tons of coal per year. The Department requests a copy of that analysis to make a determination of whether there will be any removal of fill activities at that location and a determination of whether the project as proposed has independent utility.**

CIT has a lease option with the Port of St. Helens, which owns the Port Westward (PWW) dock. In addition to CIT, the Port has an existing user and prospective tenants at the dock. Due to lack of consistent maintenance, the existing PWW dock is missing items used in normal operating conditions. Such items include a bull rail and fendering system and is all above the water line. However, any dock maintenance and repair work needed for all users is the responsibility of the Port. Since the PWW dock is a multi-use facility with more than one existing or intended user, it is our understanding that the Port will be pursuing maintenance work to replace the missing items to return the dock to its prior condition.

Until the time the Port has completed this work, our engineering analysis shows that we can perform our transloading operations at the dock as-is utilizing operational parameters, including that a ship would not be able to dock during high winds.

Thus, we do not plan to perform maintenance or repair activities associated with the project and will operate despite the work being performed by the Port. Hence, no removal or fill at this location.

5. **Purpose and Need and Alternatives Analysis: In a letter dated April 11, 2012, we requested a broader alternatives analysis based on the purpose of "exporting Powder River basin coal to Asia". Please include the criteria upon which each alternative was evaluated.**

CIT evaluated six alternatives. Ultimately, only the preferred alternative met the evaluation criteria. The evaluation criteria used for the project are based on the Applicant's project purpose and need, environmental concerns associated with coal transport, and the social and economic implications of coal export facility development and operations, as described in more detail in the Environmental Review (ER).

In summary, the purpose of the proposed action is to construct a new, environmentally responsible and advanced barge loading dock at the Port of Morrow to serve as part of the Applicant's Port of Morrow coal receipt and barge loading facility. The Port of Morrow facility will become part of an environmentally responsible coal transportation project in the Pacific Northwest for the export of low-sulfur intermountain coal. The need for the project is based on an increasing global demand for a consistent, reliable supply of cleaner coal to meet growing energy needs. The alternative analysis is provided below.

		Alternative Evaluation Criteria				
		Ability to Minimize Train Traffic Through Urban Areas	**Ability to Reduce the Exposure of Coal to the Atmosphere**	**Ability to Utilize Existing Infrastructure**	**Ability to Operate in 2013/ 2014**	**Meets Purpose and Need**
Alternatives Evaluated	**Preferred Alternative:** Construct a New Loading Dock, Barge Transport to Port Westward	+	+	-	+	+
	No Action Alternative A: If a permit is not granted the Applicant may utilize existing CEMEX loader "as is," Barge Transport to Port Westward	+	-	+	+	-
	No Action Alternative B: No construction or operation associated with the MPP	+	+	-	-	-
Alternatives Considered but Rejected from Further Evaluation	Unit Train Coal Transport to Viable Port below Bonneville Dam	-	-	+	-	-
	Enclosed Barge Transport to Alternative Port below Bonneville Dam	+	+	-	-	+
	OGV to the Port of Morrow	+	+	-	-	-

Note: + : Meets criteria
- : Does not meet criteria

The table above illustrates the pathway for selecting the preferred alternative. A (+) indicates that the alternative, as described below, meets the Applicant's evaluation criteria while a (-) indicates that an alternative fails to meet the criteria. For example, the preferred alternative meets the criteria of *minimizing rail traffic through urban areas* because coal will be received at River Mile 271 and not transported by rail through the Columbia River Gorge National Scenic Area or Portland/Vancouver. However, the preferred alternative fails to meet the criteria *of utilizing existing infrastructure* since a new dock is proposed for construction. The preferred alternative meets four out of the five evaluation criteria. All other alternatives meet two or three out of five.

Alternative Development and Screening Process. Evaluation criteria were developed on the basis of environmental concerns associated with coal transport along with social and economic implications of coal export facility development and operations. The five criteria (see the table above) lead to the implementation of an environmentally responsible coal receiving and transfer facility on the West Coast of the U.S. that provides economic and social benefits.

Minimizing train traffic through urban areas mitigates unfavorable social impacts of rail and roadway congestion. Reduction of coal exposure to the atmosphere while in transit alleviates air quality and any potential coal dust impacts associated with coal transport. Utilization of existing infrastructure reduces overall environmental impacts and landscape change due to development and construction activities and helps achieve the operation timeline goals of the Applicant. Meeting the purpose and need of the project objectives is a critical component in screening appropriate alternatives.

6. **During the application review, the Department identified a non-wetland compensatory mitigation plan as a potential requirement for this project. It is our understanding that you plan to remove pilings for mitigation. Please provide a complete mitigation plan, including a functional assessment, according to OAR 141-085-0765.**

We are currently working with NMFS and USACE to identify mitigation that appropriately accounts for ESA impacts of dock construction. In addition we are working to ensure we meet the requirements of OAR 141-085-0765, to fulfill DSL's mitigation requirements. We have a signed letter with the Morrow County Soil and Water Conservation District (SWCD), agreeing to act as the mitigation project sponsor. As you can see from the functional assessment attached, the values lost from the dock are minimal. The dock is located in an area of poor quality habitat, with limited variations of life stages occurring in the

area. We anticipate mitigation to be compatible with such impacts as well as what has been required of similar docks. We will work with the SWCD and other stakeholders to identify mitigation that replaces the lost functions and values as required to meet DSL's requirements. The DSL mitigation plan will be forthcoming in early fall.

Along with the information provided above, Coyote Island Terminal has provided detailed information (including the Environmental Review and Biological Assessment) well beyond that which DSL has required of other applicants for a dock. We will provide you the mitigation plan in the next few months. In order to provide these documents for DSL's review, we confirm our mutual agreement with DSL to extend the decision deadline until November 1st , 2013. Together, this information satisfies the requirements of DSL. If this information is not adequate, we ask that you assist us by providing examples of other, recently permitted, docks where a greater level of information and detail was requested, provided and used in the decision making process. We again ask that you treat us consistently and fairly in determining that our application meets your regulations.

Please feel free to contact me if you have any questions about the information provided or if you wish to discuss this further.

Best Regard,

John Thomas

Enclosure: (1)

Cc: Lori Warner-Dickason

Mary Abrams

PUBLIC

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

BNSF RAILWAY COMPANY'S OPENING EVIDENCE AND ARGUMENT

Richard E. Weicher
Jill K. Mulligan
BNSF RAILWAY COMPANY
2500 Lou Menk Drive
Fort Worth, TX 76131
(817) 352-2353

Samuel M. Sipe, Jr.
Anthony J. LaRocca
Brooke L. Gaede
Kathryn J. Gainey
Roy E. Litland
STEPTOE & JOHNSON LLP
1330 Connecticut Avenue, N.W.
Washington, DC 20036
(202) 429-3000

ATTORNEYS FOR
BNSF RAILWAY COMPANY

March 16, 2010

TABLE OF CONTENTS

Counsel's Summary of Evidence and Legal Argument 1

Factual Background 9

Argument 16

I. The Board Should Declare that BNSF May Establish Rules Designed to Limit the Emission of Coal Dust from Coal Trains Operating Over its Lines. 16

II. BNSF's Coal Dust Emissions Standards Are Not Unreasonable. 20

A. The Reasonableness Inquiry 20

B. It Was Rational for BNSF to Conclude that Coal Dust Emissions Need to Be Curtailed Rather than Dealt with Exclusively through Maintenance. 21

C. BNSF Acted Rationally in Adopting a Performance Based-Emissions Standard. 22

D. BNSF's IDV.2 Standards Are Practical and Conservative. 24

III. BNSF's Position Regarding Compliance with its Coal Dust Emissions Standard 25

A. The Board's Review of Any Compliance Provisions that BNSF Might Adopt Would Be Limited to the Application of those Provisions to BNSF Common Carrier Shippers. 25

B. A Proposed Framework For Addressing Enforcement of the Challenged Rule 26

Verified Statement of Gregory C. Fox

Verified Statement of Stevan B. Bobb

Verified Statement of William VanHook

Verified Statement of Craig Sloggett

Verified Statement of Charles Sultana

Verified Statement of G. David Emmitt

Verified Statement of Erol Tutumluer

Confidential Exhibits, Volume I, filed under seal

Confidential Exhibits, Volume II, filed under seal

Highly Confidential Exhibits, filed under seal

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

BNSF RAILWAY COMPANY'S OPENING EVIDENCE AND ARGUMENT

In accordance with the Board's decision served on December 1, 2009, BNSF Railway Company submits its opening evidence and argument in this declaratory order proceeding. Petitioner Arkansas Electric Cooperative Corporation ("AECC") has asked the Board to declare BNSF's coal dust emissions standards set out in BNSF's Rules Publication 6041-B, Items 100 and 101, to be an unreasonable rule or practice and an unlawful refusal to provide service. For the reasons set out in detail below and in the attached Verified Statements, BNSF urges the Board to find that BNSF is entitled to establish operating rules that limit the amount of coal dust that can be emitted from loaded coal cars in transit over rail lines in the Powder River Basin ("PRB") and to find that the specific coal dust emissions standards set out in BNSF's Rules Publication 6041-B, Items 100 and 101 are not unreasonable.

COUNSEL'S SUMMARY OF EVIDENCE AND LEGAL ARGUMENT

Coal dust emitted from moving coal trains is pervasive along the rail lines in the PRB. Coal dust deposits are visible between the rails, between the sets of tracks, along bridge abutments and in creek beds.

New Track Construction – Fall 2006
M3 Mile Post 52 – Orin Subdivision
Photograph May 2007
5
2

ING NOSE
FROG

Additional photographs of coal dust deposits are included in Counsel's Exhibit 1. Even in areas that appear to be free of coal dust, coal accumulations are found just beneath the surface.

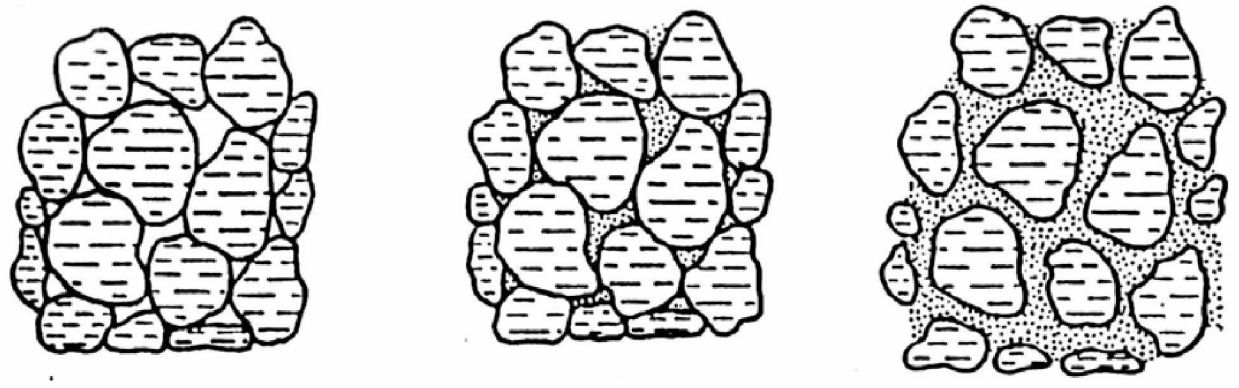
See additional photographs in Counsel's Exhibit 2. Maintenance work uncovers vast amounts of coal dust deep in the rail ballast under the track structure.

See additional photographs in Counsel's Exhibit 3. It is undeniable that coal dust is emitted in large quantities off of the top of loaded coal cars in transit along the PRB lines, and anyone who has spent time in the PRB is aware of the problem.

Short videos of coal dust episodes are contained on the CD at Counsel's Exhibit 4. When a coal train passes, it is usually necessary to avert your face or roll up your car window to avoid being pelted with coal dust flying off the coal cars. A parked car left near the rail lines will be covered with black coal dust by the end of the day.

Coal dust is a serious contaminant of rail ballast and therefore presents a serious problem for railroad operations, as rail ballast is critical to the integrity of a railroad's track structure. Ballast provides structural support for the heavy loads applied by trains moving over the tracks and provides for the drainage of water from under the tracks. When ballast becomes fouled, its

ability to support heavy loads is compromised, as illustrated in the following figure:



(a) Clean ballast (b) Partially fouled ballast (c) Heavily fouled ballast

See the attached Verified Statement of Professor Tutumluer. In 2005, two derailments occurred on the Joint Line, the rail line in the PRB owned jointly by BNSF and Union Pacific Railroad Company ("UP") that extends from Coal Creek Junction, WY in the North to Shawnee Junction, WY in the South. The presence of coal dust in the ballast was a contributing factor to the derailments. Since 2005, several studies have shown that the physical properties of coal dust make it one of the worst possible contaminants of ballast.

The coal dust falling onto the railroad right of way and fouling the railroad ballast belongs to the coal shippers who take ownership of their coal at PRB coal mines. The coal is the shippers' freight and therefore it is their responsibility to keep their coal in the loaded railcars. Unsurprisingly, BNSF does not allow the freight of any other shipper to escape from the railcars and damage the rail property. While BNSF has dramatically expanded its maintenance and inspection of the PRB rail lines to deal with the increasing problem of coal dust, BNSF should not be required to clean up after the shippers' freight has fallen out of the loaded cars. Moreover, expanded maintenance is not an acceptable solution to a problem that has the potential for disrupting the PRB coal supply chain. The risk of service interruptions from coal dust and the

impact of expanded maintenance on limited PRB rail capacity mean that the only responsible solution to this problem is to take measures to keep the coal in the loaded cars.

Since the 2005 derailments, BNSF has paid over $4 million to consultants to set up an extensive data gathering network and it has collected a considerable amount of data on the sources of coal dust and the alternatives for curtailing coal dust emissions. BNSF has measured the coal dust emissions from thousands of trains passing Milepost 90.7 on the Joint Line and Milepost 558 on BNSF's Black Hills Subdivisions. The data show that it is possible to identify specific trains that are emitting excessive levels of coal dust as they pass a particular location. Using the data, BNSF calculated limits on coal dust emissions at those two locations that would, if met by all passing trains, substantially eliminate coal dust. BNSF set these standards only after it concluded that it had done enough testing and data collection to support the standards. The standards, set out in the BNSF operating rules at issue in this proceeding, are conservative and achievable.

It is possible that other environmental scientists and statisticians would take different approaches to setting a limit on coal dust emissions than the approach that BNSF has taken. But the question here is not whether BNSF's standards are the only defensible standards. Rather, the question here is whether BNSF's standards are a reasonable response to a problem that could have a serious impact on the reliability of PRB coal transportation. New monitoring equipment might become available and new coal dust detection techniques might be developed in the future. But it has been almost five years since the 2005 derailments, and BNSF's studies and experience since then have confirmed the need to act now to curtail coal dust emissions. It would be highly imprudent to put off further action until the perfect solution—if it even exists—can be found.

BNSF has not dictated what measures PRB shippers and their mine agents must adopt to meet the coal dust emissions limits. Under BNSF's approach, individual shippers and their mine agents have the leeway to determine the most efficient and cost-effective method of coal dust suppression. BNSF has actively assisted shippers and mines in identifying effective dust suppression approaches. Through extensive laboratory and field testing, BNSF has shown that it is possible to substantially eliminate coal dust emissions and has collected data that will allow shippers and mines to choose optimal solutions. By leaving the solution to individual shippers and mines, BNSF believes that a market will emerge in which suppliers of coal dust suppression methods and products will have the incentive to innovate and develop the least costly and most effective dust suppression measures.

BNSF explains in this opening evidence and argument why the Board should reject the claim of petitioner Arkansas Electric Cooperative Corporation that the coal dust emissions standards in BNSF's Rules Publication 6041-B Items 100 and 101 are unreasonable. BNSF's submission in this opening evidence and argument has two components: (1) Counsel's Summary of Evidence and Legal Argument, and (2) Verified Statements of seven witnesses and accompanying exhibits.

The witnesses submitting Verified Statements on behalf of BNSF and the subject matter of their testimony are identified below.

Gregory C. Fox: Mr. Fox is BNSF's Vice President, Transportation. Mr. Fox led BNSF's efforts to restore operations on the Joint Line after the 2005 derailments and subsequently to rehabilitate the track structure. He initiated a proactive coal dust study to ensure that the service dislocations experienced in the aftermath of the 2005 derailments would not recur. Mr. Fox explains that the coal dust emissions standards that resulted from that coal dust study are necessary and appropriate operating rules that are intended to ensure safe, efficient and reliable PRB coal transportation service.

Stevan B. Bobb: Mr. Bobb is Group Vice President, Coal Marketing for BNSF. Since taking that position in 2006, Mr. Bobb has been extensively involved in outreach to PRB

coal shippers and mines to keep them informed about BNSF's ongoing study of coal dust and to help explore dust suppression alternatives. Mr. Bobb describes his efforts to promote a consensual solution to the problem of coal dust in which shippers will voluntarily accept responsibility for curtailing coal dust emissions.

William VanHook: Mr. VanHook is Assistant Vice-President and Chief Engineer-Systems Maintenance and Planning for BNSF. He is the BNSF employee who has had primary responsibility for investigating the causes and the scope of the coal dust problem that BNSF has encountered on its PRB coal lines and for overseeing the development of standards intended to limit the emissions of coal dust from loaded coal cars. Mr. VanHook provides an overview of the steps BNSF has taken to understand and address the coal dust problem.

Craig Sloggett: Mr. Sloggett is General Director Maintenance for BNSF with responsibility for maintenance and maintenance planning on BNSF's Powder River Division. Mr. Sloggett describes the unprecedented maintenance challenges presented by coal dust accumulations in the PRB and explains why expanded maintenance is not a responsible solution to the problem of coal dust in the PRB. He explains why coal dust emissions must be substantially curtailed to ensure reliable coal transportation service.

Charles Sultana: Mr. Sultana is a Six Sigma Specialist in BNSF's Mechanical Department. Mr. Sultana is responsible for bringing an advanced level of analytical and problem solving skills to bear on important problems identified by BNSF's management. Mr. Sultana was asked in 2006 to work with BNSF's coal dust study group to help understand and evaluate the extensive data being gathered on coal dust emissions and to develop a conservative and achievable limit on coal dust emissions based on the data. Mr. Sultana describes the process by which the standards at issue here were developed and explains the logic underlying the standards.

G. David Emmitt: Dr. Emmitt is the President and Senior Scientist of Simpson Weather Associates ("SWA"), a scientific research and development firm that BNSF hired in 2005 to assist in BNSF's coal dust study. Dr. Emmitt, who had worked with Norfolk Southern Railway Company in the 1980s to address coal dust issues, describes the extensive data gathering network that SWA helped BNSF set up. Dr. Emmitt also explains how SWA helped BNSF identify changes in the loading profile of coal cars to reduce coal dust emissions and how SWA has assisted BNSF and its shippers to evaluate coal dust suppression measures, particularly the application of surfactants.

Erol Tutumluer: Dr. Tutumluer is Professor of Civil and Environmental Engineering at University of Illinois at Urbana-Champaign. He has done extensive research on issues relating to railroad track structure and has studied in detail the impact of coal dust on rail ballast integrity. Dr. Tutumluer explains that based on the physical and mechanical properties of coal dust, it is one of the worst possible ballast fouling agents. When rail ballast is fouled by coal dust, the load bearing capacity of the track structure is significantly reduced, which can lead to unstable track conditions and, potentially, to derailments.

FACTUAL BACKGROUND

The facts relevant to the issues in this proceeding are discussed in detail in the Verified Statements of BNSF's witnesses. The most salient facts are summarized briefly below.

The PRB rail lines are among the highest volume rail lines in the world. Coal originated in the PRB moves primarily to electrical utilities located throughout the western United States and is interchanged with eastern railroads for delivery to utilities in the east as well. Two carrier operations over the Joint Line began in 1984, and in that year approximately 76 million tons of coal were originated by BNSF and UP predecessors on the Joint Line. By 1997, Joint Line originated tonnage had increased to 212 million tons, and by 2008, the Joint Line traffic had increased another 53 percent to 375 million tons of coal. Thousands of loaded coal cars move each day out of the PRB on the Joint Line and on BNSF's Black Hills Subdivision lines. PRB coal transportation is a critical component of the U.S. energy supply chain.

A 1983 Joint Line Agreement between BNSF and UP predecessors governs rail operations over the Joint Line. This Agreement, which was approved by the Interstate Commerce Commission, establishes BNSF as the operator of the Joint Line, makes BNSF responsible for the maintenance of the Joint Line, and gives BNSF the right to establish rules for Joint Line operations without discrimination in favor of either party.

On May 14 and 15, 2005, two derailments occurred on the Joint Line within a few miles of one another. These derailments and the work required to repair the affected lines severely disrupted coal operations in the PRB. BNSF, in consultation with UP, took immediate short-term measures to address the derailments and to rehabilitate track and roadbed conditions. But the remedial track maintenance reduced available track capacity and required slow orders because of safety concerns. As a result, coal loadings at PRB mines served by the Joint Line

were briefly halted after the derailments and were substantially reduced during the rest of 2005. Congestion and reduced loadings on the Joint Line depleted some utilities' coal stockpiles just as they were about to experience high demand for electricity during the hot summer months.

BNSF studied the causes of the derailments and concluded that the derailments had resulted from a confluence of events. An extraordinary amount of rain and snow had fallen at the same time that the frozen ground was thawing and additional sub-surface moisture was rising up through the roadbed. Coal dust accumulations in the rail ballast had exacerbated the drainage problems caused by the excessive moisture in the roadbed. The mixture of coal dust and water caused the ballast to weaken to the point that the roadbed no longer provided adequate support for the rails.

BNSF concluded that it had to take measures to prevent a recurrence of the derailments and the severe service disruption caused by these outages. BNSF had been studying the problem of coal dust and possible dust suppression measures before the derailments, but BNSF substantially expanded its efforts to understand the scope and causes of the coal dust problem in the PRB and to investigate possible ways to address the problem of coal dust emissions. BNSF gave the highest priority to the study. BNSF retained an environmental and energy research and development firm, SWA, to assist in setting up a data gathering network so that there would be a solid factual record for understanding the coal dust problem and developing possible solutions. SWA had worked extensively with Norfolk Southern Railway Company in the 1980s on coal dust issues in the East. SWA worked with BNSF and an environmental engineering firm, Conestoga-Rovers Associates ("CRA"), to implement the data gathering network and to set up protocols for conducting field and laboratory tests and data analyses.

The data gathering network set up after the derailments consisted of three basic parts. First, an extensive network of dustfall collectors was set up at several different locations along the PRB rail lines. Coal accumulating in the dustfall collectors is gathered at 30-day intervals and measured. These instruments allow BNSF to keep track of overall coal dust deposition rates along the PRB lines and at varying distances from the track. However, these dust collectors cannot be used to measure dust emissions from individual trains.

Second, SWA set up Trackside Monitors ("TSMs") at Milepost 90.7 on the Joint Line and at Milepost 558 on BNSF's Black Hills Subdivision lines. The TSMs consist of a tower on which is mounted a weather system and a sophisticated electronic dust monitor referred to as an e-sampler. The dust monitor measures the number of dust units in the air at five-second intervals. It is therefore able to measure the total amount of coal dust emitted by a passing train as the train moves past the TSM location. Dust monitors are mounted on both sides of the track so that dust levels can be measured on the downwind monitor for each train. Equipment installed on and near the tracks allows BNSF to identify each train and therefore to produce reliable train-specific coal dust measurements.

Third, SWA assisted BNSF in monitoring coal dust emissions from certain instrumented trains so as to test the effectiveness of various dust suppression measures. The instruments include mobile weather stations (called Rail Transport Emission Profiling Systems or "RTEPS") and Passive Collectors ("PCs") that are attached to the cars in a test train. The passive collectors are mounted on the rear sill of cars at specified intervals within the train and the coal captured in the PCs over the course of a train trip can be measured and compared to determine the impact of various suppression alternatives being tested. For example, since 2005, SWA and BNSF have run several instrumented trains testing the effectiveness of different surfactants on limiting the

amount of coal dust released in transit. Surfactants are chemical solutions that are sprayed onto the top of loaded coal to keep the coal from being blown out of a car during transit.

BNSF worked closely with its shippers and their mine agents to inform them of the results of BNSF's extensive data gathering efforts. BNSF regularly attended meetings of the National Coal Transportation Association ("NCTA"), whose members include numerous coal shippers and mines, and made extensive presentations on the results of the ongoing tests and analyses. BNSF also undertook numerous studies at the request of NCTA members to investigate various issues of concern to shippers and the mines and presented the results of those studies to the NCTA.

In addition to these data gathering efforts, BNSF sought to understand better the physical impact of coal dust on rail infrastructure. Since 2006, BNSF has worked with Dr. Erol Tutumluer, a Professor of Civil and Environmental Engineering at University of Illinois at Urbana-Champaign, who has done extensive studies of railroad track structure and the causes of track failures. Dr. Tutumluer advised that while coal dust had not previously been identified as a significant ballast contaminant, it actually has characteristics that make it one of the worst possible fouling agents. He found that coal dust has a very high water holding capacity which limits drainage in ballast fouled by coal dust. His tests also showed that ballast contaminated by coal dust has a much lower load bearing capacity than ballast fouled with other contaminants, which is an obvious problem for PRB lines that carry a greater volume and annual tonnage of freight than any other rail lines in the United States. Particularly when it gets wet, coal dust can have a highly destabilizing effect on rail ballast.

BNSF concluded that coal dust emissions had to be substantially eliminated. During BNSF's study of the coal dust problem, BNSF was surprised to see how quickly coal dust

accumulated in the ballast. In one area of new track construction, BNSF discovered a few months after the new track had been installed that the ballast had already become fouled. BNSF carried out a coal dust cleaning effort in 2008, focused on gathering visible deposits of coal dust along the right of way, in creek beds next to tracks, and along bridge abutments, and filled over 300 railcars with coal dust for disposal at a landfill.

Expanded maintenance, while necessary to deal with the rapid accumulation of coal dust, is clearly not an adequate or responsible solution to a problem that has the potential for disrupting the supply of PRB coal. It is often difficult to detect coal dust before it becomes a problem because the coal dust quickly makes its way down into the ballast. Visual inspection of the rail bed cannot be relied on to locate areas where fouling has occurred. More widespread maintenance activity must be carried out to make sure problems do not develop, but such extraordinary maintenance of way activities are intrusive and disrupt train operations. Tracks must be taken out of service and slow orders issued to allow maintenance work to proceed. Maintenance effectively consumes capacity on the railroad, and on the heavily traveled PRB lines, the capacity available for maintenance activities is limited. Eventually, new track would need to be added just to be able to maintain the existing rail infrastructure.

BNSF therefore set out to determine whether there were ways to meaningfully limit coal dust emissions from loaded railcars. BNSF determined that coal dust emissions could be reduced by changing the load profile of loaded coal cars. SWA had previously studied the aerodynamics of loaded coal cars for Norfolk Southern. SWA provided BNSF with an idealized load profile which, if achieved during the loading process, would reduce the impact of wind and air currents on the loaded coal and thereby reduce coal dust emissions during transit. PRB mines adopted a modified loading chute that makes it possible, if sufficient care is given during the

loading process, to achieve the ideal load profile. The load profile and modified loading chute design are described in Appendix A to BNSF's Rules Publication 6041-B. Subsequent monitoring of loading practices indicates that additional care needs to be taken in the loading process to achieve the load profile.

Even if coal cars are loaded to the ideal load profile, substantial dust emissions still occur. Therefore, BNSF set out to identify a coal dust emission limit that could be established as an operating rule applicable to the Joint Line and BNSF's Black Hills Subdivision. BNSF concluded that the data gathered at the TSMs set up with the assistance of SWA could be used to set a limit on coal dust emissions at the location of the TSMs which, if met by all trains passing the TSMs, would effectively eliminate coal dust at those locations. The data gathered by BNSF on test trains and in the dustfall collectors showed that coal trains emit dust sporadically throughout a trip. However, BNSF concluded that if shippers pursued methods sufficient to limit coal dust emissions to levels permitted at the TSM location, e.g., the application of a surfactant to the loaded coal car, those same measures would effectively limit coal dust emissions along the entire length of the movement and the problem of dusting on coal lines would be effectively eliminated. The TSM dust monitors would act like a "traffic cop" at a fixed location to ensure that coal dust emissions had been successfully curtailed along the PRB rail lines.

BNSF carried out extensive field and laboratory tests on the electronic dust monitors and concluded that the readings taken from these monitors between September 2005 and August 2007 could be used to set a coal dust emission standard that could be applied to individual trains and used to identify specific trains emitting unacceptable amounts of coal dust. The dust monitors measure in real time the number of dust units emitted by a train passing the TSM. The dust units for a particular train can be summed up while the train passes the TSM location to

produce an Integrated Dust Value ("IDV.2") for the train. Mr. Sultana identified a maximum IDV.2 value for each TSM location which, if met by all trains at that location, would give BNSF a very high degree of confidence that at least 85% (and possibly as much as 95%) of the coal dust emissions historically measured at that TSM location would be eliminated. The emissions limits are set out in the BNSF's Rules Publication 6041-B. Mr. Sultana explains his methodology in detail in his Verified Statement.

BNSF has given individual shippers the flexibility to choose a dust suppression method that ensures compliance with BNSF's coal dust emissions standards. One promising way to ensure compliance is to apply a surfactant to the top of a loaded coal car. BNSF and its consultants carried out numerous laboratory and field tests beginning in 2005 on the effectiveness of various surfactants in reducing coal dust emissions. As noted above, several instrumented trains were run to determine the relative effectiveness of different chemical surfactants. BNSF found that the use of surfactants, particularly with properly groomed coal cars, can substantially eliminate coal dust emissions. BNSF is in the process of carrying out at the request of several PRB shippers a large scale trial of dust suppression alternatives, and BNSF has expanded its use of instrumented trains to assist in developing data through the current trial that will enable shippers to choose effective dust suppression measures.

BNSF first established its coal dust emissions standard as an operating rule under the Joint Line Agreement and communicated the new rule to UP on November 7, 2008. BNSF subsequently published its coal dust emissions standards in BNSF's Rules Publication 6041-B on April 30, 2009 and expanded the rule to cover BNSF's Black Hills Subdivision on May 27, 2009. The coal dust emissions standards in BNSF's Rules Publication had an effective date of November 1, 2009. On October 2, 2009, AECC filed a petition for a declaratory order seeking a

declaration from the Board that BNSF's coal dust emissions standards set out in BNSF's Rules Publication constitute an unreasonable rule or practice and an illegal refusal to provide service. AECC also sought a stay of the effective date of BNSF's emissions standards to give the Board an opportunity to address AECC's declaratory order petition. BNSF responded on October 21, 2009, indicating that it had suspended the effective date of the emissions standards in BNSF's Rules Publication 6041-B until August 1, 2010 and further stating that it welcomed the opportunity to have the Board examine the reasonableness of BNSF's measures to address the problem of coal dust in the PRB. On December 1, 2009, the Board initiated this proceeding.

ARGUMENT

I. The Board Should Declare that BNSF May Establish Rules Designed to Limit the Emission of Coal Dust from Coal Trains Operating Over its Lines.

In this declaratory order proceeding, BNSF seeks confirmation from the Board that it is pursuing a legally permissible course of action in establishing rules that are designed to limit the emission of coal dust from coal trains operating over its lines. BNSF believes that the standards that have been challenged here are needed to assure safe, efficient and reliable operations on BNSF's coal lines. The goal of these standards is not simply to protect BNSF's physical plant from being degraded by coal dust but also to guard against the risks of disruption in the provision of coal transportation service.

Long-established judicial and agency decisions compel the conclusion that BNSF can regulate coal dust emissions from trains operating over its lines. These decisions establish that rail carriers have broad authority to adopt operating rules to promote safe, efficient, and reliable operation of their railroads. *See Platt v. LeCocq*, 158 F. 723, 730-31 (8th Cir. 1907) ("A common carrier has the right to conduct its business in its own way in accordance with the rules of the common and statutory law. . . . It has the right to make and enforce reasonable regulations

which may lawfully fix the times, the places, the methods, and the forms in which it will receive the various commodities it undertakes to carry, and the rules which it thus adopts are presumptively right and reasonable."); *M. Longo Fruit Co. v. Ill. Traction Sys.*, 38 I.C.C. 487, 489 (1916) ("Both this Commission and the courts have held that carriers have the right to make reasonable and appropriate rules respecting the acceptance and transportation of traffic."). Unsurprisingly, rail carriers' power to set reasonable operating rules is accompanied by the power to modify existing operating rules and practices. *See Robinson v. Baltimore & O.R. Co.*, 129 F. 753, 755 (4th Cir. 1904) (noting the established rule that "the power to make reasonable regulations as to the manner and place where the railroad would receive coal for shipment implied the power to change and modify such regulations from time to time upon reasonable notice to the public").

A rail carrier's broad authority to establish operating rules that promote safety and efficiency was recently affirmed by the Board's decision in *N. Am. Freight Car Ass'n v. BNSF Railway Co.*, STB Dkt. 42060 (Sub-No. 1) ("*Freight Car*") at 6 (Jan. 24, 2007), which rejected an unreasonable-practices challenge to BNSF's charges for holding empty private cars on its system. The Board recognized that BNSF's charges "encourage shippers to utilize their private cars more efficiently" and that BNSF's past practice of not imposing such charges "does not mean that [the new charges are] unlawful . . . under today's conditions." *Id.* Under the logic of the *Freight Car* decision, the fact that BNSF had not taken steps prior to the issuance of the challenged standards to restrict coal dust emissions is not a valid reason for questioning the standards. The growth in coal volumes over the Joint Line and other lines have made it necessary to restrict coal dust emissions "under today's conditions."

Long-standing case law supports the authority of BNSF to adopt the very sort of operating rule that is at issue in this proceeding. Rail carriers' broad authority to establish operating rules includes the power to set reasonable standards for packing and loading freight in railcars. *See, e.g., In re Suspension of W. Classification No. 51, I.C.C. No. 9*, 25 I.C.C. 442, 486 (1912) ("Carriers have an undoubted right to demand and insist upon secure packages for the protection of the commodities contained in them, as well as for the protection of other freight."). Moreover, the ICC long ago held that railroads could require shippers to bear the expense of special measures necessary to prevent cargo such as grain and flaxseed from leaking from railcars. *See Chicago Bd. of Trade v. Abilene & S. Ry. Co.*, 220 I.C.C. 753, 761 (1937) ("We find that, as the installation of grain doors is an incident of loading bulk grain, it is not unreasonable to require that the shipper should, at his own expense, install the doors furnished by the carriers and made available to him . . . ."); *In re W. Trunk Line Rules, Regulations, and Exceptions to Classifications*, 34 I.C.C. 554, 578 (1915) (allowing rail carrier to issue rule "that shipments of flaxseed in bulk will not be accepted for transportation unless loaded in cars which have been properly lined at shipper's expense to prevent loss by leakage").

It follows from rail carriers' broad authority to set packing and loading standards designed to prevent leakage that BNSF may set reasonable standards designed to minimize the emission of coal dust. Similar authority is regularly exercised through a range of rules intended to ensure safe and efficient carrier operations. In the context of loading railcars, these rules recognize the commonsense principle that the best way to ensure safe, efficient, and reliable rail operations is for shippers to load freight in a manner that does not allow the freight to escape from railcars. This commonsense principle is reflected in BNSF's general loading rule, which provides that the "[s]hipper is responsible for loading railcar . . . so that lading will not be

released, discharged or inadvertently removed from railcar during rail carrier handling . . . ." *See* Fox Verified Statement ("V.S."), Exhibit 4. BNSF has numerous rules that apply this general rule in particular contexts. For example, there are rules governing the manner in which heavy equipment is loaded and secured in railcars to ensure safe operations and avoid service disruptions. *See* Fox V.S., Exhibit 5. Other rules govern the loading of scrap metal into open top cars so that the scrap metal does not escape from the cars in transit. *See* Fox V.S., Exhibit 6. Additionally, there are operating rules governing the leakage of materials in transit. *See* Fox V.S., Exhibit 7.

Like all of these rules, BNSF's coal dust emissions standards fit within rail carriers' broad authority to adopt operating rules that promote safe, efficient, and reliable operations by requiring shippers to keep their freight in railcars. The coal dust emissions standards are entirely consistent with BNSF's common carrier obligation because they are intended to assure that the transportation that BNSF is required to provide as a common carrier is operationally sound and consistently reliable.[1]

Importantly, the Board's predecessor, the Interstate Commerce Commission, has previously recognized BNSF's authority to promulgate reasonable rules governing rail

[1] Apart from promoting reliable common carriage, the coal dust emissions standards at issue here are an appropriate means of protecting BNSF's interest in preventing its property from being degraded by coal dust contamination. It would clearly be a trespass if a party, without permission, entered BNSF's right of way and dumped coal dust on the tracks. *See* Restatement (Second) of Torts § 158(a) ("One is subject to liability for trespass, irrespective of whether he thereby causes harm to any legally protected interest of the other, if he intentionally enters land in the possession of the other, or causes a thing . . . to do so."). The heavy emissions of coal dust that BNSF has experienced are the effective equivalent of having coal dumped on BNSF's right of way without its permission. BNSF has a legitimate interest in acting to protect its interest in its property. Indeed, a regular feature of railroad operating rules is that, in addition to promoting safe and efficient transportation, they have the effect of protecting a rail carrier's interest in its real property and tangible assets. For example, there are rules that set specific standards so that rail cars do not damage BNSF's property beyond normal wear and tear. *See* Fox V.S., Exhibit 8.

operations over the PRB Joint Line. Under the Joint Line Agreement between BNSF and UP predecessors, BNSF is entrusted with maintaining safe and efficient operations over the Joint Line. Section 2.7 of the Agreement provides that operations over the Joint Line shall be "in strict accordance with the Consolidated Code of Operating Rules and such other rules and regulations as promulgated by [BNSF], as modified and amended from time to time. . . ." The Joint Line Agreement was approved by the ICC in connection with its approval of the construction and operation of the Joint Line. *See Chicago & N. W. Transp. Co. Approval of Terms of Construction, Ownership & Operation of a Line of R.R. in Campbell & Converse Counties, Wyo.*, ICC Finance Docket No. 29066 (served Oct. 22, 1982).

II. BNSF's Coal Dust Emissions Standards Are Not Unreasonable.

A. The Reasonableness Inquiry

Because Congress has not defined in 49 U.S.C. § 10702 what constitutes a reasonable rule or practice, "[t]he [Board] has been given broad discretion to conduct case-by-case fact-specific inquiries to give meaning to these terms, which are not self-defining, in the wide variety of factual circumstances encountered." *Granite State Concrete Co. v. STB*, 417 F.3d 85, 92 (1st Cir. 2005) (rejecting challenge to STB's conclusion that railroad operating restrictions were reasonable). In performing this inquiry, the Board should not substitute its judgment for BNSF's judgment. Instead, the focus of the inquiry is whether BNSF's coal dust tariff is reasonable. The issue, in other words, is not whether the coal dust emissions standard that BNSF has adopted is the standard that the Board would have adopted if the Board were in the business of imposing railroad operating rules, but whether there is a rational basis for the approach BNSF has taken to dealing with the coal dust problem and whether the standard that BNSF adopted is rationally related to the problem it seeks to address.

B. It Was Rational for BNSF to Conclude that Coal Dust Emissions Need to Be Curtailed Rather than Dealt with Exclusively through Maintenance.

There can be no serious dispute that the accumulation of coal dust on BNSF's coal lines poses a risk to safe and efficient operations on the Joint Line and BNSF's other PRB coal lines. The combination of coal dust accumulation and heavy flooding in 2005 led to serious disruptions in coal transportation service that must be avoided in the future. BNSF is committed to preserving the integrity of the coal supply chain.

In its initial Petition for a Declaratory Order, AECC contended that the adverse effects of coal dust emissions should be addressed exclusively through "normal maintenance." AECC's Petition for Decl. Order at 3. Based on BNSF's experience, that suggestion is simply not realistic. BNSF has determined that not even the enhanced levels of maintenance that BNSF has been pursuing are sufficient to eliminate all the risk inherent in coal dust accumulation. As explained in the Verified Statement of Craig Sloggett, who has responsibility for maintenance and maintenance planning on BNSF's Powder River Division, BNSF has been pursuing extraordinary maintenance efforts on the Joint Line and Black Hills Subdivision. Sloggett V.S. at 6-9. Even with these efforts, it has not been possible to keep up with the rapid accumulation of coal dust. Sloggett V.S. at 5-6.

Gregory C. Fox, Vice President of Transportation for BNSF, explains that "[f]rom a maintenance of way perspective, it is better to keep coal dust out of the ballast in the first place, rather than to undertake extraordinary measures to maintain a railroad that is compromised by coal dust." Fox V.S. at 8. This is the case because, as Messrs. Fox and Sloggett explain, there are limitations on what even vigilant maintenance can accomplish. One limitation stems from the difficulty of identifying all areas where ballast has been fouled by the accumulation of coal dust. While many areas potentially compromised by coal dust accumulation are visible to the

naked eye, there are other areas where the surface of the roadbed or shoulder ballast reveals no visible accumulation of dust, and yet the ballast beneath the surface has been fouled. If the sub-surface dust has built up rapidly, the areas of undetected dust buildup may not be addressed in a timely manner, even under a regime of enhanced maintenance.

A second drawback in relying exclusively on maintenance to address the coal dust problem, is that maintenance activities impinge upon rail operations, and the more intensive the maintenance is, the greater the impingement. Fox V.S. at 8-9; Sloggett V.S. at 9. Maintenance requires that tracks be taken out of service and that slow orders be issued. The effect is to reduce line-haul capacity. As Mr. Fox explains, "it is not a question of simply expanding maintenance to deal with coal dust. Eventually, new track would need to be added just to be able to maintain the existing rail infrastructure." Fox V.S. at 8.

BNSF believes that addressing the problem of coal dust solely through enhanced maintenance is not a responsible way to address the risk of potential disruption in the supply of PRB coal to coal-fired electric utilities. The Board itself has stated that it "views the reliability of the nation's energy supply as crucial to this nation's economic and national security, and the transportation by rail of coal and other energy resources as a vital link in the energy supply chain." *Establishment of a Rail Energy Transportation Advisory Committee*, STB Ex Parte No. 670, at 2 (served July 17, 2007). Given the vital public interest in assuring the reliable transportation of coal, BNSF has concluded that it must act to limit coal dust emissions rather than merely dealing with them after the fact.

C. BNSF Acted Rationally in Adopting a Performance Based-Emissions Standard.

The IDV.2 coal dust emissions standards at issue in this proceeding are performance-based standards in that they measure whether individual coal trains emit quantities of dust that

exceed or fall below a specified dust emissions level. As an alternative approach, BNSF could have prescribed an activity-based standard for limiting coal dust emissions. That is, BNSF could have required shippers to put tops on their coal cars, or it could have required them to spray the coal loaded in cars with surfactants. BNSF elected to adopt a performance-based standard because it believed that that approach would give shippers the leeway to determine on an individual basis the method of complying with the standard that best suits each shipper's needs.

The performance based approach not only allows shippers to choose how they will comply with the emissions standards, but it should also encourage market-based innovations in coal dust emission control techniques that will result over time in reduced costs and improved methods of dust suppression. As BNSF's witnesses Messrs. Bobb and VanHook note, various suppliers of coal dust suppression products are already competing to supply shippers with products that will allow them to achieve compliance with the emissions standards. Given the size of the potential market – over 300 millions tons per year of PRB coal – one would expect vigorous competition to supply shippers with effective surfactants and alternative dust suppression products. The likely result of such competition is the availability of improved dust suppression products at lower cost.

The Board has been a strong proponent of market-based, private sector solutions to a wide variety of problems that arise in the rail transportation sector. By adopting a performance based standard, BNSF has sought to create an environment in which market based solutions to the coal dust problem are most likely to emerge. There is no reason to conclude that BNSF's approach is anything other than reasonable.

D. BNSF's IDV.2 Standards Are Practical and Conservative.

BNSF's witnesses explain in detail the steps that BNSF took to develop the IDV.2 emissions standards at issue in this proceeding. In fashioning its standards, BNSF relied upon (1) extensive data collection,[2] (2) extensive analysis of the data,[3] and (3) statistically sophisticated methods to formulate an emissions standard that is practical given the limited options for measuring dust emitted from moving coal trains.[4]

BNSF applies its coal dust emissions standards to loaded coal trains moving past track-side dust monitors at specific locations on BNSF's coal lines. This approach is practical because it allows the dusting from individual trains to be monitored without disrupting mine loading or train operations. Given the episodic nature of coal dusting and the large geographic territory covered by moving coal trains, the "traffic cop" approach to the monitoring of coal dust emissions is a logical way to apply the IDV.2 standards to individual trains.

The IDV.2 standards themselves are conservative, as Mr. Sultana explains. The standards were devised specifically by identifying a desired level of reduction in coal dust emissions and by taking into account the variability in the e-samplers used to monitor coal dust emissions. By establishing a dust level of 300 IDV.2 on the Joint Line, Mr. Sultana identified a dust emissions level that any shipper should be able to achieve if it makes a good faith effort to comply with BNSF's standard. The same is true for the standard that Mr. Sultana developed for the Black Hills Subdivision.

---

[2] *See* VanHook V.S. at 4-8; Emmitt V.S. at 4-12.

[3] *See* VanHook V.S. at 4-8; Emmitt V.S. at 4-12.

[4] *See* Sultana V.S. at 6-11.

It may be that the specific IDV.2 levels that BNSF calculated will be the target of second guessing in this proceeding. But those levels are not "arbitrary" as AECC contended in its Petition for Declaratory Order. The standards are the product of careful investigation and analysis by highly trained professionals. BNSF has been thorough and rigorous in its search for a solution to the coal dust problem, and this includes the development of the specific IDV.2 standards by Mr. Sultana. It is certainly possible that a more refined IDV.2 standard may be developed in the future as more sophisticated dust measurement equipment becomes available. But it would be irrational to deem the existing standards unreasonable simply because they do not meet some illusory ideal of accuracy.

III. BNSF's Position Regarding Compliance with its Coal Dust Emissions Standard

A. The Board's Review of Any Compliance Provisions that BNSF Might Adopt Would Be Limited to the Application of those Provisions to BNSF Common Carrier Shippers.

One of the many unfounded claims in AECC's Petition for a Declaratory Order was the assertion that BNSF's rules publication setting forth its coal dust emissions standard constitutes "a refusal to provide service." Declaratory Order Petition at 1. As BNSF explained in its reply to AECC's petition, BNSF has not adopted any particular measures to ensure compliance with its coal dust emissions standards. Consideration of specific enforcement measures is therefore premature. However, BNSF understands that there is an interest in what approach to compliance it would pursue if it became necessary to implement enforcement measures, so BNSF offers a framework for its likely approach to enforcement.

As a threshold matter it is important to recognize that the Board has authority to assess the reasonableness of the challenged emissions standards only as they apply to BNSF's common carrier transportation. Thus, the only question that could arise before the Board regarding

enforcement is whether BNSF could require its common carrier shippers to comply with the coal dust emissions standards set forth in BNSF's Rules Publication. BNSF intends to apply the coal dust standards to its contract shippers in accordance with the terms of privately negotiated coal transportation contracts, but BNSF may not disclose or discuss specific terms of those confidential agreements in this proceeding.

The coal dust standards set out in BNSF's Rules Publication do not apply to UP's Joint Line coal shippers unless and only to the extent that they are also BNSF coal shippers. However, BNSF is responsible for operating the Joint Line and, as BNSF's witness Stevan Bobb explains, BNSF has issued an operating rule under the Joint Line Agreement with UP that adopts the same coal dust emission standard set out in the Rules Publication at issue here. The operating rule requires that the coal dust emissions standard must be met as soon as practicable for all movements on the Joint Line. BNSF expects that UP will comply with the operating rule.

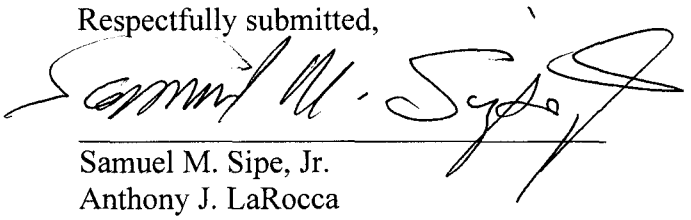
B. A Proposed Framework For Addressing Enforcement of the Challenged Rule

BNSF expects that shippers will voluntarily comply with the coal dust standards at issue here if the Board finds that they are not unreasonable. If any enforcement measures were necessary, they would be set out in separate notices and they would be limited to circumstances of inadvertent or intentional non-compliance. BNSF's enforcement approach would turn on individual shippers' good faith intention to comply with the coal dust emissions standards. Shippers' intent to comply would be presumed unless or until there is a failure by a shipper's train to meet the IDV.2 level. At that point, BNSF would consider requiring that the shipper execute a certificate indicating its intent to comply with BNSF's coal dust standards.

Where a shipper has executed a certificate indicating its intent to comply with the standards but is not immediately able to implement its proposed method of compliance or the

compliance method adopted is ineffective and the standard is not met, BNSF might consider publishing a new operating item that would provide for some type of special handling charge for the non-compliant coal trains. BNSF would hope that instances of willful non-compliance with the emissions standards would be non-existent. Were such a circumstance to arise, BNSF would reserve the right to decline to provide service until the shipper had manifested a good faith intention to comply with the standards.

Respectfully submitted,



Samuel M. Sipe, Jr.
Anthony J. LaRocca
Brooke L. Gaede
Kathryn J. Gainey
Roy E. Litland
STEPTOE & JOHNSON LLP
1330 Connecticut Avenue, N.W.
Washington, DC 20036
(202) 429-3000

ATTORNEYS FOR
BNSF RAILWAY COMPANY

Richard E. Weicher
Jill K. Mulligan
BNSF RAILWAY COMPANY
2500 Lou Menk Drive
Fort Worth, TX 76131
(817) 352-2353

March 16, 2010

CERTIFICATE OF SERVICE

I hereby certify that on this 16th day of March, 2010, I caused a copy of the foregoing, along with the Confidential and Highly Confidential Exhibit Volumes, to be served on the following Parties of Record by hand delivery or by Federal Express:

Mr. Eric Von Salzen
McLeod, Watkinson & Miller
One Massachusetts Avenue, NW, Suite 800
Washington, DC 20001
evonsalzen@mwmlaw.com

Counsel for Arkansas Electric Cooperative Corporation

Mr. Joe Rebein
Shook, Hardy & Bacon LLP
2555 Grand Blvd.
Kansas City, Missouri 64108-2613
jrebein@shb.com

Counsel for Union Pacific Railroad Company

Ms. Sandra L. Brown
Thompson Hine LLP
1920 N Street, NW, Suite 800
Washington, DC 20036
Sandra.Brown@ThompsonHine.com

Counsel for Ameren Energy Fuels and Services Company and Texas Municipal Power Agency

Mr. Kelvin J. Dowd
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
kjd@sloverandloftus.com

Counsel for Consumers Energy Company

Mr. John H. LeSeur
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
jhl@sloverandloftus.com

Counsel for Western Coal Traffic League

Mr. C. Michael Loftus
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
cml@sloverandloftus.com

Counsel for Concerned Captive Coal Shippers

Mr. Michael F. McBride
Van Ness Feldman, PC
1050 Thomas Jefferson Street, NW
Suite 700
Washington, DC 20007-3877
mfm@vnf.com

Counsel for American Public Power Association, Edison Electric Institute, and National Rural Electric Cooperative Association

Mr. G. Paul Moates
Sidley Austin LLP
1501 K Street, NW
Washington, DC 20005
pmoates@sidley.com

Counsel for Norfolk Southern Railway Company

Mr. Frank J. Pergolizzi
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036
fjp@sloverandloftus.com

Counsel for Entergy Arkansas, Inc., Entergy Gulf States Louisiana, LLC, and Entergy Services, Inc.

Mr. Paul Samuel Smith
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Room W94-316 C-30
Washington, DC 20590
paul.smith@dot.gov

Mr. Thomas W. Wilcox
GKG Law, PC
Canal Square
1054 Thirty-First Street, NW, Suite 200
Washington, DC 20007-4492
twilcox@gkglaw.com

Counsel for National Coal Transportation Association and TUCO Inc.

Mr. Charles A. Stedman
L.E. Peabody & Associates, Inc.
1501 Duke Street, Suite 200
Alexandria, Virginia 22314

and a copy of the foregoing, without the Confidential and Highly Confidential Exhibit Volumes, by Federal Express on the following party of record:

Mr. Paul R. Hitchcock
Associate General Counsel
CSX Transportation, Inc.
500 Water Street, J-150
Jacksonville, Florida 32202
Paul_Hitchcock@CSX.com

Kathryn J. Gainey

Counsel's Exhibits

COUNSEL'S EXHIBITS

EXHIBIT 1

New Track Construction – Fall 2006
M3 Mile Post 52 – Orin Subdivision
Photograph May 2007
5
2

Orin Subdivision MP 45.7

2009
Note coal dust
Accumulation
Alongside track

BNSF

04/29/2009

Orin Subdivision 90.5 - 97

2009
What you end up
With when ballast
Contaminated with
Coal dust and it
rains

BNSF

EXHIBIT 2

05/05/2008 14:10

New Track Construction – Fall 2006
M3 Mile Post 52 – Orin Subdivision
Photograph May 2007

Nacco Bridge

EXHIBIT 3

CATERPILLAR
PLASSER AMERICAN
09/11/2008 13:19

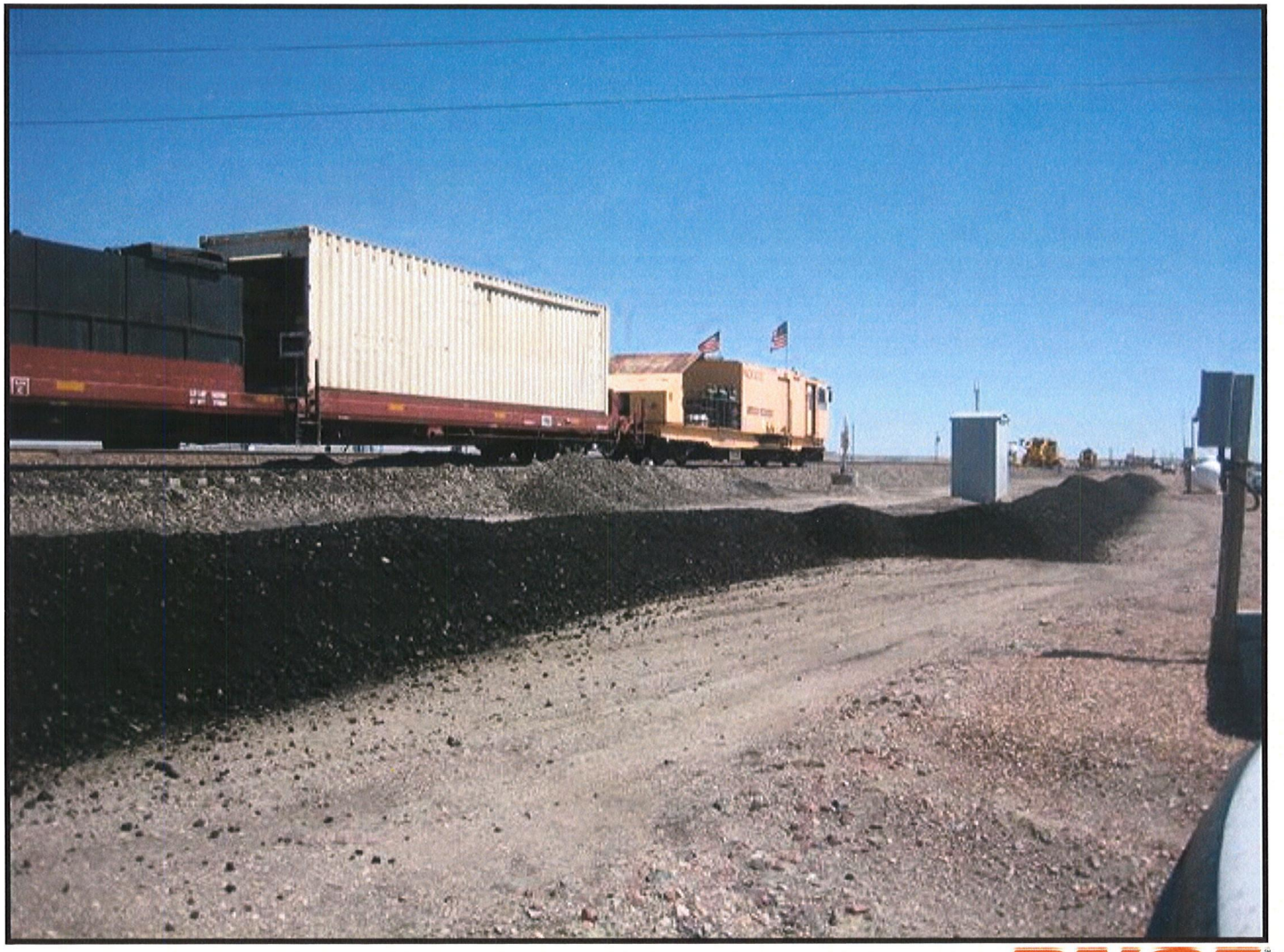
Reno Subdivision - UC01

2009
Undercutter work
Note normal ballast
Is not "black".

BNSF

Reno Subdivision - UC01

2009
Undercutter work



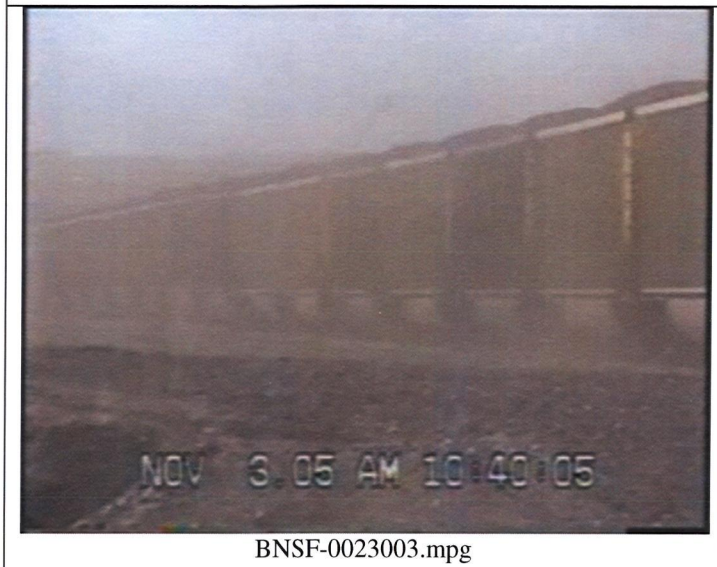
BNSF

EXHIBIT 4

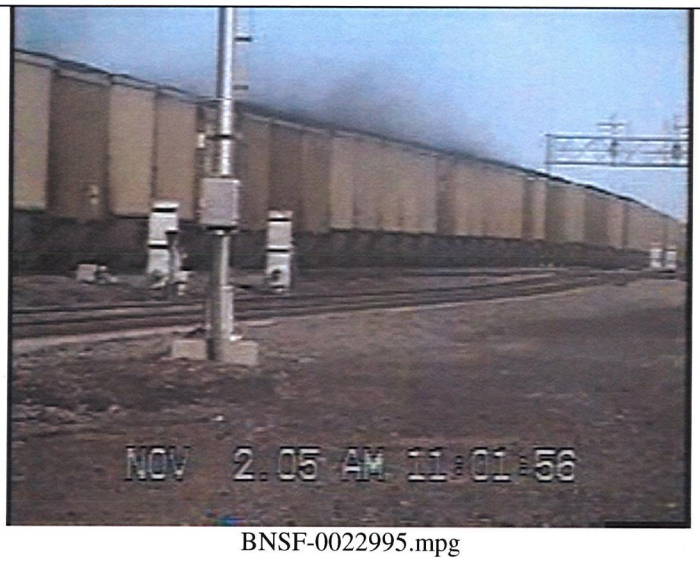
Counsel's Exhibit #4 (On CD)

BNSF-0023002.mpg

BNSF-0022999.wmv



BNSF-0023003.mpg



BNSF-0022995.mpg

VERIFIED STATEMENT OF GREGORY C. FOX

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF GREGORY C. FOX IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is Gregory C. Fox. I am Vice President, Transportation of the BNSF Railway Company, a position I have held since May 2007. In this position, I have responsibility for leading BNSF's transportation team, which includes Field and Network Operations, Locomotive Distribution, and Crew Management. The team includes almost 20,000 employees and has an annual budget that exceeds $2.2 billion.

The purpose of my verified statement is to explain to the Board that coal dust emissions from rail cars must be substantially eliminated to ensure the safe, efficient, and reliable operation of rail lines in the Powder River Basin ("PRB"). Coal fired electric utilities throughout the United States rely upon an assured supply of Powder River Basin coal. BNSF is not willing to incur the risk of supply disruptions that could occur if coal dust accumulates in the roadbed, fouls the ballast that supports our track structure and thereby compromises the integrity of that track structure. BNSF must be able to limit coal dust emissions in the interest of providing reliable coal transportation service. I urge the Board to find that BNSF's coal dust emissions standards at issue in this proceeding are a reasonable means of addressing the coal dust problem that we have encountered on our railroad.

Work Experience and Education

I began my railroad career in 1984 as a corporate management trainee for the former Burlington Northern Railroad. During my early years I held operations positions such as trainmaster, terminal trainmaster, and terminal superintendent. In 1988, I became Manager, Finance and Strategic Planning, and I subsequently held a series of positions in Finance until 1992, when I was promoted to Director, Information Technology, Information Systems Services. Over the next ten years, I held a series of technology-related positions including Assistant Vice President, ISS; Vice President, eBusiness; Vice President, Technology Services; and Chief Information Officer.

In September 2002, I was named Vice President, Engineering, a position I held until I was named to my present position in May 2007. As Vice President, Engineering, I oversaw BNSF's efforts to provide safe, efficient, and reliable physical infrastructure, tracks, signal systems, bridges, tunnels, and buildings. From 2006 to 2007, I also served on the Board of Governors of the American Railway Engineering and Maintenance Association, which recommends standards for various engineering aspects of railroad infrastructure.

I have a B.S. in Finance and Transportation Management from the University of Colorado and a Masters of Business Administration in Corporate Finance from Avila College.

Concerns About the Impact of Coal Dust on PRB Lines Predated the 2005 Derailments.

Since the 1970s, BNSF and its predecessor Burlington Northern has had to deal with coal dust accumulations on the right of way. When I became Vice President, Engineering, in September 2002, BNSF understood that accumulated coal dust affected the reliability of rail switches and contaminated the ballast, but we did not fully appreciate the magnitude of the impact that coal dust could have on the integrity of the roadbed. We thought the problems

caused by coal dust were mainly limited to the reliability of switches, the risk of the coal dust catching fire, and the burdens of increased maintenance requirements. The increased maintenance included undercutting and switch undercutting, other surfacing requirements, and increased switch maintenance. This additional maintenance activity affected operations on the Joint Line since maintenance work reduces track capacity and causes slow orders as trains on adjacent track must travel below maximum speed to ensure the safety of the maintenance operations.

Although we were generally aware that coal dust caused problems, we had not intensively studied coal dust, we were not aware of the magnitude of the adverse impact to the track structure, nor had we adopted specialized programs to deal with the coal dust problem. However, by late 2002, coal dust became a source of heightened concern regarding the long term stability of the roadbed. With steadily increasing traffic volumes on the Joint Line, coal dust deposits on the right of way far surpassed BNSF's historical experience. As a result, in December 2003, BNSF undertook a study to quantify the magnitude of the problems associated with coal dust on the roadbed.

Throughout 2004, BNSF continued to monitor and study the rate of coal dust accumulation, the magnitude of the deposits, and the seasonal and locational impacts of coal dust accumulation on Joint Line operations and maintenance. This review was intended to form the basis of a long term plan that would address the increasing amounts and rate of coal dust deposits on the roadbed while ensuring that BNSF could accommodate the increasing volumes of coal traffic on the Joint Line.

In late 2004, preliminary findings from the coal dust study were reviewed internally within BNSF's engineering department. *See* Ex. 1. In the first quarter of 2005, a cross-

functional team within BNSF was formed to develop and coordinate a long term strategy for dealing with coal dust deposits along the Joint Line that would allow BNSF to meet the need for rising demand for coal shipments. By early May 2005, we believed that we had sufficiently quantified the coal dust problem to present our findings to BNSF's CEO. *See* Ex. 2.

While we were concerned about the increasing accumulations of coal dust, rail operations on our coal lines were satisfactory through the early spring of 2005. The Joint Line had accommodated record volumes in 2004 and the first four months of 2005. BNSF had increased its inspection and maintenance activities to deal with coal dust and we were confident that this expanded maintenance activity would be adequate to support Joint Line operations until long-term solutions could be implemented to address the problem of coal dust accumulations. However, subsequent events demonstrated that we had underestimated the risks posed by coal dust.

The May 2005 Derailments on the Joint Line Made it Clear that Coal Dust Presents a Serious and Unacceptable Risk to Reliable Service.

On May 14, 2005, a BNSF coal unit train derailed on the Joint Line. On May 15, 2005, less than eighteen hours later, a UP coal unit train derailed on the Joint Line a few miles away from the first derailment. These derailments and the work required to repair the affected lines severely disrupted coal operations in the PRB. BNSF, in consultation with our Joint Line co-owner Union Pacific, took immediate short-term measures to address the derailments and to rehabilitate track and roadbed conditions. As Vice President, Engineering, I led BNSF's efforts to restore operations on the Joint Line as quickly as possible. We immediately cleaned the site and rebuilt the track so that train operations could be resumed within a matter of days, although at a reduced level. Over the next few months, we undertook comprehensive rehabilitation

measures such as undercutting substantial portions of the Joint Line, putting in new ballast, and cleaning turnouts.

Although we tried to minimize the disruption to the around-the-clock service that Joint Line shippers rely upon, the remedial track maintenance unavoidably reduced available track capacity and required slow orders because of safety concerns. As a result, coal loadings at PRB mines served by the Joint Line were briefly halted after the derailments and were substantially reduced during the rest of 2005. Congestion and reduced loadings on the Joint Line depleted some utilities' coal stockpiles just as they were about to experience high demand for electricity during the hot summer months. It was widely reported that some coal shippers sought alternate supplies of power on the open market.

As in all cases of derailments, BNSF investigated the causes of the May 2005 derailments. We concluded that the derailments were attributable to a confluence of events. First, an extraordinary amount of rain and snow had fallen over a short time period in late April and early May. Drying cycles were not long enough to allow moisture to drain from the roadbed. Second, temperatures were warm enough by mid-May that the frozen ground was thawing and additional sub-surface moisture was rising up through the roadbed. Third, the coal dust accumulations in the rail ballast had exacerbated the drainage problems caused by the excessive moisture in the roadbed. The mixture of coal dust and water caused the ballast to weaken to the point that the roadbed no longer provided adequate support for the rails.

Some coal shippers have claimed that the 2005 derailments on the Joint Line were the result of inadequate maintenance. In fact, we had been maintaining the Joint Line and our other coal lines to a high standard. Our ability to accommodate record volumes of coal up to the point of the derailments confirmed our belief that the coal lines were well maintained. In retrospect, if

we had understood the full impact coal dust has on the track structure or if we had been able to anticipate the extraordinary weather events of late April/early May, we would have undertaken additional, extraordinary maintenance measures that might have prevented the derailments. But viewing our maintenance of the coal lines based on how we were performing and what we knew up to the time of the derailments, I do not believe our maintenance practices can be faulted. And it certainly makes no sense to say that inadequate maintenance caused the derailments because our pre-derailment maintenance was not in any way sub-standard.

BNSF Must Be Able to Establish Operating Rules to Ensure Efficient and Reliable Service.

The May 2005 derailments caused BNSF to focus on the problem of coal dust with a heightened sense of urgency. While we have never claimed that coal dust was the sole cause of the derailments, it was absolutely clear that the presence of coal dust in the ballast had contributed to the derailments and that coal dust was a ballast fouling agent that could be expected to weaken the track structure. While BNSF expanded its inspection and maintenance activities to prevent the recurrence of another derailment, the risk of serious operating problems would remain as long as substantial quantities of coal dust were being emitted from loaded cars and being deposited on the right of way. Therefore, immediately following the May 2005 derailments, BNSF initiated a high priority study to understand the full extent of the coal dust problem and to identify ways of eliminating or substantially reducing coal dust emissions from loaded coal cars. I put William VanHook, Assistant Vice President of Engineering in charge of the coal dust project. I asked him to keep our coal shippers and the coal mines informed of our progress in the study and, in particular, to work with the National Coal Transportation Association ("NCTA"), as NCTA had acknowledged the importance of addressing the problem of coal dust. *See* Ex. 3.

Under Mr. VanHook's supervision, BNSF and its consultants collected a large amount of data on the sources of coal dust in the PRB and the alternatives for curtailing coal dust emissions. As described in other witness statements, BNSF collected a large amount of data on coal dust emissions over a period of two years. We determined that the best way to deal with the coal dust problem would be to adopt a performance standard that would require coal shippers to limit emissions of coal dust from loaded cars. Using the data we had collected, BNSF established a limit on coal dust emissions which, if met by all coal trains moving on the Joint Line and on BNSF's Black Hills Subdivision, would substantially eliminate coal dust from the railroad right of way. The development of those emissions standards is addressed by other witnesses in this proceeding. BNSF adopted its Joint Line coal dust emissions standards first as an operating rule that applies to coal trains moving on the Joint Line, including Union Pacific trains. The Joint Line emissions standard, as well as the Black Hills Subdivision standard, was subsequently made applicable to BNSF common carrier shippers through BNSF's rules publication. As described by other BNSF witnesses, the standards are readily achievable by shippers that make a good faith effort to meet them.

It is standard practice in the rail industry for rail carriers to adopt operating rules designed to ensure safe, efficient, and reliable rail operations. Numerous operating rules govern the way freight is loaded and secured in railcars to ensure safe operations and avoid operating disruptions. Under BNSF's general loading rule, shippers are responsible for securely loading their freight so that the freight stays in rail cars. *See* Ex. 4 at BNSF_COAL_DUST_0082736. Other rules apply this general rule in particular contexts. For example, operating rules govern the manner in which heavy equipment and scrap metal are loaded and secured in railcars to ensure safe operations and avoid service disruptions. *See* Exs. 5-6. Additionally, there are

operating rules that govern leakage of freight in transit. *See* Ex. 7. Other rules set specific standards for railcars so that the cars do not damage BNSF's property beyond normal wear and tear. *See* Ex. 8.

BNSF's coal dust emissions standards are like numerous other operating rules that require rail shippers to take actions with respect to the freight they load into railcars to ensure the safe and efficient movement of trains. Some coal shippers contend that BNSF should not be permitted to address coal dust through an operating rule designed to limit coal dust emissions. These shippers claim that BNSF should be required to deal with coal dust after it has fallen onto the right of way through expanded maintenance. But shippers of other commodities are not allowed to contaminate BNSF's right of way and compromise the integrity of our track structure simply because BNSF can fix the damage after the fact. The coal that falls onto the railroad right of way belongs to the shippers and it is their responsibility to keep it in the cars.

From a maintenance of way perspective, it is better to keep coal dust out of the ballast in the first place, rather than to undertake extraordinary measures to maintain a railroad that is compromised by coal dust. The challenges of detecting coal dust deposits that are not readily apparent on the surface but have worked their way into the ballast means that we cannot be certain that enhanced maintenance will always address the problem before it manifests itself. Moreover, maintenance of way activities are intrusive and disrupt train operations. Tracks must be taken out of service and slow orders issued to allow maintenance work to proceed. Maintenance effectively consumes capacity on the railroad, and on a very heavily traveled line like the Joint Line, the capacity available for maintenance activities is limited. Therefore, it is not a question of simply expanding maintenance to deal with coal dust. Eventually, new track would need to be added just to be able to maintain the existing rail infrastructure.

Finally, addressing the problem of coal dust through expanded maintenance is not a responsible way to deal with a problem that has the potential for disrupting the supply of PRB coal. The risk of service interruptions on PRB coal lines, including the Joint Line, requires that coal dust be kept from falling out of the loaded cars onto the right of way. Balancing the burdens of coal dust emissions restrictions against the risk of service disruption resulting from compromised track structure, leads to a very clear answer – we must take the steps necessary to avoid the risk of service disruption. There is no reason for the Board to second guess this conclusion.

The solution to the coal dust problem is to require that shippers take measures necessary to keep their coal in the coal cars. BNSF's coal dust emissions standards represent a reasonable limit on coal dust that shippers should be required to meet.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

Gregory C. Fox

Gregory C. Fox

VERIFIED STATEMENT OF STEVAN B. BOBB

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF STEVAN B. BOBB IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is Stevan B. Bobb. I am Group Vice President, Coal Marketing for BNSF Railway Company ("BNSF"), a position I have held since the spring of 2006. In this position I have responsibility for the sales and marketing of BNSF's coal transportation services. Coal transportation is one of BNSF's four principal lines of business. In 2009, we transported 283 million tons of coal. The vast majority of this coal originates at mines located in the Powder River Basin ("PRB") of Wyoming. Coal originated in the PRB moves primarily to electrical utilities located throughout the western United States and is interchanged with eastern railroads for delivery to utilities located in the East as well. Coal transportation is a critical component of the domestic U.S. energy supply chain, and BNSF transports the largest volume of coal to domestic receivers of any U.S. railroad.

The purpose of my verified statement is to address from the marketing perspective both the problems created by coal dust emissions and potential ways to prevent those problems. As past events demonstrate, the accumulation of coal dust on densely traveled coal lines creates the risk of significant disruption to our rail operations, and also to the operations of our competitor the Union Pacific Railroad Company ("UP") who is a joint owner of the PRB Joint Line with us. Disruption of rail operations threatens the coal supply chain and creates serious risks of curtailed

energy generation. BNSF has concluded that those risks can best be controlled by limiting coal dust emissions from rail cars while in transit. We believe that effective measures exist to control coal dust emissions and that the shippers who own the coal that falls onto our railroad line have the ability and responsibility to adopt such measures. BNSF has established coal dust emissions standards in the interest of maintaining the integrity of the coal supply chain, and we are optimistic that coal shippers will recognize that it is in their own larger interest to take voluntary measures to limit coal dust emissions.

Education and Work Experience

I have a B.S. in Agriculture from North Dakota State University. I joined BNSF's predecessor, the Burlington Northern Railroad, in 1987 and have been employed continuously by the railroad since that date. Following some early work in information systems and marketing support, my career has been spent primarily in line marketing positions. This has included extensive work in Minerals and Chemicals Marketing, where I eventually rose to the level of Vice President Minerals Marketing in June 1996. I subsequently became Vice President Chemicals Marketing in October 1996, Vice President of Agricultural Commodities Marketing and then Group Vice President, Agricultural Products Marketing. I became Group Vice President, Coal Marketing, which is my current position, in the spring of 2006. In addition to these marketing positions, I spent one year in an operations job as General Manager of BNSF's Texas Division in 2005 and a year as Vice President Business Unit Operations in 2004.

Operation of and Volume Growth over the PRB Joint Line

The Powder River Basin in northeastern Wyoming produces the largest volume of coal of any producing region in the United States and provides approximately 40 percent of the coal consumed in the country. Both BNSF and UP have access to the PRB. A critical artery for

accessing the PRB mines that produce the majority of PRB coal is the 103 mile segment of railroad owned jointly by BNSF and UP that extends from Coal Creek Junction, WY in the North to Shawnee Junction, WY in the South.

A 1983 Joint Line Agreement between BNSF and UP predecessors governs rail operations over the Joint Line. This Agreement, which was approved by the Interstate Commerce Commission, establishes BNSF as the operator of the Joint Line, makes BNSF responsible for the maintenance of the Joint Line, and gives BNSF the right to establish rules for Joint Line operations without discrimination in favor of either party. The Joint Line Agreement is attached to this statement as Exhibit 1.

The Joint Line began operating as a joint facility in 1984. Traffic levels and Joint Line capacity have both increased tremendously over the intervening period. Combined BNSF/UP coal tonnage originated on the Joint Line increased from approximately 76 million tons in 1984 to 212 million tons in 1997. Over the eight year period from 1997 to 2005, Joint Line coal tonnage originations increased another 113 million tons (or 53 percent) to 325 million tons. Joint Line coal tonnage reached a high of 375 million tons in 2008, but has dropped off somewhat from that level due to the recession.

The capacity of the Joint Line has steadily increased over the 26-year period of Joint Line operations. What began as a single track railroad with limited passing sidings has grown to a triple track railroad, with sections that are quadruple tracked. The Joint Line has sufficient capacity to accommodate over 60 loaded coal trains per day, and an equal number of empties. The maximum capacity of the existing Joint Line plant is estimated to be over 400 million tons.

The growth in Joint Line coal traffic and capacity is significant for two related reasons. First, this growth underscores the increasingly critical role that the Joint Line plays in the energy

supply chain. Second, this growth in coal volumes originating on the Joint Line is a primary reason why coal dust has emerged as a major problem on our railroad. Greater volumes transported over the rails means more coal dust emissions and the faster build-up of coal dust along the right of way.

Awareness of the Coal Dust Problem

In May 2005 while I was working as General Manager of BNSF's Texas Division, I became aware that two derailments had occurred on the PRB Joint Line and that those derailments, coupled with the need to repair the affected lines, caused serious disruption to coal operations in the PRB. I also learned indirectly that while heavy precipitation coupled with spring thaws was a triggering cause of the derailments, the accumulation of coal dust in the ballast underlying the track structure had been a significant contributing cause of the derailments. While anyone who was employed with the company at the time would have been aware of the derailments and the challenges to our operations and our shippers' operations, I did not have any personal involvement with the derailments or issues associated with coal dust in 2005.

I began to learn in detail about the coal dust problem in the spring of 2006 when I took over the job of Group Vice President, Coal Marketing. I learned about coal dust from my predecessor, Tom Kraemer, and I learned about it in greater detail from Bill VanHook, a BNSF Assistant Vice President & Chief Engineer Systems Maintenance and Planning, who had been tasked by our senior management with the job of understanding and addressing the coal dust problem. Over time, as I had occasion to travel to the PRB, I also learned about the coal dust problem from my own first hand observations, as the presence of dusting was and continues to be readily apparent from the observation of coal dust blowing out of loaded coal cars and visibly accumulating along the right of way.

In my transition to coal marketing, I learned that BNSF engineering personnel, including Mr. VanHook, had engaged in considerable study and concluded that unacceptable quantities of coal dust were accumulating along the right of way of portions of BNSF's coal network, including the Joint Line and other lines in and adjacent to the PRB, and that these accumulations posed risks to the integrity of the track structure, which in turn posed risks to the coal supply chain. I learned that Mr. VanHook and others at BNSF were in the process of trying to understand the science of coal dust in various different dimensions, including (1) the monitoring and measurement of coal dust levels; (2) the effect of coal dust on ballast and track structure; and (3) the identification of effective measures for limiting coal dust emissions. Work in each of these areas was already underway when I joined the Coal Marketing Department in the spring of 2006, a year after the PRB derailments. This work has continued without interruption over the last four years and progressed to the point that BNSF believes that we will be able to solve the coal dust problem. Doing so will require a collective, affirmative effort on the part of the shippers that own the coal and the coal mines that sell it to them, as well as the railroads that haul PRB coal.

Continuing Outreach to Coal Mines and BNSF Coal Shippers

BNSF's approach to the coal dust problem has involved continuing outreach to PRB coal mines and to the electrical utilities that are the principal shippers of PRB coal. The mines must be part of the solution to the coal dust problem because they are the shippers' agents and they are the entities that load the coal dust into coal cars. The nature of the loading affects the level of the dusting. The shippers must participate in the solution to the coal dust problem because the shippers own the coal and they bear responsibility for the commodities that they ask us to transport. The concept of shipper responsibility for controlling spillage of commodities shipped

over the railroad is an established one in our industry. Just as the railroad cannot accept leakage of toxic chemicals from defective valves on tank cars, it should not be expected to accept emissions of coal from coal cars that foul the ballast and compromise the integrity of the track structure. It is particularly appropriate that coal shippers participate in the solution to the coal dust problem because a principal objective of that solution is to avoid disruptions to the coal supply chain that could result from compromised track structure.

When I first took over as head of Coal Marketing, BNSF outreach on coal dust was focused on a coal shipper and producer trade association, the National Coal Transportation Association. That is, we were performing a joint coal dust study with various sub-committees working on different facets of the issue. At this time our communications and position explanations regarding coal dust issues were primarily with the NCTA coal dust working group. We understood that NCTA was communicating directly with its broader membership. Eventually our focus shifted from interactions primarily with NCTA to direct interactions with BNSF coal shippers, individually and through a variety of public forums.

We have not interacted with UP shippers unless they happen also to be BNSF shippers, in which case we deal with them on coal dust, as on other matters, solely in their role as BNSF shippers. However, because UP operates over the Joint Line and because coal dust emitted from trains operated by UP to transport its customers' coal is a source of the coal dust problem, we have issued a Joint Line operating rule, applicable both to BNSF and UP, that incorporates the coal dust emissions standard set forth in BNSF's rules publication. That rule was communicated to UP's Executive Vice President – Operations from BNSF's Chief Operating Officer on November 7, 2008, and is attached hereto as Exhibit 2.

A significant amount of my personal attention over the past four years has been devoted to meeting with coal mines and BNSF shippers on issues related to coal dust. We have found the attitude of the mines to be generally constructive and have made tangible progress towards reducing coal dust emissions through efforts focused on the loading of coal trains. Specifically, our consultants from Simpson Weather Associates performed studies indicating that coal dust emissions could be reduced by shaping the profile of the coal loaded into coal cars. The proper profile of the loaded coal can be achieved by using a modified coal loading chute and by careful attention to the loading process by the individuals overseeing that process. This portion of our mitigation program has been a success, as all coal mines have installed the modified loading chutes that allow the proper profile to be achieved. They have also been generally receptive to our proposals to provide real-time feedback on the loading of coal cars through the use of laser monitoring devices so that their loading operators are able to achieve optimal loading profiles. This implementation of improved loading techniques has been a positive, although somewhat modest, step in reducing coal dust emissions.

I personally have attended dozens of meetings with individual coal shippers on coal dust issues over the past several years, as well as numerous meetings and conferences attended by multiple shippers at which the topic of coal dust was addressed. Throughout these discussions, whether in private or otherwise, my efforts have focused on promoting a consensual solution to the coal dust problem whereby shippers will voluntarily accept responsibility for curtailing emissions of coal dust. We have sought to do this through an approach designed to be deliberate, fact-based and transparent. We have shared the coal dust science with our shippers. We have shared our test results. We are now involved in an extensive trial of measures that can be used by shippers to limit coal dust emissions. We undertook the facilitation of this trial at the request

of several customers. To date, we have been encouraged by the level of mine and shipper participation in the trial. Our hope and expectation is that when shippers have seen first-hand that there are effective methods available to limit coal dust emissions to acceptable levels, they will voluntarily adopt those methods.

Adoption of a Performance Based Standard

Mr. VanHook describes in his Verified Statement the process that BNSF went through to develop the coal dust emissions standards at issue in this proceeding. After consultation with senior BNSF management, those standards were first placed in BNSF's rules publication on April 30, 2009 for the Joint Line and May 27, 2009 for the Black Hills Subdivision. BNSF established the emissions standards only once we believed that we had done enough testing and analysis to justify imposing the standards. As explained by others, we believe that the standards we have adopted are conservative in the sense that any shipper that makes a good faith effort to comply with the standard will be able to achieve compliance. And we believe that widespread acceptance of the standard will solve the coal dust problem.

The IDV.2 standards set out in our rules publication are performance based in that they establish a level of dusting that should not be exceeded. The standards do not specify behavior that must be pursued to comply with the standards. By adopting a performance based standard rather than prescribing a particular method of controlling coal dust emissions, BNSF sought to allow individual industry members to determine the most efficient and cost effective method of coal dust containment. As shippers will have the incentive to select cost effective suppression methods, vendors of various coal dust emission suppression methods and products will have the incentive to continue to innovate to come up with less costly and more effective suppression

measures. We are already seeing this process unfold, as multiple vendors of dust suppression products have sought to participate in the ongoing trial.

We believe that the adoption of our emissions standards will have benefits for the mines and shippers beyond maintaining the integrity of the coal route that they rely on. Coal dust suppression at the mine origin and the utility destination is one set of additional benefits that we anticipate. We also understand that other beneficial treatments are now available (such as suppressing spontaneous combustion) that utilize some of the same application infrastructure used to curtail dust emissions. Another useful byproduct of the coal dust standard is the dissemination of testing information from our monitoring devices that will allow shippers to observe the level of dust reduction being achieved. By providing individual train performance data of the shippers' trains as they pass the TSM sites, they will be able to see over time the effectiveness of their efforts in mitigating the loss of coal off of the rail cars using whichever method they desire to use.

We are hopeful that voluntary compliance with our standard by the shipping community will eliminate any need to adopt enforcement measures. However, if it should be necessary to adopt enforcement measures at some time in the future, we will provide sufficient advance notice to give interested parties an opportunity to raise any issues related to those measures before they are implemented.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

Stevan B. Bobb

VERIFIED STATEMENT OF WILLIAM VANHOOK

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF WILLIAM VANHOOK IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is William VanHook. I am Assistant Vice-President and Chief Engineer-Systems Maintenance and Planning for BNSF Railway. Since 2005, I have been responsible for coordinating and overseeing BNSF's efforts to study the scope of the coal dust problem in the Powder River Basin ("PRB") and to investigate measures to curtail coal dust emissions. The purpose of my Verified Statement is to describe for the Board the extensive measures that BNSF has taken since 2005 to address the problem of coal dust in the PRB. As I explain below, the emission of coal dust from loaded coal cars presents a serious challenge in maintaining the structural integrity of one of the most important portions of the rail network in the United States. I urge the Board to affirm BNSF's authority to address this problem and to affirm the reasonableness of BNSF's requirement that there be limits on the emission of coal dust from coal cars in transit.

As AVP Engineering at BNSF, I have responsibility for ensuring that the BNSF rail network is built and maintained to a level that permits efficient and reliable transportation for BNSF's shippers. Among other things, I oversee the development and implementation of a $1.5 billion annual capital maintenance budget and a $900m operating budget for the engineering department. I support BNSF's engineering field personnel and make sure they have the

information and resources necessary to maintain BNSF's physical plant. I oversee the Engineering Information Technology Group, which is responsible for the collection of a vast amount of engineering information and for making that information available in a usable and accessible form to BNSF's field personnel. I facilitate BNSF's inspection of tracks and track structure through end user programs and interfaces. I am responsible for BNSF's large fleet of test and rail maintenance cars, including its track geometry cars, rail detection cars, and rail and switch grinders. I interact with the Federal Railroad Administration and other government regulatory agencies on matters relating to track conditions and formulation of new regulations through various Railroad Safety Advisory Committee meetings.

I have been employed by BNSF for 16 years. Since 1995, I have been responsible for the construction of new track, signal, bridge and facilities initially for one region of BNSF, then subsequently for the entire BNSF system, as director construction, AVP Construction Santa Fe Lines and AVP Engineering Services. In 2001, I was appointed to my current position with system maintenance responsibilities. I have over 30 years of railroad experience. Prior to joining BNSF, I was employed by the Norfolk & Western Railway, the Southern Pacific Railroad, the Atchison, Topeka & Santa Fe Railroad, the Chicago, Missouri & Western Railroad and the Norfolk Southern Corporation. At each of these railroads, I was in the engineering department and my responsibilities were varied, including track maintenance, building maintenance, expansion of the physical plant, establishment of and maintaining track standards, oversight of signal and bridge maintenance, and planning and scheduling of overall company capital maintenance programs and operating budgets. I have a bachelors and masters degree from the State University of New York, Buffalo, in civil engineering.

The 2005 Joint Line Derailments Led to a Concerted and High Priority Effort to Understand and Address the Problem of Coal Dust.

In 2004, I became aware of the persistent and difficult problems that were caused by coal dust that was being blown out of loaded coal cars in transit from PRB coal mines. Spontaneous fires were occurring along the right of way on the PRB lines from the large volumes of accumulated coal dust. Rail switches were being fouled by the coal dust. Coal dust was piling up along bridge abutments and creek beds. Slow orders on the heavily traveled PRB lines were increasing as BNSF carried out increased maintenance activity to deal with the coal accumulations. I also became aware of complaints from local ranchers in Wyoming about coal dust deposits on their property.

I did not have primary responsibility for dealing with coal dust issues in 2004 but I participated in several presentations and discussions of the issue. Indeed, just a few days before the derailments occurred in 2005, I participated in a high level internal meeting that addressed BNSF's on-going study of the coal dust problem. *See* Exhibit 1. At the meeting, we were informed about the efforts of BNSF's division managers to understand the sources and amount of coal dust accumulating on the right of way and BNSF's preliminary views regarding alternatives to deal with the problem. BNSF had already conducted field measurements of coal dust and analyses of ballast contaminated by coal dust.

On May 14 and 15, 2005, two derailments occurred on the Joint Line within a few miles of one another. Gregory Fox, who was BNSF's Vice President, Engineering at the time, took the lead in dealing with the immediate consequences of the derailments. The sites were cleaned and the track was put back into service. Over the next several months, BNSF undertook a comprehensive rehabilitation of the Joint Line which reduced track availability and coal shipments. BNSF studied the causes of the derailments and concluded that the derailments had

resulted from a combination of unusual weather conditions – an extraordinary amount of rain and snow had fallen during the spring thaw – and high levels of coal dust in the ballast which had weakened the track structure due to the lack of proper ballast support.

While Greg Fox focused on the short-term engineering and maintenance responses to the derailments, he asked me to take the lead on dealing proactively with the coal dust problem from a long-term standpoint. It was clear that BNSF had to take measures to prevent a recurrence of the derailments and the severe adverse service impact to our customers caused by these outages. The widespread presence of such large quantities of coal dust along the right of way and in our track structure was not acceptable on high volume rail lines like those in the PRB that were of such critical importance to the rail network and to the nation's economy. BNSF decided to expand substantially its prior efforts to understand the scope and causes of the coal dust problem in the PRB and to investigate possible ways to curtail coal dust emissions. I took the lead on this new project.

BNSF has given the highest priority to these efforts. Throughout my work on this project I have consulted with senior management at BNSF, informed them of my progress and obtained approval for the actions we have taken. It was widely agreed among senior BNSF management that the presence of large quantities of coal dust on the right of way presented unacceptable risks to the reliability of coal transportation in the PRB. We also believe that over time coal dust deposits on BNSF's track and right of way will grow outside of the PRB. Unless measures are taken to curtail coal dust emissions, service to other shippers could be adversely affected.

BNSF Immediately Set Up an Expanded Data Collection Network so that the Coal Dust Problem Could Be Addressed on a Scientific Basis.

The fact that large quantities of coal dust escape from loaded coal cars in transit is undeniable. Accumulations of coal dust are obvious in many areas along the right of way in the

PRB. *See* Exhibit 2. Plumes of coal dust can often be seen from passing coal trains. *See* Exhibit 3. When standing near the rail lines, I have often had to avert my face when a loaded coal train passes to avoid being pelted with coal particles. I have even heard the impact from coal on my hard hat after turning my face away from the coal pieces coming off the top of the rail cars. As we expanded our investigation, we have also observed coal deposits on our track structure outside of the PRB, although to a lesser degree than is seen on the PRB trackage. This is particularly evident on certain subdivisions where our coal traffic was and is a fairly significant part of our overall traffic.

While the problem of coal dust is obvious, BNSF wanted to make sure that any efforts it took to deal with the problem were based on a solid factual and scientific basis. So BNSF undertook to develop facts and data that would support any actions it took to address the problem. To help BNSF collect the necessary data, BNSF retained Simpson Weather Associates ("SWA"), an environmental firm that had substantial experience in addressing the problem of coal dust emitted from moving coal trains. SWA had worked extensively with the Norfolk Southern in the late 1970s and 1980s to address the problem of coal dust emissions from loaded rail cars of export coal moving from West Virginia to Norfolk and I believed that SWA could help BNSF expand and improve its data collection efforts. Before the derailments, BNSF had been working with an environmental engineering firm, Conestoga-Rovers and Associates ("CRA"), to conduct preliminary studies of coal dust accumulations. I concluded that it would help to bring SWA into this effort to work with CRA and take advantage of SWA's particular expertise in the area of coal dust. SWA began working extensively with BNSF in the summer of 2005 and has worked with BNSF since then. The President of SWA, G. David Emmitt, is

submitting a Verified Statement in this proceeding that describes the data collection efforts and protocols initiated by SWA from 2005 until the present.

To summarize briefly those efforts, SWA first set up an expanded network of dustfall collectors. Prior to the derailments, CRA had set up dust traps that collected dust accumulating on the ground next to the tracks. BNSF estimated that an average of about 80 pounds of coal dust accumulated each year in the coal traps. *See* Exhibit 1 at BNSF_COALDUST_0035071. SWA recommended that BNSF use a somewhat more sophisticated dustfall collector that was mounted slightly above the ground to estimate dust fall rates. SWA also recommended that several dustfall collectors be set up perpendicular to the tracks to measure the rate at which dust falls onto the right of way at different distances from the track and that the network of dustfall collectors be expanded along the Joint Line. *See* Exhibit 4. BNSF implemented these recommendations.

SWA also provided us with information on the use of surfactants and grooming of the coal loads in rail cars as was being done for Norfolk Southern export coal at the mines in West Virginia. Surfactants are chemicals sprayed onto the loaded coal to form a protective crust or an adhesive layer that holds the coal inside the car. I discuss in more detail below the use of surfactants on loaded railcars and the benefits that can be obtained by grooming loaded cars or by changing the load profile of the coal loaded into coal cars.

SWA also recommended that BNSF establish a Track Side Monitor ("TSM") station that would gather data on coal dust emissions from individual coal trains and collect additional information to help put the dust emission data in context. A TSM consists of a weather station and an electronic dust monitoring device mounted on a tower. *See* Exhibit 5 at BNSF_COALDUST_0079694. Based on designs SWA had used with NS, SWA provided

BNSF with a TSM that we set up at Milepost 90.7 on the Joint Line. We looked at several different sites for the TSM and chose Milepost 90.7 because that was a location where significant dust had accumulated in the past and because power was available nearby to support the TSM instruments. A tower was set up initially on one side of the track and later expanded to both sides of the track so that the dust monitor on the eastside tower could measure coal dust emissions from passing trains when the wind was blowing from the west and the westside monitor could measure coal dust when the wind was blowing from the east. The TSMs collect data on the ambient conditions and dust readings for each train passing the TSM and transmit the data directly to SWA. BNSF began collecting data on all passing trains in September 2005.

An important part of the TSM is the dust monitor, referred to as an e-sampler. The e-sampler measures the amount of dust emitted by individual trains passing the location of the TSM tower on which the e-sampler is mounted. *See* Exhibit 6. The e-samplers used in our TSMs are the best equipment available for measuring dust emissions in the field in part because they take measurements often enough to determine accurately the coal dust levels during the entire period that a train is passing by the TSM. I insisted that BNSF use state of the art equipment and I am confident from the research performed by SWA that no other equipment available today would provide the same level of detail and reliability as the instruments used in the TSMs. Of course, the environmental monitoring technology is evolving and it is possible that new or more sophisticated generations of dust monitoring devices will become available in the future. BNSF will remain open to using superior dust monitoring equipment as it becomes available. But the problem of coal dust must be addressed now, and BNSF is therefore relying on the best dust monitoring equipment that is available today.

The third data gathering approach recommended by SWA was also based on work that SWA had done for NS. SWA developed a set of instruments that could be mounted on individual coal trains and used to collect data along the entire route of movement of the train. The instruments consist of (1) a Rail Transport Emission Profiling System ("RTEPS") device, which is essentially a combination of a mobile weather station and an airborne dust monitor similar to the e-samplers used at the TSMs, and (2) Passive Collectors ("PCs"), which are metal boxes attached to the sill of coal cars that collect coal dust particles that are blown off of the loaded cars. *See* Exhibit 7. These instrumented trains are the best and quickest way of determining whether a particular coal dust containment technique is effective. For example, as discussed further below, it was possible to use the RTEPS/PCs to determine the relative effectiveness of different chemical surfactants without testing a large number of trains, which would have been necessary if we relied only on data gathered by the TSMs. With the permission of individual shippers, BNSF, CRA and SWA were able to set up RTEPS/PCs on trains where some cars were treated with a surfactant and other cars were left untreated. The relative effectiveness of a particular surfactant could be determined by comparing the amount of dust collected in the PCs attached to treated and untreated cars. I discuss in more detail below the tests that BNSF, CRA and SWA conducted on surfactants and the conclusions that we reached based on these tests.

BNSF Kept Its Coal Shippers Closely Informed of These Efforts and Responded to Numerous Questions and Data Requests from the Shippers.

From 2005, shortly after the derailments, and continuing through most of 2007, BNSF worked intensively with the National Coal Transportation Association ("NCTA") to provide results of tests and data analyses on coal dust issues and to respond to questions from NCTA members. NCTA is an association of coal producers, rail car owners and coal consumers that

deals with issues relating to coal transportation. We participated in quarterly meetings of NCTA and worked with a number of NCTA committees to collect, analyze, and distribute data and other information that BNSF was developing as it studied the problem of coal dust. We provided NCTA with regular updates on the studies that were being carried out. To give the Board an understanding of the high level of interaction with NCTA and the detailed presentations that BNSF was making to coal shippers during this time period, I attach to this statement some representative presentations that BNSF made to NCTA from November 2005 through August 2007. *See* Exhibit 6; *see also* Exhibit 8. BNSF employees and consultants attended the NCTA meetings and engaged in extensive dialog with NCTA members regarding coal dust issues. Employees of Union Pacific Railroad Company ("UP") also participated extensively in the NCTA presentations.

BNSF did far more than just keep NCTA members informed of the results of its data collection and analysis. From 2005 through 2007, BNSF also performed numerous studies at the request of NCTA members. During this time period, BNSF spent nearly $2 million on efforts to respond to NCTA members' questions. As we continued our studies in 2008 and 2009, we spent an additional $2.2 million. These expenses do not include the costs incurred by UP for its portion of the coal dust study efforts under the Joint Line Agreement. I describe below some of the studies we performed.

One of the mines suggested that the size of coal loaded into coal cars might affect the amount of dust that is emitted from the loaded cars in transit. Specifically, the mine was interested in knowing whether coal dust emissions could be substantially reduced by crushing coal to 3 inch pieces instead of 2 inch pieces. BNSF used several trains equipped with RTEPS/PCs over 5 days to test the relative dust emissions from coal that had been crushed to 2

inches versus 3 inches. We found that there was a notable reduction in coal dust emissions, about 30%, from the use of 3 inch coal. *See* Exhibit 5 at BNSF_COALDUST_0079736-42. We provided NCTA with the results of our study. I am not aware that the mines made any changes in their practices or that the shippers requested any changes in mine processes based on these study results.

BNSF advised NCTA members that its primary concern was that coal dust was contaminating the track structure, most importantly the track ballast, which could lead to an unstable track structure under circumstances similar to those in 2005. Some NCTA members speculated that the contaminants BNSF was finding in the rail ballast were attributable to brake dust released from rail car brake shoes rather than coal escaping from the coal cars. BNSF collected samples of contaminated ballast and samples of brake dust and carried out several analyses, including x-ray diffraction tests and infrared spectra analyses, to determine whether brake shoe dust was present in the ballast in significant quantities. These tests showed that the contamination in the ballast was attributable to coal dust and not brake shoe dust. *See* Exhibit 5 at BNSF_COALDUST_0079792-808. We presented the results of these studies to NCTA members.

Some NCTA members expressed skepticism that the coal that was accumulating on the right of way had come off of the top of loaded coal cars and they speculated that the problem of coal dust accumulation might instead be primarily attributable to coal leaking out of the bottom of bottom dump coal cars. Some coal cars used in the PRB are cars that are loaded from the top but release the coal at the utility destinations through outlet doors on the bottom of the car. If the bottom doors on these cars are not tightly closed when the cars are loaded, coal can escape through the bottom doors onto the right of way. To determine the relative amount of coal that is

lost through bottom dump cars we equipped several cars with fiberglass bins that collected the coal dust lost through the bottom of the car. *See* Exhibit 9. We concluded that on average, these cars lost about 12 pounds per 100 miles per car per trip. *See* Exhibit 5 at BNSF_COALDUST_0079788-89 (average of all values). BNSF and UPRR both took action by repairing their steel bottom dump rail cars to ensure adherence to maintenance standards for bottom dump cars and to minimize any losses of coal through the bottom of cars. BNSF also issued Coal Car Bottom Outlet Door System Validation Procedures to our mechanical rail car inspection teams to check bottom outlet door latches, to view outlet doors for gaps, to verify that the secondary lock is properly engaged, and to check primary lock indicators to see if they are damaged or need adjustment. If a defective door is identified, the car would be taken out of service and sent to the mechanical shop for repairs. *See* Exhibit 10; *see also* Exhibit 11.

We then compared the bottom dump losses with the loss of coal from the top of loaded cars. The amount of coal lost off of the top of a car could not be collected and measured directly, but we were able to make rough estimates of the coal losses from the top of loaded cars using lasers to measure the volume of coal in a car at the beginning of a trip and the volume of coal in the car at the end of the trip. This analysis basically measured the difference in the elevation of the coal in the car before and after the train moves a certain distance. Based on these analyses, we estimated that somewhere between 250 and 750 pounds per car are lost in transit. *See* Exhibit 8 at BNSF_COALDUST_0034962-66. We also found research carried out in Canada that concluded that as much as 2% of the total volume of coal in the rail car (2 tons from a 100 ton car) can be lost in transit. These are only rough estimates and more precise measurements could be made in the future of the amount of coal lost out of the top of cars as they move from the mines to the utilities. But the analyses on which these estimates are based make it clear that

substantial volumes of coal are blown out of coal cars in transit and that the volume of coal emitted from the top of coal cars substantially exceeds the amount of coal escaping from the bottom of the cars. We also presented the results of these analyses to NCTA.

Another issue raised by NCTA members was the availability of water near the mines for use in applying surfactants to loaded coal cars. Surfactants are usually delivered to the mines in a concentrated form and they need to be combined with water before being applied to the coal. There was a concern that inadequate supplies of water existed in the PRB to support widespread use of surfactants. Mark Murphy of CRA did a study of potential water sources. He found that while surface water resources were relatively scarce in the region, there were adequate sources of well water to support the use of surfacants. *See* Exhibit 5 at BNSF_COALDUST_0079809; *see also* Exhibit 12.

BNSF Determined That Coal Dust Emissions From Loaded Coal Cars Have To Be Curtailed.

As our analysis of the coal dust problem progressed, it became clear that the only effective and responsible way to deal with the problem was to substantially reduce coal dust emissions from loaded coal cars. The derailments and our further studies confirmed that coal dust emissions had to be substantially eliminated. Coal dust is a particularly serious contaminant of track ballast and poses serious challenges when it accumulates along rail lines such as those in the PRB that handle extraordinarily large volumes of coal traffic. Ballast is the layer of coarse granite aggregate on which the rails and ties rest. The track structure relies on ballast as the foundation of its structural integrity, very similar to a bridge span relying on the bridge abutments for its foundation. The purpose of railroad ballast is to provide drainage and structural support for the heavy loads that are transmitted to the ballast from the wheels of a heavy train on the rail, the rail on the tie plates or pads, the tie plates or pads on the ties and then ultimately to

the ballast. When the ballast is fouled by contaminants, its load bearing properties are adversely affected and the track structure integrity can become severely compromised. These problems are especially acute with coal dust which acts like clay and becomes "slimy" or slippery when wet, thereby compromising the interlocking capabilities of the individual granite rocks in the ballast. Wet coal dust further prevents the drainage of water out of the ballast section.

In 2006, BNSF commissioned a study by Professor Erol Tutumluer at the University of Illinois at Urbana-Champagne to examine the properties of fouled ballast. Professor Tutumluer had conducted preliminary tests on ballast collected at a derailment location in Nebraska and he proposed to expand his tests to include different types of ballast and different types of ballast contaminants, including coal dust. *See* Exhibit 13. Professor Tutumluer carried out his study and reported to BNSF his conclusion that coal dust was a particularly severe source of ballast fouling. He noted that while coal dust had not previously been identified as a significant ballast contaminant, in fact, it has characteristics that make it one of the worst fouling agents. He found that coal dust has a very high water holding capacity which limits drainage in ballast fouled by coal dust. His tests also showed that ballast contaminated by coal dust has a much lower load bearing capacity, which is an obvious problem for PRB lines that carry a greater volume and annual tonnage of freight than any other rail lines in the United States. Particularly when it gets wet, coal dust can have a highly destabilizing effect on rail ballast. *See* Exhibit 14. Since providing BNSF with the results of his study, Professor Tutmuluer has continued to examine the properties of coal dust and is submitting a Verified Statement to the Board in this proceeding on the character of coal dust as a ballast fouling agent.

Coal dust accumulates rapidly and in large quantities along the PRB rail lines. We have been surprised at the rate of accumulation. As explained by Craig Sloggett, BNSF's General

Director of Maintenance & Planning in his Verified Statement, we have found significant accumulations of coal dust on PRB lines to occur within as short a period as six months. In one area, we found that brand new track installed with clean materials from the native ground up to the track level had been contaminated with coal dust in a few months. On one bridge, we replaced the ballast materials in 2007 down to the concrete structure or tub that the ballast and track sits in, and we found in 2009 that the entire process needed to be repeated because of coal dust contamination all the way down to the bottom of the concrete tub. There were at least 12 inches of compacted ballast contaminated by coal dust all the way to the bottom of the tub. In 2008, we carried out a large coal dust clean-up exercise, focusing on coal that had accumulated above ground in creek beds, next to the tracks and along bridge abutments. We filled over 300 rail cars with the dust that had been collected and transported the coal to a landfill.

While the coal dust accumulates rapidly and visibly in some areas, it is often difficult to detect because it quickly makes its way down into the ballast. As Mr. Sloggett explains, on some sections of track that appear to be clean, coal dust can be right below the top rocks and further down below the surface. *See* Exhibit 15. This makes it difficult to carry out surgical maintenance of fouled ballast. Visual inspection of the rail bed cannot be relied on to locate areas where fouling has occurred. As a result, more widespread maintenance activity must be carried out to make sure problems do not develop. For example, on high volume rail lines, BNSF would expect to undercut the track structure generally on 10-year cycles. Undercutting involves removal and replacement of the ballast and locations are prioritized based upon condition. We are finding that in some areas on the Joint Line, undercutting may be needed as often as every two or three years.

This increased maintenance activity is not only costly, it also substantially reduces the capacity of the rail lines. Traffic must be slowed down to allow the maintenance activity to be safely carried out. In addition, BNSF is forced to carry out extraordinary inspection and track monitoring activity, particularly during rainy months, in an effort to detect problems caused by coal-fouled ballast before service is affected. While the additional inspection and monitoring activity is being carried out, the tracks cannot be used to provide service. With the severe winter weather in Wyoming, we are limited to performing our capital maintenance work in the summer or mild weather months, putting great pressure on capacity that is already strained.

It is not acceptable to operate the high volume PRB lines while constantly trying to play catch-up with the coal dust emitted from loaded rail cars. BNSF's approach is to proactively operate a safe and efficient railroad. The problem of coal dust is not one that can or should be dealt with through maintenance but has to be addressed by substantially eliminating the dust that is emitted onto the rail lines from loaded coal cars.

BNSF Has Taken the Steps Within Its Control To Curtail Coal Dust Emissions.

One of the first things that Dr. Emmitt noticed when he started working with BNSF in 2005 was that the profile of loaded coal in the coal cars had steep angles and irregular surfaces that made the coal susceptible to being blown off during transit. He had done studies for NS on the benefits of loading coal cars with a more aerodynamic profile and he recommended that the load profile of coal cars loaded at PRB mines also be changed. He provided us with an ideal load profile design for a rounded breadloaf shape. *See* Exhibit 16. This breadloaf shape took into account the natural angle of repose of the PRB coal, which is the slope that a coal pile would naturally take from the effect of vibration and wind through a train's movement. When the breadloaf angles match the natural angle of repose at the beginning of the trip, the coal is less

likely to blow off of the top of the car during the trip, since the coal is already in its natural angle of repose.

Some NCTA members were concerned that modifying the load profile would reduce the amount of coal that could be loaded into the coal cars. They were also concerned that the load profiling would increase the time to load a train. SWA did laser analyses of loaded coal cars and showed that use of a more aerodynamic load profile would simply redistribute the coal within a car without reducing coal volumes. It was evident that in poorly loaded cars there were air pockets in the back and front of the rail car where coal could be redistributed without reducing the loading volumes. We determined that a modified loading chute design could be used by the mines to produce a more aerodynamic load profile. *See* Exhibit 17. We starting working with one mine to test the new loading chute and we found that it improved the load profile without impeding the loading process. This mine also confirmed that it could load the coal into the train without adversely increasing loading time. We then worked with the other PRB mines to persuade them to use the improved loading chutes. *See* Exhibit 18.

Changing the load profile reduces coal dust emissions, but the precise extent of the reduction is uncertain. Data from the dustfall collectors suggests that the reduction in coal dust that has resulted from modified loading profiles has been in the range of 15% to 20%. *See* Exhibit 19 at BNSF_COALDUST_0064122. One reason for the limited benefits we have seen is that the use of a modified loading chute alone does not guarantee that the ideal load profile is achieved. The loading operator plays an important role in loading cars with the proper profile, and we have found that sufficient care is not always given to the loading process. In an effort to improve loading practices, SWA has established a Coal Car Load Profiling System ("CCLPS"), which uses lasers to read the loading profile of a car shortly after it has been loaded and allows

us to give immediate and reliable feedback to mines on the profile of the loaded cars. *See* Exhibit 20. Even if loading practices were perfect, improved loading would not eliminate the majority of coal dust emissions.

Another early and effective step that BNSF has taken to reduce coal dust was the overhaul and enhanced maintenance of bottom dump coal cars in BNSF's car fleet to reduce dusting from the bottom. As noted above, our analyses showed that substantially more coal was being lost from the top of loaded coal cars than from the bottom of bottom dump cars. However, coal losses from those bottom dump cars were significant and cannot be ignored. Therefore we instituted a multi-year program to expand the inspection and repair of the older fleet of bottom dump steel cars. Car doors have been tightened and adjusted and gaps or holes in the bottom of the cars have been caulked shut. New maintenance practices have been instituted to ensure proper operation of the bottom dump doors as described previously.

Further Reductions In Coal Dust Emissions Can Only Be Achieved Through Shipper Compliance With the Coal Dust Emissions Standards that Are the Subject of this Proceeding.

The improved loading of loaded coal cars and the enhanced repair and maintenance of bottom dump rail cars addresses only a small part of the coal dust problem. Effective curtailment of coal dust must include strict limits on the emission of coal from the top of loaded coal cars. BNSF does not load coal cars and the freight loaded into the cars does not belong to BNSF. The steps necessary to limit coal dust emissions from the top of loaded coal cars must be taken by the shippers and the mines. No shipper of any other commodity is allowed to release their commodity onto BNSF's rail lines or property and to create the risk of serious service disruptions by contaminating the rail ballast. BNSF has no interest in dictating how the shippers and the mines choose to limit coal dust emissions. BNSF's only interest is in substantially

eliminating the coal dust emissions. Indeed, by leaving to the shippers and mines the flexibility to address the issue of coal dust emissions as they see fit, BNSF believes that competition and market forces will lead to the adoption of the most efficient and cost-effective remediation approaches for the shippers and the mines.

The most obvious way to eliminate coal dust emissions from loaded cars would be to cover the loaded cars with tops. If the shippers and their mine agents were currently covering all loaded coal cars, no coal dust emission standard would be needed. The use of car tops would effectively eliminate the coal dust problem. But BNSF realizes that significant costs might be involved in converting to the use of car tops. Moreover, other technologies may become available that could generate the same benefits as car tops with less cost. Therefore, BNSF chose to adopt an emissions limit instead of prescribing any particular coal dust suppression approach. This gives shippers and their mines the freedom to adopt the measures they believe will be the most efficient and cost effective in meeting the emissions limit.

The coal dust emissions standards at issue in this proceeding and the process of adopting them are described in detail in the Verified Statement of Charles Sultana. Mr. Sultana is an expert in the Six Sigma methodology, which is a process for solving business problems that relies heavily on facts and data. As explained above, BNSF had been collecting massive amounts of data on coal dust emissions since 2005. In particular, since September 2005, the TSM set up at Milepost 90.7 had been collecting train-specific data on coal dust emissions on all trains passing that milepost. When Mr. Sultana joined BNSF in 2006, Mr. Sultana was asked to help understand and evaluate the data being collected. I subsequently asked Mr. Sultana to bring his data analysis skills to bear on identifying a coal dust emissions standard which, if met by all

trains passing Milepost 90.7, would substantially eliminate coal dust emissions at that point on the Joint Line.

The adoption of a coal dust emission standard applicable to trains passing a particular milepost flows from the practical requirements of measuring coal dust from moving trains at a fixed location. It is analogous to the use of a traffic policeman to enforce speed limits on a long stretch of highway. As a practical matter, the traffic policeman must choose a spot and measure speed from that spot only. There can be no assurance that a car exceeding the speed limit at the measurement location actually was speeding on other sections of the highway or that a car below the speed limit at that location had never exceeded the speed limit on other sections of the highway. But the practical limits on enforcement require that enforcement efforts be limited to a single location. Those same practical factors required that we develop a standard applicable to Milepost 90.7, which was where the equipment used to measure coal dust emissions was located for the Joint Line and where the data on coal dust emissions had been gathered since September 2005.

Mr. Sultana started with the train-specific data for trains passing Milepost 90.7 from September 2005 through August 2007. As described by Mr. Sultana and Dr. Emmitt, SWA had used the data collected by the electronic dust monitors on the TSMs to identify an "Integrated Dust Value" or "IDV" for each passing train. The IDV was a measurement of the number of coal dust units emitted by the train when passing Milepost 90.7. By August 2007, SWA had improved on the calculation of the IDV and was now using an improved form called IDV.2. *See* Exhibit 21. Mr. Sultana added together all of the IDV.2 units associated with the trains passing Milepost 90.7 from September 2005 through August 2007 and identified the IDV.2 value which, if it had not been exceeded by any of the passing trains during that time period, would have

eliminated 95% of the total dust units emitted by the passing trains. The value he identified was an IDV.2 of 134.

As Mr. Sultana explains, he also found that the e-sampler dust monitors used on the TSMs produced somewhat varying IDV.2 readings on the same air sample of coal dust. This variation is unavoidable given the equipment being used, but Mr. Sultana concluded that it could be addressed by setting a maximum IDV.2 level that takes account of the variation through accepted statistical techniques. Mr. Sultana identified the range of variability and concluded that a train producing coal dust at an IDV.2 level of 134 could produce an IDV.2 reading on another dust monitor of as much as 300. Therefore, to be sure that trains producing 134 or less would not be found to violate the IDV.2 standard, he set the maximum IDV.2 standard to 300. *See* Exhibit 22. As Mr. Sultana explains, the standard is very conservative. Mr. Sultana performed the same analysis using data that had been collected at Milepost 558.2 on BNSF's Black Hills Subdivision and set a maximum IDV.2 level of 245.

When SWA provides BNSF with IDV.2 data on trains passing the TSM, SWA excludes trains where the dust reading might not be properly attributable to the train, for example when the train passed the TSM just as another train was passing on a parallel track. We found that in 2009 almost 14% of trains passing Milepost 90.7 for which there were usable IDV.2 data exceeded the IDV.2 standard. However, this does not mean that only 14% of the PRB coal trains are emitting large amounts of coal dust on the PRB lines. It means only that 14% of the PRB trains are emitting coal at levels above our performance standard at the specific point where the TSM is installed. Coal dust emissions from moving coal trains are highly episodic. A loaded coal train could pass Milepost 90.7 with no coal emissions only to emit a large plume of coal dust a mile or less away. Tests we carried out using instrumented trains show that episodes of

dusting occur all along the PRB rail lines. *See* Exhibit 23. Our monitoring efforts are limited by the practical need to set up monitoring devices at a fixed location. However, we are confident that if the shippers and mines take action that is sufficient to substantially eliminate coal dust emissions at Milepost 90.7, those same efforts will result in the substantial elimination of coal dust along the entire Joint Line and Black Hills Subdivision lines. For example, if the shippers and mines adopt surfactant programs that limit coal dust emissions at Milepost 90.7 on the Joint Line and Milepost 558.2 on the Black Hills Subdivision to the levels specified in the standards at issue here, BNSF is confident that coal dust throughout the PRB will be eliminated.

BNSF Has Conducted Substantial Testing of Surfactants That Yields Promising Results.

Surfactant application is a well established way to reduce coal dust emissions from coal cars in transit. *See* Exhibit 24. I understand that NS has successfully used surfactants to curtail emissions and that surfactants are also used in Canada. Surfactants can be used to create a crust or artificial lid that keeps coal dust in the car. Other surfactants create an adhesive coating that causes coal particles to stick together. There are several different coal surfactants available on the market today with a range of characteristics.

BNSF began testing surfactants even before the derailments in 2005 as a means of reducing coal dust emissions. After retaining SWA, we expanded substantially our testing of surfactants. SWA conducted laboratory tests on dozens of products for characteristics likely to reduce or eliminate coal dust emissions. SWA did tests on the erosion properties of treated coal, the effect of rain simulation, solar heat, wind, curing time, penetration depth, static strength, and freeze recovery. BNSF tested numerous products to ensure that products used in field tests would not corrode railcars, were not harmful to handle, and were non-hazardous to field personnel. One of BNSF's coal shippers tested surfactants in its laboratory to make sure the

surfactants were not harmful to a utility's boilers. Through these tests, we identified numerous promising surfactant products and set up field tests on the effectiveness of those products.

I have described above the instrumented trains that use RTEPS/PCs that monitor ambient conditions and coal losses throughout an entire route of movement. Beginning in 2005, we used those trains to test the effectiveness of various surfactants. We generally set up the trains so that the RTEPS instruments were mounted onto one of the last cars on the train. The RTEPS would allow us to monitor conditions like wind speed, humidity, or rainfall that might have an impact on the effectiveness of a particular surfactant. Then, with the shipper's permission, we would divide the train into groups of treated and untreated cars and mount PCs on the rear sill of the last car in each group. We would then collect and weigh the dust collected in the PCs to determine the effect of surfactant treatment on the loss of coal from the car. Based upon the testing and evaluations we have completed, we are confident that proper application of a quality surfactant onto a properly profiled loaded coal car can reduce coal dust emissions from the rail car top by more than 85%.

When BNSF extended the effective date of its Rules Publication 6041-B, items 100 and 101, in October 2009, BNSF announced, in response to requests from our shippers, that it would conduct a large-scale trial of dust mitigation methods, focused on surfactants, to give shippers and the mines further opportunities to assess potential remediation measures. The trial, which is currently underway, will give shippers and the mines an opportunity to test various products and to assess their effectiveness in reducing coal dust emissions. *See* Exhibit 25. Products are selected for the trial only if they first pass the SWA laboratory analysis showing that the products have promising dust suppression characteristics and the BNSF tests showing that they are not harmful. There is a selection committee consisting of shippers and mines that will determine

which products to test after the initial testing of two products is completed. We are conducting field tests using the RTEPS/PCs described above. Testing is conducted on trains that are half-treated, leaving the other half untreated as a control, and performance reports on each train tested are sent to all the trial participants. We are also monitoring the dust emissions from passing trains using the TSMs and providing the IDV.2 data generated by the dust monitor on the TSMs to the participants in the trial. The trials are expected to run until the end of August 2010, and the total tonnage to be tested is 36.2 million tons. BNSF is confident that the data generated in the current trial will give shippers and the mines information that will allow them to make informed decisions regarding what measures they should adopt to achieve compliance with BNSF's coal dust emissions standards.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

William VanHook

VERIFIED STATEMENT OF CRAIG SLOGGETT

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF CRAIG SLOGGETT IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

I am Craig Sloggett, General Director, Maintenance for BNSF Railway Company ("BNSF"). My office is located in Gillette, Wyoming, and I have responsibility for the overall maintenance and maintenance planning on BNSF's Powder River Division, which territory includes all of the BNSF coal routes into and out of the Powder River Basin ("PRB"), including both the Joint Line and the Black Hills Subdivision. In this capacity, I oversee two Division Engineers who are responsible for the entire Powder River Division and all engineering personnel under their supervision. Further, I am responsible for the maintenance of the signal, bridge and other property of the BNSF on the Powder River Division, exclusive of mechanical and communication facilities.

The purpose of my verified statement is to convey from my firsthand experience the magnitude of the coal dust problem on the Joint Line and Black Hills Subdivision and the impact that coal dust is having on the railroad. I will also explain why, from the perspective of BNSF's maintenance-of-way efforts, it is essential to limit emissions of coal dust from railcars.

I have worked for BNSF or its predecessor, the former Burlington Northern Railroad, for 32 years, during which time I have held a variety of positions with responsibility for railroad engineering and maintenance. I began my career in 1978 as a track laborer. After holding

various front-line maintenance jobs, I became a supervisor, first as Assistant Roadmaster and then as Roadmaster. In the early-to-mid 1990s, I was the Roadmaster responsible for the line from Gillette, Wyoming to Edgemont, South Dakota on the Black Hills Subdivision, which is one of BNSF's primary coal routes leading to and from the PRB coal mines. I was later promoted to various capital planning positions and eventually became a Manager of Gangs with responsibility for all maintenance gangs across four of BNSF's Divisions. In 1998, I became a Division Engineer overseeing all maintenance-related personnel for BNSF's Southwest Division. This Division includes the New Mexico portion of the high density BNSF intermodal route between Los Angeles and Chicago (referred to as the "transcon"), as well as several New Mexico coal mines served by BNSF. In 2007, I became Division Engineer for the Powder River Division with responsibility for overseeing all maintenance-related personnel for that Division. Later in 2007, I was promoted to General Director, Maintenance for the Powder River Division, which is the position I currently hold.

Coal Dust is Accumulating at Alarming Rates and Threatening Track Stability.

My first position in the PRB was as Roadmaster on the Black Hills Subdivision in the early-to-mid 1990s. At that time, small amounts of coal dust were visible in certain parts of my territory but the coal dust did not accumulate in quantities that had a significant or adverse impact on track integrity. When I returned to the area in 2007 as Division Engineer, I was shocked by the amount of coal dust accumulating in the ballast, on the track, and on the railroad right of way on both the Black Hills Subdivision and the Joint Line. I recall my first trip to the Powder River Basin in my new position in 2007. I was driving alongside the Joint Line track near Nacco Junction. I saw ahead of me on the track the headlight of the lead locomotive on a loaded coal train encircled in a cloud of black dust. This is a regular occurrence on the Joint

Line and Black Hills Subdivision. I have experienced on many occasions the feeling of being pelted with coal particulates when standing on the railroad right of way while a loaded coal train passes by. When I park my white truck along the coal routes, it becomes covered in black coal dust from passing trains.

Since my return to the Powder River Division, I have seen firsthand the extent to which the accumulation of coal dust causes damage to the railroad infrastructure, in particular, to the ballast that is so critical to permitting moisture to drain away from the railroad ties and track. When ballast becomes fouled with coal dust and cannot drain properly, it begins to break down, lose its stability, and allow railroad ties to break and/or the track to move out of alignment, which can lead to train derailments if not repaired. These are unsafe conditions that require the imposition of a slow order or speed restriction until appropriate maintenance can be performed or, in some cases, require the track to be taken out of service altogether so that necessary repairs can be made immediately so that the affected area may provide for the safe passage of trains again. For example, in May 2008, our inspectors imposed 25 mph slow orders on multiple sections of track between MP 90.5 and 103.6 that were severely fouled with coal dust until track windows could be scheduled to perform undercutting to clean and replace fouled ballast. In October 2007, when we discovered a section of track near MP 75.3 with extensive ballast contamination, we lowered the track speed limit from 50 mph to 25 mph until the track could be taken out of service for undercutting. These are only two examples of numerous slow orders and track windows required to address the accumulation of coal dust and its effects on the track structure.

During seasons of high precipitation, particularly though not exclusively in the spring and summer, railroad track structure is particularly vulnerable to moisture. In the spring in

Wyoming, the frozen ground begins to thaw, releasing moisture. During the spring thaw, we typically experience snow and rain, which adds to the moisture level in the ground. When railroad ballast is fouled with coal dust, it is unable to serve its primary purposes of allowing moisture to drain away from the track and supporting the track structure. Heavy rain or snow can quickly overwhelm the ability of fouled ballast to drain water away from the track. Summer rains can cause the same problem. Pictures illustrate the effect of coal dust and moisture on ballast most effectively. *See* Exhibits 1-3. Track structure with fouled ballast deteriorates very quickly in wet conditions. I have seen sections of track that appear to be in sound structural condition and then, within 24 hours of a precipitation event, a portion of the track begins to dip or sink, as the ballast below it retains water and begins to give way.

Fouled ballast can be difficult to detect. In some instances, the presence of mud or other moisture and the accumulation of coal dust may indicate to track inspectors that ballast may be fouled. In other instances, there are no obvious visible signs, as most railroad ballast is hidden within the track structure and only the rock on top is visible. On the Joint Line, ballast must extend a minimum of 12 inches below the bottom of concrete ties and it is difficult to see into the ballast beyond the first inch or two without digging into the ballast itself. Exhibit 4 contains a picture of track that appeared to be in good working condition on the surface. However, when BNSF engineering personnel dug into the ballast, they discovered extensive coal dust contamination several inches below the surface.

Coal dust accumulation on the track (e.g., on the tie plates, on top of the bottom flange of the rail, and on the ties) and on the right of way is more visible than coal dust accumulation in ballast and therefore easier to detect. Even though visible, such accumulation may also cause significant problems for the railroad. For example, coal dust accumulation on the track interferes

with the proper inspection of ties and rail by BNSF engineering personnel and is likely to work its way into the ballast. When coal dust accumulates at switch locations, over which a train switches from one track to another, it can impede the proper working of switches, ignite from the heat generated by railroad heaters used to keep the switches from freezing in the winter, and, due to increased vibration from a train passing through a switch, coal dust can vibrate down into the lower levels of the ballast section supporting the switch, taking moisture with it when wet. *See, e.g.*, Exhibit 1. Coal dust fires burn and smolder for long periods of time and can be very difficult to extinguish, particularly when they are fueled by large amounts of coal dust, both on and off the track. When coal dust accumulates on the right of way, it can also catch fire and burn for miles along the track.

The coal dust problem today is quite evident from the visible accumulation on both the Joint Line and Black Hills Subdivision. The accumulation I have experienced in the last three years far exceeds the minor accumulation that I saw while working on the Black Hills Subdivision 15 to 20 years ago. It is a constant battle to remove coal dust from the track and surrounding areas and to repeatedly clean ballast across the territory that has become severely fouled with coal fines. Below are a few examples of the very rapid accumulation of coal dust emitted from passing trains:

- In the early spring of 2009, we undercut a fouled section of track ballast near MP 90.5. In October of 2009, we undercut a section next to the one undercut in the spring and purposely overlapped the prior track ballast. The new "clean" ballast from that section was already severely fouled with coal dust in just a few months. *See* Exhibit 1.

- BNSF recently constructed additional main line track on the Joint Line. In some locations the Joint Line now consists of three main lines (triple track) and in other locations the Joint Line consists of four main lines (quadruple track). For new track construction, BNSF first prepares the subgrade and then

places the subballast, ballast, ties and track along the new segment, without switches. Once the track is complete, BNSF then installs switches in the new track, which involves removing small sections of newly laid track and ballast to insert switches that allow trains to travel from one track to another. When we installed a switch in new quadruple track at MP 74, we discovered that the new ballast installed just a few months earlier was already contaminated with approximately 3 to 4 inches of coal dust that had filtered down through the ballast. We uncovered similar contamination when we installed a switch at MP 33, where we had recently installed new triple track.

- In 2006, before my return to the Powder River Division, BNSF undertook extensive ballast replacement in switch locations on the Joint Line. In 2007, many of these switches were reballasted because they had already become severely fouled with coal dust.

BNSF is Undertaking Unprecedented Maintenance Efforts to Address Coal Dust Emissions.

BNSF has undertaken extraordinary maintenance efforts on the Joint Line and Black Hills Subdivision to combat the accumulation of coal dust and its adverse impact on the railroad. In 32 years of railroad maintenance across the BNSF system, I have never seen another territory that requires such extensive maintenance. BNSF performs a variety of extra work not performed elsewhere on its system to prevent coal dust accumulation and associated fouled ballast. This work includes efforts to identify potential track problems, to remove coal dust from the ballast, and to remove coal dust from the track and right of way.

During periods of high precipitation and moisture in the Powder River Basin, in particular snow, rain and ground thawing in the spring and rains in the summer, we augment normal track inspection efforts by bringing railroad officers and other engineering department employees from all over the system to the Joint Line and Black Hills Subdivision to ride trains 24 hours a day. These efforts are in addition to and serve to supplement the inspections performed by BNSF track inspectors assigned to this territory. BNSF further supplements its

manual inspections with mechanical inspections by a track geometry car and a Track Strength Testing, Analysis and Recording ("TrackSTAR") car, both of which make detailed measurements of the track and rail condition and report irregularities outside of acceptable criteria. The TrackSTAR car also applies thousands of pounds of horizontal force on the rails and measures the movement of the rails outward. During the spring and summer, BNSF has brought a track geometry car to the Powder River Division to run continuously across these critical line segments to assist in the early detection of deteriorating track conditions. No other territory on BNSF has made these extraordinary inspection efforts a standard part of its inspection program.

Undercutting is a ballast maintenance technique used by railroads that involves lifting the track and ties off the ballast, removing the underlying ballast, cleaning it, and replacing it with clean ballast. As Division Engineer in the Southwest Division, it was my experience that the ballast on the majority of the BNSF transcon route, which is a high density line used primarily for intermodal traffic, needed to be undercut once every 15 to 20 years, while certain limited sections might need to be undercut every 10 or more years. In my experience working in the Powder River Division over the last three years, we have determined that certain segments of the Joint Line must be undercut every 2 to 3 years as a direct result of coal dust accumulation in the ballast. Other segments of the Joint Line where the coal dust may not accumulate as quickly must be undercut at least every 5 to 6 years, at least three times as often as the majority of BNSF's high density transcon line through New Mexico that services only a small number of coal trains. Below are several examples of track segments for which BNSF has had to accelerate its undercutting program in order to address coal dust fouled ballast:

- In October 2007, we discovered that a section of track near MP 75.3 was severely fouled with coal dust and required

immediate undercutting. That section had just been undercut in the fall of 2005 following the May 14, 2005 Joint Line derailment of a BNSF train that occurred less than a mile from that location. *See* Exhibit 5.

- Also in October 2007, inspection revealed coal dust fouled ballast on the bridge at MP 62, near the site of the May 15, 2005 Joint Line derailment of a UP train. This location had been undercut in August 2005 but needed to be undercut again in 2008. *See* Exhibit 4.

- In May 2008, our inspectors identified sections of track between MP 90.5 and 103.6 that required immediate undercutting. This track had been undercut and reballasted in September 2005, just 31 months prior. BNSF had planned to undercut this section of track in 2009, but the planned work had to be moved up to 2008, just over 2.5 years since the last undercutting. The root cause of this additional maintenance was determined to be coal dust accumulation that had fouled the ballast. *See* Exhibit 2.

- In August 2008, inspection revealed that main track one on the bridge near Nacco Jct., which had been undercut three years ago that very week, was fouled with coal dust and needed to be undercut again. *See* Exhibit 6.

In addition to more frequent undercutting, BNSF currently performs another ballast maintenance technique called shoulder ballast cleaning on the entire Joint Line annually. This technique involves removing all ballast at the shoulder of the track, removing accumulated particulates and replacing it with clean ballast. In my position as Division Engineer on the BNSF transcon route in New Mexico, we found that undercutting the track approximately every 15 to 20 years was sufficient to maintain ballast integrity and that the additional maintenance of shoulder ballast cleaning was not required.

BNSF has also undertaken extraordinary efforts to remove coal dust from the track and from the right of way. BNSF employs a variety of extra measures not performed elsewhere on its system to remove coal dust. Vacuum trucks are regularly employed to vacuum coal from the track and, in particular, the switch areas. BNSF uses a badger ditcher, which is a machine that

runs on the track and has an attachment with a digging wheel that picks up coal dust that has accumulated between the tracks. BNSF uses front end loaders and motor graters to consolidate accumulated coal dust along the right of way into piles for disposal or to recycle the coal dust for use as road base on the access roads along the BNSF right of way.

In 2008, BNSF undertook a large scale effort to remove accumulated coal dust from portions of the Joint Line with the greatest accumulation. The coal dust was consolidated into piles totaling more than 28,000 tons and loaded into more than 300 rail cars for disposal at a landfill. This volume does not include coal dust that had been previously vacuumed or used as roadbase. BNSF is currently engaged in another effort similar in scope to that performed in 2008 to remove additional volumes of accumulated coal dust. Without significant reduction in coal dust emissions, I expect that we will need to perform such large scale removals on a regular basis going forward.

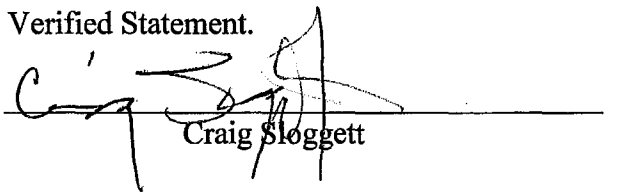
Both the Joint Line and Black Hills Subdivision are in operation 24 hours a day, 365 days a year. In order to perform the majority of its maintenance work, including undercutting, shoulder ballast cleaning, and most coal dust cleanup and removal, BNSF must slow or stop train traffic on the railroad line on or near where this work is being performed to ensure the safety of our workers and to ensure the safe passage of trains as we work on the track structure itself. To do so, BNSF may issue a slow order, restricting trains to a certain speed, or place a track window, during which time the track is out of service for maintenance, requiring trains to use other tracks as available. Wherever possible BNSF attempts to minimize the disruption that slow orders and track windows have on the flow of trains, but given that trains operate continuously around the clock, train delays are inevitable when the trains are slowed down or necessary track is taken out of service, thereby reducing the effective capacity of the railroad.

Conclusion

As described herein, BNSF performs extensive maintenance on the Joint Line and Black Hills Subdivision that is not required on its other line segments. These extraordinary efforts are necessary on these line segments to prevent failure of the track and underlying ballast, which is increasingly fouled with coal dust emitted from the continuous passing of loaded trains. As long as significant volumes of coal dust continue to be permitted to escape from trains, BNSF will face the risk of ballast fouling and resulting track instability. Due to the hidden nature of fouled ballast, there will always be the possibility that fouled ballast could go undetected. This risk of undetected fouled ballast underscores the need to address coal dust at the source by limiting emissions from loaded coal trains rather than attempting to clean up the coal after it has spilled out of coal cars.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010



Craig Sloggett

VERIFIED STATEMENT OF CHARLES SULTANA

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF CHARLES SULTANA IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is Charles Sultana. I am a Six Sigma Specialist in the Mechanical Department of BNSF Railway Company ("BNSF"). As I explain below, the Six Sigma methodology is a process for solving business problems that relies heavily on facts and data. As BNSF's Six Sigma Specialist, I had primary responsibility for developing the specific coal dust emissions standards that are at issue in this declaratory order proceeding. As I explain below, BNSF's coal dust emissions standards are based on a large quantity of data collected and carefully analyzed over several years from the coal dust emitted by trains operating in the Powder River Basin ("PRB"). My responsibility was to analyze the data for purposes of identifying an achievable and conservative limit on coal dust emissions that would, if met by all shippers, substantially eliminate coal dust on the PRB rail lines. The purpose of my verified statement is to describe for the Board the development and logic of the emissions standards that I developed.

The Six Sigma Methodology

I was hired by BNSF in 2006 as a Six Sigma Specialist in BNSF's Mechanical Department. Since I arrived at BNSF, I have worked on projects in the Engineering and Mechanical departments as well as the Finance and Marketing departments. My primary

responsibility is to bring an advanced level of analytical and problem solving skills as developed and incorporated in the Six Sigma methodology to important problems identified by BNSF management. I was certified as a Six Sigma "Black Belt" in 2000, representing mastery of the Six Sigma methodology, and certified as a "Master Back Belt," the highest Six Sigma qualification level, in 2009. I have a Bachelor of Science degree in Mathematics from University of Texas at Arlington.

The Six Sigma methodology is a disciplined, data-driven methodology for eliminating defects and variation in any business system. The word "Sigma" represents the standard deviation within a population, i.e., the amount of variability within a defined population. The theory underlying the Six Sigma methodology is that if there are six standard deviations between the process mean (the average value of a given population) and the nearest specification limit (the upper or lower acceptable value), practically no member of the population will fail to meet specifications. The purpose of the Six Sigma methodology is to find ways to reduce variation in a given population.[1] The Six Sigma process is data intensive and relies heavily on statistical analyses.

When I arrived at BNSF, I was asked by Lisa Stabler, Assistant Vice President of Mechanical Quality and Reliability, to work with a group of BNSF employees and outside consultants that were investigating the problem of coal dust in the PRB. I was informed that large quantities of coal dust were being emitted from loaded coal cars moving on the Joint Line and on BNSF's Black Hills Subdivision and that coal was being deposited on BNSF's right-of-way, where it contaminated the rail ballast and created the risk of unstable track conditions.

---

[1] For more information on the Six Sigma process, *see* Peter S. Pande et al., *The Six Sigma Way: An Implementation Guide for Process Improvement Teams* (2002) (general overview); American Society for Quality, http://www.asq.org/certification/six-sigma/index.html (last visited Feb. 25, 2010) (explaining certification courses).

Extensive data collection was underway to understand the scope of the coal dust problem. Ms. Stabler asked me to help understand and evaluate the data that were being collected.

Initial Efforts to Assess the Scope of the Coal Dust Problem

Shortly after being assigned the coal dust project, I went to Gillette, Wyoming, to investigate the physical properties of the coal in the Powder River Basin that made it susceptible to dusting. I examined the way the coal is mined, how it is stored, crushed, loaded, and transported and I took samples at different stages of the process. I measured the dustiness of coal at each stage to determine where coal dust appeared to be created. I concluded that the coal coming out of a mine's storage silo, where the crushed coal is kept prior to being loaded into empty coal cars, had substantially more dust than the coal entering the silo. It appeared that coal dust might be created in the silo by the shifting of coal as coal moved within and through the coal silo or that coal dust was accumulating in pockets within the silo and therefore deposited in large quantities in the cars during the loading process. We informed the mines of the results of these preliminary observations.

I also carried out various analyses of data being collected in the field by BNSF on coal trains in transit to determine whether it was feasible to isolate specific factors that caused dusting to occur on coal trains in transit. When I began working on the coal dust problem, BNSF was working extensively with Simpson Weather Associates ("SWA") to set up a data collection system relating to coal dust emissions. The data collection system that was being implemented had three parts. First, a network of dustfall collectors had been established at various locations along the PRB lines. These collectors measured the aggregate volume of coal dust that accumulated over a 30-day period of time at a specific location. The data from dustfall collectors therefore provided a broad overview of dustfall patterns over time. However, they did

not provide information that could be linked to particular train movements. So while the data confirmed that dusting had indeed occurred, I did not believe these data would be particularly useful in setting a coal dust emission standard applicable to individual trains.

Second, and more important for my purposes, BNSF and SWA had set up a Track Side Monitor ("TSM") at milepost 90.7. The TSM is a combination weather tower and coal dust monitor that collects data on each train as it passes by the TSM. *See* Exhibit 1. Towers were set up on both sides of the tracks so that dust readings could be made from the downwind tower. The dust monitor on the TSM is a sophisticated electronic device, called an e-sampler, that measures coal dust in the air at five-second intervals. SWA had developed a methodology for summing up all of the dust units recorded by the e-sampler in five-second intervals over the period of time that a particular train was passing the TSM. SWA was also able to identify and exclude from the dust units measured by the e-samplers the dust units that were attributable to the diesel locomotives on the train and the dust units attributable to background dust in the air before and after the passage of the train. The graph attached at Exhibit 2 illustrates the process by which these adjustments to the e-sampler readings were made. Using this approach, SWA was able to calculate a total number of coal dust units measured by the e-samplers for specific trains as they passed Milepost 90.7. The total dust unit calculation for a particular train was called the "Integrated Dust Value" or IDV of that train.

By the time I started working on the coal dust project, SWA had collected IDV data on thousands of trains passing Milepost 90.7. However, not all IDV calculations were considered reliable indicators of the amount of dust attributable to a particular train. For example, if a loaded train passing Milepost 90.7 was closely following another loaded train, it was possible that the coal dust units attributable to the second train were in fact produced by the first train.

Therefore, SWA excluded IDV readings where two trains passed within minutes of one another. Even with these exclusions, SWA had IDV data for several thousand trains.

SWA and BNSF's Technical Research and Development group had also set up several test trains with instruments mounted on the trains. The instruments included an Rail Transport Emission Profiling System ("RTEPS") and Passive Collectors ("PCs"). The RTEPS are essentially mobile weather stations that record real time data regarding ambient conditions (e.g., temperature, rainfall, humidity, wind speed) over the course of a train trip. *See* Exhibit 3. The Passive Collectors are boxes attached to the sill of coal cars that collect coal dust particles as they are blown off of the loaded coal. *See* Exhibit 4. Passive Collectors were generally set up on several different cars in a test train. RTEPS data was recorded over the full length of the train trip and the coal collected in the PCs would be gathered at various intervals along the trip.

Through these three data-gathering approaches, BNSF had collected a vast amount of data on coal dust and coal dust emissions in the PRB. Before attempting to develop a specific coal dust emission standard, I did several analyses of the data collected by SWA to see whether it was possible to isolate specific causes of coal dust emissions from loaded trains. For example, I looked at the data collected by SWA from the Track Side Monitors to analyze the effect of wind and train speed on the emission of coal dust from trains passing Milepost 90.7. I determined the vector speed for each train from the TSM data on the wind speed, wind direction and train speed at the time the train passed Milepost 90.7 and did a regression analysis of vector speed and dusting episodes as measured by the TSMs.

This analysis suggested that the relationship between dusting events and vector speed was not a linear one. Wind was clearly an important factor in dust emissions, but I found that as vector speed increased, the amount of dust emitted from a passing train did not increase in a

linear fashion. *See* Exhibit 5. I did additional analyses to determine whether other factors such as time of day would explain the dust events occurring at Milepost 90.7 and found no other significant relationships. I concluded from these analyses that the causes of coal dust emissions at Milepost 90.7 were largely attributable to factors affecting the coal before the trains arrived at the TSM monitoring station. For example, the dryness of the coal by the time a train reached Milepost 90.7 clearly affected the likelihood that dust would be emitted. Wet coal loaded into the coal cars at the mines could dry out at varying rates based on weather conditions. The amount of dust in the coal itself when loaded into the cars would also affect the likelihood of dust emissions at Milepost 90.7.

Creation of an IDV-Based Coal Dust Standard

After working for a few months on the coal dust project, I was asked by William VanHook, Assistant Vice President and Chief Engineer - Systems Maintenance and Planning, the person heading up BNSF's efforts on the coal dust issue, to determine whether a coal dust emission standard could be developed that would identify, on a train-specific basis, trains emitting exceptional levels of coal dust. In response, starting in late 2006, I focused my efforts on the development of a coal dust emission standard.

As noted above, the TSMs mounted at Milepost 90.7 calculated an IDV for each loaded train passing that point on the Joint Line. By late 2006, when I started working on the development of a coal dust emission standard, SWA had made IDV calculations for over 10,000 trains. I concluded that the IDV calculations could be used to set a performance standard that would allow BNSF to identify trains that are producing excessive amounts of coal dust. However, before establishing a specific performance standard, I wanted to be sure that the measurements being made by the e-samplers used to calculate IDV values were reliable. I was

somewhat concerned about the month-to-month variation I was seeing in the IDV data that had been collected. Therefore, over several months I worked with SWA to conduct laboratory and field tests of the e-samplers to determine the extent to which the e-samplers could produce varying measurements of the same coal dust source.

In these tests, two e-samplers were placed side-by-side with a common air intake to make coal dust measurements of the same source of coal dust. At Milepost 90.7, we mounted two e-samplers side-by-side and collected dust data from the devices for several months. We also did laboratory tests where we did the side-by-side tests on three additional e-samplers in pairs of two (1/2, 1/3, 2/3). In total, we had nearly 400 data points showing simultaneous measurements from two e-samplers in the side-by-side tests. We found that each of the side-by-side e-samplers generated a somewhat different reading of dust units even though the same source was being analyzed. For example, one e-sampler unit might read 100 dust units while another e-sampler at its side might read 125 dust units from the same dust source. We concluded that the likely cause of this variation was the fact that coal dust particles are not evenly distributed in the air. However, the data we collected from these e-sampler tests allowed us to determine the range of variation in e-sampler readings from a common source. My study results are set out at Exhibit 6.

The variation in e-sampler readings meant that it was not possible to have a high degree of confidence that a particular e-sampler reading of coal dust units could be replicated exactly by other e-samplers measuring the same dust source. However, the test results also made it possible to have a high degree of confidence that a particular e-sampler reading would be within a defined range of possible values as measured by other e-samplers. Therefore, I concluded that a valid standard for coal dust emissions could be based on the e-sampler readings taken at Milepost 90.7 so long as it took account of the variation inherent in the e-samplers measuring coal dust.

To develop an appropriate coal dust emission standard, I started with the IDV data collected from the TSM at Milepost 90.7 on all trains passing that location from September 2005 through August 2007 (excluding the data for trains that passed too close to one another to produce reliable values, as discussed above). As I explained above, the IDV for a particular train represents the number of dust units measured by the e-sampler during the passage of that train by Milepost 90.7. By August 2007, when I began my data analysis, SWA had improved on the development of the IDV calculation by removing additional data associated with locomotives and with background dust values. A description of SWA's improvement upon the IDV calculation is set out in Exhibit 7. The improved IDV calculations are referred to as IDV.2. SWA revised all prior IDV calculations for the trains moving between September 2005 and August 2007 to recalculate IDV.2 values for each train using the improved IDV.2 logic.

I took the IDV.2 calculations for all usable trains from this period and added together the dust units that had been measured for that group of trains over the two-year period. This produced a total of about 2 million dust units. I could then determine an IDV.2 value which, if not exceeded by the trains in the group, would have reduced those 2 million dust units by varying percentages. For example, if my goal was to achieve a 50% reduction in the 2 million dust units, I would seek to identify the IDV.2 value which, if not exceeded by any of the trains in the data set, would have resulted in only 1 million dust units being emitted from the study trains during the study period. For a 75% reduction, I would seek to identify the IDV.2 value which, if not exceeded by any of the trains in the data set, would have resulted in only 500,000 dust units being emitted from the study trains during the study period.

To carry out this analysis, I plotted on a graph the threshold IDV.2 levels on one axis and on the other axis the percentage reduction in dust units for the corresponding threshold IDV.2

levels. *See* Exhibit 8 at BNSF_COALDUST_0039335. Exhibit 8 is an October 9, 2007 internal presentation I made at BNSF describing my methodology. The graph showed the percentage of dust units that would have been reduced if all trains in the data set had been at or below specific "threshold" IDV.2 levels. For example, the graph shows that if no trains operated with an IDV.2 level above 2,000, about 25% of the dust units would have been eliminated. Similarly, if an IDV.2 level of 1,000 had never been exceeded by the trains in the data set, about 50% of the dust units would have been eliminated. I was told by Steve Bobb, the Group Vice President, Coal Marketing, who was an active participant in the coal dust review group at BNSF, that I should strive for a 95% reduction in coal dust. I determined that an IDV.2 level of 134, if never exceeded by the trains in the data set, would have achieved a 95% reduction in coal dust units at Milepost 90.7.

This was not the end of the analysis, however, because it was necessary to take into account the variability in e-samplers. As discussed above, two e-samplers measuring the same coal dust source could produce IDV.2 values within a defined range. To determine the range of variability of the e-samplers, I charted all the data from the side-by-side e-sampler measurement tests from the laboratory and in the field. See the two fitted line plots on Exhibit 8 at BNSF_COALDUST_0039336. Each point on the plot represents the IDV.2 values recorded on two e-samplers that had been placed side-by-side. The chart shows for any given IDV.2 value on Monitor B (x axis) the corresponding IDV.2 value that was produced by Monitor A (y axis) in the side-by-side test. In the right-hand chart, the solid line is the ideal regression line of all plotted values and values between the dashed lines contain 90% of all the values. By using 90% of the values, 5% of the values were above the dotted line and 5% were below the line. This allowed me to account for 95% of the expected variation in the dust monitors. The chart goes

past 2,000 but I was interested in what is happening around 134 IDV.2, which I had previously determined to be the threshold IDV.2 value for eliminating 95% of the coal dust units. The chart to the left is a blow up of the chart on the right, focusing on the values only up to 500 IDV.2

To account for the e-sampler variability, I placed a vertical line at 134 on the x-axis. The points along that vertical line indicate that a reading of 134 on Monitor B corresponded to readings on Monitor A of between about 100 and about 300. Therefore, to be within the upper limit of the 90% dotted lines, the value on Monitor A could be as high as 300. I did the same analysis for Monitor A by drawing a horizontal line at 134 from the y axis. Again, to be within the upper limit of the 90% dotted lines, a reading of 134 on Monitor A could have been as high as about 280 on Monitor B. The values of 280 and 300 are close enough that an IDV.2 standard of 300 would give 95% confidence that the actual IDV.2 value of the reading is at least 134. In other words, taking the variability of the e-samplers into account, it is 95% certain that a train producing over 300 IDV.2 dust units is actually producing over 134 IDV.2 dust units.

This is a highly conservative standard. It is certainly possible that a train producing, for example, 250 IDV.2 dust units is actually producing 250 IDV.2 dust units, far in excess of what is needed to eliminate 95% of the coal dust. But given the variability of the e-samplers, it is also possible that the train producing 250 IDV.2 dust units is actually producing less than 134 dust units. Therefore, BNSF set the IDV.2 limit at 300 to make sure that trains in fact producing less than 134 IDV.2 units would not be found to violate the standard.

I then returned to the graph discussed above that compared the percentage reduction of coal dust units to IDV.2 levels. See Exhibit 8 at BNSF_COALDUST_0039337. The data show that at a 300 IDV.2 level, there is a high degree of confidence that coal dust emissions would be reduced by at least 85%. If none of the trains in the data set had an IDV.2 exceeding 300, 85%

of the total coal dust from these trains would have been eliminated. Thus, while BNSF wanted to set a standard that achieved a 95% reduction in coal dust emissions, the variability of the e-samplers required that we accept a somewhat lower reduction. Given the conservative approach I took, I have a high degree of confidence that compliance with the coal dust emissions standard by all trains passing Milepost 90.7 will eliminate at least 85% of the dust emissions at Milepost 90.7.

I conducted a similar analysis to determine a coal dust limit using TSM data for trains passing Milepost 558. *See* Exhibit 9. My analysis of the Milepost 558 data produced an IDV.2 limit of 245.

Verification of the IDV.2 Methodology

Before BNSF established the IDV.2 standard as an operating rule, I wanted to obtain an independent review of the approach I had taken in developing the coal dust emissions standards. I first contacted a firm called Six Sigma Qualtec and provided them with the data set I had used to develop the IDV.2 standard and explained to them BNSF's basic objectives. Qualtec raised two issues with my analysis. First, they noticed that the data had numerous zero values (IDV.2 readings of zero) and they suggested that the zero values should not be used. I disagreed. It is not a valid scientific approach to exclude data unless there is reason to believe the data are flawed or unreliable. Given the highly episodic nature of coal dust emissions, where loaded coal will remain highly stable for periods of time before being released, there was no reason to believe that the zero IDV.2 readings reflected a flaw in the instruments or data; instead, those zero values reflected that certain trains did not emit dust at measurable levels at Milepost 90.7. Qualtec also noted that the variability of the e-samplers was not constant across the entire range of IDV.2 values. While this was true, it was not particularly relevant to the standard BNSF had

developed because the variability of IDV.2 values in the range of the standard that I had determined (around 134) was relatively constant.

We contacted another independent Six Sigma firm, Smarter Solutions, to review our standard setting process. Smarter Solutions had a Six Sigma Master Black belt who had worked previously with the type of specialized equipment BNSF was using at the TSMs to calculate IDV.2 values. After reviewing my analysis and the underlying data, Smarter Solutions concluded that it was appropriate to leave the zeros in the analysis. They further concluded that there was no reason to address the fact that variability was not constant over the entire range of IDV.2 values, since variability was relatively constant within the range of values where the standards were being set. Overall, Smarter Solutions agreed that the approach I had taken was a reasonable one. *See* Exhibit 10. In fact, they concluded that BNSF was probably being too conservative, and they suggested that an IDV.2 value of 231.4 could be used as the dust emissions limit at Milepost 90.7. Nevertheless, BNSF chose to remain with its conservative limit of IDV.2 300. BNSF implemented that standard as a Joint Line operating rule and included that standard in BNSF's rules in 2009.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

Charles Sultana

VERIFIED STATEMENT OF G. DAVID EMMITT

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF G. DAVID EMMITT IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is G. David Emmitt. I am the President and Senior Scientist of Simpson Weather Associates ("SWA"). SWA is a scientific research and development firm that focuses on environmental and energy issues. For over twenty five years, I have worked at SWA on matters related to fugitive coal dust and its mitigation. SWA was retained by BNSF in 2005 to assist BNSF in understanding the scope of the problem of coal dust escaping from loaded coal trains in the Powder River Basin ("PRB") and to investigate remediation measures. The purpose of my statement is to describe for the Board the extensive data collection and analysis that I and my firm have carried out for BNSF in the past five years to provide BNSF with a quantitative foundation for establishing standards on coal dust emissions.

Background and Experience

In 1975 I received a Ph.D. in Environmental Sciences (Atmospheric Physics) from the University of Virginia, Charlottesville, Virginia. After a post doctorate tenure as a Visiting Scientist at the Max Planck Institute for Meteorology in Hamburg, Germany, I spent the first five years of my career studying hail storms in South Africa while maintaining my association with the University of Virginia as a Research Assistant Professor. In 1981, I accepted a position of Visiting Space Scientist at NASA's Marshall Space Flight Center in Huntsville, Alabama. Since

my tenure at NASA, I have continued to be actively engaged in the use of airborne Doppler Wind LIDARs to investigate the atmosphere (tropical cyclones, tornadoes, etc.) and to prepare for a future space-based wind LIDAR. In 1983, I joined SWA and brought my LIDAR research with me. In 1984, I became involved in basic and applied research associated with fugitive dust emissions from coal piles. This interface between the atmosphere and a significant environmental issue became the focus of laboratory, field and theoretical investigations continuing to the present. SWA has become known for its unique expertise in the understanding, monitoring and control of fugitive coal dust emissions from coal storage piles and rail cars. My CV is attached to this statement as an Appendix.

During the past 26 years, I have led a small team of researchers in projects funded primarily by the private sector (coal companies, railroads, chemical companies, and utilities) focused upon reducing product losses from coal storage piles and open rail cars. In addition, I have received funding from the Center for Innovative Technology to develop techniques for imaging the load profiles of coal in rail cars. The scope of our work ranges from the theoretical (mathematical expressions for the propensity of coal to be blown into the air by the action of air in motion) to the operational deployment of scanning lasers to produce 3D images of the coal loaded in rail cars. SWA continues to perform laboratory evaluations of chemical binders, often referred to as "surfactants" or "topper agents," used to control fugitive dust emissions. I use the term "binder" in this statement to refer to these chemical solutions.

SWA is best known for its unique capabilities in the area of fugitive coal dust emissions from rail cars. My first project involving material losses from coal cars was funded by Norfolk Southern Railway ("NS") in 1987, and led to an extensive, five-year study. Through the use of instrumented caboose, laboratory and field experiments, SWA expanded its understanding of

how coal is lost during transit and how to reduce those losses through load profiling and chemical binders. SWA also developed unique technologies for assessing coal losses. These technologies include the TrackSide Monitor ("TSM") which is installed next to the tracks to detect and quantify dust emissions from passing trains, the Rail Transport Emission Profiling System ("RTEPS") which is attached to the rear sill of coal cars and the laser based Coal Car Load Profiling System ("CCLPS") which provides a 3D image of the coal load in a rail car. NS continues to operate a program of fugitive dust control and performance monitoring based on SWA techniques in Virginia, Ohio and Pennsylvania, and provides annual reports on its performance.

The Problem of Coal Dust

The scope of coal mining operations and coal transportation in the PRB is impressive. A large amount of coal is moved out of the PRB. Thousands of loaded coal cars are transported over the same rail lines each day. If coal escapes from these loaded cars and is deposited on the right of way, coal will accumulate rapidly. Others have studied the impact of coal deposits on rail ballast integrity and have found that coal dust accumulation has serious adverse effects on rail ballast integrity.

The presence of coal along the right of way on the Joint Line in eastern Wyoming is obvious to anyone that has spent time in the area. In many places, there are visible deposits along the right of way. In other places, removing the small top layer of soil or ballast reveals coal beneath the surface. I have spent much of my professional career working with railroads and I have never seen such extensive right-of-way contamination as that which occurs in the PRB from coal that has escaped from coal cars.

There are a multitude of factors that influence the amount of coal that escapes from coal cars in transit and contaminates the rail ballast. The type of coal at particular mines, the size of

the coal loaded into coal cars, the way the coal is processed at the mines, and the way coal is loaded by the mines into coal cars all have an impact on the amount of coal that is lost in transit. Numerous other factors also impact dusting. Weather is an important factor. Dry coal tends to escape from coal cars much more readily than moist coal, so weather conditions that produce dry coal can dramatically affect the amount of coal escaping from coal cars. Wind conditions – particularly the strength and direction of wind relative to the train movement – also affect the amount of coal dust produced by moving coal cars. Train speed is a primary and obvious covariate with coal dust emissions.

Simple observation of coal trains in transit makes it clear that dusting, *i.e.*, instances when dust escapes from the moving car, is highly episodic. Coal dusting does not regularly occur at the same time or place for each coal train. Coal that is moist and relatively stable when loaded can dry out as the train moves through dry air until the coal surface becomes highly unstable. In my experience, a coal train can be moving rapidly with no emission of coal dust and suddenly large plumes of dust can escape with no apparent immediate cause. My opinion is that while the coal from some mines tends to have a higher incidence of coal dusting than others, all mines experience some significant dusting events of their coal during transit.

Coal Dust Data Collection and Analysis

In May 2005, there were two coal train derailments within days of one another on the Joint Line that caused massive dislocations in rail operations in the PRB. I understand that BNSF subsequently concluded that the presence of coal dust in the ballast contributed to those derailments. Shortly after the derailments, BNSF retained SWA to obtain a better understanding of the scope of the coal dust problem in the PRB and to begin to identify ways to remediate coal dust accumulation. A major objective of the work my firm was asked to perform was to

rigorously collect and analyze data relating to the loss of coal from the tops of moving coal cars.

Even before I started working with BNSF in 2005, BNSF had been studying the problem of coal dust. An environmental engineering firm, Conestoga-Rovers Associates ("CRA"), had worked with BNSF to get a basic understanding of the scope of the coal dust problem. With CRA's assistance, BNSF had set up dust fall collectors near the rail ballast along the Joint Line to assess the amount and type of coal that was escaping from moving coal cars. BNSF had also looked at ballast samples to determine the extent of fouling produced by the presence of coal in the ballast.

After the derailments, BNSF wanted to expand its data collection efforts and to identify measures that could be taken to remediate coal dust emissions. BNSF retained SWA to assist in those efforts. I have worked extensively with BNSF since 2005 to define the coal dust problem in and near the PRB and to help BNSF keep its shippers informed of BNSF's investigations. I have also kept the Union Pacific Railroad Company ("UP") informed of SWA's work relating to the Joint Line, as UP is a co-owner of the Joint Line. I attended several meetings of the National Coal Transportation Association ("NCTA") and made numerous presentations at those meetings reporting on the research SWA was carrying out for BNSF.

Our efforts for BNSF focused on the following areas.

Load Profiling

One of the first things I did after being retained by BNSF was to advise BNSF on the benefits of changing the profile of the coal loaded into the coal cars. I have studied the dynamics of coal dust emissions extensively. I applied that knowledge in my work with NS to change the loading profile of coal in NS coal cars to reduce the emission of dust from their cars. It was

immediately clear to me from my review of coal car loading in the PRB that a change in the loading profile could also bring about a measureable reduction in PRB coal losses during transit.

Coal cars were being loaded with trapezoidal shapes and sharp edges. But as the cars move, the wind and vibration of the cars tend to groom the coal in the cars into a more aerodynamic shape. In this process of self-grooming during transit, substantial amounts of coal are blown around and off of the cars. I advised BNSF that the mines should load coal cars into the shape that would naturally be created by the wind to minimize the disruption of the coal during transit. *See* Exhibit 1.

While I had done studies of the optimal load profile for NS on eastern coal, PRB coal had different characteristics. Therefore, I did additional testing to determine an appropriate profile for the PRB coal. The important issue here was the angle of repose for dry PRB coal. I determined that a 30-degree angle was appropriate – if coal was loaded at an angle exceeding 30 degrees, coal would seek a 30-degree angle as it dried and the loose coal would blow off of the cars as it settled into the 30-degree angle. I provided BNSF with an optimum load profile and helped BNSF convince the mines to modify their loading behavior. *See* Exhibit 2.

We initially encountered resistance from mines in seeking a change in the loading profile. One concern was that a modified loading profile would reduce the amount of coal that could be loaded into the cars. I did some tests with laser imaging and showed the mines that the modified profiles would simply redistribute the coal in the car but would not reduce the amount of coal that could be loaded into the cars. Since then, the mines have modified their loading chutes and the loading profile has improved. *See* Exhibit 3.

I also assisted in conducting field tests to determine the amount of coal dust emissions that could be reduced by loading coal to the proper loading profile. Our initial tests were

performed by grooming loaded coal cars with a type of rake attached to a back hoe, although later tests were conducted on coal cars that had been loaded with modified loading chutes. I describe below the process that I developed for testing coal trains in transit using specialized instruments, including a Passive Collector ("PC") mounted on the rear sill of loaded coal cars. A PC is a metal box that captures coal dust blown into the box as the train moves. To test the relative impact of a properly profiled coal car, we attached PCs to the rear sill of cars that had been groomed by the profile bars and to cars that had not been groomed. We collected the coal that accumulated in the different PCs over a train trip and weighed the coal deposits. These simple tests performed on a very limited number of trains suggested that proper grooming of coal cars could achieve in some cases over 30% reduction in coal loss during transit. *See* Exhibit 4. I have subsequently come to believe, based upon dustfall collector data, that in practice the actual reduction in coal emissions from grooming is considerably less than 30%. *See* Exhibit 5 at BNSF_COALDUST_0064122. I believe the substantially smaller benefit we are seeing is likely attributable to widely varying loading practices at the mines, which do not always give proper attention to the load profile during the loading process. Use of a modified loading chute is not enough to ensure proper grooming of coal cars. In order to monitor loading practices and load profiles, SWA will install permanent CCLPS systems. The CCLPS system is a laser imaging system that produces a 3-D image of the loading profile of a passing loaded coal car. *See* Exhibit 6. Our objective is to provide immediate feedback to mine loading operators on the profile of loaded cars so that the mines can refine their loading practices to achieve the proper loading profile.

Track Side Monitors

My work for NS also involved establishing field monitoring stations that can sample the amount of coal dust emitted by particular trains. Building on my NS experience, I provided BNSF with design specifications and instruments for Track Side Monitors. A TSM is a combination of a weather system and a dust monitor mounted on a tower about 60 feet to the side of the track. *See* Exhibit 7. The dust monitor data collected from these instruments is telemetered directly to SWA from Wyoming to Charlottesville, Virginia.

The weather system on the TSM provides real time continuous measurement of wind speed and direction, precipitation, temperature and relative humidity. The dust monitor on the TSM is mounted on the tower at about the height of the top edge of the cars. The dust monitor is an electronic device, the Met One Instruments E-Sampler, which continuously draws in ambient air, passes light through the air and measures the scattering of light that results from particles in the air. *See* Exhibit 8. The dust monitors produce a relative measure of the amount of dust in the air in dust units. The dust monitors are highly sophisticated instruments that are programmed to self-calibrate every 12 hours. They are the only such units that we have found suitable for long-term outdoor operations. It is my view that the E-Sampler dust monitors are the best possible equipment available for field monitoring and sampling of dust emissions from individual moving coal trains. In particular, the continuous sampling of air every five seconds allows measurement of dust emissions over the entire length of the passing train.

Two E-Sampler dust monitors are located at the Milepost 90.7 TSM on the Joint Line, one on a tower west of the tracks and one on a tower east of the tracks. Two E-Sampler dust monitors are also located at Milepost 558.2 TSM on BNSF's Black Hills Subdivision, one on the north and one on the south side of the tracks. Two E-Sampler dust monitors have also been set up at Milepost 693.4 TSM on BNSF's Big Horn Subdivision on the north and south sides of the

tracks. At or near each location of the TSM, there is an Automatic Equipment Identifier ("AEI"), or other railroad train presence devices that allow us to identify each passing train. In addition, wheel detectors have been installed on the tracks at each TSM location that indicate train presence. The wheel detectors are also used to determine the train's speed. *See* Exhibit 9 at BNSF_COALDUST_0000693.

As indicated, the E-Sampler monitors dust by continuously sampling the air. Dust monitor readings are collected and stored every five seconds, whether a train is present or not. Wheel detectors and AEI data provided by the railroad indicate when the dust monitor readings can be assigned to a specific train. The dust readings registered by the dust monitors of each five-second sample, which effectively produce a snapshot of that point in time, are then integrated over the entire time period that the train is passing the TSM to determine a relative comparable measure of the amount of dust that was emitted by a passing train. The results can be plotted on a graph. *See* Exhibit 10 at BNSF_COALDUST_0039367.

As seen in the graph, there are spikes in the dust readings associated with the passage of the diesel locomotives. The dust readings associated with the diesel locomotives can be identified and removed from the calculation of the total number of dust units. In addition, it is clear from the graph that the dust monitors register background dust before and after the passage of a train. In order to focus only on the coal dust emitted from a passing train, this background dust reading is also removed from the total. In addition, only the dust values above the background level are included in the calculation. What is left after these adjustments is a reading of the total amount of coal dust, in relative "dust units," that are emitted by a passing train. The total is called the "Integrated Dust Value" or "IDV" of a particular train. The IDV.2 referred to in the BNSF Rules Publication at issue in this case reflects certain improvements in the logic

used to calculate the dust units associated with the passing trains, as described in Exhibit 10. Some trains are not assessed an IDV.2 because of high or variable background dust measurements, coincident train passage or equipment malfunction.

The E-Sampler dust monitors used at the TSMs exhibit some variability when measuring coal dust, as do all monitors to some degree. In other words, two dust monitors may give slightly different dust unit readings for the same plume of dust. SWA and BNSF conducted laboratory and field tests of these monitors to determine the extent of the variability. Tests were conducted with side-by-side dust monitors. The variation in dust unit readings from these side-by-side tests appears to be attributable to the fact that individual dust particles have varying size and shape and are not evenly distributed in the air. Thus, even when a common source of coal dust is tested, light will be reflected differently on the different particles in each sample, leading to somewhat divergent readings. Mr. Charles Sultana of BNSF took account of this variability in the E-Sampler dust monitors when he determined the IDV.2 limit that is at issue in this case. BNSF's use of the E-Samplers and the corresponding IDV.2 calculations for individual trains provides BNSF with a reliable way to monitor coal dust levels on a train-specific basis and to identify trains emitting excessive levels of coal dust.

Dustfall Collectors

As I noted above, before I began working for BNSF, BNSF and its consultants at CRA had set up a number of dustfall collectors to get an idea of the amount of coal that was escaping from loaded coal trains. I used SWA's modified dustfall collector design, based upon the American Society for Testing and Materials ("ASTM") standard, and expanded the network of collectors. *See* Exhibit 11 at BNSF_COALDUST_0080213-17. Dustfall collectors are an approved ASTM method of measuring dust fall at specific locations. I also recommended that

the dustfall collectors be set up at varying distance from the tracks so that the amount of coal dust could be evaluated as a function of distance from the tracks.

The dustfall collectors cannot be used to determine the amount of coal that is emitted from individual trains. As discussed above, we use the TSMs to measure coal dust emitted from individual trains. Rather, the dustfall collectors measure the coal deposited at a particular location over time. Coal is collected from the dustfall collectors for approximately 30 days and the amount of coal accumulation is measured. Over time, it is possible to detect patterns of coal dust emissions and deposits on the ground. For example, it is clear that coal dust emissions appear to be greatest in winter months, due to higher wind speeds and lower atmospheric moisture. *See* Exhibit 11 at BNSF_COALDUST_0080217. The dustfall collectors will also be a valuable tool to measure the overall impact of dust suppression measures taken by coal shippers when BNSF's coal dust standards go into effect.

Instrumented Trains

Based on my work with NS, I also adopted for BNSF testing devices that can be mounted on individual coal cars on particular trains. The devices consist of a Rail Transport Emission Profiling System and Passive Collectors. *See* Exhibit 11 at BNSF_COALDUST_0080229-30. The RTEPS contains several instruments that are used to monitor various external factors that can affect coal dust emissions. The RTEPS includes an airborne dust monitor similar to the E-Samplers used at the TSMs, a precipitation gauge, a monitor for ambient temperature and relative humidity, a propeller anemometer, an infrared sensor to measure the surface temperature of coal in the car, and a Global Positioning System. The RTEPS is mounted directly onto a car in a test train, usually a car toward the end of the train. The RTEPS collects data for the test train

on the ambient stresses (e.g., temperature, wind conditions) applicable over the entire route of the train.

In addition, the instrumented trains contain PCs, which, as described previously, are wind tunnel designed boxes mounted on the rear sill of a coal car. The boxes collect coal that is blown into the boxes over the course of a train trip. These passive collectors are usually mounted on several cars in the test train. Passive collectors are typically mounted at least 20 cars behind the lead locomotive to avoid contamination of the materials collected in the passive collectors by influences of the locomotives. At various intervals along the route, the passive collectors are emptied and the coal accumulated in the collector is weighed.

Since 2005, we have conducted more than 100 tests with the RTEPS/PC instruments. One objective of these tests was to confirm that substantial amounts of coal dust are being emitted from the top of coal cars. In BNSF's discussions with coal shippers and mines, there was some skepticism at first that coal was actually coming off the top of coal cars in significant quantities. The RTEPS/PC analyses showed that there were in fact significant episodes of coal dust emissions along the route of movement. *See* Exhibit 12.

The instrumented trains were also used to test the effectiveness of modifying the loading profile, as discussed above. Instrumented trains were also used to test other possible dust suppression measures, most importantly, the use of binders or surfactants. SWA's efforts to assist BNSF and its shippers to understand the value of binder use is discussed below.

Binder Testing

There is substantial experience outside of the PRB in the use of chemical binders to limit coal dust emissions from moving coal cars. Binders can be used as "body treatments" or "topical treatments." When used as body treatments, the binder is applied before the coal is loaded into

the car. As topical treatments, binders are sprayed on top of a loaded coal car. Topical binders limit coal dust emissions by creating a crust of individual particles stuck together that prevents dust from escaping or by creating a flexible, adhesive coating on top of the coal. Binders have been used by NS to control coal dust emissions for their export coal in the East. Binders are also widely used in Canada and in Australia to limit coal dust emissions.

BNSF asked SWA to assist in evaluating the impact of binders on coal dust emissions. Many binders are available for use on loaded coal cars. The various chemicals have different characteristics and varying degrees of effectiveness in coal dust suppression. Indeed, the same chemical binder may act differently when used on coal of different type or mixed with water having differing chemical properties. We performed extensive laboratory tests on different chemical binders to determine whether the products met basic standards. SWA's tests included tests for the depth of penetration by the sprayed surfactant, the curing and drying time and simulated wind/thermal stresses, among other things. *See* Exhibit 13. SWA has tested close to 100 products.

In addition, SWA used the trains set up with RTEPS/PCs to carry out field tests on certain selected binders. Since 2005, SWA has carried out these instrumented train tests on over 100 trains with coal cars that had been treated with binders. The field tests generally involved applying the binder solution on half of the loaded cars on a train and leaving the other half of the train untreated. Passive collectors were mounted on cars in both sections of the test trains. The coal dust from each PC was collected and measured. We found that the effectiveness of binders varied based on the chemical used, the ambient conditions at the time of application, and the care with which the binders were applied. We also found that the binders worked best when applied to loaded coal cars that had been loaded according to our suggested load profile. Our tests

showed that coal dust emissions from loaded coal cars could be reduced as much as 95% to 98% when properly loaded and treated with dust suppressing binders. *See* Exhibit 14. It is clear that there are products available to coal shippers and the mines that would effectively eliminate coal dust from moving trains.

BNSF has recently initiated a more extensive field test of binders with the participation of several coal shippers, mines and chemical vendors. The objective of the current field test is to give the interested parties the data that will allow them to evaluate and compare the effectiveness of different chemical binders and to choose optimal mitigation measures. SWA is assisting BNSF in this field test. SWA is conducting laboratory tests on binders that will be used in the field tests to determine whether they meet basic standards necessary to achieve a substantial reduction in coal dust emissions. SWA is also assisting in the preparation of instrumented trains that will be used in the field tests and will be collecting and compiling the data from the test trains to share with participants in the trial.

Based on my research, data analysis and testing of coal dust, I am confident that the use of careful profiling of coal loads and application of appropriate binding agents to the top of loaded coal cars would bring about a reduction of coal dust emissions sufficient to meet BNSF's IDV.2 standard.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

G. David Emmitt

GEORGE DAVID EMMITT

Simpson Weather Associates, Inc.
809 E. Jefferson Street
Charlottesville, VA 22902
Telephone: (434)979-3571; Fax: (434)979-5599
e-mail: gde@swa.com; http://www.swa.com

EDUCATION:

Ph.D., 1975, University of Virginia, Charlottesville, VA, Major: Meteorology
"Momentum redistribution by enhanced mixing over a heated island"

M.S., 1972, University of Virginia, Charlottesville, VA, Major: Environmental Sciences, "Wind wave prediction on impounded water bodies: a case study, Smith Mountain Lake"

B.S., 1969, Eastern Nazarene College, Wollaston, Massachusetts, Major: Physics

PRESENT EMPLOYMENT:

April 1998-present	President and Senior Scientist, Simpson Weather Associates, Inc.
July 1992-present (int)	Research Associate Professor (Scholar in Residence), University of Virginia, Department of Environmental Sciences

PREVIOUS EMPLOYMENT:

August 1986-April 1998	Executive Vice President & Senior Scientist, Simpson Weather Associates, Inc.
August 1983-August 1986	Vice President, Simpson Weather Associates, Inc.
July 1981 - August 1983	Visiting Space Scientist, Universities Space Research Association, NASA/MSFC, Huntsville, AL

January 1978 - December 1980	Research Assistant Professor, University of Virginia, Department of Environmental Sciences, Charlottesville, VA
August 1978 - July 1981	Cloud Physics Consultant, Butler National Corporation Lenexa, KS
August 1976 - January 1978	Visiting Scientist, Max-Planck Institut fur Meteorologie Hamburg, West Germany
August 1975 - August 1976	Research Associate/Assistant Professor, University of Virginia

PROFESSIONAL ACHIEVEMENTS:

2008: Appointed to the Interactive Information and Processing Systems Committee of the American Meteorological Society
2007: Appointed Member of ISETCSC External Advisory Committee
2006: Nominated for the National Academy of Sciences (Atmospheric Panel)
2005: Member of Mission Definition Team for global laser wind sounder
2004: Selected member of NOAA's Thorpex Science Implementation Team
2002: Elected Fellow, American Meteorological Society
2001: Selected member of NASA's Global Tropospheric Wind Sounder Science Team
2000: Selected member of NASA's Code Y Information Technology Subcommittee of Earth Science Advisory Committee
2000: Elected Chair of NASA's Working Group on Space-based Hydrology Mission
1999: Elected Chair of NASA's Consolidated Space Operations Contract (CSOC) Science Working Group
1999: Selected member of NASA's New Data Information System Study team
1998: Elected Chairman, NASA's EOSDIS Science Panel
1997: Mission Scientist on NASA's Space Readiness of Coherent Lidar Experiment
1996: Chairman, NASA/GSFC's DAAC User Working Group
1994: Received "Heros of Reinvention" Award from Vice President Gore in recognition of work done on NASA's Earth Observing System Data Information System
1993: Appointed to NASA's Focus Team on Science and Data Organization/Access
1992: Selected to serve on NASA/CNES (USA/French) Joint Science Team for a space-based Doppler lidar.

1991: Selected to serve on NASA's EOSDIS Version Ø Science Advisory Panel.

1991: Elected to serve as Chairman of NASA's Hydrologic Cycle Data Access and Archive Working Group.

1990: Selected as member of NASA's Earth Observing System Data Information System Science Advisory Panel.

1989: Selected to serve on NASA's Lidar Atmospheric Wind Sounder Science Team to guide the development, deployment and use of a space-based lidar for global wind measurement.

1988: Served on NASA's GLOBE science committee for research on the global distribution of aerosol backscatter.

1987: Served on EPA's Meteorology Division In-House Peer Review Panel.

1987: Served on the 5-man Cloud/Chemistry Cloud Physics Organization's Experiment Design Committee (DOE/NSF).

1986: Selected to serve on NASA panel for a Lidar Atmospheric Wind Sounder (LAWS) as an EOS facility.

1985: Served as member of the NASA organizing committee for Symposiums and Workshops on Global Wind Measurements.

1985: Served on advisory panel for the SPACE/MIST storm research field experiment (1986).

1984-87: Member of American Meteorological Society's Cloud Physics Committee.

1982: Received NASA Award for work on the design, execution and analysis of a flight program to sample the exhaust cloud associated with the launch of the NASA Shuttle.

1981: Received NASA Group Award for research done with the NASA airborne Doppler lidar wind measurement experiments conducted during the CCOPE in Montana.

PUBLICATIONS: Reviewed

Pu, Z., L. Zhang, and **G. D. Emmitt** (2010), Impact of airborne Doppler wind lidar profiles on numerical simulations of a tropical cyclone, Geophys. Res. Lett., 37, L05801, doi:10.1029/2009GL041765.

Riishojgaard, L. P. , R. Atlas and **G. D. Emmitt**, 2004: The impact of Doppler wind observations on a single-level meteorological analysis. J. Applied Met., 43, 810-820.

Emmitt, G.D., 2003: Satellite measurement of hurricane upper level winds using Doppler lidar. Chap. 13b in Hurricanes: Coping with Disaster, R.H. Simpson, R. Anthes and M. Garstang (eds.), American Geophysical Union, 360 pp.

Emmitt, G.D., 1999: Fugitive coal dust: An old problem demanding new solutions. Port Tech. Internat., No. 9, 125-128.

Baker, W.,E., **G.D. Emmitt**, P. Robertson, R.M. Atlas, J.E. Molinari, D.A. Bowdle, J. Paegle, R.M. Hardesty, R.T. Menzies, T.N. Krishnamurti, R.A. Brown, M.J. Post, J.R. Anderson, A.C. Lorenc, T.L. Miller and J. McElroy, 1994: Lidar measured winds from space: An essential component for weather and climate prediction. Bull. Amer. Meteor. Soc., 76, 869-888.

Garstang, M., B. E. Kelbe, **G. D. Emmitt** and W. London, 1987: Generation of convective storms over the escarpment of northeastern South Africa. Mon. Wea. Rev., 115, 429-443.

Addis, R. P., M. Garstang and **G. D. Emmitt**, 1984: Downdrafts from tropical oceanic cumulus. Bound.- Layer Meteor., 28, 23-49.

Frank, W., and **G. D. Emmitt**, 1981: Computation of vertical energy fluxes in moist atmosphere. Bound.-Layer Meteor, 21, 223-230.

Frank, W., **G. D. Emmitt** and C. Warner, 1981: Multiscale analyses of low level vertical fluxes on day 261 of GATE. J. Atmos. Sci., 38, 1964-1976.

Augstein, E., M. Garstang and **G. D. Emmitt**, 1980: Vertical mass and energy transports by cumulus clouds in the tropics. Deep Sea Research, Supplement I to Vol. 26, 9022.

Barnes, G., **G. D. Emmitt**, B. Brummer, M. A. LeMone and S. Nicholls, 1980: The structure of a fair weather boundary layer based on the results of several measurement strategies. Mon. Wea. Rev., 108, 349-364.

Emmitt, G. D. and B. Brummer, 1979: Wind measurements with a ship based

theodolite. Meteor Forschungergebnisse, 23, 53-62.

Emmitt, G. D., 1978: Tropical cumulus interaction with and modification of the subcloud layer. J. Atmos. Sci., 35, 1485-1502.

Garstang, M., P. D. Tyson and **G. D. Emmitt**, 1975: The structure of heat islands. Rev. Geophys. Space Sci., 13, 139-165.

PUBLICATIONS: Conference Proceedings/Presentations

2007: Airborne wind lidar for atmospheric boundary layer research (invited paper) , (G.D. Emmitt), Lidar Remote Sensing for Environmental Monitoring VIII, SPIE Optics + Photonics, San Diego, CA, 28-30 August 2007.

2007: Requirements and technology advances for global wind measurement with a coherent lidar: a shrinking gap (Invited paper), (Kavaya, M,J. Yu, G. J. Koch, F. Amzajerdian, U. N. Singh and G. D. Emmitt), Lidar Remote Sensing for Environmental Monitoring VIII, SPIE Optics + Photonics, San Diego, CA, 28-30 August 2007.

2006: CCLPS estimates of coal loss by wind erosion, (G. D. Emmitt and D. Carre), National Coal and Transportation Association special meeting, St. Louis, MO. 19-20 February, 2006.

2006: Observing System Simulation Experiments at NCEP (Masutani, M., J.S. Woolen, S.J. Lord, T. J. Kleepsies, G.D. Emmitt, H. Sun, S. Wood, S. Greco, J. Terry, R. Treadon and K. Campana), Office Note 451, EMC/NCEP/NWS/NOAA

2005: Automated detection of frontal systems from numerical model-generated data (Xiang Li, Rahul Ramachandran, Sara J. Graves, Sunil Movva, Bilahari Akkiraju, **David Emmitt**, Steven Greco, Robert Atlas, Joseph Terry, Juan-Carlos Jusem), KDD 2005: 782-787

2005: Automated detection of frontal systems from numerical model-generated data (Li, X., R. Ramachandran, S. Graves, S. Movva, B. Akkiraju, G. D. Emmitt and S. Greco, R. Atlas, J. Terry, and J.-C. Jusem), the *11th ACM SIGKDD Inter. Conf. on Knowledge Discovery and Data Mining*, Chicago, U.S.A., August 21-24

2005: Investigation of flows within complex terrain and along coastlines using an airborne Doppler wind lidar: Observations and model comparisons (S. Greco and G. D. Emmitt) Annual Amer. Met. Soc.Conference ,Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, San Diego, CA, January.

2005: Airborne Doppler Wind Lidar Investigations of OLEs over the Eastern Pacific and the Implications for Flux Parameterizations (Emmitt G.D., C. O'Handley, S. Greco, R. Foster and R.A. Brown), Annual Amer. Met. Soc. Conference ,Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, San Diego, CA, January.

2005: Investigation of flows within complex terrain and along coastlines using an airborne Doppler wind lidar: Observations and model comparisons (Greco, S. and G.D. Emmitt),Annual Amer. Met. Soc. Conference, Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, San Diego, CA, January

2004: Combining direct and coherent detection for Doppler wind lidar (G. D. Emmitt),Laser Techniques for Atmospheric Sensing, Maspalomas, Gran Canaria, Spain, 14-16 September.

2004: Using surface returns to remove residual pointing errors for an airborne Doppler lidar (G. D. Emmitt and C. O'Handley), Laser Techniques for Atmospheric Sensing, Maspalomas, Gran Canaria, Spain, 14-16 September.

2004: Dynamical and microphysical characteristics of turbulent waves in and above the marine boundary layer: an integrated perspective from the TODWL data base (G. D. Emmitt, S. A. Wood, D. Bowdle, R. Foster, S. M. Hannon, and H. Jonsson), Remote Sensing of the Atmosphere, Ocean, Environment, and Space, Honolulu, Hawaii, 8-11 November.

2004: Autonomous aerial observations to extend and complement the Earth Observing System: a science driven, system oriented approach (S. P. Sandford, F. W. Harrison, J. E. Johnson, W. C. Edwards, G. Qualls, J. Langford, W. L. Jones, G. D. Emmitt, H. H. Shugart), Remote Sensing of the Atmosphere, Ocean, Environment, and Space, Honolulu, Hawaii, 8-11 November.

2004: Global OSSE at NCEP (Masutani, M., S. J. Lord ,J.S. Woolen, W. Yang, H. Sun , T.J. Kleepsies, G.D. Emmitt, S.A. Wood, B. Katz, R. Treadon, J.C. Derber, S. Greco and J. Terry), AMS Preprint Volume for the 8th Symposium on IOAS for Atm., Ocean and Land Surface, , 12-15 January, Seattle, WA.. 53-56.

2003: Observing system simulation experiments for NPOESS – assessment of Doppler wind lidar and AIRS (M. Masutani, J.C. Woollen, S.J. Lord, G.D. Emmitt, S. Wood, S. Greco, T.J. Kleespies, H. Sun, J. Terry, J.C. Derber, R.E. Kistler, R.M. Atlas, M.D. Goldberg, and W. Wolf), AMS The Simpson Symposium, Long Beach, CA, February.

2003: Analysis of simulated observations from a Doppler wind lidar (L.P. Risshojgaard, R. Atlas, and G.D. Emmitt), AMS 12th Conf. Satellite Meteorology, Long Beach, CA, February.

2003: Airborne wind lidar to evaluate air/ocean exchanges at high wind speeds (G.D. Emmitt and C. O'Handley), AMS 12th Symposium on Meteorological Observations and Instrumentation (SMOI), Long Beach, CA, February.

2003: Observing systems simulation experiments using the NCEP data assimilation system (S.J. Lord, M. Masutani, J.S. Woollen, J.C. Derber, R.E. Kistler, T.J. Kleespies, H. Sun, G.D. Emmitt, S. Wood, S. Greco, J. Terry, and R.Atlas), AMS 7th Symposium on Integrated Observing Systems, Long Beach, CA, February.

2003: Recent observing system simulation experiments at the NASA DAO (R. Atlas, G.D. Emmitt, J. Terry, E. Brin, J. Ardizzone, J.C. Jusem, and D. Bungato), AMS 7th Symposium on Integrated Observing Systems, Long Beach, CA, February.

2003: OSSEs to determine the requirements for space-based lidar winds for weather prediction (R. Atlas, G.D. Emmitt, J. Terry, E. Brin, J. Ardizzone, J.C. Jusem, and D. Bungato), SPIE's Laser Radar Technology and Applications VIII, Orlando, FL, April.

2003: Comparisons between modeled and actual performance of Doppler lidar used in atmospheric remote sensing (G.D. Emmitt), AeroSense Photonics for Defense and Security, Orlando, FL, April.

2003: Airborne coherent Doppler lidar: investigation of the marine boundary layer and ocean surface motions (G.D. Emmitt, S. Greco, and C. O'Handley), AeroSense Photonics for Defense and Security, Orlando, FL, April.

2003: Using a bi-axis scanning airborne coherent Doppler lidar to measure marine boundary layer winds and ocean waves (G.D. Emmitt and C. O'Handley), CLRL 2003, Bar Harbor, ME.

2003: Airborne Doppler wind lidar to evaluate cloud and water vapor motion vectors from GIFTS (G.D. Emmitt), SPIE's 48th Annual Meeting, San Diego, CA, August.

2003: Investigation of backscatter/wind correlations using an airborne 2-micron coherent Doppler wind lidar (G.D. Emmitt and C.O'Handley), SPIE's 48th Annual Meeting, San Diego, CA, August.

2003: Validation of meso-scale model winds in complex terrain and coastal regions using an airborne coherent Doppler wind lidar (G.D. Emmitt, S. Greco, S. Wood, and C. O'Handley, W. Nuss, and D. Miller), ISTP, Leipzig, September.

2003: Processing airborne coherent Doppler lidar returns from the ocean surface and the layer adjacent to the surface (G.D. Emmitt and C. O'Handley), SPIE 5240, Barcelona, Spain, September.

2003: Comparing the potential numerical weather prediction impacts of several

Doppler wind lidar concepts (G.D. Emmitt), SPIE 5234A, Barcelona, Spain, September.

2002: Airborne Doppler lidar surface returns: Data products other than tropospheric winds (G.D. Emmitt and C. O'Handley), SPIE Remote Sensing of the Atmosphere, Ocean, Environment and Space, Hangzhou, China, October.

2002: Progresses and future plans for OSSE/NPOESS. Conference on Weather Analysis and Forecasting (Masutani, Michiko; Woollen, John C.; Lord, Stephen J.; Derber, John C.; Emmitt, G. David; Kleespies, Thomas J.; Terry, Joseph; Sun, Haibing; Wood, Sidney A.; Greco, Steven; Atlas, Robert; Goldberg, Mitch; Yoe, Jim; Baker, Wayman; Velden, Christopher; Wolf, Walter; Bloom, Steve; Brin, Genia and O Handley, Christopher), 19th and Conference on Numerical Weather Prediction, 15th, San Antonio, TX, 12-16 August 2002 (preprints). American Meteorological Society, Boston, MA, 2002, Paper 1.6. Call Number: Reprint # 3867

2002: Water surface returns as a function of incidence angle at 2 μm (G.D. Emmitt and C. O'Handley), ILRC meeting, Quebec, Canada, July.

2002: 2 μm Doppler lidar returns from water surfaces and the overlying aerosols (G.E. Emmitt, C. O'Handley, J. Rothermel, S. Johnson, D. Bowdle, P. Kromis, B. Bluth and H. Jonsson), SPIE meeting, Seattle, WA, July.

2002: Joint Exploration of 3-D Global Atmospheric Models and Related Remote Sensing Data Products with Temporal Displacements of Several Days (Emmitt, G and Greco, S), *Computing Science and Statistics*, 34, /I2002Proceedings

2002: Impact assessment of a Doppler wind lidar for NPOESS/OSSE (S.J. Lord, M. Masutani, J.C. Woollen, J.C. Derber, G.D. Emmitt, S.A. Wood, S. Greco, R. Atlas, J. Terry, and T.J. Kleespies), AMS Sixth Symp. Integrated Observing Systems, Orlando, FL, January.

2001: Adaptive target of wind observations: the climate research and weather forecasting perspective (G.D. Emmitt and Z. Toth), AMS Fifth Symp. Integrated Observing Systems,
Albuquerque, NM, January.

2001: The challenges of accessing the future impact of space-based Doppler wind lidars while using today's global and regional atmospheric models (S. Wood, G.D. Emmitt, and S. Greco), AMS Fifth Symp. Integrated Observing Systems, Albuquerque, NM, January.

2001: Observing system simulation experiments for NPOESS (S.J. Lord, M.

Masutani, J.C. Woollen, J.C. Derber, R. Atlas, J. Terry, G.D. Emmitt, S.A. Wood, S. Greco, T.J. Kleespies, and V. Kapoor), AMS Fifth Symp. Integrated Observing Systems, Albuquerque, NM, January.

2001: Global wind observational requirements and the hybrid observing system approach (G.D. Emmitt), AMS Fifth Symp. Integrated Observing Systems, Albuquerque, NM, January.

2001: Simulating space-based lidar performance using global and regional scale atmospheric numerical models (G.D. Emmitt and S.A. Wood), Optical Remote Sensing Topical Meeting, Coeur d' Alene, ID, February.

2001: Feasibility and science merits of a hybrid technology DWL (G.D. Emmitt), 11th Coherent Laser Radar Conf., Malvern, England, July.

2001: The impact of Doppler lidar wind observations on a single-level meteorological analysis (L.P. Riishojgaard, R. Atlas and G.D. Emmitt), SPIE Lidar Remote Sensing for Industry and Environmental Monitoring, II, San Diego, CA, July 29-August 3.

2001: Calibration and initial results from the OSSEs for NPOESS (M. Masutani, J.S. Woollen, J. Terry, S.J. Lord, T.J. Kleespies, G.D. Emmitt, S.A. Wood, S. Greco, J.C. Derber, R. Atlas and M. Goldberg), AMS 11th Conf. Satellite Meteor. and Oceanogr., Madison, WI, October.

2000: DLSM: A coherent and direct detection lidar simulation model for simulating space-based and aircraft-based lidar winds (S.A. Wood, G.D. Emmitt and S. Greco), AeroSense 2000, Orlando, FL, April.

2000: Lidar simulations over hurricane Bonnie using CAMEX-3 data, a lidar simulation model and numerical model analyses (S. Greco, S.A. Wood, G.D. Emmitt, M. Nicholls and R. Pielke, Sr.), AMS 24th Conf. Hurr. And Trop. Meteor., Ft. Lauderdale, FL, May.

2000: Hybrid technology Doppler wind lidar: assessment of simulated data products for a space-based system concept (G.D. Emmitt), SPIE Lidar Remote Sensing for Industry and Environment Monitoring, Sendai, Japan, October.

2000: Using coherent Doppler lidar to estimate river discharge (G.D. Emmitt, C. O'Handley, and G.D. Spiers), SPIE Lidar Remote Sensing for Industry and Environment Monitoring, Sendai, Japan, October.

1999: Implementing a Doppler wind lidar on NPOESS using adaptive targeting strategies (G.D. Emmitt, Z. Toth and R. Atlas). AMS Third Symposium on Integrated Observing Systems, Dallas, TX, January 10-15.

1999: SPARCLE: Mission overview and status (G.D. Emmitt, M. Kavaya and T. Miller). 10th Biennial Coherent Laser Radar Technology and Applications Conf., Mt. Hood, OR,
June 28-July 2.

1999: Pointing knowledge for SPARCLE and space-based Doppler wind lidars in general (G.D. Emmitt, T. Miller and G. Spiers). 10th Biennial Coherent Laser Radar Technology and Applications Conf., Mt. Hood, OR, June 28-July 2.

1999: Capitalizing on the SPARCLE investment (G.D. Emmitt and T. Miller). 10th Biennial Coherent Laser Radar Technology and Applications Conf., Mt. Hood, OR, June 28-July 2.

1998: The Space Readiness Coherent Lidar Experiment (SPARCLE) Space Shuttle Mission (M.J. Kavaya and G.D. Emmitt. Proc. SPIE Conf. on Laser Radar Technology and Applications III, Orlando, FL, April.

1998: SPARCLE: A first step towards space-based global tropospheric wind observations (G.D. Emmitt). IGARSS '98 Managing Natural Resources Conf., Seattle, WA, July 6-10.

1998: SPARCLE: An approved shuttle mission to demonstrate tropospheric wind sensing using a coherent 2-micron Doppler lidar (G.D. Emmitt). SPIE Annual Meeting, San Diego,
CA, July 19-24.

1998: SPARCLE: A space-based mission to demonstrate global monitoring of tropospheric winds with a Doppler lidar (G.D. Emmitt). SPIE Optical Remote Sensing for Industry and Environmental Monitoring, Beijing, China, September 15-17.

1998: SPARCLE: Validation of observing system simulations (SPAce Readiness Coherent
Lidar Experiment) (G.D. Emmitt and T. Miller). SPIE International Symposium on Remote Sensing, Barcelona, Spain, September 21-24.

1997: An HDF tutorial for the scientific investigator and small data providers (S. Greco, L. Wood and G.D. Emmitt). Proc. AMS 13th Internat. Conf. on IIPS for Meteorology, Oceanography and Hydrology, Long Beach, CA, February, 402-404.

1997: Optical remote sensors as components of an airborne hurricane observing system (S.A. Wood, G.D. Emmitt and S. Greco). Proc. AMS First Symp. Integrated Observing
Systems, Long Beach, CA, February 39-44.

1997: Relevance of cloud statistics derived from LITE data to future Doppler wind lidars (D.M. Winker and G.D. Emmitt). Paper presented at the 9th Conf. on Coherent Laser
Radar, Linköping, Sweden, June.

1997: Status of space-based DWL activities in the United States (G.D. Emmitt and W. Baker). Paper presented at the 9th Conf. on Coherent Laser Radar, Linköping, Sweden, June.

1996: Procontrol: Automated fugitive dust control system (G.D. Emmitt, L.S. Wood, E.M. Calvin, and S. Greco), Proc. Seventh Annual Environment Virginia '96 Symp., 36-43, Lexington, VA, April.

1996: Minimizing groundwater consumption for required fugitive dust control programs (G.D. Emmitt), Proc. Seventh Annual Environment Virginia '96 Symp., 244-251, Lexington, VA, April.

1995: Simulation studies of the impact of space-based wind profiles on global climate studies (R. Atlas and G.D. Emmitt) . Proc. AMS Sixth Symp. on Global Change Studies, Dallas, TX, January.

1995: Ground-based Doppler lidar signal processing in the vicinity of strong backscatter and/or wind inhomogeneities using a progressive context method (G.D. Emmitt, S.A. Wood and D.L. Bai) Paper presented at the Optical Society of America's CLEO '95 Meeting, Baltimore, MD, May.

1995: Coherent vs incoherent space-based Doppler lidar sampling patterns: Accuracy and representativeness (G.D. Emmitt). Paper presented at the Coherent Laser Radar Topical
Meeting, Keystone, CO, July 23-27.

1995: A coherent lidar simulation model for simulating space-based and aircraft-based lidar winds (S.A. Wood, G.D. Emmitt, D. Bai, L.S. Wood, S. Greco) . Paper presented at the Opt. Soc. of America's Coherent Laser Radar Topical Meeting, Keystone, CO, July 23-27.

1995: Simulating clouds within a space-based Doppler lidar wind sounder simulation model (G.D. Emmitt and S.A. Wood) Paper presented at the CIDOS-95 Conf., Hanscom
AFB, MA, October 24-26.

1994: Query scenarios for interdisciplinary scientists interfacing with EOSDIS, Version 0, Series II(S.A. Wood, G.D. Emmitt, K. McDonald). Paper presented at AMS Tenth Internat. Conf. on Interac. Info. and Process. Systems (IIPS) for

Meteor., Oceanogr. and Hydrol., Nashville, TN, January 23-28.

1994: Beta testing of EOSDIS Version 0 using query scenarios from interdisciplinary scientists. Poster paper presented at the IEEE 7th Internat. Working Conf. on Scientific and Statistical Database Management, Charlottesville, VA, September 28-30, 280-282.

1994: Ocean wave motion effects on space-based airborne Doppler lidar wind sounders (G.D. Emmitt). Paper presented at the Optical Society of America's Annual Meeting, October 2-7, Dallas, TX.

1994: Resolving ageostrophic winds with a space-based Doppler lidar wind sounder (G.D. Emmitt). Paper presented at the Fifth Symp. on Global Change Studies, Nashville, TN.

1994: A portable scanning lidar for real-time detection of fugitive dust emissions from multisource facilities (G.D. Emmitt). Paper presented at the Eighth Joint Conf. on Appl. Air Poll. Meteor. with A&WMA.

1993: A Continuous Emission Monitoring and Modeling CEM/M) system for fugitive particulate emissions from coal handling complexes (G.D. Emmitt, C. DiMarzio and R.
Doll). Paper presented at the 96th National Western Mining Conference and Exhibition, March, Denver, CO.

1993: Simulation of space-based Doppler lidar wind measurements using ground-based single shot observations (G.D. Emmitt, J. Dieudonné, S.A. Wood and L. Wood). Paper presented at the Optical Remote Sensing of the Atmosphere Sixth Topical Meeting, March, Salt Lake City, UT.

1993: Integration of LOWTRAN into global circulation models for observing system simulation experiments (S.A. Wood and G.D. Emmitt). Paper to be presented at the Conference on Atmospheric Transaction Models, June, Boston, MA.

1993: Using ground-based coherent Doppler lidars to evaluate algorithms for shot management and signal processing of proposed space-based wind sounders (G.D. Emmitt). Paper presented at the Coherent Laser Radar: Applications and Technology Topical Meeting, July, Paris, France.

1993: System simulation studies in support of a technology and product demonstration mission for a space-based coherent Doppler lidar wind sounder (G.D. Emmitt). Paper
presented at the Coherent Laser Radar: Applications and Technology Topical Meeting, July, Paris, France.

1991: Simulated wind measurements with a low power/high PRF space-based Doppler lidar (G.D. Emmitt and S.A.Wood). Optical Remote Sensing of the Atmosphere, Fifth Topical Meeting, Williamsburg, VA, November 18-21.

1991: Global three-dimensional distribution of LAWS observations based upon aerosols, water vapor and clouds (S.A. Wood, G.D. Emmitt and L.S. Wood). Optical Remote Sensing of the Atmosphere, Fifth Topical Meeting, Williamsburg, VA, November 18-21.

1991: Query scenarios for interdisciplinary scientists interfacing with EOSDIS - A prototyping exercise (G.D. Emmitt, S.A. Wood and E. Calvin). Proc. AMS Seventh Internat. Conf. on Interactive Information & Processing Systems for Meteorology, Oceanography and Hydrology, New Orleans, LA, January 14-18, 246-248.

1991: Using a global spectral model in an observing system simulation experiment for LAWS - An EOS wind measuring system (T.N. Krishnamurti, J. Xue, G. Rohaly, D. Fitzjarrald, G.D. Emmitt, S. Houston and S.A. Wood). Proc. AMS Second Symposium
on Global Change Studies, New Orleans, LA, January 14-18, 23-27.

1991: Implications of several orbit inclinations for the impact of LAWS in global climate studies (R. Atlas and G.D. Emmitt). Proc. AMS Second Symposium on Global Change Studies, New Orleans, LA, January 14-18, 28-32.

1991: Simulating thin cirrus clouds in observing system simulation experiments (OSSE) for LAWS (G.D. Emmitt and S.A. Wood). Proc. AMS Seventh Symp. on Meteorol. Observa. and Instru., Special Session on Laser Atmospheric Studies, New Orleans, LA, January 14-18, 460-462.

1991: A reference atmosphere for LAWS trade studies: An update (S.A. Wood and G.D. Emmitt). Proc. AMS Seventh Symp. on Meteor. Observa. and Instru., Special Session on Laser Atmospheric Studies, New Orleans, LA, January 14-18, J94-J97.

1991: Optimal nadir scan angle for a space-based Doppler lidar wind sounder (G.D. Emmitt). Proc. Seventh Symp. on Meteor. Observa. and Instru., Special Session on Laser Atmospheric Studies, New Orleans, LA, January 14-18, J98-J99.

1991: An index of observation opportunities for EOS laser based instruments (G.D. Emmitt). Paper presented at the Second Symp. on Global Change Studies, New Orleans, LA, January 14-18.

1991: Clear line of sight (CLOS) statistics within cloudy regions and optimal

sampling strategies for space-based lidars (G.D. Emmitt and G. Séze). Proc. AMS Seventh Symp. on Meteor. Observa. and Instru., New Orleans, LA, January 14-18, 440-442.

1989: Simulation of a space-based Doppler lidar wind sounder - sampling errors in the vicinity of wind and aerosol inhomogeneities (with S. Wood). Fifth Conference on Coherent Laser Radar, Munich, FRG, June.

1989: Simulated space-based Doppler lidar performance in regions of backscatter inhomogeneities (with S. Wood). Optical Society of America's Conference on Lasers and Electro-Optics, Anaheim, CA, January.

1988: Subvisible cirrus in space-based Doppler lidar simulations (with S. Wood). Atmospheric Transmission Conference, AFGL, Hanscom, MA, June.

1988: Ground-based simulation of a space-based Doppler lidar atmospheric wind sounder (with S. Wood). Optical Society of America's Conference on Lasers and Electro-Optics, Anaheim, CA, April.

1988: Direct measurement of boundary layer winds over the oceans using a space-based Doppler Lidar Wind Sounder. American Meteorological Society's Third Conference on Satellite Meteorology and Oceanography, Anaheim, CA, February.

1987: Assessment of error sources for one component wind measurements with a space-
based Doppler lidar (with J. W. Bilbro). Optical Society of America's Fourth Conference on Coherent Laser Radar: Technology and Applications, Aspen, Colorado, July.

1987: Error analysis for total wind vector computations using one component measurements from a space-based Doppler lidar. Optical Society of America's Fourth Conference on Coherent Laser Radar: Technology and Applications, Aspen, Colorado, July 1987.

1987: Impact of a space-based Doppler lidar wind profiler on our knowledge of hurricanes and tropical meteorology (with S. H. Houston). AMS 17th Conference on Hurricanes and Tropical Meteorology, Miami, Fl, April 1987.

1987: A numerical investigation of the role of whisker production in dry ice seeding experiments (with R.D. Farley). AMS 11th Conference on Weather Modification, Edmonton, Alberta, Canada, October 1987.

1986: Assessment of measurement error due to sampling perspective in the space-based Doppler lidar wind profiler (with S. Houston). Second Conference on

Satellite Meteorology/Remote Sensing and Applications, May 13-16, Williamsburg, VA.

1986: Constraints on resolving meso-α and meso-ß phenomena using a space-based Doppler lidar wind profiler (with S. Houston). Second Conference on Satellite Meteorology/Remote Sensing and Applications. May 13-16, 1986, Williamsburg, VA.

1986: Topographical influences on radar echo properties --implications to weather modification projects in mountainous terrain (with W. London). Tenth Conference on
Weather Modification, May 27-30, Arlington, VA.

1986: Dry ice pellet whiskers--laboratory evaluation of their production and potential importance to cloud seeding. Tenth Conference on Weather Modification, May 27-30, Arlington, VA.

1985: Convergence and vorticity structures in convective storm outflows as detected by an airborne Doppler lidar velocimeter. 14th Conference on Severe Local Storms, October 29-November 1, Indianapolis, IN.

1985: Discrimination of local and synoptic scale forcing of cumulus convection along the eastern Transvaal escarpment using Meteosat imagery. Second Annual Conference of the South African Society for Atmospheric Sciences, November 11-12, Pretoria, SA.

1985: Doppler lidar sampling strategies and accuracies-regional scale. Paper presented at the Symposium and Workshop on Global Wind Measurements, July 29-August 1, Columbia, Maryland.

1984: Behavior of cylindrical dry ice pellets in the presence of supercooled water droplets--field and laboratory experiments. Paper presented at the Ninth Conference on Weather Modification, May 21-23, Park City, Utah.

1984: Airborne simulation of a satellite based Doppler lidar (J.W. Bilbro and G.D. Emmitt), Proc. of the SPIE, Vol. 493, National Symposium and Workshop on Optical Platforms, pp. 321-325.

1983: Anatomy of drought. Symposium on Atmospheric Sciences in South Africa, October 18-20, Pretoria, South Africa. (M. Garstang and G. D. Emmitt).

1983: Evolution of the Nocturnal Boundary Layer as Sensed by a Doppler Lidar Velocimeter. Paper presented at 2nd Topical Meeting on Coherent Laser Radar; Technology and Applications, August 1-4, Aspen, Co.

1983: Ground based CO_2 Doppler lidar wind measurements of winds in the vicinity of cumulus convection. Paper presented at 9th Conference on Aerospace and Aeronautical Meteorology of the AMS, June 6-9, Omaha, NE.

1982: Conical lidar scanning from low earth orbit--the effects of meso-α and convective scale atmospheric phenomena. Paper presented at 11th International Laser Radar Conference, July, Madison, WI.

1980: Measurements of wind shear at the Mod-1 site, Boone, North Carolina (M. Garstang, J. W. Snow and G. D. Emmitt). A Collection of Technical Papers, Paper No. AIAA-80-0648-CP, pp. 200-204.

1980: Measurement of wind shear at the Mod-1 site, Boone, North Carolina. Paper presented at AIAA/SERI Wind Energy Conference, April 9-11, Boulder, CO.

1980: Mesoscale nocturnal boundary layer jets. Minisymposium on Mesoscale Phenomena and their Interactions, September, Geophysical Fluid Dynamics Laboratory, NOAA, Princeton, N.J.

1978: Determination of σ by direct and indirect cloud transport measurements. Paper presented at the GATE Symposium on Oceanography and Surface Layer Meteorology, Kiel, West Germany, May 16-20.

1976: Mass and energy transports of convective clouds, G.D. Emmitt, M. Garstang and J. Simpson. Paper presented at the 10th Tech. Conf. on Hurricanes and Tropical Meteorology, AMS, July, Charlottesville, Va.

PUBLICATIONS: Reports

1972: Remote sensing as a source of data for outdoor recreation planning (W.E. Reed, H. G. Goodell and G. D. Emmitt). Final report to Department of the Interior, Bureau of Outdoor Recreation, Contract No. 1-14-07-3, 210 pp.

1974: The structure of heat islands (P.D. Tyson, M. Garstang and G. D. Emmitt, 1974:. Occasional paper #12, Department of Geography and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa, 71 pp.

1975: The first 1000 m above a GATE ship (M. Garstang, J. Simpson, G. D. Emmitt, G. Barnes, E. Tollerud). Paper presented at the 9th Tech. Conf. on Hurricanes and Tropical Meteorology, Key Biscayne, FL.

1975: Momentum redistribution by enhanced mixing (G.D. Emmitt). Paper presented at the 9th Tech. Conf. on Hurricanes and Tropical Meteorology, AMS,

May, Key Biscayne, FL.

1977: The U. S. GATE tethered balloon system: A discussion of the measurements (M. Garstang, G. D. Emmitt, G. Barnes, D. Fitzjarrald, E. Tollerud and J. D. Brown). Part 3 of Report #2 NSF grant #ATM74-21702 and Final Report on NOAA contract #04-6-
158-44067, 89 pp.

1981: Rain Augmentation in Nelspruit (M. Garstang, G. D. Emmitt and B. Kelbe). Final Report to Water Research Commission, Pretoria, R.S.A., p. 266.

1982: MSFC Doppler lidar experiments and operations plans for 1982/83 ground based research (G.D. Emmitt, J. W. Bilbro, G. H. Fichtl and D. Fitzjarrald). ES-84, NASA, Marshall Space Flight Center, Huntsville, AL 35812.

1984: NASA/MSFC ground-based Doppler lidar Nocturnal Boundary Layer Experiment (NOBLEX)(G.D. Emmitt). Prepared for Marshall Space Flight Center, Huntsville, AL, under Contract NAS8-34010. NASA Contractor Report 3778.

1984: Evaluation of two 1-D cloud models for the analysis of VAS Soundings (G.D. Emmitt). Prepared for Marshall Space Flight Center, Huntsville, AL, under Contract NAS8-34767. NASA Contractor Report 3771.

1985: Convective storm downdraft outflows detected by NASA/ MSFC's airborne 10.6 □m pulsed Doppler lidar system (G.D. Emmitt). Prepared for Marshall Space Flight Center, Huntsville, AL, under Contract NAS8-35597. NASA Contractor Report 3898.

1986: Simpson Weather Associates, Inc. and Kansas International Corporation Limited, Program for Atmospheric Water Supply, 1983-86 Final Report to the Water Research Commission, Pretoria, South Africa.

1987: Contributor to Laser Atmospheric Wind Sounder (LAWS); Instrument Panel Report (Chairman R. J. Curran) (G.D. Emmitt), NASA Earth Observing System, Volume IIg, NASA Headquarters, Washington, D.C.

1994: Norfolk Southern Rail Emission Study (NSRES). Final Rept., February.

1999: NASA Post-2002 Land Surface Hydrology Mission Component for Surface Water Monitoring: HYDRO-SAT HYDROlogical SATellite (C. Vörösmarty, C. Birkett, L. Dingman, D. Lettenmaier, Y. Kim, E. Rodriguez and G.D. Emmitt). Report from the NASA Post-2002 Land Surface Hydrology Planning Workshop, Irvine, CA, April 12-14.

PRESENTATIONS: Seminars/Workshops

2007: Integrating airborne DWL and PBL Models in realtime (G. D. Emmitt, C. O'Handley, S.A. Wood and S. Greco), Working Group on Space-Based Lidar Winds, Miami, FL, February 6 -9.

2007: Prospecting for thermals using an airborne DWL (G.D. Emmitt and C. O'Handley), Working Group on Space-Based Lidar Winds, Miami, FL, February 6 -9.

2007: Correlations of wind shear and clouds: numerical model results (S.A. Wood and G.D. Emmitt), Working Group on Space-Based Lidar Winds, Miami, FL, February 6 -9.

2007: Simulations of hybrid DWL performance with GLAS cloud penetrating statistics (G. D. Emmitt and S. A. Wood), Working Group on Space-Based Lidar Winds, Miami, FL, February 6 -9.

2007: Doppler wind lidar flights: prospecting for vertical motions to enhance SkyWalker performance (G. D. Emmitt, C. O'Handley and S. Greco), DARPA , Arlington, VA, January 31.

2006: Adaptive targeting of a space-based Doppler wind lidar: data and technology implications (G. D. Emmitt), SPIE Europe Remote Sensing, Stockholm, Sweden, September 11 – 14.

2006: Using ICESAT observations to obtain CFLOS statisitics for use in the design of space-based lidars (invited paper) (G. D. Emmitt and S. Greco), SPIE Europe Remote Sensing, Stockholm, Sweden, September 11 – 14.

2006: Tropospheric wind profiler: multi-spectral DWL (G. D. Emmitt), NASA/ESTO lidar workshop, Washington, DC, June.

2006: GLAS cloud statistics and their implications for a hybrid mission (G. D. Emmitt and S. Greco), Working Group on Space-Based Lidar Winds, Welches, OR, June 28 – 30.

2006: New sampling perspectives for TODWL (G. D. Emmitt and C. O'Handley), Working Group on Space-Based Lidar Winds, Welches, OR, June 28 – 30.

2006: Development of a remote sensing testbed for tropospheric air quality and winds (M. Newchurch, et.al and G. D. Emmitt), Working Group on Space-Based Lidar Winds, Welches, OR, June 28 – 30.

2006: OSSE plans related to a hybrid mission and ADM follow-on missions (G.

D. Emmitt), Working Group on Space-Based Lidar Winds, Welches, OR, June 28 – 30.

2006: Planning for airborne DWL participation in PARC (G.D. Emmitt and M. Hardesty), Working Group on Space-Based Lidar Winds, Welches, OR, June 28 – 30.

2006: April test train: preliminary CCLPS results, NCTA specials meeting, Denver, CO, June 21.

2006; Optimizing rail availability for PRB coal transport: summary of trends (G. D. Emmitt), NCTA special meeting, Denver, CO, June 21.

2006: Recommendations for the PRB coal loss mitigation program (G. D. Emmitt), NCTA special meeting, Denver, CO, June 21.

2006: Coal loss study update (G. D. Emmitt and E. D. Carre), NCTA workshop, St Louis, MO, February 21.

2006: CCLPS estimates of coal losses by wind erosion (G. D. Emmitt and E. D. Carre), NCTA workshop, St Louis, MO, February 21.

2006: Adaptive targeting schemes and their technology implications (G. D. Emmitt), Working Group on Space-Based Lidar Winds, Key West, FL, January 16.

2006: Latest simulations for a tropospheric wind sounder on NPOESS and beyond (G. D. Emmitt, S. A. Wood, B. Gentry and M. Kavaya), Working Group on Space-Based Lidar Winds, Key West, FL, January 16.

2006: NPOESS P3I and follow-on threshold operational mission (G. D. Emmitt and S. A. Wood), Working Group on Space-Based Lidar Winds, Key West, FL, January 16.

2006: Status of TODWL and GWOLF (G. D. Emmitt and C. O'Handley), Working Group on Space-Based Lidar Winds, Key West, FL, January 16.

2006: Adaptive targeting OSSEs for planning a space-based Doppler wind lidar (G. D. Emmitt, S. A. Wood, S. Greco, M. Matsutani, J. Woolen, Z. Toth and Y. Song), AMS annual meeting, IOAS-AOLS, January.

2005: Using airborne lidar data in models: an adaptive targeting approach (G. D. Emmitt), UAH, Huntsville, AL Seminar series, November 28.

2005: Coal losses from railcars: summary of data analyses (G. D. Emmitt, D. Carre, L.Wood and C. Palomares), NCTA special meeting, Ft. Worth, TX, November 15.

2005: OSSEs at GSFC (G. D. Emmitt and R. Atlas), Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: OSSEs at NCEPm(M. Matsutani, J. Woolen, Z. Toth, G. D. Emmitt and S. Lord), Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: Investigation of the utility of airborne DWL data in mesoscale models (G. D. Emmitt, S. A. Wood and S. Greco, Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: Scaling TODWL and GWOLF performance to space (G. D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: SNR issues: definitions, theory and practice (G. D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: Simulating a dual technology DWL at 833 km (G. D. Emmitt, S. Wood, M. Kavaya and B. Gentry), Working Group on Space-based Lidar Winds, Welches, OR, June 28 – 30.

2005: Preliminary results of GLAS data base study of CFLOS statistics (G. D. Emmitt and S. Greco), Working Group on Space-Based Lidar Winds, Sedona, AZ, February 1 – 3.

2005: Mars related opportunities for DWL applications (G. D. Emmitt, G. Koch, M. Kavaya and U. Singh), Working Group on Space-based Lidar Winds,Sedona, AZ, February 1 – 3.

2005: Status of NCEP and GSFC OSSEs with DWLs (S. Lord, R. Atlas, G. D. Emmitt), Working Group on Space-based Lidar Winds,Sedona, AZ, February 1 – 3.

2005: Investigation of backscatter/wind correlations using an airborne 2-micron coherent Doppler wind lidar (G. D. Emmitt, C. O' Handley, D. Bowdle and H. Jonsson), Working Group on Space-based Lidar Winds,Sedona, AZ, February 1 – 3.

2005: Airborne WindSat Validation Program (Gasiewski, A. J, P. Gaiser, H.

Graber, and G. D. Emmitt), White paper submitted to NPOESS (Mango), January 11.

2004: Airborne Doppler lidar for WindSat Cal/Val (G. D. Emmitt, S. A. Wood, C. O'Handley, S Greco, H. Jonsson), WindSat Cal/Val and Science Meeting, Solomons Md, 17-18 November.

2004: The importance of CALIPSO to the design of follow-on lidars, inparticular, Doppler wind lidars (G. D. Emmitt), CALIPSO Workshop, NCEP, Silver Springs, Md., June 10.

2004: Comparison of measured and modeled aerosol backscatter during TODWL/2003 (D. Bowdle, G.D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: Using surface returns to correct for aircraft motion induced errors (G.D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: The DSLM on-line (S. Wood and G.D. Emmitt), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: GWOLF and VALIDAR comparisons (M. Kavaya, G. Koch, G.D. Emmitt, and S. Wood), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: Comparisons of TODWL soundings with MM5, microwave sounders, towers, and other wind sensors (G.D. Emmitt, S. Wood, S. Greco, and C. O'Handley), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: Status of IPO-funded hybrid feasibility and airborne testbed (G.D. Emmitt, B. Gentry, M. Hardesty, and M. Kavaya), Working Group on Space-based Lidar Winds, Sedona, AZ, January 27-29.

2004: OSSEs for realistic DWL concepts (G.D. Emmitt and R. Atlas), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Potential contribution of multiple Doppler wind lidars to a prospective CHEM/ CLOUD experiment in Huntsville, Alabama (G.D. Emmitt, M. Newchurch, and D. Bowdle), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Using TODWL and in situ particle probes to understand the backscatter signature of marine, boundary layer organized structures (D. Bowdle, G.D.

Emmitt, and S. Wood), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Using TODWL data to validate marine boundary layer models (R. Foster, R. Brown, C. O'Handley, and G.D. Emmitt), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Hybrid DWL simulations for OSSEs (G.D. Emmitt and S. Wood), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Accuracy of airborne Doppler lidar using threading and ground returns (G.D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2004: Status of TODWL and GWOLF activities and plans for future airborne DWL (G.D. Emmitt, B. Gentry, M. Hardesty, and M. Kavaya), Working Group on Space-based Lidar Winds, Frisco, CO, June 29-July 1.

2003: Simulating cloud and water vapor motion winds form a nature run (C. O'Handley and G. D. Emmitt), March 6.

2003: IPO Cal/Val for a space-based wind observing system (G.D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, Oxnard, CA, February 17-19.

2003: Status of Hybrid DWL study (G.D. Emmitt, S. Wood, and G.D. Spiers), Working Group on Space-based Lidar Winds, Oxnard, CA, February 17-19.

2003: GWOLF 2003 (G.D. Emmitt, C. O'Handley, M. Kavaya and G. Koch), Working Group on Space-based Lidar Winds, Bar Harbor, ME.

2003: IPO-funded airborne lidar experiments: TODWL 2003 (G.D. Emmitt, S. Greco, C. O'Handley, and S. Wood), Working Group on Space-based Lidar Winds, Bar Harbor, ME.

2003: Investigation of the marine boundary layer and validation of numerical models using an ONR/IPO airborne Doppler wind lidar (G.D. Emmitt), NRL seminar, Moneterey, CA, August.

2003: Airborne Doppler lidar for basic atmospheric research and calibration of space-based wind sensors (G.D. Emmitt , B. Bluth and H. Jonsson), NASA/MSFC seminar, Huntsville, AL.

2003: Airborne Doppler lidar investigation of flow within complex terrain and marine boundary layers (G.D. Emmitt), Invited talk, Arizona State University,

November.

2002: Hybrid DWL: simulations of expected data products for use in OSSEs (D. Emmitt and S. Wood), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Status of IPO's Cal/Val study: the TODWL Spring 2002 checkout flights (D. Emmitt, C. O'Handley, and D. Bowdle), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Investigation of the marine LAS with an airborne Doppler wind lidar (D. Emmitt, C. O'Handley, D. Bowdle), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Nadir angle dependence of water surface return at 2 microns using TODWL (D. Emmitt and C. O'Handley), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: TODWL: Between flight programs (D. Emmitt and P. Gatt), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Technology plan for the coherent subsystem of a space-based hybrid Doppler wind lidar (M. Kavaya, A. Amzajerdian, U. Singh, J. Yu, and D. Emmitt), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Technology roadmap for a direct detection Doppler lidar subsystem (B. Gentry, M. McGill, G. Schwemmer, B. Heaps, and D. Emmitt), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: Status of the Doppler Lidar Simulation Model (DLSM) for GTWS (S. Wood and D. Emmitt), Working Group on Space-based Lidar Winds, North Conway, NH, July 15-18.

2002: A space-based coherent wind lidar point design for the NASA/NOAA Draft Science and Operational Data Requirements (M. Kavaya, D. Emmitt, R. Frehlich, F. Amzajerdian, U. Singh), Working Group on Space-based Lidar Winds, Key West, FL, January 23-25.

2002: Status of TODWL and other IPO funded activities (G.D. Emmitt et al.), Working Group on Space-based Lidar Winds, Key West, FL, January 23-25.

2002: A hybrid DWL concept for instrument and mission analyses (D.Emmitt, B. Gentry, and M. Kavaya), Working Group on Space-based Lidar Winds, Key West, FL, January 23-25.

2002: Discussion of the GTWS reference atmospheres and their use (D. Emmitt), Working Group on Space-based Lidar Winds, Key West, FL, January 23-25.

2001: Status of bracketing OSSEs at NCEP for several DWL notional concepts (G.D. Emmitt), Working Group on Space-based Lidar Winds, Oxnard, CA, February 7-9.

2001: Developing a CAL/VAL plan for a space-based Doppler wind lidar (G.D. Emmitt), Working Group on Space-based Lidar Winds, Oxnard, CA, February 7-9.

2001: IPO funded airborne DWL for CAL/VAL planning (G.D. Emmitt), Working Group on Space-based Lidar Winds, Oxnard, CA, February 7-9.

2001: Updated report on Hybrid technology DWLs (G.D. Emmitt), Working Group on Space-based Lidar Winds, Oxnard, CA, February 7-9.

2000: Adaptive targeting study for DWL operations (G.D. Emmitt, Z. Toth, E. Kalnay, R. Atlas). Working Group on Space-based Lidar Winds, Boulder, CO, June 21-23.

2000: Update on the feasibility study for a hybrid technology DWL (G.D. Emmitt). Working Group on Space-based Lidar Winds, Boulder, CO, June 21-23.

2000: Simulated DWL observations for the global OSSEs at NCEP: Coverage, accuracy, and systematic errors (G.D. Emmitt). Working Group on Space-based Lidar Winds, Boulder, CO, June 21-23.

2000: HYDROSAT: An opportunity for space-based Doppler lidar (G.D. Emmitt). Working Group on Space-based Lidar Winds, Boulder, CO, June 21-23.

2000: Update on IPO-funded wind lidar studies (G.D. Emmitt). Working Group on Space-based Lidar Winds, Daytona Beach, FL, January 26-28.

2000: Status of the Hybrid DWL feasibility study (G.D. Emmitt). Working Group on Space-based Lidar Winds, Daytona Beach, FL, January 26-28.

2000: HYDRA-SAT and the role of coherent Doppler lidar (G.D. Emmitt). Working Group on Space-based Lidar Winds, Daytona Beach, FL, January 26-28.

2000: The role of DWL OSSE's and appropriate metrics for a commercial wind data buy
(G.D. Emmitt). Working Group on Space-based Lidar Winds, Daytona Beach, FL, January

26-28.

1999: Recent results of IPO funded OSSE efforts at NCEP and GSFC (G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: SPARCLE data product validation plan: Mission scientist's assessment (G.D. Emmitt, R. Menzies and D. Bowdle). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: SPARCLE "Challenges" B Pointing (G.D. Emmitt, T.Miller and G. Spiers). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: SPARCLE performance modeling (G. Spiers and G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Follow on mission(s) for SPARCLE (M. Kavaya, G.D. Emmitt and T. Miller). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Status of OSSEs at NCEP (R. Atlas and G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Review of observational requirements for global DWL winds (G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Adaptive targeting with a space-based DWL (G.D. Emmitt and R. Atlas). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Update of LITE analyses of cloud and aerosol backscatter statistics (D. Winker and G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: SPARCLE Science Team Meeting (G.D. Emmitt). Working Group on Space-based Lidar Winds, Key West, FL, January 19-22.

1999: Status of the NASA New Millennium Program. Presented for C. Raymond by G.D. Emmitt. Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: Status of wind lidar OSSEs at NCEP (G.D. Emmitt and R. Atlas). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: SPARCLE: What happened, lessons learned, what next (T. Miller and G.D.

Emmitt). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: Results of the ALADIN (ISS) impact study. Presented for W. Wergen et al. By G.D. Emmitt, Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: A notional hybrid DWL on the roadmap to an operational system (G.D. Emmitt). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: Data requirements and specifications (G.D. Emmitt). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: OSSEs and impact metrics definitions (G.D. Emmitt). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: Benefits of a pre-data buy DWL demo mission (G.D. Emmitt). Working Group on Space-based Lidar Winds, Mt. Hood, OR, July 6-9.

1999: An overview of the potential space-based application of coherent Doppler lidar to measure the surface velocity of rivers (G.D. Emmitt). NASA-USGS Workshop on Remote Sensing of River Stage and Discharge, Herndon, VA, September 23-24.

1999: Airborne Doppler lidar observations of river transects (MACAWS) (G.D. Emmitt and J. Rothermel). NASA-USGS Workshop on Remote Sensing of River Stage and Discharge, Herndon, VA, September 23-24.

1998: SPARCLE mission science plan (G.D. Emmitt). NOAA Working Group on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: Pointing knowledge: GPS/INS (G. Kamerman and G.D. Emmitt). NOAA Working Group on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: Velocity error budget (G. Spiers and G.D. Emmitt). NOAA Working Group on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: Simulated performance of SPARCLE and follow-on missions (G.D. Emmitt). NOAA Working Group on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: Simulating coherent and direct detection DWLs for IPO OSSEs (G.D. Emmitt). NOAA Working Group on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: The validation program. OSSEs (G.D. Emmitt). NOAA Working Group

on Space-based Lidar Winds, Key West, FL, January 20-22.

1998: Calibration of the GPS/INS (G.D. Emmitt and G. Spiers). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: Cloud statistics from LITE and relevance to wind lidar performance (D. Winker and G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: An approach to evaluating the merits of a hybrid technology Doppler wind lidar (G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: Update of target atmospheres for use in DWL concept studies (S. Wood and G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: Inverted quasi-conical partial VAD processing of MACAWS data taken during turns (G.D. Emmitt, S. Wood and S. Greco). NOAA Working Group on Space-Based Lidar
Winds, Boulder, CO, July 13-16.

1998: Update on recent OSSEs (R. Atlas, S. Wood and G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: What is a useful wind measurement? (G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1998: Review of the lidar working group data requirements (G.D. Emmitt). NOAA Working Group on Space-Based Lidar Winds, Boulder, CO, July 13-16.

1997: Status of performance simulations in support of the shuttle and NPOESS missions (G.D. Emmitt), NOAA Working Group on Space-based Lidar Winds, Daytona, FL, January 21-23.

1997: Issues related to the comparison of DWL technologies and the simulation of their performance (e.g., wallplug efficiences and beta vs. wavelength) (G.D. Emmitt), NOAA Working Group on Space-based Lidar Winds, Daytona, FL, January 21-23.

1997: Proposed role of OSSEs for CAMEX III (G.D. Emmitt), NOAA Working Group on Space-based Lidar Winds, Daytona, FL, January 21-23.

1997: Relevance of LITE data analysis to space-based DWL performance (G.D. Emmitt and D. Winker), NOAA Working Group on Space-based Lidar Winds,

Northglenn, CO, July 15-17.

1997: Update on OSSEs for NPOESS and CAMEX III (G.D. Emmitt, S. Wood, L. Wood, and S. Greco), NOAA Working Group on Space-based Lidar Winds, Northglenn, CO, July 15-17.

1997: Status report on NASA's DWL shuttle mission -- The science/data perspective (G.D. Emmitt, S. Wood, and M. Kavaya), NOAA Working Group on Space-based Lidar Winds, Northglenn, CO, July 15-17.

1997: Issues related to DWL scanning, sampling and LOS co-processing (G.D. Emmitt, S. Wood, B. Rye), NOAA Working Group on Space-based Lidar Winds, Northglenn, CO, July 15-17.

1996: Use of MACAWS data to address issues related to a space-based DWL (G.D. Emmitt, S. Greco and J. Rothermel) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Daytona Beach, FL, February 6-9.

1996: Figures of Merit for DWL OSSEs (G.D. Emmitt and R. Atlas) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Daytona Beach, FL,February 6-9.

1996: Effects of wind shear on signal processing (G.D. Emmitt) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Daytona Beach, FL,February 6-9.

1996: Data volume issues for a 2□m small-sat mission (G.D. Emmitt and S.A. Wood) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Daytona Beach, FL, February 6-9.

1996: Preliminary cloud and cloud porosity statistics from LITE (G.D. Emmitt and D. Winker) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Daytona Beach, FL, February 6-9.

1995: Use of NASA/NOAA ground-based lidar data to evaluate several signal processing strategies (G.D. Emmitt) Paper presented at the NOAA Working Group on Space-based Lidar Winds, Clearwater, FL, January 31-February 2.

1995: Revised outlook for mid/upper tropospheric returns for a small-satellite wind lidar (G.D. Emmitt) Paper presented at the NOAA Working Group on Space-based Lidar Winds, Clearwater, FL, January 31-February 2.

1995: OSSEs in support of a small-satellite mission (G.D. Emmitt) Paper presented at the NOAA Working Group on Space-Based Lidar Winds, Clearwater, FL,January 31-February 2.

1995: Status of efforts by the U.S.A. Working Group on Space-Based Lidar Winds (G.D. Emmitt and W.E. Baker) Paper presented at the ESA Doppler Wind Lidar Workshop, Noordwijk, The Netherlands, September 20-22.

1993: Update on LAWS data simulations (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, January, Clearwater Beach, FL.

1993: Design considerations for a Quick LAWS (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, January, Clearwater Beach, FL.

1993: Update on ground-based lidar observations (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, January, Clearwater, FL.

1992: Simulated LAWS performance profiles (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, July, Cape Cod, MA.

1992: LAWS power budget simulations (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, July, Cape Cod, MA.

1992: Review of mission science objectives for LAWS (G.D. Emmitt). Paper presented at the LAWS Science Team Meeting, July, Cape Cod, MA.

1991: LAWS, a career in global transports. Seminar given at Florida State University, Tallahassee, FL, January 14-18.

1990: Shot management for LAWS. LAWS Simulation Workshop, March, Goddard Space Flight Center, Greenbelt, MD.

1990: Optimal scanning pattern in partly cloudy regions. LAWS Science Team Meeting, August 1-3, Boulder, CO.

1990: Optimal sampling strategies for space-based laser wind sounders. Seminar at Laboratoire de Météorologie Dynamique, June 8, Ecole Polytechnique, Palaiseau, France.

1990: Preliminary estimates of LAWS global observation opportunities below 15 km. GLOBE Meeting, March 7-8, Huntsville, AL.

1990: Optimal sampling strategies in partly cloudy regions for space-based laser wind sounders. Seminar at Laboratoire de Météorologie Dynamique, Ecole Normal Supérieure, September, Paris, France.

1990: Role of OSSEs in the design of a space-based lidar wind sounder. Seminar at European Center for Medium Range Forecasts, September 4, Reading, England.

1989: LAWS - Can it provide more than just winds? Seminar at NASA Langley Research Center, Hampton, VA, October.

1987: Windstorms: site-specific risk assessment. American International Group's Fall 1987 Seminar on Geophysical Hazards, New York, N.Y., December.

1980: Nocturnal boundary layer measurements made with a tethered balloon. SESAME 1979 Data Users Workshop, January, Boulder, CO.

1979: Seminar on hail suppression and its implications. Departmental Seminar, University of Virginia, April.

1977: Use of direct and indirect estimates of cumulus transports to estimate total active cloud cover. Seminar paper given at MPI fur Meteorologie, Hamburg, West Germany.

1977: Elected to present final report of the GATE Workshop Boundary Layer Group at the International Conference on the energetics of the tropical atmosphere, Tashkent, U.S.S.R., September; report published in proceedings of the conference.

1977: Invited participant at the GATE summer workshop (3 papers), Boulder, Colorado, July 29-August 12.

1977: Technical aspects of tethered balloon operations. Seminar paper given at the Danish Atomic Energy Laboratories, RISϕ, Denmark.

1977: Cumulus convection below cloud base. Seminar paper given at the Danish Atomic Energy Laboratories, RISϕ, Denmark.

1976: Tropical cumulus activity below cloud base. Seminar paper given at MPI fur Meteorologie, Hamburg, West Germany.

1974: Opportunities for physicists in a Department of Environmental Sciences (G.D. Emmitt). Given at Eastern Nazarene College, Wollaston, MA.

RESEARCH

Principal Investigator: NOAA's Integrated Program Office's (IPO) feasibility study for hybrid Doppler wind lidars

Principal Investigator: NOAA's IPO observing system simulation experiments for space-based DWLs

Principal Investigator: NOAA's IPO targeted observing strategies for wind lidars

Principal Investigator: NOAA's IPO calibration/validation plan for space-based DWLs

Principal Investigator: NOAA's IPO twin otter Doppler wind lidar (TODWL) for cal/val strategy development

Principal Investigator: NASA LaRC, Modification of the Doppler lidar simulation model

Principal Investigator: Provincial Energy Ventures Dust Suppression System Design

Principal Investigator: NASA GSFC – GTWS Science Definition efforts

Principal Investigator: Storm top divergence studies using the LAWS, NASA/Marshall Space Flight Center.

Principal Investigator: Cloud top and planetary boundary layer wind measurements using a space-based lidar, SBIR, U.S. Air Force.

Principal Investigator: Simulation experiments to assess LAWS' impact on global climate change modeling, NASA.

Principal Investigator: Vertical velocity structures significant to space-based and ground- based lidar anemometry, CNES, France.

Principal Investigator: Norfolk Southern Rail Study.

Co-Principal Investigator: Interdisciplinary research scenario - Version Ø, NASA.

Principal Investigator: EOS Laser atmosphere wind sounder (LAWS) investigation, NASA.

Principal Investigator: Space-based Doppler lidar sampling strategies -- algorithm development and simulated observation experiments, NASA.

Principal Investigator: PLACEM, Pier IX Terminal Company/Shell Mining.

Principal Investigator, Interdisciplinary research scenario - Version 0, NASA.

Principal Investigator, Airborne/space-based Doppler lidar wind sounders: Sampling the PBL and other regions of significant B and u inhomogeneities, NASA.

Principal Investigator, Lidar mapping of cloud tops and cloud top winds, SBIR, AFGL.

Principal Investigator: Tropospheric wind observations with Doppler lidars: SPARCLE and follow-on missions, NASA.

Principal Investigator: CAMEX-3, NASA.

Principal Investigator, DTA Pile Moisture Modeling project.

Fugitive coal dust emission project at Elk Run Coal Company

Fugitive coal dust emission project for Norfolk Southern

Design of Procontrol System for SINCOR, Jose, Venezuela

VERIFIED STATEMENT OF EROL TUTUMLUER

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB Finance Docket No. 35305

PETITION OF ARKANSAS ELECTRIC COOPERATIVE CORPORATION FOR A DECLARATORY ORDER

VERIFIED STATEMENT OF EROL TUTUMLUER IN SUPPORT OF BNSF RAILWAY COMPANY'S OPENING EVIDENCE

My name is Erol Tutumluer. I am Professor of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign where I have studied and published papers regarding the effect of fugitive coal dust upon railroad ballast. The purpose of my Verified Statement is to describe for the Board my findings that coal dust has a pernicious effect upon railroad ballast.

Introduction

Fouling of the railroad ballast occurs when spaces or voids in this unbound aggregate layer are filled with finer sized materials. As a fouling agent, coal dust from coal trains accumulating in the ballast has become a major concern. I have studied the most probable adverse impacts of coal dust on railroad ballast on drainage and load carrying function, which were previously unknown because of the lack of technical data. As summarized below in my Verified Statement, the physical and mechanical properties of coal dust and other laboratory tests indicate that coal dust is one of the worst fouling agents when compared to mineral filler produced from aggregate breakdown and the fine-grained cohesive subgrade soils. Coal dust particles are mainly sand sized, however, they have lower density and greater plasticity, meaning that they have much greater water holding ability than subgrade soil fines, which are silty and

clayey and often plastic (i.e., they possess high moister affinity). As compared to sand particles, coal dust particles greatly reduce the ballast strength, stability, resistance to settlement under unit trains, and ultimately the load-bearing ability of fouled ballast layers. My two major papers concerning fouled ballast are attached hereto as Exhibits 3 and 4. Exhibit 3 is Tutumluer, E., Dombrow, W., and Huang, H., "Laboratory Characterization of Coal Dust Fouled Ballast Behavior," In Proceedings of the AREMA 2008 Annual Conference, Salt Lake City, Utah, September 21-24, 2008. Exhibit 4 is Huang, H., Tutumluer, E., and Dombrow, W., "Laboratory Characterization of Fouled Railroad Ballast Behavior," Transportation Research Record 2117: Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2009, pp. 93-101.

Exposure of coal dust to moisture significantly reduces the friction component of the shear strength and can cause significant reduction in load-bearing capacity. Even more drastic strength reductions can be realized when dry coal dust, never before saturated or soaked in the field and therefore having a high suction potential, is subjected to inundation and 100% saturation. This was exactly the case in 2005 when two derailments occurred on the BNSF/UP Joint Line—there was heavy precipitation after a relatively low level of precipitation for an extended period of time in the region, and in both places where the derailments happened, the ballast was heavily fouled by coal dust. The coal dust caused moisture to accumulate and caused the loss of strength of the track, resulting in the derailments, which threatened to interrupt the supply of coal to power plants.

Education and Experience

My educational background is in Civil Engineering. In 1995, I earned a Ph.D. in Civil Engineering from the Georgia Institute of Technology in Atlanta, Georgia. In 1993, I earned a

M.S. in Civil Engineering from the Georgia Institute of Technology in Atlanta, Georgia. In 1991, I earned a M.S. in Civil Engineering from Duke University in Durham, North Carolina. In 1989, I earned a B.S. in Civil Engineering from the Bogazici University in Istanbul, Turkey.

I am a transportation and geotechnical engineer and serve as Professor of Civil and Environmental Engineering at University of Illinois at Urbana-Champaign ("UIUC"). In October 2006, I was recognized with the Endowed Paul F. Kent Faculty Scholarship for my research accomplishments. In August 2008, I was promoted to full professor position in the Department of Civil and Environmental Engineering. In October 2009, the Department of Civil and Environmental Engineering extended for a new 3-year term my recognition and title of the Endowed Paul F. Kent Faculty Scholar. I have taught graduate and undergraduate courses in transportation soils engineering, subgrade soil and aggregate behavior and stabilization, introduction to transportation engineering, and pavement analysis and design at the UIUC since 1996.

I am an affiliate of the Transportation Research Board, and I have chaired its AFS50(1) subcommittee on "Applications of Nontraditional Computing Tools Including Neural Nets" for the past six years. I currently serve on committees AFP70, AFP30, AFS50, and AFD80 of the Transportation Research Board. I am a member of the AREMA Committee 1 on "Ballast," and I am currently the chair of the Pavements Committee of the American Society of Civil Engineering's Geo-Institute, which has been just recently recognized with the 2010 Committee of the Year Award from the American Society of Civil Engineering ("ASCE") Geo-Institute.

I am currently an Associate Editor for both the ASCE Journal of Computing in Civil Engineering (http://pubs.asce.org/journals/computing/default.htm) and the International Journal of Pavement Research and Technology (http://www.ijprt.org.tw). I also serve as an Editorial

Board Member for the International Journal of Pavement Engineering (Taylor and Francis Group, http://www.tandf.co.uk/journals) and the ASCE International Journal of Geomechanics (http://pubs.asce.org/journals/geomechanics/default.htm). I was the Conference Chair and Proceedings Co-Editor of the Eighth International Conference on the Bearing Capacity of Roads, Railways and Airfields, which was held at the University of Illinois, Champaign, Illinois on June 29-July 2, 2009 (http://www.BCR2A.org). My *curriculum vitae* is attached to this statement as Exhibit 1.

My research areas and expertise include testing and modeling railroad track geo-material (i.e., subgrade soils and ballast/subballast unbound aggregates); use of geosynthetics in railroad track and pavement substructure; shape, texture, angularity characterization of aggregates using video-imaging techniques; modeling of particulate media using discrete and finite element methods; and mechanistic based railroad track and pavement designs. I have authored or co-authored more than 150 technical papers in these areas.

I have extensive experience in studying the effect of coal dust on ballast behavior. I have also studied the potential for developing ground penetrating radar ("GPR") based railway track subsurface condition indices from estimates of track bed materials' physical properties and the recent BNSF project on the characterization of fouled ballast behavior. To study ballast fouling through the use of GPR scanning, I traveled to Gillette, Wyoming on July 22-25, 2007 to collect ballast aggregate samples from the Joint Line. During this visit to the Joint Line, I had a chance to personally observe the coal dust accumulation.

I have also recently studied the effects of accumulation of coal dust in the aggregate ballast layer of the railroad track structure on the BNSF/UP Joint Line and have published two major papers concerning the effect of coal dust upon fouled ballast. The research study focused

on large direct shear laboratory tests to measure strength and deformation characteristics of both clean (new) and fouled ballast aggregates at various stages of fouling with (1) non-plastic mineral filler, (2) plastic clayey soil, and (3) coal dust. This study determined material properties that could be used for modeling the ballast behavior and evaluating reductions in strength and stability. The tests were conducted at the University of Illinois on granite and limestone ballast samples. The coal dust was provided by the BNSF from the Joint Line. From the research findings, the two major papers that I previously identified were published. The first of these papers, Exhibit 3 to this statement, presents the test results on coal dust and fouling of granite type ballast material. The second of these papers, Exhibit 4 to this statement, documents the effects of three types of fouling agents: coal dust, non-plastic mineral filler, and plastic clayey subgrade soils. We found that coal dust caused the worst fouling effects and the greatest shear strength loss while non-plastic mineral filler and plastic clayey subgrade soils caused less detrimental effects as fouling agents.

I have extensive experience on other issues relating to railroad track substructure, and that experience is described in Exhibit 2 attached hereto.

Coal Dust Problem

Based upon my specific research regarding coal dust and its impact upon ballast, I have found that coal dust is one of the worst fouling agents when compared to mineral filler produced from aggregate breakdown and the fine-grained cohesive subgrade soils.

Let me start by describing ballast and its purpose. Railroad ballast is uniformly-graded coarse aggregate placed between and immediately underneath the crossties and the rail. The purpose of ballast is to provide drainage and structural support for the heavy weight applied by loaded trains. Proper functioning ballast is critical to maintain operations on high volume tracks,

such as the tracks on the Joint Line. For a proper functioning ballast, superior ballast aggregate shape properties, such as an angular crushed stone, and size distribution (gradation) are critical to provide ballast strength and stability. Proper functioning ballast gradation requires large enough spaces or voids between the aggregate to provide adequate drainage. Therefore, for ballast to function properly, it must have sufficiently large voids for drainage and structural stability.

As a section of ballast on the Joint Line ages, it is progressively fouled with fine-grained materials, such as mineral filler, plastic soil fines, and coal dust from coal trains. These materials can fill the voids and cause ballast fouling. The most commonly used method to assess track ballast condition is to check visually for evidence of fouling, pumping, or water accumulation (ponding) at ditches and shoulders. However, the surface of a ballast layer generally has a clean appearance most of the time, and it is often not possible to detect the amount of ballast fouling through visual inspection alone as the clean appearance of the surface of a ballast layer may nonetheless conceal fouled ballast. Another method for testing ballast fouling is ballast sampling and testing through laboratory sieve analyses. This laboratory method can provide some insight into the compositions of the larger aggregate particles and the amount of fines in a particular ballast section. Finally, the use of ground penetrating radar ("GPR") can also indicate the amount of ballast fouling. GPR is a nondestructive means of testing because it scans existing railroad track. The use of GPR, however, is currently at a research stage for future implementation, and it is not yet a standard practice.

Regardless of the method used to test the ballast, fouled ballast occurs when there is the loss of aggregate to aggregate contact because the voids are filled with finer sized materials. In a clean ballast sample, almost all aggregates are supposed to establish contact with each other at the aggregate surface to carry the load (as shown in Exhibit 3, at 21 Figure 2a). As shown in

Exhibit 3, page 21 Figure 2b, dirty or partially fouled ballast has the voids in between contacting aggregates filled with fine particles, but still maintains aggregate to aggregate contact. By contrast, fouled ballast has an excessive amount of fine particles, and the aggregate to aggregate contacts are mostly eliminated (as shown in Exhibit 3, page 21 Figure 2c). The aggregate particle movements are then only constrained by the fine particles filling the matrix or voids between the particles. In regards to excessive fouling conditions, for example, as in the case of 2005 Joint Line derailments when wet coal dust completely filled all voids in ballast and pumping was observed on the surface of railroad track, the low strength of the fouling agent would govern for carrying the wheel load. Hence, train derailments may occur due to unstable support under the crossties.

My research showed that different fouling agents have different effects on ballast based upon the physical and mechanical properties of the fouling agents. There are mainly three types of ballast fouling agents: (1) nonplastic mineral filler; (2) fine-grained and plastic subgrade soils; and (3) coal dust. Plasticity index refers to a certain range of gravimetric moisture content in soils determined in the laboratory as the difference between the liquid limit (at which soil behaves as a viscous fluid) and the plastic limit (lower moisture content at which a thin 1/8-inch soil thread crumbles upon rolling under your palm), and it is obtained from conducting these Atterberg limit tests on soils. The term "nonplastic" therefore refers to the low affinity and moisture absorption or holding ability of mineral fillers. Subgrade soils are fine-grained, i.e., silty, clayey, and are often plastic, meaning that they possess high moisture affinity. In our research study attached as Exhibit 3, coal dust was found to be highly plastic, meaning it has the potential to absorb water like a sponge, and was even more plastic than most commonly found plastic natural clays. Although 76% of coal dust was found to have sand-sized particles with

only 24% silt of clay sized, the high plasticity of coal dust is expected to have the most detrimental effects on mechanical properties and impact differently the engineering behavior when they foul clean ballast layers. Our research shows that in rail lines where the ballast is not exposed to coal dust, ballast fouling is due to ballast aggregate gradually powdering, i.e., breaking down, over a period of years. By contrast, in rail lines where the ballast is exposed to coal dust, the ballast is fouled very quickly by coal dust particles that accumulate in the ballast void spaces and have high potential to absorb moisture.

Research Shows That Coal Dust Is One of the Worst Ballast Fouling Agents That Has Been Studied.

I will briefly describe the test protocol we used in our research. We obtained coal dust samples from the Joint Line. In March 2007, BNSF provided four buckets of coal dust samples collected from Milepost 62.4 of the Joint Line. To determine the physical and mechanical properties of the coal dust samples, laboratory tests conducted at the University of Illinois included both dry and wet sieve analyses of the coal dust in compliance with ASTM C 136 and ASTM C 117 test procedures for determining grain size distributions, Atterberg limits, specific gravity, moisture-density compaction relationships, and shear strength properties. We compared the properties of coal dust to the physical and mechanical properties of fine-grained silty and clayey soils to identify coal dust's potential negative impact on railroad track ballast strength characteristics.

In the summer of 2007, BNSF Railway Company representatives in Gillette, Wyoming shipped to the University of Illinois approximately 2 tons of granite aggregate commonly used in the Joint Line railroad track structures as the ballast layer. To determine the physical properties of these granite aggregate materials, laboratory tests conducted at the University of Illinois included grain size distributions, specific gravity, and unit weight properties of the granite

aggregate. Using a large direct shear (shear box) testing machine, both clean and coal dust fouled granite ballast samples were then prepared and tested under dry and wet conditions in an effort to investigate shear strength properties in relation to the mechanical functions of railroad ballast.

Several laboratory tests were conducted on the Wyoming coal dust samples obtained from the Joint Line as reported in Exhibit 3. First, mechanical properties of representative coal dust samples were determined for the first time at the University of Illinois through laboratory tests, such as, grain size distribution, Atterberg limits, specific gravity, moisture-density compaction relationships, and shear strength properties. The summary of the test results are as follows:

- Coal dust Liquid Limit ("LL") = 91% – *much* higher than typical weak soils.
- Coal dust Optimum Moisture Content ("OMC") = 35% – *much* higher than typical weak soils.
- Coal dust can absorb and hold a lot of water when compared to typical weak soils such as clays and silts.
- Triaxial shear strength of coal dust at OMC = 3 psi – *very low*.
- Coal dust friction angle at OMC = 33.5 degrees obtained from direct shear tests indicated a large reduction with increasing moisture content.

Then, granite type aggregates—also received from the Joint Line near Gillette, Wyoming and commonly used in the railroad track as the ballast layer—were added coal dust at different percentages by weight and moisture contents to represent coal dust fouling in the field. When fouled samples were tested in large direct shear (shear box) equipment, we found that 25% coal dust by weight of aggregates were enough to fill up all the voids in ballast corresponding to 43% of the total volume. The summary of the test results are as follows:

- The highest shear strength values were obtained from the clean ballast at all applied normal stress levels.

- When ballast samples were fouled, the shear strength always decreased. Wet (35% OMC) coal dust fouling resulted in the lower ballast shear strengths than dry coal dust fouling.

- For the fully fouled case with 25% wet coal dust by weight of ballast, internal friction angle and cohesion obtained were equivalent to those properties of the wet coal dust itself. This implies that individual aggregate particles within ballast layer would then be completely separated by coal dust to most likely cause the worst track instability problems in the field.

These laboratory findings outlined in Exhibit 3 are the first detailed examination of the mechanical properties of coal dust. Accordingly, when subjected to precipitation, coal dust can hold excessive amounts of moisture to prevent free draining of the ballast, can keep ballast wet and saturated, and act as a lubricant between the ballast stones, enabling much greater movement within the ballast layer. While the fines' content (silt and clay size) of the coal dust was lower than that of most silty and clayey soils, the optimum moisture content of the coal dust found from standard Proctor compaction test was remarkably higher than that of some of the weak cohesive soils, which highlights its ability to hold much greater amounts of moisture than other weak soils. As Exhibit 3 explains in more detail, we concluded that the coal dust's high moisture holding capacity and the extremely low strength properties made coal dust the worst ballast fouling agent for its impact on track substructure and roadbed when compared to even the highly plastic type clayey soil fines.

I would also like to explain our test protocol for the research published in Exhibit 4. For this research, we conducted direct shear (shear box) laboratory tests at the University of Illinois on granite ballast samples to measure strength and deformation characteristics of both clean (new) and fouled ballast aggregates at various stages of fouling. Effects of the different fouling agents on ballast aggregate shear strength were studied when three types of fine materials, i.e., coal dust, plastic clayey soil and mineral filler, were added to clean ballast samples at various percentages by weight of ballast under both dry and wet (mostly optimum moisture content)

conditions. Realistic sample preparation procedures were conducted to closely simulate field fouling scenarios. The coal dust was also used as the fouling agent and mixed with clean aggregates for achieving fouling levels of 5%, 15%, and 25% by weight of ballast under dry and wet (at 35% optimum moisture content or OMC) conditions. Test results showed that when the coal dust fouling percentage increased, the ballast shear strength steadily decreased. Wet fouling was found to exacerbate this trend. Results of ballast samples fouled with clay and mineral filler also showed decreasing trends in strength properties; however, coal dust was by far the worst fouling agent for its impact on track substructure and roadbed. Approximately 15% coal dust fouling by weight of ballast caused considerable strength reductions in the ballast. In the case of ballast fully fouled with wet coal dust at 35% optimum moisture content, the friction angles obtained were as low as the friction angle of coal dust itself.

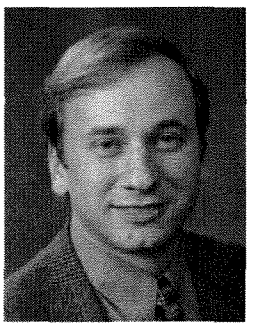
Exposure of coal dust to moisture significantly reduces the friction component of the shear strength and can cause significant reduction in load bearing capacity. Note that even more drastic strength reductions can be realized when dry coal dust that has never been saturated or soaked in the field and therefore has a high suction potential, is subjected to inundation and 100% saturation. This was exactly the case with the 2005 derailments that occurred on the BNSF/UP Joint Line, which threatened to interrupt the supply of coal to power plants. These derailments occurred as a result of heavy precipitation after a relatively low level of precipitation for an extended period of time in the region. Both of the derailments were suspected to be attributable to coal dust fouling, where coal dust spilled over the ballasts and accumulated moisture, allegedly resulting in the loss of strength of the track. In both places where derailments happened, the ballast was heavily fouled by coal dust.

I declare under penalty of perjury that the foregoing is true and correct. Further, I certify that I am qualified and authorized to file this Verified Statement.

Executed on March 15, 2010

Erol Tutumluer

EXHIBIT 1



Erol Tutumluer, Ph.D., Professor
Paul F. Kent Endowed Faculty Scholar
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign
205 N. Mathews, Urbana, IL 61801

Phone: (217) 333-8637
Fax: (217) 333-1924
E-mail: tutumlue@illinois.edu

Education

Ph.D., Civil Engineering, Civil Engineering, Georgia Tech, 1995
M.S., Civil Engineering, Georgia Tech, 1993
M.S., Civil Engineering, Duke University, 1991
B.S., Civil Engineering, Bogazici University, 1989

Professional Experience

8/2008-present	Professor, University of Illinois at Urbana–Champaign (UIUC)
2002-2008	Associate Professor, UIUC
8/1996-2002	Assistant Professor, UIUC
1/1996-8/1996	Post Doctoral Research Associate, UIUC

Academic Courses Taught

CEE 310 – Introduction to Transportation Engineering - undergraduate, UIUC
CEE 406 – Pavement Analysis and Design - undergraduate/graduate, UIUC
CEE 407 – Airport Facilities Design - undergraduate/graduate, UIUC
CEE 509 – Transportation Soils Engineering - graduate, UIUC
CEE 598 – Transportation Soil Stabilization - graduate, UIUC

Research Areas

Dr. Tutumluer has research interests in testing and modeling of pavement and railroad track geo-materials, use of geosynthetics in transportation facilities, characterization of aggregates using video-imaging techniques, modeling of particulate media using discrete and finite element methods, artificial intelligence in the form of neural network modeling, and mechanistic based pavement design. He has conducted several studies on anisotropy and stress dependency of aggregates affecting structural response and performance of flexible pavements with unbound aggregate layers sponsored by the Federal Aviation Administration (FAA), US Army Corps of Engineers, and the International Center for Aggregates Research (ICAR). He has also been working on size, shape, and angularity characterization of aggregates using video-imaging techniques sponsored jointly by the Federal Highway Administration (FHWA), the Illinois Department of Transportation (IDOT), and by the National Cooperative Highway Research Program (NCHRP).

Dr. Tutumluer's recent and currently ongoing research efforts include the Caterpillar, Inc. project on characterizing deformation behavior of oil sands mined in Canada, Association of American Railroads (AAR) project on discrete element modeling of railway ballast behavior, the Federal Railroad Administration (FRA) funded Ground Penetrating Radar based railroad track ballast condition assessment, Burlington Northern Santa Fe (BNSF) railroad gift grant to study characterization of fouled ballast behavior, railroad track substructure research jointly sponsored by FRA and AAR, O'Hare Modernization Program (OMP) project on subgrade support and stabilization of airport pavements, FAA project on

granular layer deformation analyses of National Airport Pavement Test Facility of full-scale test sections under trafficking, NCHRP 4-34 project on laser based aggregate characterization, Tensar International, Inc. project on modeling and design of geogrid reinforced flexible pavements, investigating effects of aggregate type and quality including recycled asphalt product (RAP) used as aggregate in pavement working platforms and base layers supported by IDOT, and nondestructive pavement evaluation using artificial intelligence in the form of modeling with neural networks and genetic algorithms supported by IDOT and NEXTRANS US DOT Region 5 University Transportation Center.

Honors and Awards

Best Paper Award, Geology and Properties of Earth Materials Section, Transportation Research Board, National Academy of Sciences, January 2009
Paul F. Kent Endowed Faculty Scholar, Civil and Environmental Engineering, UIUC, 2006
Listed in the "Incomplete List of Teachers Ranked as Excellent By Their Students," UIUC, 2003 & 2008
TRB Fred Burgraff Award for Excellence in Transportation Research, 2000
Collins Fellow, Academy of Excellence in Engineering Education, UIUC, 2000
General Electric Fellow, Academy of Excellence in Engineering Education, UIUC, 1999
General Electric Scholar, UIUC, 1997
Engineering Education Scholar, National Science Foundation, 1997

Professional Societies

Member of the American Society of Civil Engineers (ASCE)
Chair of the ASCE Geo-Institute's Pavements Committee
Affiliate of the Transportation Research Board (TRB)
Serves on TRB committees AFP70, AFP30, AFS50, AFS70(2), AFD80
Chair of TRB's AFS50(1) subcommittee on "Applications of Nontraditional Computing Tools Including Neural Nets"
Member of the American Railway Engineering and Maintenance of Way Association (AREMA)
Member of the Association of Asphalt Paving Technologists (AAPT)
Member of the American Society of Engineering Education (ASEE)
Member of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE)
- ISSMGE TC 3, *Geotechnics of Pavements*
- ISSMGE TC 29, Laboratory Stress Strain Strength Testing of Geomaterials
Member of the International Association for Computer Methods and Advances in Geomechanics
Voting Member of the International Society for Asphalt Pavements (ISAP)
Voting Member of the International Society for Concrete Pavements (ISCP)

Books Authored or Co-Authored, Original Editions

The Design Theory and Methodology of Asphalt Pavement Based on the Cross-Anisotropy, Co-authored by Zhenfeng Li and Erol Tutumluer, Water Publishers, China (www.waterpub.com.cn) (ISBN: 978-75084-4328-7, pages: 169, 2007)

Books Edited or Co-Edited

ASCE Geotechnical Special Publication No. 89, entitled, Recent Advances in the Characterization of Transportation Geomaterials, Proceedings Book of the Third National Conference of the Geo-Institute of ASCE, Geo-Engineering for Underground Facilities, University of Illinois at Urbana-Champaign, June 13-17, 1999. Edited by E. Tutumluer and A.T. Papagiannakis (ISBN: 0-7844-0437-2, pages: 72, 1999)

ASCE Geotechnical Special Publication No. 123, entitled, Recent Advances in Materials Characterization and Modeling of Pavement Systems, Proceedings Book of the Pavement Mechanics Symposium at the 15th ASCE Engineering Mechanics Conference (EM2002), held at Columbia University, New York, on June 4,

2002. Edited by Erol Tutumluer, Yacoub M. Najjar, and Eyad Masad (ISBN: 0-7844-0709-6, pages: 241, 2004)

ASCE Geotechnical Special Publication No. 130, entitled, Advances In Pavement Engineering, Proceedings CD-ROM of the ASCE Geo-Institute Geo-Frontiers Conference, held in Austin, Texas, on January 24-26, 2005. Sponsored by the Pavements Committee, Edited by Charles W. Schwartz, Erol Tutumluer, and Laith Tashman (ISBN: 0-7844-0769-X, 2005)

ASCE Geotechnical Special Publication No. 154, entitled, Pavement Mechanics and Performance, Proceedings Book of the ASCE Geo-Institute GeoShanghai Conference, held in Shanghai, China, on June 6-8, 2006. Sponsored by the Pavements Committee and Edited by Baoshan Huang, Roger Meier, Jorge Prozzi, and Erol Tutumluer (ISBN: 0-7844-0866-1, pages: 300, 2006)

ASCE Geotechnical Special Publication No. 169, entitled, Soil and Material Inputs for Mechanistic-Empirical Pavement Design, Proceedings CD-ROM of the ASCE Geo-Institute GeoDenver Congress, New Peaks in Geotechnics, held in Denver, Colorado, on February 18-21, 2007. Sponsored by the Pavements Committee and Edited by Erol Tutumluer, Laith Tashman, and Halil Ceylan (ISBN-13 978-0-7844-0897-1, 2007)

Bearing Capacity of Roads, Railways and Airfields, Two-Volume Hardcover and CD-ROM Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by Erol Tutumluer and Imad Al-Qadi, 1600 pages (ISBN: 978-0-415-87199-0, 2009)

Journal Publications

Hueckel, T., Tutumluer, E., and Pellegrini, R., "A Note on Nonlinear Elasticity of Isotropic Overconsolidated Clays", International Journal for Numerical and Analytical Methods in Geomechanics, Vol. 16, 1992, pp. 603-618.

Hueckel, T. and Tutumluer, E., "Modeling of Elastic Anisotropy Due to One-Dimensional Plastic Consolidation of Clays", Computers and Geotechnics 16, Elsevier Science Limited, 1994, pp. 311-349.

Tutumluer, E., and Barksdale, R.D., "Inverted Flexible Pavement Response and Performance", in Transportation Research Record 1482, Transportation Research Board, National Research Council, Washington D.C., 1995, pp.102-110.

Tutumluer, E., and Meier, R.W., "Attempt at Resilient Modulus Modeling Using Artificial Neural Networks", In Transportation Research Record 1540, Transportation Research Board, National Research Council, Washington D.C., 1996, pp. 1-6.

Tutumluer, E. and Thompson, M.R., "Anisotropic Modeling of Granular Bases in Flexible Pavements", In Transportation Research Record 1577, Transportation Research Board, National Research Council, Washington D.C., 1997, pp. 18-26.

Haussmann, L. D., Tutumluer, E., Barenberg, E. J., "Neural Network Algorithms for the Correction of Concrete Slab Stresses from Linear Elastic Layered Programs," In Transportation Research Record 1568, Transportation Research Board, National Research Council, Washington D.C., 1997, pp. 44-51.

Tutumluer, E. and Seyhan, U., "Neural Network Modeling of Anisotropic Aggregate Behavior From Repeated Load Triaxial Tests," In Transportation Research Record 1615, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 86-93.

Tutumluer, E., Garg, N., and Thompson, M.R., "Granular Material Radial Deformation Measurements Using A Circumferential Extensometer in Repeated Load Triaxial Testing", In Transportation Research

Record 1614, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 61-69.

Tutumluer, E. and Barksdale R.D., "Analysis of Granular Bases Using Discrete Deformable Blocks", Journal of Transportation Engineering, ASCE, Vol. 124, No. 6, November/December 1998, pp. 573-581.

Ceylan, H., Tutumluer, E., and Barenberg, E. J., "Artificial Neural Network Analyses of Concrete Airfield Pavements Serving the Boeing B-777 Aircraft," In Transportation Research Record 1684, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 1999, pp. 110-117.

(Fred Burggraf Award Winning Paper) Tutumluer, E. and Seyhan, U., "Laboratory Determination of Anisotropic Aggregate Resilient Moduli Using An Innovative Test Device," In Transportation Research Record 1687, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 1999, pp. 13-21.

Rao, C. and Tutumluer, E., "Determination of Volume of Aggregates: New Image Analysis Approach," In Transportation Research Record 1721, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 73-80.

Rao, C., E. Tutumluer, and Stefanski, J.A., "Coarse Aggregate Shape and Size Properties Using a New Image Analyzer," ASTM Journal of Testing and Evaluation, JTEVA, Vol. 29, No. 5, Sept. 2001, pp. 79-89.

Tutumluer, E. and Chou, F.-J., "Stress Path Testing for Proper Characterization of Unbound Aggregate Base Behavior," In Transportation Research Record 1757, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 92-99.

Seyhan, U. and Tutumluer, E., "Anisotropic Modular Ratios As Unbound Aggregate Performance Indicators," Journal of Materials in Civil Engineering, ASCE, Volume 14, Number 5, September/October 2002, pp. 409-416.

Rao, C., E. Tutumluer, and Kim, I.T. "Quantification of Coarse Aggregate Angularity Based on Image Analysis," In Transportation Research Record 1787, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 117-124.

Tutumluer, E., D.N. Little, and Kim, S.-H. "Validated Model for Predicting Field Performance of Aggregate Base Courses," In Transportation Research Record 1837, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2003, pp. 41-49.

Tutumluer, E., Santoni, R.L., and Kim, I.T., "Modulus Anisotropy and Shear Stability of Geofiber Stabilized Sands," In Transportation Research Record 1874, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2004, pp. 125-135.

Seyhan, U., Tutumluer, E., and Yesilyurt, H., "Anisotropic Aggregate Base Inputs for Mechanistic Pavement Analysis Considering Effects of Moving Wheel Loads," ASCE Journal of Materials in Civil Engineering, Vol. 17, No. 5, October 1, 2005, pp. 505-512.

Kim, I.T. and Tutumluer, E., "Unbound Aggregate Rutting Models for Stress Rotation and Effects of Moving Wheel Loads," In Transportation Research Record 1913, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2005, pp. 41-52.

Pan, T., Tutumluer, E., and Carpenter, S.H., "Effect of Coarse Aggregate Morphology on Resilient Modulus of Hot-Mix Asphalt," In Transportation Research Record 1929, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2005, pp. 1-9.

Ceylan, H., Guclu, A., Tutumluer, E., Thompson, M.R., "Use of Artificial Neural Networks for Analyzing Full Depth Asphalt Pavements," International Journal of Pavement Engineering, Vol. 6, No. 3, September 2005, pp. 171-182.

Kwon, J., Tutumluer, E., and Kim, M., "Development of A Mechanistic Model for Geogrid Reinforced Flexible Pavements," Geosynthetics International, Volume 12, No. 6, December, 2005, pp. 310-320.

Kwon, J., Tutumluer, E., and Kim, M., "Mechanistic Analysis of Geogrid Base Reinforcement in Flexible Pavements Considering Unbound Aggregate Quality," Journal of Korean Society of Road Engineers, Volume 8, No. 2, June 2006, pp. 37-47.

Pan, T., Tutumluer, E., and Carpenter, S.H., "Effect of Coarse Aggregate Morphology on Permanent Deformation Behavior of Hot Mix Asphalt," ASCE Journal of Transportation Engineering, Volume 132, No. 7, July 1, 2006, pp. 580-589.

Pan, T., Tutumluer, E., and Anochie-Boateng, J., "Aggregate Morphology Affecting Resilient Behavior of Unbound Granular Materials," In Transportation Research Record 1952, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2006, pp. 12-20.

Kim, I.T. and Tutumluer, E., "Field Validation of Airport Pavement Granular Layer Rutting Predictions," In Transportation Research Record 1952, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2006, pp. 48-57.

Al-Rousan, T., Masad, E., Tutumluer, E., and Pan, T., "Evaluation of Image Analysis Techniques for Quantifying Aggregate Shape Characteristics," Construction and Building Materials, Volume 21, Issue 5, May 2007, pp. 978-990.

Pan, T. and Tutumluer, E., "Quantification of Coarse Aggregate Surface Texture Using Image Analysis," ASTM Journal of Testing and Evaluation, Volume 35, Issue 2, March 2007.

Kim, S.-H., Tutumluer, E., Little, D.N., and Kim, N., "Effect of Gradation on Nonlinear Stress-dependent Behavior of A Sandy Flexible Pavement Subgrade," ASCE Journal of Transportation Engineering, Volume 133, Issue 10, October 2007, pp. 590-598.

Kwon, J., Tutumluer, E., and Konietzky, H. "Aggregate Base Residual Stresses Affecting Geogrid Reinforced Flexible Pavement Response," International Journal of Pavement Engineering, Volume 9, No. 4, 2008, pp. 275-285.

Tutumluer, E. and T. Pan, "Aggregate Morphology Affecting Strength and Permanent Deformation Behavior of Unbound Aggregate Materials," ASCE Journal of Materials in Civil Engineering, Vol. 20, No. 9, September 1, 2008, pp 1-11.

Anochie-Boateng, J., Tutumluer, E., and Carpenter, S.H., "Permanent Deformation Behavior of Naturally Occurring Bituminous Sands," In Transportation Research Record 2059, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2008, pp. 31-40.

Kim, M., and Tutumluer, E., "Multiple Wheel Load Interaction in Flexible Pavements," In Transportation Research Record 2068, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2008, pp. 49-60.

Al-Qadi, I.L., Dessouky, S., Kwon, J., and Tutumluer, E., "Geogrid in Flexible Pavements: Validated Mechanism," In Transportation Research Record 2045, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2008, pp. 102-109.

Kim, M. and Tutumluer, E., "Nonlinear Pavement Foundation Modeling for Three-dimensional Finite Element Analysis of Flexible Pavements," ASCE International Journal of Geomechanics, Volume 9, Number 5, October, 2009, pp. 195-208.

Huang, H., Shihui, S., and Tutumluer, E., "Moving Load on Track with Asphalt Trackbed," Vehicle System Dynamics, DOI: 10.1080/00423110903104400 2009, iFirst, Taylor and Francis, 2009, pp. 1–13.

Kwon, J., Tutumluer, E., and Al-Qadi, I.L. "A Validated Mechanistic Model for Geogrid Base Reinforced Flexible Pavements," ASCE Journal of Transportation, Volume 135, Number 12, December, 2009.

(Best Paper Award Winner, Geology and Earth Materials Section) Donovan, P. and Tutumluer, E., "Use of Falling Weight Deflectometer Testing to Determine Relative Damage in Asphalt Pavement Unbound Aggregate Layers," In Transportation Research Record 2104, Journal of the Transportation Research Board, National Research Council, Washington, D.C., 2009, pp. 12-23.

Kwon, J. and Tutumluer, E., "Geogrid Base Reinforcement with Aggregate Interlock and Modeling of the Associated Stiffness Enhancement in Mechanistic Pavement Analysis," Presented at the 88th Annual Meeting of the Transportation Research Board and Accepted for publication in an upcoming 2009 Transportation Research Record, National Research Council, Washington, D.C.

Huang, H., Shen, S., and Tutumluer, E., "Sandwich Model to Evaluate Railroad Asphalt Track-bed Performance under Moving Loads," Presented at the 88th Annual Meeting of the Transportation Research Board and Accepted for publication in an upcoming 2009 Transportation Research Record, National Research Council, Washington, D.C.

Huang, H., Tutumluer, E., and Dombrow, W., "Laboratory Characterization of Fouled Railroad Ballast Behavior," Presented at the 88th Annual Meeting of the Transportation Research Board and Accepted for publication in an upcoming 2009 Transportation Research Record, National Research Council, Washington, D.C.

Ceylan, H., Guclu, A., Tutumluer, E., Thompson, M.R., "Advanced Models for Pavement Layer Backcalculation," Accepted for publication in an upcoming issue of the ASCE Journal of Transportation Engineering.

Kim, M. and Tutumluer, E., "Validation of A Three-Dimensional Finite Element Model using Airfield Pavement Multiple Wheel Load Responses," Accepted for publication in an upcoming Special Issue of the Journal of Road Materials and Pavement Design, entitled, "Recent Advances in Numerical Simulation of Pavements."

Articles in ASCE Geotechnical Special Publications (GSPs)

Tutumluer, E., Seyhan, U., and Garg, N., "Characterization of Anisotropic Aggregate Behavior Under Variable Confinement Conditions," In ASCE Geotechnical Special Publication (GSP) No. 85, entitled, Application of Geotechnical Principles in Pavement Engineering, October 1998, pp. 1-12.

Seyhan, U. and Tutumluer, E., "Unbound Granular Material Characterization from Stress Path Loading Tests," In ASCE Geotechnical Special Publication (GSP) No. 89, entitled, Recent Advances in the Characterization of Transportation Geomaterials, Edited by E. Tutumluer and A.T. Papagiannakis, June 1999, pp. 49-60.

Seyhan, U. and Tutumluer, E., "Advanced Characterization of Granular Materials for Mechanistic Based Pavement Design," In Geotechnical Special Publication (GSP) No. 98, entitled, Pavement Subgrade, Unbound Materials, and Nondestructive Testing, Edited by M.S. Mamlouk, GeoDenver 2000 ASCE Geo-Institute Congress, Denver, August 3-8, 2000, pp. 51-72.

Tutumluer, E. and Seyhan U., "Characterization of Cross-Anisotropic Aggregate Base Behavior from Stress Path Tests," In ASCE Geotechnical Special Publication No. 123, entitled, Recent Advances in Materials Characterization and Modeling of Pavement Systems, Edited by E. Tutumluer, Yacoub M. Najjar, and Eyad Masad, 2004, pp. 18-34.

Ceylan, H., Tutumluer, E., and Barenberg, E.J., "Artificial Neural Networks for the Analysis of Slabs Under Simultaneous Aircraft and Temperature Loading," In ASCE Geotechnical Special Publication No. 123, entitled, Recent Advances in Materials Characterization and Modeling of Pavement Systems, Edited by E. Tutumluer, Yacoub M. Najjar, and Eyad Masad, 2004, pp. 223-238.

Pan, T. and Tutumluer, E., "Imaging Based Evaluation of Coarse Aggregate Size and Shape Properties Affecting Pavement Performance," In ASCE Geotechnical Special Publication No. 130, entitled, Advances In Pavement Engineering, Edited by Charles W. Schwartz, Erol Tutumluer, and Laith Tashman, ISBN: 0-7844-0769-X, 2005.

Kwon, J., Kim, M., and Tutumluer, E., "Interface Modeling For Mechanistic Analysis of Geogrid Reinforced Flexible Pavements," In ASCE Geotechnical Special Publication No. 130, entitled, Advances In Pavement Engineering, Edited by Charles W. Schwartz, Erol Tutumluer, and Laith Tashman, ISBN: 0-7844-0769-X, 2005.

Tutumluer, E. and Kwon, J., "Evaluation of Geosynthetics Use for Pavement Subgrade Restraint and Working Platform Construction," In ASCE Geotechnical Practice Publication No. 3, entitled, Geotechnical Applications for Transportation Infrastructure, Edited by Hani Titi, ISBN: 0-7844-0821-1, 2006, pp. 96-107.

Pan, T. and Tutumluer, E., "Evaluation of Visual Based Aggregate Shape Classifications Using the University of Illinois Aggregate Image Analyzer (UIAIA)," In ASCE Geotechnical Special Publication No. 154, entitled, Pavement Mechanics and Performance, Edited by Baoshan Huang, Roger Meier, Jorge Prozzi, and Erol Tutumluer, ISBN: 0-7844-0866-1, 2006, pp. 203-211.

Kim, M. and Tutumluer, E., "Modeling Nonlinear, Stress Dependent Pavement Foundation Behavior Using A General-Purpose Finite Element Program," In ASCE Geotechnical Special Publication No. 154, entitled, Pavement Mechanics and Performance, Edited by Baoshan Huang, Roger Meier, Jorge Prozzi, and Erol Tutumluer, ISBN: 0-7844-0866-1, 2006, pp. 29-36.

Kwon, J., Tutumluer, E., Al-Qadi, I.L., and Anochie-Boateng, J., "Geomaterial Characterizations of Full Scale Pavement Test Sections for Mechanistic Analysis and Design," In ASCE Geotechnical Special Publication No. 169, entitled, Soil and Material Inputs for Mechanistic-Empirical Pavement Design, Edited by Erol Tutumluer, Laith Tashman, and Halil Ceylan, ISBN: 13 978-0-7844-0897-1, 2007.

Tutumluer, E. and Kim, M., "Considerations for Nonlinear Analyses of Pavement Foundation Geomaterials in the Finite Element Modeling of Flexible Pavements," In ASCE Geotechnical Special Publication No. 176, entitled, Analysis of Asphalt Pavement Materials and Systems, Edited by Linbing Wang and Eyad Masad, ISBN: 13 978-0-7844-0924-4, 2007.

Kwon, J., Tutumluer, E., Al-Qadi, I.L., and Dessouky, S., "Effectiveness of Geogrid Base Reinforcement in Low-Volume Flexible Pavements," Presented at the ASCE GeoCongress 2008 Conference, In ASCE Geotechnical Special Publication No. 178, entitled, GeoCongress 2008: Geosustainability and Geohazard Mitigation, Edited by K.R. Reddy, M.V. Khire, A.N. Alshawabkeh , ISBN: 13 978-0-7844-0971-8, 2008.

(Invited Keynote Paper) Tutumluer, E., "State of the Art: Anisotropic Characterization of Unbound Aggregate Layers in Flexible Pavements," Presented at the ASCE Engineering Mechanics Institute (EM08) Conference in Minneapolis, Minnesota, May 18-21, 2008, In ASCE Geotechnical Special Publication No. 184, entitled, Pavements and Materials – Modeling, Testing and Performance, Edited by Z. You, A.R. Abbas, and L. Wang, ISBN: 978-0-7844-1008-0, 2009, pp. 1-16.

Tutumluer, E. and Kwon, J. "Validations of Anisotropic Aggregate Base Behavior from Full-Scale Pavement Tests," In ASCE Geotechnical Special Publication No. 187, entitled, Contemporary Topics in Ground Modification, Problem Soils, and Geo-Support, Edited by M. Iskander, D.F. Laefer and M.H. Hussein, ISBN: 978-0-7844-1023-3, 2009, pp. 441-448.

Selected Recent Articles in Peer-Reviewed Conference Proceedings

Tutumluer, E. and I.T. Kim, "Stress Rotations Due to Moving Wheel Loads and Their Effects on Pavement Materials Characterization," In Proceedings CD-ROM of the Workshop on "Pavement Engineering from a Geotechnical Perspective," 57th Canadian Geotechnical Conference, GeoQuebec 2004, Quebec City, October 24-26, 2004.

Tutumluer, E., Thompson, M.R., Garcia, G., and Kwon, J., "Subgrade Stability and Pavement Foundation Requirements," In Proceedings of the 15th Colombian Symposium of Pavement Engineering, Sponsored by the Pontificia Universidad Javeriana in Bogota, Melgar, Colombia, March 9-12, 2005.

Kwon, J., Tutumluer, E., and Kim, M., "Mechanistic Analysis of Geogrid Base Reinforcement in Flexible Pavements Considering Unbound Aggregate Quality," In Proceedings of the 5th International Conference on Road and Airfield Pavement Technology, ICPT 2005, Seoul, Korea, May 10-12, 2005.

Tutumluer, E. and Kwon, J., "Evaluation of Geosynthetics Use for Pavement Subgrade Restraint and Working Platform Construction," In Proceedings of the 13th Annual Great Lakes Geotechnical/Geoenvironmental Conference (GLGGC) on Geotechnical Applications for Transportation Infrastructure, University of Wisconsin, Milwaukee, May 13, 2005.

Ceylan, H., Tutumluer, E., Pekcan, O., Guclu, A., "Modeling of Pavement Rutting Behavior Using Artificial Neural Networks," In Proceedings of the McMat 2005 Mechanics and Materials Conference, Louisiana State University, Baton Rouge, Louisiana, June 1-3, 2005.

Tutumluer, E., Kwon, J., and Kim, M., "Modeling Geogrid Reinforced Aggregate Layers in Flexible Pavements," In Proceedings of the 11th International Conference of the Association for Computer Methods and Advances in Geomechanics (IACMAG), Turin, Italy, June 19-24, 2005.

Tutumluer, E. and Kim, I.T., "Factors Affecting Laboratory Rutting Evaluation of Airport Pavement Granular Layers," In Proceedings of the 7th International Conference on the Bearing Capacity of Roads, Railways and Airfields, held in Trondheim, Norway, June 27-29, 2005.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Nondestructive Flexible Pavement Evaluation Using ILLI-PAVE Based Artificial Neural Network Models," In CD-ROM Proceedings of the ASCE Geo-Institute GeoCongress, Geotechnical Engineering in the Information Technology Age, Atlanta, Georgia, February 26-March 1, 2006.

Pan, T., Tutumluer, E., and Carpenter, S.H. "Rutting Behavior of NCAT Pavement Test Track Superpave Asphalt Mixes Analyzed for Aggregate Morphology Effects," In Proceedings CD-ROM Volume 75, 81st Annual Meeting of the Association of Asphalt Paving Technologists (AAPT), Savannah, Georgia, March 27-29, 2006.

Kim, I.T. and Tutumluer, E., "Rutting Evaluation of Airport Pavement Granular Layers Considering Stress History Effects," In Airfield and Highway Pavements, Edited by I.L. Al-Qadi, Proceedings of the ASCE Transportation and Development Institute (T&DI) Airfield and Highway Pavement Specialty Conference, Atlanta, Georgia, on April 30-May 3, 2006, pp. 566-577.

Brar, H.S., Tutumluer, E., Thompson, M.R., Gosain, L., and Anderson, R., "Characterizing Subgrade Soils and Establishing Treatment Needs for a New Runway at the Chicago's O'Hare Airport," In Airfield and Highway Pavements, Edited by I.L. Al-Qadi, Proceedings of the ASCE Transportation and Development

Institute (T&DI) Airfield and Highway Pavement Specialty Conference, Atlanta, Georgia, April 30-May 3, 2006, pp. 272-283.

Al-Qadi, I.L., Tutumluer, E., and Dessouky, S., "Construction and Instrumentation of Full-Scale Geogrid-Reinforced Flexible Pavement Test Sections," In Airfield and Highway Pavements, Edited by I.L. Al-Qadi, Proceedings of the ASCE Transportation and Development Institute (T&DI) Airfield and Highway Pavement Specialty Conference, Atlanta, Georgia, April 30-May 3, 2006, pp. 131-142.

Roberts, R., Al-Qadi, I.L., Tutumluer, E., Boyle, J., and Sussmann, T., "Advances in Railroad Ballast Evaluation Using 2 GHz Horn Antennas," In Proceedings of the 11th International Conference on Ground Penetrating Radar, Columbus, Ohio, June 19-22, 2006.

Kwon, J., Tutumluer, E., Konietzky, H., and Keip, M.-A., "Investigation of Geogrid Base Reinforcement Mechanisms Considering Residual Stress and Confinement Effects," In Proceedings of the 8th International Conference on Geosynthetics, Yokohama, Japan, September 18-22, 2006.

Al-Qadi, I.L., Dessouky, S., and Tutumluer, E., "Reinforced Low-Volume Flexible Pavement Response to Accelerated Loading," In Proceedings of the 8th International Conference on Geosynthetics, Yokohama, Japan, September 18-22, 2006.

Tutumluer, E., Huang, H., Hashash, Y., and Ghaboussi, J., "Imaging Based Discrete Element Modeling of Granular Assemblies," In Proceedings of the Multiscale and Functionally Graded Materials Conference 2006 (FGM2006), Honolulu-Oahu, Hawaii, October 15-18, 2006.

Al-Qadi, I.L., Tutumluer, E., Dessouky, S., and Kwon, J., "Mechanistic Response Measurements of Geogrid Reinforced Flexible Pavements to Vehicular Loading," In Proceedings of the Geosynthetics 2007 Conference organized by the North American Geosynthetics Society, Washington, D.C., January 16-19, 2007.

Kim, M. and Tutumluer, E., "Nonlinear Pavement Foundation Modeling for Three-dimensional Finite Element Analysis of Flexible Pavements," In Preprint CD-ROM Proceedings of the 86th Annual Meeting of the Transportation Research Board (TRB), January 21-25, 2007.

Pan, T. and Tutumluer, E., "Permanent Deformation and Strength Characteristics of Crushed Aggregates Blended with Gravel," In Preprint CD-ROM Proceedings of the 86th Annual Meeting of the Transportation Research Board (TRB), January 21-25, 2007.

Al-Qadi, I.L., Tutumluer, E., Kwon, J., and Dessouky, S., "Accelarated Full Scale Testing of Geogrid-reinforced Flexible Pavements," In Preprint CD-ROM Proceedings of the 86th Annual Meeting of the Transportation Research Board (TRB), January 21-25, 2007.

Donovan, P. and Tutumluer, E., "Analysis NAPTF Trafficking Response Data for Pavement Foundation Deformation Behavior." In Proceedings of the 2007 FAA Worldwide Technology Transfer Conference, Atlantic City, NJ, April 15-17, 2007.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Analyzing Flexible Pavements on Lime-stabilized Soils using Artificial Neural Networks," International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, Athens, Greece, June 20-22, 2007.

Kim, M. and Tutumluer, E., "Investigation of Pavement Foundation Behavior using Axisymmetric and Three-dimensional Finite Element Analyses," International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, Athens, Greece, June 20-22, 2007.

Huang, H., Tutumluer, E., Hashash, Y. and Ghaboussi, J., "Imaging Aided Discrete Element Modeling of Railroad Ballast," International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, Athens, Greece, June 20-22, 2007.

Al-Qadi, I.L., Tutumluer, E., Dessouky, S. and Kwon, J., "Responses of Geogrid-Reinforced Flexible Pavement to Accelerated Loading," International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, Athens, Greece, June 20-22, 2007.

Al-Qadi, I.L., Dessouky, S., Kwon, J., and Tutumluer, E., "Geogrid-Reinforced Low Volume Flexible Pavements: Pavement Response and Geogrid Optimal Location," In Preprint CD-ROM Proceedings of the 87th Annual Meeting of the Transportation Research Board (TRB), January 21-25, 2008.

Kwon, J., Tutumluer, E., Al-Qadi, I.L., and Dessouky, S., "Mechanistic Model Response Predictions of Geogrid Base Reinforced Flexible Pavements," In Proceedings of GeoAmericas 2008, The First Pan American Geosynthetics Conference, Cancun, Mexico, March 2-5, 2008.

Roberts, R., Al-Qadi, I.L., and Tutumluer, E., "Railroad Structure Characterization using GPR in Alaska: A Case History," In Proceedings of the 12th International Conference on Ground Penetrating Radar, Birmingham, UK, June 16-19, 2008.

Donovan, P., and Tutumluer, E., "Anti-Shakedown of Unbound Aggregate Pavement Layers Subjected to Traffic Loading with Wander," In Proceedings of the 1st International Conference on Transportation Geotechnics and the 7th Unbound Aggregates in Roads Symposium (UNBAR7), Nottingham, UK, August 25-27, 2008.

Huang, H., Tutumluer, E., Hashash, Y., and Ghaboussi, J., "Contact Stiffness Affecting Discrete Element Modeling of Unbound Aggregate Granular Assemblies," In Proceedings of the 1st International Conference on Transportation Geotechnics and the 7th Unbound Aggregates in Roads Symposium (UNBAR7), Nottingham, UK, August 25-27, 2008.

Mishra, D., Tutumluer, E., and Butt, A.A., "Types and Amounts of Fines Affecting Aggregate Behavior," In Proceedings of the 1st International Conference on Transportation Geotechnics and the 7th Unbound Aggregates in Roads Symposium (UNBAR7), Nottingham, UK, August 25-27, 2008.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Quantifying Effects of Lime Stabilized Subgrade on Conventional Flexible Pavement Responses," In Proceedings of the 1st International Conference on Transportation Geotechnics and the 7th Unbound Aggregates in Roads Symposium (UNBAR7), Nottingham, UK, August 25-27, 2008.

Kim, M., Tutumluer, E., and Mishra, D., "Flexible Pavement Response to Multiple Wheel Loading Using Nonlinear Three-dimensional Finite Element Analysis," 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), Goa, India, October 1-6, 2008.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Artificial Neural Network Based Backcalculation of Conventional Flexible Pavements on Lime Modified Soils," 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), Goa, India, October 1-6, 2008.

Donovan, P. and Tutumluer, E., "Effect of Aircraft Load Wander on Unbound Aggregate Pavement Layer Stiffness and Deformation Behavior," ASCE Transportation and Development Institute (T&DI) Airfield and Highway Pavement Specialty Conference, Bellevue, Washington, October 15-18, 2008.

Kim, M. and Tutumluer, E., "Implications of Complex Axle Loading and Multiple Wheel Load Interaction in Low Volume Roads," ASCE Transportation and Development Institute (T&DI) Airfield and Highway Pavement Specialty Conference, Bellevue, Washington, October 15-18, 2008.

Anochie-Boateng, J. and Tutumluer, E., "Resilient Behavior Characterization of Naturally Occurring Bituminous Sands," In Preprint CD-ROM Proceedings of the 88th Annual Meeting of the Transportation Research Board (TRB), January 11-15, 2009.

Anochie-Boateng, J. and Tutumluer, E., "Characterizing Volumetric Deformation Behavior of Naturally Occurring Bituminous Sand Materials," In Proceedings of the 7th International RILEM Symposium on Advanced Testing and Characterization of Bituminous Materials (ATCBM09), Rhodes, Greece, May 27-29, 2009.

Mishra, D., Tutumluer, E., Kern, J., and Butt, A.A., "Characterizing Aggregate Permanent Deformation Behavior based on Types and Amounts of Fines," In Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by E. Tutumluer and I.L. Al-Qadi, ISBN: 978-0-415-87199-0, 2009.

Donovan, P.R., Tutumluer, E., and Huang, H., "Use of 3-dimensional Discrete Element Model to Examine Aggregate Layer Particle Movement due to Load Wander," In Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by E. Tutumluer and I.L. Al-Qadi, ISBN: 978-0-415-87199-0, 2009.

Pekcan, O., Tutumluer, E., and Ghaboussi, J., "SOFTSYS for Backcalculation of Full-depth Asphalt Pavement Layer Moduli," In Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by E. Tutumluer and I.L. Al-Qadi, ISBN: 978-0-415-87199-0, 2009.

Anochie-Boateng, J. and Tutumluer, E., "Shear Strength Properties of Naturally Occurring Bituminous Sands," In Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by E. Tutumluer and I.L. Al-Qadi, ISBN: 978-0-415- 87199-0, 2009.

Dombrow, W., Huang, H., and Tutumluer, E., "Comparison of Coal Dust Fouled Railroad Ballast Behavior – Granite vs. Limestone," In Proceedings of the 8th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Champaign, Illinois, USA, June 29–July 2, 2009; Edited by E. Tutumluer and I.L. Al- Qadi, ISBN: 978-0-415-87199-0, 2009.

Huang, H., Tutumluer, E., Hashash, Y.M.A., and Ghaboussi, J., "Discrete Element Modeling of Aggregate Behavior in Fouled Railroad Ballast," In Proceedings of the GeoHunan International Conference – Challenges and Recent Advances in Pavement Technologies and Transportation Geotechnics, Hunan, China, August 3-6, 2009.

Selected Recent Invited Lectures

"Mechanistic-Empirical Pavement Design," Workshop Lecture Jointly Presented with Dr. Dallas N. Little, Texas A&M University, at the 11th Annual Symposium of the International Center for Aggregate Research (ICAR), Austin, Texas, April 28, 2003.

"ICAR Structural Model and Mechanistic-Empirical Pavement Design," Workshop Lecture Jointly Presented with Dr. Dallas N. Little, Texas A&M University, at the 11th Annual Symposium of the International Center for Aggregate Research (ICAR), Austin, Texas, April 28, 2003.

University Invitation: "Soil Trafficability and Subgrade Stability," Invited Speaker, Department of Civil Engineering, University of Costa Rica, San Jose, Costa Rica, November 2003.

University Invitation: "Soil and Aggregate Characterization," Invited Speaker, Department of Civil Engineering, University of Costa Rica, San Jose, Costa Rica, November 2003.

University Invitation: "Mechanistic-Empirical Pavement Design," Invited Speaker, Department of Civil Engineering, University of Costa Rica, San Jose, Costa Rica, November 2003.

"Mechanistic Based Pavement Design," Invited Speaker, Seminar Lecture Jointly Presented with Dr. D.N. Little, Texas A&M University, at the 12th Annual Symposium, International Center for Aggregate Research (ICAR), Denver, Colorado, April 5, 2004.

"State-of-the-Art of Aggregate Shape Analysis Using Imaging Techniques," Invited Speaker, Seminar Lecture Jointly Presented with Dr. E. Masad, Texas A&M University, at the 12th Annual Symposium, International Center for Aggregate Research (ICAR), Denver, Colorado, April 6, 2004.

"Stress Rotations Due to Moving Wheel Loads and Their Effects on Pavement Materials Characterization," Invited Speaker, Workshop on "Pavement Engineering from a Geotechnical Perspective," 57th Canadian Geotechnical Conference GeoQuebec 2004, Quebec City, October 24, 2004.

University Invitation: "Stress Rotations Due to Moving Wheel Loads and Their Effects on Pavement Materials Characterization," Invited Speaker, Civil, Construction and Environmental Engineering Department, Iowa State University, Ames, Iowa, November 15, 2004.

University Invitation: "Imaging Based Aggregate Shape Analysis and Its Applications In Mechanics of Pavement Materials," Invited Speaker, Civil Engineering Department Seminar Series, Louisiana State University, Baton Rouge, LA, November 23, 2004.

University Invitation: "Stress Rotations Due to Moving Wheel Loads and Their Effects on Pavement Materials Characterization," Invited Speaker, Department of Civil Engineering, Bogazici University, Istanbul, Turkey, January 4 AM hours, 2005.

University Invitation: "Stress Rotations Due to Moving Wheel Loads and Their Effects on Pavement Materials Characterization," Invited Speaker, Department of Civil Engineering, Kocaeli University, Izmit, Turkey, January 4 PM hours, 2005.

"Subgrade Stability and Pavement Foundation Requirements," Invited Keynote Speaker, 15th Colombian Symposium of Pavement Engineering, Sponsored by the Pontificia Universidad Javeriana in Bogota, Melgar, Colombia, March 11, 2005.

"Imaging Based Evaluation of Course Aggregate Used in the NCAT Pavement Test Track Asphalt Mixes," Invited Speaker, 2005 Asphalt Pavements Innovations Conference, Organized by the Center for Emerging Technologies in Infrastructure at Bradley University, Peoria, April 12, 2005.

"Measurement of Particle Shape, Form, and Texture Characteristics," Invited Speaker, TRB Mid-Year Meeting on Aggregates for Highway Construction: Characterization and Performance, held during the 56th Annual Highway Geology Symposium, May 3, 2005.

"A Mechanistic Response Model for Geosynthetic Reinforced Road Pavements," Invited Speaker, 2nd Technical Textiles Conference, Sponsored by Dokuz Eylul University, Istanbul International Technical Textile and Nonwoven Fair and Exhibition - HIGHTEX, July 14, 2005.

"Building Long Lasting Pavements with Unbound Aggregate Bases," Invited Speaker, Aggregate Base Symposium, Sponsored by the Oklahoma Aggregate Association, Oklahoma City, October 4, 2005.

University Invitation: "Characterization of the Anisotropic Behavior of Unbound Aggregate Bases," Invited Speaker, Taiyuan University of Science and Technology, Taiyuan, P.R. of China, June 12, 2006.

"Geogrid Base Reinforced Asphalt Pavements: Analysis Approach and Benefits," Invited Keynote/Opening Speaker, 2nd National Geosynthetics Conference of the Turkish Chapter of International Geosynthetics Society (IGS), Bogazici University, Istanbul, Turkey, November 16, 2006.

University Invitation: "Aggregate Testing and Characterization for Transportation Facilities Design," Invited Speaker, 35th Geomechanics Colloquium, Technical University (TU) Bergakademie, Freiberg, Germany, November 17, 2006.

"Influence of Coarse Aggregate Morphology on Hot Mix Asphalt Behavior," Invited Speaker, Mini-Symposium on Pavement Modeling and Damage Mechanics held in honor Professor Samuel H. Carpenter's Accomplishments, ICAMEM Conference, Hammamet, Tunisia, December 18, 2006.

"Essentials of Mechanistic-Empirical Pavement Design and 2002 MEPDG Overview," Invited Seminar Speaker, General Directorate of Turkish Highway Agency, Ankara, Turkey, December 26, 2006.

"Geogrid Base Reinforced Asphalt Pavements: Analysis Approach, Field Validations and Benefits," Invited Speaker, Tensar Mechanistic-Empirical Pavement Design Overview, Tensar Hospitality Suite, 86th Annual Meeting of the Transportation Research Board (TRB), January 21, 2007.

"Validation of Unbound Aggregate Base Anisotropic Stiffness Characterization from Instrumented Full Scale Pavement Tests," Invited Speaker, 15th Annual Symposium, International Center for Aggregate Research (ICAR), Austin, Texas, April 10, 2007.

"Building Long Lasting Pavements with Unbound Aggregate Bases," Invited Speaker, MO/KS Aggregate Base Symposium, Sponsored by Missouri Aggregate Association and Kansas Aggregate Association, Kansas City, May 3, 2007.

University Invitation: "Geogrid Base Reinforced Asphalt Pavements: A Mechanistic-Empirical Analysis and Design Approach," Invited Speaker, Seminar Series of the Civil Engineering Department, University of Wisconsin, Madison, WI, May 21, 2007.

University Invitation: "Geogrid Base Reinforced Asphalt Pavements: A Mechanistic-Empirical Analysis and Design Approach," CCEE Distinguished Lecture, Department of Civil, Construction and Environmental Engineering (CCEE), Iowa State University, Ames, Iowa, September 28, 2007.

"Tensar Mechanistic Based Design for Geogrid Base Reinforced Flexible Pavements," Invited Keynote Speaker, 13th International Meeting on Tensar Geosynthetics, Guatemala City, Guatemala, October 15, 2007.

"Unbound Aggregate Bases," Invited Speaker, IAAP / ICAR / MLPA / NSSGA Regional Technology Transfer Seminar, Sponsored by Illinois Aggregate Association Missouri Lime Producers Association, and Illinois and Missouri Departments of Transportation, Collinsville, Illinois, October 30, 2007.

"Geosynthetics in Pavements," and "Thin Asphalt Pavements," Invited Seminar Speaker, Istanbul Asphalt Plants Industry and Trading, Inc. (ISFALT), Istanbul, Turkey, January 3 and 4, 2008.

"Overview of Current Design Techniques for Flexible Pavements with Unbound Aggregate Bases," Invited Speaker, National Aggregate Base Conference, Austin, Texas, May 14, 2008.

"State of the Art: Anisotropic Characterization of Unbound Aggregate Layers in Flexible Pavements," Invited Keynote/Opening Speaker, Symposium of Pavement Mechanics and Materials, International Conference of the ASCE Engineering Mechanics Institute (EM08), Minneapolis, Minnesota, May 18, 2008.

"Pavement Management," Invited Seminar Speaker, Istanbul Asphalt Plants Industry and Trading, Inc. (ISFALT), Istanbul, Turkey, May 29, 2008.

"Experiences with Alternative Bases," Invited Speaker, 2nd Annual National Aggregate Base Conference, National Stone, Sand and Gravel Association Annual Convention and AGG1 Forum & Expo, Orlando, Florida, March 9, 2009.

"Types and Amounts of Fines Affecting Unbound Aggregate Behavior," Invited Speaker, 17th Annual Symposium, International Center for Aggregate Research (ICAR), Austin, Texas, May 4, 2009.

"Recent Research into the Actual Behavior of Geogrids in Stabilization Applications" Invited Speaker, Jubilee Symposium on Polymer Geogrid Reinforcement, Institution of Civil Engineers, London, UK, September 8, 2009.

Selected Recent Reports

Thompson, M.R., Tutumluer, E., and Bejarano, M., "Granular Material and Soil Moduli," Final Report No. 1, FAA Center of Excellence for Airport Pavements, Civil Engineering, University of Illinois at Urbana-Champaign, 1997.

Tutumluer, E. and M.R. Thompson, "Anisotropic Modeling of Granular Bases," Final Report No. 2, FAA Center of Excellence for Airport Pavements, Civil Engineering, University of Illinois at Urbana-Champaign, 1998.

Tutumluer, E. and U. Seyhan, "Characterization of Unbound Aggregates Using the University of Illinois FastCell," Technical Report, Submitted to Applied Research Associates for Inclusion in the Final Report of the NCHRP Project 4-23, Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 1999.

Tutumluer, E., Rao, C., and Stefanski, J., "Video Image Analysis of Aggregates," Final Project Report, FHWA-IL-UI-278, Civil Engineering Studies UILU-ENG-2000-2015, University of Illinois Urbana-Champaign, Urbana, IL, July 2000.

Tutumluer, E., Adu-Osei, A., Little, D.N., and Lytton, R.L., "Field Validation of the Cross-Anisotropic Behavior of Unbound Aggregate Bases," Research Report 502-2, A Deliverable of the International Center for Aggregates Research (ICAR) 502 Project: Structural Characteristics of Unbound Aggregate Bases to Meet AASHTO 2002 Design Requirements, March 2001.

Seyhan, U. and E. Tutumluer, "Characterization of Anisotropic Granular Layer Behavior of Flexible Pavements," Final Report No. 18, FAA Center of Excellence for Airport Technology, Civil Engineering, University of Illinois, February 2002.

Kwon, J. and E. Tutumluer, "Geosynthetic Reinforcement of Pavement Structures," Summary Technical Report, Project IHR-R30, Submitted to the Illinois Department of Transportation, University of Illinois, Urbana, IL, August 2002.

Masad, E., Al-Rousan, T., Pascual, J., Button, J., Little, D.N., and Tutumluer, E., "Test Methods for Characterizing Aggregate Shape, Texture, and Angularity," Interim Report, Project 4-30, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., October 2002.

Kwon, J. and E. Tutumluer, "Use of Geosynthetics In Working Platform and Pavement Construction," Final Report, Project IHR-R30, Submitted to the Illinois Department of Transportation, University of Illinois, Urbana, IL, June 2003.

Tutumluer, E., Pan, T., and Carpenter, S.H., "Investigation of Aggregate Shape Effects on Hot Mix Performance Using An Image Analysis Approach," Final Technical Report, Pooled Fund Study TPF-5(023), UILU-ENG-2005-2003, Federal Highway Administration IL Division, University of Illinois, Urbana, IL, Feb., 2005.

Masad, E., Al-Rousan, T., Button, J., Little, D.N., and Tutumluer, E., "Test Methods for Characterizing Aggregate Shape, Texture, and Angularity," Final Report, Project 4-30A, National Cooperative Highway Research Program (NCHRP), Transportation Research Board, National Research Council, Washington, D.C., May 2005.

Brar, H., Tutumluer, E., and Thompson, M.R., "Subgrade Soil Test Results for a New Runway Construction at the O'Hare International Airport," Progress Report Submitted as Technical Note No. 19, O'Hare Modernization Program, Center of Excellence for Airport Technology (CEAT), CEE Department, UIUC, Urbana, IL, July 2005.

Kim, I.T. and Tutumluer, E., "Permanent Deformation Behavior of Airport Flexible Pavement Base and Subbase Courses," FAA Center of Excellence for Airport Technology (CEAT) Report No. 28, CEE Department, UIUC, Urbana, IL, October 2005.

Brar, H., Tutumluer, E., and Thompson, M.R., "Subgrade Soil Test Results for a New Runway Construction at the O'Hare International Airport'," Progress Report, O'Hare Modernization Program, Center of Excellence for Airport Technology (CEAT), CEE Department, University of Illinois, Urbana, Illinois, March 2006.

Al-Qadi, I.L., Tutumluer, E., Dessouky, S., and Kwon, J. "Effectiveness of Geogrid-reinforcement in Flexible Pavements: A Full-Scale Testing," Construction Report, Submitted to Tensar International, Inc. UIUC, June 2007.

Al-Qadi, I.L., Tutumluer, E., Dessouky, S., and Kwon, J. "Effectiveness of Geogrid-reinforcement in Flexible Pavements: A Full-Scale Testing," Final Project Report, Submitted to Tensar International, Inc. UIUC, June 2007.

Kwon, J. and Tutumluer, E., "Development of a Mechanistic Model for Geogrid Reinforced Flexible Pavements," Project Report, Submitted to Tensar International, Inc. UIUC, June 2007.

Kwon, J. Tutumluer, E., and Pekcan, O., "Tensar Mechanistic Analysis and Design," a Software Application for Geogrid Reinforced Pavement Analysis and Design, Submitted to Tensar International, Inc. UIUC, June 2007.

Tutumluer, E., Huang, H., Hashash, Y., Ghaboussi, J., and David, D., "Image Aided Discrete Element Modeling of Aggregate Ballast Behavior," Technology Digest TD-08-012, published by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads, March 2008.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Nondestructive Pavement Evaluation Using ILLI-PAVE Based Artificial Neural Network Models," Illinois Center for Transportation (ICT) R39-2 Project Final Report, Submitted to Illinois Department of Transportation, UIUC, July 2008.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Artificial Neural Network for Professionals (ANN-Pro) – Software and User Manual," Illinois Center for Transportation (ICT) R39-2 Project Deliverable, Submitted to Illinois Department of Transportation, UIUC, July 2008.

Pekcan, O., Tutumluer, E., and Thompson, M.R., "Soft Computing Based Pavement and Geomaterial System Identifier (SoftSYS) – Software and User Manual," Illinois Center for Transportation (ICT) R39-2 Project Deliverable, Submitted to Illinois Department of Transportation, UIUC, July 2008.

Deniz, D., Tutumluer, E., and Popovics, J., "Expansive Characteristics of Reclaimed Asphalt Pavement (RAP) Used As Base Materials," Illinois Center for Transportation (ICT) R27-27 Project Final Report, Submitted to Illinois Department of Transportation, UIUC, October 2008.

Al-Qadi, I.L., Roberts, R., Tutumluer, E., Leng, Z., and Wei, X., "New GPR Analysis Techniques for Ballast Assessment," Technology Digest, submitted to Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads, April 2009.

Editorships of Journals

Editorial Board Member, International Journal of Pavement Engineering, Taylor and Francis Group, (http://www.tandf.co.uk/journals), Co-Editors Tom Scarpas, Delft University of Technology, The Netherlands and Imad Al-Qadi, University of Illinois at Urbana-Champaign, 2004 – present.

Associate Editor, International Journal of Pavement Research and Technology, Editors-in-Chief Prof. Deng-Fong Lin, I-Shou University, Taiwan and Dr. Chung Wu, Virginia DOT, USA, Publisher: Chinese Society of Pavement Engineering, No. 300 Jhongda Rd., Jhongli City, Taoyuan County, 3200, Taiwan, R.O.C. (http://www.ijprt.org.tw), 2007 – present.

Associate Editor, Journal of Computing in Civil Engineering, Editors-in-Chief James H. Garrett, Jr., Ph.D., P.E., M.ASCE, Carnegie Mellon University and Lucio Soibelman, Ph.D., M.ASCE, Carnegie Mellon University. Publisher: ASCE, (http://pubs.asce.org/journals/computing/), 2008 – present.

Editorial Board Member, International Journal of Geomechanics, Editor-in-Chief Musharraf M. Zaman, Ph.D., University of Oklahoma, Publisher: ASCE, (http://pubs.asce.org/journals/geomechanics/), January 2009 – present.

Other Professional Service

Contributor/Co-Editor, Transportation Research Board (TRB) Circular E-C012 on "Use of Artificial Neural Networks Geomechanical and Pavement Systems," 79th Annual TRB Meeting, January 8-13, 2000 (http://www4.nationalacademies.org/trb/onlinepubs.nsf/web/circular)

Program Committee Member, 2nd International Workshop on Artificial Intelligence and Mathematical Methods in Pavement and Geomechanical Engineering Systems, University of Delaware, Newark, Delaware, August 11-12, 2000.

Planning Committee Member, ASCE Airfield Pavement Specialty Conference, Advancing Airfield Pavements, Chicago, Illinois, August 5-8, 2001.

Planning Committee Chair, "Recent Advances in Materials Characterization and Modeling of Flexible Pavements" A Symposium Sponsored by the ASCE Geo-Institute Pavements Committee at the 15th ASCE Engineering Mechanics Division Conference (EM2002) at Columbia University, New York, NY, June 2-5, 2002.

Scientific Committee Member, 6th International Conference on the Bearing Capacity of Roads, Railways and Airfields, BCRA 2002, Technical University of Lisbon, Lisbon, Portugal, 24-26 June, 2002.

Planning Committee Member, A Special Pavements Symposium at the GeoFrontiers 2005 Conference organized by the ASCE Geo-Institute, Austin, TX, January 24-26, 2005.

Scientific Committee Member, 7th International Conference on the Bearing Capacity of Roads, Railways and Airfields, BCRA 2005, Norwegian University of Science and Technology, Trondheim, Norway, June 27-29, 2005.

Planning Committee Member, Pavement Foundations Sessions at the GeoShanghai Conference organized by the ASCE Geo-Institute, Shanghai, China, June 6-8, 2006.

Technical Committee Member, ASCE Geo-Institute GeoShanghai Conference, Shanghai, China, June 6-8, 2006.

Planning Committee Chair, Pavements Track Symposium on Soil and Material Inputs for Mechanistic-Empirical Pavement Design at the GeoDenver 2007 Conference organized by the ASCE Geo-Institute, Denver, CO, February 18-21, 2007.

Scientific Committee Member, International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, National Technical University of Athens (NTUA), Athens, Greece, June 20-22, 2007.

Planning Committee Chair, Pavements Track Sessions at the GeoCongress 2008 Conference organized by the ASCE Geo-Institute, New Orleans, LA, March 9-12, 2008.

Scientific Committee Member, 10th International Conference on Application of Advanced Technologies in Transportation (AATT 2008), National Technical University of Athens (NTUA), Athens, Greece, May 27-31, 2008.

Organizing Committee Member, 6th RILEM International Conference on Pavement Cracking, Chicago, Illinois, June 16-19, 2008.

International Advisory Committee Member, 1st ISSMGE International Conference on Transportation Geotechnics, University of Nottingham, United Kingdom, September 8-10, 2008.

International Advisory Committee Member, 12th International Conference of the Association for Computer Methods and Advances in Geomechanics (IACMAG), Goa, India, October 1-6, 2008.

Conference Chair, 8th International Conference on the Bearing Capacity of Roads, Railways, and Airfields (BCR^2A), University of Illinois at Urbana-Champaign, Champaign, Illinois, June 29-July 2, 2009.

International Advisory Committee Member, GeoHunan International Conference on Challenges and Recent

Advances in Pavement Technologies and Transportation Geotechnics, Hunan, China, August 3-6, 2009.

Organizing Committee Member, GeoShanghai International Conference 2010 organized by the ASCE Geo-Institute, Shanghai, China, June 3-5, 2010.

International Advisory Committee Member, GeoHunan International Conference II: Emerging Technologies for Design, Construction, Rehabilitation, and Inspections of Transportation Infrastructures, Zhangjiajie (Hunan Province), China, June 6-8, 2011.

International Advisory Committee Member, 2nd International Conference on Transportation Geotechnics, Sapporo, Hokkaido, Japan, September 10-12, 2012.

Reviewer of technical papers/books submitted for publication:

- Transportation Research Board (TRB) Research Record Series
- Geotechnical Testing Journal, ASTM
- ASTM Journal of Testing and Evaluation
- Journal of Transportation Engineering, ASCE
- Journal of Geotechnical and Geoenvironmental Engineering, ASCE
- Canadian Journal of Geotechnical Engineering

- Journal of Materials in Civil Engineering, ASCE
- Journal of Infrastructure Systems, ASCE
- Journal of Computing in Civil Engineering, ASCE
- International Journal of Geomechanics, ASCE
- Asphalt Pavement Technology, Association of Asphalt Pavement Technologists (AAPT)
- Journal of Computer-Aided Civil and Infrastructure Engineering
- International Journal of Pavement Engineering (Edited by T. Scarpas and I. Al-Qadi, Taylor & Francis Group)
- International Journal of Road Materials and Pavement Design (Edited by H.D. Benedetto, U. Isaacson, and J.B. Sousa, Hermes Science Publications)
- International Journal of Pavement Research and Technology, Editors-in-Chief Prof. Deng-Fong Lin, I-Shou University, Taiwan and Dr. Chung Wu, Virginia DOT, USA
- International Journal for Numerical and Analytical Methods in Geomechanics, (edited by Stein Sture, John Wiley and Sons)
- Prentice Hall Publishers, Upper Saddle River, New Jersey (Pavement Analysis and Design, by Yang H. Huang, 1st and 2nd Editions)

EXHIBIT 2

Erol Tutumluer's Additional Experience

My major research focus in railroad engineering has been primarily on the aspects of track substructure. My first railroad project in 2001 was jointly funded by the AAR affiliated laboratory established at UIUC and Burlington Northern Santa Fe Railroad Company. The project involved an industry survey and review of performance and remediation methods for track substructure, including ballast, subballast, and subgrade. Specifically, the industry survey provided information for AAR members on (1) general track substructure statistics, inspection, and maintenance; (2) subgrade soil problems and railroad remedial practices; and (3) ballast/subballast related problems and railroad remedial practices.

Another railroad project funded by the Federal Railroad Administration ("FRA") involved the development of ground penetrating radar ("GPR") to evaluate railway track subsurface condition and estimate track bed materials' physical properties. The objective of the project was to test previous methods of collecting GPR data. The UIUC team was responsible for evaluating the modified common midpoint GPR technique and developing ballast thickness algorithm and quantitative assessment of the ballast and sub-ballast condition, including accurate assessment of its physical state and indications of the degree of ballast fouling, which is the main indicator of ballast degradation.

I am currently working on four research projects concerning railroads: (1) Discrete Element Modeling ("DEM") of Ballast funded by the AAR-affiliated laboratory at UIUC, (2) Railroad Track Substructure Evaluation jointly funded by AAR and the FRA, (3) Investigation of Fouled Ballast Behavior funded by BNSF Railroad Company, and finally, (4) Testing of Polyurethane Elastomer Coated Railroad Ballast funded by BASF The Chemical Company. I have presented and published several papers and AAR Technology Digests related

to these railroad projects, including at the American Railway Engineering and Maintenance of Way Association ("AREMA") conferences held from 2006 to 2009 and at the Transportation Research Board annual meetings since 2008.

The current AAR project focuses on the development of a combined image analysis and DEM approach for analyzing ballast aggregate behavior and improving ballast strength and stability and manufactured crosstie designs. This project also deals with the selection of proper ballast aggregate shape and angularity characteristics for mitigating track problems and failures due to ballast breakdown, powdering, and fouling; ballast deformation and degradation due to compaction and repeated loading; and ballast lateral movement and instability causing track buckle. In this project, we developed a validated image-aided DEM model to evaluate the size and shape properties of ballast aggregate to eventually engineer ballast track designs. In our ongoing efforts, we will use the developed DEM model to adequately predict field ballast deformation behavior obtained from settlement records of full-scale test sections, as well as bridge approaches and transition zones in the AAR Transportation Technology Center, Inc. ("TTCI") test track in Pueblo, Colorado.

BNSF Railway Company has funded a research project at UIUC with a focus on conducting large direct shear laboratory tests to measure strength and deformation characteristics of both clean (new) and fouled ballast aggregates at various stages of fouling with different type fine-grained materials (plastic subgrade soils, mineral filler, coal dust, etc.). This laboratory study also included studying the effects of coal dust fouling on the granite-type and limestone-type ballast aggregate behavior and evaluating reductions in strength and stability. This study resulted in important findings on the effects of coal dust and other ballast foulants.

My railroad track research program at UIUC was selected as the university research partner to collaborate with the AAR's TTCI for the "Track Substructure" cooperative research program established in 2009 and now jointly funded by the AAR and FRA. Under this multi-year track infrastructure research partnership program, the primary objectives are to determine the effects of heavy axle load traffic on track infrastructure; investigate root causes of mud holes and quantify their effects on track and track components; and finally, develop guidelines for track substructure diagnostics, remedy, design, and construction.

My other projects include stress dependency and anisotropy of aggregate behavior affecting structural response and performance of unbound aggregate layers in the transportation infrastructure sponsored by the Federal Aviation Administration ("FAA"), U.S. Army Corps of Engineers, and the International Center for Aggregates Research ("ICAR"). I have also studied the size, shape, and angularity characterization of aggregates using video-imaging and more recently Laser Detection and Ranging techniques sponsored throughout the last nine years by the Federal Highway Administration ("FHWA"), the Illinois Department of Transportation ("IDOT"), and by the National Cooperative Highway Research Program ("NCHRP"). In addition, I recently have researched establishing subgrade/subbase support, stability, and working platform requirements with virgin and recycled aggregates, including evaluating their expansive characteristics, for highway pavements, which was funded by IDOT. I have also researched airport pavements in a project funded by the O'Hare Modernization Program for Chicago's O'Hare Airport and the best value granular material for road foundation in a project funded by Minnesota Department of Transportation. In addition, I have been working on laboratory subgrade soils testing for Caterpillar, Inc., related to the mobility of some of its construction and compaction equipment on problematic soils, such as tar sands or oil sands. I am

also working to model geogrid reinforced unbound aggregate roadway, railroad base, and ballast layers for a leading geosynthetic producer, Tensar International, Inc.

My research has resulted in high-quality peer-reviewed journal papers, an invention disclosure for U.S. patent application, a co-authored book on anisotropic behavior of aggregate materials, co-edited a two-volume hardcover Eighth International Conference Proceedings book on the Bearing Capacity of Roads, Railways and Airfields in 2009, and co-edited five ASCE Geotechnical Special Publications in relation to my involvement, including my current chair role of the ASCE Geo-Institute's Pavements Committee. To support my research programs, I have received grants from federal agencies including FRA, FHWA, FAA, U.S. Army Corps of Engineers, NCHRP and NSF; state agencies, including single grants from Illinois, Minnesota and Indiana DOTs and pool-funded research contributions from six other state DOTs; and grants from the private sector, including companies such as AAR, BNSF Railway Company, Caterpillar, Inc., BASF The Chemical Company, International Center for Aggregates Research, Chicago O'Hare Airport O'Hare Modernization Program, and Tensar International, Inc.

I have been recognized for my teaching and scholarly service. In 1997, I was named a General Electric Scholar by the UIUC College of Engineering in 1997 and also received a certificate of recognition as an Engineering Education Scholar by the National Science Foundation ("NSF"). I was named General Electric Fellow (1999) and Collins Fellow (2000) by the Academy of Excellence in Engineering Education program administered by the College of Engineering. In 2000, I was the recipient of the Transportation Research Board's Fred Burgraff award for Excellence in Transportation Research. In 2001, I was elected as a Campus Honors Program faculty member by the Chancellor of UIUC. In 2003 and 2008, my students ranked me as excellent on the list of teachers at UIUC. In January 2009, my paper entitled the "Use of

Falling Weight Deflectometer Testing to Determine Relative Damage in Asphalt Pavement Unbound Aggregate Layers" received the Best Paper Award from the Geology and Properties of Earth Materials Section of the Transportation Research Board, National Academy of Sciences.

EXHIBIT 3

Laboratory Characterization of Coal Dust Fouled Ballast Behavior

Erol Tutumluer, Ph.D.
Associate Professor
Paul F. Kent Endowed Faculty Scholar
Corresponding Author
Phone: (217) 333-8637
Fax: (217) 333-1924
E-mail: tutumlue@uiuc.edu

William Dombrow
Graduate Research Assistant
Phone: (217) 333-6973
E-mail: dombrow@uiuc.edu

Hai Huang
Graduate Research Assistant
Phone: (217) 244-6064
E-mail: hhuang14@uiuc.edu

Civil and Environmental Engineering Department
University of Illinois at Urbana Champaign
Newmark Civil Engineering Laboratory
205 North Mathews Avenue
Urbana, Illinois 61801

Draft Manuscript Submitted for the
AREMA 2008 Annual Conference & Exposition
September 21-24, 2008, Salt Lake City, UT

Laboratory Characterization of Coal Dust Fouled Ballast Behavior

Erol Tutumluer, William Dombrow and Hai Huang

ABSTRACT

Fouling refers to the condition of railroad ballast when voids in this unbound aggregate layer are filled with finer materials. As a fouling agent, coal dust coming from coal trains and accumulating in the ballast has become a major concern for railroads. This paper aims to provide a better understanding of adverse impacts of coal dust on railroad ballast drainage and load carrying functions. First, mechanical properties of coal dust were investigated at the University of Illinois through laboratory tests such as grain size distribution, Atterberg limits, specific gravity, moisture-density compaction relationships, and shear strength properties. Then, ballast aggregates were added coal dust at different percentages by weight and moisture contents to represent coal dust fouling in the field. When fouled samples were tested in large direct shear (shear box) equipment, it was found that 25% coal dust by weight of aggregates were enough to fill up all the voids in ballast corresponding to a void ratio of 43%. When the coal dust percentage in ballast samples increased, the ballast shear strength steadily decreased. In the case of ballast fully fouled with wet coal dust at 35% moisture content, the friction angles obtained from the direct shear equipment were close to the friction angle of coal dust itself. This implies that individual aggregate particles within ballast layer would be completely separated by coal dust to most likely cause the worst track instability problems in the field.

Key Words: Railroad track, ballast, fouling, coal dust, shear strength, laboratory testing

INTRODUCTION

Railroad ballast is uniformly-graded coarse aggregate placed between and immediately underneath the crossties. The purpose of ballast is to provide drainage and structural support for the heavy loading applied by trains. As ballast ages, it is progressively fouled with fine-grained materials filling the void spaces. Methods specifically used to assess track ballast condition only deal with checking visually for evidence of fouling, pumping and water accumulation (ponding) at ditches and shoulders. Additionally, ballast sampling and testing for fouling through laboratory sieve analyses generally provide some insight into the compositions of the larger aggregate particles and the amount of fines. Nonetheless, for a better evaluation of the serviceability and proper functioning of the existing ballast layer, ballast strength and deformation behavior needs to be characterized for different percentages of fine-grained materials, such as plastic soil fines, mineral filler, and more recently coal dust coming from coal trains, which can fill the voids and cause ballast fouling.

For hundreds of years, coal has been a major energy source in the United States. Indeed, there has been a historical link between the economic progress of the U.S. and the use of coal for numerous basic needs of the country, ranging from energy for domestic purposes to industrial applications and electricity generation. As the demand for coal transportation increases with the growing energy need, the coal transportation in the U.S. strongly relies on rail transport. Since rail transport, particularly a unit train, provides the most efficient means of transporting bulk commodities such as coal (Morrison, 1985), the role of rail lines in coal transport has always been predominant.

Today, Powder River Basin (PRB) coal is the largest source of incremental low-sulfur coal supplies in the U.S. (Gaalaas, 2006). From 2000 to 2005, the 5.6 percent increase in

nationwide coal production chiefly stemmed from the concurrent expansion in PRB coal production, and the Burlington Northern Santa Fe/Union Pacific (BNSF/UP) joint line provided for over 60 percent of the total increase in PRB coal production (42 million tons of 69 million tons) from 2000 to 2005. However, while the National Coal Transportation Association forecast of the corresponding total coal shipments was 348 million tons, the joint line was able to achieve 325 million tons of the total forecast value because of major operating problems on the joint line (Gaalaas, 2006). In 2005, two derailments occurred in the BNSF/UP joint coal line in PRB which threatened to interrupt the supply of coal to power plants. Both of the derailments were suspected to be attributed by coal dust fouling, where coal dust spilled over the ballasts and accumulated moisture, allegedly resulting in the loss of strength of the track. In both places where derailments happened, ballast was heavily fouled by coal dust.

This paper presents findings from a comprehensive laboratory-testing program recently initiated at the University of Illinois to study effects of coal dust fouling on railroad ballast strength. Using large direct shear (shear box) tests, strength and deformation characteristics of granite type ballast material were investigated for both clean and coal dust fouled aggregates at various stages of fouling under both dry and wet conditions. The shear strength properties, i.e., cohesion intercept and friction angle, and the stress-strain response are linked to field ballast fouling levels to better assess the impact of coal dust fouling on track instability and ultimately loss of track support leading to derailments.

BALLAST FOULING

Selig and Waters (1994) proposed two indices to describe ballast fouling: (1) *fouling index* is the sum of the percent by weight of ballast sample passing the No. 4 (4.75 mm) sieve plus the

percent passing the No. 200 sieve and (2) *percentage of fouling* is the ratio of the dry weight of material passing 3/8 in. (9.5 mm) sieve to the dry weight of total sample. Figure 1 shows grain size distributions obtained for both clean and fouled materials. The fouled ballast material was collected from a location of derailed (track had buckled out) section of the BNSF railroad line near milepost 43 in Utica, Nebraska in spring of 2006. As indicated, these clean and fouled samples have 1.5% and 14.0% passing the No. 200 sieve (0.075mm), respectively. Although the fines content (% passing the No. 200 sieve) of the fouled sample is not very high, the *fouling index* values computed for the clean and fouled samples were 6.9 and 45.7, respectively. In this case, a *fouling index* of 45.7 corresponds to a *percentage fouling* of nearly 38% (see Figure 1).

In a clean ballast sample, almost all aggregates are supposed to establish contact with each other at the aggregate surface to carry the load (see Figure 2a). As shown in Figure 2b, dirty or partially fouled ballast will have the voids in between contacting aggregates filled with fine particles, however, still maintaining aggregate to aggregate contact. Whereas, in a fouled ballast, due to the excessive amount of fine particles, aggregate to aggregate contacts are mostly eliminated and the aggregate particle movements are then only constrained by the fine particles filling the matrix or voids between the particles (see Figure 2c). In regards to excessive fouling conditions, for example, as in the case of 2005 PRB joint line derailments with wet coal dust completely filling all voids in ballast and pumping on the surface of railroad track, the low strength of the fouling agent will govern for carrying the wheel load. Hence, train derailments may take place due to unstable support under the crossties.

MECHANICAL PROPERTIES OF COAL DUST

Coal dust sample tested in this study was collected from the PRB Orin line milepost 62.4 and was sampled on March 10, 2007. Figures 3 and 4 depict the received coal dust sample in its loose state and close-up view, respectively. To investigate first the mechanical behavior of coal dust itself, several laboratory tests were conducted at the Advanced Transportation Research Laboratory (ATREL) of the University of Illinois at Urbana-Champaign (UIUC). The following sections briefly describe the conducted laboratory tests and present the coal dust test results.

Grain Size Analysis (ASTM C 136, ASTM C 117)

To begin with, dry and wet sieve analyses of the coal dust were performed in compliance with ASTM C 136 and ASTM C 117 test procedures. As Figure 5 indicates from the more accurate wet sieve analyses, the fines content of the coal dust sample was found to be 24%, which means 76% of the coal dust particles were primarily sand sized, coarser than 0.00295 in. (0.075 mm) or retained on No. 200 sieve. The top size (D_{max}) of the coal dust sample is 0.187 in. (4.75 mm), and the particle size corresponding to 50 percent finer by weight (D_{50}) is 0.03 in. (0.76 mm).

Atterberg Limits

The Atterberg limits tests performed indicated that the coal dust sample had a plastic limit (PL) of 50%, a considerably high liquid limit (LL) of 91% thus resulting in a plasticity index (PI) of 41%. This means, at 50% water content, the coal dust starts to exhibit plastic behavior whereas at 91% water content or higher, it behaves like a viscous liquid. Note that the LL of the coal dust is significantly higher than some known weak soils, such as Panama Organic Silt (55%), Georgia Kaolinite (48%), Venezuela Clay (40%), mica powder (75%) from Terzaghi et al. (1996).

Similarly, the PI of the coal dust also exceeds typical values for weak soils, such as Panama Organic Silt (17%), Georgia Kaolinite (16%), Venezuela Clay (25%) and mica powder (20%) (after Terzaghi et al., 1996). Therefore, the high LL and PI of the coal dust sample clearly highlighted its much higher moisture holding capability compared to many silty and clayey subgrade soils.

Specific Gravity

The specific gravity of the coal dust sample was found to be 1.28, which simply meant the density of the coal dust solids was a rather low 79.9 pcf (1.28 g/cm^3) when compared to solid densities of typical soils and aggregates. These results were in accordance with the findings of Fitch (2005), who gave a specific gravity range for coal dust from 1.3 to 1.5. On the other hand, the specific gravities of clay particles typically vary from 2.5 to 2.9 with a statistical average of 2.7 whereas the average specific gravity of sand grains is about 2.65 (Terzaghi et al., 1996). Thus, compared to most soils, the coal dust is a significantly lighter material as far as the low specific gravity of its solid constituents is considered.

Standard Proctor Compaction Test (AASHTO T99/ASTM D 698)

To establish a relationship between the water content and dry density of coal dust, standard Proctor compaction test was performed at different water contents (AASHTO T99/ASTM D698). Figure 6 shows the laboratory obtained compaction curve of the coal dust samples studied. It indicates that the optimum moisture content for the coal dust is 35%, at which the maximum dry density of 54.2 pcf (0.87 g/cm^3) is achieved with the given compactive effort.

Compared to most fine-grained soils such as clays and silts, the 35% optimum moisture content (OMC) is a very high value corresponding to a quite low maximum dry density of 54.2

pcf (0.87 g/cm^3). As far as the results of the standard Proctor compaction test are considered, the coal dust displays not only higher moisture holding capability but also significantly lower dry density compared to most fine-grained soils.

Triaxial (Unconsolidated-Undrained) Test

In this test, cylindrical coal dust specimens were sheared at their OMC (35%) and maximum dry density (54.2 pcf) determined by the previously conducted standard Proctor compaction test. A servo-pneumatic test frame was used as a UTM setup to conduct triaxial tests on small 2 in. (50.8 mm) in diameter by 4 in. (101.6 mm) high specimens. Shear strength tests were conducted under unconfined and confined conditions with the monotonic loading until failure. Figure 7 shows photos of the triaxial cell and the cylindrical coal dust specimen tested. A vertical actuator applies the axial monotonic load and the confining pressures are applied through the inside the chamber.

Since the drainage valves of the triaxial cell were closed from the beginning, the samples were not allowed to consolidate under the effect of confining pressure after they reached 100% saturation and the shearing stage was achieved under undrained conditions. Since the increase in stress was carried by the pore water (Holtz and Kovacs, 1981), the internal friction angle of the coal dust is found almost equal to zero for the undrained conditions. Figure 8 shows the Mohr circles for the unconsolidated-undrained tests and the resultant Mohr-Columb failure envelope of the coal dust. As the failure envelope levels up, it is concluded that the internal friction angle (Φ) of the coal dust is approximately 1.8 degrees, i.e., almost equal to zero, which is very typical of cohesive clayey soils tested under such undrained conditions.

Figure 9 shows applied deviator stresses graphed with vertical specimen displacements at different confining pressures. Once again, there was no effect of varying confining pressure on the shear strength of the coal dust, which was obtained as the maximum deviator stress at failure of only 3.5 psi (24.1 kPa). This is almost the same as twice the amount of cohesion intercept indicated on the y-axis in Figure 8, which is often called the unconfined compressive strength (Qu) for cohesive (Φ=0) soils.

Direct Shear Test

In this test, coal dust samples at different water contents were sheared horizontally in a 3.94 in. by 3.94 in. (100mm by 100mm) shear box under different normal loads so that the relationships between the normal stress and shear stress were established. A direct shear test equipment Humboldt ShearScan 10 direct/residual apparatus utilizing the pneumatic loading concept was used to apply the vertical load to the sample. In doing so, this self-contained model eliminates the need for loading weights used in dead weight-type systems. The ShearScan 10 is complete with a 2,000-lb. (10-kN) capacity load cell, 1-in. (25.4-mm) stroke horizontal deformation transducer, 0.4-in. (10.2-mm) vertical deformation transducer and a built-in 4-channel analog data acquisition system. Figure 10 shows a picture of the ShearScan 10 direct/residual shear test device used to shear the specimen under a series of applied normal stresses.

Table 1 summarizes the results obtained from the direct shear tests and illustrates the change in the internal friction angle of the coal dust with respect to moisture content. The internal friction angles and cohesion intercepts of the coal dust samples are tabulated with regard to the moisture contents of the test samples. Considering the significant decrease in the friction

angle and as a result approximately 47% decrease in shear strength contributed by tan Φ, cohesion intercept stayed almost constant.

CLEAN AND COAL DUST FOULED BALLAST BEHAVIOR

To investigate whether the fouling condition indicated in Figure 2c takes place, i.e., fouling agent's strength dominates over the ballast layer strength properties when heavily fouled, direct shear tests were conducted at the University of Illinois on both clean and coal dust fouled ballast samples. The ballast material tested was a granite aggregate obtained from Gillette, WY and commonly used in the PRB joint line railroad track structures as the ballast layer.

Figure 11 shows the grain size distribution of the granite sample tested in compliance with ASTM C 117 test procedure. Table 2 lists the gradation sieve sizes and the percent passing each sieve properties for the clean granite aggregate. The grain size distribution conforms to the typical AREMA No. 24 ballast gradation having a maximum size (D_{max}) of 2.5 in. (63.5 mm), a minimum size (D_{min}) of 1 in. (25.4 mm), and an average particle size corresponding to 50 percent passing by weight (D_{50}) of approximately 1.77 in. (45 mm). Also listed in Table 2 are the specific gravity, unit weight and corresponding compacted air voids of the clean granite aggregates. ASTM C29 test procedure was used for finding porosity or air voids with known values of the specific gravity and volume and weight of ballast compacted.

Direct shear strength tests were performed on the reconstituted clean and coal dust fouled granite aggregate samples. Figure 12 shows the large shear box equipment used for testing at the University of Illinois. The test device is a square box with side dimensions of 12 in. (305 mm) and a specimen height of 8 in. (203 mm). It has a total 4-in. (102 mm) travel of the bottom 6-in. (152 mm) high component, which is large enough for ballast testing purposes to record peak shear stresses. The vertical (normal direction) and horizontal load cells are capable of applying

and recording up to 30-kip and 20-kip load magnitudes, respectively. The device controls and the data collection are managed through an automated data acquisition system controlled by the operator through a build-in display and the test data are saved on to a personal computer.

Direct Shear Test Procedure

1. Obtain 54 lbs. (24.5 kg) of ballast aggregate
2. Compact ballast sample into lower box (14 in. x 12 in. x 6 in. or 356 mm x 305 mm x 152 mm) using two 3 in. (76 mm) lifts. Use vibratory compactor on top of a flat Plexiglas compaction platform and compact until no noticeable movement of particles is observed (see Figure 13).
3. Obtain prescribed weight of fouling material (e,g., coal dust) and water to mix with compacted ballast.
4. Spread fouling material over compacted ballast evenly in two lifts (half of material each lift). Shakedown material using vibratory compactor after each lift. If test is conducted with wet fouling material (for example, at the optimum moisture content or OMC), pour proportional amount of water over ballast after shakedown of each lift (see Figure 14). Place upper ring (3 in. or 76 mm high) on top of lower box. Align ring with sides and back edge of box (opposite of block) and fill with single lift of ballast and compact (see Figure 15).
5. Place box and ring assembly into shearing apparatus. Clamp lower box in place. Place load bearing plate on ballast and inside upper ring. Place air-bladder on bearing-plate. Close normal force load cell over air-bladder. Open air supply and set pressure using an in-line pressure regulator (see Figure 16).

6. Adjust shear force load cell directly against the upper ring.
7. Prepare LabVIEW Data Logger software to record normal and shear force while the test is running.
8. Input shear rate of 0.48 in./min. (12.2 mm/min.) which is approximately 4% strain per minute and run test until shear force output becomes constant or 15% strain has occurred.

Direct Shear Test Results

The ballast samples were sheared horizontally in the shear box under target normal pressures of 25, 35, 45 psi (172, 241 and 310 kPa), typical ballast layer confining pressures, so that the relationships between the normal stress and shear stress could be established. The maximum shear stress at failure under each applied normal pressure was recorded from each test. This maximum shear stress typically occurred when approximately 10% shear strain was reached during testing. The shear strength $\tau_{max} = C + \sigma_n * \tan\Phi$ (where C is the cohesion intercept, σ_n is the applied normal stress, and Φ is the internal friction angle) expression was then developed for each ballast sample tested at a corresponding fouling fines content and moisture state.

Figure 17 shows the maximum shear stresses predicted under the applied normal stresses during shear box testing. As the applied normal stresses increased, the maximum shear stresses at failure or simply shear strength τ_{max} also increased primarily influenced by the ballast fouling percentage and the moisture condition of the coal dust, i.e., dry or wet at OMC = 35%. As expected, the highest shear strength values were obtained from the clean ballast at all applied normal stress levels. When ballast samples were fouled, the shear strengths typically decreased. For all the samples tested, wet coal dust fouling resulted in lower shear strengths when compared to those obtained from dry coal dust fouling. The lowest shear strength values were recorded for

the fouling level of 25% by weight of ballast when wet coal dust filled all the voids at 35% moisture content.

Table 3 shows cohesion intercepts (C) and internal friction angles (from slopes of Mohr-Coulomb envelopes in Figure 17) obtained for the clean and fouled ballast samples. The highest friction angle Φ of 45.6 was achieved for the clean granite. For the case of 25% wet coal dust fouling by weight of ballast, the friction angle computed is as low as 34.5 degrees, which is very close to 33.5 degrees at OMC for the coal dust itself. Similarly, a low cohesion intercept of 5.1 psi (35 kPa) value is close to the very low unconfined compressive strength of 3.5 psi (24 kPa) for the coal dust itself. Therefore, the shearing action in the direct shear apparatus was mainly resisted by the wet coal dust governing the behavior. Again, one should note that 35% OMC condition does not represent fully saturated coal dust state. After soaking or 100% saturation, soil suction would be destroyed thus resulting in fairly lower strengths and unstable ballast conditions.

SUMMARY AND CONCLUSIONS

Mechanical properties of representative coal dust samples obtained from the Powder River Basin (PRB) joint line in Wyoming were determined through laboratory testing at the University of Illinois. From the grain size analysis of the coal dust, material finer than 0.00295 in. (0.075 mm) or No. 200 sieve size was found to be 24%. The specific gravity of the coal dust sample was 1.28. While the fines content of the coal dust was lower than that of most silty and clayey soils, the optimum moisture content (OMC) of the coal dust determined from the standard Proctor compaction test was remarkably higher than that of some of the weak cohesive soils, which highlights its ability to hold much greater amounts of moisture. Likewise, the high liquid limit,

LL, and plasticity index, PI, of coal dust, i.e., 91% and 41%, respectively, also underscore its high moisture sensitivity. When subjected to precipitation, coal dust can therefore hold excessive amounts of moisture to prevent free draining of the ballast, i.e., can keep ballast wet and saturated, and act as a lubricant between the ballast stones, enabling much greater movement within the ballast layer.

As for the strength characteristics of the coal dust, the unconfined compressive strength of the coal dust tested was a remarkably low Qu = 3.5 psi (24.1 kPa) at the OMC of 35%. The results of direct shear tests indicated a large reduction in the internal friction angle of the coal dust with increasing moisture content. For instance, the internal friction angle of the coal dust was found as 33.5 degrees at 35% OMC whereas the internal friction angle corresponding to 43% moisture was only 19.2 degrees. Therefore, exposure of coal dust to moisture drastically reduces the friction component of the shear strength and can cause significant reduction in bearing capacity and load carrying ability.

Large-sized direct shear (shear box) laboratory tests were next conducted at the University of Illinois on granite ballast samples also obtained from the Powder River Basin (PRB) joint line in Wyoming to measure strength and deformation characteristics of both clean (new) and fouled ballast aggregates with coal dust at various stages of fouling. The grain size distribution of the aggregate conformed to the typical AREMA No. 24 ballast gradation with a maximum size (D_{max}) of 2.5 in. (63.5 mm) and a minimum size (D_{min}) of 1 in. The coal dust, also obtained from the PRB joint line, was used as the fouling agent and mixed with clean aggregates for achieving fouling levels of 5%, 15%, and 25% by weight of ballast under dry and wet (at 35% OMC) conditions.

From the direct shear tests, the highest shear strength values were obtained from the clean ballast at all applied normal stress levels which were representative of the stress states experienced in the ballast layer under train loading. When ballast samples were fouled, the shear strengths always decreased. Wet (35% OMC) coal dust fouling resulted in lower ballast shear strengths when compared to those obtained from dry coal dust fouling. For the case of 25% wet coal dust fouling by weight of ballast, internal friction angle and cohesion obtained were equivalent to those properties of the coal dust itself at 35% OMC. Therefore, the wet coal dust was governing the ballast behavior as the worst fouling agent for its impact on track substructure and roadbed when compared to even the highly plastic type clayey soil fines. Note that even more drastic strength reductions can be realized when dry coal dust, never been saturated or soaked in the field and therefore having a high suction potential, is subjected to inundation and 100% saturation.

ACKNOWLEDGEMENTS

The authors would like to thank Burlington Northern Santa Fe (BNSF) Railroad Company for providing the financial support needed to carry out this research study. The authors would also like to thank Mr. Hank Lees with BNSF for sharing his valuable knowledge and experience on the research topic and for providing help and support with obtaining materials. The assistance of Kivanc Avrenli on the coal dust tests is greatly appreciated. The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. This paper does not constitute a standard, specification, or regulation.

REFERENCES

Fitch, J., 2005, "A Much Closer Look at Particle Contamination," Practicing Oil Analysis Magazine, Issue Number 200509.

Gaalaas, T., 2006, "Update on PRB Coal Transportation: Still a Hot Issue," http://www.paceglobalcom/paceglobal/pdfs/publications/Recurring%20Articles/CA_pg32-35-June%202006.pdf, Marketwatch.

Holtz, R.D. and W.D. Kovacs, 1981, *An Introduction to Geotechnical Engineering*, Prentice Hall, Englewood Cliffs, New Jersey.

Morrison, M.B., 1985, "Transportation of U.S. Western Coal: The Impact of Deregulation on Unit Train Rates," Energy Policy, June 1985, pp. 243-252.

Selig, E.T. and J.M. Waters, 1994, *Track Geotechnology and Substructure Management*, Thomas Telford Publications, London.

Terzaghi, K., Peck, R.B., and G. Mesri, 1996, *Soil Mechanics in Engineering Practice*, 3rd edition, Wiley-Interscience Publication.

LIST OF TABLES

Table 1 Internal friction angles and cohesion intercepts of coal dust measured by direct shear tests at different moisture contents

Table 2 Properties of the clean granite aggregate

Table 3 Summary of ballast internal friction angles and cohesion intercepts

LIST OF FIGURES

Figure 1 Sample grain size distributions of clean and fouled ballast samples (25.4 mm=1 in.)

Figure 2 Critical ballast fouling stages illustrating loss of aggregate to aggregate contact

Figure 3 Sample of coal dust in its loose state

Figure 4 Close-up view of the coal dust sample studied

Figure 5 Grain size distribution of the coal dust sample

Figure 6 Standard Proctor moisture-dry density curve for the coal dust sample

Figure 7 Photographs showing the triaxial test setup and the failed coal dust specimen

Figure 8 Triaxial shear test results and the Mohr-Coulomb failure envelope for coal dust

Figure 9 Shear strength of coal dust from undrained triaxial tests

Figure 10 Photograph showing the ShearScan 10 Direct Shear Test equipment

Figure 11 Grain size distribution of the clean granite aggregate sample (25.4 mm=1 in.)

Figure 12 The shear box shear strength test equipment at the University of Illinois

Figure 13 Stages of ballast compaction

Figure 14 Mixing fouling material as outlined in steps 3 and 4

Figure 15 Loading upper ring

Figure 16 Setting-up the direct shear box apparatus

Figure 17 Direct shear box ballast strength test results

Table 1. Internal friction angles and cohesion intercepts of coal dust measured by direct shear tests at different moisture contents

Moisture Content (%)	Internal Friction Angle, Φ (Degrees)	tan Φ	Cohesion Intercept, C (psi)
33.00	34.10	0.68	1.11
35.00	33.53	0.66	1.23
37.00	31.83	0.62	1.13
39.00	27.22	0.51	1.07
41.00	21.91	0.40	1.01
43.00	19.23	0.35	0.81

Table 2. Properties of the clean granite aggregate

Granite		
Specific gravity		2.62
Unit weight		93 pcf
Compacted Air Voids		43%
Gradation		
Sieve Size		Percent Passing
in.	mm	%
2.5	63.5	100
2	50.8	82
1.5	38.1	18
1	25.4	0
AREMA		No. 24

Table 3. Summary of ballast internal friction angles and cohesion intercepts

Condition	Fouling % *	Cohesion, c (psi)	ϕ (rad.)	ϕ (deg.)	Max Shear Stress, $\tau_{max} = c + \sigma_N \tan(\phi)$	Regression Coef, R^2
Clean	0	15.24	1.022	45.6	$\tau_{max} = 15.24 + \sigma_N \tan(43.9°)$	0.99
Dry	5	13.96	0.991	43.9	$\tau_{max} = 13.96 + \sigma_N \tan(43.9°)$	0.99
	15	13.46	0.773	36.2	$\tau_{max} = 13.46 + \sigma_N \tan(36.2°)$	0.99
	25	10.90	0.668	36.6	$\tau_{max} = 10.90 + \sigma_N \tan(36.6°)$	0.97
Wet (OMC)	5	8.89	0.963	44.7	$\tau_{max} = 8.89 + \sigma_N \tan(44.7°)$	0.99
	15	11.12	0.731	37.7	$\tau_{max} = 11.12 + \sigma_N \tan(37.7°)$	0.99
	25	5.10	0.744	34.5	$\tau_{max} = 5.102 + \sigma_N \tan(34.5°)$	0.97

* percentage by ballast weight

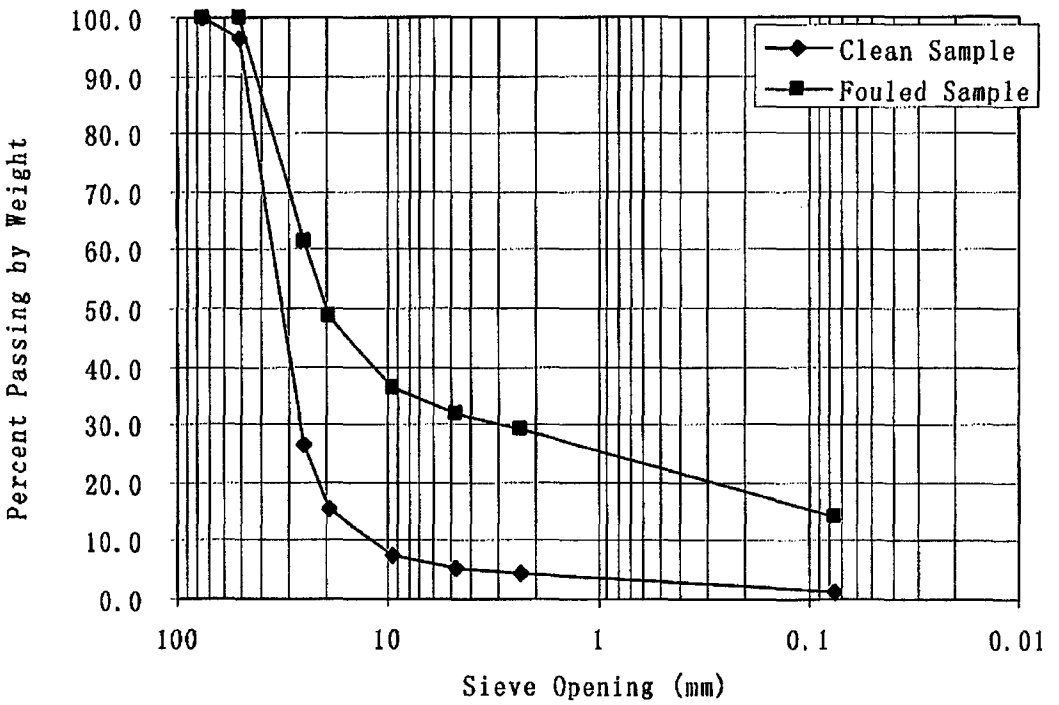
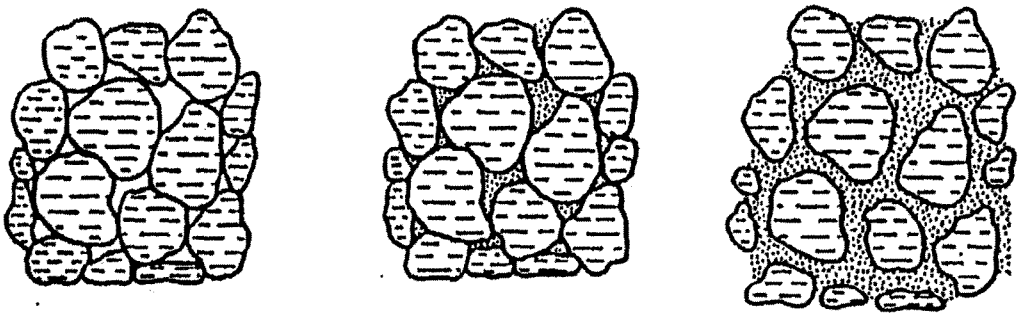


Figure 1. Sample grain size distributions of clean and fouled ballast samples (25.4 mm=1 in.)



(a) clean ballast

(b) dirty ballast with fine particles filling voids

(c) fouled ballast with aggregate to aggregate contact lost

Figure 2. Critical ballast fouling stages illustrating loss of aggregate to aggregate contact

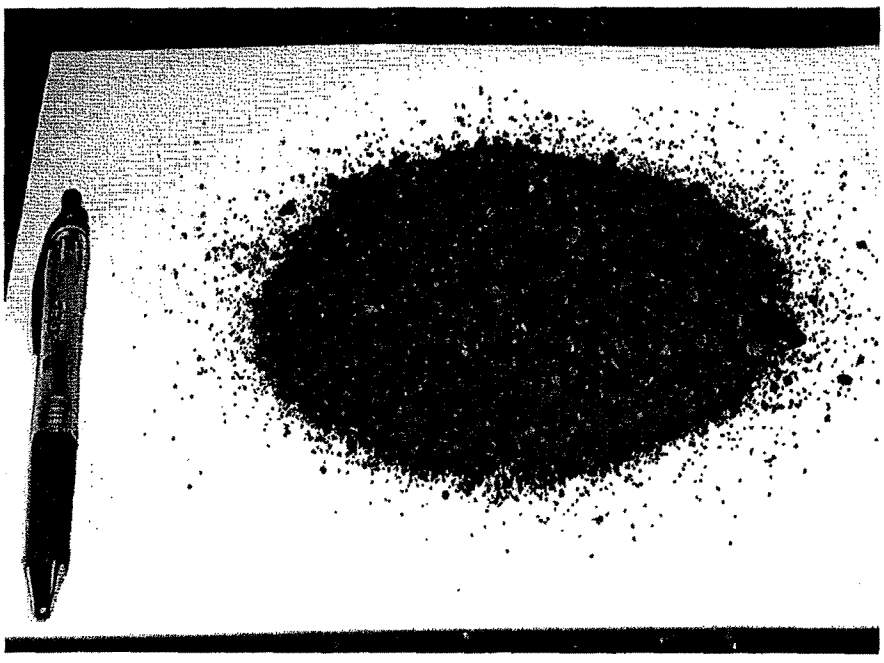


Figure 3. Sample of coal dust in its loose state

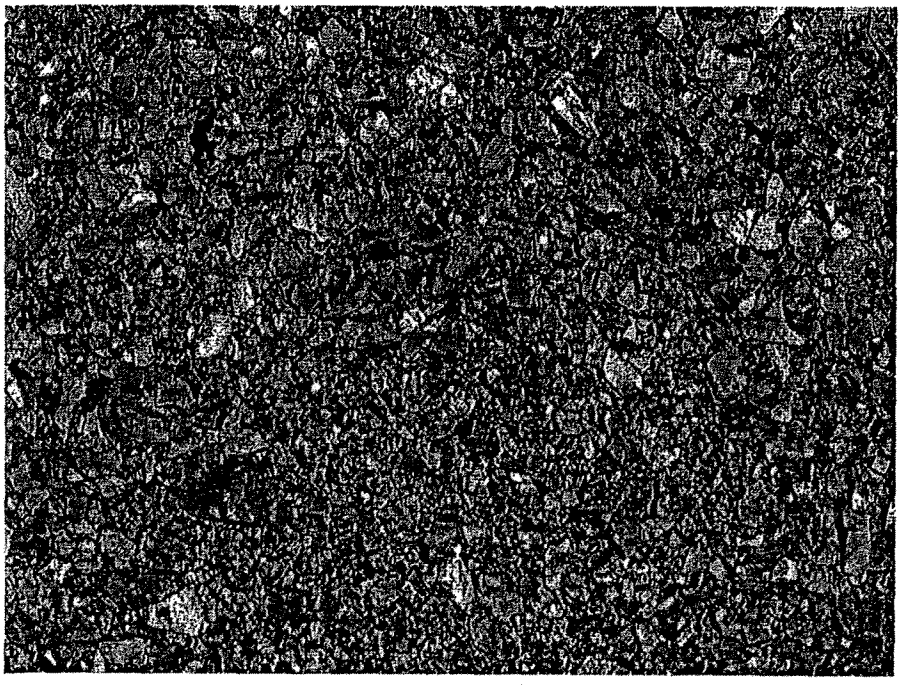


Figure 4. Close-up view of the coal dust sample studied

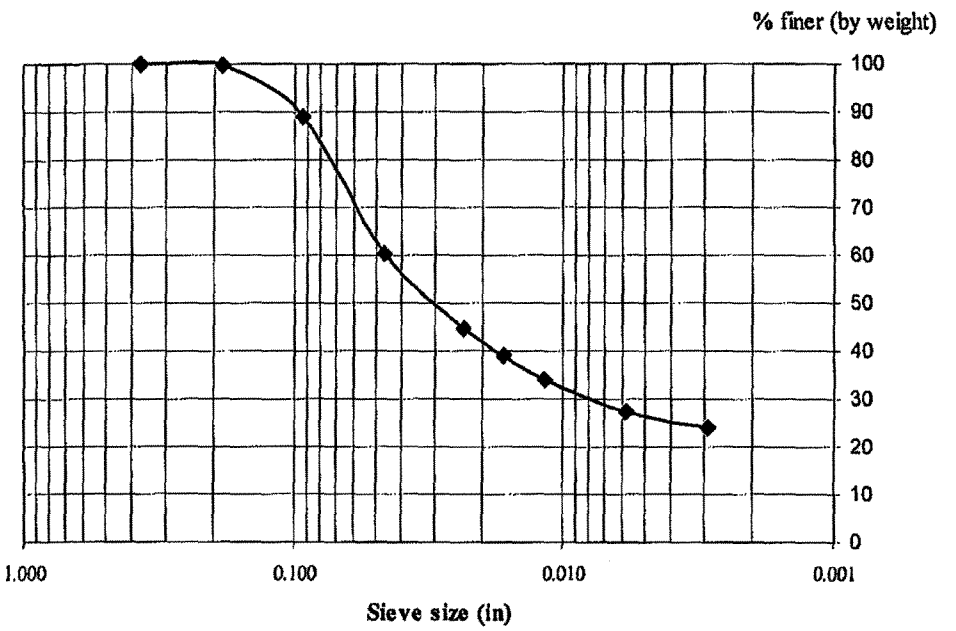


Figure 5. Grain size distribution of the coal dust sample

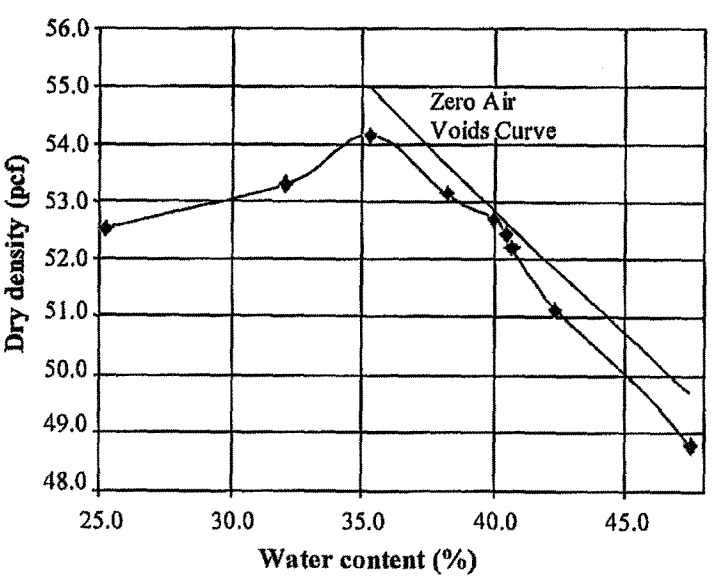


Figure 6. Standard Proctor moisture-dry density curve for the coal dust sample

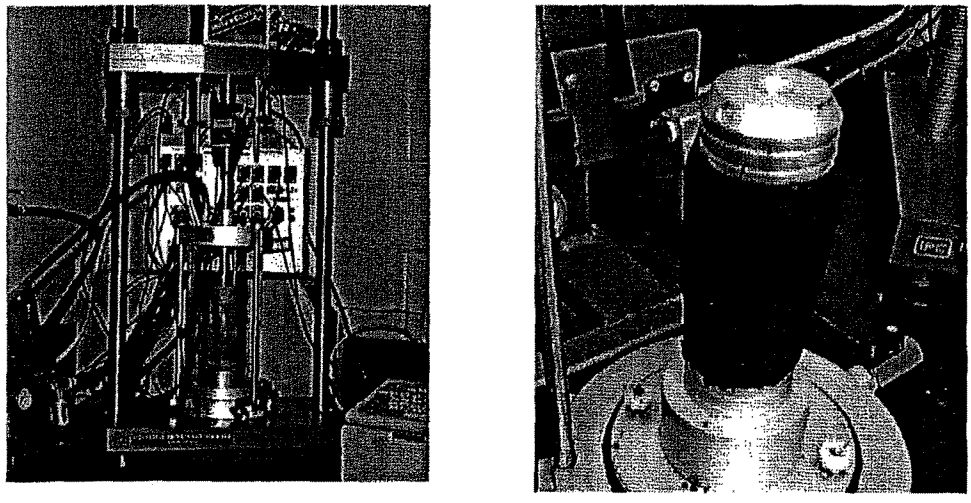


Figure 7. Photographs showing the triaxial test setup and the failed coal dust specimen

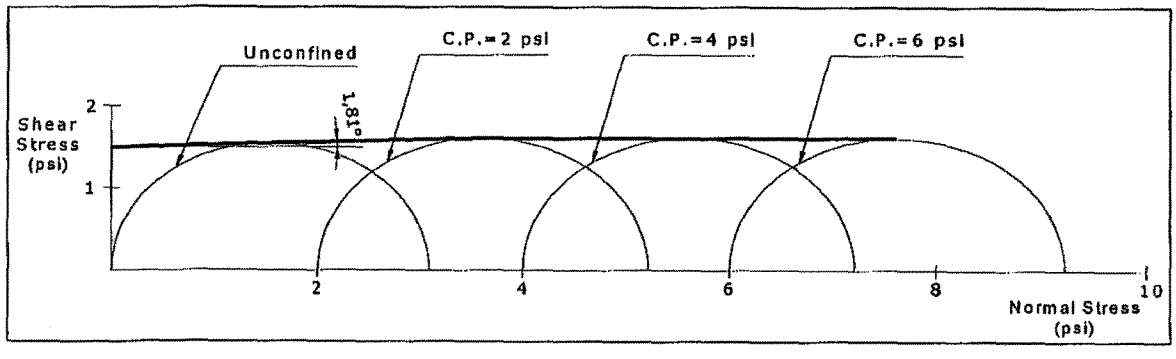


Figure 8. Triaxial shear test results and the Mohr-Coulomb failure envelope for coal dust

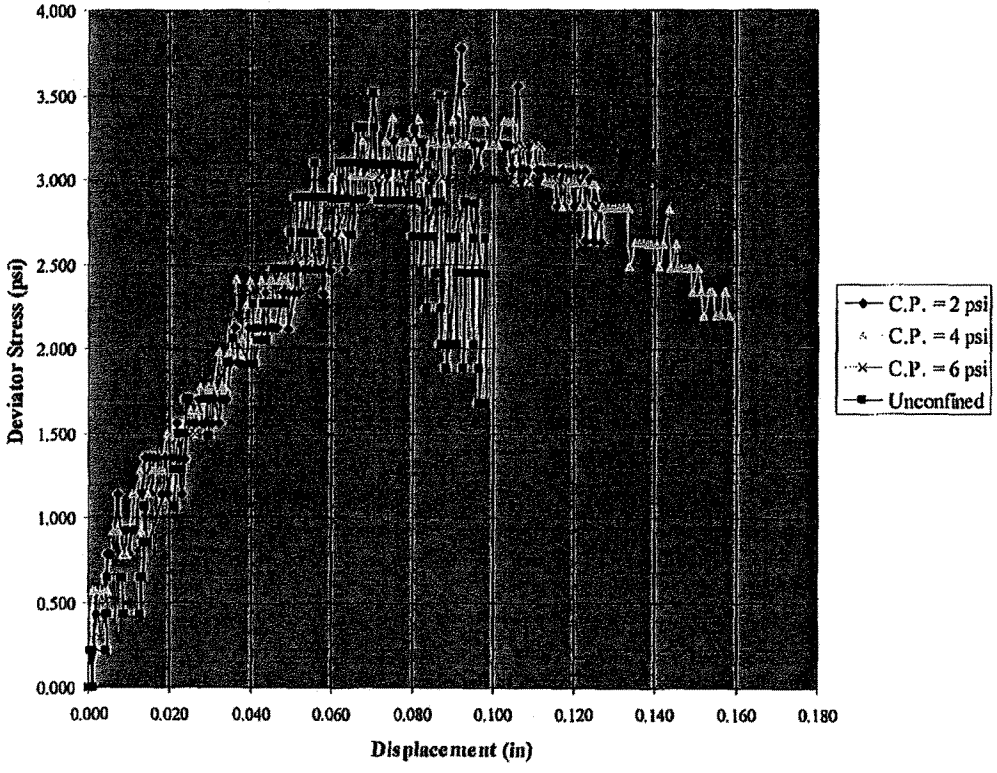


Figure 9. Shear strength of coal dust from undrained triaxial tests

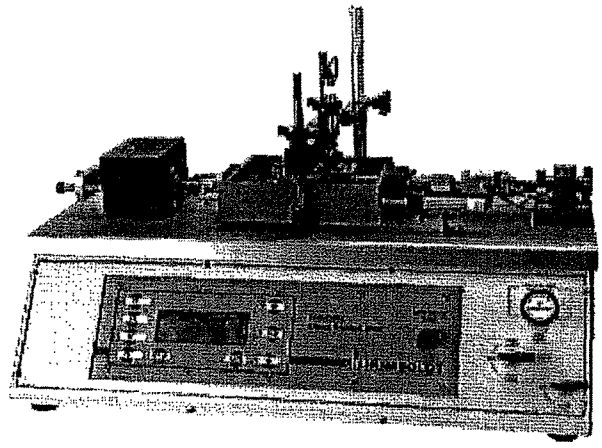


Figure 10. Photograph showing the ShearScan 10 Direct Shear Test equipment

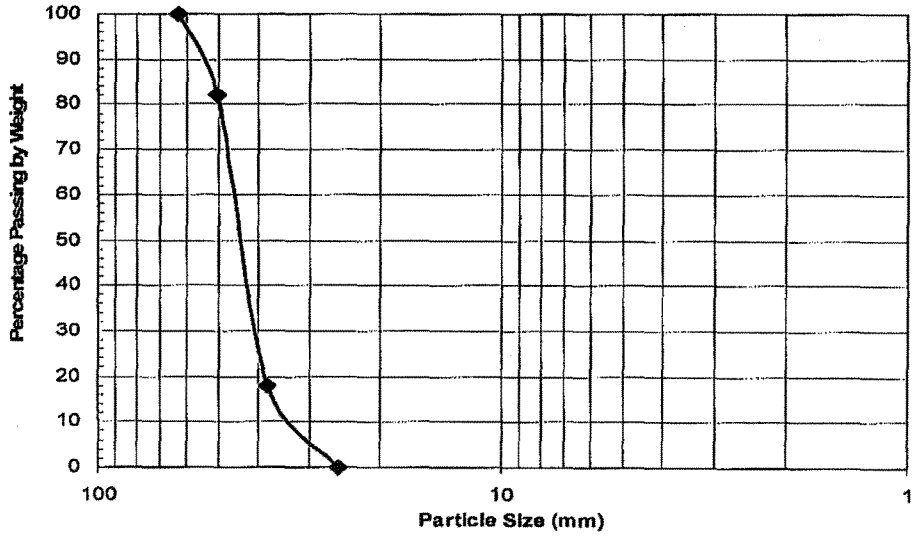


Figure 11. Grain size distribution of the clean granite aggregate sample (25.4 mm=1 in.)

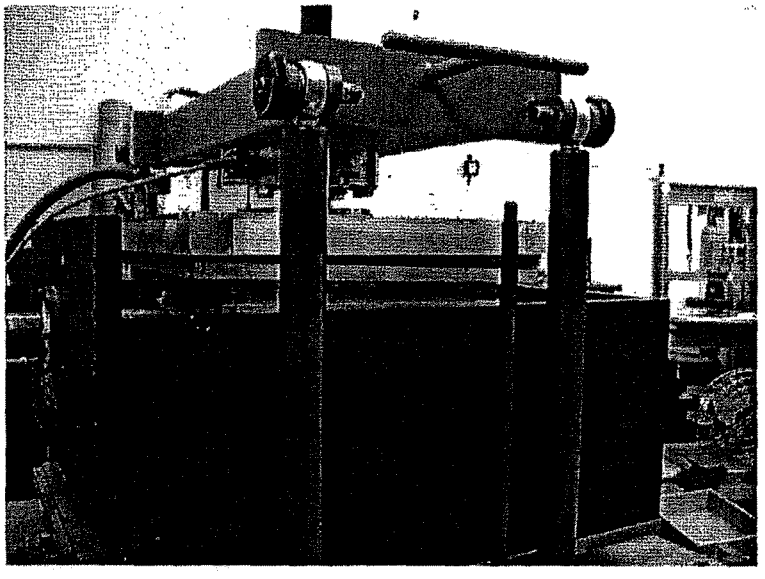


Figure 12. The shear box shear strength test equipment at the University of Illinois

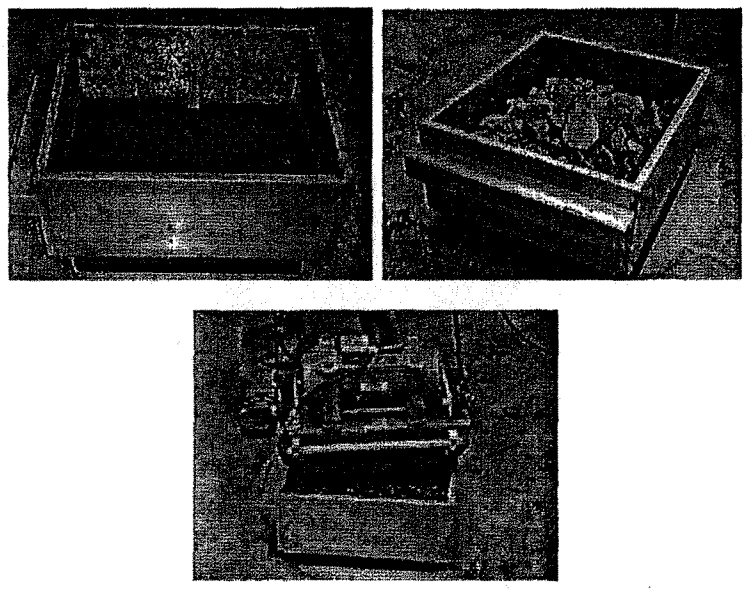


Figure 13. Stages of ballast compaction

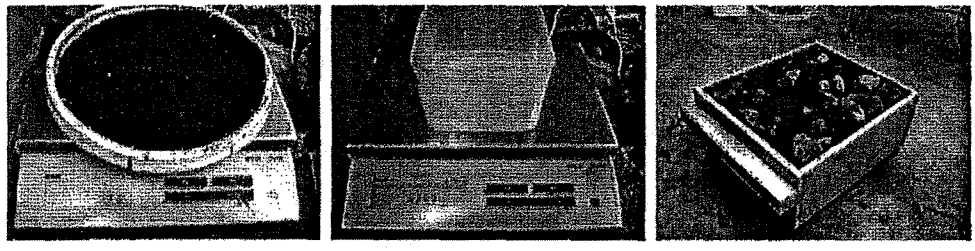


Figure 14. Mixing fouling material as outlined in steps 3 and 4

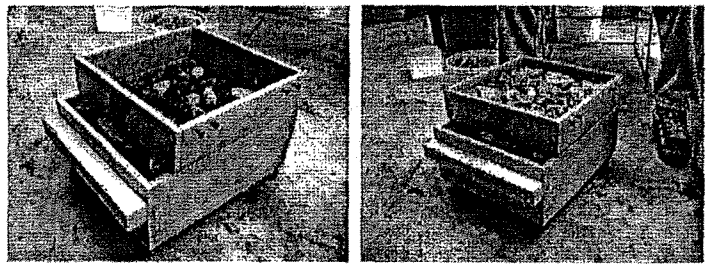


Figure 15. Loading upper ring

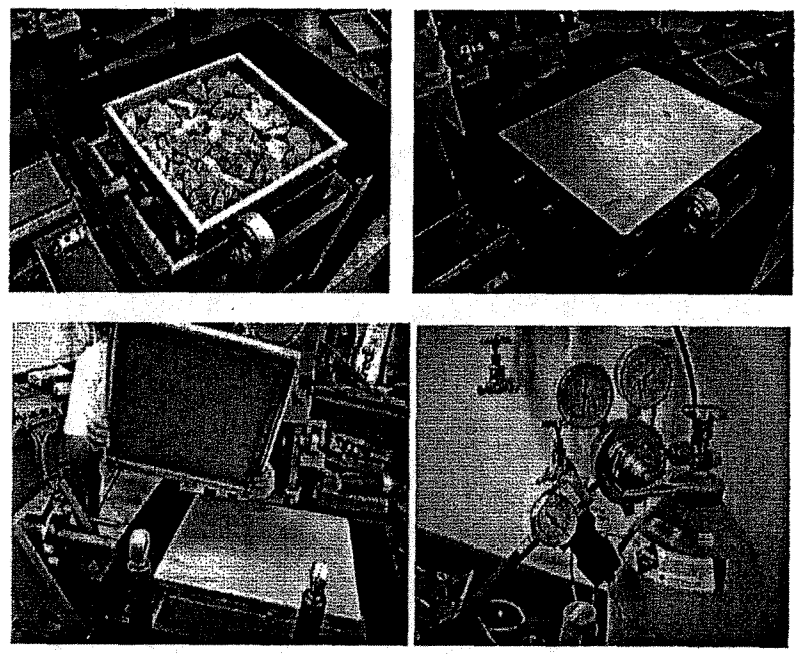


Figure 16. Setting-up the direct shear box apparatus

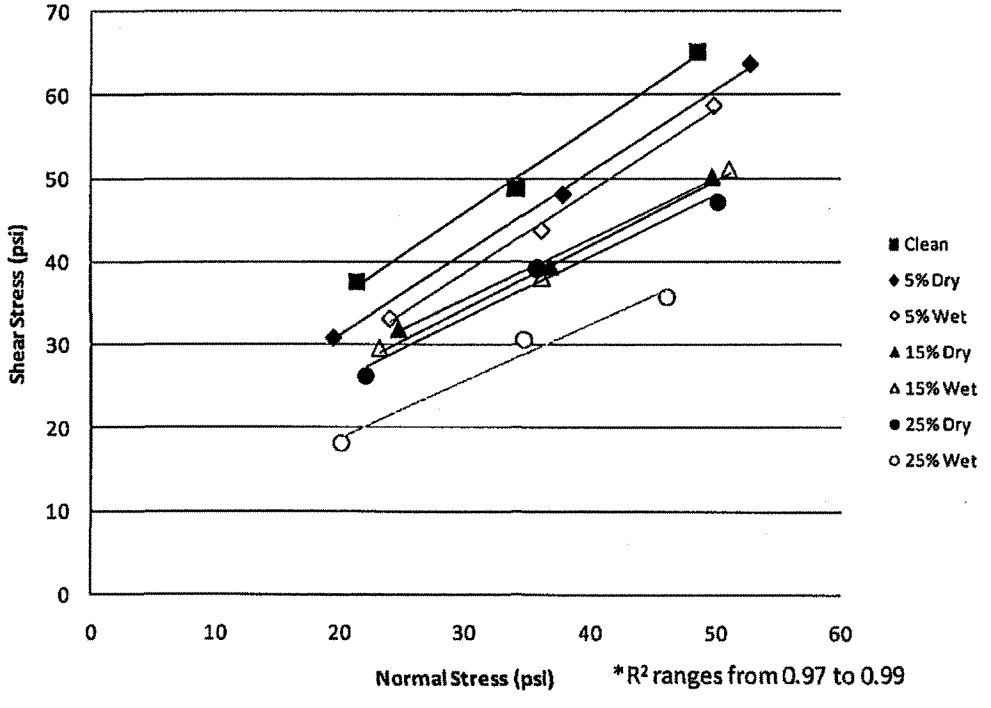


Figure 17. Direct shear box ballast strength test results

EXHIBIT 4

Laboratory Characterization of Fouled Railroad Ballast Behavior

Hai Huang, Erol Tutumluer, and William Dombrow

Fouling refers to the condition of railroad ballast when voids in this unbound aggregate layer are filled with relatively finer materials or fouling agents, which commonly come from breakdown of the ballast aggregate, outside contamination such as coal dust from coal trains, or subgrade soil intrusion. Effects of different fouling agents on ballast aggregate shear strength were studied at the University of Illinois. Through the use of a large direct shear (shear box) device, the strength properties of both clean and fouled ballast samples were determined when three types of fine materials—coal dust, plastic clayey soil, and mineral filler—were added to clean ballast samples at various percentages by weight of ballast under both dry and wet [mostly optimum moisture content (OMC)] conditions. Realistic sample preparation procedures were conducted to closely simulate field-fouling scenarios. Test results showed that when the coal dust fouling percentage increased, the ballast shear strength steadily decreased. Wet fouling was found to exacerbate this trend. Results of ballast samples fouled with clay and mineral filler also showed decreasing trends in strength properties; however, coal dust was by far the worst fouling agent for its impact on track substructure and roadbed. Approximately 15% coal dust fouling by weight of ballast was statistically significant to cause considerable strength reductions. In the case of ballast fully fouled with wet coal dust at 35% OMC, the friction angles obtained were as low as the friction angle of coal dust itself.

Railroad ballast is uniformly graded coarse aggregate placed between and immediately underneath the crossties. The purpose of ballast is to provide drainage and structural support for the loading applied by trains. As ballast ages, it is progressively fouled with materials finer than aggregate particles, filling the void spaces. Methods specifically used to assess track ballast condition deal only with checking visually for evidence of fouling, pumping, and water accumulation (ponding) at ditches and shoulders. Additionally, ballast sampling and testing for fouling through laboratory sieve analyses generally provide some insight into the compositions of the larger aggregate particles and the amount of fines. Nonetheless, for a better evaluation of the serviceability and proper functioning of the existing ballast layer, ballast strength needs to be characterized for different percentages of fine materials, such as plastic soil fines, mineral filler, and more recently coal dust coming from coal trains, which can fill the voids and cause ballast fouling.

Since rail transport, particularly a unit train, provides the most efficient means of transporting bulk commodities such as coal, the role of rail lines in coal transport has always been predominant. In 2005, two derailments occurred in the joint coal line of Burlington Northern Santa Fe (BNSF) and Union Pacific in Powder River Basin (PRB) in Wyoming, the largest source of incremental low-sulfur coal supplies in the United States. The derailments threatened to interrupt the supply of coal to power plants. Both derailments were suspected to be attributed to coal dust fouling, in which coal dust spilled over the ballasts and accumulated moisture, resulting in the loss of strength of the track. The ballast was heavily fouled by coal dust where both of the derailments occurred.

This paper presents findings from a comprehensive laboratory testing program initiated at the University of Illinois to study the effects of different fouling agents—coal dust, plastic clayey soil, and mineral filler—on railroad ballast strength. Using large direct shear (shear box) tests, strength and deformation characteristics of granite type ballast material were investigated for clean ballast and ballast fouled by different agents at various stages under both dry and wet conditions. The shear strength properties, such as cohesion intercept and friction angle, are linked to field ballast fouling levels to better assess the impact of fouling on track instability and ultimately loss of track support, leading to derailments.

BALLAST FOULING AND ITS MECHANISM

Fouling materials in ballast have been traditionally considered not favorable for railroad ballast performance. Early research studies reported that around 70% of the fouling materials were from ballast breakdown (*1–3*). Railroad company internal studies also noted that almost all fouling fines in the railroad track were commonly from aggregate breakdown (*4*). According to Selig and Waters (*5*), ballast breakdown on average accounts for up to 76% of the ballast fouling, followed by 13% infiltration from subballast, 7% infiltration from ballast surface, 3% subgrade intrusion, and 1% due to tie wear.

Selig and Waters (*5*) proposed two indices to describe ballast fouling: (*a*) fouling index is the sum of the percent by weight of ballast sample passing the 4.75 mm (No. 4) sieve plus the percent passing the 0.075 mm (No. 200 sieve) and (*b*) percentage of fouling is the ratio of the dry weight of material passing the 9.5 mm (⅜ in.) sieve to the dry weight of total sample. They also proposed that the particles retained on the 0.075 mm (No. 200 sieve) are treated as "coarse fouling materials" and particles passing the 0.075 mm (No. 200 sieve) are "fine fouling materials" (*5*).

Raymond (*6*) suggested that if fouled ballast had to be used, the liquid limit (LL) of the fines should be less than 25 to maintain the function of drainage. Raymond (*7*) also found that the aggregate breakdown was significantly influenced by the type and especially hardness of the mineral aggregate. Harder aggregates had fewer breakdowns than softer aggregates did. Later, Raymond (*8*) noted

Department of Civil and Environmental Engineering, University of Illinois at Urbana–Champaign, 205 North Mathews Avenue, Urbana, IL 61801. Corresponding author: E. Tutumluer, tutumlue@illinois.edu.

Transportation Research Record: Journal of the Transportation Research Board, No. 2117, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 93–101.
DOI: 10.3141/2117-12

that the wear of tie was more significant at the worst fouled track locations, possibly due to the abrasive effects of the slurry formed by fouling fines and water.

Chiang (*9*) conducted a series of ballast box repeated loading tests on fouled ballast. Test results indicated that ballast settlement typically increased as the amount of fouling material in ballast increased. Similarly, Han and Selig (*10*) conducted ballast box tests to evaluate the impact of fouling on ballast settlement. They concluded that the degree of ballast fouling indeed had a major impact on the ballast settlement. With an increase in the percentage fouling, both the initial and final ballast settlements increased significantly. Investigations on the strength of fouled ballast and studies on the fouling mechanism, however, have been somewhat limited.

In terms of the stability and load carrying ability of the fouled ballast layer, three volumetric phases can be identified for the different conditions of fine materials filling the void space (Figure 1). Phase I shows a clean or very slightly fouled ballast sample with almost all aggregates establishing contact with each other at the aggregate surface to sufficiently carry the load (Figure 1*a*). As shown in Figure 1*b,* Phase II will have the voids in between aggregates filled with enough fine particles to significantly reduce the strength; however, aggregate-to-aggregate contact is maintained. In a Phase III fouled ballast condition, because of the excessive amount of fine particles, aggregate-to-aggregate contacts are mostly eliminated, and the aggregate particle movements are then constrained only by the fine particles filling the matrix or voids between the particles (Figure 1*c*).

Because ballast in Phase III is no doubt unacceptable and needs immediate remedial action, ballast in Phases I and II is particularly worth studying from the aspect of how different fouling agents at different phases would affect ballast strength and therefore track stability. It is also of great importance to know the dividing line between Phase I and II because it is also the suggested starting point of maintenance activities, such as ballast cleaning. Hypothetically, if ballast aggregate particles are assumed to be spheres, it is possible to define the maximum size of the fouling materials through three-dimensional packing order computations for large and small spheres. Accordingly, Equation 1 defines the radius r of a single fouling particle approximated as a sphere to fit in between three large contacting spherical particles, each having a radius R, without separating them.

$$r = \left(\sqrt{\frac{32}{27}} - 1\right)R \tag{1}$$

Considering that the maximum size of ballast aggregates is often limited to $2R = 76$ mm (3 in.), the largest diameter of a single fouling particle can then be 6.7 mm (0.26 in.), which is smaller than the 9.5 mm (⅜ in.) suggested by Selig and Waters (*5*).

CLEAN AND FOULED BALLAST STRENGTH BEHAVIOR

Materials Tested

The ballast material tested was a granite aggregate obtained from Gillette, Wyoming, and commonly used in the PRB joint line railroad track structures as the ballast layer. Figure 2 shows the grain size distribution of the granite sample with a specific gravity of 2.62 tested in compliance with ASTM C117 test procedure. The granite aggregate size distribution conforms to the typical American Railway Engineering and Maintenance-of-Way Association (AREMA) No. 24 ballast gradation having a maximum size (D_{max}) of 63.5 mm (2.5 in.), a minimum size (D_{min}) of 25.4 mm (1 in.), and an average particle size corresponding to 50% passing by weight (D_{50}) of approximately 45 mm (1.77 in.).

From the average size of the clean ballast (45 mm), an average particle fouling size of 4 mm was chosen in this study based on Equation 1. Accordingly, the three types of fouling materials studied with this granite type ballast aggregate were coal dust, refractory clay representing a cohesive fine-grained subgrade soil, and mineral filler obtained from the crushing operations of the same granite aggregate. Figure 2 shows the typical gradations and Table 1 lists the engineering properties of these fouling materials with the moisture density information obtained from the standard Proctor ASTM D 698 test procedure. The coal dust sample tested in this study was also collected from the PRB Orin Line, Milepost 62.4, and was sampled March 10, 2007.

Testing Apparatus

Direct shear strength tests were performed on the reconstituted clean and fouled granite aggregate samples. Figure 3 shows the large shear box equipment used for testing at the University of Illinois. The test device is a square box with side dimensions of 305 mm (12 in.) and a specimen height of 203 mm (8 in.). It has a total 102-mm (4-in.) travel of the bottom 152-mm (6-in.) high component, which is large enough for ballast testing purposes to record peak shear stresses. The vertical (normal direction) and horizontal load cells are capable of

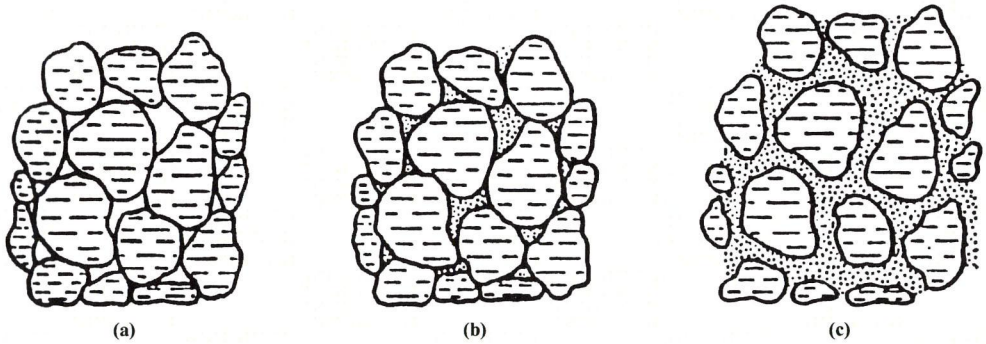


FIGURE 1 Critical ballast fouling phases: (*a*) clean ballast (Phase I), (*b*) partially fouled ballast (Phase II), and (*c*) heavily fouled ballast (Phase III).

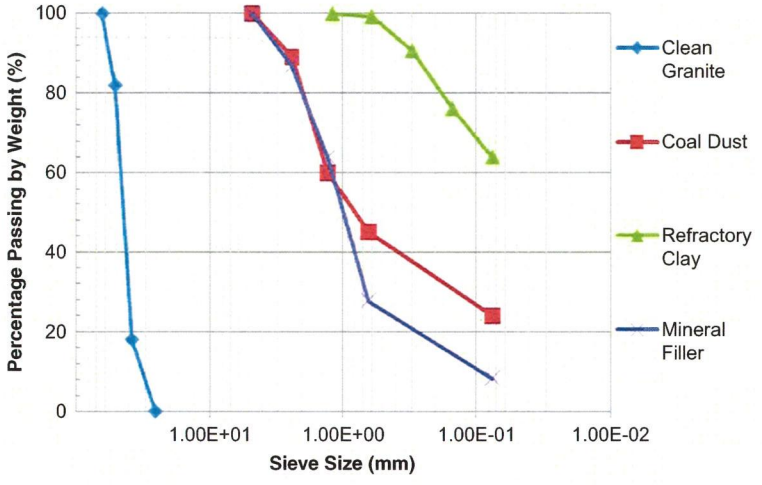


FIGURE 2 Grain size distributions of the clean ballast and fouling materials.

applying and recording up to 50-kN load magnitudes. The device controls and the data collection are managed through an automated data acquisition system controlled by the operator through a built-in display, and the test data are saved on a personal computer.

Sample Preparation

Clean ballast samples were prepared in the lower shear box to the condition similar to the field according to the following steps:

1. Place aggregates in the lower box by lifts (usually two 76-mm lifts).
2. For each lift, use vibratory compactor on top of a flat Plexiglas compaction platform and compact until no noticeable movement of particles is observed (Figure 4).
3. Record the weight of aggregate used.
4. Place upper ring (76 mm high) on top of lower box. Align ring with sides and back edge of box (opposite of block); fill with single lift of ballast and compact (Figure 4).

Granite ballast samples fouled by coal dust were prepared in a manner similar to the clean sample procedure by spreading coal dust on the ballast surface and spraying water, if needed. The individual steps are as follows:

1. Obtain clean aggregates of the same weight as previously recorded.
2. Compact ballast sample into the lower box in two lifts.
3. Obtain prescribed weight of coal dust and water (Figure 5).
4. Spread coal dust over compacted ballast evenly in two lifts (half of material each lift). Shake down material using vibratory compactor after each lift. If test is conducted with wet fouling material [for example, at the optimum moisture content (OMC)], pour proportional amount of water over ballast after shakedown of each lift (Figure 5). Note that this preparation procedure realistically simulated the actual coal dust accumulation in the ballast layer as a result of vibration caused by train loading.
5. Follow Step 4 from the clean sample preparation procedure.

Granite samples fouled with clay were prepared following a different procedure to simulate subgrade intrusion. The individual steps are as follows:

1. Obtain clean aggregates of the same weight as previously recorded.
2. Obtain described weight of clay and water.
3. Place the clay in the bottom of the lower box. If test is conducted with wet clay, thoroughly mix clay with water before placing in the lower box.
4. Place aggregates over the clay and compact in two lifts.
5. Follow Step 4 from the clean sample preparation procedure.

For preparing granite samples fouled with mineral filler, the clean ballast and the mineral filler with designated weights were premixed before placement in the lower box. The goal was to simulate the actual ballast breakdown conditions in the field. Aggregate breakdown could take place with chipped pieces and mineral filler uniformly filling the voids in the ballast layer.

TABLE 1 Engineering Properties of the Selected Fouling Materials

	Specific Gravity	LL (%)	Plastic Limit (%)	OMC[a,b] (%)	Maximum Dry Density[b] (kg/m^3)	Passing 0.075-mm or No. 200 Sieve (%)
Coal dust	1.28	91	50	35	874	24
Refractory clay	2.60	37	19	16	1,806	64
Mineral filler	2.62	NP[c]	NP[c]	11	2,193	8

[a]OMC = optimum moisture content.
[b]Obtained from standard Proctor ASTM D698 test procedure.
[c]NP = nonplastic.

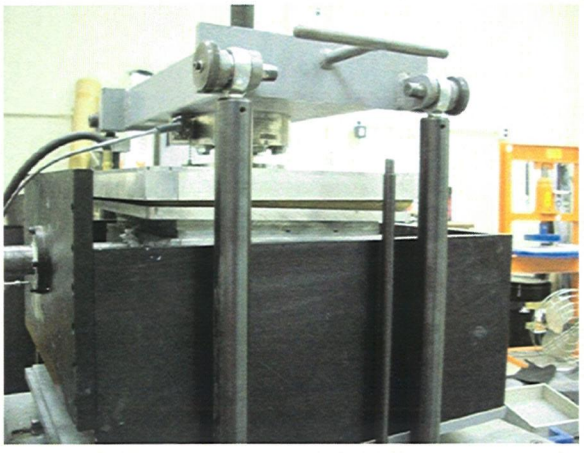


FIGURE 3 Direct shear strength test equipment at the University of Illinois.

Before testing, the box and ring assembly were placed in the shearing apparatus. The lower box was clamped in place, and the load-bearing plate was placed on the ballast but inside the upper ring. The air bladder was placed on the load-bearing plate, the air supply was opened, and normal pressure was set using an in-line pressure regulator (Figure 6). The load cell recording the applied shear force was adjusted directly against the upper ring. The Labview data logger software was initiated to record normal and shear forces during testing. The loading speed was set to an input shear rate of 12.2 mm/min (0.48 in./min), which is approximately 4% strain per minute, and the tests were run until the shear force output peaked or 15% strain occurred.

Sample Volumetrics

After the sample preparation, volumetric properties of the shear box sample were calculated on the basis of the granite aggregate properties. It is worth noting that, for all tests, the same amount of

FIGURE 4 Stages of ballast compaction and upper ring loading.

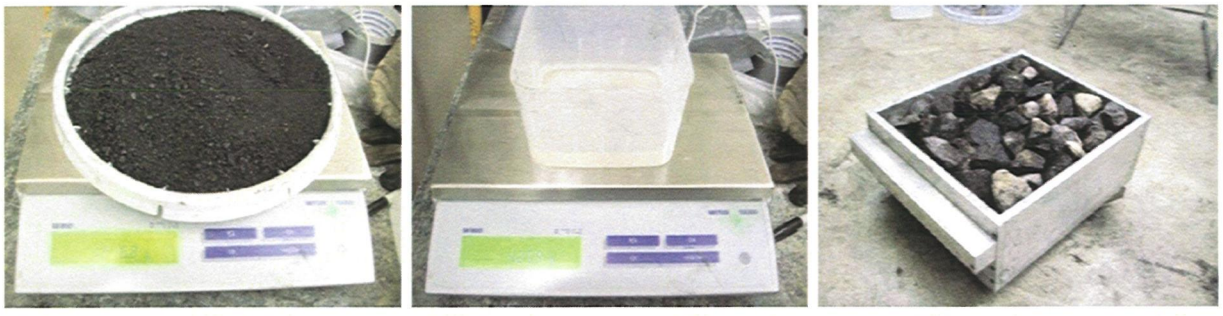


FIGURE 5 Coal dust being mixed as the fouling material.

material was used to prepare approximately the same number of aggregate contacts and a similar aggregate skeleton. That is, the voids available for fouling material to fill in were kept the same in all cases. This void space was found for the clean granite sample to be 43% of the total volume, which corresponds to a void ratio of 0.75 or 75% of the aggregate volume. ASTM C29 test procedure was used for finding porosity or air voids with the known values of the specific gravity and box volume and the weight of ballast compacted.

For the aggregate fouled with coal dust, 25% coal dust by weight of aggregate was found to completely fill in the voids of the clean granite, thus referred to here as "fully coal dust fouled" condition after sample preparation. Similarly, 32% clay by weight of aggregate and 40% mineral filler by weight of aggregate were observed to completely fill in the same void space of the clean granite for the fully fouled conditions for clay and mineral filler, respectively.

Direct Shear Test Results

The ballast samples were sheared horizontally in the shear box under target normal pressures of 172, 241, and 310 kPa (25, 35, and 45 psi), typical ballast layer confining pressures, so that the relationships between normal stress and shear stress could be established. The maximum shear stress at failure under each applied normal pressure

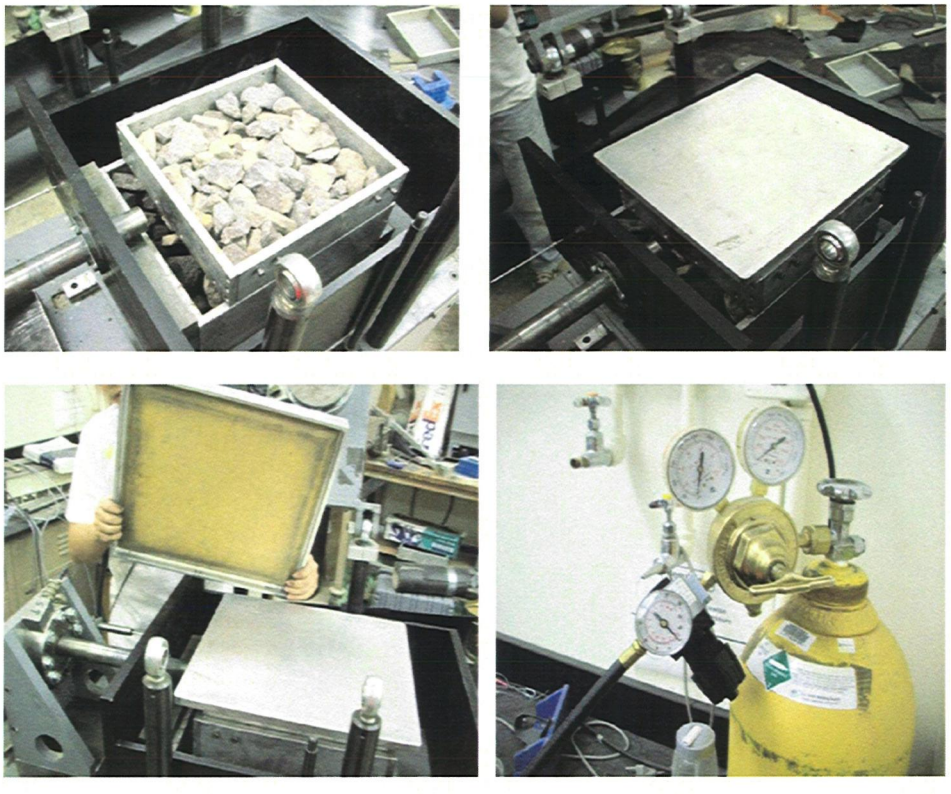


FIGURE 6 Setup of the direct shear box apparatus.

was recorded from each test. This maximum shear stress typically occurred when approximately 10% shear strain was reached during testing. The shear strength expression $\tau_{max} = C + \sigma_n * \tan\Phi$ (where C is the cohesion intercept, σ_n is the applied normal stress, and Φ is the internal friction angle) was then developed for each ballast sample tested at a corresponding fouling fines content and moisture state.

Figure 7 shows the maximum shear stresses predicted under the applied normal stresses during shear box testing for coal dust fouling in comparison with the clean granite test results. As the applied normal stresses increased, the maximum shear stresses at failure or simply shear strength τ_{max} also increased, primarily influenced by the ballast fouling percentage and the moisture condition of the coal dust (i.e., dry or wet at OMC = 35%). As expected, the highest shear strength values were obtained from the clean ballast at all applied normal stress levels. When ballast samples were fouled, the shear strengths typically decreased. For all the samples tested, fouling with wet coal dust resulted in lower shear strengths when compared with those obtained from fouling with dry coal dust. The lowest shear strength values were recorded for the fouling level of 25% by weight (fully fouled) of ballast when wet coal dust was at 35% moisture content.

Figure 8 shows the maximum shear stresses predicted under the applied normal stresses during shear box testing for clay fouling in comparison with the clean granite test results. Limited data were obtained because of the difficulties encountered during sample preparation, especially for wet clay fouling. According to the test results, the clean ballast sample still gave the highest strength. With clay being the fouling agent, the trend of decreasing strength with increasing fouling percentage could not be observed as clearly as in the case of coal dust fouling. In the clay fouling cases, the cohesion intercept (C) in the strength equation increased and the friction angle (Φ) typically decreased with the increasing fouling percentage, which made shear strength of samples less sensitive to varying normal stresses and confining pressures, as expected. This effect was even more significant in the cases fouled with wet clay, because wet clay served as a lubricant, with much lower friction angles (Φ) overall compared with the clean granite sample. It still makes sense, however, since the cohesion increased because the clay paste in the voids supplied some bonding strength, whereas the friction angle decreased because of the lubricating effect of clay paste within the aggregate-to-aggregate contact.

Figure 9 shows the maximum shear stresses predicted under the applied normal stresses during shear box testing for mineral filler fouling in comparison with the clean granite test results. In the dry case, results were similar to results from clay fouling. Once again, the clean ballast sample gave the highest shear strength. In the dry fouling cases, the cohesion intercept (C) in the strength equation increased and the friction angle (Φ) typically decreased with the increasing fouling percentage, similar to the general trend observed for samples fouled with clay. However, for the wet mineral filler tests at only 11% OMC, samples at all fouling levels behaved very closely to dry conditions, with the data points almost falling in the same line, thus indicating that mineral filler as a fouling agent is not as sensitive to moisture as the cohesive clay.

Figure 10 compares, under wet conditions, the maximum shear stresses obtained from the clean granite with those of the coal dust, clay, and mineral filler fouled samples at 5%, 15%, and 25% by weight of ballast. Note that for the 25% clay fouled samples, clay moisture content was at the LL of 37% instead of OMC, which is very close to 35% OMC of the samples fouled by coal dust. Yet, the wet coal dust sample fouled at 25% gave the worst-case scenario with the lowest shear stress values among all the samples tested. Then came the wet mineral filler fouled at 25% by weight of ballast and the wet clay fouled at 15% by weight of ballast, as indicated with the dashed lines in Figure 10. This implies that railroad ballast layers fouled with coal dust are at much higher risk of causing track instability and failures, especially after heavy precipitation, when compared with ballasts fouled because of mineral filler accumulation from aggregate breakdown or even cohesive subgrade soil intrusion.

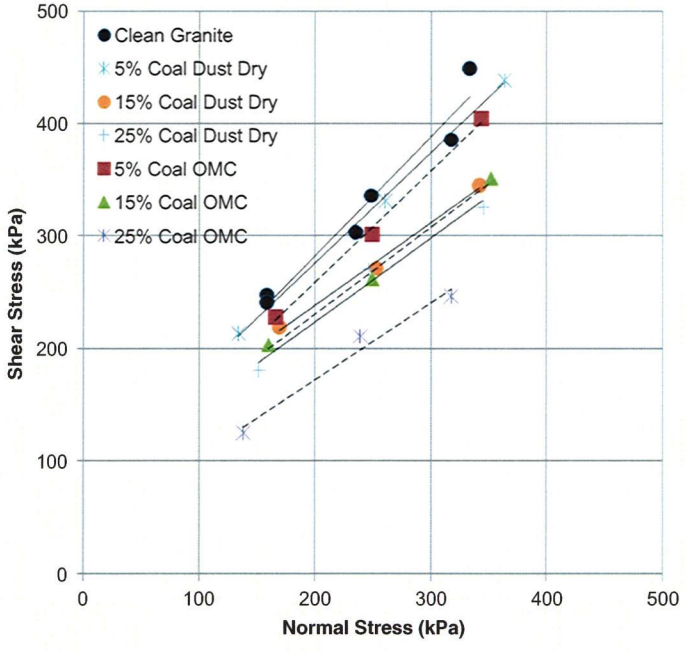


FIGURE 7 Direct shear box test results of ballast samples fouled with coal dust.

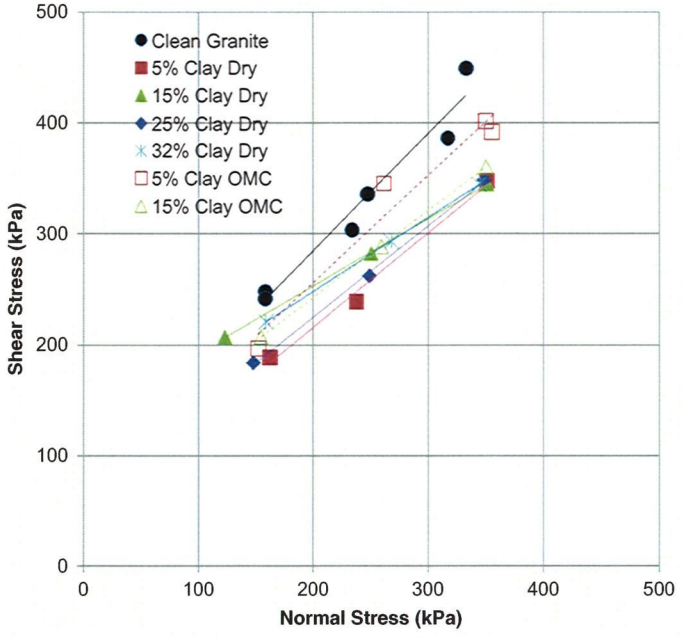


FIGURE 8 Direct shear box test results of ballast samples fouled with clay.

Because the coal dust fouling was found to be the most detrimental case, a statistical analysis was performed for the significance of the different coal dust levels affecting the critical stages of ballast fouling. As described early in this paper, it is important to determine at what fouling level a significant drop in strength would be realized. That is, there is a need to determine the reasonable dividing line between Phase I and II. For this purpose, an *F*-test statistical approach was used to evaluate the differences between the strength lines graphed in Figure 7. With a value of significance (*p*-value) of 0.0014 (much less than 0.05), 15% coal dust fouling was found to significantly decrease the strength of ballast. Because all other strength lines in Figure 7 are below the 15% dry coal dust fouling line, 15% coal dust by weight is considered to be the critical stage of coal dust fouling in terms of ballast shear strength.

Table 2 lists cohesion intercepts (C) and friction angles (Φ) obtained from the ballast testing program. High correlation coefficients, R^2

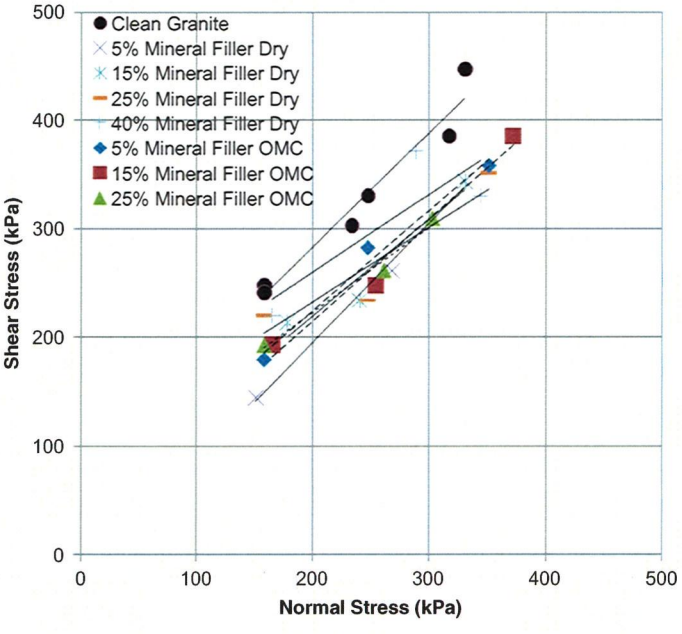


FIGURE 9 Direct shear box test results of ballast samples fouled with mineral filler.

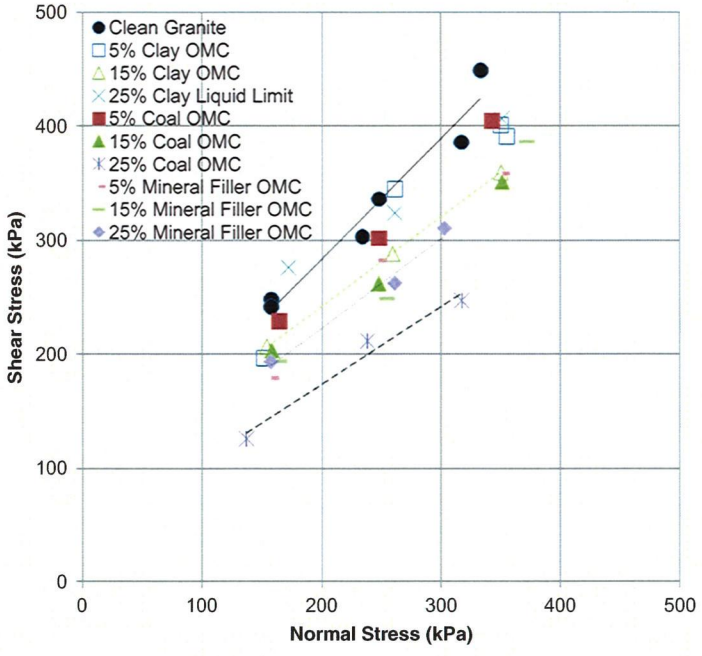


FIGURE 10 Comparisons of three fouling scenarios under wet conditions.

values, were typically obtained for the established shear strength equations except for two mineral filler samples. The clean granite typically had the highest friction angle (Φ) of 46.6°, except for the friction angle of 47.7° obtained for the low 5% dry mineral filler sample. For the case of 25% wet coal dust fouling, the friction angle computed is as low as 34.5°. This value is very close to the friction angle of 33.5°, obtained from a parallel research study (*11*), for the pure coal dust direct shear samples tested at OMC. Similarly, a low cohesion intercept of 35 kPa (5.1 psi) is close to the very low unconfined compressive strength of 24 kPa (3.5 psi) also obtained for the coal dust shear strength properties (*11*). This implies that the shearing action for the 25% coal dust fouled sample was mainly resisted in the direct shear apparatus by the wet coal dust governing the behavior. Again, one should note that 35% OMC condition does not

TABLE 2 Shear Box Direct Shear Strength Test Results

Fouling Agent	Percentage by Weight of Clean Ballast	Moisture Condition (see Table 1)	$\tau_{max} = C + \sigma_n * \tan \Phi$		Correlation Coefficient, R^2	Shear Strength τ_{max} (kPa)	
			Cohesion C (kPa)	Friction Angle (Φ)		200-kPa Normal Stress	300-kPa Normal Stress
Clean	0	Dry	72	46.6	.96	283	389
Coal dust	5	Dry	80	44.4	.99	276	374
	15	Dry	93	36.2	.99	239	312
	25	Dry	75	36.6	.98	224	298
	5	OMC	61	44.7	.99	259	359
	15	OMC	77	37.7	.99	231	309
	25	OMC	35	34.5	.97	173	242
Clay	5	Dry	44	40.5	.99	215	300
	15	Dry	131	31.2	.99	252	313
	25	Dry	59	39.5	.99	224	307
	32	Dry	114	33.7	.97	247	314
	5	OMC	61	44.1	.95	255	352
	15	OMC	85	38.0	.99	241	319
	25	LL	144	36.1	.98	290	363
Mineral filler	5	Dry	0	47.7	.99	195	305
	15	Dry	41	41.6	.93	219	308
	25	Dry	94	34.6	.85	232	301
	40	Dry	116	35.7	.71	260	332
	5	OMC	40	42.6	.98	224	316
	15	OMC	26	43.4	.97	215	309
	25	OMC	66	38.0	.98	222	300

represent a fully saturated coal dust state. After soaking or 100% saturation, soil suction would be destroyed, thus resulting in even lower strengths and unstable ballast conditions.

Table 2 also lists for direct comparison purposes the shear strength values computed under normal stress levels of 200 and 300 kPa (29.0 and 43.5 psi), typical field railroad ballast stress conditions. Most of the trends already mentioned and their effects can be clearly seen by comparing the computed shear strength values. In the case of ballast fouled by mineral filler, strength values from both dry and wet tests were very close, which may suggest that the 11% optimum moisture had a minor effect on mineral filler fouling. However, the clay fouled ballast samples at OMC give higher strength values than the dry clay fouled samples, which implies that clayey soils at OMC have higher shear strength properties. Since most geomaterials compacted at OMC usually give the best mechanical properties, future research will need to also investigate fouled ballast behavior when moisture content increases beyond optimum conditions.

SUMMARY AND CONCLUSIONS

A large direct shear (shear box) device was used to conduct laboratory tests at the University of Illinois on granite ballast samples obtained from the PRB joint line in Wyoming. The tests measured strength and deformation characteristics of both clean (new) and fouled ballast aggregates with three different fouling agents—coal dust also obtained from the PRB joint line, plastic clay, and nonplastic mineral filler obtained by crushing the same granite aggregate—at various stages of fouling. The grain size distribution of the aggregate conformed to the typical AREMA No. 24 ballast gradation with a maximum size (D_{max}) of 63.5 mm (2.5 in.) and a minimum size (D_{min}) of 25.4 mm (1 in.). Each fouling material was mixed with clean aggregates for achieving fouling levels of 5%, 15%, 25%, and sometimes up to 40% by weight of ballast under dry and wet, mostly OMC, conditions. The coal dust material was spread on the clean aggregate specimen and vibrated on top to achieve its percolation into the voids in an effort to realistically simulate coal dust falling off trains into the ballast layer in the field. The plastic refractory clay and the mineral filler were mixed with granite aggregates by means of different sample preparation techniques, again to simulate realistic field-fouling scenarios of subgrade intrusion and aggregate breakdown, respectively.

From the direct shear tests, the highest shear strength values were obtained from the clean ballast samples at all applied normal stress levels, which were representative of typical stress states experienced in the ballast layer under train loading. When ballast samples were fouled, the shear strengths always decreased. This result was mostly apparent with lower friction angles and cohesion intercepts. Wet fouling generally resulted in lower ballast shear strengths when compared with those obtained from fouling with dry coal dust. Primarily because of increasing cohesive nature (i.e., cohesion intercepts) with increasing fouling percentages, plastic refractory clay fouled samples exhibited slight increases in shear strength under both dry and wet conditions. However, samples fouled with mineral filler at 5%, 15%, and 25% were somewhat insensitive to the low 11% moisture content increase from the dry condition and resulted in similar shear strength values.

Coal dust was by far the worst fouling agent for its impact on track substructure and roadbed, and it caused the most drastic decreases in shear strength, especially at high fouling levels. Through statistical evaluation, 15% dry coal dust fouling by weight of ballast was shown to be sufficiently significant to cause critical fouling and decrease considerably the ballast strength. For the case of 25% wet coal dust fouling by weight of ballast, the lowest shear strength properties, internal friction angle and cohesion, obtained were equivalent to those properties of the coal dust itself at 35% OMC. Note that even more drastic strength reductions can occur when dry coal dust, which has never been saturated or soaked in the field and therefore has a high suction potential, is subjected to inundation and 100% saturation.

It is still difficult to make unique conclusions on ballast fouling because of the differences between laboratory and field conditions and difficulties in sample preparation process. This study is a first step of trying to better understand fouling and its effect on ballast strength and stability. Further studies and different methods of investigation are needed to fully understand ballast fouling.

ACKNOWLEDGMENTS

The authors would like to thank BNSF Railway for providing the financial support needed to carry out this research. The authors would also like to thank Hank Lees of BNSF for sharing his valuable knowledge and experience on the research topic and for providing help and support with obtaining materials. The assistance of Kivanc Avrenli on the coal dust tests is greatly appreciated.

REFERENCES

1. Selig, E. T., B. I. Collingwood, and S. W. Field. Causes of Fouling in Track. *AREA Bulletin 717,* 1988.
2. Collingwood, B. I. An Investigation of the Cause of Railroad Ballast Fouling. *Master of Science Degree Project Report No. AAR88-350P.* University of Massachusetts, 1988.
3. Selig, E. T., V. DelloRusso, and K. J. Laine. *Sources and Causes of Ballast Fouling.* Report No. R-805. Association of American Railroads, Technical Center, Chicago, Ill., 1992.
4. *Ballast Performance in Concrete Tie Track: Prairie Region, Edmonton, Geotechnical Service.* Internal Report. Canadian National Railway, 1987.
5. Selig, E. T., and J. M. Waters. *Track Geotechnology and Substructure Management.* Thomas Telford Publications, London, 1994.
6. Raymond, G. P. Design for Railroad Ballast and Subgrade Support. *Journal of the Geotechnical Engineering Division,* Vol. 104, No. 1, 1978, pp. 45–60.
7. Raymond, G. P. Railroad Ballast Load Ranking Classification. *Journal of the Geotechnical Engineering Division,* Vol. 105, No. 10, 1979, pp. 1133–1153.
8. Raymond, G. P. Track and Support Rehabilitation for a Mine Company Railroad. *Canadian Geotechnical Journal,* Vol. 37, No. 2, 2000, pp. 318–332.
9. Chiang, C. C. Effects of Water and Fines on Ballast Performance in Box Tests. *Master of Science Degree Project Report No. AAR89-366P.* University of Massachusetts, 1989.
10. Han, X., and E. T. Selig. Effects of Fouling on Ballast Settlement. *Proc., 6th International Heavy Haul Railway Conference,* Cape Town, South Africa, 1997.
11. Tutumluer, E., W. Dombrow, and H. Huang. Laboratory Characterization of Coal Dust Fouled Ballast. AREMA 2008 Annual Conference and Exhibition, Salt Lake City, UT, 2008.

The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data. This paper does not constitute a standard, specification, or regulation.

The Railway Maintenance Committee sponsored publication of this paper.

STEPTOE & JOHNSON LLP

ATTORNEYS AT LAW

Samuel M. Sipe Jr.
202.429.6486
ssipe@steptoe.com

ENTERED
Office of Proceedings
NOV 13 2010
Part of
Public Record

1330 Connecticut Avenue, NW
Washington, DC 20036-1795
Tel 202.429.3000
Fax 202.429.3902
steptoe.com

NOV 17 2010
RECEIVED

November 17, 2010

VIA HAND DELIVERY

228267

Ms. Cynthia Brown
Chief, Section of Administration
Office of Proceedings
Surface Transportation Board
395 E Street, SW
Washington, DC 20423-0001

Re: *Petition of Arkansas Electric Cooperative Corporation for a Declaratory Order*, STB Finance Docket 35305

Dear Ms. Brown:

As requested by Board staff, enclosed are two hard copies of the PowerPoint slides that BNSF Railway Company presented during oral argument in the above-referenced case on July 29, 2010, and two copies of the videos clips that were shown in the PowerPoint presentation.

Please address any questions concerning these materials to the undersigned.

Sincerely,

Samuel M. Sipe (KG)
Samuel M. Sipe, Jr.
Counsel for BNSF Railway Company

cc: Parties of Record (with enclosures)

BNSF Railway

STB Docket No. 35305

Petition of Arkansas Electric Cooperative Corporation

NOV 17 2010
RECEIVED

July 29, 2010

BNSF RAILWAY

The Board Should Conclude:

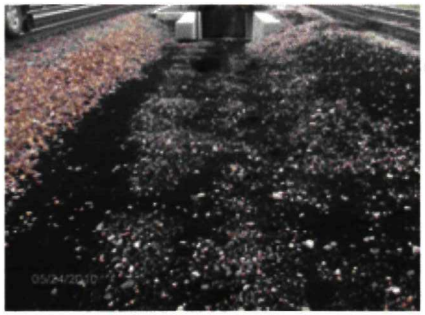
1) It is necessary to keep coal dust from blowing off of loaded trains in transit.

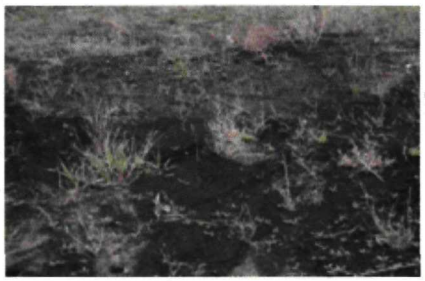
2) BNSF has the authority to issue reasonable operating rules that will curtail coal dust emissions.

3) The specific standards at issue here are reasonable.

COAL DUST EMISSIONS MUST BE SUBSTANTIALLY ELIMINATED

Coal dust fouling is extensive

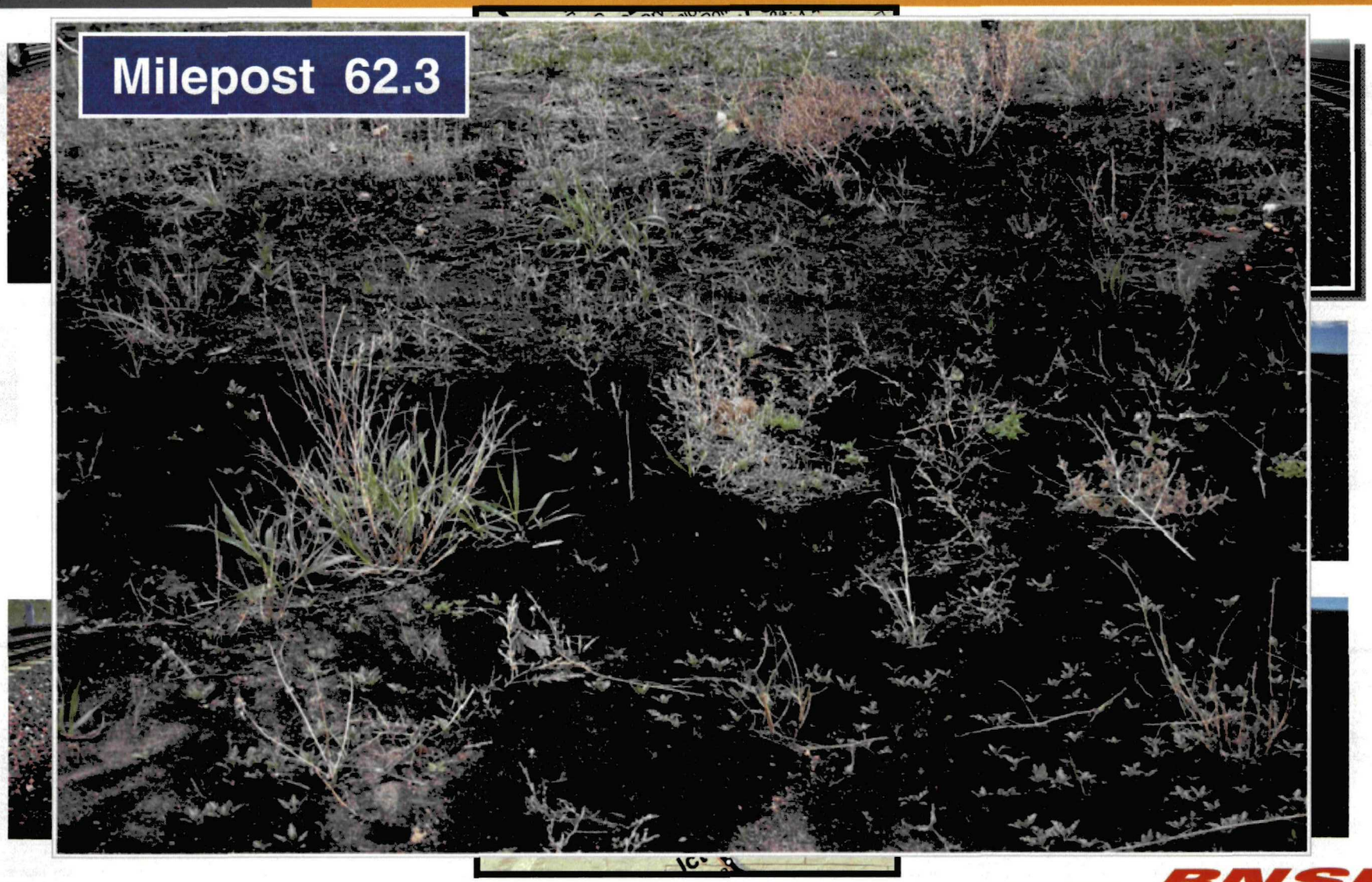




Coal dust fouling is extensive

Coal dust fouling is extensive

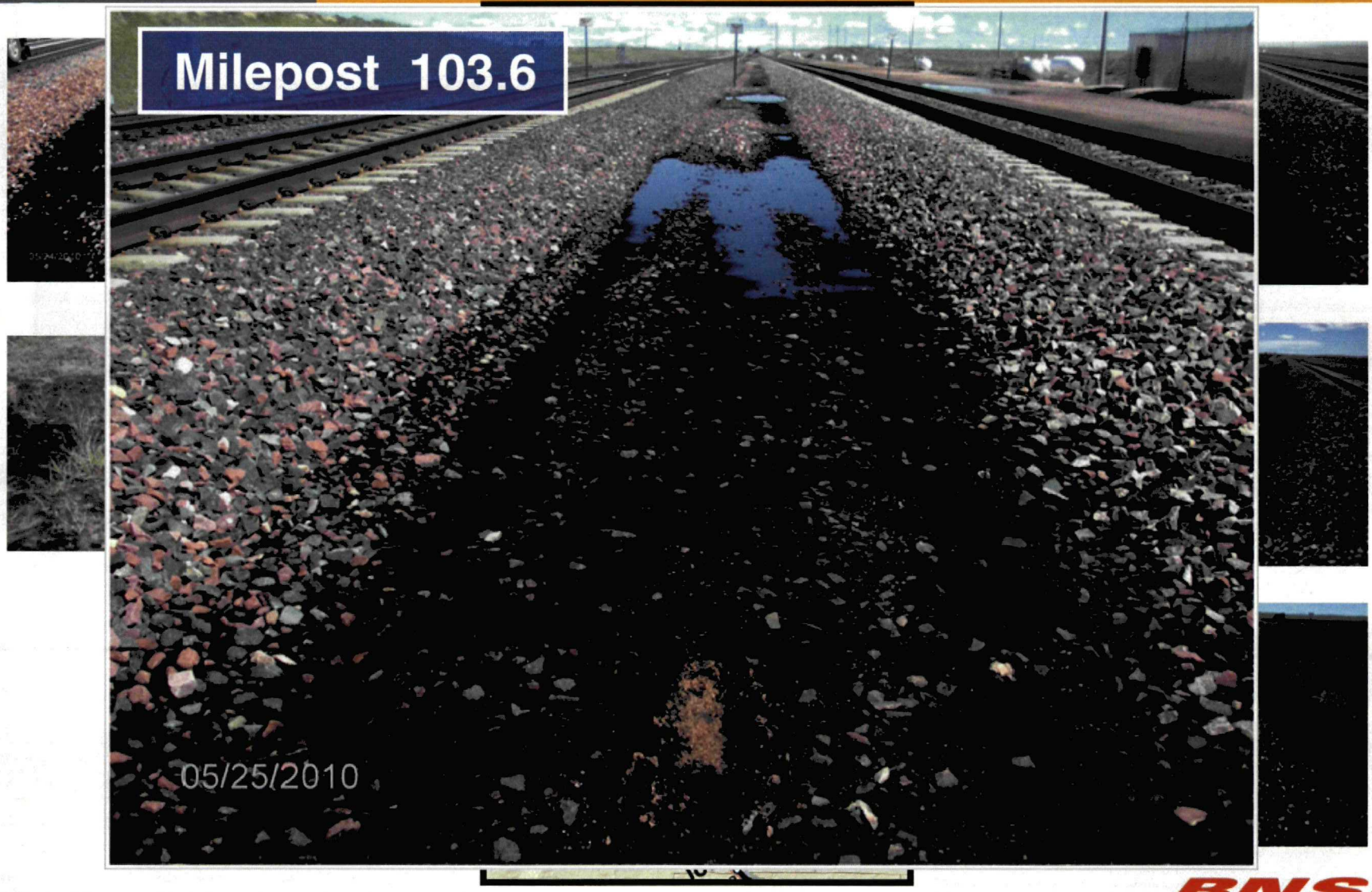
Coal dust fouling is extensive



BNSF

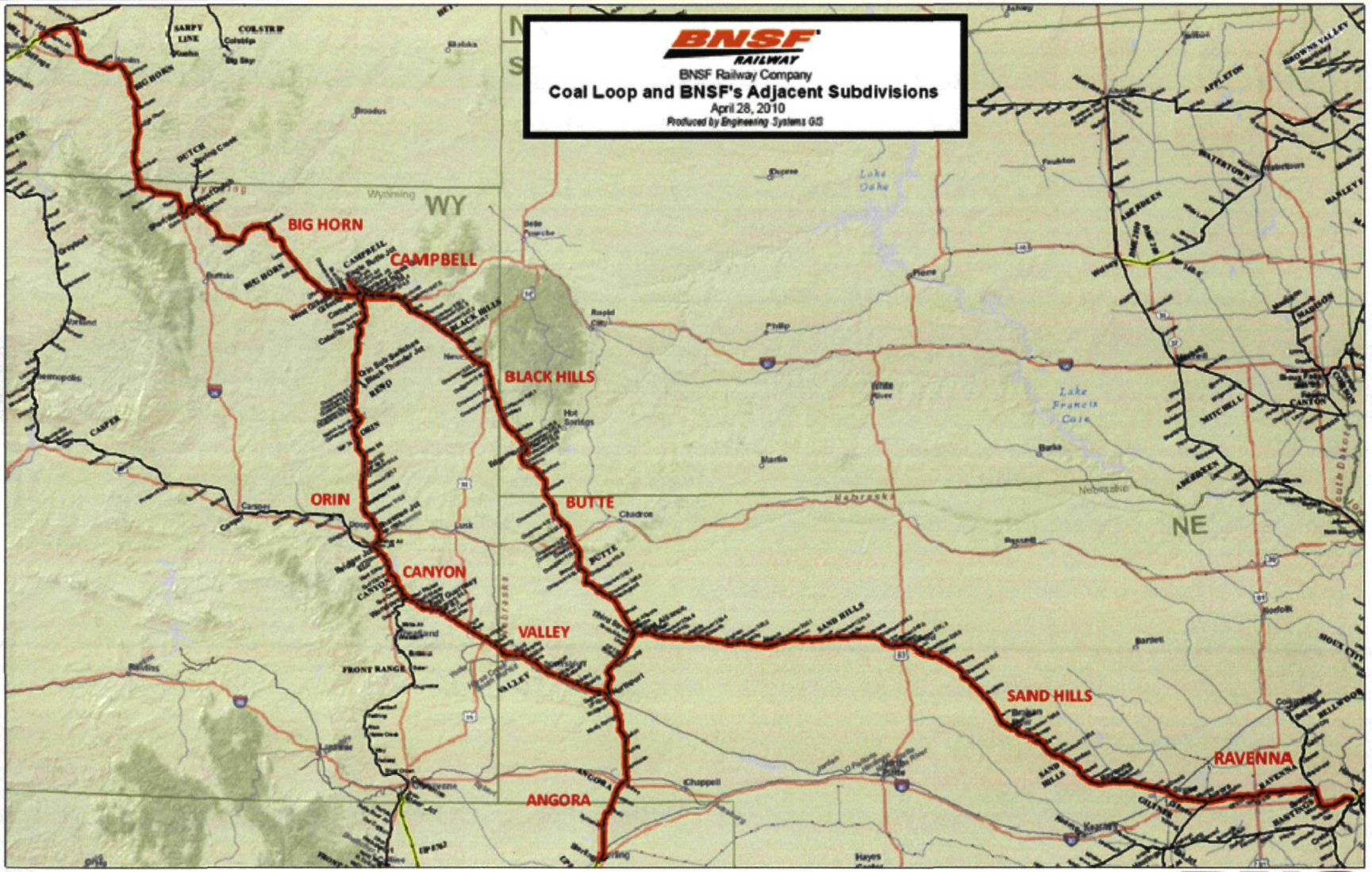
Coal dust fouling is extensive

Coal dust fouling is extensive



Coal dust fouling is extensive

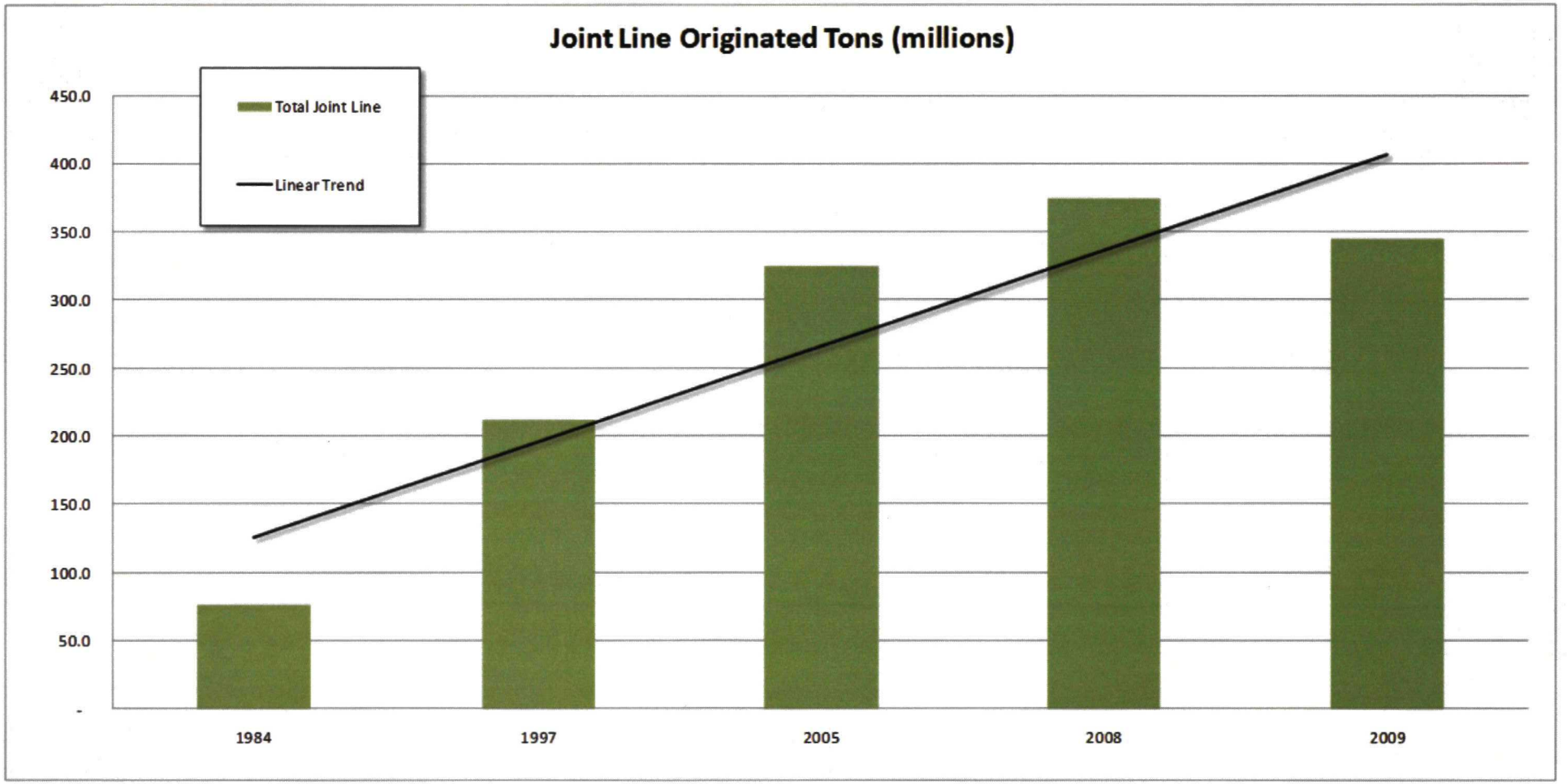
Coal dust is found on all PRB rail lines



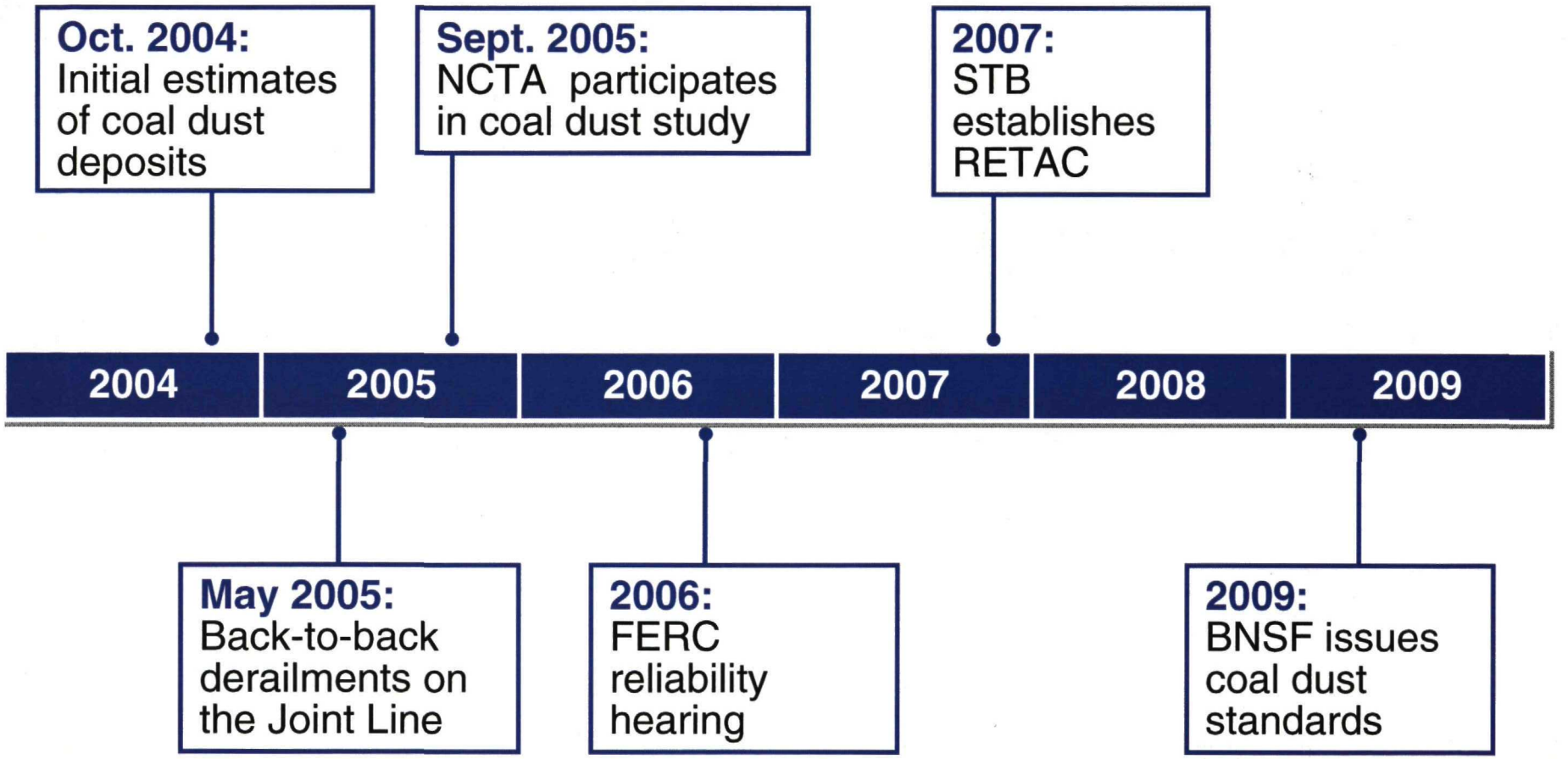
Coal dust is blown off the top of loaded cars in transit

Large amounts of coal are lost from the tops of cars

Increase in Joint Line traffic 1984-2009

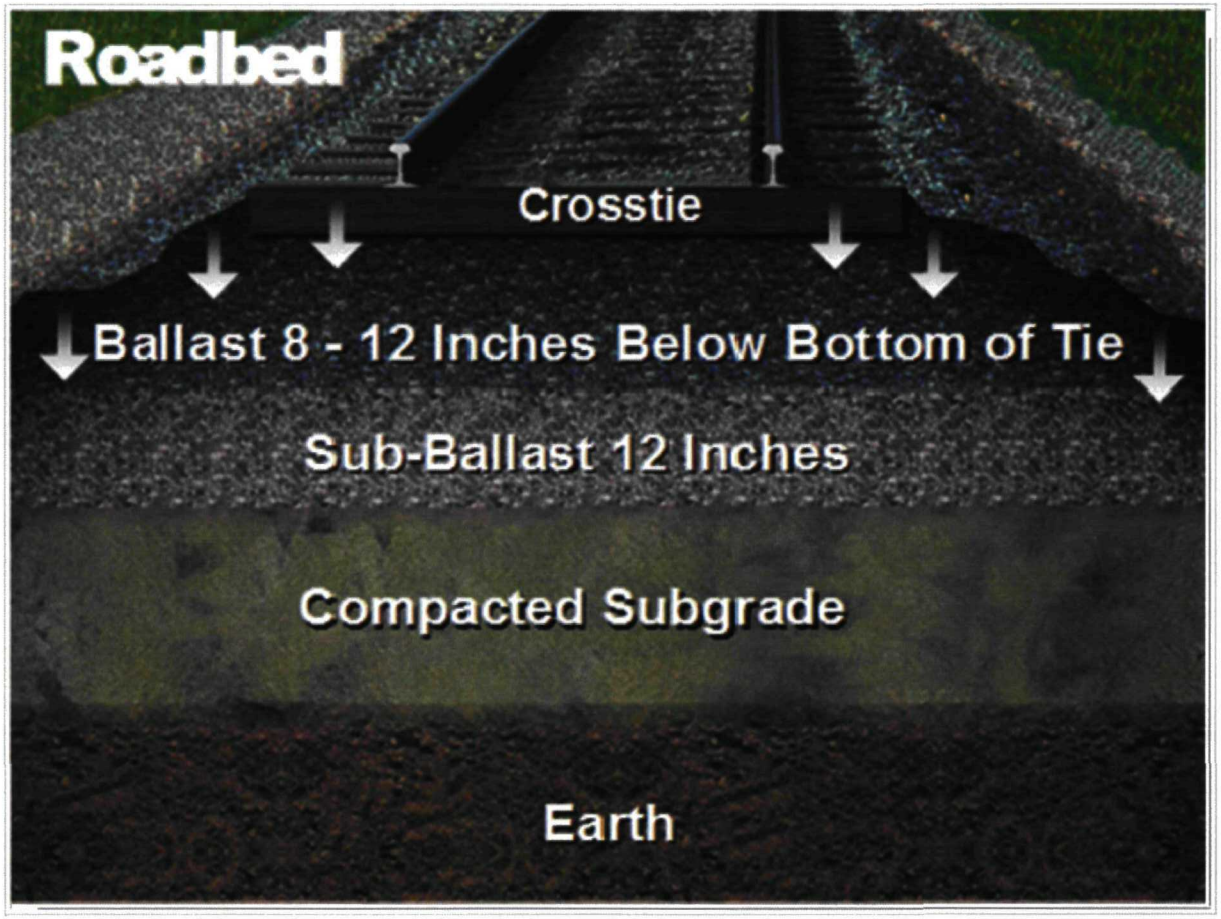


BNSF has been studying the coal dust problem for years



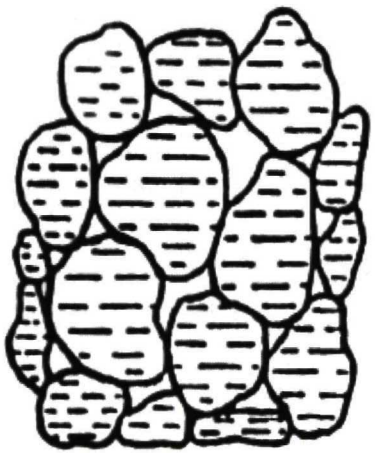
AFTER-THE-FACT MAINTENANCE IS NOT A RESPONSIBLE WAY OF DEALING WITH COAL DUST

Ballast is a crucial aspect of track integrity

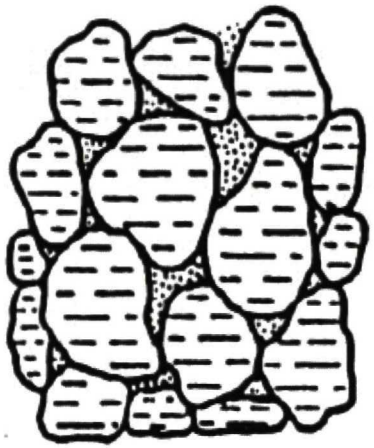


Coal is a pernicious ballast foulant

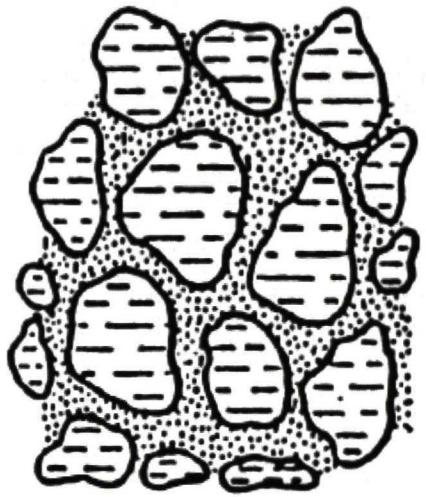
- Critical Phases of Fouling



Clean

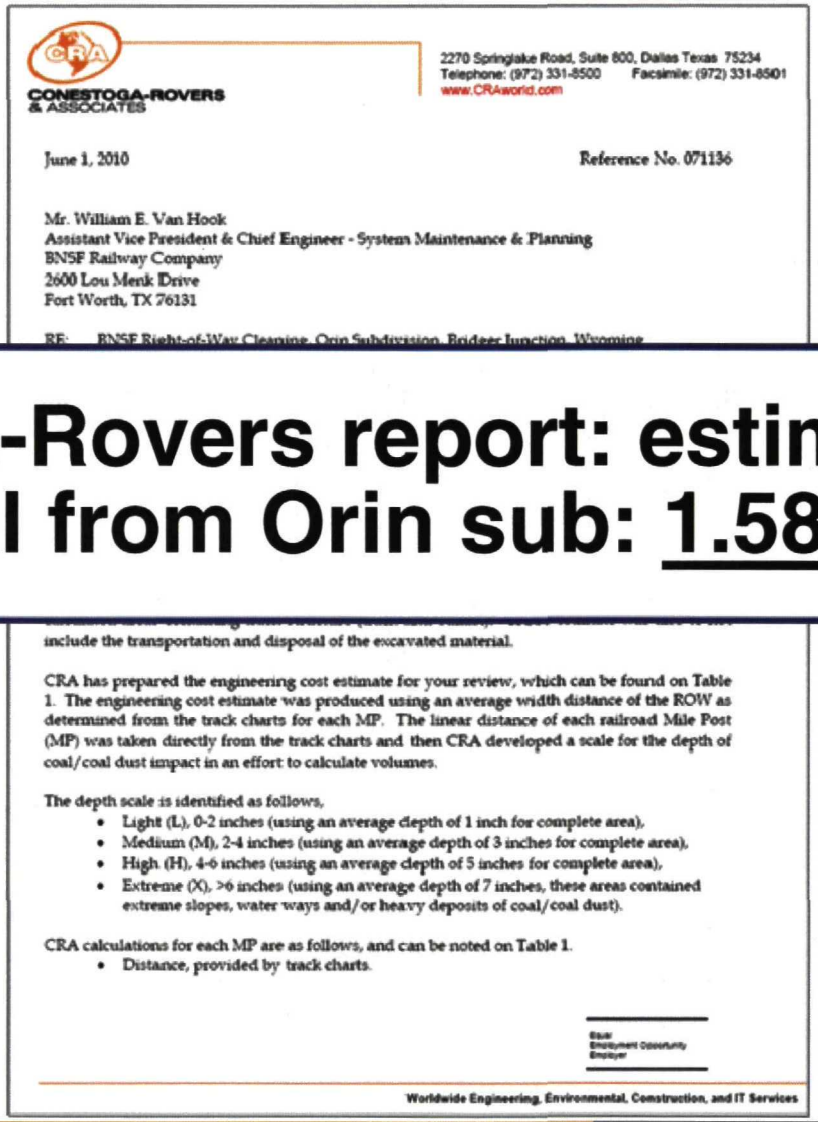


Partially to Fully Fouled



Heavily Fouled

Large volume of coal dust makes it impossible to deal with through maintenance



CONESTOGA-ROVERS & ASSOCIATES

2270 Springlake Road, Suite 800, Dallas Texas 75234
Telephone: (972) 331-8500 Facsimile: (972) 331-8501
www.CRAworld.com

June 1, 2010 Reference No. 071136

Mr. William E. Van Hook
Assistant Vice President & Chief Engineer - System Maintenance & Planning
BNSF Railway Company
2600 Lou Menk Drive
Fort Worth, TX 76131

RE: BNSF Right-of-Way Cleaning, Orin Subdivision, Bridger Junction, Wyoming

include the transportation and disposal of the excavated material.

CRA has prepared the engineering cost estimate for your review, which can be found on Table 1. The engineering cost estimate was produced using an average width distance of the ROW as determined from the track charts for each MP. The linear distance of each railroad Mile Post (MP) was taken directly from the track charts and then CRA developed a scale for the depth of coal/coal dust impact in an effort to calculate volumes.

The depth scale is identified as follows,

- Light (L), 0-2 inches (using an average depth of 1 inch for complete area),
- Medium (M), 2-4 inches (using an average depth of 3 inches for complete area),
- High (H), 4-6 inches (using an average depth of 5 inches for complete area),
- Extreme (X), >6 inches (using an average depth of 7 inches, these areas contained extreme slopes, water ways and/or heavy deposits of coal/coal dust).

CRA calculations for each MP are as follows, and can be noted on Table 1.

- Distance, provided by track charts.

Equal Employment Opportunity Employer

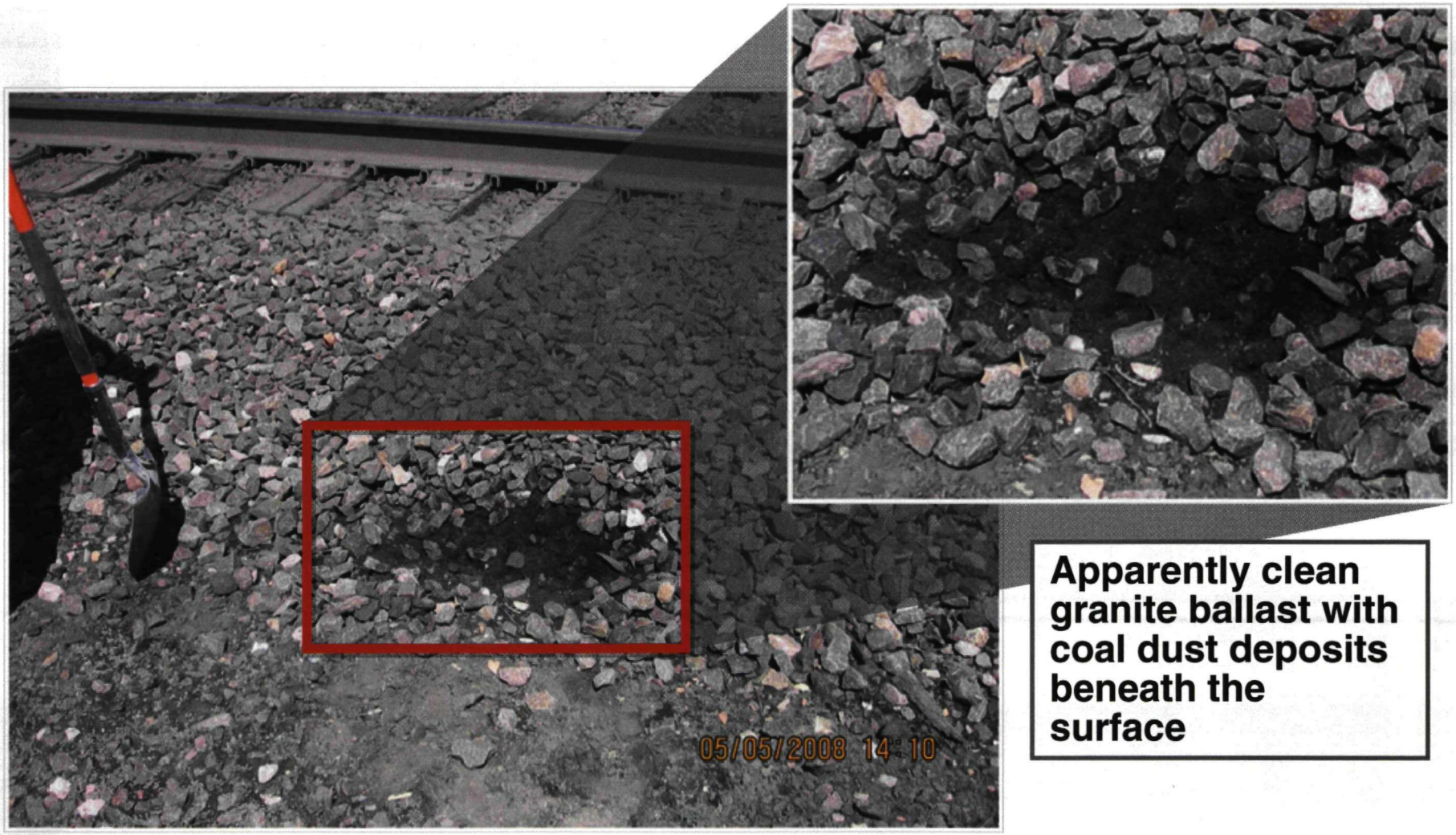
Worldwide Engineering, Environmental, Construction, and IT Services

Conestoga-Rovers report: estimated tons for removal from Orin sub: <u>1.58 Million</u>

Coal dust deposits accumulate rapidly

Coal dust accumulates in the ballast

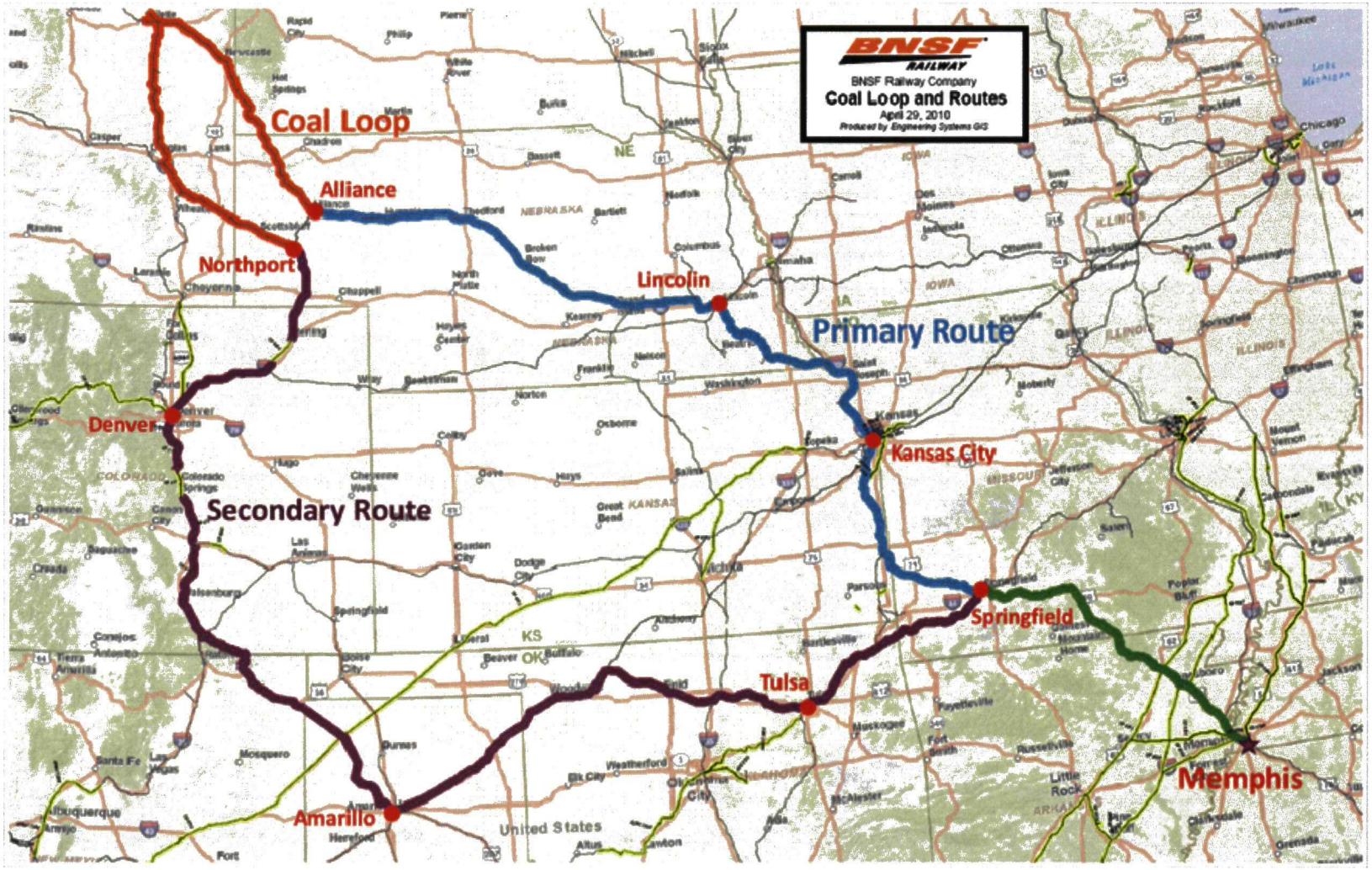
Coal dust in the ballast is often difficult to detect



Apparently clean granite ballast with coal dust deposits beneath the surface

BNSF

Lengthy reroutes are needed because of coal dust maintenance



After-the-fact maintenance does not address coal dust that falls off the right-of-way

The Chadron Record

May 4, 2010

"Coal Dust Runoff Inundates Family's Organic Garden"

BNSF

Coal dust was a contributing factor to two derailments in 2005

BNSF

THE PRECAUTIONARY PRINCIPLE ARGUES FOR PREVENTATIVE MEASURES

BNSF

BNSF's emissions standards can be implemented without large costs

Assumptions:

- **Delivered cost of coal = $30/ton**
- **Surfactant cost = 20 cents/ton**

Cost of surfactant spraying

<1%

Prevention and maintenance are not equally effective

Preventing coal dust emissions

Performing after-the-fact maintenance

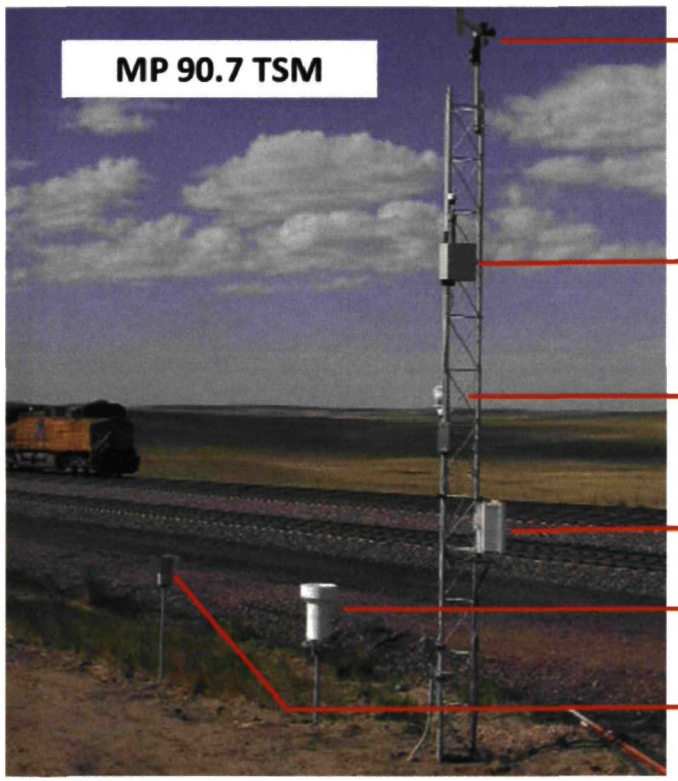
Core Legal Principles and Conclusions

- Railroads have authority to issue operating rules to promote safe and efficient transportation.
- Shippers are responsible for securing their freight.
- BNSF's coal dust operating rule is a reasonable way to ensure that shippers will take steps to limit coal dust emissions.

BNSF'S PERFORMANCE STANDARD REQUIRES MONITORING

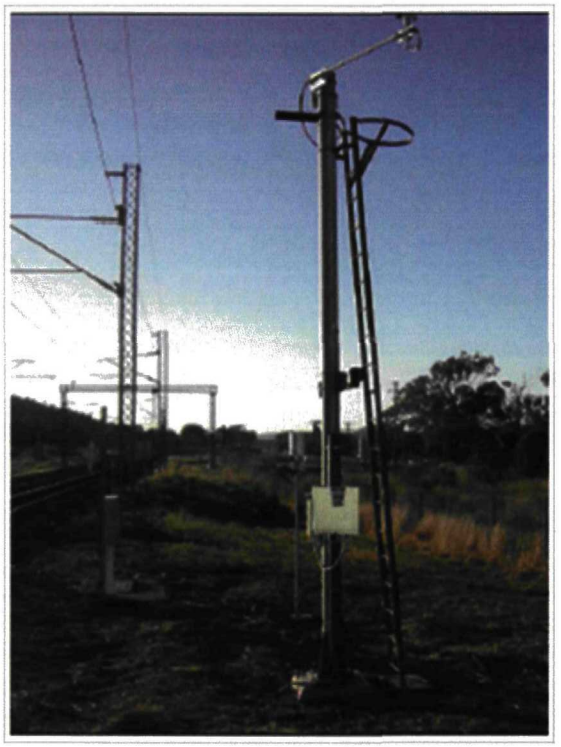
Trackside monitors

Track-side monitor at milepost 90.7



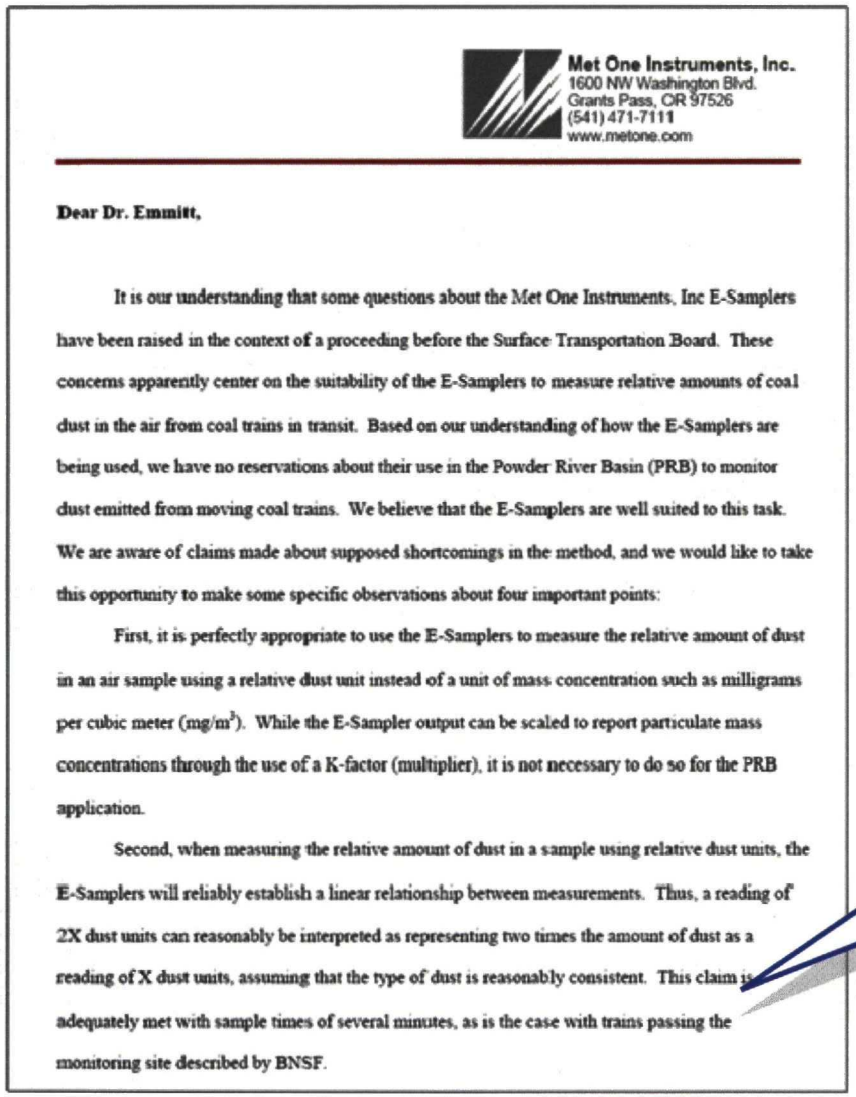
1

Trackside monitor in Queensland, Australia



Monitors detect dust clouds emitted from passing trains

BNSF's use of the dust monitors has been approved by the manufacturer



Met One Instruments, Inc.
1600 NW Washington Blvd.
Grants Pass, OR 97526
(541) 471-7111
www.metone.com

Dear Dr. Emmitt,

It is our understanding that some questions about the Met One Instruments, Inc E-Samplers have been raised in the context of a proceeding before the Surface Transportation Board. These concerns apparently center on the suitability of the E-Samplers to measure relative amounts of coal dust in the air from coal trains in transit. Based on our understanding of how the E-Samplers are being used, we have no reservations about their use in the Powder River Basin (PRB) to monitor dust emitted from moving coal trains. We believe that the E-Samplers are well suited to this task. We are aware of claims made about supposed shortcomings in the method, and we would like to take this opportunity to make some specific observations about four important points:

First, it is perfectly appropriate to use the E-Samplers to measure the relative amount of dust in an air sample using a relative dust unit instead of a unit of mass concentration such as milligrams per cubic meter (mg/m^3). While the E-Sampler output can be scaled to report particulate mass concentrations through the use of a K-factor (multiplier), it is not necessary to do so for the PRB application.

Second, when measuring the relative amount of dust in a sample using relative dust units, the E-Samplers will reliably establish a linear relationship between measurements. Thus, a reading of 2X dust units can reasonably be interpreted as representing two times the amount of dust as a reading of X dust units, assuming that the type of dust is reasonably consistent. This claim is adequately met with sample times of several minutes, as is the case with trains passing the monitoring site described by BNSF.

"Based on our understanding of how the E-Samplers are being used, we have no reservations about their use in the Powder River Basin (PRB) to monitor dust emitted from moving coal trains. We believe that the E-Samplers are well suited to this task."

– Dennis Hart, Product Engineer, MetOne Instruments

BNSF

Load Profiling

BEFORE

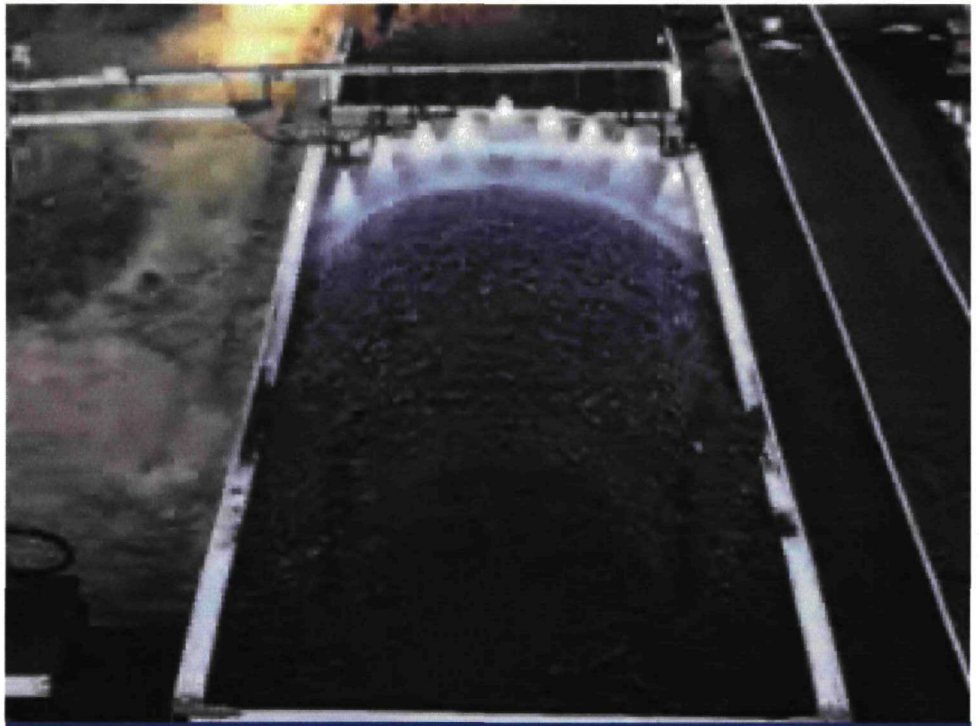
Note peaked loads, sharp lines, steep angle of repose and other irregular surfaces which are susceptible to erosion

AFTER

Note rounded contour, no sharp angles, flatter angle of repose and few irregular surfaces which are susceptible to erosion

BNSF

Surfactant Application



Surfactant spraying in the PRB

Surfactant spraying in China

BNSF'S ADOPTION OF A PERFORMANCE-BASED STANDARD

FERC convened a hearing regarding impact of coal delivery on reliability

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Discussions with Utility and Railroad Representatives
On Market and Reliability Matters

Docket No. AD06-8-000

NOTICE ON FILING COMMENTS

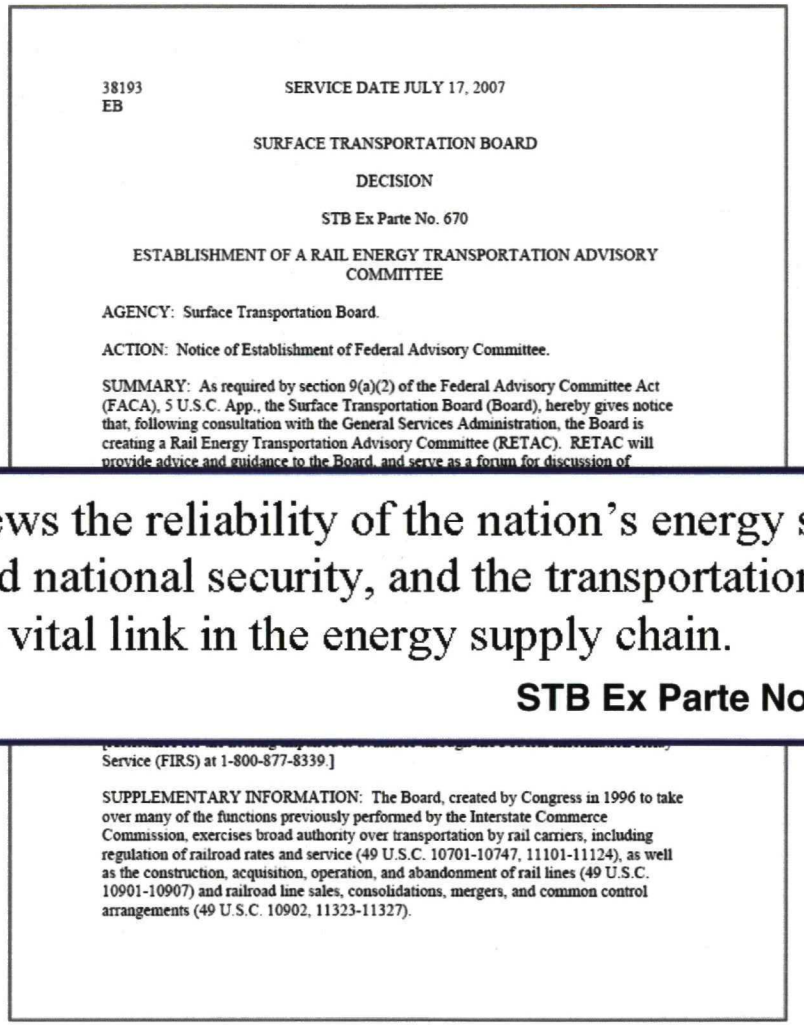
(June 30, 2006)

On June 15, 2006, the Federal Energy Regulatory Commission (FERC) met with utility and railroad representatives to discuss railroad coal-delivery matters and their impact on markets and electric reliability.

Additional comments in this docket will be accepted until **July 17, 2006**.

Magalie R. Salas
Secretary

The Board places a strong emphasis on maintaining a reliable PRB coal supply



38193 SERVICE DATE JULY 17, 2007
EB

SURFACE TRANSPORTATION BOARD

DECISION

STB Ex Parte No. 670

ESTABLISHMENT OF A RAIL ENERGY TRANSPORTATION ADVISORY COMMITTEE

AGENCY: Surface Transportation Board.

ACTION: Notice of Establishment of Federal Advisory Committee.

SUMMARY: As required by section 9(a)(2) of the Federal Advisory Committee Act (FACA), 5 U.S.C. App., the Surface Transportation Board (Board), hereby gives notice that, following consultation with the General Services Administration, the Board is creating a Rail Energy Transportation Advisory Committee (RETAC). RETAC will provide advice and guidance to the Board, and serve as a forum for discussion of

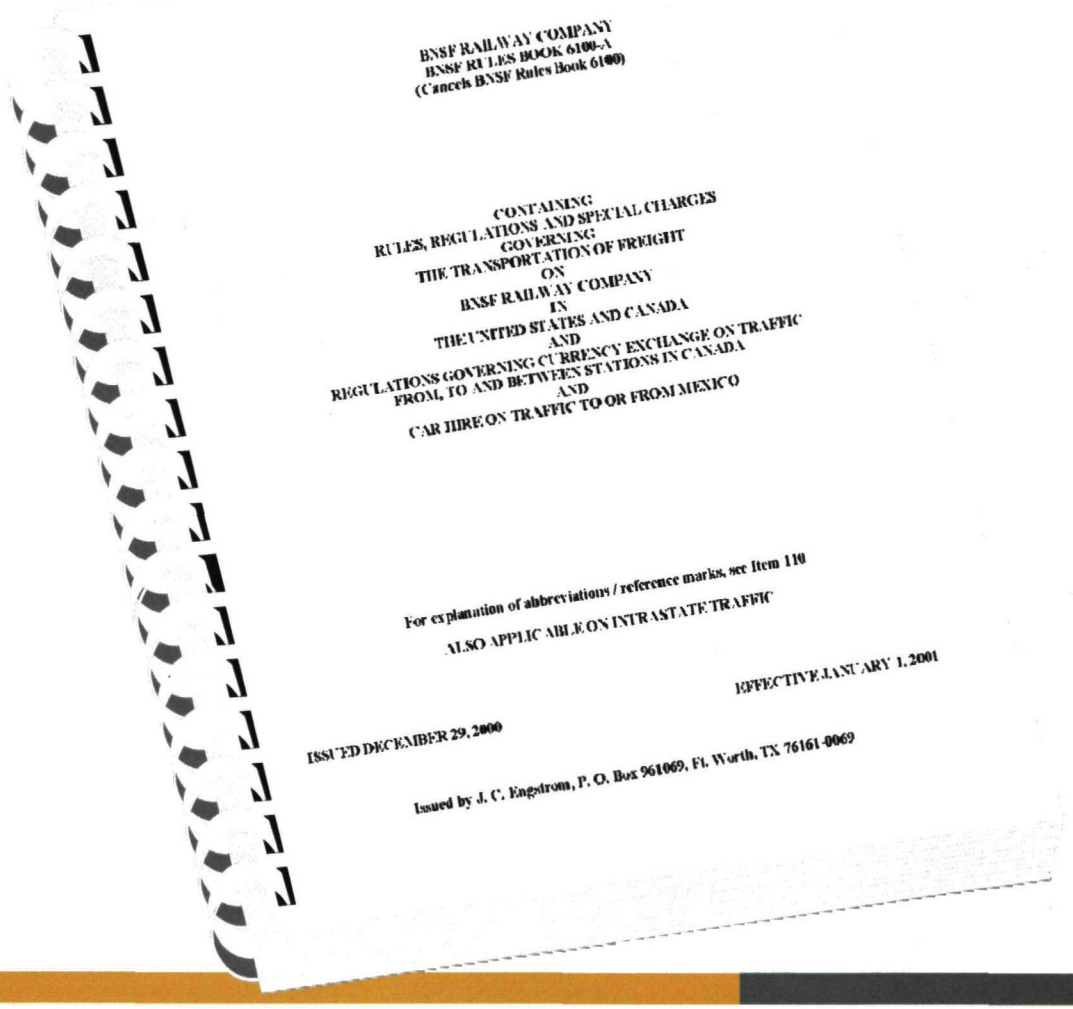
Service (FIRS) at 1-800-877-8339.]

SUPPLEMENTARY INFORMATION: The Board, created by Congress in 1996 to take over many of the functions previously performed by the Interstate Commerce Commission, exercises broad authority over transportation by rail carriers, including regulation of railroad rates and service (49 U.S.C. 10701-10747, 11101-11124), as well as the construction, acquisition, operation, and abandonment of rail lines (49 U.S.C. 10901-10907) and railroad line sales, consolidations, mergers, and common control arrangements (49 U.S.C. 10902, 11323-11327).

The Board views the reliability of the nation's energy supply as crucial to this nation's economic and national security, and the transportation by rail of coal and other energy resources as a vital link in the energy supply chain.

STB Ex Parte No. 670 (Served July 17, 2007)

There must be a rule that is generally applicable



BNSF RAILWAY COMPANY
BNSF RULES BOOK 6100-A
(Cancels BNSF Rules Book 6100)

CONTAINING
RULES, REGULATIONS AND SPECIAL CHARGES
GOVERNING
THE TRANSPORTATION OF FREIGHT
ON
BNSF RAILWAY COMPANY
IN
THE UNITED STATES AND CANADA
AND
REGULATIONS GOVERNING CURRENCY EXCHANGE ON TRAFFIC
FROM, TO AND BETWEEN STATIONS IN CANADA
AND
CAR HIRE ON TRAFFIC TO OR FROM MEXICO

For explanation of abbreviations / reference marks, see Item 110

ALSO APPLICABLE ON INTRASTATE TRAFFIC

EFFECTIVE JANUARY 1, 2001

ISSUED DECEMBER 29, 2000

Issued by J. C. Engstrom, P. O. Box 961069, Ft. Worth, TX 76161-0069

SHIPPERS MUST BEGIN TO ADOPT CURTAILMENT MEASURES

The Joint Line

Joint Line Operating Rule

"As soon as practicable, trains handling cars loaded with coal moving from individual mine origins on the Joint Line shall not emit more than an Integrated Dust Value (IDV.2) of 300 units in order to enhance retention of coal in rail cars."

NEXT STEPS

BMSF

DIESEL PARTICULATE MATTER EXPOSURE ASSESSMENT STUDY FOR THE PORTS OF LOS ANGELES AND LONG BEACH

FINAL REPORT

April 2006

California Environmental Protection Agency

Air Resources Board

State of California
AIR RESOURCES BOARD

DIESEL PARTICULATE MATTER EXPOSURE ASSESSMENT STUDY FOR THE PORTS OF LOS ANGELES AND LONG BEACH

Primary Author

Pingkuan Di, Ph.D., P.E.

Contributing Staff

Anthony Servin, P.E.
Kirk Rosenkranz
Beth Schwehr
Hein Tran

Reviewed and Approved by

Robert D. Fletcher, Chief
Stationary Source Division
Daniel E. Donohoue, Chief
Emissions Assessment Branch
Peggy Taricco, Chief
Emission Inventory Branch (PTSD)
Erik White, Manager
Technical Analysis Section

Acknowledgements

Air Resources Board staff extends its appreciation to representatives of Starcrest Consulting Group, LLC and the Ports of Los Angeles and Long Beach for providing assistance with emissions inventory data and spatial allocation of emissions. OEHHA provided the commentary on unquantified risk (Appendix D).

The staff of the Air Resources Board has prepared this report. Publication does not signify that the contents reflect the views and policies of the Air Resources Board.

DIESEL PARTICULATE MATTER EXPOSURE ASSESSMENT STUDY FOR THE PORTS OF LOS ANGELES AND LONG BEACH

TABLE OF CONTENTS

Section ..... **Page**

Part I: Summary **1**

Part II. Technical Support Document **15**

I. INTRODUCTION **15**
A. OVERVIEW 15
B. PURPOSE 16
C. DESCRIPTION OF THE PORTS 17

II. EMISSION INVENTORY DEVELOPMENT **19**
A. PORT OF LOS ANGELES 19
B. PORT OF LONG BEACH 22
C. IN-PORT AND OUT-OF-PORT EMISSIONS ALLOCATION 23
D. EMISSION INVENTORY SUMMARY 24

III. AIR DISPERSION MODELING **26**
A. AIR DISPERSION MODEL SELECTION 26
B. MODEL DOMAIN AND RECEPTOR NETWORK 26
C. MODEL PARAMETERS 29
D. SPATIAL AND TEMPORAL ALLOCATION OF EMISSIONS 29
E. METEOROLOGICAL DATA 30

IV. EXPOSURE ASSESSMENT **34**
A. OEHHA GUIDELINES 34
B. EXPOSURE ASSESSMENT 35
C. RISK CHARACTERIZATION 35
D. ESTIMATION OF NON-CANCER HEALTH 49
E. UNQUANTIFIABLE ADVERSE HEALTH EFFECTS 51
F. COMPARISONS WITH MONITORING RESULTS 51
G. UNCERTAINTIES AND LIMITATIONS 54

V. SUMMARY OF FINDINGS **57**

REFERENCES **61**

Appendices

Appendix A: Methodologies for Developing Source Category Emission Inventories A-1

Appendix B: Development of Ship Auxiliary Engine Emission Factors B-1

Appendix C: Comparison of Estimated Diesel PM Cancer Risks from Oceangoing Vessel Activity Outside of the Breakwater using Wilmington and King Harbor Meteorological Data Sets C-1

Appendix D: Unquantifiable Health Adverse Effects D-1

List of Tables

TABLE 1 Estimated 2002 Diesel PM Emissions Inventory for POLA and POLB 5
TABLE 2 Summary of Area Impacted by Risk Levels and Activity Categories (Acres)..... 9
TABLE 3 Summary of Population Affected by Risk Levels and Activity Categories... 9
TABLE 4 Comparisons of Predicted Potential Cancer Risks with Measurements 10
TABLE 5 Estimated Diesel PM Emissions per Vessel Call and 2002 Port Calls..... 20
TABLE 6 2002 Estimated Diesel PM Emissions for the POLA and POLB…..... 24
TABLE 7 Emission Source Model Parameters..... 29
TABLE 8 Temporal Distribution of Diesel PM Emissions at POLA and POLB 30
TABLE 9 Summary of Area Impacted by Risk Levels and Activity Categories (Acres)..... 38
TABLE 10 Summary of Population Affected by Risk Levels Activity Categories..... 38
TABLE 11 Comparisons of Modeling Results with Measurements 52

List of Figures

Figure 1 Estimated Diesel PM Cancer Risk from POLA and POLB..... 8
Figure 2 Aerial Photos of POLA and POLB 18
Figure 3 Estimated 2002 Diesel PM Emissions for POLA and POLB 25
Figure 4 In-Port and Out-of-Port Distribution of POLA and POLB Diesel PM Emissions 25
Figure 5a Model Receptor Domain for the Ports of Los Angeles and Long Beach..... 27
Figure 5b Depiction of the Emission Source Locations..... 28
Figure 6 Locations of Air Quality Measurement Sites around the Ports..... 31
Figure 7 Annual Wind Rose at Wilmington 32

Figure 8 Wind Speed and Stability Class Frequency Distribution at the Wilmington Meteorological Site 33
Figure 9 Estimated Diesel PM Cancer Risk from All Diesel-Fueled Engines at POLA and POLB 37
Figure 10 Estimated Diesel PM Cancer Risk from Oceangoing Vessel's Activity at POLA and POLB 40
Figure 11 Estimated Diesel PM Cancer Risk from Ship Auxiliary Engines' Hotelling at POLA and POLB 41
Figure 12 Estimated Diesel PM Cancer Risk from Commercial Harbor Craft Vessel Activity at POLA and POLB 42
Figure 13 Estimated Diesel PM Cancer Risk from Cargo Handling Equipment Activity at POLA and POLB 43
Figure 14 Estimated Diesel PM Cancer Risk from In-Port Heavy-Duty Trucks at POLA and POLB 45
Figure 15 Estimated Diesel PM Cancer Risk from In-Port Locomotive Activity at POLA and POLB 46
Figure 16 Estimated Diesel PM Cancer Risk from All In-Port Diesel Engine Activity at POLA and POLB 47
Figure 17 Estimated Diesel PM Cancer Risk from All Out-of-Port Diesel Activity at POLA and POLB 48
Figure 18 Air Quality monitoring Stations for POLA and ARB Programs 53
Figure 19 Distribution of Diesel PM Emissions by Source Categories for POLA and POLB in 2002 57
Figure 20 Population Affected within the Model Domain by Cancer Risk Levels and Source Categories 59
Figure 21 Residential Areas Impacted within the Model Domain by Cancer Risk Levels and Source Categories 59
Figure B-1 PM Emissions as a Function of Fuel Sulfur from Environmental Canada . B-2
Figure C-1 Locations of Meteorological Monitoring Sites Around the Ports C-2
Figure C-2 Wind Rose for King Harbor Meteorological Site C-3
Figure C-3 Frequency Distributions of Wind Speed and Atmospheric Stability for King Harbor Meteorological Site C-4
Figure C-4 Comparison of Estimated Diesel PM Cancer Risks from OGV's Activity in the Shipping Lanes outside the Breakwater Using Wilmington and King Harbor Meteorological Data C-5

DIESEL PARTICULATE MATTER EXPOSURE ASSESSMENT STUDY FOR THE PORTS OF LOS ANGELES AND LONG BEACH

PART I: SUMMARY

The California Air Resources Board (ARB or Board) conducted an exposure assessment (study) to evaluate the impacts from airborne particulate matter emissions from diesel-fueled engines associated with port activities at the Ports of Los Angeles and Long Beach (ports) located in Southern California. The purpose of the study was to enhance our understanding of the port-related diesel particulate matter (PM) emission impacts by evaluating the relative contributions of the various diesel PM emission sources at the ports to the potential cancer risks to people living in communities near the ports. This information will assist in the efforts underway to reduce diesel PM emissions at the ports by helping to identify the sources that have the greatest impact on potential cancer risks to nearby residents and by providing a tool that will allow evaluation of the impacts of measures planned and under development that are designed to reduce diesel PM emissions.

The study focused on the on-port property emissions from locomotives, on-road heavy-duty trucks, and cargo handling equipment used to move containerized and bulk cargo such as yard trucks, side-picks, rubber tire gantry cranes, and forklifts. The study also evaluated the at-berth and over-water emissions impacts from ocean-going vessel main and auxiliary engine emissions as well as commercial harbor craft such as passenger ferries and tugboats. For the ocean-going vessel emissions, the study evaluated the hotelling emissions, i.e. those emissions from vessel auxiliary engines while at berth, separately from the maneuvering and transiting emissions. While there are locomotive and on-road heavy-duty truck emissions associated with the movement of goods through the ports that occur off the port boundaries, these were not evaluated in this study. Future analyses will consider the impact of these off-port emissions.

The results from the study are presented in this report which is comprised of two parts. Part I, “Summary,” provides an overview and summary of the study in a less technical and more easily understood format. Part II, “Technical Support Document,” provides a description of the supporting technical basis for the study and a more comprehensive summary of the results. For simplicity, the Summary is presented in question-and-answer format. The reader is directed to Part II for more detailed information.

1. What are the major elements of the study?

The major elements of the study were:

- developing a baseline (2002) inventory of diesel PM emissions at the two ports from ocean going vessels (transit, maneuvering, and hotelling), harbor craft, cargo handling equipment, in port trucks, and in port trains,
- estimating the ambient concentration of diesel PM downwind of the ports, and

- estimating the potential cancer risk levels and other non-cancer health effects associated with the diesel PM concentrations.

2. What are the key findings from the study?

The key findings from this study are:

- Diesel PM emissions from the ports are a major contributor to diesel PM in the South Coast Air Basin.

  The combined diesel PM emissions from the ports are estimated to be about 1,760 tons per year in 2002. This represents a significant component of the regional diesel PM emissions for the South Coast Air Basin (SCAB) at about 21 percent of the total SCAB diesel PM emissions in 2002. Focusing only on diesel PM emissions occurring on port property or within California Coastal Waters (CCW)[1], the emissions from ship activities (transiting, maneuvering, and hotelling) account for the largest percentage of emissions at about 73 percent, followed by commercial harbor craft vessels (14%), cargo handling equipment (10 %), in-port heavy duty trucks (2%), and in-port locomotives (1%).

- Diesel PM emissions from the ports impact a large area and the associated potential health risks are of significant concern.

  Diesel PM emissions from the ports result in elevated cancer risk levels over the entire 20-mile by 20-mile study area. In areas near the port boundaries, potential cancer risk levels exceed 500 in a million. As you move away from the ports, the potential cancer risk levels decrease but continue to exceed 50 in a million for more than 15 miles.

  Primary diesel PM emissions from the ports also result in potential non-cancer health impacts within the modeling receptor domain. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days. Based on this study, average numbers of cases per year that would be expected in the modeling area have been estimated as follows:

  - 29 premature deaths (for ages 30 and older), 14 to 43 deaths as 95% confidence interval (CI);
  - 750 asthma attacks, 180 to 1300 as 95% CI;
  - 6,600 days of work loss (for ages 18-65), 5,600 to 7,600 as 95% CI;
  - 35,000 minor restricted activity days (for ages 18-65), 28,000 to 41,000 as 95% CI.

[1] In 1983, the ARB established the California Coastal Waters (CCW) boundary based on coastal meteorology within which pollutants released offshore would be transported onshore. The development of the boundary was based on over 500,000 island, shipboard, and coastal observations from a variety of records, including those from the U.S. Weather Bureau, Coast Guard, Navy, Air Force, Marine Corps, and Army Air Force (ARB, 1982). The CCW boundary ranges from about 25 miles off the coast at the narrowest to just over 100 miles at the widest.

- "Hotelling" emissions from ocean-going vessel auxiliary engines and emissions from cargo handling equipment are the primary contributors to the higher pollution related health risks near the ports.

  Hotelling emissions from ocean-going vessels account for about 20 percent of the total diesel PM emissions from the ports. These emissions are responsible for about 34 percent of the port emissions related risk in the modeling receptor domain based on the population-weighted average risk. These emissions resulted in the largest area (2,036 acres) where the potential cancer risk levels were greater than 200 in a million in the nearby communities. The second highest category contributing to cancer risk levels above 200 in a million was cargo handling equipment, which impacted a residential area of 410 acres and is responsible for about 20 percent of the total risk in the modeling receptor domain based on the population-weighted average risk. Reducing emissions from these two categories will have the most dramatic effect on reducing the port emissions related risks in nearby communities.

- Emissions from commercial harbor craft, in-port trucks, in-port rail, and ocean-going vessels (transit and maneuvering activities) account for about 46 percent of the port emissions related risk in the modeling receptor domain based on the population-weighted average risk. These emissions are an important contributor to elevated cancer risk levels over a very large area.

  Emissions from commercial harbor craft, on-port trucks, on-port rail, and ocean going vessels (maneuvering and transit activities) account for about 70 percent of the total diesel PM emissions for the ports. While emissions from these source categories do not have a major role in the near port risk levels, they are significant contributors to the overall elevated risk levels in the study area. Addressing the emissions from these sources is critical if we are to significantly reduce the exposure of a large population (over 2 million people) to cancer risk levels in the 50 in a million range.

3. Why is ARB concerned about Diesel PM?

Diesel engines emit a complex mixture of air pollutants, composed of gaseous and solid material. The visible emissions in diesel exhaust are known as particulate matter or PM, which includes carbon particles or "soot." In 1998, ARB identified diesel PM as a toxic air contaminant based on its potential to cause cancer, premature deaths, and other health problems. Health risks from diesel PM are highest in areas of concentrated emissions, such as near ports, rail yards, freeways, or warehouse distribution centers. Exposure to diesel PM is a health hazard, particularly to children whose lungs are still developing and the elderly who may have other serious health problems.

The health impacts of particulate matter (PM10 and PM 2.5) have been studied in epidemiological studies conducted in many different cities. Diesel particulate matter is a major component of particulate matter in many cities. Diesel particulate matter is composed of carbonaceous particles (soot) and particles that can form from nitrogen

oxides (NO_X) emitted by diesel engines. These studies have found an increase of one to two percent in daily mortality associated with each 10 $\mu g/m^3$ increase in PM10 exposure. The most vulnerable subpopulations are those with preexisting respiratory or cardiovascular disease, especially the elderly. In addition, increased hospital admissions and morbidity from respiratory disease have been associated with particulate matter exposure in adults and children. Particulate matter exposure is associated with an increased risk of lung cancer in epidemiological studies.

The ARB staff has estimated that 2,000 premature deaths statewide are linked to direct diesel PM exposure and 900 premature deaths are associated with indirect diesel PM exposure in the year 2000 alone. Exposure to fine particulate matter, including diesel PM 2.5, can also be linked to a number of heart and lung diseases. For example, the ARB staff has estimated that 5,400 hospital admissions for chronic obstructive pulmonary disease, pneumonia, cardiovascular disease, and asthma were due to exposure to direct diesel PM 2.5 in California. An additional 2,400 admissions were linked to exposure to indirect diesel PM (Lloyd, 2001). There are uncertainties in these analyses, but the non-cancer public health impacts of diesel PM exposure may outweigh the considerable public health impacts of diesel PM as a carcinogenic substance.

4. What are exposure and risk assessments?

*A **risk assessment** is a tool used to evaluate the potential for a chemical or pollutant to cause cancer and other illnesses.*

Risk assessment is a yardstick useful for comparing the potential health impacts of various sources of air pollution. For this risk assessment, the amount of diesel PM emitted from each source (e.g. cruise ships) is estimated. An air modeling computer program uses local meteorological data (e. g. wind speed and direction) to estimate the annual average ground level concentrations of diesel PM in the communities around the facility. The increased risk of developing lung cancer from exposure to a particular level of diesel PM can be estimated using the Office of Environmental Health Assessment's (OEHHA) cancer potency factor for diesel PM. The non-cancer health impacts of diesel PM exposure are possible to quantify, but the cancer health impacts have more commonly been used as the yardstick with which to compare the impacts of various diesel sources. Risk assessment has various uncertainties in the methodology and is therefore deliberately designed so that risks are not under predicted. Risk assessment is thus best understood as a tool for comparing risks from various sources, usually for purposes of prioritizing risk reduction, and not as literal prediction of the community incidence of disease from exposure.

*For **cancer** health effects, the risk is expressed as the number of chances in a population of a million people who might be expected to get cancer over a 70-year lifetime. The number may be stated as "10 in a million" or "10 chances per million". Often times scientific notation is used and you may see it expressed as 1 x 10^{-5} or 10^{-5}. Therefore, if you have a potential cancer risk of 10 in a million, that means if one million people were exposed to a certain level of a pollutant or chemical there is a chance that 10 of them may develop cancer over their 70-year lifetime. This would be 10 new cases of cancer above the expected rate of cancer in the population. The expected rate of cancer for all causes, including smoking, is about 200,000 to 250,000 chances in a million (one in four to five people).*

In a risk assessment, risk is expressed as the number of chances in a population of a million people who might be expected to get cancer over a 70-year lifetime. However, for informational purposes only, the risk is sometimes reported for other exposure times, such as a 30-year or a 9-year risk. The longer the exposure to a given air concentration, the greater the cancer risk will be. In this report, only the 70-year lifetime risk is presented. The exposure assessment study for the Ports of Los Angeles and Long Beach focuses on potential cancer cases due to exposure to diesel PM emissions. However, there is a growing body of scientific data suggesting that exposure to fine PM results in premature death and morbidity (illness) due to respiratory and cardiovascular disease. The sensitive subpopulations include people with pre-existing cardiovascular disease and respiratory disease, including asthma, particularly those who are also elderly.

5. Where are the Port of Los Angeles and the Port of Long Beach located and what port activities occur there?

The Ports of Los Angeles (POLA) and Long Beach (POLB) are located adjacent to each other on San Pedro Bay, about 20 miles south of downtown Los Angeles. Together, they form the third-largest port complex in the world. The primary purpose of the ports is to move cargo on and off ocean-going ships and onto trucks or railcars. The majority of goods are transported in containers although the ports also handle non-containerized goods such as coke and motor vehicles. These activities involve a wide variety of sources that contribute to diesel PM and oxides of nitrogen (NOx) emissions such as the ocean-going ships that participate in international trade. Other sources include trucks, locomotives, cargo handling equipment, and harbor craft such as tug boats, crew boats, and fishing vessels.

6. What are the diesel PM emissions from port-related activities at POLA and POLB?

The emissions of diesel PM from port-related activities were estimated to be approximately 965 tons per year for the POLA and 795 tons per year for the POLB in the year 2002, or a total of 1,760 tons per year for both ports. As shown in Table 1, by source category, ocean-going vessels, ship auxiliary engines' hotelling, harbor craft, cargo handling equipment, in-port heavy-duty trucks, and in-port locomotives account for about 53, 20, 14, 10, 2, and 1 percent of the mass emissions, respectively.

Table1: Estimated 2002 Diesel PM Emissions Inventory for POLA and POLB

	OGV	HOTEL	CHC	CHE	IPT	IPL	COMBINED
Diesel PM Emissions T/Y	942	343	244	172	41	18	1760
Percent of Total	53%	20%	14%	10%	2%	1%	100%

Note: OGV – Oceangoing vessels; HOTEL – Ship's auxiliary engine hotelling; CHC – Commercial harbor crafts; CHE –Cargo handling equipment; IPT – In-Port heavy-duty trucks; IPL – In-Port locomotive.

By source area, about 43 percent of the emissions occur on land-based port property and over the water within the breakwater[2] and the remaining (57 percent) occur outside of the breakwater over water. These emissions estimates include only the emissions that are occurring on port property and the over-water emissions from ocean-going ships. It does not include the more regional land-based emissions from trucks and locomotives that occur outside of the port boundaries.

The diesel PM emissions resulting from port activities have been a significant and growing contributor to regional air pollution and community exposure to toxic air pollutants. For example, in the South Coast Air Basin (SCAB), the diesel PM emissions resulting from the ports activities accounted for about 21 percent of the total SCAB diesel PM emissions in 2002. Growth forecasts predict that trade at the POLA and POLB will triple by 2020, resulting in a 60 percent increase in diesel PM emissions from current levels unless further controls are enacted.

7. How were the diesel PM concentrations near the ports estimated?

ARB staff used the United States Environmental Protection Agency (U.S. EPA) approved computer model (ISCST3) to estimate the annual average offsite concentration of diesel PM resulting from the activity at the two ports. The key inputs to the computer model were the diesel PM emissions information (magnitude, timing, and location), the meteorological data (wind speed, direction, etc.), and the dispersion coefficients (rural or urban). Meteorological data, used as a direct input to the dispersion model, are obtained from an air quality monitoring study conducted in Wilmington in 2001. The meteorological observations were located about one mile from the north boundary of the Port of Los Angeles. These data are the most recent and most representative meteorological data for the dock areas of the Ports of Los Angeles and Long Beach. Because the area surrounding the ports has urban characteristics, the modeling was done using the urban dispersion coefficients.

8. How were the potential cancer risks from diesel PM estimated?

The potential cancer risks were estimated using standard risk assessment procedures based on the annual average concentration of diesel PM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of diesel PM inhaled.

The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in OEHHA's Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (September 2003). A Tier-1 analysis assumes that an individual is exposed to an annual average concentration of a pollutant

[2] The breakwater protects POLA and POLB Harbor from rough seas and waves. The breakwater is about nine miles long (east-west) and was built in a pyramid shape with rocks from Catalina Island. The bottom on the ocean floor is 200 feet wide and the top is only 23 feet wide. Construction of the breakwater began in 1899 and took 50 years to complete. The breakwater is approximately 4.5 miles from the ports' north land boundary.

continuously for 70 years.[3] The cancer potency factor was developed by the OEHHA and approved by the State's Scientific Review Panel on Toxic Air Contaminants (SRP) as part of the process of identifying diesel PM emission as a toxic air contaminant (TAC).

9. What is the estimated potential cancer risk from all sources at the ports?

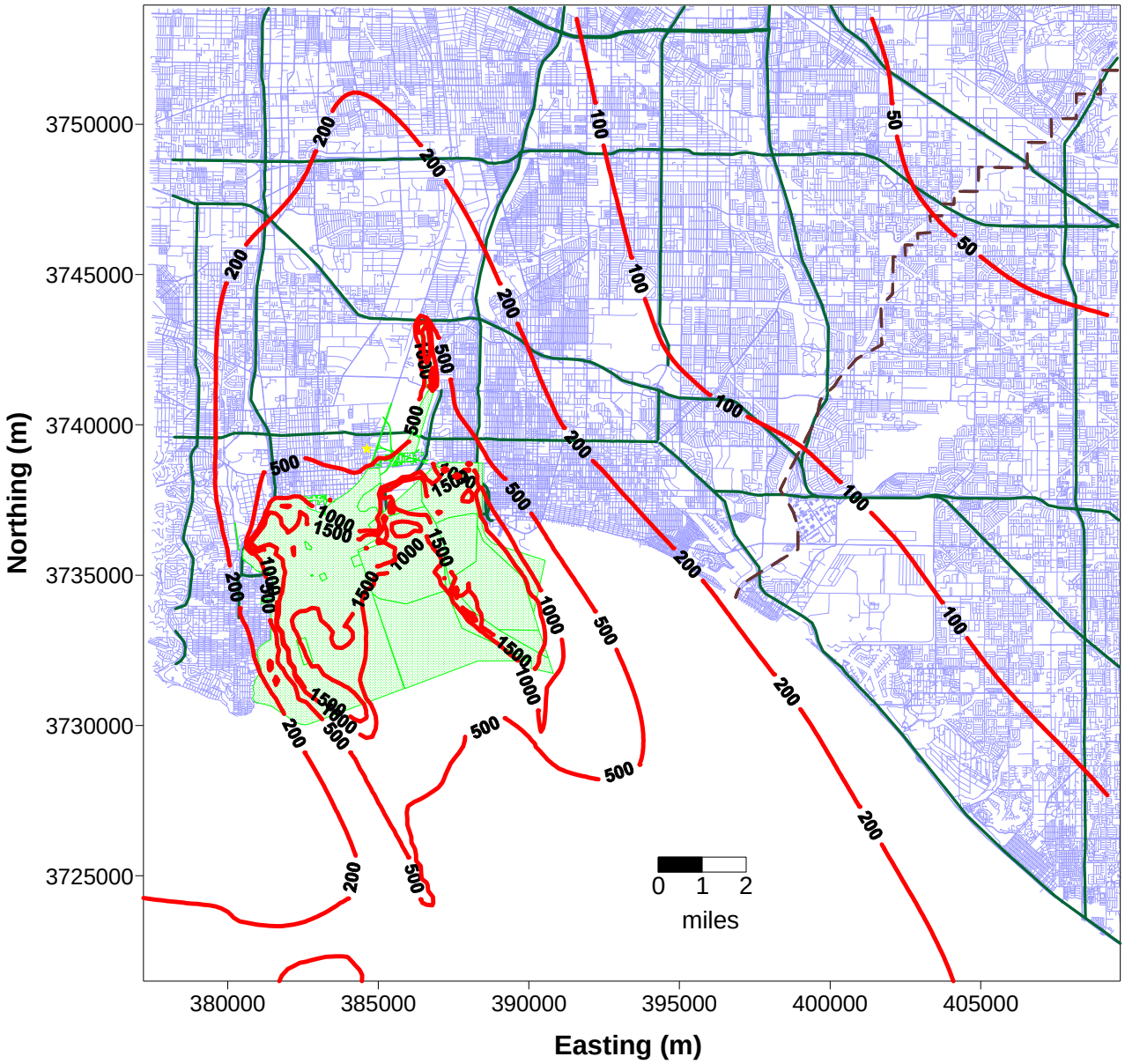
Figure 1 shows the potential cancer risk isopleths for all emission sources at the two ports superimposed on a map showing the ports and the nearby communities. The risk contour of 100 in a million extends beyond the modeling receptor domain to the north of the ports. The domain boundary is about 10 miles north of the port boundary. The area with predicted cancer risk levels in excess of 100 in a million is estimated to be about 94,000 acres, which is 57 percent of the effective land area (163,400 acres, excluding the port property and the water acreage) within the modeling receptor domain. The area in which the risks are predicted to exceed 200 in a million is also very large, covering an area of about 29,000 acres (18 percent of the effective land area within the modeling receptor domain). The areas with the greatest impact have an estimated potential cancer risk of over 500 in a million and cover about 2 percent of the effective land area within the domain. The risk isopleths of 1000 and 1500 in a million occur on the ports' property and the nearby ocean surfaces, and are not considered in this study as people do not reside in these areas.

Using the U.S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries. Nearly 60 percent of the 2 million people that live in the area around the ports have predicted risks of greater than 100 in a million. The affected population numbers for the cancer risk ranges of 100-200, 200-500, and over 500 have been estimated to be about 724,000 people, 360,000 people, and 53,000 people, respectively. The affected population numbers account for about 37, 18 and 3 percent of the total population within the modeling receptor domain, respectively. Note that the risk isopleth of 10 in a million is not shown in Figure 1 because it is outside of the modeling receptor domain. Also, note that if the modeling receptor domain expands, the impacted areas and affected population would be increased.

[3]According to the OEHHA Guidelines, the relatively health-protective assumptions incorporated into the Tier-1 risk assessment make it unlikely that the risks are underestimated for the general population.

Figure 1

Estimated Diesel PM Cancer Risk from POLA and POLB



Notes: Wilmington Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 1,760 TPY, Modeling Receptor Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m.

10. What are the relative contributions to the potential cancer risks from the various diesel PM emission sources at the ports?

The different emission sources are used at various locations on the ports property. Thus, contributions of these emission sources to exposures in the nearby neighborhoods are different. As shown in Tables 2 and 3, the emissions from cargo handling equipment and on-port heavy-duty trucks resulted in areas within the nearby communities having risk levels exceeding 500 in a million while the highest risk levels associated with the other categories were between 200 and 500 in a million. Within the modeling receptor domain, ship hotelling emissions and cargo handling equipment impacted the largest areas and affected more people than the other sources of emissions when considering the risk levels greater than 100 in a million. When considering risk levels greater than 10 in a million, all the port sources, other than in-port heavy-duty trucks and locomotives, had similar impacts, affecting at least 119,000 acres and at least 1.4 million people. By source location, the impacts resulting from the in-port emissions (within the breakwater) are much larger than those resulting from the out-of-port emissions (outside the breakwater), although the emission magnitude of the former is less than the latter (750 TPY vs 1010 TPY). Quantitatively, within the modeling domain, the population-weighted risk resulting from the in-port emissions is about 4.5 times greater than the risk resulting from the over water out-of-port emissions.

Table 2: Summary of Area Impacted by Risk Levels and Activity Categories (Acres)

Risk Level	OGV	HOTEL	CHC	CHE	IPT	IPL	COMBINED
Risk > 500	0	0	0	50	50	0	2,500
Risk > 200	110	2,036	20	410	160	40	29,000
Risk > 100	227	12,700	750	4,100	376	160	94,000
Risk > 10	163,435	160,470	125,250	119,000	29,750	11,240	163,435

Table 3: Summary of Population Affected by Risk Levels and Activity Categories (Number of People)

Risk Level	OGV	HOTEL	CHC	CHE	IPT	IPL	COMBINED
Risk > 500	0	0	0	3,200	205	0	53,000
Risk > 200	18	46,020	5,000	11,100	1,780	680	411,200
Risk > 100	1,810	221,567	22,960	82,000	8,270	4,330	1,135,000
Risk > 10	1,977,760	1,949,850	1,516,515	1,444,000	422,910	213,430	1,977,770

Notes:

1. OGV – Oceangoing vessels; HOTEL – Ship's auxiliary engine hotelling; CHC – Commercial harbor crafts; CHE –Cargo handling equipment; IPT – In-Port heavy-duty trucks; IPL – In-Port locomotive.
2. The model receptor domain of 20-mile x 20- mile with urban dispersion coefficients with a receptor resolution of 200m x 200m was used. The effective receptor modeling domain (excluding the port properties and the ocean water) is estimated to be about 255 square miles; The calculations here are ONLY based on the effective modeling receptor domain.
3. The 80th percentile breathing rate for adults over 70-year lifetime was assumed,
4. Meteorological data from Wilmington (2001) was used for POLA and POLB.
5. The risks within both ports and over the ocean water were excluded for calculations of average risks and affected areas.
6. The estimated population in this Table is ONLY based on the modeling receptor domain using the U.S. Census Bureau's year 2000 census data.
7. If the modeling receptor domain expands, the population and area affected would be increased.
8. The combined column provides the population affected and area impacted for the cumulative impacts from all the emission sources. The individual impacts are not additive since the combined impacts are greater than the sum of the individual sources. For example, cargo handling equipment and commercial harbor craft emissions may impact the same location and population. While individually the impacts may result in cancer risk levels between 100 and 200 in a million, when you combine the impacts, the resulting risks could be greater than 200 in a million.

11. How do the results compare to the monitoring programs and the SCAQMD MATES-II study?

For comparison purposes, the ARB staff compared the study results to two monitoring programs conducted by the POLA (POLA, 2005) and ARB (ARB, 2002) and to the South Coast Air Quality Management District (SCAQMD)'s second Multiple Air Toxic Exposure Study (MATES-II (SCAQMD, 2000).

The POLA is currently conducting an air quality monitoring program within the Port and in the nearby communities to estimate the ambient levels of diesel PM in proximity to the Port that are due to Port operational activities. For the comparison, the measured elemental carbon (EC) is used as the surrogate of diesel PM and it is assumed that the ratio of EC with diesel PM is 0.5. Table 4 shows the potential cancer risks based on the modeling results compared to those derived from the half year's monitoring results conducted during the period February 1 through August 5, 2005 at Wilmington community and San Pedro monitoring stations. The computer modeling performs adequately in simulating the measured diesel PM risks at the two locations.

The ARB conducted an air monitoring program in Wilmington from May 2001 to July 2002 as part of the Children's Environmental Health Program. The derived potential diesel PM cancer risks at two sites - Wilmington Park Elementary School and Hawaiian Elementary School are also listed in Table 4 and compared with the predicted risks. It is shown that the predicted results are favorably comparable with the monitored results at the two sites.

Table 4. Comparisons of predicted potential cancer risks with measurements (unit in cases per million)

Location	Port of L. A. monitoring results	ARB SB 25 monitoring results	Model prediction
Wilmington Community	585	N/A	600
San Pedro	533	N/A	500
Wilmington School	N/A	450	470
Hawaiian School	N/A	710	650

Note:

1. The ratio of elemental carbon (EC) with diesel PM has been reported to be 0.375 to 0.75 by literature. A ratio of 0.5 is used in this calculation;
2. For POLA's monitoring program, the measured EC 24-hr average concentrations over the half year from February 9 to August 5, 2005 are reported;
3. For ARB SB 25 Wilmington monitoring study, about 71% of the samples collected were below the detection limit of 1 ug EC/m^3. It is assumed that all measurements below the limit are arbitrarily assumed to be 0.5 ugEC/m^3;
4. For the detailed monitoring programs and results, please check POLA and ARB's web sites.

The ARB staff also compared the study results to the SCAQMD's MATES-II. The MATES-II study indicated that the modeled potential risk in the grid cell containing the Wilmington air quality monitoring station was 1,187 potential cancer cases per million due to diesel PM emissions from port activities, freeways, and other sources of diesel PM. This Wilmington grid cell is approximately 2 miles north of the Ports. Our study

shows a risk level of about 450 cases in a million in the same general vicinity. In the nearby residential areas within one mile from port boundaries, risk levels (from diesel PM emissions as well as other toxics) ranged from 1000 to 1500 cases in a million based on the MATES-II study. Our study shows a risk range of 500 to 1000 cases in a million from the Ports' diesel PM emissions. The differences can be attributed to different modeling configurations. For example, MATES-II used the Urban Airshed Model (UAM) model, a grid based model with 2 km grid cells, while our study used the ISCST3 model, a Gaussian plume model. In addition, MATES-II simulated diesel PM from all sources (e.g., port activities and freeway emissions) for the 1998 base year while our study was limited to diesel PM from port activities for the year 2002. Also the MATES-II study released ocean-going emissions near ground level (within the first horizontal layer of the UAM). Our study released ocean going emissions at 50 meters above "ground" (sea level) which will result in greater dispersion of emissions. [4]

12. What are the uncertainties associated with risk assessments?

The estimated diesel PM concentrations and risk levels produced by a risk assessment are based on a number of assumptions. Many of the assumptions are designed to be health protective so that potential risks to individuals are not underestimated. Therefore, the actual risk calculated by a risk assessment is intentionally designed to avoid underprediction. There are also many uncertainties in the health values used in the risk assessment. Some of the factors that affect the uncertainty are discussed below.

When available, as is the case with diesel PM, scientists use studies of people exposed at work to estimate risk from environmental exposures. There can be a wider range of responses in the general public than in the workers in the epidemiology study used to determine the cancer potency factor. Also, the actual worker exposures to diesel PM were based on limited monitoring data and were mostly derived based on estimates of emissions and duration of exposure. Different epidemiological studies suggest somewhat different levels of risk. When the State's Scientific Review Panel (SRP)[5] identified diesel PM as a toxic air contaminant, they endorsed a range of inhalation cancer potency factors (1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$) and a risk factor of 3×10^{-4} $(\mu g/m3)^{-1}$, as a reasonable point estimate of the unit risk. From the unit risk factor an inhalation cancer potency factor of 1.1 $(mg/kg\text{-}day)^{-1}$ may be calculated.

As mentioned above, there is no direct measurement technique for diesel PM. This analysis used an air dispersion modeling to estimate the concentrations to which the public is exposed. The air dispersion models are based on the state-of-the-science

[4] The higher release point was used because the average ship stack height is about 43 m tall. When the emissions are released from the top of a ship's exhaust stack, there is a plume rise that occurs which was estimated to average to be about 7 meters. This results in an average release height of 50 meters.

[5] The Scientific Review Panel (SRP/Panel) is charged with evaluating the risk assessments of substances proposed for identification as toxic air contaminants by the Air Resources Board (ARB) and the Department of Pesticide Regulation (DPR). In carrying out this responsibility, the SRP reviews the exposure and health assessment reports and underlying scientific data upon which the reports are based, which are prepared by the ARB, DPR, and the Office of Environmental Health Hazard Assessment (OEHHA) pursuant to the sections 39660-39661 of the Health and safety Code and sections 14022.

formulations which have uncertainties. Three air dispersion models – ISC, AERMOD, and CALPUFF, could be used in this study. As stated above, the primary propose of this study was to prioritize emission sources/categories from the Ports operation which are to be regulated. ISC was used in this study because of its fewer requirements for the model inputs. Although AERMOD or CALPUFF may predict somewhat different impacts in the nearby communities, we believe that the conclusions drawn from this study, especially the ranking of the emission sources/categories, may not be altered. This is because that each model assumes that the concentration is linearly proportional to emission rate, thus, the relative contributions or prioritization scheme of each emission source/category to the total impacts in the nearby communities would not be affected.

The model inputs included emission rates, release parameters, meteorological conditions, and dispersion coefficients. Each of the model inputs has an uncertainty of their own. In addition, a relative small model domain of 20 mi x 20 mi was used in this study because of the ISC model's limitation. In reality, the impacts of diesel PM from the Ports in the nearby communities could exceed the domain. Fully impacts of diesel PM from the Ports could be addressed using the long range transport model – CALPUFF in future time.

13. What are the non-cancer health endpoints associated with exposures to Diesel PM from port operations?

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (CARB, 2002). As part of this study, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) within the modeling domain. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days.

ARB staff assessed the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) within each 200 meter by 200 meter grid cell within the modeling domain. The populations within each grid cell were determined from U.S. Census Bureau year 2000 census data. Using the methodology peer-reviewed and published in the Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates, (PM Staff Report) (CARB, 2002), we calculated the number of annual cases of death and other health effects associated with exposure to the PM concentration modeled for each of the grid cells and then calculated the totals over the entire modeling area. Based on our analysis, it is estimated that the exposures to the directly emitted diesel PM from on-port operations within the modeling domain result in approximately 29 premature deaths for the 2 million people exposed per year. In addition, these exposures are predicted to result in 750 asthma attacks, 6,600 work loss days, and approximately 35,000 minor restricted activity days. In each case, the values presented represent the mean value in cases per year for the health end point listed.

These estimates are based on a well-established methodology for calculating changes in health endpoints due to changes in air pollution levels. However, since the estimates apply to a limited modeling domain (20 miles by 20 miles), the affected population is small, and hence the overall estimated health impacts are smaller than estimates made on a statewide basis. In addition, to the extent that only a subset of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact.

In this study, we also did not consider the diesel PM emissions of on-road heavy-duty trucks and locomotives related to port activities that occur off-port boundary within the SCAB (regional emissions). We estimate the off-port regional diesel PM emissions to be about 206 TPY for the both ports, or 10 percent of the total port-related emissions (206 TPY vs 1,970 TPY). These regional emissions are distributed throughout the SCAB and may result in localized health impacts to people who are live near freeways and railroad corridors within the SCAB. These health impacts will be evaluated in future studies.

14. Are there other studies planned that will evaluate the impacts of port-related diesel PM emissions?

As mentioned above, during 1998 -1999, the South Coast Air Quality Management District (SCAQMD) conducted the second Multiple Air Toxics Exposure Study (MATES-II) to determine the Basin-wide risks associated with major airborne carcinogens, including diesel PM. Currently, SCAQMD is conducting MATES-III to assess current air toxics levels within the Air Basin using updated emission inventories, refined modeling methodologies, and improved assumptions. MATES-III will incorporate all air toxic emission sources, e.g., stationary, on-road, and off-road mobile sources, and all air toxics, e.g., diesel PM, 1,3-butadiene, benzene, chromium, etc. In addition, ARB is conducting a neighborhood assessment study for Wilmington, which is nearby the ports. This study is a part of ARB's Neighborhood Assessment Program. The objective is to estimate health risks in Wilmington and surrounding areas. Like MATES-III, this project will consider all emission sources and all air toxic contaminants.

15. What activities are underway to reduce risks?

There are many efforts currently underway to reduce exposures to diesel PM. POLA and POLB have instituted voluntary programs to reduce diesel PM emissions from port operations including installation of diesel oxidation catalysts on yard equipment, funding the incremental costs of cleaner fuels, cold-ironing of ocean-going ships and providing monetary support to the Gateway Cities truck fleet modernization program. In addition, efforts at the State and local level to implement the Diesel Risk Reduction Plan and to fulfill commitments in the State Implementation Plan will also reduce emissions. For example, the new off-road engine standards adopted by ARB and the U.S. EPA will reduce emissions from new off-road engines by over 95% compared to uncontrolled levels. In the fall of 2005, ARB has considered two measures to reduce emissions from sources of diesel emissions at ports. One measure will require reductions from cargo handling equipment and the other from ship auxiliary engines. To ensure continued emission declines in the face of the expected growth, ARB is leading an effort to

develop a Port and Intermodal Goods Movement Comprehensive Emission Reduction Plan that will build upon current efforts and define the additional strategies needed to reduce public health impacts from port and related activities. This effort is part of Governor Schwarzenegger's *Goods Movement Action Plan*, a plan that reflects the Governor's desire to improve the movement of goods in California at the same time we work to improve air quality and protect public health.

PART II: TECHNICAL SUPPORT DOCUMENT

I. INTRODUCTION

Emissions from port-related goods movement are a significant and growing contributor to community air pollution. In communities with significant goods movement activity, such as communities located adjacent to California maritime ports, a particular concern is exposure to diesel particulate matter (diesel PM). This pollutant poses a lung cancer hazard for humans and causes non-cancer respiratory and cardiovascular effects that increase the risk of premature death (ARB, 1998a). The particles are readily inhaled because of their small size and can effectively reach the lowest airways of the lung. Many of the adsorbed compounds are known or suspected mutagens and carcinogens. (ARB, 2002)

To better understand the impacts from port activities, Air Resources Board (ARB) staff conducted an exposure assessment study of diesel PM emissions from port-related activities at the Ports of Los Angeles and Long Beach (ports) located in Southern California. This part provides the technical details on the exposure assessment. The reader is directed to Part I, Summary, for a less technical discussion of the study.

Overview

Risk assessment is a complex process that requires the analysis of many variables to model real-world situations. Three steps were taken to perform the exposure assessment for the ports:

- developing a diesel PM emissions inventory that reflects the amount of diesel PM released annually from port-related activities;
- conducting air dispersion modeling to estimate the ambient concentration of diesel PM that results from these emissions; and
- estimating the potential cancer risk from the modeled exposures.

The following chapters provide a description of each element of the exposure assessment. Specifically, the following information is provided:

- the methodology used to develop the port-related diesel PM emissions;
- a summary of the estimated diesel PM emissions inventory for the ports;
- a discussion on the air dispersion modeling conducted to estimate ambient concentrations of diesel PM;
- the results of the air dispersion modeling;
- an estimate of the potential impacts (potential cancer risks) to nearby residences due to exposure to ambient concentrations of diesel PM from port-related activities at the ports; and
- a comparison between the risk impacts from the various emission sources at the ports.

Purpose

In the South Coast Air Basin (SCAB), diesel PM emissions from port-related activities are a significant and growing contributor to regional air pollution and community exposures to toxic air pollutants. For example, in the SCAB, the diesel PM emissions resulting from the movement of goods through the Ports of Los Angeles (POLA) and the Port of Long Beach (POLB) accounted for about 21 percent of the total SCAB diesel PM emissions in 2002. Growth forecasts predict that trade at POLA and POLB will triple by 2020, resulting in a 60 percent increase in diesel PM emissions from current levels unless further controls are enacted. POLA and POLB operate in close proximity to several communities including San Pedro, Long Beach, and Wilmington. These nearby communities face potentially higher health risks from the port-generated diesel PM emissions.

There are many efforts currently underway to reduce exposures to diesel PM. POLA and POLB have instituted voluntary programs to reduce diesel PM emissions from port operations including installation of diesel oxidation catalysts on yard equipment, funding the incremental costs of cleaner fuels, cold-ironing of ocean-going ships, and providing monetary support to the Gateway Cities truck fleet modernization program. In addition, efforts at the State and local level to implement the ARB Diesel Risk Reduction Plan and to fulfill commitments in the State Implementation Plan will also reduce emissions. New off-road engine standards adopted by ARB and the United States Environmental Protection Agency (U.S. EPA) will reduce emissions from new off-road engines by over 95% compared to uncontrolled levels. In the fall of 2005, ARB has considered two measures to reduce emissions from port sources. One measure will require reductions from cargo handling equipment and the other from ship auxiliary engines. To ensure continued emission declines in the face of the expected growth, ARB is leading an effort to develop a Port and Intermodal Goods Movement Comprehensive Emission Reduction Plan that will build upon current efforts and define the additional strategies needed to reduce public health impacts from port and related activities.

The purpose of this exposure assessment study is to enhance our understanding of the port-related diesel PM emission impacts on communities near POLA and POLB and to assist in the evaluation of control measures under development or planned. Because the emission sources are located at various locations on the port property, the contributions of these emission sources to nearby neighborhoods will be different. Both the location of the emissions and the magnitude need to be taken into consideration when determining the degree of health risks to people who are living around the ports. To summarize, the purpose of the exposure assessment is to:

- investigate the impacts of the various port emission sources on nearby neighborhoods;
- identify the most significant emission source(s);
- prioritize possible mitigation measures to control diesel PM emissions based on the relative magnitude of health risks; and
- assist in evaluating the impacts of measures developed to reduce emissions.

Description of the Ports

POLA and POLB are located adjacent to each other on the San Pedro Bay, about 20 miles south of downtown Los Angeles. The ports are directly adjacent to the

communities of Long Beach, San Pedro, and Wilmington. The ports are primarily container ports, moving goods into and out of California in containers. However, they also handle non-containerized goods such as coke and automobiles. While the majority of the goods movement occurs during the day, the ports do operate 24 hours a day, 7 days a week, and 365 days a year. The ports are the first and second busiest seaports in the Western United States. POLA encompasses 7500 acres, 43 miles of waterfront and features 26 cargo terminals. These terminals handle nearly 150 million metric revenue tons of cargo annually. In 2004, the POLA moved in 7.4 million TEUs[6], which was a new national container record. POLB covers about 3000 acres of land. In 2004, tonnage through POLB was 73.6 million metric tons, and about 5.8 million TEUs moved through the Port. Combined, POLA and POLB are the world's third-busiest port complex, after Hong Kong and Singapore.

[6] The TEU is the international standard measure used to describe containers. A 20-foot container = 1 TEU.

2a. Port of Los Angeles (Courtesy of POLA, http://www.portoflosangeles.org)

2b. Port of Long Beach (Courtesy of POLB, http://www.polb.com)

VI.

VII. Figure 2: Aerial Photos of POLA and POLB

II. EMISSION INVENTORY DEVELOPMENT

Air dispersion models require emission inputs that properly characterize source-specific emissions for diesel PM from various activities in the ports. The port-related activities are categorized as: ocean-going vessels, auxiliary engine hotelling, commercial harbor craft, cargo handling equipment, railroad locomotives, and heavy-duty trucks. POLA and POLB recently hired Starcrest Consulting Group, LLC (Starcrest) to develop detailed emission inventories for all emission sources for POLA and three sources (cargo handling equipment, in-port locomotives, and in-port heavy-duty trucks) for the POLB. At the request of the ports, Starcrest used 2001 as the base year for POLA and 2002 as the base year for POLB. For this exposure assessment study, 2002 was chosen as the baseline year for both ports. In this chapter, we briefly describe how we projected the 2001 POLA emission inventory to 2002 and how we developed the 2002 emissions inventory for ocean-going ships, auxiliary engine hotelling and commercial harbor craft for POLB. The basic methodologies used in the emission inventory development are briefly described in Appendix A.

Port of Los Angeles

As stated above, Starcrest prepared an emission inventory for all emission sources at the POLA using 2001 as the baseline year. (Starcrest, 2004a) The inventory utilizes an activity-based approach and focuses on emissions of diesel PM for all significant sources operating in the Port. In addition to in-port activities, emissions from railroad locomotives and on-road trucks transporting port cargo were also estimated based on the activity that occurs outside the Port, but within the South Coast Air Basin boundaries. Only in-port emissions and over water emissions from ocean-going ships and harbor craft were evaluated in this exposure assessment. Our methodology for projecting the 2001 POLA inventory to 2002 is presented below.

Ocean-going Vessels

For 2001, Starcrest estimated emissions from ship cruising (includes transiting and maneuvering) and hotelling activities. To estimate the 2002 POLA emissions, ARB staff assumed that the emissions per vessel call would be the same in 2001 and 2002. Emissions per vessel call were calculated from the emissions per vessel call (expressed in emissions/call number) for each ocean-going vessel (OGV) type (i.e. auto carrier, bulk, container, cruise, general cargo, reefer, RoRo, tanker) reported in the 2001 POLA emission inventory data. Emissions per vessel call were estimated for each activity (transiting, maneuvering, hotelling). ARB staff then estimated the emissions for each OGV type in 2002 by multiplying the emissions per call in 2001 by the number of vessel calls for each of the corresponding OGV types in 2002, that is:

$$E_{POLA,2002,i} = \frac{E_{POLA,2001,i}}{CN_{POLA,2001,i}} x\, CN_{POLA,2002,i} \quad (1)$$

where $E_{POLA,2002,i}$ is the estimated emissions of OGV type i (i = 1, 10) in 2002, $E_{POLA,2001,i}$ is the emission of OGV type i at POLA for 2001 (known), $CN_{POLA,2001,i}$ and $CN_{POLA,2002,i}$ are the vessel call numbers from POLA in 2001 and 2002 for OGV type i, respectively. Table 5 provides a summary of the estimated emissions per vessel call and the actual vessel call numbers for each port in 2002.

Table 5: Estimated Diesel PM Emissions per Vessel Call and 2002 Port Calls

Vessel Type	POLA 2001 Diesel PM Emissions Per Vessel Call (T/Y-CALL)			POLA 2002 Vessel Calls	POLB 2002 Vessel Calls
	Transit*	Auxiliary – Transit	Auxiliary – Hotelling		
Auto	0.0904	0.0055	0.011	154	109
Bulk	0.0887	0.0039	0.0374	86	453
Container	0.2019	0.0109	0.0581	1,673	1,304
Cruise	0.2675	0.065	0.0975	257	36
General Cargo	0.0807	0.0047	0.0234	158	126
Miscellaneous	0.0875	0	0.1143	3	207
Other Tug	0.0353	0	0	70	51
Tanker	0.0942	0.0058	0.0986	341	546

*Transit includes both transiting and maneuvering emissions. Vessel call estimates provided by POLA and POLB.

Adjustments to the hotelling emissions were also made based on additional data obtained subsequent to release of the Starcrest inventories. Specifically, corrections were made to the emission factor for auxiliary engines running on heavy fuel oil (HFO). In addition, the assumption on the percentage of engines running on HFO and marine distillate was modified to reflect new data obtained in an ARB survey conducted in 2004. (ARB, 2004) With respect to the emission factor, for ship auxiliary engines, Starcrest utilized a single diesel PM emission factor of 0.3 g/kW-hr in calculating auxiliary engine emissions, regardless of diesel fuel type. Based on a review of published emissions data, the emission factor for HFO should be much higher. In U.S. EPA's 2002 "Commercial Marine Emission Inventory Development" report prepared by ENVIRON International Corporation, an emission factor of 1.74 g/kW-hr is reported for engines running on HFO with a 3% sulfur content. (Environ, 2002) ARB staff adjusted this emission factor to 1.5 g/kW-hr based on the average sulfur content of HFO reported as being used in the 2004 ARB survey and retained the 0.3 g/KW-hr factor for auxiliary engines operating on marine distillate.[7] (See Appendix B.) Starcrest also assumed that 50% of the auxiliary engines were operating on HFO and 50% on marine distillate.

[7] In July 2002, the European Commission published, "Quantification of Emission from Ships Associated with Ship Movements between Ports in the European Community" (Entec Report). The Entec report recommended an emission factor of 0.8 g/kW-hr for auxiliary engines operating on HFO. ARB staff

ARB's survey results established that 75 percent of the auxiliary engines use HFO and 25 percent use marine distillate. These two modifications resulted in increasing the hotelling emissions by a factor of 4 over the estimates that would have resulted from growing the Starcrest values to 2002 based on the number of ship calls.

Cargo Handling Equipment

To project the emissions inventory for cargo handling equipment from 2001 to 2002, we estimated the annual growth factors by interpolating between the 2001 baseline year and the reported 2005 emissions developed for the No Net Increase (NNI) Task Force Project. We assumed linear growth between 2001 and 2005. The emissions for cargo handling equipment developed for the NNI project for 2005 reflect both the impacts from adopted control measures and any growth that has occurred in activity. This resulted in a net annual average growth rate of about 4.5%.

In addition, the emissions for cargo handling equipment were further modified to reflect emission inventory adjustments that ARB staff have developed to support a 2005 rule-making for cargo handling equipment. These adjustments result in about a 34% decrease in the emissions from cargo handling equipment for the year 2002. The main inventory changes to the OFFROAD model methodology used to estimate emissions from cargo handling equipment include: (1) revising zero hour emission factors, and (2) revising equipment useful life, based on the data provided in a 2004 ARB Cargo Handling Equipment Survey (ARB, 2004). The zero hour emission factors are revised by calculating composite emission factors based on the percentages of off-road, on-road, and retrofitted equipment. Because on-road and retrofitted engines generally have lower emission factors than off-road engines, these revisions resulted in lower zero hour emission factors. The useful life of the equipment is used to calculate the rate that the emissions increase over the life of the equipment. The 2004 ARB CHE Survey results showed that CHE equipment useful lives are significantly longer than the useful lives used in the OFFROAD Model. Since the deterioration rate is calculated as a percentage of the zero hour emissions divided by the useful life, the revised deterioration rates are lower than the original deterioration rates used in the OFFROAD Model. Because both the zero hour emission factor and the deterioration rate are lower than those used in OFFROAD Model, the resultant emissions for cargo handling equipment are lower than those previously predicted by the OFFROAD Model for use in the 2001 POLA emission inventory.

---

believes this emission factor would result in an underestimation of diesel PM emissions. Applying U.S. EPA's methodology to estimate emissions of sulfate PM from diesel-fueled engines to an auxiliary engine operating on 2.5% sulfur HFO would generate 0.8g/kW-hr of sulfate PM alone. Because there are many other components of PM such as ash and semi-volatile compounds, the 0.8 g/kW-hr emission factor appears to only account for the sulfate PM that is generated.

Harbor Craft, In-Port Heavy-duty Trucks, and In-Port Locomotives

To project the emissions inventory for commercial harbor craft, in-port trucks, and in-port locomotives from 2001 to 2002, we estimated the annual growth factors by interpolating between the 2001 baseline year and the reported 2005 emissions developed for the No Net Increase (NNI) Task Force Project. We assumed linear growth between 2001 and 2005 for each source category. The emissions of each category developed for the NNI project for 2005 reflect both the impacts from adopted control measures and any growth that has occurred in activity. The resulted net annual average growth rates are 0.0, -6.0, and 11.0 percent for commercial harbor craft, in-port heavy-duty trucks, and in-port locomotives, respectively.

Port of Long Beach

For POLB, Starcrest developed emission inventories for three categories: cargo handling equipment, in-port locomotives, and in-port heavy-duty vehicles using 2002 as the base year. The methodologies used in estimating emissions for these categories are similar to those used in estimating corresponding emission inventories for the POLA. To complete the emission inventories for POLB, ARB staff used the methodologies described below to estimate the emissions for ocean-going vessels (transiting, maneuvering, and hotelling) and commercial harbor craft vessels.

Ocean-going Vessels

To estimate emissions from ocean-going vessels for POLB, ARB staff assumed that the emissions per vessel call for each OGV type in POLB in 2002 is the same as that for the corresponding OGV type from POLA in 2001 (see Table 5). The emissions for each OGV type calling on POLB in 2002 are estimated by multiplying the emissions per call by the number of vessel calls for the corresponding OGV type at POLB in 2002, that is:

$$E_{POLB,2002,i} = \frac{E_{POLA,2001,i}}{CN_{POLA,2001,i}} x\, CN_{POLB,2002,i} \qquad (5)$$

where $E_{POLB,2002,i}$ is the estimated emission of OGV type i at POLB for 2002, $E_{POLA,2001,I}$ is the emission of OGV type i at POLA for 2001 (known), $CN_{POLA,2001,i}$ and $CN_{POLB,2002,i}$ are the call numbers from POLA in 2001 and from POLB in 2002 for OGV type i, respectively.

Cargo Handling Equipment

Consistent with the approach used to adjust the POLA cargo handling equipment emissions inventory, POLB 2002 cargo handling equipment inventory was decreased by 34 percent to reflect the inventory updates to the methodology used to estimate

emissions from cargo handling equipment. (See discussion provided under A. Port of Los Angeles.)

Harbor Craft

To estimate emissions from harbor craft vessels operating at POLB, ARB staff used the estimates of emissions from harbor craft vessels from ARB's 2004 commercial harbor craft emission inventory. These emission estimates were based on information on vessels registered (California Department of Fish and Game), permitted (California Public Utilities Commission), or documented (U.S. Coast Guard) with a "home port" listed as "Long Beach." These vessels registered as "Long Beach" were then allocated to the nine categories (commercial fishing, charter fishing, ferries/excursion, crew and supply, pilot, tugs, tows, work boats, and others) using the harbor craft vessel composition developed in ARB's 2003 Commercial Harbor Craft Survey (released in 2004). The emissions of each category for POLB in 2004 were estimated using the emission density (emission/per vehicle per category) multiplied by the corresponding vessel number in each category, that is:

$$E_{POLB,2004} = \sum_{i=1}^{2}\sum_{j=1}^{9}\left(\frac{E_{statewide,2004}(i,j)}{N_{statewide,2004}(i,j)}\right) x\, N_{POLB,2004}(i,j) \qquad (6)$$

where $E_{POLB, 2004}$ is the estimated emissions for all harbor craft vessels at POLB for 2004, $E_{statewide, 2004}(i, j)$ is the estimated emission for engine type i and harbor craft vessel type j in the statewide for 2004, $N_{statewide, 2004}(i, j)$ and $N_{POLB, 2004}(i, j)$ are the numbers of harbor craft type j for engine type i in the statewide and in POLB for 2004 respectively, i is the index for engine type (propulsion and auxiliary), and j is the index for harbor vessel type (j = 1 to 9, defined above).

Consistent with the growth projections developed for the NNI project, it was assumed no growth in harbor craft emissions between 2001 and 2005. Based on this assumption, we assumed that for POLB, the total emissions of harbor craft vessels in the 2002 baseline year are equal to that in 2004 as calculated above.

In-Port and Out-of-Port Emissions Allocation

The emissions of different source categories are distributed at various locations in the ports and over the offshore ocean water surfaces. To investigate spatial effects of emission sources on the nearby neighborhoods, the total emissions of the two ports are spatially allocated into two broad areas: in-port and out-of-port. In-port refers to the area inside the breakwater of the ports, which is approximately 5 miles from the shoreline; the out-of-port refers to the ocean water surface beyond the breakwater, extending up to 50 miles from the ports. The land-based emissions resulting from heavy-duty truck and locomotive activities outside of the Port boundaries are not included in the "out-port" for this modeling analysis.

Emission Inventory Summary

Emission estimates by source category for POLA and POLB in 2002 are summarized in Figure 3 and Table 6. As can be seen, for both ports, OGVs (transit and maneuvering) are the biggest contributor to the combined total emissions. The next highest emission source is the hotelling of ship's auxiliary engines at berth, followed by commercial harbor craft. Cargo handling equipment is the fourth largest, in-port trucks fifth, and in-port locomotives are last. Based on the total combined emissions for the two ports, OGV accounts for about 53 percent, hotelling accounts for 20 percent, harbor craft accounts for 14 percent, cargo handling equipment accounts for 10 percent, in-port truck accounts for 2 percent, and in-port locomotive accounts for 1 percent. The emissions from POLA comprise about 55 percent of the total emissions from the two ports. The in-port and out-of-port emissions for both ports are presented in Figure 4. The in-port emissions comprise about 43 percent of the total emissions in the ports, and the remaining 57 percent occurs in over water area outside the breakwater. By source category, only OGVs and commercial harbor craft have emissions generated outside the breakwater. OGV comprises about 90 percent of the total out-of-port emissions, while commercial harbor craft accounts for the remaining 10 percent.

Table 6: 2002 Estimated Diesel PM Emissions for the POLA and POLB

	Diesel PM Emissions Tons per Year					
	Source Category					
	OGV	HOTEL	CHC	CHE	IPT	IPL
POLA	515	165	178	78	18	11
POLB	427	178	66	94	23	7
Combined	942	343	244	172	41	18

Note: OGV – Oceangoing vessels; HOTEL – Ship's auxiliary engine hotelling; CHC – Commercial harbor crafts; CHE –Cargo handling equipment; IPT – In-Port heavy-duty trucks; IPL – In-Port locomotive.

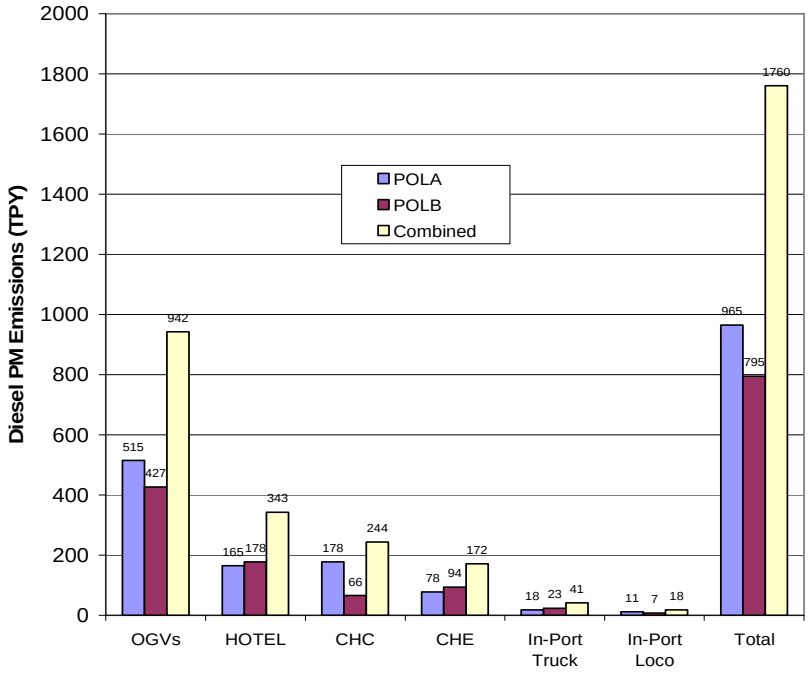
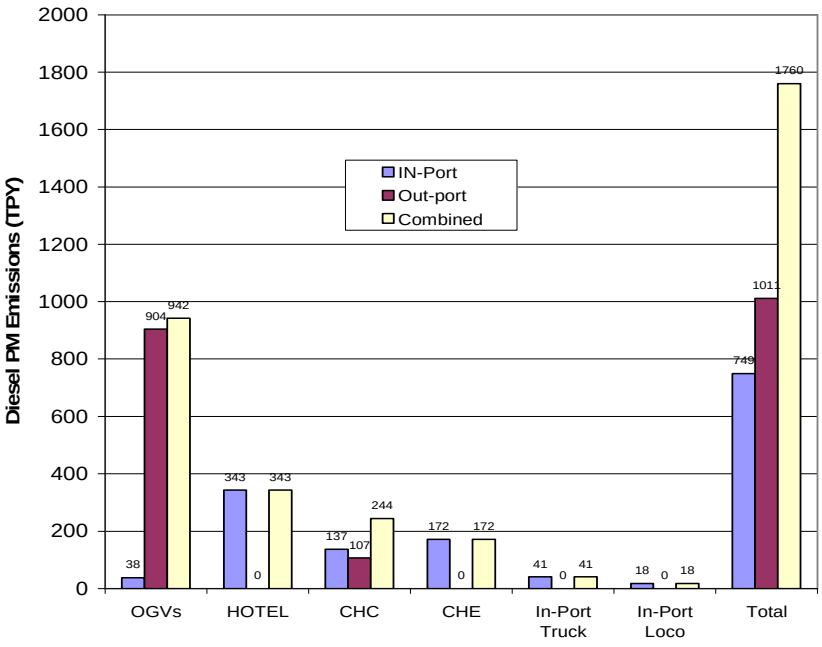


Figure 3: Estimated 2002 Diesel PM Emissions for POLA and POLB

Notes: OGV = Ocean-going Vessels; Hotel = Ship Auxiliary Engine Hotelling; CHC = Commercial Harbor Craft; CHE = Cargo Handling Equipment; In-Port Loco = In-Port Locomotives



VIII. Figure 4: In-Port and Out-of-Port Distribution of POLA and POLB Diesel IX. PM Emissions

Notes: OGV = Ocean-going Vessels; Hotel = Ship Auxiliary Engine Hotelling; CHC = Commercial Harbor Craft; CHE = Cargo Handling Equipment; In-Port Loco = In-Port Locomotives

III. AIR DISPERSION MODELING

In this chapter, we describe the air dispersion modeling performed to estimate the downwind dispersion of diesel PM exhaust emissions resulting from the activities at POLA and POLB. A description of the air quality modeling parameters, including air dispersion model selection, modeling domain, emission source distribution/allocation, model parameters, meteorological data selection, and model receptor network, is provided.

Air Dispersion Model Selection

Air quality models are often used to simulate atmospheric processes for applications where the spatial scale is in the tens of meters to the tens of kilometers. Selection of air dispersion models depends on many factors, such as, characteristics of emission sources (point, area, volume, or line), the type of terrain (flat or complex) at the emission source locations, and source receptor relationships. For this study, ARB staff selected the U.S. EPA Industrial Source Complex Model Short Term Version 3 (ISCST3, Version 02035) to simulate impacts at nearby receptors due to diesel PM emissions. The ISCST3 model is a micro-scale, steady-state Gaussian plume dispersion model applicable for estimating impacts from a wide variety of emission release patterns (point, area, line, and volume) such as those found at the ports for distances up to about 50 kilometers. The model may be used to predict annual average concentrations. ISCST3 is also able to simulate the dispersion of emissions generated from multiple sources and accommodate both continuous and intermittent sources in flat and complex terrain. ARB staff has successfully used ISCST3 model to assess public heath risk impacts of diesel PM emitted from the Roseville Railyard on nearby residential areas.

Model Domain and Receptor Network

The modeling receptor domain (study area) spans a 20 x 20 mile area as shown in Figure 5a. The domain includes both the ports, the ocean surrounding the ports, and nearby residential areas which have a population of about 2 million residents. Diesel PM emissions are released within the modeling receptor domain as well as beyond the receptor network for ocean-going vessels (see Figure 5b). The land-based portion of the modeling receptor domain, excluding the property of the ports, comprises about 65 percent of the modeling domain. A Cartesian grid receptor network (160 x 160 grids) with 200 m x 200 m resolution is used in this study. This network is convenient to identify the emission sources within the ports with respect to the receptors in the nearby residential areas. Since the exposure assessment was not designed to identify hot spots, a finer grid receptor network was not used. While receptors within the ports were included in the network, the risks from these on-site receptors were excluded from the final risk analyses. The elevation of each receptor within the modeling domain was determined from the United States Geological Service topographic data.

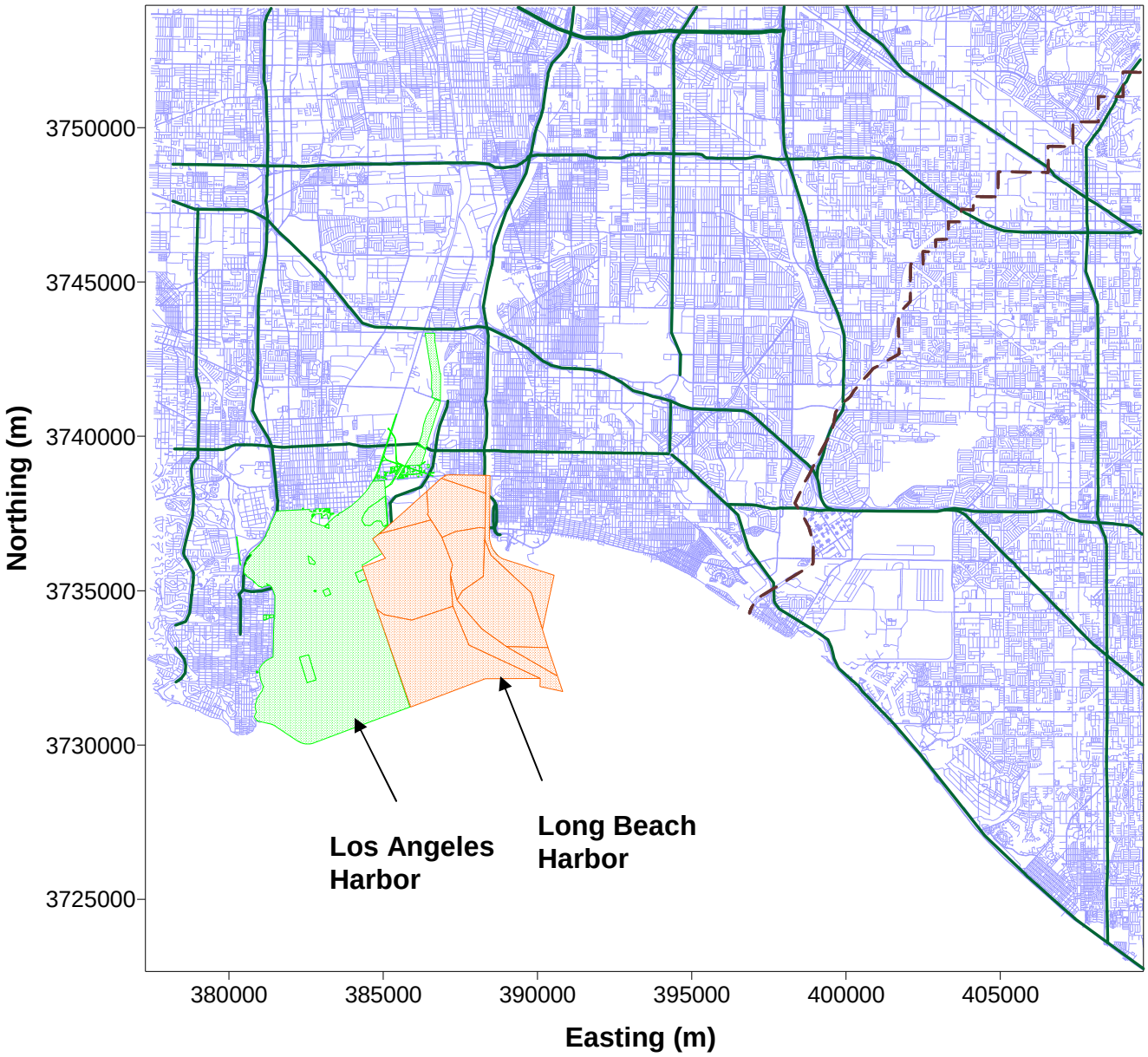


Figure 5a. Modeling Receptor Domain for the Ports of Los Angeles and Long Beach

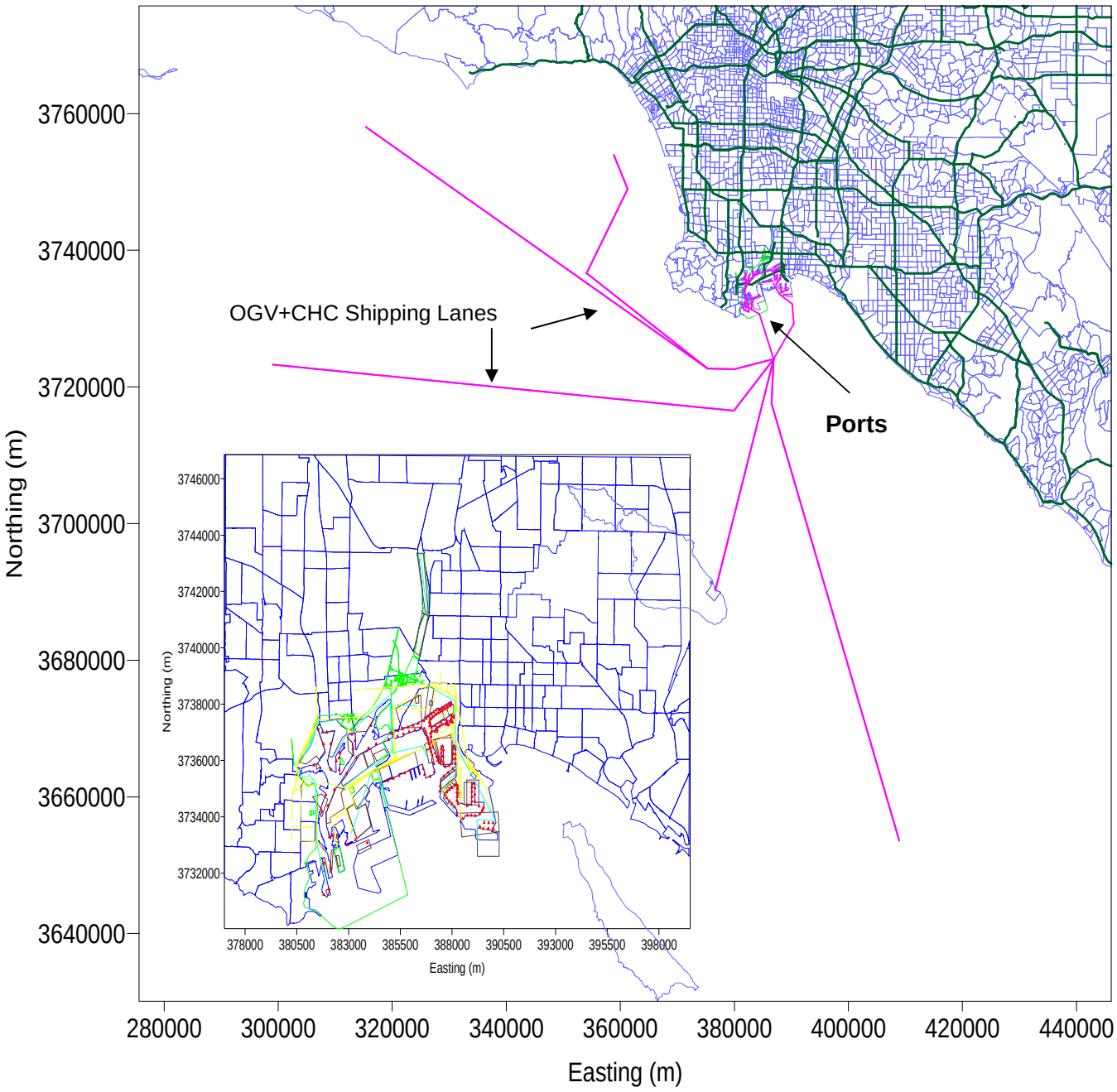


Figure 5b. Depiction of the Emission Source Locations (On the electronic version of the document, the following color codes are used to designate emission sources: Magenta = OGV+CHC, Dark Brown = CHE, Yellow = IPT, Blue = IPL, Red = Hotelling)

Model Parameters

The emission sources in the ports are characterized as area sources except for ship hotelling, which is modeled as individual point sources. Model parameters for area

sources include emission rate/strength, release height, lengths of X and Y sides of rectangular areas or vertices for polygons, and initial vertical (σ_{zo}) dimensions of the area source plume. Model parameters for point sources include emission rate, stack height, stack diameter, stack exhaust temperature, and stack exhaust exit velocity.

The OGV emissions are simulated as area sources. Starcrest provided the coordinates to establish links. The link widths in the ports and in the shipping lanes over the ocean water surface are assumed to be 160 m and 800 m, respectively. Commercial harbor craft emissions are simulated similar to the OGVs. The links are identical to those of OGVs. Cargo handling equipment emissions are simulated as area sources with the polygon features of the dispersion model. Locomotive emissions are also simulated as area sources. The links were established based on the nodes provided by Starcrest and/or estimated by ARB staff. Each link width is assumed to be 20 m. The terminal and off-terminal heavy-duty trucks are simulated similar to the railroad locomotives, except that the link width is assumed to be 35 m (three lanes in each direction + 3 meters wake width on each side). As mentioned previously, the hotelling emissions from ship auxiliary engines are simulated as individual point sources at the berths. Because stack information was not available for individual engines, the average stack height data (43 meters) provided in the Starcrest inventory report was applied to all hotelling engines. The modeling parameters for each of the emission source categories are summarized in Table 7.

Table 7: Emission Source Model Parameters

Model Parameter	OGVs	CHC	CHE	RAIL	TRUCK	HOTEL
Release Height (m)	50	6	2.4 – 3.9	5	4	H =43 m T = 618 K V = 16 m/s D = 0.5 m
Link Width (m)	-	-	-	20	35	
Link Width in Ports (m)	160	160	-	-	-	
Link Width in Shipping Lane (m)	800	800	-	-	-	
σ_{zo} (m)	23.26	2.79	1.1 – 1.8	2.33	1.86	

Note: OGV = Ocean-going vessels, CHC = commercial harbor craft, CHE = cargo handling equipment, H = release height, T = exhaust temperature, V = exhaust exit velocity, and D = stack diameter.

Spatial and Temporal Allocation of Emissions

Starcrest provided spatial emission allocation for all source categories at POLA and for three source categories - cargo handling equipment, In-port locomotives, and In-port trucks at POLB. ARB staff used GIS mapping to allocate the emissions for POLB OGVs, hotelling, and commercial harbor craft based on the descriptions provided by Starcrest. ARB staff temporally allocated all the emission sources at both ports based on discussions with terminal operators and locomotive representatives. The assumptions for the temporal distribution of the emissions are listed in Table 8. The ARB staff assumed that the temporal distribution of the emissions is the same for both ports.

Table 8: Temporal Distribution of Diesel PM Emissions at POLA and POLB

Category	Time Period	Activity Distribution	Hours Per Day
Ocean-Going Vessel	4 am – 8 pm	80%	16
	8 pm – 4 am	20%	8
Hotelling	midnight - midnight	100%	24
Harbor Craft	6 am – 6 pm	80%	12
	6 pm – 6 am	20%	12
Cargo Handling	8 am – 5 pm	80%	9
	5 pm – 3 am	15%	10
	3 am – 8 am	5%	5
Trucks	6 am – 6 pm	80%	12
	6 pm – 6 am	20%	12
Locomotives	midnight - midnight	100%	24

E. Meteorological Data

Meteorological data are selected on the basis of spatial and temporal representativeness. There are two available meteorological measurement sites around the ports: Wilmington and North Long Beach[1] (see Figure 6). The Wilmington site is about one mile away from the ports and the measurements were collected in 2001. The North Long Beach site is about four miles away from the ports where data are archived for 1981. The South Long Beach site in Figure 6 is an air quality monitoring site where meteorological data are not archived. Normally five years of the latest consecutive meteorological data are preferred by U.S. EPA for long term dispersion analyses. However, one year of data are acceptable if the data are site specific according to U.S. EPA. Therefore, ARB staff believe the Wilmington data to be the better data with respect to spatial and temporal representativeness.

The meteorological data from the Wilmington site includes hourly wind direction, wind speed, and atmospheric temperature. Atmospheric stability, rural mixing height, and urban mixing height are developed following the U.S. EPA guidance. Figure 7 presents the wind rose and Figure 8 provides the wind and stability class frequency distributions for the meteorological conditions at the Wilmington site. Based on the yearly statistics, the annual average wind speed at Wilmington is 1.8 m/s with the predominant wind directions from the northwest (about 22 percent of the time) and from the south (about 14 percent of the time). For the ISCST3 air quality model, urban dispersion coefficients are used because the area at the impacted receptors is comprised of industrial, commercial and compact residential land uses.

[1] The King Harbor meteorological monitoring station is located about 10 miles northwest of the ports on the ocean-side. To determine if diesel PM emissions transported on the ocean-side would be better simulated using King Harbor meteorological data we conducted a sensitivity study (detailed in Appendix C) and found that there is not a significant difference between using Wilmington and using King Harbor meteorological data sets based on the population-weighted risks in the modeling domain.

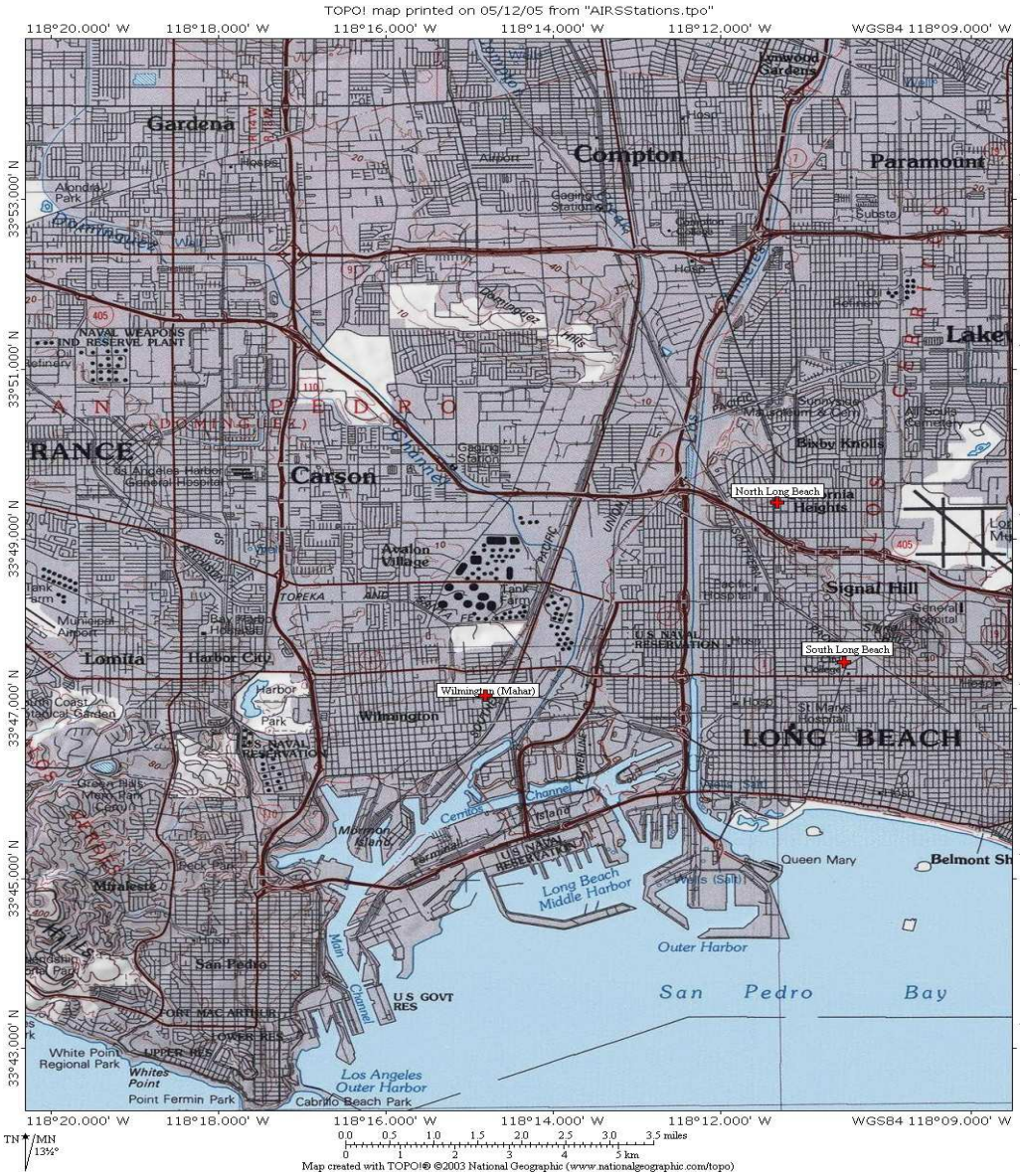


Figure 6: Locations of Surface Meteorological Measurement Sites around the Ports

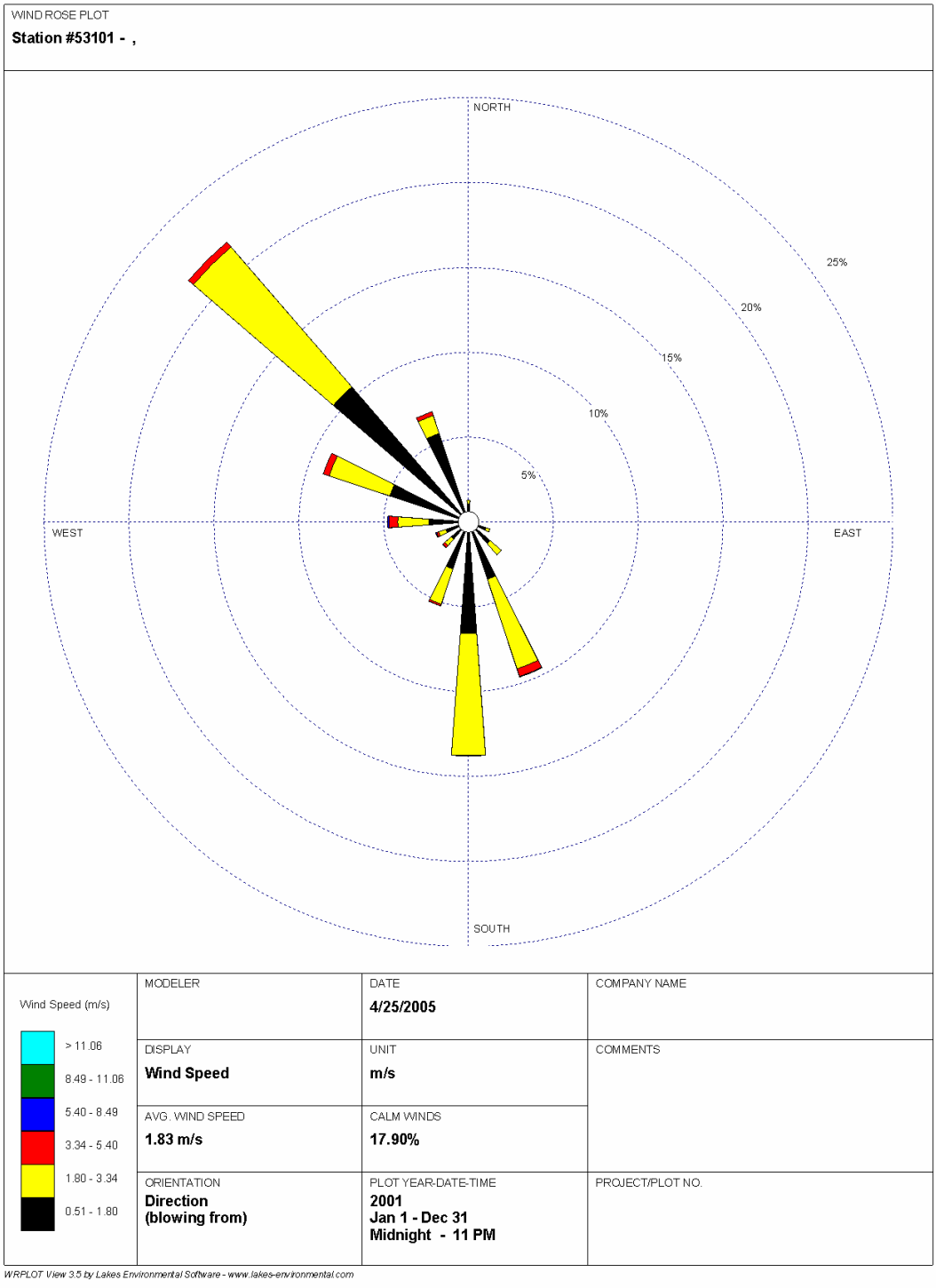


Figure 7: Wind Rose for the Period 1/1/01 to 12/31/01 at the Wilimington Meteorological Site

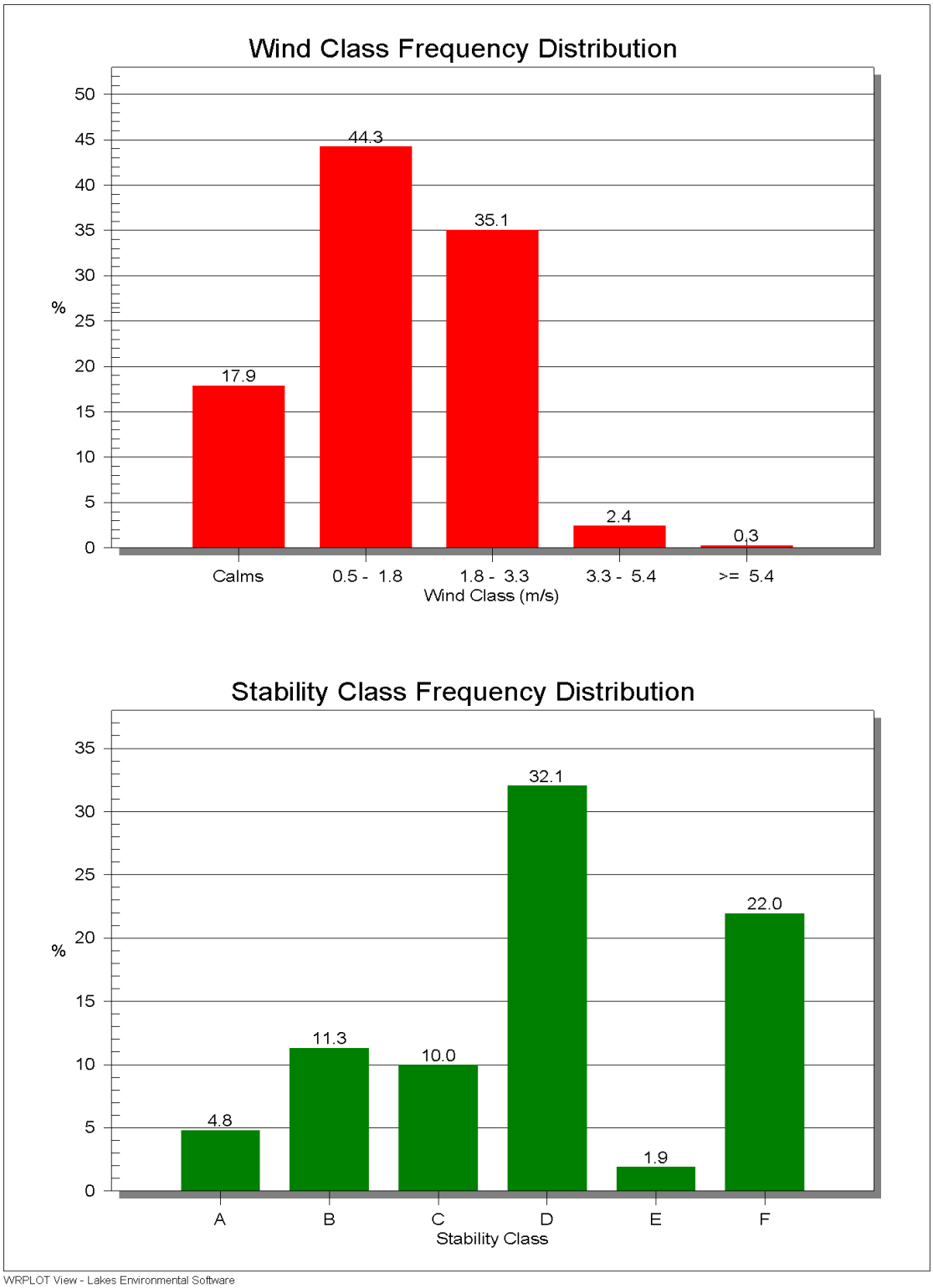


Figure 8: Wind Speed and Stability Class Frequency Distribution at Wilmington Meteorological Site.

IV. EXPOSURE ASSESSMENT

In this chapter, we briefly describe the OEHHA guidelines on health hazard risk assessment and how we used the guidelines to characterize potential cancer risks associated with exposure to diesel exhaust from the ports. We also present preliminary air dispersion modeling results for the ports.

OEHHA Guidelines

The Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA guidelines, 2002a) outlines a tiered approach to risk assessment, providing risk assessors with flexibility and allowing for consideration of site-specific differences. Tier- 1 is a standard point-estimate approach that uses a combination of the average and high-end point-estimates. This approach will be used in this risk assessment.

The OEHHA guidelines recommend that all health hazard risk assessments present a Tier-1 evaluation for the Hot Spots Program, even if other approaches are also presented. For Tier-1, OEHHA provides two values for breathing rate, one representing an average and another representing a defined high-end value. The average and high-end of point-estimates are defined in terms of the probability distribution of values for that variate. The mean (65th percentile) represents the average values for point-estimates and the 95th percentile represents the high-end point-estimates from the distributions identified in the OEHHA guidelines. In 2004, ARB recommended the interim use of the 80th percentile value (the midpoint value of the 65th and 95th percentile breathing rate) as the minimum value for risk management decisions at residential receptors for the breathing pathway. The 80th percentile corresponds to a breathing rate of 302 Liters/Kilogram-day (302 L/Kg-day). This risk assessment will use the 302 L/Kg-day value and will assume that the receptors will be exposed for 24 hours per day for 70 years. If a receptor is exposed for a shorter amount of time to the annual average concentration of diesel PM the cancer risk will be proportionately less.

The relationship between a given level of exposure to diesel PM and the cancer risk is estimated by using the diesel PM cancer potency factor. A description of how the diesel cancer potency factor was derived can be found in the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant (ARB, 1998) and a shorter description can be found in the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors (OEHHA 2002b). The use of the diesel unit risk factor for assessing cancer risk is described in the OEHHA Guidelines. The potential cancer risk is estimated by multiplying the inhalation dose by the cancer potency factor (CPF) of diesel PM ($1.1\ (mg/kg\text{-}d)^{-1}$).

Exposure Assessment

A number of variables can have significant impacts on exposure. These include emission estimates, meteorological conditions, and exposure duration of residents. The emissions affect the risk levels linearly; as emissions increase, so does the risk. Meteorological conditions can have a large impact on the resultant ambient concentration of a toxic air pollutant with higher concentrations found along the predominant wind direction. Key variables in human exposure are a person's proximity to the emission plume, how long he or she breathes the emissions (exposure duration), the person's breathing rate, and body weight. The longer the duration of exposure, the greater the potential risk.

Risk Characterization

Risk characterization is defined as the process of obtaining a quantitative estimate of risk, including a discussion of its uncertainty. The risk characterization process integrates the results of air dispersion modeling and relevant toxicity data (e.g., diesel PM cancer potency factor) to estimate potential cancer or noncancer health effects associated with contaminant exposure. It is important to note that no background or ambient diesel PM concentrations are incorporated into the risk quantification. The risk assessment only considers the cancer risk by the inhalation pathway because the risk contributions by other pathways of exposure are known to be negligible relative to the inhalation pathway and difficult to quantify.

As stated in Chapter III, the modeling receptor domain of 20 mi x 20 mi with a grid resolution of 200 m x 200 m was used in the modeling exercise. The effective land area (excluding the Port property and the over water region) is about 255 square miles. The population within the modeling receptor domain is about 2 million based on the U.S. Census Bureau's year 2000 census data. The risk numbers, impacted areas, and affected population presented below are based on the effective land area within the modeling domain; that is, the risk, the area, and the population within the ports property and over the ocean surface are excluded from this analysis. Note that if the modeling domain expands, the risks, impacted areas, and affected population presented in this analysis would be changed.

Risk Characterization for All Emission Sources

Figure 9 shows the risk isopleths for all diesel PM emission sources from POLA and POLB superimposed on a map that covers the ports and the nearby communities. The risk contour of 100 in a million exceeds the modeling receptor domain in the north direction of the ports, which is about 10 miles away from the ports boundary. The area with predicted cancer risk levels in excess of 100 in a million within the modeling receptor domain is estimated to be about 94,000 acres, which is 57 percent of the effective land area within the modeling receptor domain (see Table 9). The area in which the risks are predicted to exceed 200 in a million is also very large, covering an area of about 29,000 acres (18 percent of the effective land area within the modeling receptor domain). The areas with the greatest impact have an estimated potential

cancer risk of over 500 in a million, which cover about 2 percent of the effective land area within the domain. The risk isopleths of 1000 and 1500 in a million occur on port property and the nearby ocean surfaces, which is not included in this study because people do not reside in these areas.

Using the U.S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries. As shown in Table 10, the affected population numbers for the risk ranges of 100-200, 200-500, and over 500 have been estimated to be about 724,000, 360,000, and 53,000, which account for 37, 18 and 3 percent of the total population within the modeling domain, respectively. In other words, nearly 60 percent of 2 million people live in the area around the ports that has predicted risks of greater than 100 in a million. Note that the risk isopleth of 10 in a million is not shown in Figure 9 because it exceeds the modeling receptor domain. Spatially, the emission sources are located at various locations on port property and the outside of the breakwater, thus the contributions of these emission sources to the nearby neighborhoods would be different. Below, we discuss the contributions from the various sources at the ports to the community risks.

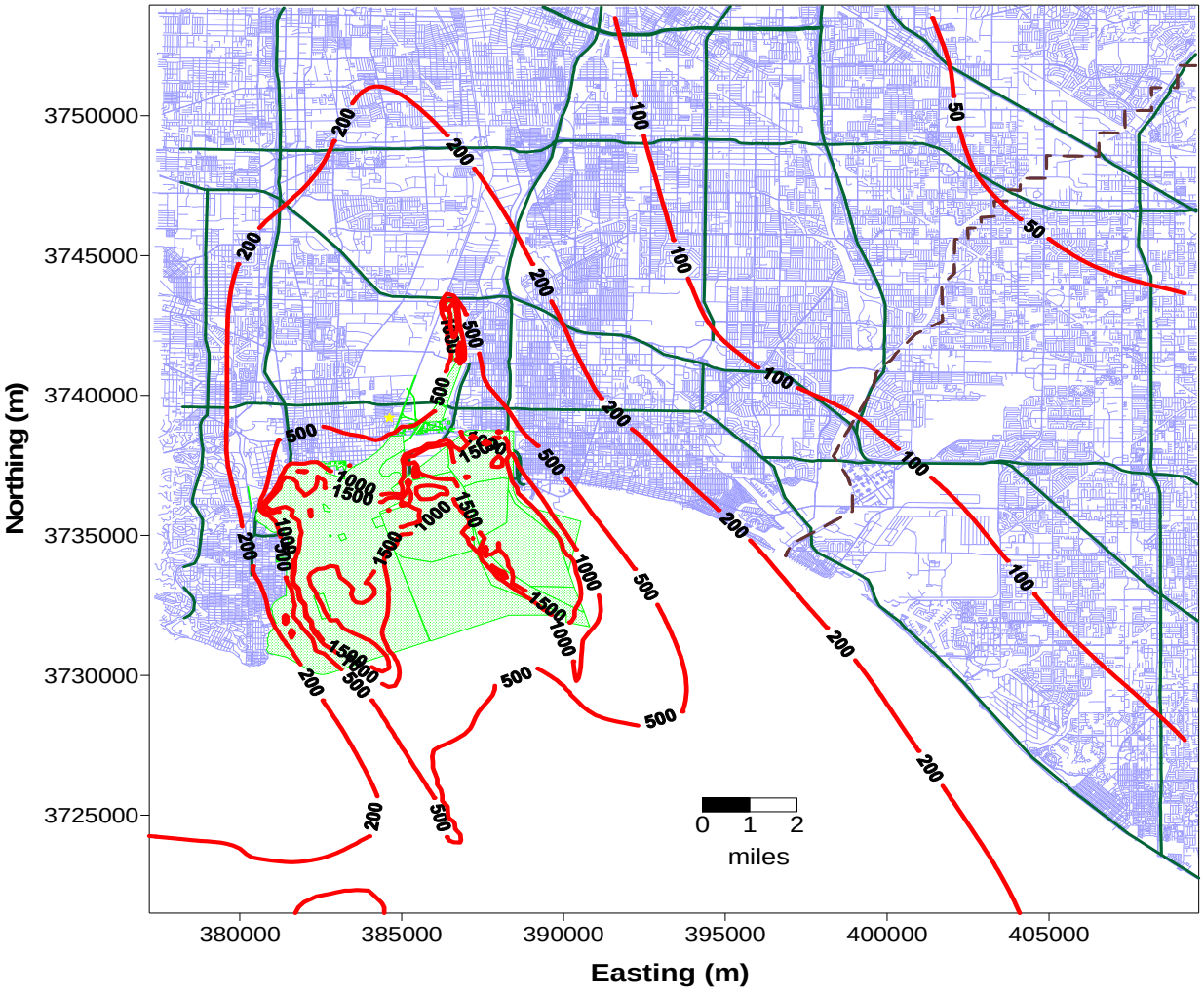


Figure 9. Estimated Diesel PM Cancer Risk from All Diesel-Fueled Engines at POLA and POLB (Wilmington Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Total Emissions = 1,760 TPY, Modeling Receptor Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Risk Characterization for Individual Emission Sources

The different emission sources are used at various locations on the ports property in the harbor and over ocean beyond the breakwater. Thus, the contributions of these emission sources to exposures in the nearby neighborhoods are different. As shown in Tables 9 and 10, the emissions from cargo handling equipment and on-port trucks resulted in areas within the nearby communities having risk levels exceeding 500 in a million while the highest risk levels associated with the other categories were between 200 and 500 in a million. Within the model domain, ship hotelling emissions and cargo handling equipment impacted the largest areas and affected more people than the other sources of emissions when considering the risk levels greater than 100 in a million. When considering risk levels greater than 10 in a million, all the port sources, other than in-port trucks and locomotives had similar impacts, affecting at least 119,000 acres and at least 1.4 million people. By source location, the impacts resulting from the in-port

emissions (within breakwater) are much larger than those resulting from the out-port emissions (outside of breakwater), although the emission magnitude of the former is less than the latter (750 TPY vs 1010 TPY). Quantitatively, within the modeling receptor domain, the population-weighted risk resulting from the in-port emissions is about 4.5 times of that resulting from the over water out-of-port emissions.

Table 9: Summary of Area Impacted by Risk Levels and Activity Categories (Acres)

Risk Level	OGV	HOTEL	CHC	CHE	IPT	IPL	COMBINED
Risk > 500	0	0	0	50	50	0	2,500
Risk > 200	110	2,036	20	410	160	40	29,000
Risk > 100	227	12,700	750	4,100	376	160	94,000
Risk > 10	163,435	160,470	125,250	119,000	29,750	11,240	163,435

Table 10: Summary of Population Affected by Risk Levels and Activity Categories (Number of People)

Risk Level	OGV	HOTEL	CHC	CHE	IPT	IPL	COMBINED
Risk > 500	0	0	0	3,200	205	0	53,000
Risk > 200	18	46,020	5,000	11,100	1,780	680	411,200
Risk > 100	1,810	221,567	22,960	82,000	8,270	4,330	1,135,000
Risk > 10	1,977,760	1,949,850	1,516,515	1,444,000	422,910	213,430	1,977,770

Notes:

9. OGV – Ocean-going vessels; HOTEL – Ship's auxiliary engine hotellng; CHC – Commercial harbor crafts; CHE –Cargo handling equipment; IPT – In-Port trucks; IPL – In-Port locomotive.
10. The model receptor domain of 20 mile x 20 mile for urban dispersion coefficients with a grid resolution of 200m x 200m was used. The effective modeling receptor domain (excluding the port properties and the ocean water) is estimated to be about 255 square miles. The calculations here are ONLY based on the effective modeling receptor domain.
11. The 80th percentile breathing rate for adults over 70-year lifetime was assumed.
12. Meteorological data from Wilmington (2001) are used for POLA and POLB.
13. The risks within both ports and over the ocean water were excluded for calculations of average risks and affected areas.
14. The estimated population in this Table is ONLY based on the modeling receptor domain using the U.S. Census Bureau's year 2000 census data.
15. If the modeling receptor domain expands, the numbers of population and area affected would be increased.
8. The combined column provides the population affected and area impacted for the cumulative impacts from all the emission sources. The individual impacts are not additives since the combined impacts are greater than the sum of the individual sources. For example, cargo handling equipment and commercial harbor craft emissions may impact the same location and population. While individually the impacts may result in cancer risk levels between 100 and 200 in a million, when you combine the impacts, the resulting risks could be greater than 200 in a million.

Below, we provide additional discussion on each of the contributions of each of the emission source categories and present the predicted risk isopleths for individual sources.

Ocean-Going Vessels

Figure 10 presents the predicted risk isopleths for the diesel PM emissions from the OGVs (transiting and maneuvering emissions only). The area impacted by these emissions is very large (has a large footprint) and many of the risk isopleths extend beyond the boundaries of the modeling receptor domain. The area within the modeling domain in which the cancer risks are predicted to be greater than 100 in a million is small, covering an area of about 227 acres with a population size of 1,800. The potential cancer risk levels between 50 to 100 in a million are located in nearby areas north of the ports. All areas within the modeling receptor domain are predicted to have an estimated potential cancer risk of over 10 in a million. From the point of view of the emission magnitude, OGVs contributed about half of the total emissions (940 of 1,760 TPY). This disproportional phenomenon can be attributed to the fact that the diesel PM emissions from OGVs are distributed over a very wide area and most of these emissions (about 96 percent) are emitted from the offshore shipping lanes which begin approximately 5 miles beyond the port breakwater and extend to about 50 miles away from the ports. In other words, only a small portion of the transiting and maneuvering emissions (about 4 percent) are emitted in the ports. In addition, the vessels have an average physical stack height of 43 meters above the water surface (final plume rise modeled as 50 m), resulting in diluted plumes over a wide area.

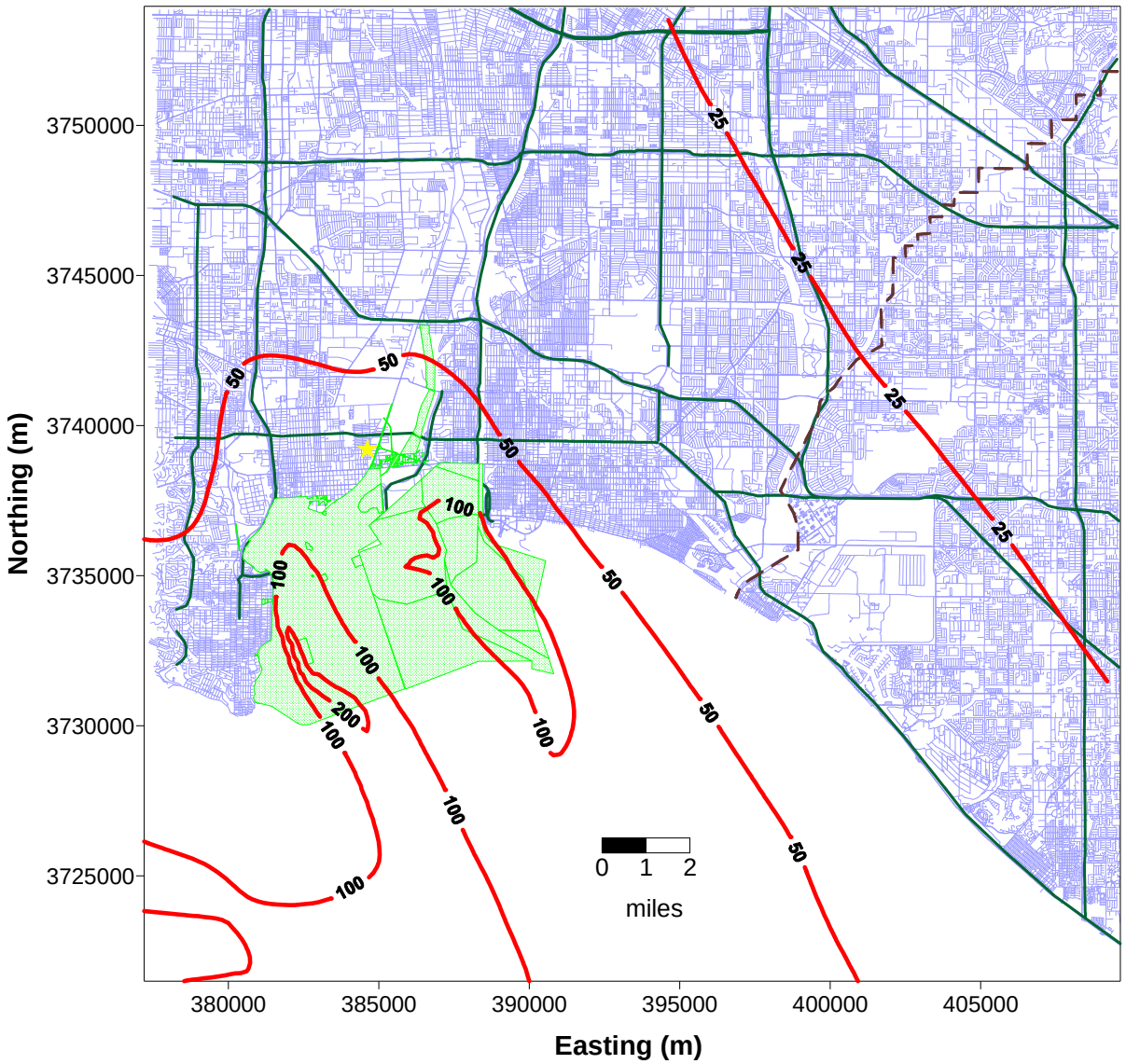


Figure 10. Estimated Diesel PM Cancer Risk from Ocean-Going Vessel's Activity at POLA and POLB (Wilmington Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 942 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Hotelling

The emissions from ship auxiliary engines' hotelling resulted in a significant risk impact to the nearby communities. As shown in Figure 11, the potential cancer risk level ranges from 50 to 200 in a million. The area in which the risks are predicted to exceed 100 in a million has been estimated to be about 12,700 acres with a population of 221,600. Hotelling emissions from auxiliary engines result in cancer risk levels over 10 in a million in about 98 percent of the effective modeling domain. Compared to the OGVs, the emission from the auxiliary engines hotelling is approximately 36 percent of the OGVs (343 TPY vs 942 TPY), but the predicted population-weighted average risk

from the hotelling is about 1.5 times of that from the OGVs. This is not surprising because the emissions from hotelling activities are located within the ports, which are close to nearby communities.

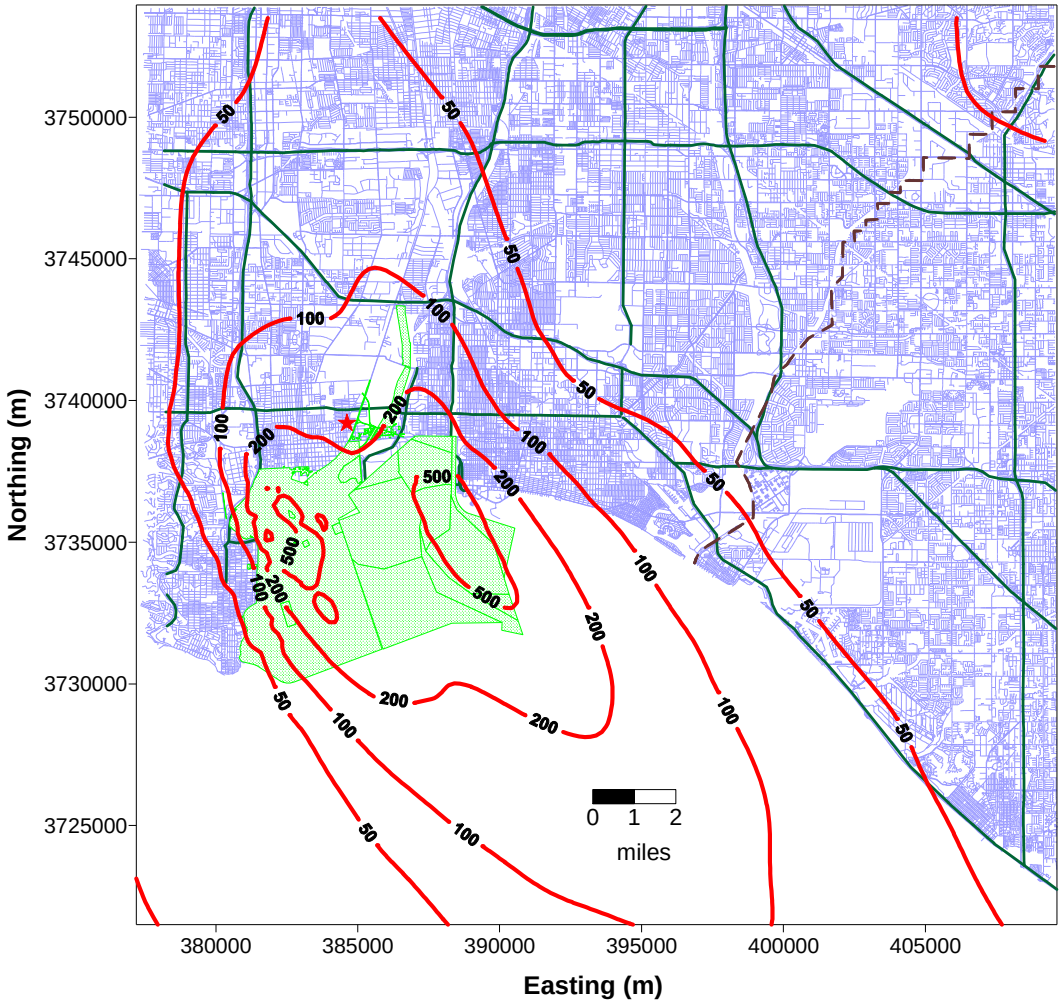


Figure 11. Estimated Diesel PM Cancer Risk from Ship Auxiliary Engines' Hotelling at POLA and POLB (Wilmington Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 343 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Commercial Harbor Craft

The emissions from commercial harbor craft resulted in a moderate risk level in the nearby communities around the ports (Figure 12). The area in which the risks are predicted to exceed 100 in a million has been estimated to be about 750 acres with a population of 23,000. Overall, about 77 percent of the effective modeling receptor domain have estimated cancer risk levels of over 10 in a million due to emissions from commercial harbor craft.

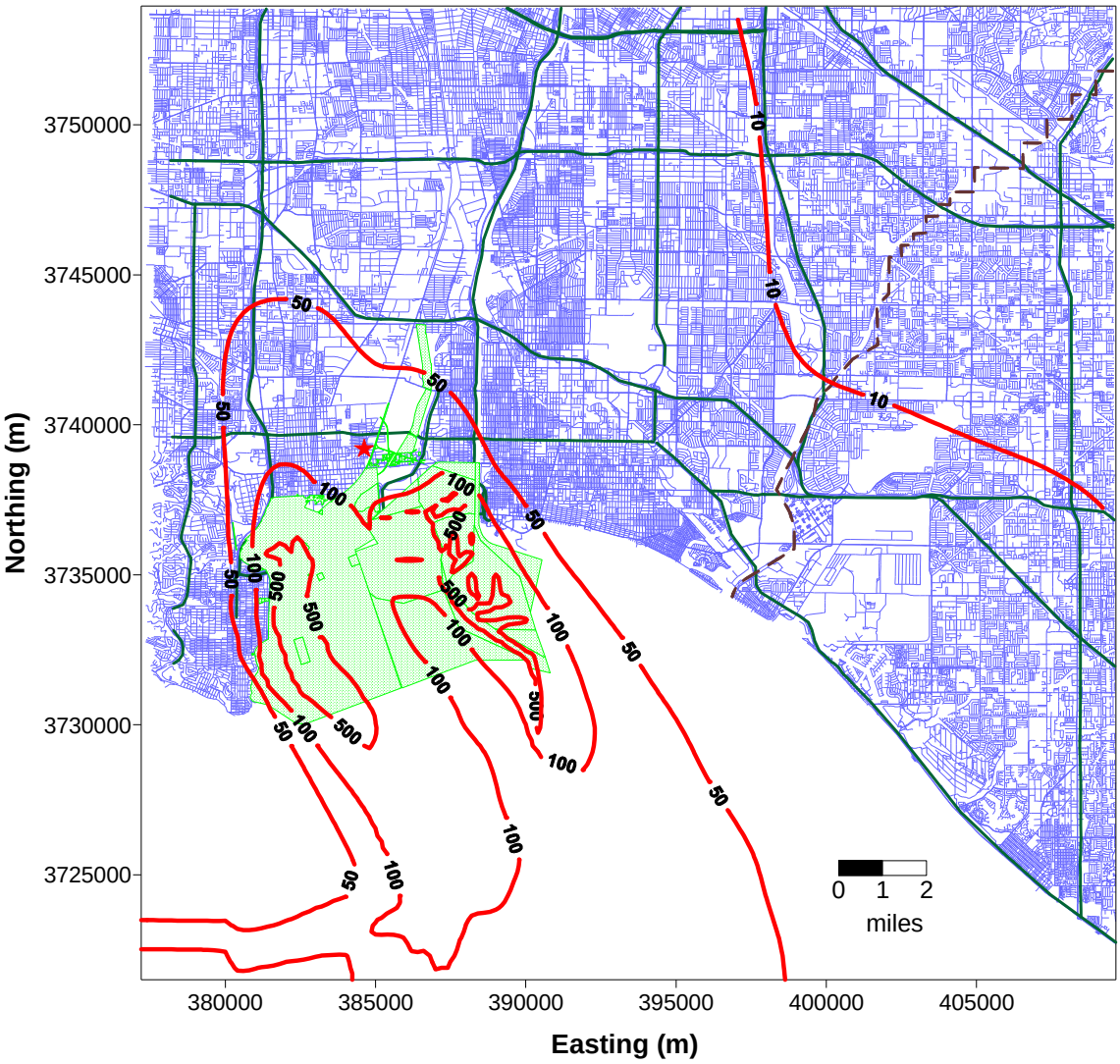


Figure 12. Estimated Diesel PM Cancer Risk from Commercial Harbor Craft Vessel Activity at POLA and POLB (Wilmington Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 244 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Cargo Handling Equipment

The ground-based activities of cargo handling equipment generated an estimated emission of about 172 TPY, which accounts for about 10 percent of the total emissions inventory for the ports. The emissions resulted in significant risk impacts on the nearby residential areas. As shown in Figure 13, the area in which the risks are predicted to exceed 100 in a million has been estimated to be about 4,100 acres with a population of 82,000. For the highest risk level of over 500 in a million, the impacted areas have been estimated to be about 50 acres and about 3,200 people living around the ports are

exposed to the risk level. Overall, about 73 percent of the effective modeling receptor domain has an estimated risk level of over 10 in a million and about 73 percent of 2 million people who are living in the domain are exposed to the risk level. From Figure 13, we can see that the finger-like isopleth jutting to the north exists. This is caused by sources located within the narrow finger-like port property that contribute about 17 TPY of emissions to the downwind direction area (north). Based on the population-weighted spatial average risk, the emission sources from cargo handling equipment are the second biggest contributor to the nearby communities.

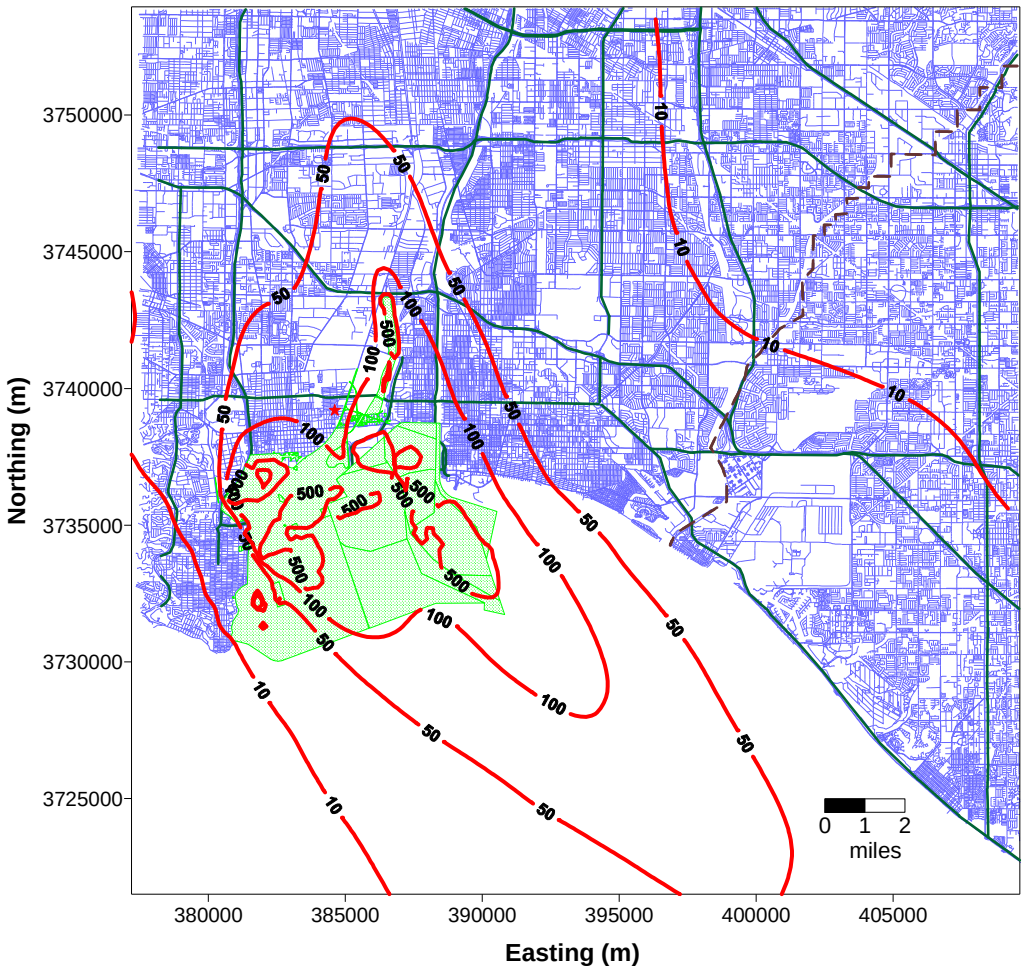


Figure 13. Estimated Diesel PM Cancer Risk from Cargo Handling Equipment Activity at POLA and POLB (Wilmington Met Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 172 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

In-Port Trucks and Locomotives

Compared with other emission sources, the emissions from in-port heavy-duty trucks and locomotives are relatively small, accounting for about 3 percent of the emissions inventory. These ground-based emissions resulted in localized health risk impacts. As shown in Figures 14 and 15, the higher risk level of 100 to 200 in a million occurs on port property. The exposure risk level to the nearby residents is relatively small. For in-port heavy-duty trucks, about 18 percent of the effective modeling domain has an estimated risk level of over 10 in a million, affecting about 21 percent of the residents within the model domain. Similarly, for in-port locomotives, about 7 percent of the effective modeling receptor domain has an estimated risk level of over 10 in a million, affecting about 11 percent of the residents. It is important to note that there are emissions of heavy-duty trucks and locomotives that are released beyond the boundaries of the ports and impact residents living along freeways, rail yards and rail corridors, and distribution centers. The impacts from these emissions (e.g., freeway diesel PM) are not included in this analysis.

In this study, we did not consider the diesel PM emissions of on-road heavy-duty trucks and locomotives related to port activities that occur off-port boundary within the SCAB (regional emissions). We estimated the off-port regional diesel PM emissions to be about 206 TPY for the both ports, or 10 percent of the total port-related emissions (206 TPY vs 1,970 TPY). These regional emissions are distributed throughout the SCAB and may result in localized health impacts to people who are live near freeways and railroad corridors within the SCAB. These health impacts will be evaluated in future studies.

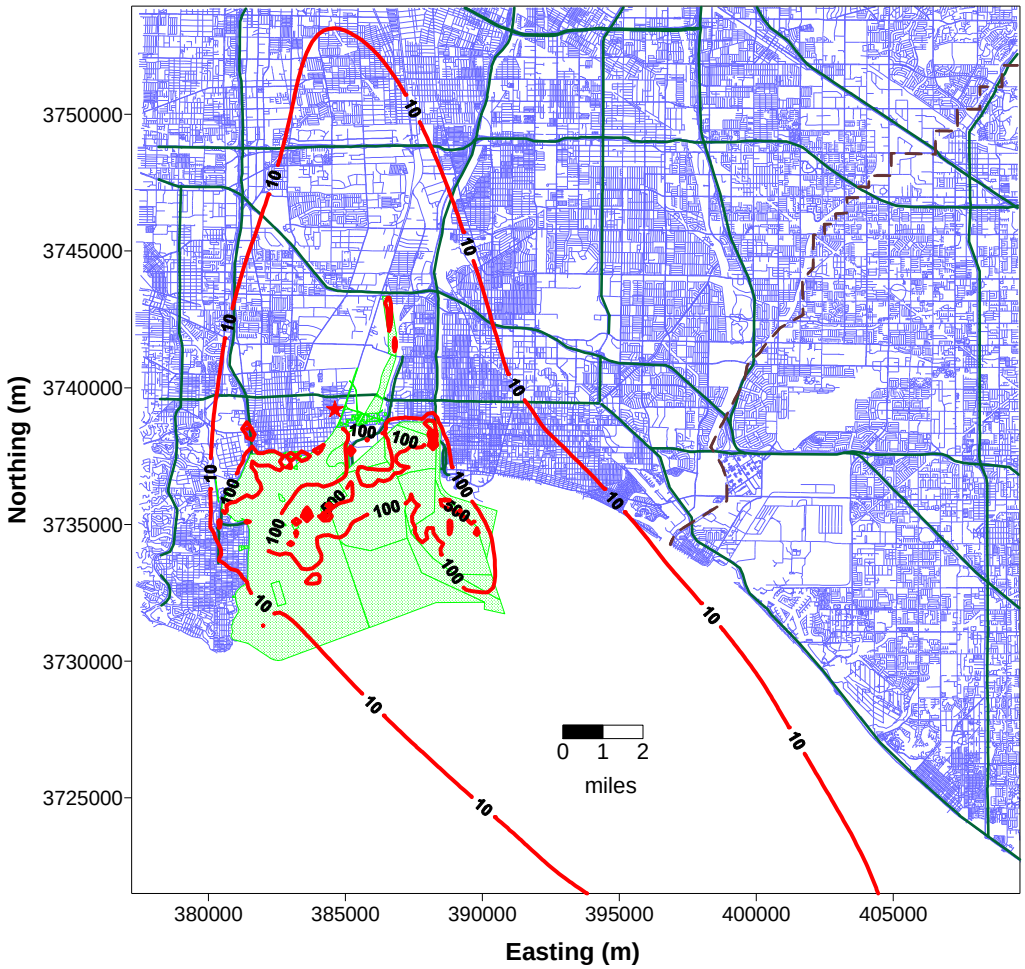


Figure 14. Estimated Diesel PM Cancer Risk from In-Port Heavy Duty Trucks at POLA and POLB (Wilmington, Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 41 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

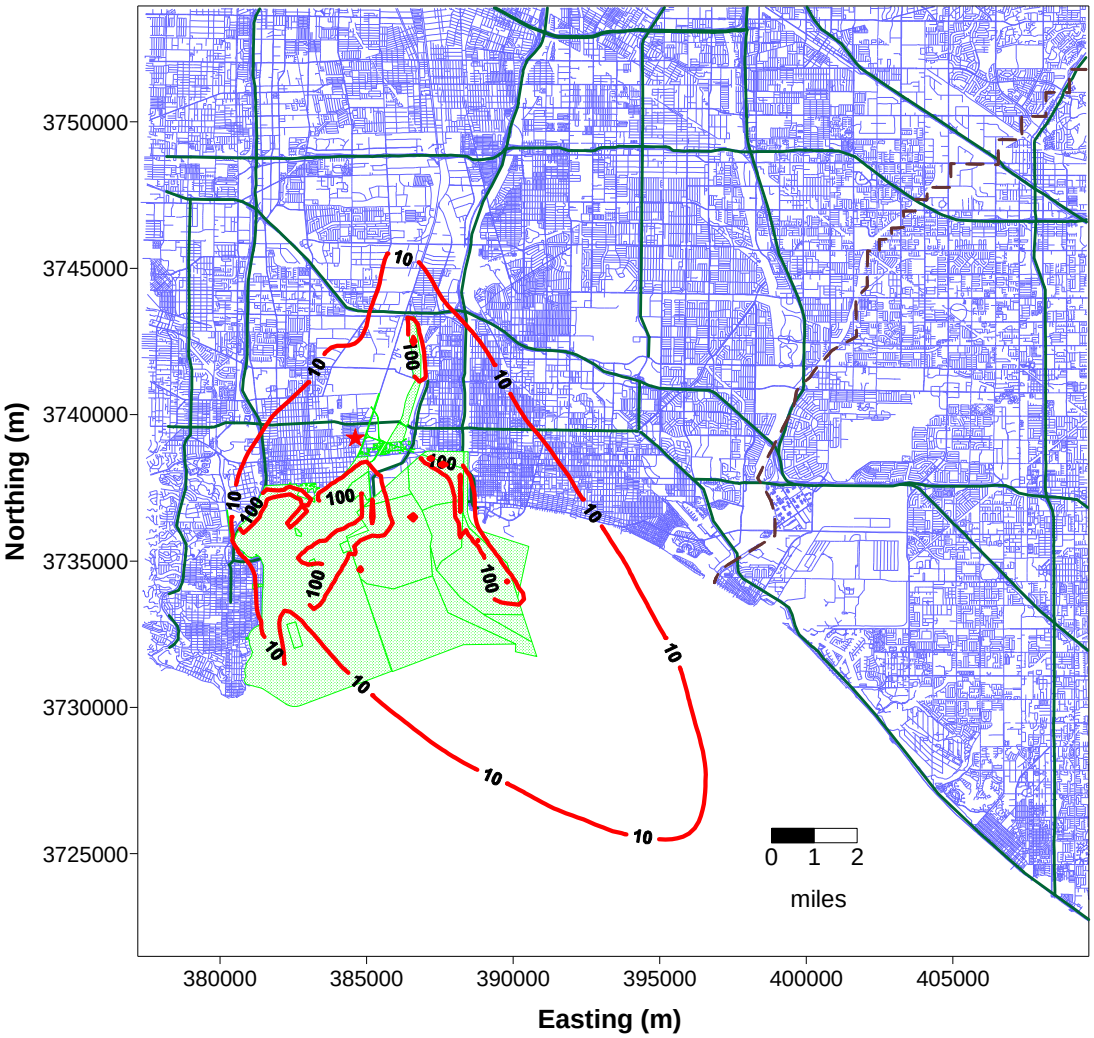


Figure 15. Estimated Diesel PM Cancer Risk from In-Port Locomotive Activity at POLA and POLB (Wilmington, Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 18 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

In-Port vs Out-of-Port Emissions

As mentioned previously, a comparison between the impacts from in-port, i.e., those emissions that occur on port land-based property and within the breakwater zone, and the out-of-port, i.e., those emissions from oceangoing ships and harbor craft that occur beyond the breakwater, was made. Although the in-port activities generate fewer emissions than the out-of-port activities (750 TPY vs 1010 TPY), the in-port emissions resulted in much higher health risk level in the nearby communities than the out-of-port emissions (see Figures 16 and 17). Quantitatively, based on the population-weighted average cancer risk within the modeling domain, the potential cancer risk level resulting from the in-port activities is about 4.5 times of that resulting from the out-of-port activities. Possible reasons have been explained above. That is, there are greater

distances between the out-of-port emission sources and the receptors in the nearby communities. This analysis identifies the emission sources within the ports as the most significant to health risk to the nearby communities.

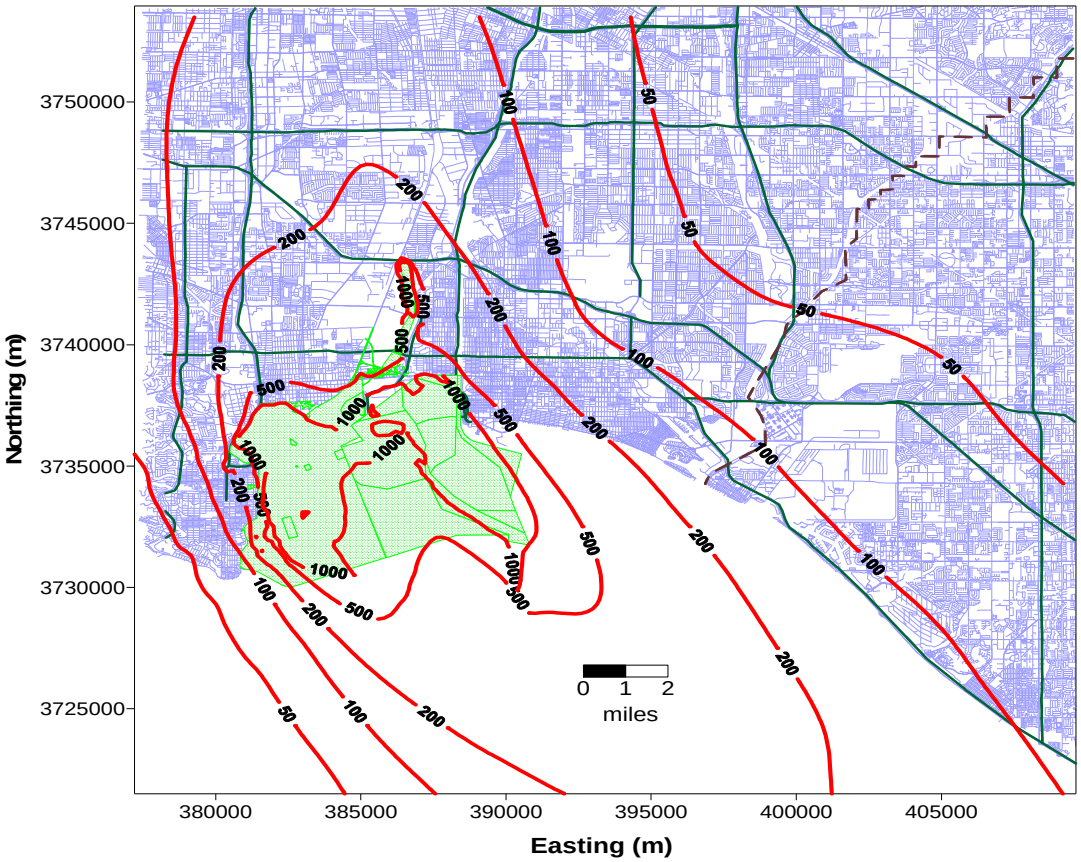


Figure 16. Estimated Diesel PM Cancer Risk from All In-Port Diesel Engine Activity at POLA and POLB (Wilmington, Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 750 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

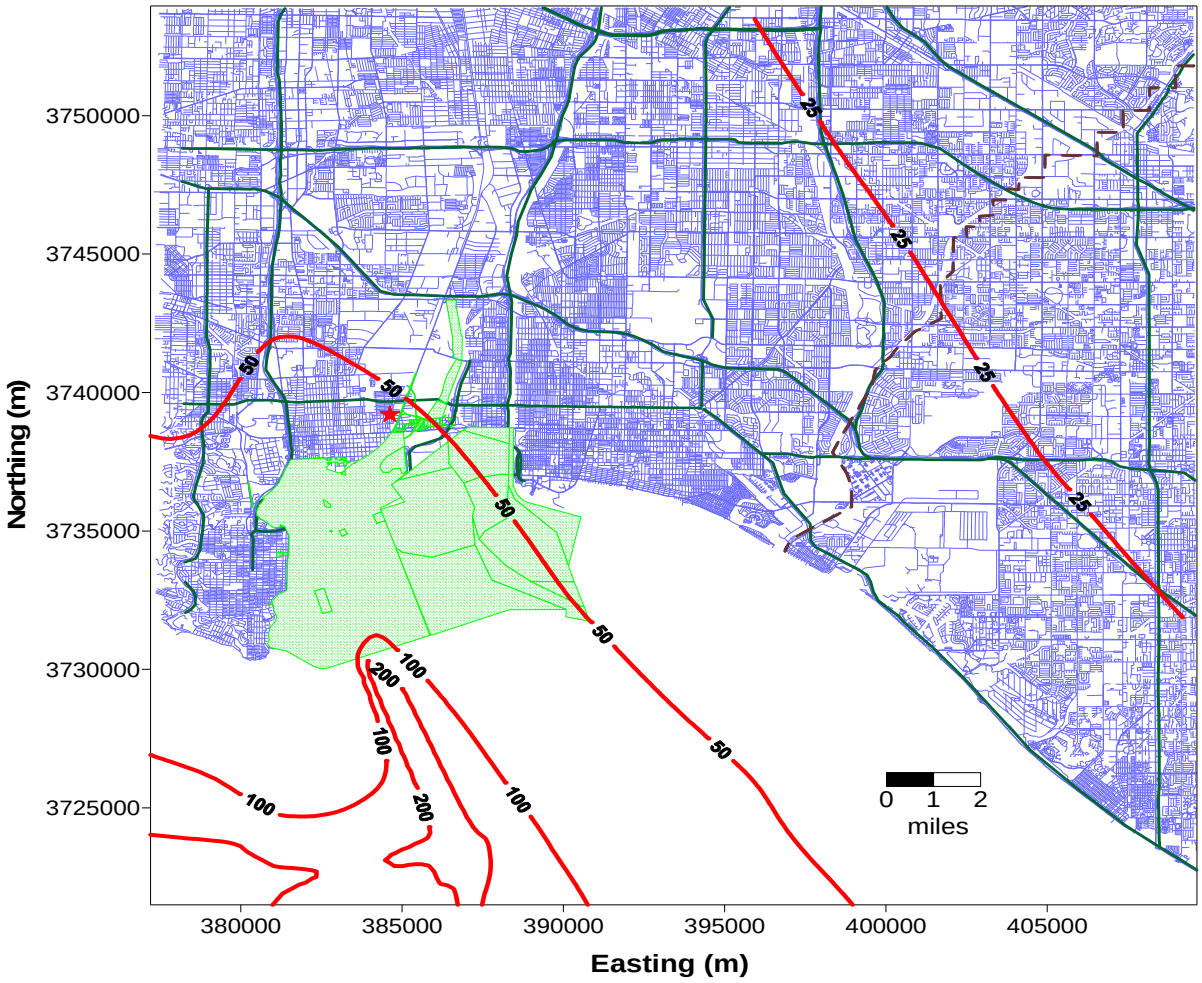


Figure 17. Estimated Diesel PM Cancer Risk from All Out-of-Port Diesel Activity at POLA and POLB (Wilmington, Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission = 1010 TPY, Modeling Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Estimation of Non-cancer Health Endpoints

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (CARB, 2002). As part of this study, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) within the modeling domain. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days.

Ambient levels of directly emitted diesel PM were predicted for 200 meter by 200 meter grid cells within the modeling domain, and the populations within each grid cell were determined from U.S. Census Bureau year 2000 census data. Using the methodology peer-reviewed and published in the Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates, (PM Staff Report) (CARB, 2002), we calculated the number of annual cases of death and other health effects associated with exposure to the PM concentration modeled for each of the grid cells. The totals over the entire modeling area were then calculated. For each grid cell, each health effect was estimated based on concentration-response functions derived from published epidemiological studies relating changes in ambient concentrations to changes in health endpoints, the population affected, and the baseline incidence rates. The selection of the concentration-response functions was based on the latest epidemiologic literature, as described in the PM Staff Report (CARB, 2002) and in Lloyd and Cackette (2001).

Based on our analysis, we estimate that the average number of cases per year that would be expected in the modeling area is as follows:

- 29 premature deaths (for ages 30 and older), 14 to 43 deaths as 95% confidence interval (CI);
- 750 asthma attacks, 180 to 1300 as 95% CI;
- 6,600 days of work loss (for ages 18-65), 5,600 to 7,600 as 95% CI;
- 35,000 minor restricted activity days (for ages 18-65), 28,000 to 41,000 as 95% CI.

Several assumptions were used in our estimation. They involve the selection and applicability of the concentration-response functions to California data, exposure estimation, subpopulation estimation, baseline incidence rates, and the threshold. These are briefly described below.

- Premature death calculations were based on the concentration-response function of Krewski et al. (2000). The ARB staff assumed that concentration-response function for premature mortality in the model domain is comparable to that in the Krewski study. It is know that the composition of PM can vary by region, and not all constituents of PM have the same health effects. However, numerous studies have shown that the mortality effects of PM in California are comparable to those found in other locations in the United States, justifying our use of Krewski et al's results. Also, the U.S. EPA has been using Krewski's study for its

regulatory impact analyses since 2000. For other health endpoints, the selection of the concentration-response functions was based on the most recent and relevant scientific literature. Details are in CARB's PM Staff Report (CARB, 2002).

- The ARB staff assumed the model-predicted exposure estimates could be applied to the entire population within each modeling grid. That is, the entire population within each modeling grid of 200 m x 200 m was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- The ARB staff assumed the grid cell population had similar age distributions as the county in which it was located. The subpopulation used for each health endpoint was calculated by multiplying the all-age population for each grid cell by the county-specific ratio of the subpopulation used for the endpoint over the all-age population. For example, mortality estimates were based on subpopulations age 30 or more estimated from ratios of people over 30 over the entire population, specific for each county. These estimates were needed because information on the particular subpopulation in each modeling grid was not available.

- The ARB staff assumed the baseline incidence rates were uniform across each modeling grid, and in many cases across each county. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment. The incidence rates match those used by U.S. EPA.

- Another assumption pertains to the threshold, the lowest level at which health impacts can be assessed. There is some evidence that the PM effect coefficient may be larger at lower levels of PM and smaller at higher levels. However, we assumed no threshold in our calculations. That is, the effects can be estimated down to zero.

It should be noted that because the estimates apply to a limited modeling domain (20 miles by 20 miles), the affected population is small, and hence the overall estimated health impacts are smaller than estimates made on a statewide basis. In addition, to the extent that only a subset of health outcomes is considered here, the estimates should be considered an under-estimate of the total public health impact.

E. Unquantifiable Adverse Health Effects

In this analysis, we did not quantify all possible health adverse effects associated diesel PM emitted from Ports. For example, the effects of diesel PM on infant mortality, premature births, and low birth weight are not presented. Appendix D provides a brief overview of potential health effects of diesel PM not captured in the quantitative risk assessment and non-cancer health evaluation.

Comparison with Monitoring Results

In this section, we compare the potential cancer risks from this modeling study to the diesel PM risks based on ambient monitoring results from the Port of Los Angeles's (POLA) monitoring conducted during the period February 9 through August 5, 2005, and from ARB's 2002 Wilmington monitoring data collected as part of the Children Health Study. We also compare this study results with the South Coast Air Quality Management District (SCAQMD)'s second Multiple Air Toxic Exposure Study (MATES-II). (SCAQMD, 2000)

Comparison with POLA's Monitoring Results

The POLA is currently conducting an air quality monitoring program on Port property and in the nearby communities. The primary objective of this monitoring is to estimate the ambient levels of diesel PM in proximity to the Port that are due to operational activities at the Port .

There are four monitoring stations deployed within the Port and in the nearby communities (see Figure 18). The Wilmington community station is the primary monitoring station located about one mile north of the Port boundary. Due to its proximity to Port operations and the prevalence of onshore wind flows, this station has the potential to experience elevated ambient diesel PM impacts from Port emissions. The San Pedro station is located within the San Pedro community, on the Liberty Hill Plaza Building. This location is near the western edge of Port emission sources and adjacent to residential areas in San Pedro. The other two stations – Coast Boundary Station and Source-Dominated Station, are located within the Port property.

Each monitoring station measures PM_{10}, and $PM_{2.5}$. The PM samples are analyzed for elemental carbon (EC), a component of air pollution that has been used as indicator of diesel PM. The monitoring stations collect samples over specific 24-hour periods in three-day intervals over a 12-month period. In its latest update, the POLA has released the measured EC 24-hr average concentrations for the period from February 9 to August 5, 2005. To estimate the concentration of diesel PM based on the monitored concentrations of EC, ARB staff used an EC to diesel PM ratio of 0.5. The ratio of EC to diesel PM has been reported to be 0.375 to 0.75 in literature. (Shi, et al., 2000, Pierson, et al., 1983, and Hildemann et al., 1991)

Table 11 shows the potential cancer risks based on the modeling results compared to those calculated using the monitored EC concentrations for the Wilmington and San

Pedro monitoring sites. It can be seen that there is excellent agreement between the predicted cancer risk levels based on modeling and the cancer risk levels based on the monitoring data at both monitoring sites. A comparison was not made for the other two monitoring sites because they are located within the port property. Any risks within the port property are not reported in this study because of issues associated with the proximity of the emission sources and on port receptors.

Comparison with ARB's Wilmington Monitoring Results

The ARB conducted air monitoring in Wilmington from May 2001 to July 2002 as part of the Children's Environmental Health Program. Two monitoring sites were chosen – Wilmington and Hawaiian. Wilmington site is located near Wilmington Park Elementary School and the Hawaiian site is located at Hawaiian Elementary School (also see Figure 18 for locations). The ambient levels of EC were monitored at the two sites, but about 70 percent of the samples collected were below the detection limit of 1.0 µg EC/m^3. It is assumed that all measurements below the limit are arbitrarily assumed to be 0.5 µg EC/m^3. The monitoring results are summarized and compared with our predicted results (see Table 11). It also can be seen that the predicted results compare favorably with the monitored results at the two sites.

Table 11. Comparison of the predicted potential cancer risks with measurements conducted by POLA and ARB (cases per million)

Location	Port of L. A. monitoring results	ARB SB 25 monitoring results	Model prediction
Wilmington Community	585	N/A	600
San Pedro	533	N/A	500
Wilmington School	N/A	450	470
Hawaiian School	N/A	710	650

Note:

5. The ratio of elemental carbon (EC) with diesel PM has been reported to be 0.375 to 0.75 by literature. A ratio of 0.5 is used in this calculation;
6. For POLA's monitoring program, the measured EC 24-hr average concentrations over the half year from February 9 to August 5, 2005 are reported;
7. For ARB SB 25 Wilmington monitoring study, about 70% of the samples collected were below the detection limit of 1 ug EC/m^3. It is assumed that all measurements below the limit are arbitrarily assumed to be 0.5 ugEC/m^3;
8. For the detailed monitoring programs and results, please check POLA and ARB's web sites.

Figure 18. Air Quality Monitoring Stations for the POLA and ARB Programs
(Courtesy of POLA, http://www.portoflosangeles.org)

Comparison with the SCAQMD MATES-II Study

We also compared the modeling results to the SCAQMD's second MATES-II study. The MATES-II study indicated the modeled potential risk in the grid cell containing the Wilmington air quality monitoring station is 1,187 potential cancer cases per million due to diesel PM emissions from port activities, freeways, and other sources of diesel PM. This Wilmington grid cell is approximately 2 miles north of the ports. Our modeling

study shows a risk level of about 450 cases in a million in the same general vicinity. In the nearby residential areas within one mile from port boundaries, cancer risk levels (from diesel PM emissions as well as other toxics) ranged from 1000 to 1500 cases in a million based on the MATES-II study. Our study shows a cancer risk range of 500 to 1000 cases in a million from diesel PM emissions. The differences can be attributed to different modeling configurations. For example, MATES-II used the Urban Airshed Model (UAM) model, a grid based model with 2 km grid cells, while our study used the ISCST3 model, a Gaussian plume model. In addition, MATES-II simulated diesel PM from all sources (e.g., port activities and freeway emissions) for the 1998 base year while our study was limited to diesel PM from port activities for the year 2002. Also the MATES-II study released ocean-going emissions near ground level (within the first horizontal layer of the UAM). Our study released ocean going emissions at 50 meters above "ground" (sea level) which will result in greater dispersion of emissions.

G. Uncertainty and Limitations

Risk assessment is a complex process which requires the integration of many variables and assumptions. Due to these variables and assumptions, there are uncertainties and limitations with the results. Generally, the assumptions are designed to be health protective so that the estimates of risks to individuals are not underestimated. Below is a discussion of uncertainty associated with the key elements used in a risk assessment. These key elements are the heath risk values, the air dispersion modeling used to predict diesel PM concentrations, and the model input parameters.

Uncertainty Associated with Health Values

Scientists often use animal studies to predict how a chemical affects humans in the development of health values that are then used in a risk assessment. Scientists cannot be sure that humans will respond exactly the same way as animals do to a chemical. Also, animals used in these studies are often given very high doses of a chemical to produce negative health effects. These doses are much higher than what people are actually exposed to in the environment. When available, as is the case with diesel PM, scientists use studies of people exposed at work to develop health values to estimate potential cancer risk from environmental exposures. This can introduce uncertainty in the potential risk estimated for the general public because there is a wide range of responses among all individuals, and there can be a wider range of responses in the general public than in the workers in an epidemiology study. In addition, for diesel PM, the actual worker exposures to diesel PM were based on limited monitoring data and were mostly derived based on estimates of emissions and duration of exposure. Different epidemiological studies also suggest somewhat different levels of risk. When the Scientific Review Panel (SRP) identified diesel PM as a toxic air contaminant, they endorsed a range of inhalation cancer potency factors (1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$) and a risk factor of 3×10^{-4} $(\mu g/m3)^{-1}$, as a reasonable estimate of the unit risk. From the unit risk factor an inhalation cancer potency factor of 1.1 $(mg/kg\text{-}day)^{-1}$ may be calculated.

Uncertainty Associated with Air Dispersion Modeling

As mentioned previously, there is no direct measurement technique for diesel PM. This analysis used air dispersion modeling to estimate the concentrations to which the public is exposed. While air dispersion models are based on the state-of-the-art formulations, there are uncertainties associated with the models. The primary purpose of this study was to prioritize emission sources/categories from the Ports operation which are to be regulated. The U.S. EPA Industrial Source Complex – Short Term (ISCST) model was selected for use in this study because of our experience using this model and it was the U.S. EPA's preferred air dispersion model at the time this analysis was performed.

Uncertainty Associated with the Model Inputs and Domain

The model inputs include emission rates, emission release parameters, meteorological conditions, and dispersion coefficients. Each of the model inputs has uncertainty associated with it. Among these inputs, emission rates and meteorological conditions have the greatest affect on modeling results. The emission rate for each source was calculated from the emission inventory. The emission inventory has several sources of uncertainty including: emission factors, equipment population and age, equipment activity, load factors, and fuel type and quality, The uncertainties in the emission inventory can lead to over predictions or under predictions in the modeling results. To minimize uncertainty, we relied on the most current information available.

Meteorological conditions can play a key role in predicted pollutant concentrations. These meteorological parameters include wind speed, wind direction, atmospheric stability, and ambient temperature. For this modeling study, we used wind data from the Wilmington site. We assumed that this wind data was applicable over the entire study area (400 square miles). This is a conservative (health protective) assumption and will tend to over predict the impact of emissions somewhat, particularly for emissions released offshore.

Another critical meteorological condition that can affect pollutant concentration is the mixing height. The greater the mixing height, the greater the volume of air is available to dilute the pollution concentration. For this modeling study, we assumed an average annual mixing height of about 700 meters. This value compares favorably with U.S. Navy mixing height measurements at Point Mugu and San Nicholas Island. (Lee Eddington, 2006)

As stated previously, a model domain of 20 miles x 20 miles was used in this study because of the ISCST model's limitation. In reality, the impacts of diesel PM from the Ports in the nearby communities exceed the model domain. Based on some preliminary modeling estimates, we believe that an additional six million people outside the modeling study area are exposed to an annual average diesel PM concentration of about 0.08 $\mu g/m^3$. Additional study using a long range transport model may be conducted to better address the full impacts outside of this model domain.

Unquantified Adverse Effects

It is not possible to quantify all possible adverse health effects associated with diesel PM emitted from Ports. This is because peer-reviewed methodologies to quantify all of the health effects do not currently exist. Appendix D provides a brief overview of potential health effects from port-related emissions not captured in the quantitative risk assessment and non-cancer health evaluation.

V. SUMMARY OF FINDINGS

The study evaluated the diesel PM emissions on a mass basis and with respect to what impacts those emissions have on potential cancer risks in communities near the ports. With respect to the mass emissions, the combined diesel PM emission from both ports is estimated to be about 1,760 tons per year in 2002. This represents a significant component of the regional diesel PM emissions for the South Coast Air Basin at about 21% of the total basin wide diesel PM emissions in 2002.

Focusing only on the on-port diesel PM emissions, as shown in Figure 19, the emission from ship activities (maneuvering, transiting, and hotelling) account for the largest percentage of emissions at about 73% followed by commercial harbor craft vessels (14%), cargo handling equipment (10%), in-port heavy-duty trucks (2%), and in-port locomotives (1%).

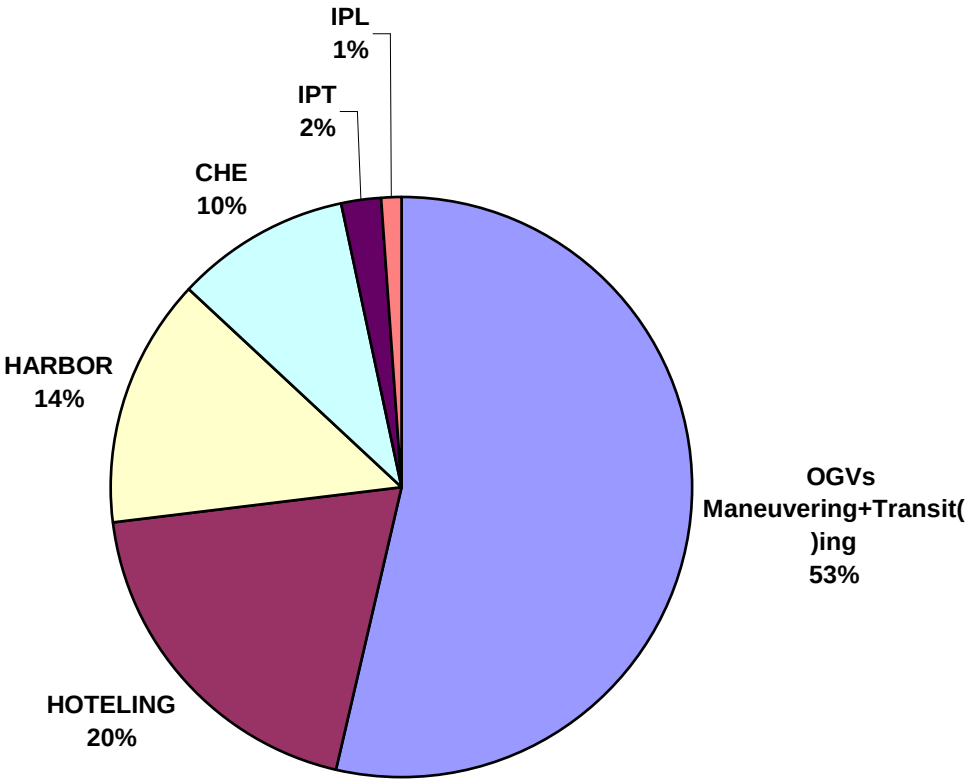


Figure 19: Distribution of Diesel PM Emissions by Source Categories for POLA and POLB in 2002

The combined diesel PM emissions from the ports result in elevated cancer risk levels over the entire 20 mile by 20-mile study area. In areas near the Port boundaries, potential cancer risk levels exceed 500 in a million. As one moves away from the ports, the potential cancer risk levels decrease but continue to exceed 50 in a million for almost the entire modeling domain. Potential cancer risk and the number of acres impacted for several risk ranges are summarized as follows:

- Risk levels greater than 500 in a million (based on 70 years of exposure) occur over about 2,500 acres in which about 53,000 people live.

- Risk levels between 200 and 500 in a million occur over about 26,500 acres in which about 360,000 people live.

- Risk levels between 100 and 200 in a million occur over about 64,500 acres in which about 724,000 people live.

- Risk levels between 10 and 100 in a million occur over about 70,000 acres in which about 843,200 people live.

- The overall, almost all people living within the modeling domain (about 2 million) are exposed to a risk level of greater than 50 in a million and about 97 percent of the areas within the domain are impacted at or above this risk level.

The exposure assessment demonstrated that the land-based or near dock diesel PM emissions were responsible for greater impacts than the emissions that occurred outside the breakwater. Quantitatively, within the modeling receptor domain, the population-weighted risk resulting from the in-port or near dock emissions is about 4.5 times of that resulting from the over-water out-of-port emissions. The results from the exposure assessment also revealed that the contribution of the individual emission sources to the community exposures does not follow the same relationship as the mass emissions. Ship hotelling emissions, while responsible for about 20 percent of the mass emissions, were the emissions that resulted in the largest area and population impacted where the potential cancer risks were greater than 200 in a million (see Figures 20 and 21). Hotelling emissions are also responsible for 34 percent of the total risk in the model domain based on the population-weighted average risk. The second highest category was cargo handling equipment which is responsible for about 22 percent of the total risk in the model domain based on the population-weighted average risk followed by commercial harbor craft, and in-port heavy-duty trucks. When considering risks greater than 10 in a million, all categories except in-port heavy-duty trucks and in-port locomotives affected more than 1.4 million people and impacted more than 119,000 acres where residents live. For the in-port trucks and locomotives, the risk level of greater than 10 in a million affected about 423,000 people and impacted about 30,000 acres.

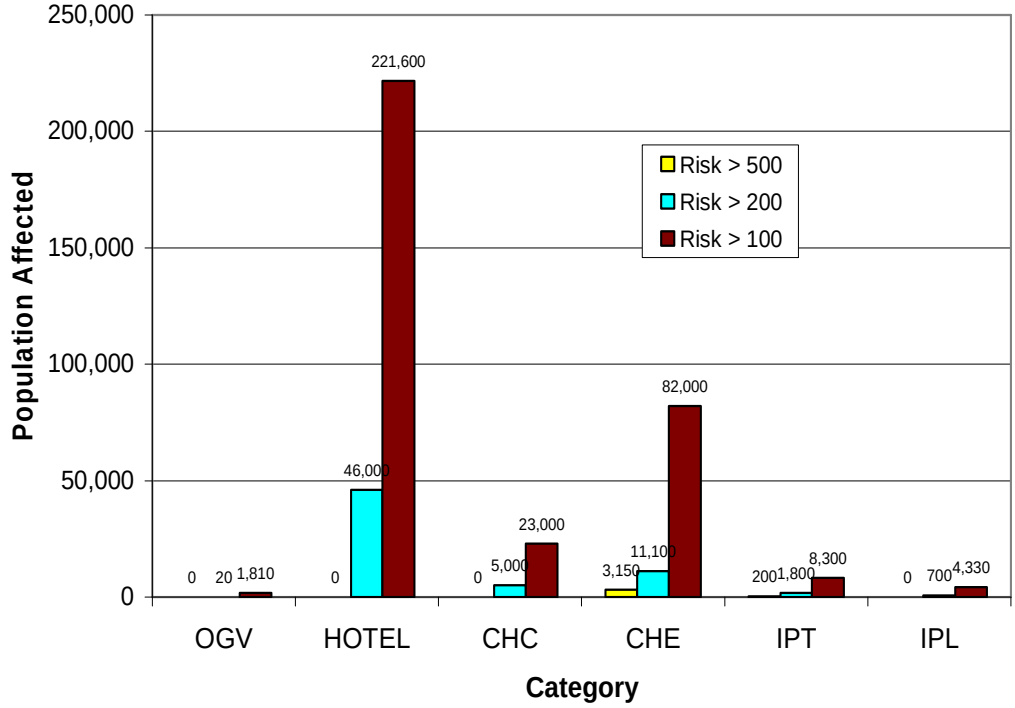


Figure 20: Population Affected within the Model Domain by Cancer Risk Levels and Source Categories

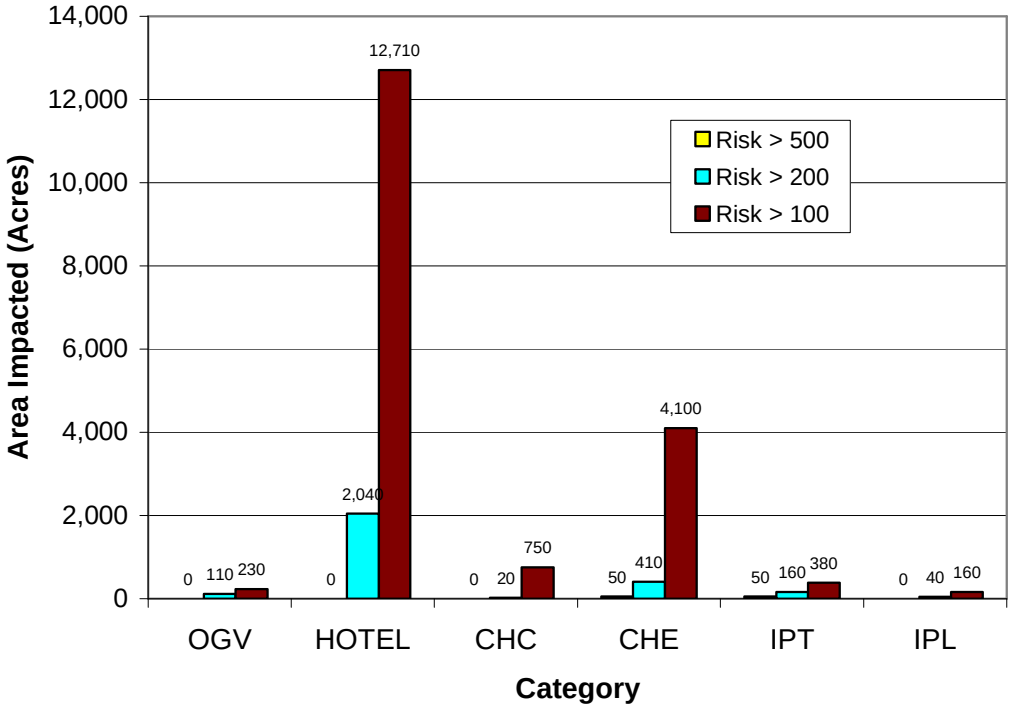


Figure 21: Residential Areas Impacted within the Model Domain by Cancer Risk Levels and Source Categories

The relationship between the various source categories is summarized below. Based on the mass emissions, population-weighted average risk, the size of areas impacted,

and the number of people affected, the emission sources or categories can be ranked as the follows:

- By the mass emissions
  OGV > HOTEL > HARBOR > CHE > TRUCK > LOCO

- By the risk level (population weighted):
  HOTEL > CHE ≈ OGV > HARBOR > TRUCK > LOCO

- By the area impacted (R > 100 in a million):
  HOTEL > CHE > HARBOR > TRUCK > OGV > LOCO

- By the population affected (R > 100 in a million):
  HOTEL > CHE > HARBOR > TRUCK > LOCO > OGV

- By the area impacted (R > 10 in a million):
  OGV > HOTEL > HARBOR > CHE > TRUCK > LOCO

- By the population affected (R > 10 in a million):
  OGV > HOTEL > HARBOR > CHE > TRUCK > LOCO

In conclusion, emissions from cargo handling equipment and hotelling emissions from ocean-going vessel auxiliary engines are the primary contributors to the high potential cancer risk levels near the ports. Reducing emissions from these two categories will have a dramatic effect on reducing the cancer risk levels in nearby communities. Emissions from commercial harbor craft, in-port trucks, in-port rail, and ocean-going vessel (transit and maneuvering activities) do not contribute greatly to the near source risk, but are an important contributor to elevated cancer risk levels over a very large area. While emissions from these source categories do not have a major role in the near port risk levels, they are significant contributors to the overall elevated risk levels in the study area. Addressing the emissions from these sources, while not as critical for reducing near port risk levels, is critical if we are to significantly reduce the exposure of a large population (over 2 million people) to cancer risk levels in the 50 in a million range.

REFERENCES

California Air Resources Board. *Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant; Part A, Exposure Assessment*; As Approved by the Scientific Review Panel on April 22, 1998. (ARB, 1998a)

California Air Resources Board. *The 2002 California Almanac of Emission and Air Quality*, 2002. (ARB, 2002)

California Air Resources Board. *ARB Recommended Interim Risk Management Policy for Inhalation-Based Residential Cancer Risk*. 2004.

California Air Resources Board. *Roseville Rail Yard Study*, 2004.

California Air Resources Board. *Barrio Logan Report – A Compilation of Air Quality Studies in Barrio Logan*, 2004.

California Air Resources Board. *2004 ARB Cargo Handling Equipment Survey,* 2004, *http://www.arb.ca.gov/msprog/offroad/cargo/presentations/051805survey.pdf.*

California Air Resources Board. *California Air Resources Board and Office of Environmental Health Hazard Assessment. Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates*, available at http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm. 2002.

California Air Resources Board. *Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates (PM Staff Report)*. 2002.

Environ. *Commercial Marine Emissions Inventory Development*, 2002.

Hildemann, L. M., Markowski, G. R., Cass, G. R. Chemical composition of emission from urban sources of fine organic aerosol, *Environmental Science & Technology*, 1991, 25: 744-759.

Krewski D, Burnett R, Goldberg MS, Koover K, Siemiatycki J, Jerrett M *et al*. *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality*. Research Report of the Health Effects Institute, 2000.

Lee Eddington, U. S. Navy, Private communication, 2006.

Lloyd, A. C. and Cackette, T. A. Diesel Engines: Environmental Impact and Control, *J. of Air and Waste Management Association*, 2001, 51: 809-847.

OEHHA. *The Air Toxics Hot Spot Program Risk Assessment Guidelines: Part IV-Technical Support Document for Exposure Analysis and Stochastic Analysis*. Office of Environmental Health Hazard Assessment. September, 2000.

OEHHA. 2002a. *Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*. Office of Environmental Health Hazard Assessment. June, 2002.

OEHHA. 2002b. *The Air Toxics Hot Spot Program Risk Assessment Guidelines: Part II-Technical Support Document for Describing Available Cancer Potency Factors*. Office of Environmental Health Hazard Assessment. June, 2002.

Pierson, W. R., Bruchaczek, W. W. Particulate matter associated with vehicles on the road, *Aerosol Science & Technology*, 1983, 2: 1-40.

Pope CA, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, and Health CW*. Particulate Air Pollution As A Predictor Of Mortality In A Prospective Study Of U.S. Adults* Am. J. Respir. Crit. Car Med 151:669-674. 1995.

Port of Los Angeles. *2001 Baseline Emissions Inventory*, prepared by Starcrest Consulting Group, LLC, June, 2004.

Port of Los Angeles. *Report to Mayor Hahn and Councilwoman Hahn by No Net Increase Task Force*, June, 2005.

Port of Long Beach. *2001 Baseline Emissions Inventory*, prepared by Starcrest Consulting Group, LLC, February, 2004.

Shi, J. P., Mark, D. and Harrison, R. M. Characterization of particles from a current technology heavy-duty diesel engine, *Environmental Science & Technology,* 2000, 34: 748-755.

South Coast Air Quality Management District (SCAQMD). *The Multiple Air Toxics Exposure Study (MATES-II) for the South Coast Air Basin*, 2000.

U.S. EPA. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Model*, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. EPA-454/B-95-003a, September 1995.

Yuan, J., Venkatram, A., and Isakov, V. Dispersion from ground-level sources in a shoreline urban area, *Atmospheric Environment*, 2006, 40: 1361-1372.

Appendix A

Methodologies for Developing Source Category Emission Inventories

A. Port of Los Angeles

Starcrest prepared an emission inventory for all emission sources using 2001 as the baseline year. The inventory utilizes activity-based approach and focuses on emissions of diesel PM for all significant sources operating in the Port. In addition to in-port activities, emissions from railroad locomotives and on-road trucks transporting port cargo were also estimated based on the activity that occurs outside the Port, but within the South Coast Air Basin boundaries. Only on-port emissions were evaluated in this exposure assessment. The basic methodologies for developing source category diesel PM emission inventory are briefly described as follows:

Ocean-Going Vessels

Starcrest staff used the activity-based approach to estimate emissions from various types of ocean-going vessels (auto carriers, bulk carriers, containerships, cruise ships, general cargo ships, ocean-going tugboats, refrigerated vessels, roll-on roll-off ships, and bulk liquid tankers). The approach was chosen because it makes use of actual location-specific information and can account for site-specific and/or activity-specific emissions levels. For OGVs, emissions were estimated as a function of vessel power demand (expressed in kW-hrs) multiplied by an emission factor (expressed in g/kW-hr). The basic equation for calculating emissions is as follows:

$$E = MCR * LF * A * EF \quad (A1)$$

Where E is the emission, MCR is the maximum continuous rated engine power (kW), LF is the load factor (unitless), A is the activity (hours), EF is the emission factor (g/kW-hr).

For propulsion engines, the load factor is defined as a ratio of a vessel's power output at a given speed to the vessel's MCR power. At normal service speed, a ship probably has a load factor of close to 80%. For intermediate speeds, the load factor was calculated as:

$$LF = (AS / MS)^3 \quad (A2)$$

Where AS is the actual speed (knots), and MS is the maximum speed (knots).

For propulsion engines, the diesel PM emission factors of 1.92 and 0.72 g/kW-hr were used for slow speed and medium speed operation modes, respectively. Note that if an

engine load is below 20%, an adjustment factor should be applied. The following equations can be used to calculate the adjustment factors for diesel PM when the load is at or lower than 20%:

$$AF = 9.8238 * (LF)^{-0.8117} \quad \text{(A3)}$$

Where AF is the adjustment factor for diesel PM (unitless), and LF is the load factor (in percent). Note that if the load factor were 20%, the adjustment factor would be 1.

For auxiliary engines, emissions were estimated following the same logic as for propulsion engines but differed in estimating load factors, which were based on data available in technical literature. The emission factors of 0.30 g/kW-hr for distillate oil and 1.5 g/kw-hr for residual oil were used for both medium-speed and high-speed diesel engines.

For vessel hotelling at berth, emissions were estimated using the same logic as for auxiliary engines except for activity data. The activity utilized the default hotelling times (in hours) which were obtained from the Port's vessel call database and then averaged by terminal and ship type. So, the default hotelling times (see Table 2.31 in the Report of Los Angeles) represent average hotelling times for each ship type and can be used when terminal-specific hotelling times are not available.

Harbor Craft

The harbor craft vessels are categorized as: assist tugboats, towboats and push boats, ferries and excursion vessels, crew boats, work boats, government vessels, dredges and dredging support vessels, commercial fishing vessels, and recreation vessels. The emissions associated with the harbor vessels are generated within the port and out at ocean. Based on the survey conducted by CARB, the percentages of time spent within the port harbor, up to 25 miles, and from 25 to 50 miles are 54, 35, and 11 percent, respectively.

The basic equation used by Starcrest to estimate harbor vessel emissions is:

$$E = PW \times Act \times LF \times EF \quad \text{(A4)}$$

Where E is the emission (g/yr), PW is the engine's power (kW), Act is the activity (hr/yr), LF is the load factor, and EF is the emission factor (g/kW-hr).

The activity data (engine information and operation time per year) were obtained from the ARB's survey. The emission factors were obtained from the EPA's database (EPA, 1999, ''Final Regulatory Impact Analysis: Control Emissions from Compression-Ignition Marine Engines", EPA420-R-99-026). The deterioration rates were not taken into account for the emission estimates. The engine load factors were obtained from the EPA NON-ROAD model. For assist tugboats, a 31% average engine load factor was used, and for the other categories, the 43% engine load factor was assumed.

Cargo Handling Equipment

Cargo handling equipment consists of various types of off-road equipment and vehicles used to move cargo within terminals and other off-road areas. The emission estimates were estimated using ARB OFFROAD model.

The basic equation for calculating emissions of off-road equipment and vehicles is as follows:

$$E = EF \times HP \times LF \times Act \times FCF \qquad (A5)$$

Where E is the emission (tons), EF is the emission factor (g/hp-hr), HP is the average rated horsepower for the equipment type and horsepower category (HP), LF is the load factor (assumed average percentage of full load), Act is the equipment activity (hrs/yr), and FCF is the fuel correction factor.

The activity data were collected by the Port from the terminal operators. The OFFROAD model was run in "by-model year" mode, meaning that the model took into account emission factors for specific model year group, and the number of pieces of equipment in each of the subgroups. The equipment was grouped based on horsepower range as: up to 25 hp, 26-50 hp, 51-120 hp, 121-175 hp, 176-250 hp, 251-500 hp, 501-750 hp, and 751hp and up. Within the groups, the horsepower and annual hours of use were averaged, and the averages were input into the model.

The emission factors can be expressed as a combination of the base emission factor for the equipment model year (g/hp-hr) plus a deterioration factor, that is:

$$EF = EF_{base} + DF \qquad (A6)$$

Where EF_{base} is the base emission factor for a given horsepower range and model year (g/hp-hr), and DF is the deterioration factor (estimate of emission increase as an engine ages, expressed as g/hp-hr-hr). The OFFROAD model assumes that the equipment's annual operating hours have been constant over the life of the equipment. The model also assumes that deterioration continues as a constant rate over the life of the equipment. The equation for the deterioration factor is:

$$DF = DF_{base} \times Act \times Age \qquad (A7)$$

Where Act is the equipment activity (hrs/yr), and Age is the age of equipment (yrs).

Railroad Locomotives

Railroad operations are classified into two types of activities: line haul and switching. Starcrest staff used two methods to estimate emissions. For in-port switching operations, the emissions were estimated based on the throttle notch data and schedule/operational information provided by the switching companies along with U.S. EPA data on emission rates by throttle notch. Off-port switching emissions were estimated using throttle notch, U.S. EPA emission factors, and fuel use data provided by the railroad companies. For the line haul operation within the Port, emissions were estimated based on schedule and throughput information provided by terminal operators and on U.S. EPA operational and emission factors. For off-port line haul operations, the emissions were estimated using detailed cargo movement and fuel use information provided by the line haul companies.

Heavy-Duty Vehicles

For this emission inventory, heavy-duty diesel-fueled vehicle (HDV) activity has been divided into two components: on-road (off-terminal) travel and on-terminal operations. For estimating on-terminal HDV emissions, Starcrest staff collected on-terminal traffic information, including gate operation schedules, on-terminal speeds, time and distance traveled on terminal while dropping off and/or picking up loads, and time spent idling at the entry and exit gates, through the interview with terminal personnel. For estimating on-road (off-terminal) HDV emissions, the off-terminal truck travel activity was developed by a consultant company (Meyer Mohaddes Associates, Inc. (MMA)) using a travel demand model. The on-road truck travel information included the number of trucks traveling on defined roadway segments, the distance and average speeds on those segments between defined intersections. Off-terminal and on-terminal emissions were estimated by multiplying the emission factors derived by EMFAC2002 by the time and distance parameters established for the terminals. Note that for on-terminal vehicles, there are two types of activity: engine running with vehicles moving a given speed, and engine idling with vehicles at rest.

B. Port of Long Beach

For POLB, Statcrest has developed emission inventories for three categories: cargo handling equipment, in-port locomotives, and in-port heavy-duty vehicles using 2002 as the base year. The methodologies used in estimating emissions for these categories are similar to those used in estimating corresponding emission inventories for POLA. To complete the emission inventories for POLB, ARB staff used the scale-up/down approaches to estimate the emissions for ocean-going vessels (cruises and hotelling) and harbor craft vessels.

<u>OGVs (Cruise and Hotelling)</u>

To estimate emissions from ocean-going vessels for POLB, ARB staff assumed that the unit emission for each OGVs type in POLB in 2002 is the same as that for the corresponding OGVs type from POLA in 2001. The emissions of each OGVs type for

POLB in 2002 are estimated by multiplying the unit emission per call of POLA in 2001 by the call number of the corresponding OGVs type at POLB in 2002, that is:

$$E_{POLB,2002,i} = \frac{E_{POLA,2001,i}}{CN_{POLA,2001,i}} x CN_{POLB,2002,i} \qquad \text{(A8)}$$

where $E_{POLB,2002,i}$ is the estimated emission of OGV type i at POLB for 2002, $E_{POLA,2001,I}$ is the emission of OGV type i at POLA for 2001 (known), $CN_{POLA,2001,i}$ and $CN_{POLB,2002,i}$ are the call numbers from POLA in 2001 and from POLB in 2002 for OGV type i, respectively.

Harbor Craft

To estimate emissions from harbor craft vessels operating at POLB, ARB staff used the estimates of emissions from harbor craft vessels from ARB's 2004 commercial harbor craft emission inventory. These emission estimates were based on information on vessels registered (California Department of Fish and Game), permitted (California Public Utilities Commission), or documented (U.S. Coast Guard) with a "home port" listed as "Long Beach." These vessels registered as "Long Beach" were then allocated to the nine categories (commercial fishing, charter fishing, ferries/excursion, crew and supply, pilot, tugs, tows, work boats, and others) using the harbor craft vessel composition developed in ARB's 2003 Commercial Harbor Craft Survey (released in 2004). The emissions of each category for POLB in 2004 were estimated using the emission density (emission/per vehicle per category) multiplied by the corresponding vessel number in each category, that is:

$$E_{POLB,2004} = \sum_{i=1}^{2} \sum_{j=1}^{9} \left(\frac{E_{statewide,2004}(i,j)}{N_{statewide,2004}(i,j)} \right) x N_{POLB,2004}(i,j) \qquad \text{(A9)}$$

where $E_{POLB,\ 2004}$ is the estimated emissions for all harbor craft vessels at POLB for 2004, $E_{statewide,\ 2004}(i, j)$ is the estimated emission for engine type i and harbor craft vessel type j in the statewide for 2004, $N_{\ statewide,\ 2004}(i, j)$ and $N_{POLB,\ 2004}(i, j)$ are the numbers of harbor craft type j for engine type i in the statewide and in POLB for 2004 respectively, i is the index for engine type (propulsion and auxiliary), and j is the index for harbor vessel type (j = 1 to 9, defined above).

According to the NNI Calculator, the growth of harbor craft vessels from 2001 to 2005 in POLA is almost zero (0.1 percent). We assume that for POLB, the total emission of harbor craft vessels in the baseline year 2002 is equal to that in 2004 as calculated above.

Appendix B

Ship Auxiliary Engine Emission Factor Development

Public comments were received recommending a different PM emission factor than the one ARB used for auxiliary engines. To estimate diesel PM emissions from ship auxiliary engines, ARB staff used an average PM emission factor of 1.5 g/kw-hr for residual fuel oil with an average sulfur level of 2.5 wt. %. Several comments believed that ARB has overestimated the ship hoteling emissions because this emission factor is higher than other published sources (Entec 2002 and Environ 2002).

Concerning the Entec emission factor, ARB staff contacted David Cooper of IVL, the primary author of the Entec report, to understand the development of the Entec emission factor. Mr. Cooper indicated that this was a composite emission factor developed from medium and high speed main engines and auxiliary engines. The data originated from IVL testing and Lloyds data. He indicated that the sulfur level of the residual oil tested ranged from 0.4 to 2.5%. ARB staff have estimated that the average sulfur level for this data set is in the vicinity of 1.5% for the composite emission factor. Therefore, ARB staff believe that 0.8 g/kw-hr is an appropriate emission factor for lower sulfur levels (near 1.5%), but is not representative for 2.5% fuel sulfur levels.

While ARB staff does not have a complete list of the cited IVL data, we believe the PM emissions, where fuel sulfur is included, may have originated from Environment Canada.

In developing the ARB's original emission factor of 1.5 g/kw-hr, ARB staff used an average emission factor of 1.7 g/kw-hr for 3% fuel sulfur as reported in Table 3-8 of the Environ 2002 report. The emission factor for 2.5% fuel sulfur was estimated using a relationship between fuel sulfur and emissions, originally developed by EPA and making slight adjustments in the brake specific fuel consumption rate needed to convert from kg/tonne to g/kw-hr.

Figure B-1 shows the Environment Canada (MSED 97-04) PM emissions data as a function of fuel sulfur, using data where fuel sulfur was reported. The relationship between emissions and fuel sulfur content was estimated by a curve fit of the data. The ARB estimated emission factor, the Entec composite emission factor and the Environ estimated emission factor are also indicated on the figure.

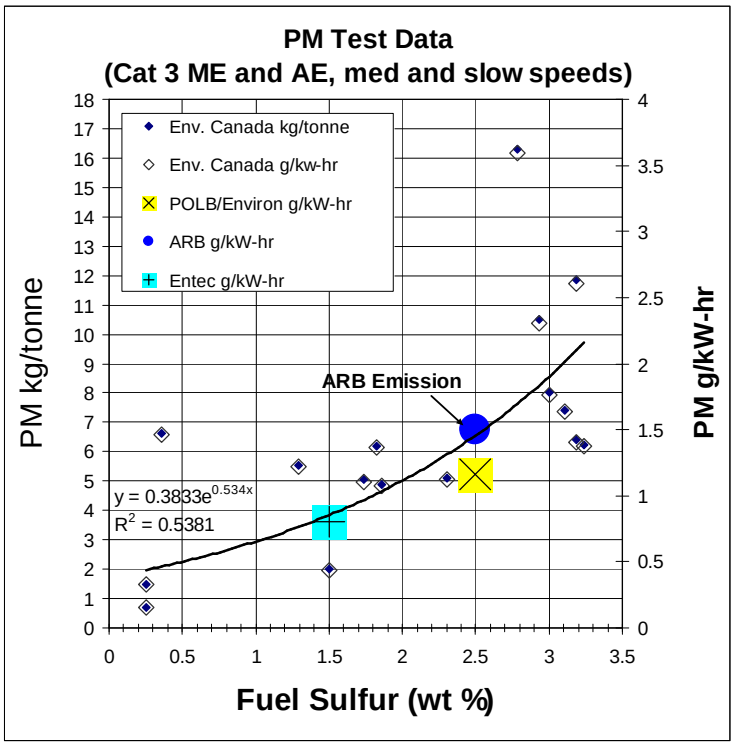


Figure B-1. PM emissions as a function of fuel sulfur from Environment Canada (MSED 97-04)

Concerning the Environ emission factor, ARB staff believes that the methodology Environ used to adjust the emission factor is based on a curve fit of category 3 main engine data from three sources: one data point from Maeda 2004, one data point from Fleisher 1998, and six data points representing a partial data set from Environment Canada 1997 (reported as Lloyds). The relationship developed for PM emission factor as a function of fuel sulfur provides an estimation of 1.16 g/kw-hr at 2.5% sulfur using the Environ methodology.

ARB staff do not agree with the use of the partial data set from Environment Canada when a more complete set including data from auxiliary engines is available. The Environment Canada report includes a total of 12 data points for Category 3 main and auxiliary engines, where fuel sulfur is reported. ARB staff used a similar methodology (shown in Figure A-1), but included the larger data set from Environment Canada, where sulfur levels were reported. This methodology provides an estimate of 1.5 g/kw-hr for a fuel sulfur level of 2.5%.

Based on an analysis of the widely cited Environment Canada study (MSED 97-04), ARB staff recommend the use of an average emission factor 1.5 g/kw-hr for an average residual oil fuel sulfur level of 2.5 wt. %.

Appendix C

Comparison of Estimated Diesel PM Cancer Risks from Ocean-Going Vessel Activity Outside of the Breakwater using Wilmington and King Harbor Meteorological Data Sets

Purpose. As discussed in the main report, about 95% of ship's emissions (maneuvering + transiting) are generated in the outside shipping lanes of the breakwater. Due to the blocking effect of the Palos Verdes Hills, wide variations in meteorological conditions could occur within the Ports and in the outside (ocean side) of the Ports. We conducted a sensitivity study to investigate possible effects of ocean side meteorological conditions on the cancer risk in the Port's nearby communities using King Harbor meteorological data set and compare to what we conducted in the main report using Wilmington meteorological data.

Meteorological Data. Among available meteorological monitoring sites around the Ports, we have chosen King Harbor site as representative to the ocean side. King Harbor is about 10 miles the northwest of the Ports (see Figure C-1). The wind rose for King Harbor site is presented in Figure C-2. The annual average wind speed is about 2.93 m/s, which is higher than that of Wilmington site (1.83 m/s). The winds were predominantly from the west approximately 15%, west-southwest approximately 22%, and southwesterly about 18% of the time, with wind speeds ranging from 0.5 to 11 m/s. As showed in Figure C-3, the data has a higher frequency of atmospherically stable conditions (stability E and F) compared with Wilmington met data (37% vs 24%).

Modeling Approach. We used the same air quality model (ISC), modeling receptor domain, modeling parameters, emission rate, and receptor spacing as what we utilized in the main report except for the meteorological data. Note that the emissions resulting from OGVs within the breakwater are not included in the sensitivity run.

Modeling Results. Estimated diesel PM cancer risks in the nearby communities around the Ports within the modeling domain using two different meteorological data sets (Wilmington and King Harbor) are presented in Figure C-4. Within the modeling domain, the contour lines of 100 and 200 in a million lie in the southwest ocean water surface of the Ports for both meteorological data sets. As with the population-weighted cancer risks within the domain, Wilmington data set resulted in 4% higher risk than King Harbor data set. The population-weighted impact difference between using Wilmington and using King Harbor meteorological data sets is not significant. In other words, using Wilmington or King Harbor meteorological data for out-of-port diesel PM emissions does not alter our conclusions drawn in the main report.

Conclusions. There does not appear to be a significant difference between using the Wilmington or King Harbor meteorological data in terms of the population-weighted cancer risks within the defined modeling receptor domain.

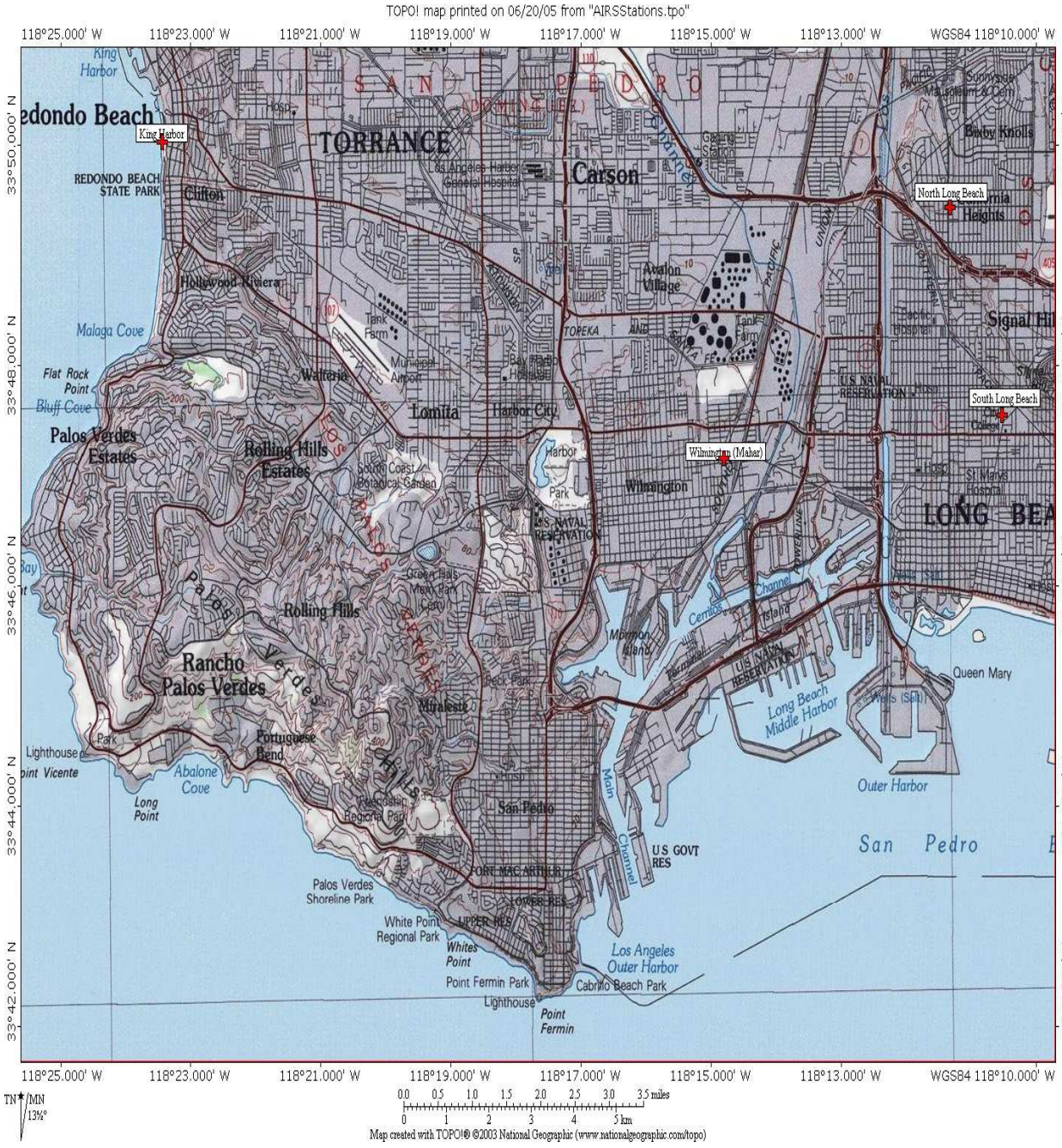


Figure C-1. Locations of Meteorological Monitoring Sites around the Ports

King Harbor (1981)

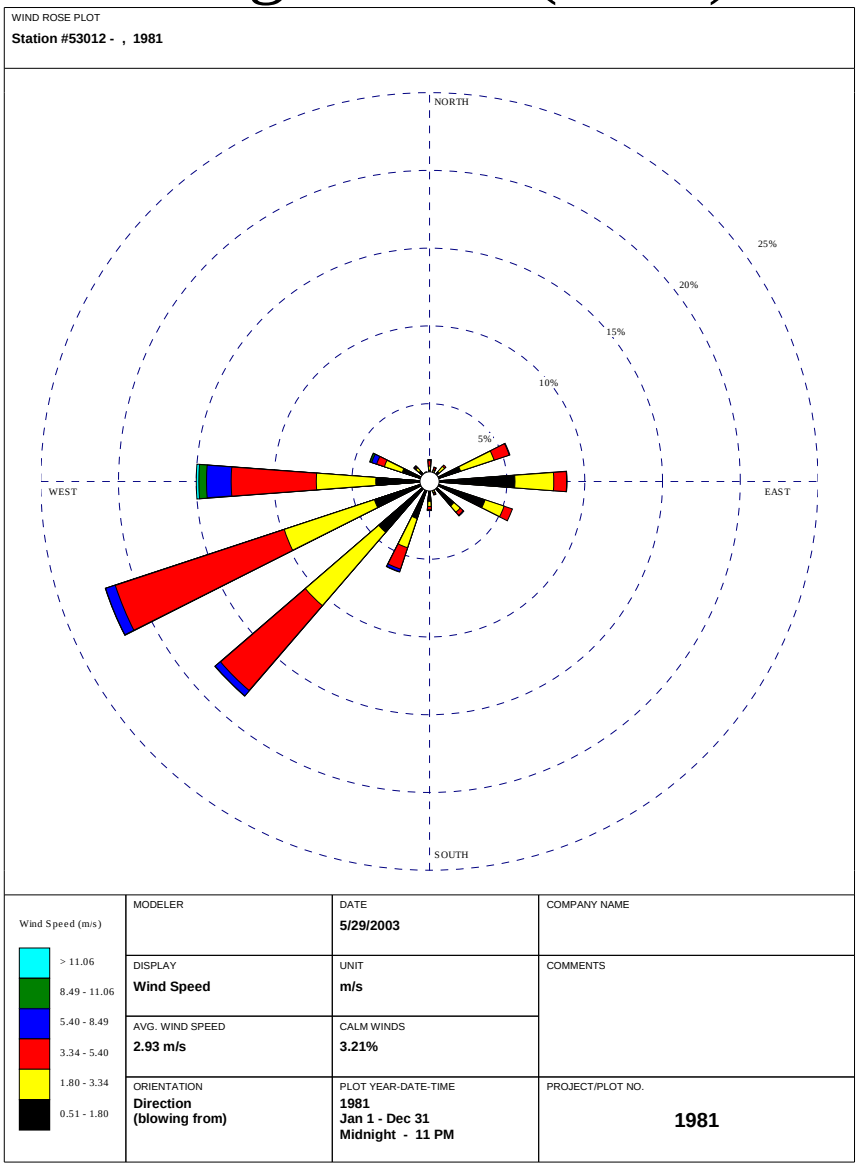


Figure C-2. Wind Rose for King Harbor Meteorological Site

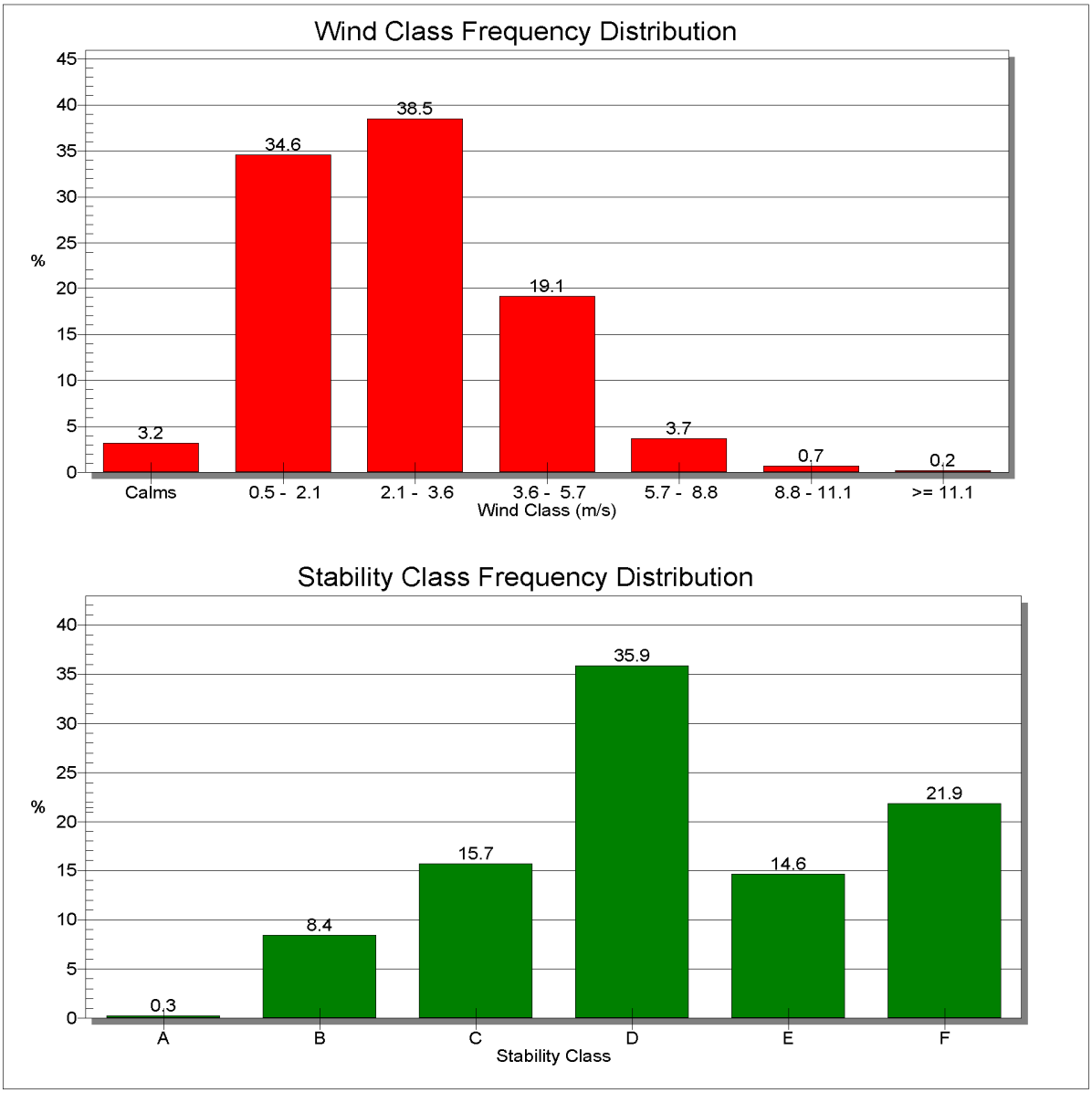


Figure C-3. Frequency Distributions of Wind Speed and Atmospheric Stability for King Harbor Meteorological Site

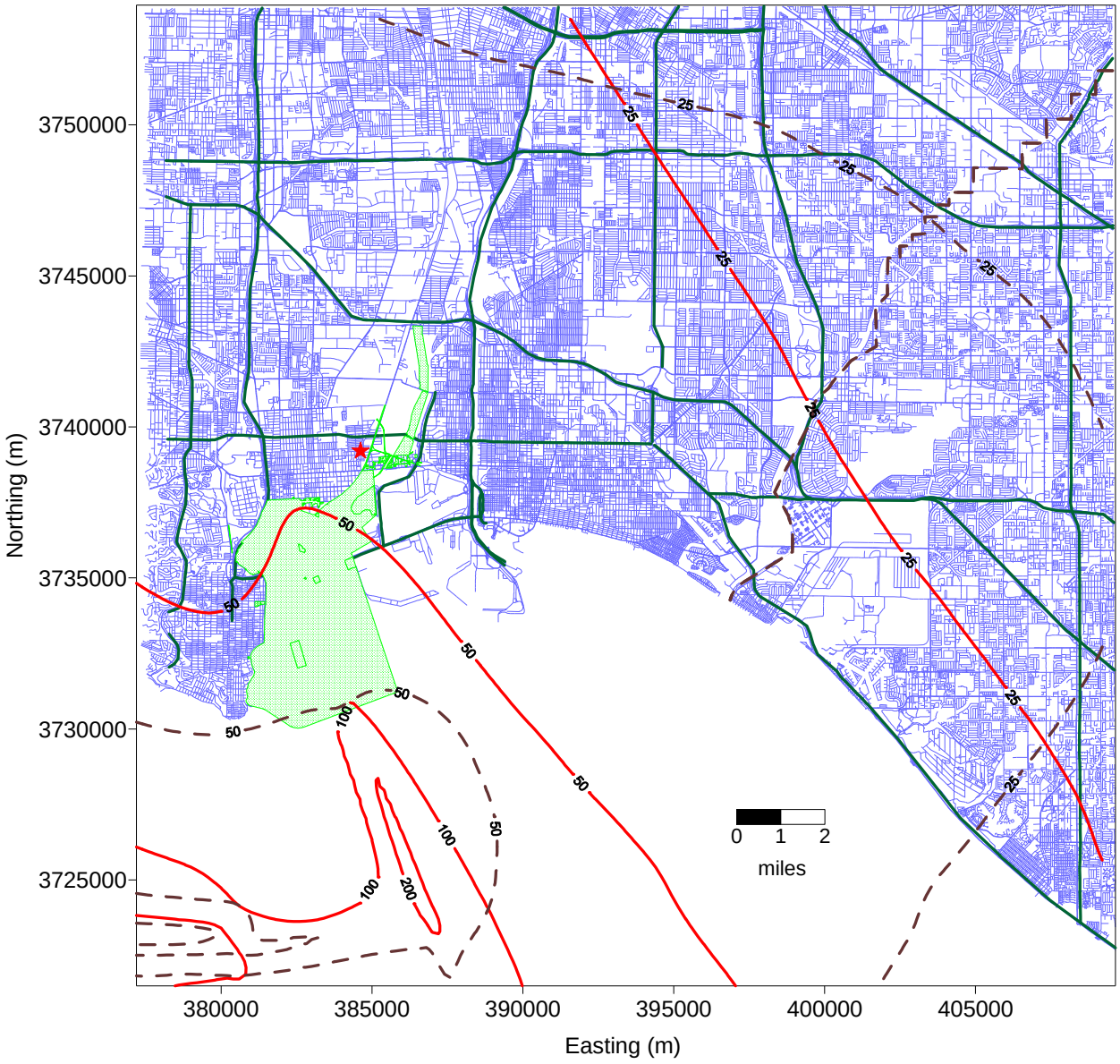


Figure C-4. Comparison of Estimated Diesel PM Cancer Risks from OGV's Activity in the Shipping Lanes outside of the Breakwater using Wilmington (solid lines) and King Harbor (dashed lines) Meteorological Data (Urban Dispersion Coefficients, 80th Percentile Breathing Rate, Emission= 904 TPY, Modeling Receptor Domain = 20 mi x 20 mi, Resolution = 200 m x 200 m)

Appendix D

Unquantifiable Adverse Health Effects

The combustion of fuel produces thousands of compounds that may affect human health. Although the earlier chapters of this document quantify the cancer and non-cancer risks of diesel exhaust particulate matter, there are additional health effects from PM and other pollutants that cannot yet be easily quantified. Information is rapidly evolving about the health impacts from airborne particulate matter, particularly ultrafines, and the mechanisms by which particulate matter, including that from diesel engines, induces health effects. When the diesel exhaust health risk assessment was conducted in 1998, we did not know about these other health impacts, and thus they are not quantified by current risk assessments. Additional resources are required to adequately characterize those non-cancer health risks which are quantifiable and it is important to initiate a comprehensive evaluation process of these potential health impacts over the next few years.

The following is a very brief overview of the health effects of diesel exhaust not captured in the earlier quantitative risk assessment and this field is rapidly evolving with new experimental findings and insights being published regularly. This chapter describes qualitatively some of those health risks. They include: adverse birth outcomes and non-quantified respiratory ailments in children, underlying physiological changes associated with heart disease and stroke, effects on the immune system, endocrine disruption, neurotoxicity, and risks resulting from multi-media exposures and cumulative impacts. It is important to note that some of these health effects (i.e., adverse birth outcomes, immune effects, and atherosclerosis) are measured at current ambient levels of particulate matter.

Birth Outcomes

Air pollution has been directly associated with low birth weight, preterm delivery, and cardiovascular birth defects (Maisonet *et al*., 2001;Ritz *et al*., 2000; Ritz *et al*, 2002; Ha *et al*, 2001; Gilboa *et al*, 2005; Wilhelm and Ritz, 2003, 2005). Preterm delivery and low birth weight are risk factors for infant mortality and life-long disability. Also, a number of studies have linked particulate air pollution to infant mortality (Woodruff *et al*, 1997, Hee-Ha *et al*, 2003; Bobak and Leon, 1999) from respiratory causes. There is not enough information at this time to identify the levels of exposure that pose a significant risk of these adverse effects.

Respiratory Ailments in Children

Traffic Studies

The health impacts of air pollution on children are of particular concern. Studies have shown associations between traffic-related pollution and effects in children, including chronic bronchitis symptoms, wheeze, cough, allergic rhinitis, asthma induction, and upper and lower respiratory tract infections (Jaakkola *et al*., 1991; Osterlee *et al*.,

1996;Wjst *et al*., 1993; van Vliet *et al*., 1997; Venn *et al*, 2001; Kim *et al*., 2004). Recent evidence (Gauderman *et al*., 2004; Kunzli *et al*, 2004) indicates that air pollution exposure can impair lung function growth in children. The long-term consequences of lower lung function can include shorter lifespan, as lung function peaks in young adulthood and declines thereafter; lung function is the most significant predictor of mortality in the elderly (Schuneman *et al*. 2000; Hole *et al*., 1996).

Asthmagens

There are a number of indications in the occupational epidemiology literature (Delfino, 2002) and animal studies that some air toxics are associated with induction and exacerbation of asthma. These include chemicals that are products of fuel combustion, such as formaldehyde and acrolein. In addition, it has been shown in numerous studies that diesel exhaust particulate matter can enhance allergic asthma (Diaz-Sanchez 1999, 2000). Short-term exposure directly to diesel exhaust has also been shown to enhance airway responsiveness (Nordenhall *et al*, 2001). Urban particulate is associated with asthma exacerbation in numerous studies (Ostro *et al*., 1995, 2001;Delfino *et al*., 2002).

Heart Disease and Stroke

It is relatively straightforward to identify levels of airborne levels of PM that can cause death and to some extent illness from effects on the cardiovascular system. But air pollution is also associated with an increase in the underlying health conditions, such as atherosclerosis, that can increase the risk of both heart disease and stroke. Air pollutants that produce these effects include polycyclic aromatic hydrocarbons (PAHs), which produce atherosclerosis in animal models. Fine particulate matter was associated with increased atherosclerosis in humans (Kunzli *et al*, 2005), and in animals (Suwa *et al*., 2002). Heart attacks can be triggered by short-term exposure to traffic-related pollutants in those at risk (Peters *et al*. 2004). There are a number of published investigations and much ongoing research about the inflammatory processes underlying cardiovascular disease. Mechanisms underlying atherosclerosis involve inflammatory responses and oxidative stress triggered by particulate matter pollution (Li *et al*., 2002; Libby, 2002; Dick *et al*., 2003; Stone, 2004). Within the cell, toxicity to mitochondria (the energy generating subcellular organelle) results in cellular dysfunction and death (Hiura *et al*., 2000). Thrombotic events are likely also triggered by ultrafine particles (Schultz *et al*., 2005).

Carbon monoxide (CO) reduces available oxygen to the blood cells. Any chronic CO exposure, including exposures that result from port activities, likely contributes to underlying heart disease. Other air pollutants associated with fuel combustion, such as arsenic (present in some heavy fuel oils), may also play a role in cardiovascular diseases.

Some evidence exists that living near a major roadway with simultaneous exposure to traffic-related air pollution shortens life expectancy (Finkelstein *et al*, 2004; Hoek *et al*., 2002). One study showed that myocardial infarction is triggered following short-term exposure to elevated traffic pollution in cars, public transit, or on motorcycles or bikes (Peters *et al*., 2004). Risk assessments that utilize air dispersion models to estimate

"average" concentrations in a specific area may underestimate risk if that area is surrounded by major roadways.

Immune System Effects

Many studies have looked at the enhancement of the allergic response following intranasal instillation of diesel exhaust particles and may cause people to become allergic to airborne substances that they would not otherwise be allergic to (Nel *et al*, 1998, Diaz-Sanchez *et al*, 1999, 2000, Saxon and Diaz-Sanchez, 2000). Similar results have been obtained in animal models (Maejima *et al*, 2001). In addition, immune suppression (Burchiel *et al.*, 2004) has been observed in experimental animals exposed to diesel exhaust resulting in increased susceptibility to respiratory infection (Castranova *et al*., 2001). These responses are due to chemical components of diesel exhaust particulate that affect the proper functioning of the immune system. Other products of combustion, including PAHs and dioxins, also affect the immune system. The levels of exposure to these substances that can affect the immune system currently cannot be quantified.

Endocrine Disruption

Dioxins have been measured in exhaust from trucks. Dioxins and related compounds are known to disrupt thyroid hormone levels in the blood following exposure at levels found in the environment. Port activities likely contribute to the dioxin load in the immediate environment, but the effect on human health cannot be easily quantified. In addition, exposure of cells in culture and experimental animals to diesel exhaust has resulted in changes in reproductive hormones (Taneda *et al.*, 2000) resulting in decreased sperm production (Yoshida *et al*., 1999) and feminization of male rodent offspring (Watanabe and Kurita, 2001).

Neurotoxicity

Concerns are emerging about potential neurotoxicity from ultrafine particulate matter. It has been known for some time that very fine particles can cross membranes readily, including nervous system tissue. Recent studies on inhaled ultrafine particles indicate widespread distribution following exposure including into the brain cells (Oberdoerster *et al*., 2005). Oxidative stress was induced in the brain of fish exposed to nanoparticles in water (Oberdoerster, 2004). Mice exposed to concentrated airborne particulate matter (both fine and ultrafine) had elevated inflammatory markers in the brain compared to controls (Campbell *et al*., 2005). Thus, there is a real possibility of neurotoxicity from ultrafine particles.

Quality of Life

Some effects of air pollution are difficult to quantify, but may still be significant. For example, lost school days resulting from pollution-related respiratory ailments contribute to poorer learning, which may ultimately affect an individual's income as adults. While this is somewhat quantifiable, the overall quality of life that is affected by air pollution cannot be quantified, and therefore it is excluded from any benefits assessments.

Similarly, the decrease in days of physical activity due to air pollution decreases overall health (particularly for children) by reducing exercise, and increasing obesity and related health problems such as diabetes and heart disease later in life. Similarly, it is not possible to quantify the social costs stemming from the reduced quality of life for children who have many restricted activity days due to exacerbation of asthma as a result of air pollution.

Atmospheric Transformation

Most risk assessments do not consider the effects of air pollutants that are created by chemical reactions in the atmosphere from other pollutants that are emitted from fuel combustion and other human activities. For example, nitrogen oxides and hydrocarbons emitted as a result of port activities contribute to the formation of ozone, the main component of urban smog and secondarily formed particulate matter. The impacts that port activities have on ozone and secondarily formed particulate matter formation have not been considered in assessments of port activities, but these impacts could be substantial.

Multi-media Exposure and Cumulative Impacts

It is not easy to estimate risks from exposures to pollutants that are initially airborne but then deposit onto surfaces and waterways. For example, goods movement activities contribute to non-point source runoff that contaminates coastal and bay waters with a number of toxicants, including PAHs, dioxins, and metals. Exposures to pollutants that were originally emitted into the air can also occur as a result of dermal contact, ingestion of contaminated produce, and ingestion of fish that have taken up contaminants from water bodies. These exposures can all contribute to an individual's health risk.

In most risk assessments, chemicals are evaluated without consideration of other pollutants that may add to the risks posed by the chemicals being assessed. The typical risk assessment does consider cumulative impacts on a specific organ of the body for multiple chemicals that originate from other sources of emissions in the area. However, there generally are no methods at present for evaluating cumulative impacts posed by exposures to multiple pollutants. For these reasons, it is often not possible to fully evaluate the health risks in a community that is impacted by multiple sources of pollution.

References

Bobak M and Leon DA (1999) The effect of air pollution on infant mortality appears specific for respiratory causes in the postneonatal period. Epidemiology 10:666-670.

Burchiel SW, Lauer FT, McDonald JD, Reed MD. (2004) Systemic immunotoxicity in AJ mice following 6-month whole body inhalation exposure to diesel exhaust. Toxicol Appl Pharmacol 196:337-345.

Campbell A, Oldham M, Becaria A, Bondy SC, Meacher D, Sioutas C, Misra C, Mendez LB, Kleinman M. (2005) Particulate matter in polluted air may increase biomarkers of inflammation in mouse brain. Neurotoxicology 26:133-40.

Conceicao GMS, Miraglia SGEK, Kishi HS, et al. (2001) Air pollution and child mortality: A time-series study in Sao Paulo, Brazil Environ Health Perspect 109(Suppl3): 347-350.

Delfino RJ, Zeiger RS, Seltzer JM, Street DH, McLaren CE. (2002) Association of asthma symptoms with peak particulate air pollution and effect modification by anti-inflammatory medication use. Environ Health Perspect 110:A607-A617.

Diaz-Sanchez D, Garica MP, Wang M, Jyrala M, Saxon A. (1999) Nasal challenge with diesel exhaust particles can induce sensitization to a neoallergen in the human mucosa. J allergy Clin Immunol 1183-1188.

Diaz-Sanchez D, Garcia MP, Saxon A. (2000) Diesel exhaust particles directly induce activated mast cells to degranulate and increase histamine levels and symptom severity. J Allergy Clin Immunol 106:1140-46.

Dick CAJ, Brown DM, Donaldson K, Stone V. (2003) The role of free radicals in the toxic and inflammatory effects of four different ultrafine particle types. Inhalation Toxicol 15:39-52.

GaudermanWJ, Avol E, Gilliland F et al. (2004) The effect of air pollution on lung development from 10 to 18 years of age. NEJM 351:1057-67.

Gilboa SM, Mendola P. Olshan AF, et al. (2005) Relation between ambient air quality and selected birth defects, Seven County Study, Texas, 1997-2000. Am J Epidemiol 162:238-252.

Ha E-H, Hong Y-C, Lee B-E et al. (2001) Is air pollution a risk factor for low birth weight in Seoul? Epidemiology 12:643-648.

Ha E-H, Lee, J-T, Kim H, et al. (2003) Infant susceptibility of mortality to air pollution in Seoul, South Korea. Pediatrics 111:284-290

Hiura TS, Li N, Kaplan R, Horwitz M, Seagrave J-C, Nel AE. (2000) The role of mitochondrial pathway in the induction of apoptosis by chemicals extracted from diesel exhaust particles. J Immunol 165:2703-2711.

Jaakkola JJK, Paunio M, Virtanen M et al. (1991) Low-level air pollution and upper respiratory infections in children. Am J Pub Health 81:1060-1063.

Kim J, Smorodinsky S, Lipsett M, et al. (2004) Traffic-related air pollution near busy roadways. The East Bay Children's Respiratory Health Study. Am J Resp Crit Care Med 170:520-526.

Kunzli N, Jerrett M, Mack WJ, Beckerman B, LaBree L, Gilliland F, Thomas D, Peters J, Hodis HN. (2004) Ambient air pollution and atherosclerosis in Los Angeles. Environ Health Perspect 113:201-206.

Li N, Sioutas C, Cho A Schmitz D, Misra C, Sempf J, Wang M, Oberley T, Froines J, Nel A. (2003) Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage. Environ Health Perspect 111:455-60.

Li N, Venkatesan MI, Miguel A, Kaplan R, Gujuluva C, Alam J, Nel A. (2000) Induction of heme oxygenase-1 expression in macrophages by diesel exhaust particle chemicals and quinines via the antioxidant-responsive element. J Immunol 165:3393-3401.

Maejima K, Tamarua K, Nakajima T, Taniguchi Y, Saito S, Takenaka H. (2001) Effect of the inhalation of diesel exhaust, kanto loam dust, or diesel exhuats without particles on immune responses in mice exposed to Japanese cedar pollen. Inhalation Toxicol 13:1047-1063.

Maisonet M, Bush TJ, Correa A, Jaakkola JK. (2001) Relation between ambient air pollution and low birth weight in the Northeastern United States. Environ Health Perspect 109 (Suppl3):351-356.

Nel A, Diaz-Sanchez D, Ng D, Hiura T, Saxon A. (1998) Enhancement of allergic inflammation by the interaction between diesel exhaust particles and the immune system. J Allergy Clin Immunol 102:539-554.

Nordenhall C, Pourazar J, Ledin J-O, Sandstrom T, Adelroth E. (2001) Diesel exhaust enhances airway responsiveness in asthmatic subjects. Eur Respir J 17:909-915.

Obersoerster E. (2004) Manufactured nanomaterials (Fullerenes, C60) induce oxidative stress in the brain of juvenile largemouth bass. Environ Health Perspect 112:1058-1062.

Oberdorster, G., Oberdforster, E., and Oberdorster, J. (2005) Nanotechnology: An emerging discipline evolving from studies of ultrafine particles. Environ Health Perspect 113:823-839.

Ostro BD, Lipsett MJ, Mann JK, Braxton-Owens H, White MC. (1995) Air pollution and asthma exacerbations among African-American children in Los Angeles. Inhalation Toxicol 7:711-722.

Ostro B, Lipsett M, Mann J, Braxton-Owens H, and White M. (2001) Air pollution and exacerbation of asthma in African-American children in Los Angeles. Epidemiology 12:200-208.

Peters A, vonKlot S, Heier M, Trentinaglia I, Hormann A, Wichmann HE, Lowel H. (2004) Exposure to traffic and the onset of myocardial infarction. NEJM 351:1721-30.

Ritz B, Yu F, Chapa G, Fruin S. (2000) Effect of air pollution on preterm birth among children born in Southern California between 1989 and 1993. Epidemiology 11:502-511.

Ritz B, Yu F, Fruin S, et al. (2002) Ambient air pollution and risk of birth defects in Southern California. Am J Epidemiol 155:17-25.

Saxon A, Diaz-Sanchez D. (20000) Diesel exhaust as a model xenobiotic in allergic inflammation. Immunopharmacology 48:325-327.

Stone PH. (2004) Triggering myocardial infarction. NEJM 351:1716-1718.

Suwa T, Hogg JC, Quinlan KB, Ohgami A, Vincent R, vanEeden SF. (2002) Particulate air pollution induces progression of atherosclerosis. J Am Coll Cardiol. 39:943-945.

Taneda S, Hayashi H, Sakata S, Yoshino S, Suzuki A, Sagai M, Mori Y. (2000) Anti-estrogenic activity of diesel exhaust particles. Biol Pharm Bull 23:1477-80.

Watanabe N, Kurita M. (2001) The masculinization of the fetus during pregnancy due to inhalation of diesel exhaust. Environ Health Perspect 109:111-119.

Wilhelm M and Ritz B. (2003) Residential proximity to traffic and adverse birth outcomes in Los Angeles County, California, 1994-1996. Environ Health Perspect 111:207-216.

Wilhelm M. and Ritz B. (2005) Local variations in CO and particulate air pollution and adverse birth outcomes in Los Angeles County, California, USA. Environ. Health Perspect 113:1212-1221.

Yoshida S, Sagai M, Oshio S, Umeda T, Ihara T, Sugamata M, Sugawara I, Takeda K. (1999) Exposure to diesel exhaust affects the male reproductive system of mice. Int J Androl 22:307-315.

STEPTOE & JOHNSON LLP
ATTORNEYS AT LAW

Samuel M. Sipe Jr.
202.429.6486
ssipe@steptoe.com

1330 Connecticut Avenue, NW
Washington, DC 20036-1795
Tel 202.429.3000
Fax 202.429.3902
steptoe.com

August 5, 2010

VIA ELECTRONIC FILING

Ms. Cynthia Brown
Chief, Section of Administration
Office of Proceedings
Surface Transportation Board
395 E Street, SW
Washington, DC 20423-0001

Re: *Petition of Arkansas Electric Cooperative Corporation for a Declaratory Order*, STB Finance Docket 35305

Dear Ms. Brown:

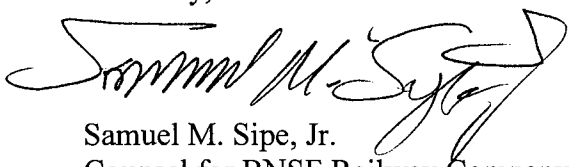
This letter responds to requests for BNSF Railway Company to provide additional information on two matters raised by Board members at the July 29, 2010 hearing in the above-referenced case.

First, in response to a request from Vice Chairman Mulvey, attached is a list of academic and industry articles and reports related to coal dust that we have been able to locate. We have identified whether the materials on our list were already included in the record in this proceeding, are readily available on the internet, or are being provided to the Board as attachments to this letter. We have seen references to a few other articles and reports, but have not included them on our list if we have been unable to locate a copy.

Second, Commissioner Nottingham asked BNSF to advise the Board whether BNSF loaded the railcars above the sill during its removal of coal dust that had accumulated near certain waterways in 2008. We confirmed that BNSF did not load the railcars above the sill. We note that one of the articles on the attached list addresses the question raised by Commissioner Nottingham as to whether loading coal below the sill would reduce coal dust emissions. This article indicates that this loading technique reduces the load capacity of each railcar by more than ten percent without a statistically significant reduction in coal dust emissions. *See* Edward M. Calvin, G. D. Emmitt & Jerome E. Williams, A Rail Emission Study: Fugitive Coal Dust Assessment and Mitigation, *Proceedings for the Seventh Annual Environment Virginia '96 Symposium*, 44, 48, Lexington, Virginia (April 11-12, 1996).

Please contact the undersigned if you have any questions regarding this letter.

Sincerely,



Samuel M. Sipe, Jr.
Counsel for BNSF Railway Company

cc: Chairman Daniel R. Elliott III
Vice Chairman Francis P. Mulvey
Commissioner Charles D. Nottingham
Parties of Record

Coal Dust Articles and Reports

Aurecon Hatch, Coal Leakage from Kwik-Drop Doors: Coal Loss Management Project Queensland Rail Limited Reference H327578-N00-EE00.08 Revision 1 (July 21, 2009) (available at http://www.qrnetwork.com.au/media-and-community-centre/environmental-policies/Coal-loss-management.aspx).

Kenneth Axtell & Chatten Cowherd, Environmental Protection Agency, Project Summary: Improved Emissions Factors for Fugitive Dust from Western Surface Coal Mining Surfaces, EPA-600/S7-84-048 (July 1984) (attached).

Christopher F. Blazek of Benetech Inc., The Role of Chemicals in Controlling Coal Dust Emissions, *presented at the American Coal Council, PRB Coal Use: Risk Management Strategies and Tactics Course*, Dearborn, Michigan (June 2003) (attached).

Edward M. Calvin, G. D. Emmitt, & Jerome E. Williams, A Rail Emission Study: Fugitive Coal Dust Assessment and Mitigation, *Proceedings for the Seventh Annual Environment Virginia '96 Symposium*, 44-53, Lexington, Virginia (April 11-12, 1996) (attached).

Connell Hatch, Barney Point Coal Terminal Dust Benchmarking Study: Gladstone Port Coal Dust Study, Reference HR02-03 Revision 0, *prepared for Gladstone Ports Corporation* (July 14, 2008) (available at http://www.gpcl.com.au/gpc_benchmarking_studies.html).

Connell Hatch, Final Report: Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains, Goonyella, Blackwater, and Moura Coal Rail Systems, Reference H327578-NOO-EE-00.00 Revision 1, *prepared for Queensland Rail Limited* (Mar. 31, 2008) (available at http://www.qrnetwork.com.au/media-and-community-centre/environmental-policies/Coal-loss-management.aspx).

Connell Hatch, RG Tanna Dust Benchmarking Study: Gladstone Port Coal Losses and Air Quality, Reference HR02-03 Revision 4, *prepared for Central Queensland Ports Authority* (March 12, 2008) (available at http://www.gpcl.com.au/gpc_benchmarking_studies.html).

Connell Hatch, Interim Report, Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains, Goonyella, Blackwater, and Moura Coal Rail Systems, Reference H-327578 Revision 0, *prepared for Queensland Rail Limited* (Jan. 31, 2008) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

Connell Hatch, Draft: Coal Loss Literature Review, Reference H327578-N00-CF00 Revision 0, *prepared for Queensland Rail Limited* (Jan. 11, 2008) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

Douglas L. Cope & Kamal K. Bhattacharyya, A Study of Fugitive Coal Dust Emissions in Canada, *prepared for The Canadian Council Ministers of the Environment* (Nov. 2001) (attached).

G. D. Emmitt, Fugitive Coal Dust: An Old Problem Demanding New Solutions, *Port Tech. Int'l.*, 9:125-128 (1999) (attached).

George D. Emmitt, Linnea S. Wood, Edward M. Calvin, & Steven Greco, Procontrol: Automated Fugitive Dust Control System, *Proceedings for the Seventh Annual Environment Virginia '96 Symposium*, 36-43, Lexington, Virginia (April 11-12, 1996) (attached).

George D. Emmitt, Minimizing Groundwater Consumption for Required Fugitive Dust Control Programs, *Proceedings for the Seventh Annual Environment Virginia '96 Symposium*, 244-251, Lexington, Virginia (April 11-12, 1996) (attached).

A.D. Ferreira, D.X. Viegas & A.C.M. Sousa, Full-Scale Measurements for Evaluation of Coal Dust Release from Train Wagons with Two Different Shelter Covers, *91 Journal of Wind Engineering & Industrial Aerodynamics*, 1271-1283 (2003) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

A.D. Ferreira & P.A. Paz, Wind Tunnel Study of Coal Dust Release from Train Wagons, *92 Journal of Wind Engineering & Industrial Aerodynamics*, 565-577 (2004) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

Claudio Guarnaschelli, Environmental Protection Service: Fisheries and Environment Canada, In-Transit Control of Coal Dust From Unit Trains, Report No. EPS 4-PR-77-1 (May 1977) (attached).

H. Huang, E. Tutumluer, & W. Dombrow, Laboratory Characterization of Fouled Railroad Ballast Behavior, *Transportation Research Record No. 2117: Journal of the Transportation Research Board, National Resource Council,* Washington, D.C., 93-101 (2009) (attached to the Opening Verified Statement of Dr. Erol Tutumluer, Exhibit 4).

Katestone Environmental & Introspec Consulting, Field Trial Program for the Observation of Potential Slip Failure or Other Movement in the Surface of Coal in Wagons During Transport From Mine to Port, *prepared for Queensland Rail Limited* (Feb. 3, 2009) (available at http://www.qrnetwork.com.au/media-and-community-centre/environmental-policies/coal-loss-management.aspx).

Ross Leeder, Wes Hutny & John Price, Train Transportation Coal Losses: A Wind Tunnel Study, *AISTech 2007: Proceedings of the Iron & Steel Technology Conference Volume I*, 129-138 (May 7-10, 2007) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

George Noble, Sander E. Sundberg, and Michael Bayard, Coal Particulate Emissions From Rail Cars, *Proceedings from the Air Pollution Control Association Specialty Conference on Fugitive Dust Issues in the Coal Use Cycle*, Rep. No. CONF-8304206, 82-92 (April 1983) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

QRNetwork, *Coal Dust Management Plan: Coal Loss Management Project*, Version Draft V10D (Feb. 22, 2010) (available at http://www.qrnetwork.com.au/media-and-community-centre/environmental-policies/coal-loss-management.aspx).

Report of the Joint Subcommittee Studying Ways to Reduce Emissions from Coal-Carrying Railroad Cars to the Governor and the General Assembly of Virginia, Senate Document No. 23 (Jan. 1997) (available at http://leg2.state.va.us/DLS/H&SDocs.NSF/Published+by+Year?OpenForm&StartKey=1997&ExpandView).

B. Roebuck, N. P. Vaughan, & K. Y. K. Chung, Performance Testing of the OSIRIS Dust Monitoring System, 34 (3) *Ann. Occup. Hyg.* 263-279 (1990) (included in the workpapers of the Rebuttal Verified Statement of Dr. Mark Viz).

Simitars: Queensland Government, A Business Unit of the Department of Mines and Energy, Gladstone Airborne Coal Dust Monitoring: Complete Report for QRNational, Report No. oe101776f3 (Jan. 18, 2008) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

Simpson Weather Associates, Norfolk Southern Rail Emission Study, *prepared for Norfolk Southern Corporation* (Dec. 30, 1993) (included in the workpapers of the Reply Verified Statement of Dr. Mark Viz).

E. Tutumluer, W. Dombrow, & H. Huang, Laboratory Characterization of Coal Dust Fouled Ballast Behavior, *Proc. AREMA 2008 Annual Conference*, Salt Lake City, Utah (September 21-24, 2008) (attached to the Opening Verified Statement of Dr. Erol Tutumluer, Exhibit 3).

Edmund P. Wituschek, & Douglas L. Cope, Environment Canada, Coal Dust Control: Recommended Practices for Loading, Unloading, and Transporting Coal by Rail, Regional Report No. 86-17 (April 1986) (attached to the Rebuttal Verified Statement of William VanHook, Exhibit 2).

United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Cincinnati, OH 45268

Research and Development

EPA-600/S7-84-048 July 1984

EPA

Project Summary

Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources

Kenneth Axetell, Jr. and Chatten Cowherd, Jr.

The primary purpose of this study was to develop emission factors for significant surface coal mining operations that would be applicable at Western surface coal mines and would be based on widely acceptable, state-of-the-art sampling and data analysis procedures. The approach was to develop emission factors for individual mining operations in the form of equations with correction factors to account for site-specific conditions. Factors were determined for three particle size ranges—less than 2.5 μm (fine particulate), less than 15 μm (inhalable particulate), and total suspended particulate.

A total of 265 tests were run at three mines during 1979 and 1980. The following sources were sampled: Drilling (overburden), blasting (coal and overburden), coal loading, bulldozing (coal and overburden), dragline operations, haul trucks, light- and medium-duty vehicles, scrapers, graders, and wind erosion of exposed areas and coal storage piles. The primary sampling method was exposure profiling; however, upwind-downwind, balloon, wind tunnel, and quasi-stack sampling methods were used on sources unsuitable for exposure profiling.

Several variables that might affect emission rates, such as vehicle speed, were monitored during the tests. Significant correction parameters in the emission factor equations were then determined by multiple linear regression analysis. Confidence intervals were also calculated for each of the factors.

Data for determination of deposition rates were obtained, but scatter in the data prevented the development of an algorithm. Control efficiencies for two unpaved road control measures were estimated.

The full report concludes with a comparison of the generated emission factors with previous factors, a statement regarding their applicability to mining operations, and recommendations for additional research in Western and other mines.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Operations of surface coal mines vary from mine to mine, and the relative amounts of dust produced by the different operations will vary greatly. A ranking of the sources was performed to determine which significant particulate sources warranted sampling, based on average mine conditions. The most significant dust-producing operations are shown in Table 1.

Sampling Program

The number of mines to be surveyed was set at three—a compromise between sampling over the widest range of mining/meteorological conditions by visiting a large number of mines and obtaining the most tests within the given budget and time limits by sampling at only a few mines. The three mines selected were in diverse geographic areas in the Western coal fields having the largest strippable reserves: Fort Union (North

Dakota), Powder River Basin (Montana-Wyoming), and San Juan River (New Mexico-Arizona). These mines had most of the significant dust-reproducing operations, and most operations could be sampled at more than one location in each mine. While sampling was limited to several weeks at each mine, seasonal variations in emission rates were considered by sampling during three of four seasons.

A total of 265 tests (245 of them on uncontrolled sources) were conducted during four sampling periods. Table 1 summarizes the tests by mine and by source. The total number of samples required for each source to achieve a 25 percent relative error at a 20 percent risk level was determined statistically. The calculated sample size could not be obtained from some sources because of difficulties encountered in the field, such as source inactivity, inability to place the sampling array in the required location due to topographical barriers, unstable wind directions, and low or high windspeeds. A major effort was made to obtain a statistically adequate sample size for haul trucks, the major dust-producing source.

Table 1. Summary of Tests Performed

Source	Sampling technique	Mine 1	Mine 2	Mine 1W[a]	Mine 3	Total
Drilling, ovb.[b]	Quasi-stack	11	-	12	7	30
Blasting, coal	Balloon	3	6		7	16
Blasting, ovb.	Balloon	2			3	5
Coal loading (shovel/truck or front-end loader)	Uw-dw[c]	2	8		15	25
Bulldozing, ovb.	Uw-dw	4	7		4	15
Bulldozing, coal	Uw-dw	4	3		5	12
Dragline	Uw-dw	6	5		8	19
Haul trucks	Profiling	7[d]	9	10[e]	9	35
Light- and medium-duty trucks	Profiling	5	5		3	13
Scrapers	Profiling	5[d]	6	2	2	15
Graders	Profiling		5		2	7
Exposed area, ovb.	Wind tunnel	11	14	3	6	34
Exposed area, coal	Wind tunnel	10	7	6	16	39
Total		70	75	33	87	265

[a] Winter sampling period.
[b] ovb. = overburden.
[c] Uw-dw = upwind-downwind.
[d] Five of these tests were comparability tests (profiling and upwind-downwind).
[e] Six of these tests were done by upwind-downwind.

Sampling Techniques

A thorough review of possible fugitive dust sampling techniques indicated that no one technique was adequate to sample all sources. Exposure profiling, designated as the preferred technique, was used whenever possible (63 profiling tests were performed). Each of the five different sampling techniques used in the study is described briefly in the following paragraphs.

The exposure profiler consisted of a portable tower (4 to 6 m in height) supporting an array of sampling heads Each sampling head was operated as an isokinetic exposure sampler The air-flow stream passed through a settling chamber that trapped particles larger than about 50 μm, and then flowed upward through a horizontally position, standard 8 x 10 in. glass fiber filter. Sampling intakes were positioned directly into the wind, and sampling velocities were adjusted to match the mean windspeed at each height (as determined immediately prior to the test). Windspeed was monitored by hot-wire anemometers throughout the test, and flow rates were adjusted for major changes in mean windspeed. Operating concurrently with the profiler, dichotomous samplers placed at two heights on the tower determined particle size distribution. Duplicate dustfall buckets located at the profiler and 20 and 50 m downwind of the source provided information on deposition.

The exposure profiler concept was modified for sampling blasting operations. The large horizontal and vertical dimensions of the blast plumes required a suspended array of samplers as well as ground-based samplers in order to sample over the plume cross-section in both dimensions. Five 47-mm polyvinyl chloride (PVC) filter heads and sampling orifices were attached to a line suspended from a tethered balloon. The samplers were located at different heights (2.5, 7.6, 15.2, 22.9, and 30.5m), and each sampler was attached to a wind vane so that the orifices would face directly into the wind. The samplers were connected to a ground-based pump with flexible tubing. The pump maintained an isokinetic flow rate for a windspeed of 5 mph. To avoid equipment damage from blast debris and to obtain a representative sample of the plume, the balloon-suspended samplers were located about 100 m downwind of the blast area. The balloon-supported samplers were supplemented with five hi-vol/dichotomous sampler pairs spaced 20 m apart and located on an arc at the same distance as the balloon from the edge of the blast area.

The upwind-downwind array used for sampling point sources included 15 samplers (10 hi-vol and 5 dichotomous). One of each sampler type was located upwind of any dust from the source. Initially, downwind samplers were placed at nominal distances of 30, 60, 100, and 200 m; however, these distances had to be frequently modified because of physical obstructions (e.g., highwall) or potential interfering sources. Two samplers of each type were placed at a distance of 30 m, three hi-vols and two dichotomous samplers at 60 m, three hi-vols at 100 m, and one hi-vol at 200 m. Both sampler types were mounted on tripod stands at a height of 2.5 m, the highest manageable height for this type of rapid-mount stand. The downwind array was modified slightly for sampling line sources. It consisted of two pairs of hi-vol/dichotomous samplers at 5, 20, and 50 m and two hi-vols at 100 m. The two rows of samplers were separated by 20 m. The upwind-downwind method allowed indirect measurement of deposition through calculation of apparent emission rates at a series of downwind distances.

A portable wind tunnel consisting of an inlet section, a test section, and an outlet diffuser was used to measure dust emissions generated by wind erosion of exposed areas and storage piles. The test section has a 1 by 1 ft cross section so it could be used with rough surfaces. The open-floored test section was placed directly on the 1 by 8 ft surface to be tested, and the tunnel air flow was adjusted to predetermined values that corresponded to the means of NOAA windspeed ranges. Tunnel windspeed was measured by a pitot tube at the downstream end of the test section and related to windspeed at the standard 10 m height by means of a logarithmic profile. An emission-sampling module

was located between the tunnel outlet and the fan inlet to measure particulate emissions generated in the test section. The sampling train, which was operated at 15 to 25 ft^3/min, consisted of a tapered probe, cyclone precollector, parallel-slot cascade impactor, backup filter, and hi-vol motor. Interchangeable probe tips were sized for isokinetic sampling over the desired tunnel windspeed range.

For quasi-stack sampling of overburden drilling, a wooden enclosure with 4 by 6 ft end openings was fabricated in the field. During each test, the enclosure was placed adjacent to, and downwind of the drill platform. The cross section of the enclosure was divided into four rectangles of equal area, and a hot-wire anemometer measured wind velocity at the center of each rectangle. Four exposure profiler samplers with remote flow controllers were used to sample in the four enclosure subareas. Sampler flow rates were adjusted at 2-to 3-minute intervals to near-isokinetic conditions with the windspeed measurements. This sampling technique did not measure particle size distribution of deposition.

Source Characterization

Many independent variables influence particulate emission rates from mining sources. If these variables are to be quantified and included as parameters (correction factors) in the emission factor equations, suspected variables must be measured for each emission test.

Summary of Results

Total suspended particulate (TSP) and inhalable particulate (IP) emission rates are presented in Table 2. For some sources, the number of test values is lower than the number of tests reported in Table 1. This indicated elimination of data after a test was completed. For example, the plume may have missed the sampling array for most of the period or the sampler may have malfunctioned. Most of the tests for which no data are presented in Table 2 (36 out of 44) were run on exposed areas. These tests were unproductive because eroding particles could not be generated on the test surfaces, even at the highest windspeed simulated in the wind tunnel.

The geometric mean values in Table 2 are *not* emission factors; no consideration has been given to correction factors at this point.

The relative standard deviations of emission rates by individual sources ranged from 0.7 to 1.5. Relative standard deviation is a measure of sample variation.

Table 2. Emission Rates by Source

Source	No. of values	Units	Geometric mean emission rate TSP	Geometric mean emission rate IP	Range of emission rates from individual tests TSP	Range of emission rates from individual tests IP
Drilling, ovb.[a]	30	lb/hole	1.16		0.04-7.29	
Blasting, coal	14	lb/blast	28.7	10.5	1.6-514 0	0.4-142.8
Blasting, ovb.	4	lb/blast	74.3	40.0	35.2-270.0	16.9-93.9
Coal loading (shovel/truck or front-end loader)	25	lb/ton	0.039	0.010	007-1.090	0.002-0.378
Bulldozing, ovb.	15	lb/h	3.70	1.96	0.9-20.7	0.48-32.60
Bulldozing, coal	12	lb/h	46.0	20.5	3 0-439.0	0.9-236.0
Dragline	19	lb/yd^3	0.050	0.013	0.004-0.400	0.002-0.061
Haul trucks	33	lb/VMT	9.1	4.1	0.6-73 1	0.4-42.1
Light- and medium-duty trucks	11	lb/VMT	2.43	1.54	0.35-9.0	0.34-5.1
Scrapers	14	lb/VMT	24.3	11.7	3.9-355 0	1.4-217.0
Graders	7	lb/VMT	5.8	2.8	1.8-34.0	0.9-15.4
Exposed area, ovb.	10	lb/acre-s	0.0803	0.0549	0.0107-0.537	0.0073-0 336
Exposed area, coal	27	lb/acre-s	0.0980	0.0642	0.0096-2.27	0.0053-1.40

[a] *ovb. = overburden.*

For most sources with at least 10 data points, emission rates varied more than two orders of magnitude; however, similar variations were noted in independent variables thought to have an effect on emission rates.

Multiple Linear Regression Analysis

The method for developing correction factors was based on multiple linear regression (MLR). Briefly, values for all variables being considered as possible correction factors were first tabulated by source along with the corresponding TSP emission rates for each test. The data were then transformed to their natural logarithms (ln) because a preliminary analysis had indicated the emission rates were lognormally rather than normally distributed. The transformed data were applied to the MLR program, specifying the stepwise option and permitting entry of all variables that increased the multiple regression coefficient.

Wind Erosion Sources

The emission rates reported in Table 2 for wind erosion from coal pile surfaces and exposed ground areas were obtained by testing several naturally occurring surfaces at successively increasing windspeeds simulated in the wind tunnel. Analysis of SP (the size fraction less than 30 μm) and IP emission rates indicated that the rates (1) increased with windspeed above a threshold level on newly exposed surfaces and (2) decreased sharply with time after the onset of erosion.

Threshold velocities for detectable movement of surface particles were unexpectedly high. This was attributed to the presence of natural crusts on many of the surfaces tested. The decay in emission rates with time was explained by the limited quantity of particles in any specified particle size range present on the surface (per unit area) that could be removed by wind erosion at a particular windspeed. The available quantity, or erosion potential could be restored by a disturbance of the surface such as the addition or removal of material from a storage pile or the plowing of an exposed ground area.

Particle Size Distribution

Emission factors were developed for three size ranges—fine particulate (FP, <2.5 μm); inhalable particulate (IP, <15 μm); and total suspended particulate (TSP, no well-defined upper cut point, but approximated as 30 μm). Dichotomous samplers generated the FP and IP data and hi-vol samplers generated the TSP data. Suspended particulate (SP) emission rates determined from exposure profiling tests were not actually TSP; rather, these rates were the fraction of total particulates less the 30 μm in aerodynamic diameter. Only a calculated estimate of the suspended fraction could be made because the profiler samplers indiscriminately collect all particle sizes present in the plume.

Independent data analyses were performed on IP and TSP/SP data to derive emission factors for these two size ranges. Data analysis problems associated with the very low concentrations prevented determination of emission factors for the FP size fraction by calculation of emission rates followed by multiple linear regression. Instead, net FP concentrations for

all tests were expressed as a fraction of TSP or SP, and the average fraction for each source was applied to the TSP/SP emission factor for that source to calculate an FP emission factor.

Table 3 shows the average ratios of FP and IP to TSP or SP emission rates by source. The IP fractions were reasonably consistent, varying from 0.30 to 0.67. In general, these ratios were lower than the frequently quoted average ratio of 0.65 for urban ambient monitoring. These ratios were based on measurements taken near the sources. As the emissions proceed downwind, greater deposition in the TSP fraction should increase the ratio.

The variation of FP/TSP ratios was much wider, from 0.026 to 0.196. The 0.196 value for bulldozing overburden appeared to be an anomaly, however. Exclusion of this value makes the range 0.026 to 0.074. The fairly consistent ratios of FP and IP to TSP for different sources indicate that the size distribution is similar in all fugitive dust sources at mines.

Three different particle sizing methods were evaluated early in the study—cascade impactors, dichotomous samplers, and microscopy. Side-by-side comparison of these methods showed that the cascade impactors and dichotomous samplers gave approximately the same particle size distributions. In contrast, the microscopy data varied widely. It was concluded that microscopy is a useful tool for semiquantitative estimates of various particle types, but it is inadequate for primary particle sizing of fugitive dust emissions. Despite several unresolved problems involved in the generation of fine particle data for fugitive dust sources, data from the present study are thought to be reasonable based on their consistency and the observed agreement between dichotomous and cascade impactor data.

Table 3. Average Particle Size Distributions by Source

Source	No. of tests	Average IP/TSP	Std. dev. of IP/TSP	Average FP/TSP	Std. dev. of FP/TSP
Blasting	18	0.46	0.29	0.051	0.039
Coal loading	24	0.30	0.15	0.030	0.035
Bulldozing, coal	12	0.49	0.24	0.031	0.033
Bulldozing, ovb.	14	0.54	0.50	0.196	0.218
Dragline	19	0.32	0.22	0.032	0.040
Haul trucks[a]	28	0.52	0.08	0.033	0.037
Light- and medium-duty vehicles[a]	11	0.65	0.16	0.074	0.078
Scrapers[a]	14	0.49	0.07	0.026	0.021
Graders[a]	7	0.48	0.10	0.055	0.041
Coal storage piles[a]	27	0.61	0.08		
Exposed areas[a]	10	0.67	0.06		

[a]*Expressed as fractions of SP (<30 μm) rather than TSP.*

Deposition

The emission factors in this study were all developed from sampling data obtained very near the source. Emissions are subject to deposition as distance from the source increases

A secondary objective of this study was to develop a deposition function specifically for use with the mining emission factors. Deposition rates were measured by two different methods—dustfall catch and apparent source depletion at successive distances from the source. Although initial side-by-side testing of the two methods indicated that apparent source depletion gave the better results, dustfall measurements were still taken at 5, 20, and 50 m from the source as part of the exposure profiling tests; these dustfall measurements proved to give much more reliable estimates of deposition rates during most of the sampling at the three mines.

The deposition rates by test were correlated with several potential variables such as windspeed and particle distribution. These analyses did not reveal any significant relationships that could form the basis for an empirical deposition function. Because these analyses were nonproductive and the primary method for measuring deposition (apparent source depletion in upwind-downwind sampling) gave unusable results, a deposition function cannot be presented at this time

If additional testing is performed to develop a deposition function, dustfall measurement is recommended as the sampling method. The main shortcoming of dustfall as a measurement of deposition is that it measures total particulate rather than the amount of deposition in the TSP or IP range.

Control Measures

Two mining control measures—application of water and application of a calcium chloride solution—were evaluated by comparing emission rates from treated and untreated areas. Testing was done on the same or adjacent lengths of roadway under similar traffic and meteorological conditions so that the only substantial variable between test pairs was application of the dust control. The number of tests available for determination of control efficiencies was limited and statistically inadequate.

The results of 1-hour test periods immediately after watering (shown in Table 4) indicate that water at a rate of 0.05 gal/yd^2 reduced particulate emissions from haul roads by 60 to 70 percent and those from coal loading by 78 percent. Maintenance of that range of efficiencies would require the reapplication of water at an approximate frequency of once per hour. Results showed that calcium chloride still reduced particulate emission rates from an access road by 95 percent about three months after its application, but no information was obtained on the life expectency of this control. Application rate for the 30 percent solution of calcium chloride was 0.6 gal/yd^2.

Table 4 shows that control efficiencies for IP were essentially the same as those for TSP, whereas those for FP were slightly lower. The 60 to 70 percent control efficiency for watering haul roads was higher than the 50 percent widely reported in the technical literature, possible because testing was done right after the water was applied.

Comparison of Sampling Techniques

The two major sampling techniques, exposure profiling and upwind-downwind sampling, were run simultaneously on a common source for several tests to determine relative performance.

Profiling towers and the upwind-downwind samplers (hi-vols and dichotomous samplers) were placed 5, 20, and 50 m downwind of the sources to measure the decrease in particulate flux with distance. This design allowed the indirect determination of deposition rates. Duplicate hi-vols and dichotomous samplers were placed at each of three distances, and two additional hi-vols were located 100 m downwind of the source. Upwind samplers consisted of three hi-vols and a dichotomous sampler,

Table 4. Control Efficiencies for Watering and Calcium Chloride

Source	Control measure	Size fraction	No. Tests		Avg. Emission rate, lb/VMT[a]		Mean control eff., %
			Uncontrolled	Controlled	Uncontrolled	Controlled	
Haul road, Mine 2	Watering	TSP[b]	4	4	5.3	2.2	59
		IP	4	4	2.8	1.1	61
		FP	4	4	0.19	0.08	58
Haul road, Mine 3	Watering	TSP[b]	4	5	16.3	5.0	69
		IP	4	5	8.9	2.4	73
		FP	3	5	0.21	0.10	54
Coal ldg., Mine 3	Watering	TSP	5	9	0.188	0.042	78
		IP	4	9	0.053	0.010	81
		FP	4	9	0.0028	0.0009	68
Access road, Mine 1	Calcium chloride	TSP[b]	3	2	6.8	0.35	95
		IP	3	2	5.4	0.34	95
		FP	3	2	0.74	0.09	88

[a] *Emission factors for coal loading are expressed in units of lb/ton.*
[b] *Measured as SP, the size fraction less than 30 μm.*

all located 20 m from the upwind edge of the source.

Haul trucks and scrapers were selected for sampling in the comparison study. Because they are ground-level moving point sources (line sources) that emit from relatively fixed boundaries, both sampling methods were applicable and the required extensive sampling array could be located without fear of the sources changing location. Also, haul trucks and scrapers are two of the largest fugitive dust sources at most surface coal mines.

Five tests of each source were run over a 15-day period. All five tests of each source were performed at the same site, so only two sites (one for each source) and one mine were involved in the comparison study.

These data were subjected to Analysis of Variance (ANOVA) to evaluate whether differences in emission rates by sampling method, source, and downwind distance were statistically significant. Sampling method and downwind distance were found to have significant effects ($\sigma = 0.20$) on both TSP and IP emission rates; emission source (haul truck or scraper) was not a significant variable. The emission rates produced by profiling averaged 24 percent higher for TSP and 52 percent higher for IP than corresponding upwind-downwind emission rates, according to the ANOVA results.

Both methods of sampling showed large overall reductions in TSP and IP emission rates with distance. In 6 of 10 tests, however, profiling showed lower emission rates at the closest sampling sites (5 m) than at the middle sites (20 m). These inverted values were attributed to a systematic bias between measurements taken by two contractors, each of whom operated one of these profilers. The reduction of IP emission rates with distance was surprising, because very little deposition of sub-15 μm particles was expected over a 50-m interval.

The reason for the relatively poor comparisons between emission rates obtained by the two sampling/calculation methods was traced primarily to the precision of the samplers. It was not possible to establish from the data which sampling method was more accurate because the paired results were compared with each other rather than a known standard. Error analyses performed, after the side-by-side sampling led to the conclusion that the accuracy of state-of-the-art testing of fugitive emissions is ±25 to 50 percent with either of these two sampling methods.

Conclusions

Resulting Emission Factors

The emission factors resulting from this study (Table 5) are in the form of equations with correction factors for independent variables that were found to have a significant effect (generally at the 0.05 risk level) on each source's emission rates. The range of independent variable values over which sampling was conducted, and for which the equations are valid, are also shown in the table. Any ambient air quality analysis using these emission factors should have some provision for considering deposition.

The 80 and 95 percent confidence intervals for TSP were presented in the report. The average 80 percent confidence interval was -20 to +24 percent, less than the relative error anticipated in the study design.

The emission factors are for uncontrolled emission rates. Control efficiencies of a few control measures were estimated in limited testing, of the report. These control efficiencies should be applied to the calculated emission factors in cases where such controls have been applied or are anticipated.

A comparison of the emission factors developed in this study with others based on actual testing in surface coal mines indicated ratios of new to existing factors ranging from 0.4 to 2.2.

Limitations to Applications of Factors

Although these emission factors were designed to be widely applicable through the use of correction factors, the following limitations should be considered in their application:

1. The factors should be used only for estimating emissions from Western surface coal mines. There is no basis for assuming they would be appropriate for other types of surface mining operations, or for coal mines located in other geographic areas, without further evaluation.
2. Correction factors used in the equations should be limited to values within the ranges tested (see Table 15-1 of the full report). This is particularly important for correction factors with a large exponent, because of the large change in the resulting emission factor associated with a change in the correction factor.
3. These factors should be combined with a deposition function for use in ambient air quality analyses. After evaluation of the deposition data from this study, no empirical deposition function could be developed. Any function subsequently developed from these data should have provision for further deposition beyond the distance of sampling in this study (100-200m).
4. The factors were obtained by sampling at the point of emission and do not address possible reductions in emissions from dust being contained within the mine pit.
5. As with all emission factors, these mining factors do not assure the calculation of an accurate emission value from an individual operation. The emission estimates are more reliable when applied to a large number of operations, as in the preparation of an emission inventory for an entire mine. The emission

Table 5. *Summary of Western Surface Coal Mining Emission Factors*

Source	TSP/IP	Prediction equation for emission factor	FP fraction of TSP	Units	Range of correction parameters
Drilling	TSP	1.3	None	lb/hole	None
Blasting	TSP	$\frac{961\ A^{0.8}}{D^{1.8}\ M^{1.9}}$	0.030	lb/blast	A = area blasted, ft^2 = 1076 to 103,334 M = moisture, % = 7.2 to 38 D = depth of holes, ft = 20 to 135
	IP	$\frac{2550\ A^{0.6}}{D^{1.5}\ M^{2.3}}$			
Coal loading	TSP	$1.16/M^{1.2}$	0.019	lb/ton	M = 6.6 to 38
	IP	$0.119/M^{0.9}$			
Bulldozing, coal	TSP	$78.4\ s^{1.2}/M^{1.3}$	0.022	lb/h	s = silt content, % = 6.0 to 11.3 M = 4.0 to 22.0
	IP	$18.6\ s^{1.5}/M^{1.4}$			
Bulldozing, ovb.	TSP	$5.7\ s^{1.2}/M^{1.3}$	0.105	lb/h	s = 3.8 to 15.1
	IP	$1.0\ s^{1.5}/M^{1.4}$			M = 2.2 to 16.8
Dragline	TSP	$0.0021\ d^{1.1}/M^{0.3}$	0.017	lb/yd^3	d = drop distance, ft = 5 to 100 M = 0.2 to 16.3
	IP	$0.0021\ d^{0.7}/M^{0.3}$			
Scrapers	TSP	$(2.7 \times 10^{-3})s^{1.3}W^{2.4}$	0.026	lb/VMT	s = 7.2 to 25.2 W = vehicle weight, tons = 36 to 64
	IP	$(6.2 \times 10^{-4})s^{1.4}W^{2.5}$			
Graders	TSP	$0.040\ S^{2.5}$	0.031	lb/VMT	S = vehicle speed, mph = 5.0 to 11.8
	IP	$0.051\ S^{2.0}$			
Light- and medium-duty vehicles	TSP	$5.79/M^{1.0}$	0.040	lb/VMT	M = 0.9 to 1.7
	IP	$322/M^{1.3}$			
Haul trucks	TSP	$0.0067\ w^{1.3}L^{0.2}$	0.017	lb/VMT	w = average number of wheels = 6.1 to 10.0 L = silt loading g/m^2 = 3.8 to 254.0
	IP[a]	$0.0051\ w^{1.5}$			

[a] *Silt loading was not a significant correction parameter for the IP fraction.*

factors are also more reliable when estimating emission over the long term because of short-term source variation.

6. Appropriate adjustments should be made in estimating annual emissions with these factors to account for days with rain, snow cover, temperature below freezing, and intermittent control measures
7. The selection of mines and their small number may have biased final emission factors, but the analysis did not indicate that a bias exists.
8. The confidence intervals cited in Table 13-10 of the full report estimate how well the equations predict the measured emission rates at the geometric mean of each correction factor. For predicting rates under extreme values of the stated range of applicability of the correction factors, confidence intervals would be wider
9. Error analyses for exposure profiling and upwind-downwind sampling indicated potential errors of 30 to 35 percent and 30 to 50 percent, respectively, independent of the statistical errors due to source variation and limited sample size.
10. Geometric means were used to describe average emission rates because the data sets were distributed lognormally rather than normally. This procedure makes comparison with previous emission factors difficult, because previous factors were all arithmetic mean values.
11. Wind erosion emission estimates should be restricted to calculation of emissions relative to other mining sources; they should not be included in estimates of ambient air impact.

Recommendations

A comprehensive study that has evaluated alternative sampling and analytical techniques is bound to identify areas where additional research would be valuable. Also, some inconsistencies surface during the data analysis phase, when it is too late to repeat any of the field studies. Therefore, a brief list of recommendations for further study is presented here.

1. Sampling at Midwestern and Eastern coal mines is definitely needed so that emission factors applicable to all surface coal mines are available.
2. A resolution of which deposition function is most accurate in describing fallout of mining emissions is still needed. Closely related to this is the need for a good measurement method for deposition for several hundred meters downwind of the source (dustfall if recommended for measurements up to 100 or 200 m). In the present study, both the source depletion and dustfall measurement methods were found to have deficiencies.
3. A method for obtaining a valid size distribution of particles over the range of approximately 1 to 50 μm under near-isokinetic conditions is needed for exposure profiling. The method should utilize a single sample for sizing rather than building a size distribution from fractions collected in different samplers.
4. The emission factors presented herein should be validated by sampling at one or more additional

Western mines and comparing calculated values with the measured ones.

5. Standardized procedures for handling dichotomous filters should be developed. These should address such areas as numbering of the filters rather than their petri dishes, proper exposure for filters used as blanks, transporting exposed filters to the laboratory, equilibrating filters prior to weighing, and evaluation of filter media other than Teflon for studies where only gravimetric data are required.
6. One operation determined in the study design to be a significant dust-producing source, shovel/truck loading of overburden, was not sampled because it was not performed at any of the mines tested. Sampling of this operation at a mine in Wyoming and development of an emission factor would complete the list of emission factors for significant sources at Western coal mines (see Table 2-1 of the full report).
7. Further study of emission rate decay over time from eroding surfaces is needed. In particular, more information should be obtained on the effect of wind gusts in removing the potentially erodible material from the surface during periods when the average windspeed is not high enough to erode the surface
8. More testing of controlled sources should be done so that confidence in the control efficiencies is comparable to that for the uncontrolled emission rates.

Kenneth Axetell, Jr. is with PEDCo Environmental, Inc., Kansas City, MO 54108; and Chatten Cowherd, Jr. is with Midwest Research Institute, Kansas City, MO 64110.

***Jonathan G. Herrmann** and **Thompson G. Pace** are the EPA Project Officers (see below).*

The complete report, entitled "Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources," (Order No. PB 84-170 802; Cost: $23.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

*USGPO: 1984-759-102-10615

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

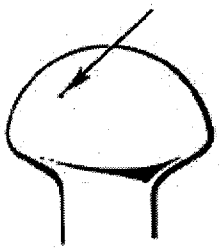
Official Business
Penalty for Private Use $300

PS 0000329
U S ENVIR PROTECTION AGENCY
REGION 5 LIBRARY
230 S DEARBORN STREET
CHICAGO IL 60604

The Role of Chemicals in Controlling Coal Dust Emissions

By
Christopher F. Blazek, VP Marketing, Benetech Inc.
Presented at the American Coal Council
PRB Coal Use: Risk Management Strategies & Tactics Course
June 25, 26, 2003, Hyatt Regency Dearborn, Michigan

Defining the Dust Issue



A Micron-Size Dust Particle on a Pin Head

Dust consists of solid particles carried by air currents. Coal dust originates at impact points (including crushing and grinding), from previous accumulations, or from weathering. A wide range of particle sizes can be produced during a dust generating process. Larger particles settle more quickly than smaller particles, and the smallest particles can remain in the air indefinitely. Dust is typically measured in micrometers (commonly known as microns). Coal dust can range is size from over 100 µm to less than 2 µm. As a comparison, red blood cells are typical 8 µm and human hair ranges from 50-75 µm in size

In coal processing operations, dust is generated-

- When coal is broken by impact, abrasion, crushing, grinding, etc.
- Through release of previously generated dust during operations such as loading, dumping, and transferring
- Through recirculation of previously generated dust by wind or by the movement of workers and machinery

The amount of dust emitted by these activities depends on the physical characteristics of the material and the way in which the material is handled.

Fibrogenic dust, such as free crystalline silica or asbestos, is biologically toxic and, if retained in the lungs, can form scar tissue and impair the lungs' ability to function properly. PRB coal dust exceeds this 1% silica content as is regulated by OSHA to a level not to exceed 2.0 µm/m^3 of air volume. Furthermore, excessive concentrations of dust in the workplace may reduce visibility, may cause unpleasant deposits in eyes and nasal passages, and may cause injury to the skin or mucous membranes by chemical or mechanical action. From an occupational health view point, dust is classified by size into three primary categories:

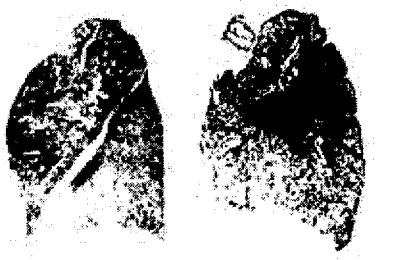
- Respirable dust
- Inhalable dust
- Total dust

Respirable dust refers to those dust particles that are small enough to penetrate the nose, upper respiratory system, and travel deep into the lungs. Generally, the body has little ability to remove this respirable dust from the lungs. IMHA defines respirable dust as the fraction of airborne dust that passes a through a sieve, with 100% passing through 10 µm. The EPA describes inhalable dust as that size fraction of dust which

enters the body, but is trapped in the nose, throat, and upper respiratory tract. The diameter of this dust is about 10 µm and greater. Total dust includes all airborne particles, regardless of their size or composition.

Excessive dust emissions can cause both health and work place problems including:

- Health hazards
  - Occupational respiratory diseases
  - Irritation to eyes, ears, nose and throat
  - Irritation to skin
- Risk of dust explosions and fire
- Damage to equipment
- Impaired visibility and accidents
- Unpleasant odors
- Problems in community relations
- Regulatory citations and fines



Healthy Lung Contaminated Lung

Excessive or long-term exposure to harmful respirable dusts may result in a respiratory disease called pneumoconiosis. Pneumoconiosis is a general name for a number of dust-related lung diseases including:

- **Silicosis** - Silicosis is a form of pneumoconiosis caused by the dust of quartz and other silicates. The condition of the lungs is marked by nodular fibrosis (scarring of the lung tissue), resulting in shortness of breath. Silicosis is an irreversible disease; advanced stages are progressive even if the individual is removed from the exposure.
- **Black Lung** - Black lung is a form of pneumoconiosis in which respirable coal dust particles accumulate in the lungs and darken the tissue. This disease is progressive. Although this disease is commonly known as black lung, its official name is coal worker's pneumoconiosis (CWP).
- **Asbestosis** - Asbestosis is a form of pneumoconiosis caused by asbestos fibers. This disease is also irreversible.

Chemical Dust Suppression Systems

Chemical Dust suppression systems can be used to reduce dust emissions. Although installing a dust control system does not assure total prevention of dust emissions, a well-designed dust control system can further protect workers and often provide other benefits such as:

- Reducing cleanup and maintenance costs
- Reducing equipment wear, especially for components such as bearings and pulleys on which fine dust can cause a "grinding" effect and increase wear or abrasion rates
- Increasing worker morale and productivity
- Assure continuous compliance with existing health and environmental regulations
- Increase plant availability and reliability
- Reduce plant water use relative to water only systems

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

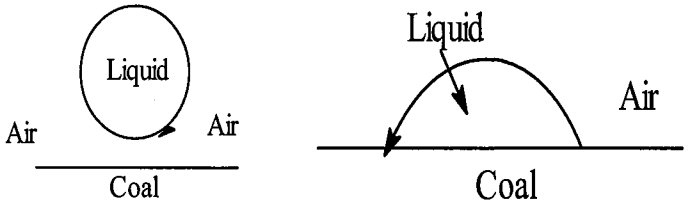
Proper planning, design, installation, operation, and maintenance are essential for an efficient, cost-effective, and reliable chemical dust suppression system. Applications for chemical dust suppression systems in the coal yard include:

- Coal transfer points
- Coal pile and car top residual, sealers & encrusting agents
- Haul road dust control
- Flow enhancers
- Washdown systems
- Yard spray systems

Application Issues

Surface Tension

Coal dust suppression is a complex phenomena; necessitating the use of surface active agents. Coal is water hating (hydrophobic), repelling water from the coal surface. In order to make the coal surface less hydrophobic, a surface active material is added to the water. The surface active material lowers the surface tension of the water to a value closer to that of the coal allowing it to be adsorbed on the surface of the coal. The water, by adsorbing on the coal surface, renders it less hydrophobic. The following figure depicts the phenomena.



Untreated coal on the left and wet coal on the right.

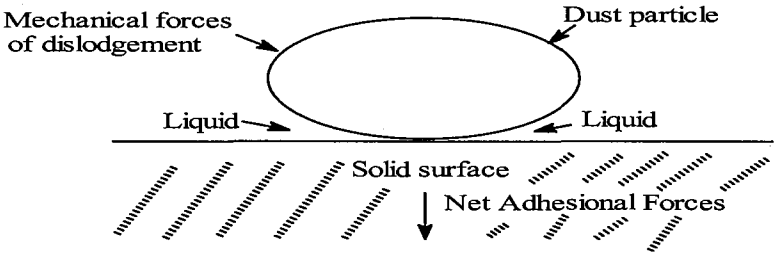
The surface active agent forms a microscopic liquid film as a means of increasing the adhesion of the coal dust particles. An effective dust suppressant must wet (making it less water hating) the surface of the coal, maintaining a moist environment, and bind the coal dust particles to the coal to prevent regeneration of the dust. Benetech offers a full range of optimized dust suppression products based on our expertise in surface science. These non-flammable, non-toxic, non-explosive and biodegradable products can be used to suppress dust via wetting, foaming, residual, or emulsification processes.

By evaluating contact angles and spreading coefficients of numerous surfactant molecules, Benetech has identified the structure/ property relationships of commercial surfactants and their interaction, contributing to optimum wetting and adhesion. All Benetech formulations contain synergistic combinations of wetting agents, necessary for providing fast, efficient, and effective dust suppression as well as agents to enhance foam quality and overcome problems associated with hard or brackish waters.

The figure below depicts the adsorption and adhesion phenomena associated with effective dust suppression. The wetting of the coal involves the displacement of air from

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

the surface by a liquid; namely, water or an aqueous solution. The addition of a surfactant to the water, by reducing the surface tension of water and perhaps the interfacial tension between the water and the coal particle making spontaneous spreading possible. This occurs in three steps involving adhesion (solid liquid interface at the expense of both liquid - gas and solid - gas) spreading (formation of liquid – gas and liquid - solid at the expense of solid – gas) and immersion (solid – gas interface is replaced by a solid – liquid) wetting.



Adsorption and adhesion phenomena associated with effective dust suppression.

Effective wetting of the coal dust can be achieved by-

- **Static Spreading** - The material is wetted while stationary. Important factors include the diameter and contact angle of water droplets. In general, surface coverage can be increased by reducing either the contact angle or droplet diameter.
- **Dynamic Spreading** - The material is wetted while moving. The droplet impact velocity, surface tension of the liquid, the material size, and the droplet diameter are important variables in dynamic spreading. The surface coverage can be Increasing the surface coverage can be achieved either by reducing the surface tension or by increasing the impact velocity.

Both static and dynamic spreading of a droplet can be increased by reducing the surface tension and thus decreasing the droplet diameter. However, the impact velocity of smaller droplets decreases faster due to frictional drag and less momentum, which, in turn, reduces dynamic spreading. An optimum droplet diameter for maximum material surface coverage must therefore be determined.

Factors Affecting Surface Wetting

Droplet Size

Surface wetting can be increased by reducing the droplet diameter and increasing the number of droplets. This can be achieved by reducing the surface tension/contact angle. The surface tension of pure water is 72.6 dyne/cm. It can be reduced from 72.6 to 28 dyne/cm by adding minute quantities of surfactants. This reduction in surface tension (or contact angle) results in-

- Reduced droplet diameter
- An increase in the number of droplets

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

- A decrease in the contact angle

Impact Velocity

Surface wetting can be increased by increasing the impact velocity. Impact velocity can be increased by increasing the system's operating pressure. Due to the frictional drag of the turbulent air, the impact velocity of the droplet is less than its discharge velocity from the nozzle. Smaller droplets lose velocity faster than larger ones. To cover the greatest surface area, the best impact velocity for a given droplet diameter must be determined for each operation.

Factors Affecting Collision

The collision between dust particles and water droplets occurs due to the following three factors:

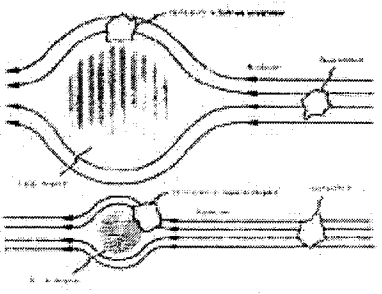
- Impaction/interception
- Droplet size/particle size
- Electrostatic forces

Impaction/Interception

When a dust particle approaches a water droplet, the airflow may sweep the particle around the droplet or, depending on its size, trajectory, and velocity; the dust particle may strike the droplet directly, or barely graze the droplet, forming an aggregate.

Droplet Size/Particle Size

Droplets and particles that are similar in size have the best chance of colliding. Droplets or dust particles that are smaller in size relative to the particle or droplet being impacted may never collide but just be swept around one another.



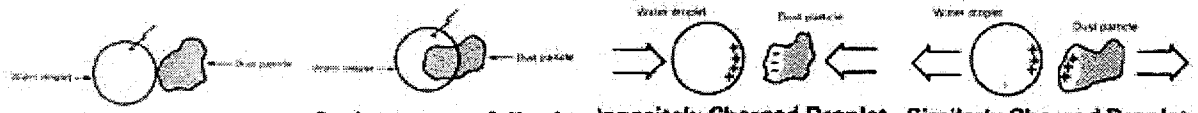
Effect of Droplet Size
Schowengerdt and Brown

Electrostatic Forces

The presence of an electrical charge on a droplet affects the path of a particle around the droplet. When particles have an opposite or neutral charge, collision efficiency is increased.

Airborne Dust Capture

When fine droplets are sprayed into the airborne dust, the droplets and dust particles collide and agglomerates are formed. When these agglomerates become too heavy to remain airborne, they settle. Wetting the bulk material also lowers the tendency to generate dust. Keeping the material damp immobilizes the dust, and very little material becomes airborne.



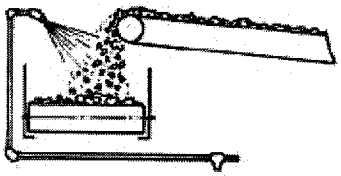
Collision Between Dust Particle and Water Droplet

Coalescence or Adhesion Between Dust Particle and Water Droplet

Oppositely Charged Droplet and Particle Attract Each Other

Similarly Charged Droplet and Particle Oppose Each Other

Finely atomized water sprays are normally used at transfer points without excessive turbulence or when the velocity of dust dispersion is less than 200 ft/min. The optimum droplet size, water usage, relative velocity, and number and location of nozzles depend on the conditions at individual transfer points.



Wet Dust Suppression System

Types of Dust Suppression Systems

Chemical Dust Suppression Systems fall into four broad categories:

- **Water Sprays with Surfactant** - This method uses surfactants to lower the surface tension of water. The droplets spread further and penetrate deeper into the coal. Surfactants can also be used to reduce the friction factor between wet coal particles and transfer surfaces to mitigate pluggage issues.
- **Foam** - Water and a special blend of surfactant make the foam. The foam increases the surface area per unit volume, which increases wetting efficiency.
- **Water Sprays with Binders, Humectants, and Surfactants** – This method uses a binder to create a longer residual suppression effect. The purpose of the humectant is to retard the moisture evaporation process. The surfactant enhances wetting.
- **Emulsions –** Emulsions of water and surfactants are used to suspend normally immiscible binders to create a residual effect suppressant. Oil and latex based emulsions are examples of suppression agents used as car top and pile sealers and road haul suppressants.

Suppression Chemicals

Based on its' expertise in surface science, Benetech offers a wide range of optimized dust suppression products in all of the above categories. These products are non-flammable, non-toxic, non-explosive and biodegradable and can be used to suppress dust via either foam or wetting action.

Coal dust suppression is a complex phenomena; necessitating the use of surface active agents. Coal is water hating (hydrophobic), repelling water from the coal surface. In order to make the coal surface less hydrophobic, a surface active material is added to the water. The surface active material lowers the surface tension of the water to a value closer to that of the coal allowing it to be adsorbed on the surface of the coal. The water by adsorbing on the coal surface renders it less hydrophobic.

The surface active agent forms a microscopic liquid film as a means of increasing the adhesion of the coal dust particles. An effective dust suppressant must wet (making it less water hating) the surface of the coal, maintaining a moist environment, and bind the coal dust particles to the coal to prevent regeneration of the dust. By evaluating contact angles and spreading coefficients of numerous surfactant molecules, Benetech has

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

identified the structure/ property relationships of commercial surfactants and their interaction, contributing to optimum wetting and adhesion. All Benetech formulations contain synergistic combinations of wetting agents, necessary for providing fast, efficient, and effective dust suppression for a variety of coal types under both hard and brackish water conditions.

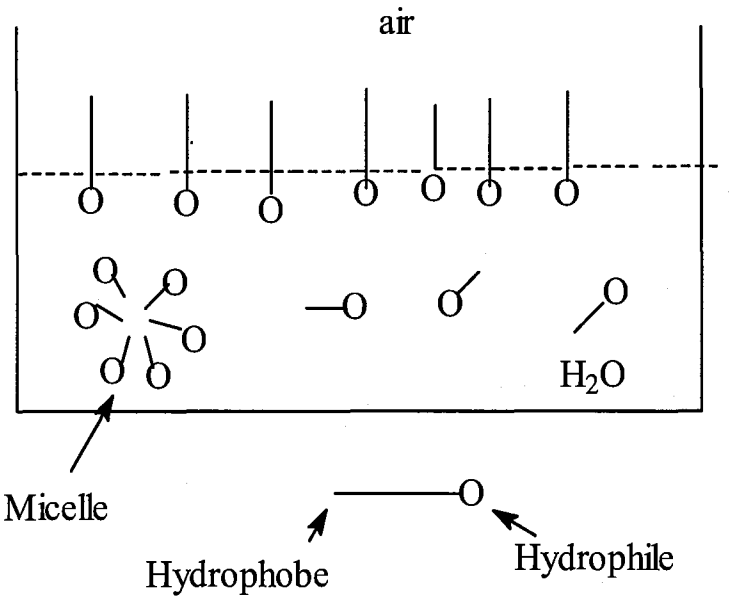
Wetters

Coal, a hydrophobic substance, is difficult to be wet with hydrophilic water. In order to wet the surface of coal a surface active agent that lowers the coal air/ air water surface tension is required. A surfactant is a material that, when present at low concentration in a system, has the property of adsorbing onto the surface of the system and of altering to a marked degree the surface properties of the system. A surfactant molecule is a molecule containing two diverse groups. It is composed of a hydrophilic (water loving) head and a hydrophobic (water hating) tail. Two fundamentally dissimilar groups within a single molecule is the most fundamental characteristic of a surfactant. The surface activity is determined by the structural makeup of the two groups. Water is a highly structured substance because of the strong hydrogen bonds between hydrogen and oxygen. When added to water the hydrophobic tail is incompatible and is rejected by the water and is ejected to the surface or interface where it forms a monolayer, thereby lowering the surface tension (See Figure). If the molecule did not contain the water loving head, it would be completely ejected and form a separate immiscible phase. Upon saturation of the solid/ air interface the surfactant forms micelles in the water solution. The concentration of the surfactant at which micelles begin to form is known as the critical micelle concentration (CMC).

The most common hydrophobe is a hydrocarbon, specifically an eight to eighteen carbon chain. The hydrophile can be anionic, cationic or nonionic. Surfactants in which the hydrophilic moiety is a sulfate or sulfonate are anionic. When the hydrophilic group is a polyether group the surfactant is nonionic.

Wet dust suppression requires the formation of microscopic liquid films as a means of increasing the adhesion of coal dust particles through hydrogen bonding. The wetting agent, because of the large surface area must adsorb on the coal particles spontaneously and efficiently. This requires the surfactant to be a highly branched and symmetrical molecule such that it diffuses rapidly from the hydrophilic water environment to the interface where it is adsorbed at the coal/air interface. The highly branched hydrophobe makes micelle formation difficult, hence increasing the number of monomers in solution making diffusion to the interface more rapid and promoting better wetting.

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690



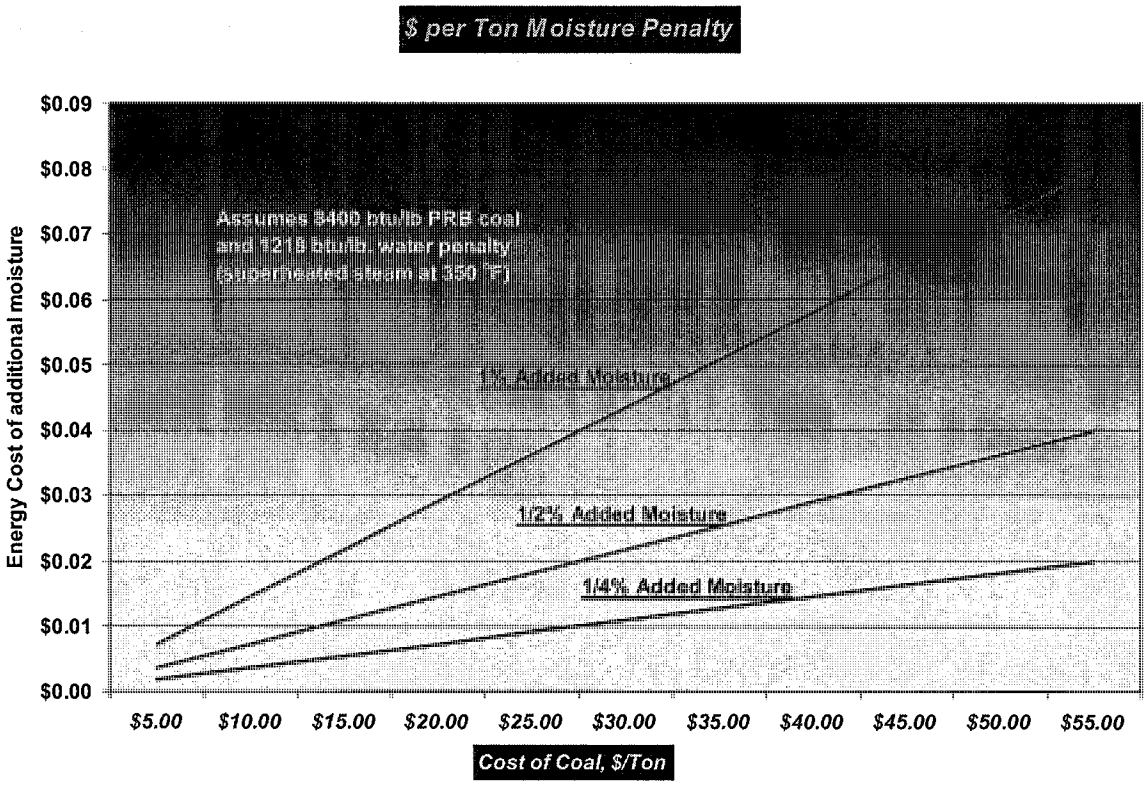
Foamers

Aqueous foamable compositions can be used to suppress coal dust particles. A unique property of foam is its ability to blanket a mass of coal, thereby forming a physical barrier against the dispersion of dust. The foam barrier makes it difficult for the coal dust particles to get airborne. It is preferable to trap the particles before they get airborne. Foam suppression is useful in situations where the quantity of available water is limited or it is desirable to limit the amount of water applied to the coal. The penalty for excess water addition is presented in the following Figure.

Foaming agent formulations frequently contain a wetting agent and a polymer to give body to the foam and reduce the chances of the coal particles becoming airborne after the foam has collapsed. The foam generated is preferably a small bubble foam (100 to 200 microns) allowing efficient trapping of dust particles. A stream of foam interacts with coal particles especially the larger fines. When the foam bubbles impact the coal dust particles, the particles are wetted by the imploding bubbles and captured. Many fine droplets are also released from the collapsing foam, which scrub more fine coal particles. The same principles governing the interaction of coal dust particles with surfactant solutions also govern their action with foam systems.

Foam is a non-equilibrium dispersion of gas bubbles in a relatively smaller volume of liquid. Pure liquids do not foam. Foam is produced when a gas is introduced into a solution whose surface film has viscoelastic properties. The resulting foam possesses a honeycomb arrangement. An essential ingredient in liquid based foam is surface active molecules. These materials reside at the air/ liquid interface and are responsible for both the tendency of a liquid to foam and the stability of the resulting dispersion of gas bubbles. Just as surfactants self-organize (form micelles) in the bulk solution as a result of their hydrophilic and hydrophobic segments, they also preferentially adsorb and

organize at the solution – vapor interface. In the case of the aqueous surfactant solution, the tails protrude into the vapor and leave only the hydrophilic heads in contact with the solution. The favorable energetics of the arrangement can be observed and measured by the reduction in the interfacial surface tension. The surfactant concentration is at or slightly above the CMC in most optimized foam situations. At concentrations below the CMC the liquid/ air surface is not saturated and the foam effectiveness is reduced. At concentrations considerably above the CMC the solution loses its film elasticity and the bubbles will collapse. While, the reduced surface tension is not in itself responsible for the foaming; the primary benefit is that less mechanical energy need be supplied to create the large interfacial area in foam.



Many factors promote foam formation. Low equilibrium surface tension, the smaller the cross sectional area the molecule occupies at the air/liquid interface the lower the surface tension and the closer packed the film. A high bulk phase viscosity promotes a slow draining rate for the bubbles and hence more foam. A moderate surface phase viscosity, a moderate rate of attaining equilibrium surface tension and presence of electrical double layer in the surface film also contribute to increased foam. The design of an efficient foam dust suppressant formulation requires a delicate balance of foam wetting properties, as well as consideration of water hardness.

Residual Suppressants

In order to maintain the suppression of the dust for long periods of time, a polymeric hydrophilic material is added. The polymer whether it is anionic or nonionic forms mixed micelles and mixed monolayers with the primary wetting agent. The mixed monolayers are then adsorbed onto the coal. The high molecular weight polymeric material effectively forms a shield preventing the escape of the moisture and ensures that dust particles remain stuck or adhered to each other and to the bulk coal. The polymer also acts as a nucleating agent allowing the micelles to more efficiently form and holding them in the area of the coal. Due to the large molecular weight of the polymers and the presence of hydrophilic groups, they can bind with several coal particles increasing the effective density of the coal particles preventing dusting. Typical polymers include compounds such as ligninsulfonate and polyacrylamides. It is thought that polyacrylamides may serve to reduce the rate of evaporation of water and thereby extend the life of the treatment. In addition to ligninsulfonates, a wide range of other binding agents has been used for long term coal dust control. These major classes of binders include:

- Polymer solutions
- Polymer emulsions
- Oils and oil emulsions
- Asphalt and asphalt emulsions

Humectants

Residual dust suppressant systems must also maintain the moisture content to prevent regeneration of dust. Consequently, the Benetech formulation contains both a humectant and a binder. The humectant is a water loving material which forms strong hydrogen bonds with water making its' removal from the system difficult. When humectants are used alone, such as salts (commonly used for haul road dust control), they have to be used in large amounts. Commonly employed salts include calcium, magnesium, and sodium chlorides and their mixtures. Surfactants are frequently combined with hygroscopic salts to improve the extent of coal dust capture and binding.

Emulsions

Polymer Emulsions

The largest single application of polymer emulsions is for pile sealing and railcar top coating prior to shipment to prevent dust formation and coal loss from the car tops. Latex emulsions, similar to those used in the paint industry are typically deployed. Surfactants are usually added to improve its coal wetting ability.

Asphalt and Asphalt Emulsions

Asphalt or asphalt emulsions have also been used in coal dust control. The use of an asphalt emulsion, in combination with surfactants to wet the coal rapidly, has also been used for rail car top coating and stackout pile sealing. An interesting aspect of these emulsions is their ready ability to "break". Certain surfactant solutions can be used to pre-wet the coal, so that a subsequently applied asphalt emulsion will break to leave a dust suppressing film on the coal surface.

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

Oils and Oil Emulsions

The use of oil as a coal surface treatment has a long history. Not only does a thin oil film provide an antidusting effect, it also adds heating value to the coal and improves the coal's bulk density – a factor of importance in coke making. Oil emulsions have the advantage that they can be diluted with water for better dispersion. Oil-soluble surfactants can also improve the antidusting properties of oils for treating coal. Oil emulsions can also "break" when they come into contact with certain surfactants.

Laboratory Testing

The effectiveness of a surfactant in modifying the wetting properties of a liquid can be evaluated by determining the spreading coefficient of the surfactant solution. This can be done by measuring both the surface tension of the surfactant solution, and the contact angle the solution makes with the substrate. The Walker and "Drop Box" test represent other common methods for evaluating surfactant effectiveness. The Walker test, first proposed by Walker and co-workers in 1952 was the first laboratory procedure to measure coal dust wetting. In this procedure, approximately 1 gram (1/4 teaspoon) of <200 mesh coal is gently floated on the surface of an aqueous solution of water plus the wetting agent. The time it takes for the coal dust to completely sink is measured and reported. Pure water shows wetting times measured in hours, where even small concentrations of some wetting agents will give wetting times of less than five minutes. This test is useful for evaluating in the laboratory the effectiveness of a given wetting or residual formulation. There is a strong inverse correlation between wetting time and initial dust suppression.

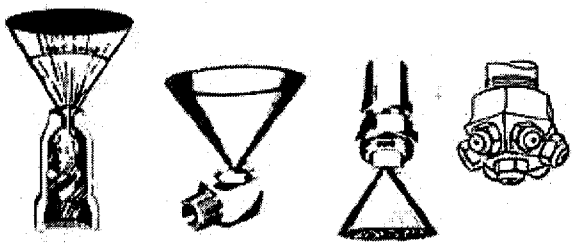
Surfactants are also known to interact with each other producing synergistic enhancement of wetting effects. Wetting agents, especially anionic and nonionic surfactants exhibit synergistic behavior, promoting a more rapid diffusion to the wetting front. Preferred surfactant systems have an optimized ratio of several surfactants. By using mixtures of surfactants one can use less surfactant than would be required for a single surfactant system.

Design of a Water-Spray System

Dust particles need to be trapped in the air and before they become airborne. An important factor in trapping air borne dust particles is the droplet size of the sprayed formulation. Droplets with a clean surface have higher capture efficiencies for dust particles than droplets already containing a trapped particle. The best surfactant system will rapidly remove the trapped dust particle to the interior of the droplet. Consequently, a coarse droplet will more efficiently capture dust than a smaller droplet. The droplet size must also be optimized with the surfactant wetting system for effective suppression. It is easiest and most desirable to knockdown the coal dust particles before they become airborne. This is accomplished by the wet dust suppression formulations.

The spray nozzle is the heart of a water-spray system. Therefore, the physical characteristics of the spray are critical. Factors such as droplet size distribution and velocity, spray pattern and angle, and water flow rate and pressure all vary depending on the nozzle selected. Following is a general discussion of these important factors:

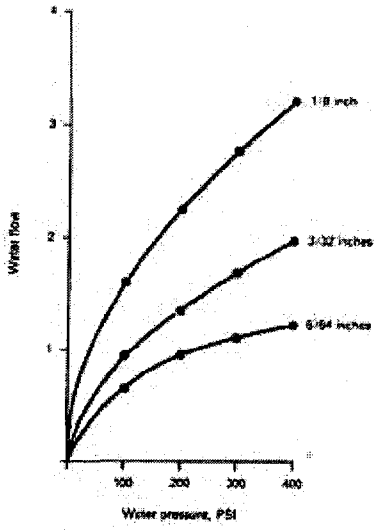
- **Droplet Size**- The nozzle's droplet size distribution is the most important variable for proper dust control. The droplet size decreases as the operating pressure increases. Information about the droplet size data at various operating pressures can be obtained from the nozzle manufacturer. For wet dust suppression systems, coarse droplets (200-500 µm) are recommended. For airborne dust capture systems, very fine droplets (10-150 µm) may be required. The fine droplets usually are generated by fogging nozzles, which may use either compressed air or high-pressure water to atomize water in the desired droplet range.
- **Droplet Velocity** - Normally, higher droplet velocities are desirable for both types of dust control through water sprays. Information on the droplet velocity can be obtained from the nozzle manufacturer.
- **Spray Pattern** - Nozzles are categorized by the spray patterns they produce:
  - Solid-cone nozzles product droplets that maintain a high velocity over a distance. They are useful for providing a high-velocity spray when the nozzle is located distant from the area where dust control is desired.
  - Hollow-cone nozzles produce a spray patter in the form of circular ring. Droplet range is normally smaller than the other types of nozzles. They are useful for operations where dust is widely dispersed.
  - Flat-spray nozzles produce relatively large droplets that are delivered at a high pressure. These nozzles are normally useful for wet dust suppression systems.
  - Fogging nozzles produce a very fine mist (a droplet size distribution ranging from submicron to micron). They are useful for airborne dust control systems.



- **Spray Angle** - Each nozzle has a jet spray angle. The size of this angle is normally available from the manufacturer. A knowledge of spray angle and spray pattern is essential to determine the area of coverage and, therefore, the total number of nozzles needed.
- **Flow Rate** - The flow rate of water through a nozzle depends on the operating pressure. The flow rate and operating pressure are related as follows:

$$\text{Water flow rate} = K\sqrt[2]{\text{operating pressure}}$$

where K = nozzle constant



Water Flow/ Pressure

Knowledge of the water flow rate through the nozzle is necessary to determine the percentage of moisture added to the material stream. The following factors should be considered in selecting the nozzle location:

- It should be readily accessible for maintenance.
- It should not be in the path of flying material.
- For wet dust suppression systems, nozzles should be **upstream** of the transfer point where dust emissions are being created. Care should be taken to locate nozzles for best mixing of material and water. For airborne dust capture, nozzles should be located to provide **maximum time** for the water droplets to interact with the airborne dust.

Water Flow and Compressed Airflow Rates

Once the nozzle is selected, its spray pattern and area of coverage can be used to determine water flow rate and/or compressed airflow rates and pressure requirements. These must be carefully coordinated with the maximum allowable water usage. Water flow rates will be highly variable depending on the size and type of coal, the application location, and the throughput of coal.

Piping Design

The piping should be designed so that each nozzle receives water or compressed air at specified flow rates and pressures. Drains must be provided at the lowest point in each sub circuit of the piping system to flush the air and water lines in winter months. Heat trace and insulation must also be provided at locations where the temperature may drop below 32° F. The heat tracing should be able to provide approximately 5 watts per linear foot for water pipes up to 2 in. in diameter. The pump and other hardware, such as valves and gauges, should also be placed in a heated enclosure or heat traced and insulated to prevent freezing during winter months.

Instruments

Pressure and flow gauges are recommended to monitor system performance. These instruments should be located as close to the point of application as possible. For situations where it is desirable to activate wet suppression systems only when the material is flowing (for example, if the belt conveyor is running empty, water sprays need not be on), a solenoid-activated valve may be installed in the water line. The solenoid can be activated by instruments such as the level controller or zero speed switch. This approach will reduce water usage, reduce maintenance and cleanup, and reduce or prevent freeze up problems. It is important that electrical, control, and instrumentation meet local condition electrical code requirements. This is typically NEMA 4/9 and Class 2, Div 1, Groups F for dust.

Application Locations

Chemical dust suppressants can be used to control dust at a number of locations. These include:

- Coal Transfer Points
- Coal Pile, Car Top, Residual, Sealers and Encrusting Agents
- Haul Road Dust Control
- Flow Enhancers
- Washdown Systems
- Yard Spray Systems
- Flyash Pug Mills

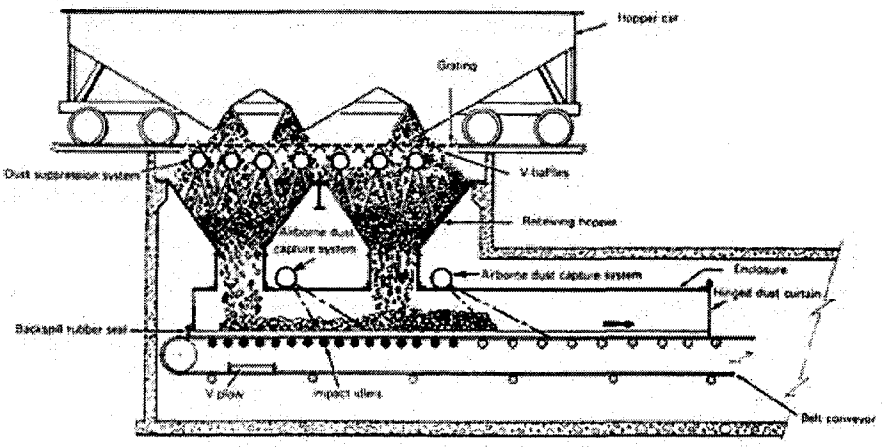
Selection of the application points will be based on a number of factors such as degree of needed dust control, need for downstream dust control, desire for residual control especially on piles and haul roads, restriction on water use, proper spray access to material, availability of support utilities (i.e., water, air, electricity), ease of support equipment placement (i.e., sheds, chemical storage tanks), and length of required supply piping.

In the coal yard, typical application locations include:

- Rail unloading system hopper area
- Barge unloading system hopper area
- Trestle rail unloading area
- Truck / payloader unloading hopper area
- Hopper reclaim feeders/transfer points
- Transfer chutes within towers
- Prior to stackout for stackout dust control as residual dust control from piles
- Bucket reclaim area on stacker / reclaimers
- Yard spray systems to provide residual effectiveness
- Sizing and crushing areas
- Washdown systems to enhance cleaning and reduce water consumption
- In chute areas to reduce wet coal pluggage
- At trippers, cascade, and reversing decks to control dust emissions within the plant and in bunkers and silos

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

The following diagram presents a typical chemical dust suppression arrangement at a bottom dump rail unloading system. As with all applications, site specific conditions will influence exact spray nozzle header locations to maximize contact with airborne dust and the bulk coal material. Good chemical dust suppression systems can reduce dust levels over 90%, reduce respirable dust below OSHA requirements of 2.0 $\mu m/m^3$, and maintain opacity levels below 10%.



Railroad Dump to Conveyor

1851 Albright Road, Montgomery, IL 60538 PH: 800-843-2625 FX: 630-844-8690

E. CALVIN

PROCEEDINGS
for the
Seventh Annual

ENVIRONMENT VIRGINIA '96

SYMPOSIUM

A TWO-DAY CONFERENCE
ON
ENVIRONMENTAL MANAGEMENT
AND POLLUTION PREVENTION

APRIL 11-12, 1996

Cameron Hall at Virginia Military Institute
Lexington, Virginia

Presented by
the Virginia Department of Environmental Quality
and VMI Research Laboratories, Inc.

A RAIL EMISSION STUDY: FUGITIVE COAL DUST ASSESSMENT AND MITIGATION

Edward M. Calvin
G. D. Emmitt
Simpson Weather Associates
Charlottesville, Virginia

Jerome E. Williams
Norfolk Southern Corporation
Roanoke, Virginia

ABSTRACT

A four-year study on fugitive coal dust emissions has produced estimates of coal loss during rail transport and developed suppression techniques that can reduce dusting from rail cars by 95 to 99%. The critical issues of emission characterization and material loss quantification had to be resolved before cost effective dust control strategies could be implemented and evaluated. Laboratory assessments, computer-based simulations, and field experiments were used to model and quantify coal dust emissions. These methods revealed coal losses along a ~500 mile-long rail corridor of up to 0.6 tons/car, with typical losses of 0.2 to 0.4 tons/car from metallurgical coals occurring under sunny, dry and windy conditions. A combination of load-top grooming, surfactants, and chemical binding agents proved to be the most effective method for reducing fugitive coal dust emissions during transit.

INTRODUCTION

Fugitive coal dust from in-transit coal cars does not appear to violate ambient air-quality standards. In fact, track-side monitoring of PM-10/TSP yielded no firm basis for remedial action. At issue, however, is the railroad's goal to reduce coal dust emissions and their impact as a nuisance pollutant.

Most of the evidence of fugitive coal dust emissions comes from anecdotal reports of dust plumes or the observations of coal deposition along the rail corridors. Without any standards of objectivity, coal dust complaints have given rise to the perception of significant a coal dust problem. Accordingly, a study was designed to relate the perceived problem (i.e., visual emissions) to the existence of quantifiable material losses (i.e., material losses that may represent significant environmental impact and/or financial consequences).

Previous attempts to quantify material losses produced mixed and controversial results, (Brown and Speichert, 1976; Guarnaschelli, 1977; Hardy Associates, 1979; Cope, 1980; McCoy, 1980; Williams, et al., 1982; Nobel, et al., 1983; Morrison, Hershfield Ltd., 1983; Cope, et al., 1984; Swan Wooster Engineering Co. Ltd, 1985; Environmental Sciences Ltd., 1985; Cope, et al., 1986; Wituschek, et al., 1986; Stewart, et al., 1987; Mikula and Parsons, 1988). Therefore, the characterization and quantification of losses along Norfolk Southern's (NS) rail corridors were identified as critical issues to be resolved before prescribing effective control strategies. Since early 1991, NS and Simpson Weather Associates (SWA) have conducted numerous laboratory and field-rail experiments to assess the magnitude of material losses and develop techniques to mitigate fugitive coal dust emissions during transit. A coal shipper, CONSOL also contributed to the field studies. This paper presents an overview of the study's ongoing efforts and results to date.

GENERAL STUDY APPROACH

The Norfolk Southern Rail Emission Study (NSRES) was conducted within one rail corridor, through which primarily export metallurgical (met) coal was transported. The choice of the rail corridor was based on its variety of terrain, relatively heavy volume of coal traffic, and the number of coal-dust complaints received. Metallurgical coal was chosen since, in most cases, it is considered more dusty than steam coal.

Field Trials

In an attempt to overcome some of the problems encountered in previous studies, the NSRES employed a number of independent field measurements to 1) act as quality-assurance checks within data sets, 2) to identify and understand aberrant measurements, and 3) to corroborate findings between data sets. Much of the early field data was gathered using a specially designed research caboose. As the study progressed, the instrumentation became more compact, thus reducing the need for the research caboose.

Scale Weights

The first of the field data sets is car weights. These weights were measured using static, decoupled, electronic scales. The scales have a reported accuracy of 0.01%. The weights were taken of selected cars before transit and then again after transit. As a reference, a scale monitor car that traveled with each weighing experiment was weighed at both locations to determine a scale correction factor. In addition, a tarped coal car was used, on occasion, as a second reference. It was assumed that no coal was lost during transit from the tarped car, and moisture loss and gain was minimized. To accurately evaluate the weight changes in coal cars moving from mine to port, moisture variations were taken into account. To account for moisture changes, a water budget was developed containing all known variables of moisture movement in and out of coal cars. Measured rainfall and estimated evaporation values were assigned to the water budget variables so that moisture changes could be used to adjust the scale weight differences. Moisture change correction factors were also empirically generated from coal samples collected in the field. In spite of all the precautions taken to assure accurate scale weights, an uncertainty in coal losses $\pm$ 200 lbs. still remains. This is most likely due to inherent scale inaccuracies and moisture changes that cannot be precisely measured, such as water dripping out the bottom of hopper doors. Because similar problems with scale weights have been encountered in other railroad work, we decided not rely on scale weight changes as the sole determinate for material losses. Rather, we used scale weights and three other methods jointly to arrive at a material loss estimates. These other methods are described below.

Load-top Volume Changes

The second method used to estimate material losses involved measuring the volume changes on the top of the coal loads from the mine to port. For the first several fields trials, a series of photographic transects were taken in selected coal cars at various points along the rail corridor. Scaled photographs of the same cars were compared throughout the trip and material losses were calculated based on volume losses within a given car. Coal within each car settling was taken into account and samples were taken to obtain bulk densities for the mass-loss calculations. It should be noted, that as a part of these calculations, we assumed that no coal was detrained from the top, flat portion of the coal load during transit. Because of this assumption, mass-loss calculations based on volume losses tended to ***underestimate*** actual material losses.

The photographic method of calculating, while general successful, encountered problems related to the changes in bulk densities of coal as it dries and drifts and inadequate measurements in the fronts and rears of cars where significant erosion and redeposition can occur during transit. In addition, the photographic method was very labor intensive. Consequently, another method was developed to estimate volume changes and evaluate redistribution of coal within a car. This method, called the Coal Car Load Profiling System (CCLPS), used three cameras to produce a digital contour map of the coal surface and calculate volume changes from mine to port within a given car. Recently, the CCLPS data gathering process has evolved into an infrared laser-based system which is smaller, faster, and does not require special lighting as did the three-camera technology.

Real-time Observations

To characterize the nature of fugitive dust emissions and develop an understanding of the wind erosion processes on coal cars during transit, an instrument package was designed to monitor a variety of environmental parameters in real time as the cars moved down the rail corridor. The instrument package, Rail Transport Emissions Profiling System (RTEPS) measured the following variables: wind speed, wind direction, rainfall, coal surface

temperature, coal temperature and moisture at two different depths, fugitive emissions (using a real-time aerosol sensor, or RAS), air temperature, and relative humidity. All of these data were collected and stored in a data logger attached to RTEPS and were retrieved via a lap top computer at various locations along the corridor. A time-lapse video camera was also part of RTEPS to provide visual records of emission events.

Passive Collection

To directly sample detrained material in transit, passive collectors were designed and built to mount on the rear sill of test cars. The passive collectors were sampled a various stops along the rail corridor to help identify the dustiest portions of the trip.

Dust Suppression Techniques

Once is was determined how much coal was being lost during transit, several mitigation techniques were evaluated, including:

- water only (40 to 100 gallons/car, depending on the experiment);
- grooming ("rounding" of the load profile) only;
- water and compaction;
- surfactants only;
- surfactants plus binding agents;
- binding agents only; and
- tarped cars (used as control cars for various experiments).

Experiments were also conducted where the average train speeds were decreased, and where trips were run mostly at night to decrease emissions. While lower train speeds and coal surface temperatures produced less stress on the coal loads and therefore lower emissions, such operational constraints were neither sufficiently effective nor practical and therefore were not seriously considered as permanent mitigation techniques. In addition, several load profile modifications were used alone, and with the treatments listed above, to abate fugitive dust emissions. Initially, a "normal" profile had a trapezoidal cross-section as shown in Figure 1a. After it was shown that profile modification alone significantly reduced emissions, the "bread-loaf" or groomed profile became the norm (Figure 1b). Other grooming/loading options included loading the coal flat, at or below the car sill level, loading lower than normal, and reshaping the top of the load into the "bread-loaf" shape. For clarification, the following definitions are given for surface treatments.

> Normal profile: for the first sixteen field trials, cars that had a trapezoidal cross-section (Figure 1a); for the last fourteen field trials, cars that had an arcuate or " bread-loaf" cross-section (Figure 1b).
>
> Groomed profile: any car that had an arcuate cross-section, or was modified to eliminate angular or trapezoidal cross-section.
>
> Untreated cars: cars that may or may not be groomed, but received no additional water spray, surfactants, nor chemical binders.
>
> Treated cars: cars that may or may not be groomed, but did receive additional water spray and/or surfactants, and/or chemical binders.

RESULTS

Laboratory Evaluations

Using the relative dusting index generated from the SARTDX experiments, coals were ranked according to their dusting potential. The final overall rankings were based on combining three dusting parameters: 1) wind speed

threshold (WST), or the lowest wind speed at which emissions were detected; 2) maximum real-time aerosol monitor (RAM) readings; and, 3) total integrated emissions (IE), the calculated area under the entire emissions curve.

Interestingly, when the overall dustiness rankings based on the above three parameters were compared to what the rankings would have been based only on moisture content and fines content, the rankings were found to be discordant. While it is assumed that moisture content and size consist do play a role in a coals' dusting potential, it is clear that other factors (e.g., coal chemistry, moisture migration through the coal, and angle of repose) can play an equally important or even dominant role in dusting during transit.

For the 19 different coals tested in the SARTDX experiments, the inherent coal moisture contents ranged from 2.8 to 11.4%. In order to test all coal samples under the same conditions, it was necessary to dry all samples to approximately 1.5% moisture content ($\pm$ 0.5%). It is fully recognized that such drying procedures do not reflect actual field conditions, as moisture contents vary significantly from mine to mine. However, the drying process allowed for marked and consistent delineations between the different coals' dusting potential, which was the objective of the SARTDX experiments. Figures 2 a and b, below, show SARTDX wind tunnel plots for two coals. Coal # 1, (Figure 2a) displays a moderate tendency to dust, while Coal # 2 (Figure 2b) shows a much greater propensity to dust during transport. This is displayed in the upper parts of the graphs, along the "Mini-Ram" axis.

Field Studies

Scale Weight Changes

During the field trials, 317 cars were weighed. For the earlier field experiments, a normal profile for a fully loaded coal hopper was trapezoidal in cross-section, had a smooth flat top-surface, and was stacked approximately eighteen to twenty-four inches above the car sill. After taking moisture changes into account, the normally loaded, untreated cars lost an average of 0.36 tons ($\pm$ 0.1 tons), n = 52. The range for the scale-weight losses was from 0 to 0.6 tons, and some cars actually showed a weight gain--due to water uptake during transport. The greater losses occurred during the most severe (hottest and driest) conditions in the summer months, when wind and train speed averages were highest compared to other field trials.

Those cars that were loaded at or below the sill appeared to loose less coal in most cases, compared to normally loaded and untreated loads, but this difference was not statistically significant. Furthermore, these loading techniques reduced the load capacity for each car by 10 to 15%. Since loading at or below the sill gave mixed dust control results and reduced the load capacity, this dust suppression strategy was abandoned.

For the most recent field trials, the normal load-out procedure was changed to a "bread loaf" profile. The change in profile produced a measurable reduction in the weight losses for the untreated cars, with an average of approximately 0.20 tons ($\pm$ 0.1), down from the 0.36 tons for ungroomed cars. While load profile changes produced significant decreases in weight losses, further reduction in material losses (95 to 99% from untreated cars, based on passive collection) was achieved by applying surfactants and/or binding agents to the groomed profiles.

RTEPS Data

The RTEPS instrument package offered an independent and corroborative perspective of material losses compared to the scale weight changes and passive collection. RTEPS was not designed to quantify material losses, but to record in real time the intensity and frequency of dusting "events." We emphasize that the emissions are a relative measure (relative to no emissions), and do not represent material losses. There is a strong positive correlation between frequent, intense dusting events during the course of a trip and its scale weight changes and passive collection. Furthermore, the higher the average coal surface temperatures, wind speeds and train speeds, the more frequent and intense the dusting events became (Fig. 3). While riding behind the coal trains in the research caboose, it was clear that dusting increased when coal cars passed through tunnels, over trestles, and

close to topographic interfaces. RTEPS data also showed that emissions were most frequent during accelerations between fifteen and thirty miles per hour. The most frequent and intense emissions occurred when the study trains passed other trains moving in the opposite direction at track speeds.

Load-top Volume Changes

The original photographic method for estimating volume changes produced material loss estimates of 0.11 to 0.76 tons, with an average of 0.31 tons (n = 31). For these same cars, scale weight losses averaged 0.36 tons, thus providing some credence to the claim that the photographic method underestimates material losses. An example of "before" and "after" transects are shown in Figure 4. The photographic method also laid the foundation for an automated volume-change detection system such as CCLPS. As CCLPS becomes further developed, we hope to obtain more and more reliable results from our volume/mass-loss calculations.

Trip Stress Index (TSI)

In order to compare the stresses from trip to trip, an index was devised from information collected with RTEPS. Air temperature, coal surface temperature, and wind speed were combined to arrive at a Trip Stress Index (TSI), allowing direct comparison of the stresses from each trip. A relationship between passive collection and TSI was revealed through data analyses and is discussed below.

Passive Collection

Over the course of the thirty field trials, a total of 360 passive collector samples have been taken. The combination of profile modification and chemical sprays has resulted in a 95 to 99% reduction in coal losses compared to normal trapezoidal load profiles according to passive collection data. Statistical analyses of passive collection show that treated cars can be distinguished from untreated cars with a 99.9% confidence level. Table 1 depicts the average passive collection over all trips for untreated versus treated cars. The 153 passive collector samples not shown were either collected during "experimental" treatments, or there was no direct comparison available for treated versus untreated cars for a given experiment.

There appears to be no useful correlation between scale weight changes and passive collection on a car-by-car basis, likely due to the inherent scale inaccuracies and moisture content variations. This is another reason not to rely on the scale weight changes alone for material loss estimates, but instead, to apply independent loss estimates techniques. However, a clear relationship between passive collection and TSI is revealed in Figure 5. This relationship appears to be exponential. On the other hand, the data suggest that there is some threshold above which passive collection (i.e., fugitive emissions) significantly increases.

Surface Treatment Evaluations

As previously mentioned in the "Methodology, Surface treatments" section, a variety of surface treatments were tested during the study for their dust suppression capabilities. Using untreated cars as the reference for judging the success of treatments, results from RTEPS show that water-only treatments, whether sprayed on at the mines or en route, suppressed fugitive emissions for a maximum of only two to three hours under stressful conditions during a thirty-six to seventy-two hour trip. In fact, untreated surfaces actually emitted less dust than water-only treated cars under certain conditions (e.g. freezing temperatures). This was the case for both groomed and ungroomed cars. Grooming alone reduced passive collection and scale weight losses from an average of 0.36 tons to 0.20 tons during the most stressful trips. When profile grooming was combined with chemical treatments, even greater reduction in fugitive emissions was realized, up to 95% over untreated cars.

CONCLUSIONS

A total of thirty field trials have been conducted to date for the NSRES.

Analyses and stratification of a 360,000-car database yielded a standard deviation of about 6 tons in dump weights, masking any meaningful signal for weight losses for the NSRES.

Material losses based on scale weight changes for ungroomed, untreated cars averaged about 0.36 tons/car under high stress trip conditions.

Material losses based on scale weight changes for groomed, untreated averaged about 0.20 tons/car in the high stress trip conditions.

Intensity and frequency of emissions are greatest when the train is accelerating between 15 and 30 miles per hour, and when passing on-coming trains.

Increased fugitive emission events are associated with tunnels, trestles, and topographic interfaces.

The relationship between the Trip Stress Index and passive collection indicated that there is a stress threshold above which fugitive emissions significantly increase.

Based on passive collection, material losses from groomed, treated cars were reduced by up to 95% over untreated and ungroomed cars.

ACKNOWLEDGMENTS

This work was primarily funded by the Norfolk Southern Corporation, with additional assistance from CONSOL.

REFERENCES CITED

1. Brown, R.A.S. and Speichert, A., 1976, Wind Entrainment of Coal Particles and its Control; Engineering Division, Alberta Research Council, Edmonton, Alberta.
2. Cope, D., Wituschek, E., Poon, D., Haliburton, D., 1984, Report on the Emission and Control of Fugitive Coal Dust from Unit Trains in Canada, Environmental Protection Service, Environment Canada, Regional Report 84-425.
3. Cope, D., Wituschek,E. Poon, D., 1984, Chemical Sealants for Control of Wind-blown Dust from Unit Coal Trains--A Listing of Products and Specifications, Environmental Protection Service, Environment Canada, IP-13.
4. Cope, D., Poon, D., Wituschek, E., Haliburton, D., 1986, Report on the Emission and Control of Fugitive Coal Dust from Coal Trains, Department of the Environment, Conservation and Protection, Environmental Protection Service, Pacific Region, Environment Canada, Regional Program Report 86-11.
5. Guarnashelli, C., 1977, In-transit Control of Coal Dust from Unit Trains, Environmental Protection Service, Fisheries and Environment Canada, Repot Number EPS 4-PR-77-1.
6. Mikula, R.J. and Parsons, I.S., 1988, Coal Dustiness: Characterization and Control, Canadian Centre for Mineral and Energy Technology, Coal Research Laboratories, Division Report CRL 88-23(OP, J).
7. Morrison, Hershfield, (MH) Limited, 1983, Testing of Emission Factors--Fugitive Coal Dust from Coal Trains (A Laboratory Evaluation), Environmental Protection Service, Environment Canada, IP-1.
8. Nobel, G., Sandberg, S.E., Bayard, M., 1983, Coal Particulate Emissions from Rail Cars, in Fugitive Dust Issues in the Coal Use Cycle, Proceedings of APCA Specialty Conference, April 11 to 13, 1983.
9. Schuyler, G.D., Waechter, C.E.T. of Morrison, Hershfield, Theakston and Rowan, (MHTR) Limited, 1982, The Testing of Rail Car Sealant Sprays and Loading Techniques Designed for the Abatement of Fugitive Coal Dust (A Laboratory Evaluation), Air Pollution Directorate, Environment Canada, DSS File 40SS.KE145-1-0459, Report 4812021.
10. Stewart, J.E., Craft, R.C., Daniel, F.L., Minx, R.P., Rogers, E.F., III, 1988, Report of Fugitive Emissions from Storage and Rail Transport of Coal, Virginia State Air Pollution Control Board, Hapmton Roads Region.
11. Swan Wooster Engineering Company, Limited, 1985, Development of a Design and Test Program for Automated Coal Cars Covers, Environmental Protection Service, Environment Canada, IP-45.
12. Wituschek, E.P. and Cope, D.L., 1986, Coal Dust Control--Recommended practices for loading, unloading and transporting coal by rail, Environment Canada, Regional Report No. 86-17.

Table 1. Passive Collection for Untreated Versus Treated Cars

UNTREATED CARS AVERAGE (g)	TREATED CARS AVERAGE (g)
n = 113	n = 94
131	5

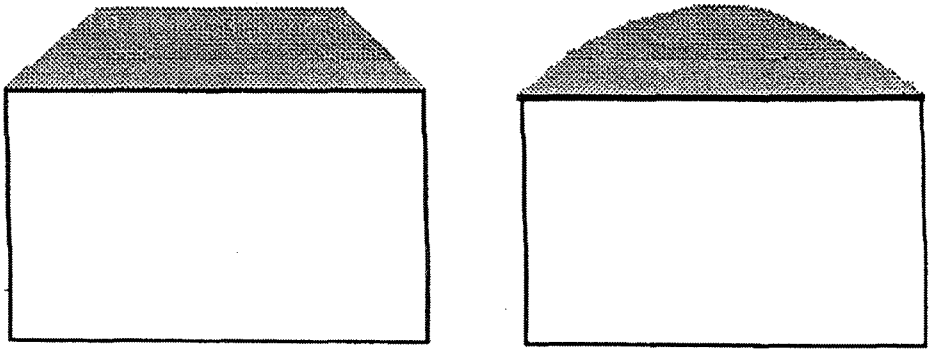


Figure 1a (left) and 1b (right). Cross Sections of Coal Hoppers with Trapezoidal Profiles (1a) and Rounded Profiles (1b)

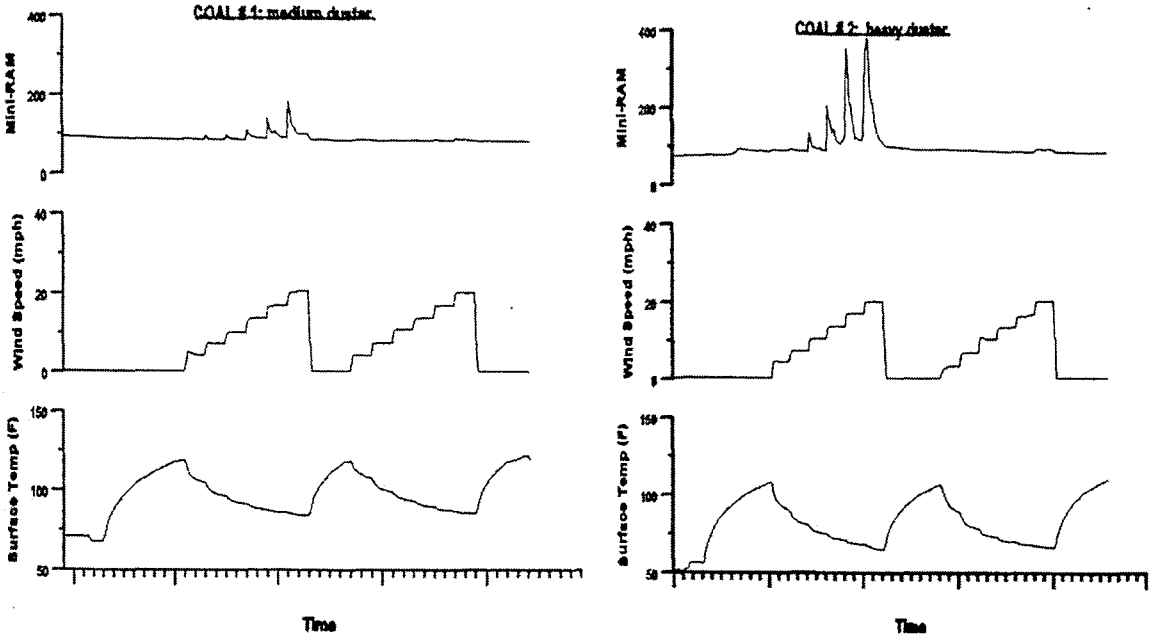


Figure 2a (left) and 2b (right). Graphical Difference Between "Medium" and "Heavy" Dusty Coals According to SARTDX Procedures

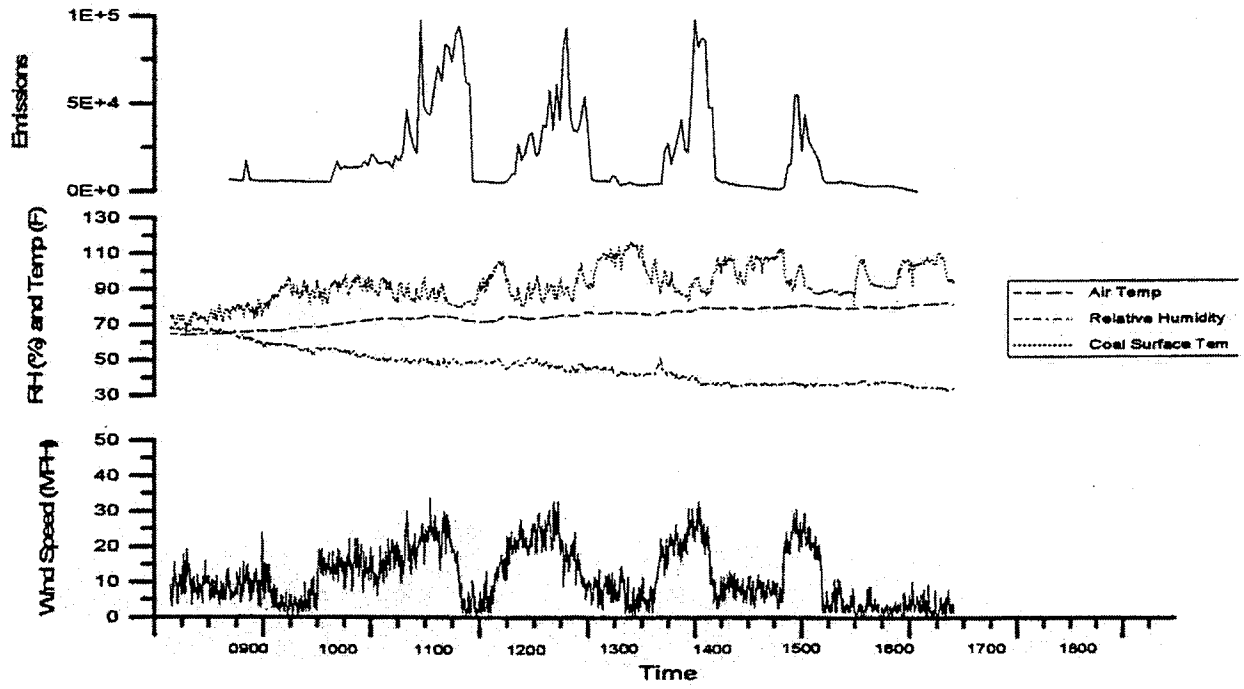


Figure 3. A Typical RTEPS Trip Profile Showing the Correlation Among Emissions, Coal Surface Temperature, and Wind Speed

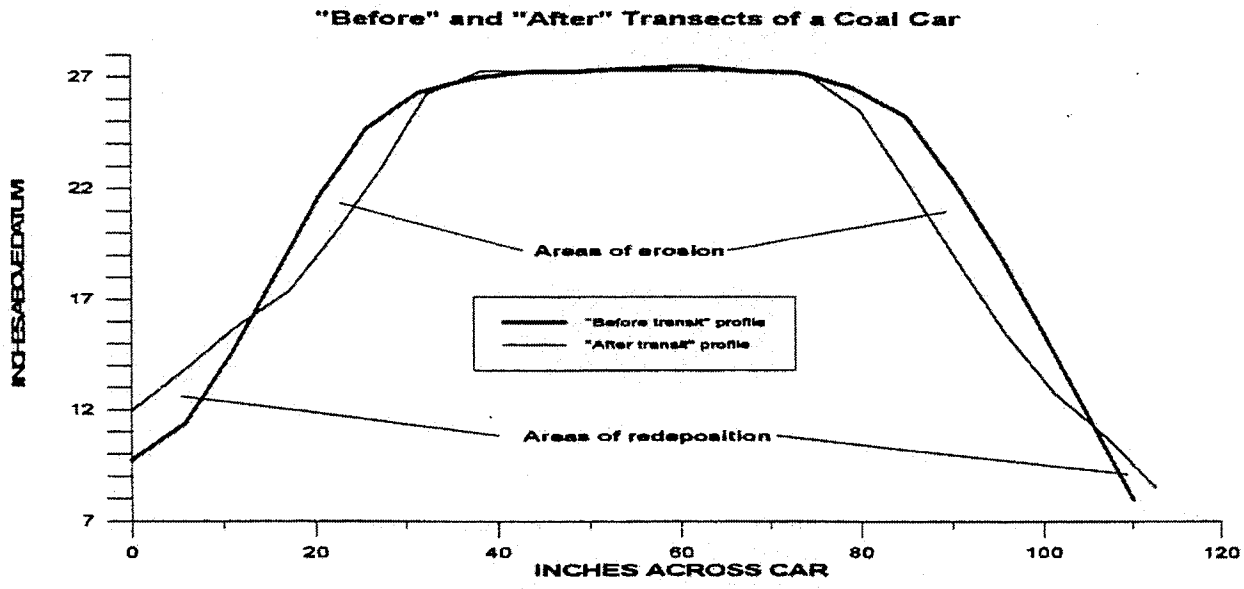


Figure 4. An Example of a Photographic Transect Across an Untreated Car Showing Areas of Erosion and Deposition

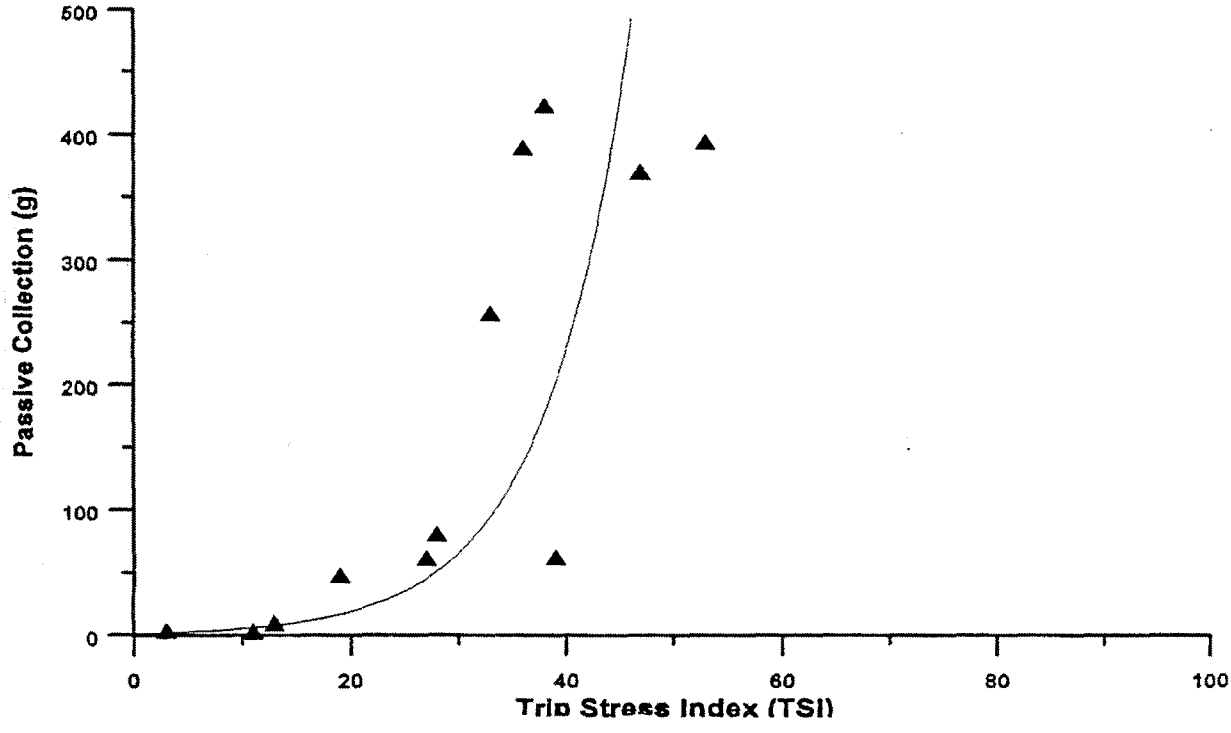


Figure 5. Trip Stress Index Versus Passive Collection

A Study of

Fugitive Coal Dust Emissions In Canada

November 2001

The Canadian Council of Ministers of the Environment (CCME)

A Study of

Fugitive Coal Dust Emissions In Canada

November 2001

For:

The Canadian Council of Ministers of the Environment (CCME)

Prepared for the CCME by:
Douglas L. Cope
and
Kamal K. Bhattacharyya

Submitted by:
D. COPE ENTERPRISES
930 Maple Hill Road
Oxford Station, Ontario
K0G 1T0

Scientific Authority:
Contract # 163-2001
T. Wakelin
Air Resources Branch
BC Ministry of Environment, Lands and Parks

Contract # 208-2002
C. Vézina
Pollution Data Branch
Environment Canada

DISCLAIMER NOTICE

This report has had a limited technical review by the CCME and the content does not necessarily reflect the views and policies of the CCME or its members. Mention of trade names or commercial products does not constitute endorsement for use.

This unedited version of the report is undergoing a limited distribution to transfer the information to people working in related studies. This distribution is not intended to signify publication and, if the report is referenced, it should be cited as an unpublished report for the CCME.

Any comments concerning the contents of the report should be directed to:

Tony Wakelin
Air Resources Branch
Ministry of Environment, Lands and Parks
Mailing:
PO Box 9341, Stn Prov Govt, Victoria, B.C. V8W 9M1
Location:
3rd Floor 2975 Jutland Rd., Victoria, B.C. V8T 5J9
Phone: (250) 356-0634 FAX: (250) 356-7197
e-mail: Tony.Wakelin@gems5.gov.bc.ca

Christian Vézina
Criteria Air Contaminant Division
Pollution Data Branch
Environment Canada
PVM, 351 St. Joseph Blvd.
Hull, Quebec, K1A 0H3
Tel: (819) 994-2975
Fax: (819) 953-9542

ACKNOWLEDGEMENTS

D. Cope Enterprises

Wishes to acknowledge,
With kind thanks,
The information supplied by

T. Wakelin, British Columbia MELP
C. Vézina, M. DesLauriers, & G. Ternan Environment Canada
Kelly Der, GVRD
Numerous contacts in the Environment Canada Regional Offices in Vancouver, Toronto and Halifax, plus
Personnel with the governments of the provinces of
Nova Scotia, New Brunswick, Manitoba, Alberta, and British Columbia
and
numerous Internet sources
plus
Information supplied by
Stelco, Dofasco, Luscar Ltd., and Teck Corp.
Nova Scotia Power Corp.
The Coal Association
The BCR and CPR
Natural Resources Canada
the United States Environmental Protection Agency
and
the United States Department of Energy
that proved invaluable in the preparation of this report.

A more complete list of all who contributed to this report is presented in Appendix C.

TABLE OF CONTENTS

Acknowledgements
Table of Contents
List of Tables
Executive Summary
Abbreviations
Glossary of Terms

Chapter 1 - Introduction
1.1 Estimating Fugitive Coal Dust Emissions
1.2 Particulate Matter – PM_{10}, $PM_{2.5}$ and Total
1.2.1 Nuisance Dusting
Chapter 2 – Coal in Canada in 2000
2.1 Coal Mines
2.2 Imported Coal
2.3 Exported Coal
2.4 Transportation – Rail, Truck and Vessels
2.4.1 Rail Transport
2.4.2 Truck Transport
2.4.3 Vessels, Ship and Barge, Transport
2.5 Storage Piles
2.6 End-Use Facilities
Chapter 3 – Estimating Fugitive Coal Dust Emissions
3.1 Federal - Provincial Estimates for Fugitive Coal Dust Emissions
3.2 Parameters Affecting Emissions and Control
3.2.1 Weather
Chapter 4 – Coal Mining – Fugitive Coal Dust Emission and Control
4.1 Coal Mining
4.1.1 Underground Coal Mines
4.1.2 Surface Coal Mines
4.1.3 Process Plant Emissions
4.2 Emission factors – Coal Mines
4.3 Fugitive Dust Control - Coal Mines
4.4 Emissions Estimates - Coal Mines
4.5 Discussion – Fugitive Coal Dust from Coal Mining Operations
Chapter 5 – Rail Transport – Fugitive Coal Dust Emission and Control
5.1 Rail Transport
5.2 Emission Factors – Rail Transport
5.2.1 CAC Inventory Emission Factors
5.2.2 British Columbia Emission Factors
5.2.3 Recent Findings Regarding Coal Car Dusting EFs
5.2.3.1 Weather En Route – Analyses
5.2.4 Recommended EF for Rail Transportation of Coal
5.2.4.1 Emission Factors for Dusting from Empty Trains
5.3 Fugitive Dust Control – Rail Transport
5.3.1 Environment Canada's 1986 Recommended Practices
5.3.2 Rail Car Dust Control at the Mines - 2000
5.3.2.1 Crust-Retention at End of Journey
5.3.3 Railcar Dust Control - The Railways
5.3.4 Railcar Dust Control - Terminals
5.4 Coal Dust Emissions Estimates –Rail Transport – 2000
5.4.1 Application of a Precipitation Factor
5.5 Discussion – Fugitive Coal Dust Emissions – Rail Transportation

TABLE OF CONTENTS (continued)

Chapter 6 – Truck Transport of Coal – Fugitive Dust Emission and Control
6.1 Truck Transport
6.2 Emission Factors – Trucks
6.3 Dust Controls – Trucks
6.4 Coal Dust Emissions Estimates – Trucks
6.5 Discussion – Fugitive Coal Dust – Truck Transportation
Chapter 7 – Coal Storage Piles – Fugitive Dust Emission and Control
7.1 Coal Storage Piles
7.2 Emission Factors - Storage Piles
7.3 Dust Control – Storage Piles
7.4 Coal Dust Emissions Estimates – Storage Piles
7.5 Discussion – Fugitive Coal Dust Emissions – Storage Piles
Chapter 8 – Coal Terminals – Fugitive Dust Emission and Control
8.1 Coal Terminals
8.2 Emission Factors - Coal Terminals
8.3 Dust Controls - Coal Terminals
8.4 Emissions - Coal Terminals
8.5 Discussion – Fugitive Coal Dust – Coal Terminals
Chapter 9 – Fugitive Coal Dust Emissions - Trends 1985 to 2020
Chapter 10 – Recommendations & Uncertainty
10.1 Coal Dusting Monitoring Program from Unit Trains for Establishing Emission Factors
10.2 Coal Dust Emissions from Trucks
10.3 Coal Storage Piles and Coal Terminals
10.4 Coal Mining Fugitive Dust Emissions
10.5 The Influence of Weather on Fugitive Dust Emissions
10.6 Uncertainties in Emission Factors

References

Appendix A – Information Sources
Appendix B – Nuisance Coal Dusting from Unit trains
Appendix C – Coal Dust Control, Recommended Practices for Loading, Unloading and Transporting Coal by Rail – 1986

List of Tables

Table 1.1 Coal in Canada in 2000
Table 1.2 General Areas of Nuisance Fugitive Coal Dust Complaint

Table 2.1 Canadian Coal Mines - 2000
Table 2.2 Coal Imported into Canada - 2000
Table 2.3 Canadian Coal Exports - 2000
Table 2.4 Canadian Railway Coal Car Fleets in Western Canada
Table 2.5 Rail Shipment of Coal in Canada - 2000
Table 2.6 Quantity of Coal Shipped by Rail in Canada - 2000
Table 2.7 Coal Moved by Truck in Canada - 2000
Table 2.8 Coal Moved by Ship or Barge - 2000
Table 2.9 Major Coal Storage Sites in Canada – 2000

Table 4.1 CAC 1995 Inventory Coal Mining – Uncontrolled Emission Factors
Table 4.2 US EPA AP-42 Table
Table 4.3 Uncontrolled Fugitive Coal Dust Estimates for Coal Mining Operations for 2000

Table 5.1 Approximate Rail Distances for Coal Transport in Canada
Table 5.2 Rail Car Coal Dust Emission Factor Comparison
Table 5.3a Linear versus Non-Linear Rail Dust Emission Factors
Table 5.3b Additional Linear vs Non-Linear Rail Dust Emission Factors
Table 5.4 Maximum Temperature Readings (Tmax in °C) for 2000
Table 5.5 Wind Measurement Averages - Hope, BC for 2000
Table 5.6 Recorded Precipitation - 2000
Table 5.7 Precipitation Days and Snow Days in 2000
Table 5.8 Comparison of Different EFs for LFV Emissions in 2000
Table 5.9 Comparison of Scaling Factors
Table 5.10 Train Coal Dust Mitigation Techniques
Table 5.11 Train Dust Control – Equipment 2001
Table 5.12 Train Dust Control - Procedures - 2001
Table 5.13 Railway - Train Dust Control Procedures
Table 5.14 Coal Terminals - Rail Car Dust Controls – Equipment & Procedures – 2001
Table 5.15a CAC EF Conventional Rail Dust Emissions Estimates – 2000 – Total Particulate
Table 5.15b CAC EF Conventional Rail Dust Emissions Estimates – 2000 - PM_{10} and $PM_{2.5}$
Table 5.16a New CAC EF Rail Dust Emissions Estimates – 2000 – Total Particulate
Table 5.16b New CAC EF Rail Dust Emissions Estimates – 2000 – PM_{10} and $PM_{2.5}$
Table 5.17a New BC MELP EF Rail Dust Emissions Estimates – 2000 – Total Particulate
Table 5.17b New BC MELP EF Rail Dust Emissions Estimates – 2000 – PM_{10} and $PM_{2.5}$
Table 5.18 Precipitation Factor Example

Table 6.1 Coal Truck Transportation Emission Factors – 2000 – Total Particulate
Table 6.2 Emissions Estimates for Coal Transported by Truck – 2000

Table 7.1 Dust Control Storage Piles

Table 8.1 Fugitive Dust Emission Factors - Coal Handling - Total Particulate
Table 8.2 Emissions Estimates for Coal Terminal Operations - 2000

Table 9.1 Clean Coal Production in Canada 1990 to 1995
Table 9.2 Forecast of Coal Consumption in Canada
Table 9.3 Coal Rail Fugitive Dust Emissions Estimates Lower Fraser Valley 1985 to 2000

EXECUTIVE SUMMARY

In Canada in 2000, coal was mined in five provinces, imported into seven, exported from three and consumed in nine. Coal was transported by barge, ship, truck and by rail. The coal came from mines in Alberta, British Columbia, Saskatchewan, New Brunswick, Nova Scotia, and the United States and was moved to ports and end-use facilities from Newfoundland to British Columbia.

As a result of the activities associated with the mining, shipping, importing, exporting and consuming of coal, coal dust may become airborne or become a *fugitive emission.* However, because of the dispersed and diverse nature of the various operations involved, fugitive coal dust emissions cannot be readily measured. Therefore federal, provincial and regional environment agencies must rely on estimates in order to compute overall emissions totals.

To estimate fugitive coal dust emissions for coal industry operations one requires data related to the following variables:

- quantity of coal mined, handled or shipped,
- the frequency of the activity or operation,
- the length of the activity (distance or time),
- the properties of the coal used,
- the efficiency of control measures, and
- local weather parameters at the time of the activity.

When possible, this information is then combined within an average emission factor (EF) for the particular operation or activity.

The purpose of this study is to attempt to estimate fugitive coal dust emissions for the various operations in the coal cycle from mine to end-use facility in Canada for 2000. However, because nuisance coal dust from trains has been an environmental issue for decades, particular emphasis is placed the emission factors and the emissions estimates from the transport of coal by rail.

Emissions for coal mining in Canada in 2000 were attempted using the latest production data that were available. An attempt was also made to estimate fugitive coal dust emissions at major Coal Terminals and from truck transport for 2000. While the Coal Terminal and truck transport estimates provide and indication as to the emissions from these two sectors, the uncertainties involved in the calculations were extremely high and they should only be considered rough estimates.

Fugitive dusting can also occur in relation to coal storage piles. Unfortunately, while some data in relation to coal storage piles were assembled for 2000, there was insufficient information available to allow fugitive dust estimates to be calculated. Fugitive dust emission from coal storage piles is an area where additional study is required.

In 2000, coal was transported by ship and barge in Canada. However, while some information on these activities has been presented, because of insufficient data, no fugitive dust emission estimates in relation to ship or barge transport were attempted.

As noted, a significant portion of this investigation focuses on fugitive coal dust emissions related to the transport of coal by rail in Canada in 2000. The accuracy of the present emission factors (EFs) for estimating fugitive coal dust from unit trains has been questioned. Therefore, an attempt was made to find new or revised emission factors for that sector. Coal rail transport databases were queried and contacts made in Canada, the United States and Australia.

It was discovered that coal dust emissions from trains are of concern in other countries, particularly in the state of Virginia in the USA. However, no emission factors for coal rail transport appear to have been created, since those developed in the early 1980s.

Regardless, while no new emission factors were discovered, the investigation revealed areas where changes to the present emission factors and their application could improve the accuracy of the rail generated fugitive coal dust estimates in emissions inventories.

For estimating fugitive coal dust emissions from rail transport on a national basis, it is recommended that a modified version the basic emission factor used for the estimates in Environment Canada's national *Criteria Air Contaminants (CAC) Inventory* be used. One modification is to accept that the basic emission factor is for the uncontrolled fugitive dust emissions and not for 75% control as presently assumed. Another modification is in regard to the use of that formula. It is felt that instead of the current practice of using the formula to produce new estimates for each provincial distance segment, an overall estimate for the entire rail journey should be produced. That overall estimate should then be prorated by distance segment. The BC Ministry of Environment Lands and Parks (MELP) currently uses the latter technique to prorate emissions for the Lower Fraser Valley.

For estimating fugitive coal dust emissions from rail, it is recommended that, the basic CAC EF be modified using:

- New PM_{10} and $PM_{2.5}$ scaling factors,
- A precipitation factor,
- An adjusted dust control factor of 99%, and
- A linear distance factor to prorate emissions.

In this study, all of the above factors were employed to estimate emissions for the rail transport sector of the coal industry in 2000.

New scaling ratios for the conversion of total particulate estimates to PM_{10} and $PM_{2.5}$ emissions are suggested. The results of this investigation suggest that the scaling factors presently used by both Environment Canada the BC MELP are too high or too great. Experiments conducted in the 1980s indicated that a fraction of the coal emitted by rail cars is likely greater in size than is allowed for by the present scaling factors.

Also, while using a dust control efficiency of 99% may appear excessive, it is the dust control efficiency currently assumed by Environment Canada for assessing national rail coal dust emissions. The use of an efficiency of 99% is also supported by the visible dusting evidence gathered in 2000 for coal trains in British Columbia. Only about 1% of the loaded coal trains, observed in Hope, BC in 2000, were assessed as 'heavy' emitters in terms of visible dust emissions.

In regard to inventories of fugitive coal dust, the present practice is for the federal and provincial agencies to estimate fugitive coal dust emissions only for coal mining and coal rail transportation. The fugitive dust emissions from truck transport, coal storage piles and large Coal Terminals are not estimated. However, many storage piles and Coal Terminals are located near populated areas. Therefore, it is recommended that emissions from these sources be included in future inventory estimates of fugitive coal dust.

The operations in relation to coal storage piles frequently produce fugitive dust emissions, and the activities involved with storage pile management are many and can vary from day to day. Consequently, the variables involved in estimating emissions are numerous. However, if data related to specific storage piles were available, there are emission factors that could be used for estimating emissions from these sources. It is suggested that regional, provincial and/or national agencies may wish to investigate the possibility of gathering the data required to estimate emissions from the coal storage piles that are located in or near large urban areas.

In addition to the issue of more accurate estimates for PM_{10}, $PM_{2.5}$ and total emissions of fugitive coal dust, there is the issue of nuisance soiling. Since the 1970s, nuisance soiling has been a problem in relation to coal blown from loaded railcars that travel from the Alberta and BC borders to Vancouver. Therefore, in Appendix B this report includes an updated overview of the issue of nuisance soiling from coal blown from railcars.

For unit coal trains, visible dusting incidents cannot be quantitatively linked to overall dust control efficiency. However, the number of visible dust events related to unit coal trains that were reported in 2000 confirm that the emissions control effectiveness of the dust suppressant systems used by certain mines that ship coal to Vancouver was less than 100% in that year.

ABBREVIATIONS

AP-42	-	US EPA Compilation of Air Pollutant Emission Factors
BC MELP	-	British Columbia Ministry of Environment Lands and Parks
CA	-	Coal Association of Canada
CAC	-	Criteria Air Contaminants (Inventory of Environment Canada)
CBDC	-	Cape Breton Development Corporation
CEPA	-	Canadian Environmental Protection Act
CCME	-	Canadian Council of Ministers of the Environment
CCMTA	-	Canadian Council of Motor Transport Administrators
CTA	-	Canadian Transportation Agency
EIA	-	U.S. Department of Energy, Energy Information Administration
EPA	-	U.S. Environmental Protection Agency
EPWG	-	Emissions and Projections Working Group (see NEIPTG)
LFV	-	Lower Fraser Valley – Hope to Vancouver British Columbia
MELP	-	British Columbia Ministry of Environment, Lands and Parks
NAICC	-	National Air Issues Co-ordinating Committee
NCACI	-	National Criteria Air Contaminant Inventory
NEIPTG	-	former name of the EPWG
PART	-	Total Particulate as used by Environment Canada CAC Inventory
PDB	-	Pollution Data Branch, Environment Canada
$PM_{2.5}$	-	Particulate Matter 2.5 micron and smaller
PM_{10}	-	Particulate Matter 10 micron and smaller
TSP	-	Total Suspended Particulate

Glossary of Terms

Emission Factor (EF)	- An estimate or statistical average of the rate at which a contaminant is released to the atmosphere as a result of some activity divided by the level of that activity. The Emission Factor (EF), therefore, relates the average quantity of each contaminant emitted according to an appropriate base quantity. EFs are usually expressed as a weight of contaminant divided by a unit weight, volume, distance or duration of associated activity that emits the pollutant. EFs are usually obtained from data of varying degrees of accuracy and may be presented for either uncontrolled sources or facilities having air pollution control devices in place.
fine particulate matter	- all particulate matter less than 10 microns in diameter includes both PM_{10} and $PM_{2.5}$ fractions
friable	- easily crumbled
fugitive emissions	- air pollution derived from human activities that do not emanate from a particular point, such as an exhaust pipe or stack. Coal dust from trains and roadway dust are examples of fugitive emissions.
opacity	- the percentage of light transmitted from a source that is prevented from reaching a light detector
overburden	- the rock and/or earth covering a seam of coal
Particulate Matter (PM)	- any aerosol that is released to the atmosphere in either solid or liquid form. [Includes Particulates]
$PM_{2.5}$	- airborne particulate matter with a mass median diameter less than 2.5 μm
PM_{10}	- airborne particulate matter with a mass median diameter less than 10 μm
parts per million (ppm)	- a volumetric concentration measurement of contaminants
smoke (diesel)	- all particles, including aerosols, suspended in the exhaust stream of a diesel engine that absorb, reflect, or refract light
Total Suspended Particulate (TSP)	- airborne particulate matter with an upper size limit generally considered to be approximately 75 μm in aerodynamic equivalent diameter.
transmittance	- the fraction of light transmitted from a source which reaches a light detector
unit train	- a train with a similar consist of cars and that carries only one cargo. For the purposes of this report, that cargo is coal.

Fugitive Coal Dust Emissions In Canada

Chapter 1

Introduction

In Canada in 2000, coal was mined in five provinces, imported into seven, exported by three and consumed in nine.*

Table 1.1 Coal in Canada in 2000

Province	Mine	Import Coal	Consume Coal
British Columbia	Yes		Yes
Alberta	Yes	Yes	Yes
Saskatchewan	Yes		Yes
Manitoba		Yes	Yes
Ontario		Yes	Yes
Quebec		Yes	Yes
New Brunswick	Yes	Yes	Yes
Nova Scotia	Yes	Yes	Yes
PEI			
Newfoundland		Yes	Yes
All Territories			

* Data as reported by the Coal Association of Canada (CA 2001)

As a result of the activities associated with the mining, transportation, storing, transfer and consumption of coal, coal dust became airborne or became a *fugitive emission*. These airborne fugitive emissions are the subject of this investigation.

1.1 Estimating Fugitive Coal Dust Emissions

Fugitive coal dust emissions are of concern because of their possible adverse health affects, their tendency to soil or to be a nuisance pollutant, and the possibility of their causing cross-contamination of other bulk products.

While the implications of fugitive coal dust emissions on the health of workers in the coal industry (and related industries) are of major importance, they are beyond the scope of this investigation. The objective of this report is to attempt to determine the levels of fugitive coal dust emissions in Canada as they may relate to contributions to urban levels of particulate matter, PM_{10} and $PM_{2.5}$ and to nuisance soiling in 2000.

In general, because of the dispersed and diverse nature of the various operations involved in the extraction, processing, loading, storage, unloading and shipping of coal, fugitive

coal dust emissions cannot be readily measured. Therefore federal and provincial environment agencies must rely on estimates. To estimate fugitive coal dust emissions for each coal industry operation one must gather data related to the following variables:

- The quantity of coal mined, handled or shipped,
- The frequency of the activity or operation,
- The length of the activity (distance or time),
- The properties of the coal used,
- The efficiency of control measures, and
- The local weather parameters at the time of the activity.

This information is then combined within an emission factor (EF) for the particular operation or activity.

One purpose of this study is to attempt to gather the emission factors, activity data and coal throughput for the various operations in the coal cycle from mine to end-use facility in 2000 and to estimate emissions of PM_{10}, $PM_{2.5}$ and total particulate. Particular attention is paid to the emissions of fugitive coal dust from unit trains.

An estimate can never be more than just that, an estimate of what is really happening. However, one way of improving the accuracy of estimates is by improving the emission factors used to produce the estimate. Fugitive coal dust from unit trains is one area where the current EFs used by federal, provincial and regional agencies to develop emission estimates require review.

An example as to why accurate fugitive coal dust emission estimates from unit trains are required is a statement from a recent report on the results of the BC program to test smoke emissions from on-road Heavy-Duty Vehicles. (Newhook 2000)

> *In the Vancouver area, despite representing only about 4% of the registered vehicle fleet, Heavy-Duty Diesel Vehicles are estimated to be significant sources of both NOx and PM, contributing 15% of total mobile source NOx and 16% of total mobile source-related PM. The contribution to overall PM would be greater except for a large amount of PM attributable to fugitive coal dust blown from trains, which accounts for 37% of the total mobile source PM inventory.*

In other words, if the emissions estimates for rail generated fugitive coal dust are inaccurate, they may mask the overall contribution of other sources of PM in an airshed.

1.2 Particulate Matter – PM_{10} $PM_{2.5}$ and Total

Particulate matter air pollution refers to a mixture of solid and liquid particles suspended in the air. The smaller particulates are sometimes described as an aerosol, which refers to a stable mixture of particles suspended in a gas. Airborne particulate matter is a mixture of chemical species and size fractions. Airborne particles usually range in diameter from 0.005 to 100 microns in size. *Total Suspended Particulate* (TSP) refers to particulate up to 75 microns in aerodynamic diameter. However, the particles of greatest concern, from a human health perspective, are those with an aerodynamic diameter of less than 10 microns, since they can penetrate the lung.

In Canada for ambient air assessment, fine particulates are currently divided into two distinct fractions. Particulates that are less than 2.5 microns in size ($PM_{2.5}$) and the

coarser fraction particulates that are less than 10 microns in aerodynamic diameter (PM_{10}). Minute particulates in the ambient air may occur naturally or be man-made. At present there is a Canada-wide Standard for $PM_{2.5}$ and PM_{10} has been declared toxic under the new *Canadian Environmental Protection Act* (CEPA). (Canada Gazette Part II, 9 May 2001)

1.2.1 Nuisance Dusting

In addition to the issue of fugitive coal dust in regard to human health, and the estimation of those emissions for inventory purposes, there is the problem of nuisance dusting. In this study, an attempt has been made to separate these two issues. However, they are linked, and an overview of nuisance dusting problems, in particular nuisance dusting from unit trains, has been included for completeness. (See Appendix B)

Nuisance soiling or dusting is not specifically defined in the federal government's *Canadian Emissions Inventory of Criteria Air Contaminants*. (Deslauriers 1999) However, in regard to its investigations into fugitive coal dusting, the Australian Environment Department has developed to following definition: (AMEEF 2001)

> *Nuisance dust is a term generally used to describe dust that reduces environmental amenity without necessarily resulting in material environmental harm.*

While attempts to estimate the PM_{10} and $PM_{2.5}$ portions of total fugitive coal dust emissions are relatively new, complaints and investigations into nuisance pollution regarding fugitive coal dust emissions in Canada have a history in many areas of the country.

Table 1.2 General Areas of Nuisance Fugitive Coal Dust Complaints Registered in Canada 1980 to 2000

Province or Territory	Mines	Storage Piles	Trains	Trucks	Terminals and Loading to Ships
British Columbia		yes in 1980s	27 in 2000		yes in 2000
Alberta				road dust only	
Saskatchewan					
Manitoba		yes in 1980s			
Ontario		yes in 1990s			yes in 1980s
Quebec					yes in 1980s
New Brunswick					
Nova Scotia		yes in 1980s			yes in 1980s
PEI					
Newfoundland					
All Territories					

In Table 1.2, the intent is to show the areas where dusting is or has been a problem, and where, to the best that could determined during this short investigation, official complaints have been registered. It was not possible to list number of complaints received in certain areas; since some were community related and involved numerous complaints regarding the same incident.

Dusting from trains is the prime focus of this investigation. In 2000, complaints regarding nuisance dusting from 27 unit coal trains were registered in BC. (See Appendix B)

In British Columbia, nuisance dusting from coal trains has been a source of citizen complaint since 1974. More recently, according to officials with the Canadian Pacific Railway (CPR), there were incidents of dusting in 1994 and sporadically from 1994 to 2000. (CTA 2000)

> *The CPR typically received only a couple of sporadic complaints per year, usually in early summer and usually from residents in the Agassiz and Kent regions.*

Similar dust complaints from residents in the area of Flood, BC were received by Canadian National (CN) in the early to mid-1990s.

Fugitive dust complaints regarding coal emissions from storage piles, either at coal terminals or at end-use facilities, have been registered in at least four provinces since 1974. By the late 1980s, the complaints regarding nuisance dusting that had been received by Environment Canada in connections with coal storage piles included the following: (Cope 1988)

- The International Pier in Sydney, Nova Scotia,
- The storage piles on a pier at Port Stanley, Ontario, and
- The coal stored at the Nanticoke, Ontario power plant.

In 1987 there was an investigation by the Environment Canada and the provincial government regarding complaints from nearby residents of coal dusting from the storage pile and handling at the International Pier in Sydney, Nova Scotia. (Ternan 87)

In the 1980s there were a series of 'town hall' meetings in Port Stanley, Ontario regarding nuisance coal dust complaints in regard to the storage and handling of coal at the port. The coal was for the nearby Saint Mary's Cement plant. Complaints regarding coal dusting in Port Stanley were also received by Environment Canada in the 1990s.

In the 1980s, dusting complaints regarding storage piles and coal transfer operations at ports were registered in Quebec City and in connection with three of the coal terminals in British Columbia. (Cope 1988)

In British Columbia in 2000, the Greater Vancouver Regional District (GVRD) received one complaint regarding dusting from storage piles at the coal export facility at Roberts Bank. (GVRD 2001)

In Manitoba, in the past, nuisance-dusting complaints have been registered by private citizens who reside near Manitoba Hydro's Selkirk Generating Station. However, the possibility of future complaints is moot, since it is reported that over the next two years the Selkirk plant will be converted to natural gas to displace all coal use.

In Alberta, complaints have been received by government agencies regarding fugitive dust generated by coal trucks on haul roads from mine to power plants. These complaints were related to dust emissions from the coal cargo and from road dust.

All of these incidents related to public nuisance dusting from windblown coal illustrate that coal does become airborne and does cause problems in Canada.

Chapter 2

Coal in Canada in 2000

As noted in Chapter 1, in Canada in 2000, coal was mined in five provinces, imported into seven, exported by three and consumed in nine. In this Chapter, the data available at in the spring of 2001 for the coal industry in Canada in 2000 are presented. In many instances, data for 2000 were not available. Cautions have been added to the text, if the data used for emissions calculations were not for 2000.

2.1 Coal Mines

The coal mines operating in Canada in 2000 are illustrated in Table 2.1. While the production data for most of the mines was available for 2000, for a number, 1999 data were used. It was felt that for most cases the changes from 1999 to 2000 were minor.

In regard to fugitive dusting from coal trains, because of its nature and the distances it is shipped, the coal mined in Alberta and British Columbia is the main focus of this study.

The Lignite coal mined in Saskatchewan is by its nature less friable (therefore fewer fines) than most of the Alberta and BC coals. Also, the majority of the Saskatchewan coal is shipped only short distances by truck from mine to end-use facilities. Similarly, in New Brunswick, although the coal is closer to western coal in nature than is the Saskatchewan lignite; it is generally shipped shorter distances than the Alberta and BC coal.

In Nova Scotia, the majority of the province's production was from an underground mine in Cape Breton, and most of that coal was shipped only a short distance from the mine to a local power plant. However, that one remaining underground mine in Cape Breton, the Prince mine, closed in November 2001.

Some of the smaller mines in Nova Scotia ship coal by rail and truck over longer distances, but the quantities are small. There is no historical record of dusting complaints in regard to these shipments.

The majority of coal in Canada is mined in the open in operations that are referred to as open pit or strip mines. By their nature these operations generate dust from blasting, drilling, overburden removal, loading, hauling, unloading, processing, and final transport loading. These two mine types are as defined by their names. In general, an open pit operation takes place in a more concentrated area than does a strip mine. For open pit mines the coal seams may be in a deep pit that extends deep into the ground, or as a pit into the side of a hill or mountain. In some cases such as the Minto area of New Brunswick, coal that was once mined using underground mining techniques is now mined by removing hundreds of feet of rock and dirt, the *overburden*, to get at the coal deep in the ground. A large open pit is formed as a result of this overburden removal. A surface strip mine is a mining operation where, in general, the coal seam is not as deep under the ground than it is in an open pit operation. The coal is mined by stripping the overburden from the surface using devices such as draglines or bulldozers to reach the coal that is below.

Table 2.1 Canadian Coal Mines 2000

Mine	Prov.*	Type	Location	Marketable Coal Production 2000
				(10^6 Tonnes)
Bullmoose	BC	Open Pit	Tumber Ridge, NE **Closing 2003**	1.60
Coal Mountain	BC	Open Pit	SE	2.30
Elkview (Balmer)	BC	Open Pit	SE	3.00
Fording River	BC*	Open Pit	SE	8.30
Greenhills	BC*	Open Pit	SE	4.20
Line Creek	BC	Open Pit	SE	3.50
Quinsam	BC	Underground	Vancouver Island	0.24
Quintette	BC	Open Pit	Northeast – **Closed 2000**	1.00
Willow Creek	BC	Open Pit	Northeast - **open 2001?**	0.00
Coal Valley	**Alta**	Strip	Hinton, NW mid	1.00
Genesee	**Alta***	Strip	Warburg - Mid	3.60
Gregg River	**Alta**	Open Pit	NW mid – **Closed 2000**	2.10
Highvale	**Alta**	Strip	NW	13.00
Luscar	**Alta**	Open Pit	Hinton, NW mid	2.80
Obed	**Alta**	Open Pit	Hinton, NW mid	1.80
Paintearth (+Vesta)	**Alta**	Strip	Mid	3.50
Sheerness (+Montgomery)	**Alta**	Strip	Mid	4.00
Smoky River	**Alta***	Underground + Open Pit	Grande Cache, NW **Closed 2000?**	1.80
Whitewood	**Alta***	Strip	NW	2.30
Bienfait	Sask	Strip	Estevan, SE	2.00
Boundary Dam/Shand (Utility)	Sask	Strip	SE	6.50
Costello	Sask	Strip	Estevan, SE	?
Poplar River	Sask	Strip	SW	4.00
Minto	**NB***	Open Pit	SE - **Closing?**	0.24
Alder Point	NS*	Surface	Cape Breton	0.06
Coalburn	NS	Surface	Thorburn, Pictou County	0.03
Little Pond	NS*	Surface	Cape Breton	0.01
Prince (Phalen closed 00)	NS	Underground	Cape Breton - **Closed 2001**	0.98
Springhill Project	NS*	Surface	Springhill, Cumberland Cty	0.01
St. Rose	NS	Surface	Inverness County	0.03
Stellarton	NS	Surface	Stellarton, Pictou County	0.20

* production information is estimated from 1999 data

While underground mines once dominated the coal mining industry in Canada, in 2000 there were only three underground mines accounted for in the information available on coal mines. One underground mine is located in the interior of Vancouver Island near Comox and the other is the Prince mine in Cape Breton (now closed). Until the end of 2000 there was a combined underground and open pit mining operation in the Smoky River area of Alberta. Since this mine's equipment was listed for sale late in 2000, it was assumed that the mine was closed by the end of 2000. In the 1980s there was also an underground hydraulic coal mine in the area of Sparwood, BC, but this mine is now closed.

2.2 Imported Coal

In 1998 almost 19 million tonnes of coal were imported into Canada. While details related to all imports were not available, the total for 2000 was judged to be similar to the amount imported in 1998, Table 2.2.

For example, in 1998 coal was reported as imported into Alberta, Manitoba and Quebec. (CA 2001) However, information as to similar imports in 2000, and as to how that coal was shipped, was not available.

Fortunately, imported coal for the steel mills in southern Ontario in 2000 was reported. The coal for these mills is landed by ship at or near company facilities on Lake Ontario and Lake Erie. See Table 2.8. (Stelco 2001, Dofasco 2001)

A large quantity of coal is imported each year by *Ontario Power Generation* (OPG) Inc. (OPG is ex-Ontario Hydro). While it is thought that most of this coal arrives by ship and is unloaded at or near the company power plants, this could not be confirmed. Little new information was available regarding the coal imported by Ontario Power Generation Inc. in 2000. However, the total quantity that is imported by OPG annually will change by 2005 when the Lakeview coal generating station is slated to switch to natural gas. Larger cuts in OPG's imports could also occur if the company also switches the Nanticoke plant to natural gas.

The coal imported into New Brunswick arrives by ship at Belledune and is used at the nearby Belledune Power Plant. (NB 2001)

In 2000 Nova Scotia Power Corporation imported just over 2 million tonnes of coal. It arrived by ship at either the International Pier in Sydney or at Auld Cove in the Strait of Canso. With the recent announcement of the closure of the Prince mine in Cape Breton, the quantity of coal imported into Nova Scotia may increase in the near future.

In 2000, a small amount of coal was also imported by ship into Halifax for a private company near Brookfield. It is assumed that this coal was trucked from Halifax to Brookfield, Table 2.6. The coal that is imported into Newfoundland is landed at Sept. Iles, Quebec and shipped by train to Labrador City.

For the purposes of estimating fugitive coal dust emissions, it was assumed that most of the coal imported into Canada in 2000 was landed by ship. It was also assumed that most was landed at end-user port facilities or nearby and transferred by truck, or other wheeled movers, short distances to the end-user facilities.

During the last 20 years fugitive dusting incidents have been reported for coal handled or stored at a number of the receiving terminals and at end-user docks associated with imported coal.

Table 2.2 Coal Imported into Canada - 2000

	Destination	Landed at	Delivered by	Imports
				tonnes
Alberta	**Alberta Total =**			**6,324***
Manitoba	**Manitoba Total =**			**493,902***
Ontario	St. Mary's Cement	Port Stanley	ship	?
	Dofasco	Hamilton	ship	1,500,000
	Stelco	Hilton Works, Hamilton	ship	1,026,660
	Stelco	Lake Erie Works	ship	744,629
	Lambton Power Plant			3,421,680*
	Nanticoke Power Plant			7,236,809*
	Lakeview Power Plant			1,243,452*
	Ontario Total =			**15,173,231**
Quebec	**Quebec Total =**			**847,043***
NB	Belledune Power Plant	Belledune	ship	**1,022,070**
NFLD	Iron Ore Coy, Labrador City	Sept. Iles	ship	**49,471**
NS	NS Power Corp	International Pier, CB	ship	1,200,000
	NS Power Corp	Auld Cove, St. of Canso	ship	850,000
	Lafarge Canada, Brookfield	Halifax	ship	35,000
	NS Total =			**2,085,000**
			Total Canada =	19,677,041

* 1998 data

2.3 Exported Coal

In 2000, three coal terminals in British Columbia and one in Ontario exported Coal, Table 2.3

These four terminals are large operations that feature a circular loop of track for unloading mile long unit trains. Some of these terminals handle a variety of bulk products in addition to coal.

These four coal terminals feature rotary-dumpers for emptying their coal cars. These dumpers operate with cars that are fitted with special couplers that allow individual cars to be dumped without the necessity of decoupling.

The Neptune, Thunder Bay and Roberts Bank rotary-dumpers are located inside housings that limit dusting during the unloading operations.

In the 1990s, it is reported that the Quinsam mine on Vancouver Island exported coal via a small terminal facility on Texada Island in the Strait of Georgia. It was reported that this mine did not export coal in 2000.

Table 2.3 Canadian Coal Exports - 2000

Terminal	Name Location	Prov	tonnes	Mines that may have Supplied Export Coal in 2000
Westshore Terminals Ltd.	Roberts Bank Vancouver	BC	22,500,000	Coal Valley, Gregg River Luscar, Obed, Alta Coal Mountain, Elkview, Line Creek, Fording River, Greenhills, BC Powder River Basin, Montana Powder River Basin, Wyoming
Neptune Bulk Terminals (Canada) Ltd.	Vancouver Harbour Vancouver	BC	4,962,000	Coal Valley, Gregg River Luscar, Obed, Alta Smoky River, Alta
Texada Island	Texada Island Strait of Georgia	BC	0	Quinsam, BC
Ridley Terminals Inc.	Ridley Island Prince Rupert	BC	6,000,000*	Coal Valley, Gregg River Luscar, Obed, Alta Bullmoose, Quintette, BC
Thunder Bay Terminals Ltd.	McKellar Island Thunder Bay	Ont	1,830,000*	Coal Valley, Gregg River Luscar, Obed, Alta Coal Mountain, Line Creek, BC Bienfait, Sask Powder River Basin, USA
	Canada Exports	=	35,292,000	

* 1999 data from the Coal Association

2.4 Transportation – Rail, Truck and Vessels

Coal from Canadian mines is moved to market by rail, truck, barge or ship. As far as could be determined, in 2000, most of the coal imported into Canada arrived by ship and was unloaded near the facilities where it would be used.

2.4.1 Rail Transport

In Western Canada, unit trains are used to move coal from mines along the BC/Alberta border to terminals in Vancouver, Prince Rupert and Thunder Bay, Tables 2.5 and 2.6.

In Saskatchewan unit trains are used to move lignite coal from the Poplar River mine approximately 20 km to the Poplar River Power Plant. The Bienfait mine ships lignite coal by rail to Ontario for use at power plants near Thunder Bay. The rest of the lignite coal mined in Saskatchewan is moved by truck to nearby power plants.

In Western Canada, three rail companies haul domestic coal by unit train: (Table 2.4)

- Canadian Pacific (CP)
- Canadian National (CN)
- British Columbia Railway (BCR)

Table 2.4 Canadian Railway Coal Car Fleets in Western Canada

Railway Company	CP	CN**	BCR
1985			
Train Sets	19	12	9
Total Cars	2250	1379	889
2001			
Train Sets	?	12	2
Total Cars	3211*	1379	~200

* includes 625 new cars added in 2000 and an additional 625 that will be added in 2001. (CPR 2000)

** An information update for 2000 was not available

In 2000, the Canadian National reported that it transports metallurgical and thermal coal for the export market in a unit train configuration in rotary gondola cars. The length of the CN unit trains is 112 cars for their 53-foot cars (including new aluminum cars) and 102 cars for standard 58-foot steel car sets. CN also moves coal, metallurgical coke, and petroleum coke in small car blocks or single cars in other types of equipment, such as covered hoppers and bottom dump cars. (CN 2001)

CP added 625 new coal cars in 2000 and added 625 more new cars in 2001. (CP 2000) With the closing of one mine in Northeast BC, the BCR now operates fewer coal car sets than it did in the 1980s.

The movement of coal by rail in Atlantic Canada is on a much smaller scale than in the West. In the 1980s, some of the coal from the Minto mine in New Brunswick moved by rail to a power plant near the Quebec border. However, in 2000, it was reported that Minto coal was shipped by truck to the local power plant at Grand Lake and to the power plant at Belledune, NB. (NB 2001)

In Nova Scotia, details regarding all of the coal movements were not available. However, it is known that the majority of the coal from the Prince mine (the only large active mine in that Glace Bay group in 2000) was shipped by unit train approximately 8 km to the Lingan power plant.

While coal was shipped in other parts of Canada in 2000, it is felt that little of this coal is shipped by rail.

The Iron Ore Company of Canada imported a small quantity of coal for use at its facility near Labrador City. This coal was landed by ship in Sept. Iles, Quebec and taken by rail to Labrador.

In addition to imports, both the Roberts Bank and Thunder Bay terminals are reported to be experimenting with transshipping coal for export from the Powder River Basin in the USA via their terminals. This coal will enter and be transported through Canada in unit trains. The exact routes are not known at this time.

Unfortunately, as noted, during the short span of this investigation, information on the method of transporting most of the imported coal in Canada in 2000 was not available.

Table 2.5 Rail Shipment of Coal in Canada - 2000

Ship by Rail in 2000 from	From	To ⇒	Roberts Bank, BC	Neptune, BC	Ridley Island, BC	Thunder Bay, Ont	Other Destinations
Originating Mine	**Prov.**	**Transport Railway Coy.**					
Bullmoose	BC	BCR/CN			yes		
Coal Mountain	BC	CP	yes			yes	
Elkview (Balmer)	BC	CP	yes				
Fording River	BC	CP	yes				
Greenhills	BC	CP	yes				
Line Creek	BC	CP	yes			yes	
Quintette	BC	BCR/CN			yes		
Coal Valley *	**Alta**	CN	yes	yes	yes	yes	
Gregg River *	**Alta**	CP	yes	yes	yes	yes	
Luscar *	**Alta**	CN	yes	yes	yes	yes	
Obed *	**Alta**	CN	yes	yes	yes	yes	
Smoky River	**Alta**	CN		yes			
Bienfait	Sask	CN & CP				yes	Ont Power
Poplar River	Sask	Dedicated rail					Sask Local
Prince	**NS**	Dedicated rail					NS Local
Imported Coal							
For Iron Ore Company	Nfld	?					Que to Labrador
Transshipment							
Powder River Basin, Montana	**BC**		yes				
Powder River Basin, Wyoming	**BC**		yes				
Powder River Basin	Ont					yes	

* coal may not have been shipped to all four terminals in 2000. Breakdown not known.

Table 2.6 Quantity of Coal Shipped by Rail in Canada - 2000

Mine	Prov.	Status 2000	millions of tonnes
Bullmoose	**BC**	Closing 2003	1.60
Coal Mountain	**BC**	operating	2.30
Elkview (Balmer)	**BC**	operating	3.00
Fording River	**BC**	operating	8.30
Greenhills	**BC**	operating	4.20
Line Creek	**BC**	operating	3.50
Quintette	**BC**	closed in 2000	1.00
Coal Valley	Alta	operating	1.00
Gregg River	Alta	closed in 2000	2.10
Luscar	Alta	operating	2.80
Obed	Alta	operating	1.80
Smoky River	Alta	closed in 2000?	1.80
Bienfait	**Sask**	operating	2.00
Poplar River	**Sask**	local train	4.00
Prince (Phalen)	NS	operating	0.98
Imports by Rail			
For Iron Ore Cy	**Nfld**	via Que	0.05
Transshipment			
Powder River Basin, Montana	RB, BC	test only	?
Powder River Basin, Wyoming	RB, BC	test only	?
Powder River Basin	**TB, Ont**	test only	?

2.4.2 Truck Transport

In this report, for emissions calculation purposes, the transport of coal by truck refers only to the movement of marketable coal away from the property of the originating mine, Table 2.7. The information reported in Table 2.7 does not include the movement of coal from mine face to preparation facility or to mine load-out. For these operations, and the fugitive emissions associated with them, it was assumed that emissions related to these activities are included in, and accounted for, under 'mining' operations.

In Saskatchewan, trucks are used to move lignite coal from mine to market in all operations with the exception of those described in Section 2.4.1 for the Poplar River and the Bienfait mines. Most truck shipments in the province involve the movement of the lignite coal to nearby power plants.

As noted, in the 1980s, some of the coal from the Minto mine in New Brunswick moved by rail, however, in 2000 it was reported that all coal from the Minto mine was moved by truck to the nearby Grand Lake power plant or to the Belledune power plant. (NB 2001) For the future, NB Power has recently announced a plan to shut the Grand Lake facility in 2004. The fate of Minto coal and the mine is not known at this time.

Also, information was not available in regard to the movement of the coal imported by the Nova Scotia Power Corporation. For this report it was assumed that it was moved by truck. Similarly for a small amount of coal imported by ship to Halifax for a private company near Brookfield. It was assumed that the coal was trucked from Halifax.

In 2000 the Quinsam mine on Vancouver Island shipped coal by truck to port facilities in the Comox area where the coal was loaded on barges for shipment to end-use plants in the Lower Fraser Valley.

Also in British Columbia in 2000, the Bullmoose mine in the Northeast moved its coal by truck from the mine approximately 36 kilometers to the rail load-out.

2.4.3 Vessels, Ship and Barge, Transport

In 2000, all of the coal exported from Canada from the terminals listed in Section 2.3 was loaded into and transported by ship. Although it could not be confirmed at the time of writing, it was assumed that most of the coal imported into Canada in 2000 also arrived by ship, Section 2.2.

Other coal that is moved by water in Canada includes a quantity that is shipped by barge from Comox, BC. In the 1990s some of this coal was barged to Texada Island, BC for export. However, in 2000 the coal from Comox was reported as shipped by barge to local end-use facilities, likely cement plants, in the Lower Fraser Valley.

The coal from mines in BC and Alberta that arrives by rail at Thunder Bay is loaded into ships for transport to Ontario and to export.

Table 2.7 Coal Moved by Truck in Canada - 2000

Mine	Prov.	To		Distance km	millions of tonnes
Bullmoose	BC	Truck to Rail Load-out		36	1.60
Quinsam #	BC	Truck to Barge		50	0.24
Genesee *	Alta	Genesee Power Plant		10	3.60
Highvale **	Alta	Keephills Power Plant		10	3.63
Highvale **	Alta	Sundance Power Plant		10	9.37
Paintearth	Alta	Battle River Power Plant		5	3.50
Sheerness	Alta	Sheerness Power Plant		5	4.00
Whitewood *	Alta	Wabamun Power Plant		10	2.30
Boundary Dam/Shand **	Sask	Boundary Dam Power Plant		10	4.84
Boundary Dam/Shand **	Sask	Shand Power Plant		10	1.66
Bienfait #	Sask	Char Facility		5	0.20
Minto	NB	Grand Lake Power Plant		35	0.122
Minto#	NB	Belledune Power Plants		270	0.122
Alder Point #	NS	Domestic Coal Yard		40	0.06
Little Pond	NS	Lingan Power Plant		20	0.01
Springhill Project #	NS	Trenton Power Plant		100	0.01
St. Rose #	NS	Trenton Power Plant		200	0.03
Stellarton #	NS	Trenton Power Plant		10	0.20
Coalburn#	NS	Trenton Power Plant		20	0.03
Coal Imported by		**Landed at**	**For use by**		
NS Power Corp.#	NS	International Pier	Lingan & Pt Aconi	20	1.20
NS Power Corp.#	NS	Auld Cove	Trenton & P Tupper	100	0.85
Lafarge Canada#	NS	Halifax	Kilns at Brookfield	80	0.035
St. Mary's Cement#	Ont	Port Stanley, Ont.	St. Mary's Ont.	80	?

** prorated by Megawatts for Power Plant **# distances are approximations** *1999 data

The quantity of western coal shipped to Ontario Power Generation for use in their Power Plants was not available, but the quantities used by Dofasco and Stelco in their steel operations is shown in Table 2.8. (Selco 2001, Dofasco 2001)

Stelco received one trial shipment of coal from Western Canada in 2000. This coal arrived by ship from Thunder Bay. The company has planned for four such shipments, or approximately 94,000 tonnes, in 2001.

In 2000 Nova Scotia Power Corporation imported just over two million tonnes of coal. It arrived by ship at either the International Pier in Sydney or at Auld Cove in the Strait of Canso. (NS Power Corp, 2001) A small amount of coal was also imported by ship to Halifax for use by a private company near Brookfield. It was assumed that this coal was trucked from Halifax.

The data regarding the movement of coal by ship and barge in Canadian waters in 2000 was extremely limited. In regard to the emissions of fugitive coal dust, no information as to the nature of the shipments made by water was available. It was assumed that all coal shipped by powered vessels was in covered holds, therefore emissions while underway should be minimal. The only reported shipments by barge were from Vancouver Island to facilities in and around Vancouver. Whether the barges were covered or open was not reported. No attempt has been made to estimate emissions from ships or barges while underway.

Table 2.8 Coal Moved by Ship or Barge - 2000

Port Where Landed	Destination	Source	Port Shipped From	Quantity 2000 tonnes
Canadian Coal				
Hamilton, Ontario	Dofasco	Western Canada	Thunder Bay, Ont	200,000
Hamilton, Ontario	Stelco	Western Canada	Thunder Bay, Ont	94,000
Port Stanley, Ont	St. Mary's Cement	?	?	?
Ontario	?	Coal Mountain, BC	Thunder Bay, Ont	?
Ontario	?	Line Creek, BC	Thunder Bay, Ont	?
Texada, BC	by barge for export	Quinsam, BC	Comox, BC	0
Vancouver, BC	by barge	Quinsam, BC	Comox, BC	240,000
Imported Coal				
Internaional Pier, Sydney	Lingan & Point Aconi PPs	?	?	1,200,000
Auld Cove, S of Canso	Point Tupper & Trenton PPs	?	?	850000
Halifax, NS	Lafarge, Brookfield	?	?	35,000
Belledune, NB	Belledune PP	?	?	1,022,070
Sept. Isle, Quebec	Iron Ore Coy, Labrador City	?	?	49,471
Hamilton, Ontario	Dofasco	USA	?	1,500,000
Hamilton, Ontario	Stelco	USA	Toledo or Sandusky	1,026,660
Lake Erie, Ontario	Stelco	USA	Toledo or Sandusky	744,629
Sarnia, Ont	Ont Power Gen Lambton PP	USA	?	?
Nanticoke, Ont	Ont Power Gen Nanticoke PP	USA	?	?
Toronto, Ontario	Ont Power Gen Lakeview PP	USA	?	?

2.5 Storage Piles

At many junctures during the process that takes coal from mine face to end-use facility, coal will be stored. This storage may be long or short term. The coal may be stockpiled in the open or it may be housed in a containment structure.

In Western Canada it is not uncommon for mines to have rail load-out facilities that feature coal storage silos that can hold up to a full unit train load (over 10,000 tonnes of coal) or more. However, at end-use facilities and import/export terminals, because of the size of the operations, it is more common for coal to be stored in uncovered piles.

For this study, because of the limited data that were available, the discussion of dusting from storage piles in Canada must remain general. An attempt has been made to list the facilities in Canada in 2000 that were *likely* to have stored coal in piles (mines excluded), Table 2.9

Table 2.9 Major Coal Storage Sites in Canada – 2000

Port or End-Use Facility		Prov	Total Coal Throughput
Terminals			**tonnes**
Westshore, Roberts Bank		BC	22,500,000
Neptune, Vancouver		BC	4,962,000
Texada Island		BC	0
Ridley, Prince Rupert		BC**	6,000,000
Thunder Bay		Ont**	1,830,000
Landed at	**For**		
Hamilton	Dofasco	Ont	1,500,000
Hamilton	Stelco	Ont	1,026,660
Lake Erie	Stelco	Ont	744,629
Port Stanley		Ont	?
	St. Mary's Cement	Ont	?
Sept. Iles		Que	49,471
	Iron Ore Coy	Nfld	49,471
Montreal?		Que	731,000
	End Use for ?	Que**	731,000
Halifax		NS	35,000
	Lafarge Brookfield	NS	35,000
Comox		BC	240,000
	Cement Plants LFV	BC	240,000
Other Facilities			
Char Facility		Sask#	200,000
Domestic Coal Yard		NS	60,000

Port or End-Use Facility		Prov	Total Coal Throughput
Landed at	**For Power Plant**		
Sarnia	Lambton PP	Ont*#	3,421,680
Nanticoke	Power Plant	Ont*#	7,236,809
Toronto	Lakeview PP	Ont*#	1,243,452
Belledune	Power Plant	NB	1,143,570
International Pier, CB		NS	1,200,000
	NS Power Corp	NS	1,200,000
Auld Cove		NS	850,000
	NS Power Corp	NS	850,000
Other Power Plants			**tonnes**
Genesee Power Plant		Alta**	3,600,000
Sundance Power Plant		Alta#	9,368,344
Keephills Power Plant		Alta#	3,631,656
Battle River Power Plant		Alta	3,500,000
Sheerness Power Plant		Alta	4,000,000
Wabamun Power Plant		Alta**	2,300,000
Selkirk Power Plant		Man	276,483
Brandon Power Plant		Man	275,930
Grand Lake Power Plant		NB	121,500
Lingan Power Plant		NS	1,670,000
Trenton Power Plant		NS	820,000
Point Aconi Power Plant		NS	385,000
Point Tupper Power Plant		NS	425,000
Thunder Bay Power Plant		Ont*#	624,197
Atikokan Power Plant		Ont*#	423,861
Boundary Dam Power Plant		Sask#	4,840,426
Shand Power Plant		Sask#	1,659,574
Poplar River Power Plant		Sask#	4,000,000

* 1998 data ** 1999 data # prorated by megawatts

2.6 End-Use Facilities

Many of the 'end-use' facilities for coal in Canada in 2000 are also as listed in Table 2.9. While there were more small users in each province, the facilities listed are those that account for the bulk of the coal consumed in Canada in 2000.

In 2000, fugitive coal dust emissions at end-use facilities were likely associated with the unloading and movement of coal to and from storage piles located at or near the facilities.

Chapter 3
Estimating Fugitive Coal Dust Emissions

As noted earlier, fugitive coal dust emissions cannot be readily measured and must be estimated. In general, because of the widespread nature of most coal operations, they are usually treated as *Area Sources* for the purpose of estimating emissions. Area Sources are defined as: *Activities or sources of emissions that are too numerous or too small to be accounted for on an individual basis.* (Deslauriers 1999) Therefore, federal and provincial environment agencies and the coal industry must rely on general emission estimates for evaluating the impact of windblown fugitive coal dust.

There are many variables that can affect fugitive coal dust emissions, and hence emission estimates. Since these parameters can vary from site to site and from case to case, it is difficult to accurately estimate fugitive emissions. In general, collective averages must be employed. Unfortunately, under most circumstances, combining generalized emission factors (EFs) with generalized activity data is the only method that is available for estimating fugitive coal dust emissions.

Historically, fugitive coal dust emissions for each coal industry sector or operation are estimated by combining the quantity of coal mined, handled or shipped with the frequency of the activity or operation. The general equation for estimating uncontrolled fugitive coal dust emissions is:

$$\textit{Uncontrolled Emissions} = \textit{EF} \times \textit{Quantity of Coal} \times \textit{Activity Factor} \quad (3.1)$$

Where:

EF = the emission factor for the activity in kg/tonne of coal
Quantity of Coal = the quantity in tonnes that is mined or moved
Activity Factor = the number of times (or duration or distance) the activity takes place in a year

To account for the impact of emissions controls modify equation 3.1 by applying a percentage related to control efficiency:

$$\textit{Controlled Emissions} = \textit{EF} \times \textit{Quantity of Coal} \times \textit{Activity Factor} \times (100 - \textit{Control Efficiency})/100 \quad (3.2)$$

Where:

Control Efficiency = the % efficacy of the control
i.e. if the Control Efficiency is 99% enter 99 in the formula.

3.1 Federal - Provincial Estimates for Fugitive Coal Dust Emissions

The Canadian Emissions Inventory of Criteria Air Contaminants (CAC Inventory) is published every five years by Environment Canada. (Deslauriers 1995, 1999) That inventory attempts to draw together data from across the country on the emissions of Particulate Matter, Sulphur Oxides, Oxides of Nitrogen, Carbon Monoxide and Volatile Organic Compounds. The CAC Inventory collects information from each province and territory to assemble its emissions estimates.

For particulate emissions until the 1990 inventory, only emissions of Total Particulate Matter (TPM) were reported. For the 1995 and future inventories, emissions of PM_{10} and $PM_{2.5}$ have been added to the TPM emission estimates.

The emission factors and formulas employed in the CAC Inventory to estimate fugitive coal dust emissions are described in the *1995 Criteria Contaminants Emissions Inventory Guidebook*, section 1.9.1 Industrial Sector: Coal Mining and Processing. (NEIPTG 1999)

For computing emission estimates PM_{10} and $PM_{2.5}$, Environment Canada, the provinces and the United States Environmental Protection Agency (EPA) apply scaling factors to the emission factors developed for estimating total particulate matter or PART. Emissions of PM_{10} and $PM_{2.5}$ are calculated by multiplying the appropriate scaling factor by either the EFs or the calculated emissions.

In general, the techniques used by Environment Canada, and the provinces to estimate fugitive coal dust emissions do not differ. The one exception is in British Columbia where officials used a different EF for estimating emissions for the rail transport of coal. Therefore, for the 1995 CAC Inventory, *coal dusting from unit trains* was the only sector where a province used a fugitive coal dust emission factor and technique that was different from the one used by Environment Canada. (See Chapter 5)

The techniques for estimating fugitive coal dust emissions for the coal industry from coal mine to end-user are discussed in the ensuing chapters. In general, unless it was discovered that there were problems in relation to the techniques employed for the *1995 CAC Inventory* estimates, those methods were used in this report. (Deslauriers 1999)

3.2 Parameters Affecting Emissions and Control

As noted, because of their fugitive or unconfined nature, it is difficult to predict or estimate the severity of coal dust emissions from any source. The factors that may affect fugitive coal dust emissions regardless of source include:

- type of coal
- coal fines content
- coal moisture content
- frequency of activity or frequency of disturbance of the coal
- surface area exposed
- ambient conditions: precipitation, wind speed, heat, freezing

3.2.1 Weather

As noted, one of the factors that will have an effect on fugitive coal dusting is the local ambient weather. The factors likely to have the most influence on fugitive dusting are precipitation, maximum temperature and wind speed and direction.

In general, most fugitive dusting complaints in regard to nuisance soiling, regardless of source, have been associated with periods of high temperature, high wind and little or no precipitation. For coal carried by rail over long distances in open rail cars in unit trains, it is not just the local weather at the time of emissions that can influence the severity of the dust emissions episodes. Hot and dry weather 'up route' of the emissions can influence the emissions at the point of observation. See discussion Section 5.2.3.1.

Chapter 4
Coal Mining - Fugitive Coal Dust Emission and Control

4.1 Coal Mining

The mining of coal comprises a number of activities depending upon mine type. In 2000 in Canada, there were three types of coal mines: underground, open pit and strip mines.

4.1.1 Underground Coal Mines

As noted in Chapter 2, in Canada in 2000 there were two underground coal-mining operations, accounted for in the information available on coal mines, plus a third that combined an underground mine with an open pit mine. (Table 2.1)

Underground mines by their nature will emit far less fugitive dust, above ground, into the local ambient environment than surface mines of a similar productivity. In this report, when estimating emissions for the two underground operations in 2000, dust emissions were only calculated for surface unloading activities.

4.1.2 Surface Coal Mines

As noted in Chapter 2, there were two general types of surface coal mine in operation in Canada in 2000, *Open Pit Mines* and *Strip Mines*. For surface and open pit mines, fugitive coal dust can be generated in connection with any one of the following operations:

- Overburden Removal and Replacement
- Drilling and Blasting
- Dragline or Bulldozer Operation
- Loading and Unloading
- Transfers Mine to and from Process Plant

The drilling and blasting may be associated with both the overburden removal operation or to the actual mining of the coal seam. The overburden, the earth or rock covering the coal seam must be broken up and moved to another site. This may be accomplished using bulldozers, shovels, mobile loaders and trucks and/or by a dragline.

Once the overburden has been removed, the coal must be moved from the mine face to the processing plant. This may be achieved by number of means that may include loaders, draglines, trucks, and/or conveyor systems. Coal dust will be become airborne and fugitive emissions will result as a result of any one of these repetitive operations.

For air pollution inventory purposes, it is virtually impossible to account for every one of these operations at every mine in each province. Therefore, the norm is for activities to be grouped together. An attempt is then made to present emission factors for each of the groups of activities in terms of the total coal mined each year, Section 4.2.

4.1.3 Process Plant Emissions

Most coal undergoes some level of processing after it is mined and before it is shipped to the end-user. The processing required may be a relatively simply operation that involves the crushing or breaking of the coal into a size that can be used by an end-user. However, many operations in Western Canada use more sophisticated processing. The processing of coal often involves a complex series of steps that may include sizing, washing, cleaning and sometimes drying operations. These operations usually take place in a coal cleaning or processing building. The extent to which different shipments of coal from the same mine are processed can also vary depending upon the requirements of the end-user or customer.

While coal dust may become wind borne as a result of coal-cleaning and processing operations, these emissions cannot truly be described as 'fugitive'. The processing operations at the majority of mines in western Canada normally take place in enclosed structures. These operations usually require emission controls that are covered under provincial permits and emissions will be regulated accordingly. This is particularly true for operations that require coal to be processed and thermally dried.

Emissions related to *Coal Processing* plants are not included in this report because:

1. They are "processing plants" and not an open wind-blown fugitive dust sources,
2. They are contained in structures with sophisticated emissions controls,
3. The emissions and their control should be known and covered by provincial permits,
4. Loading to and from the plants is covered under general mining fugitive emissions, and
5. Virtually all of their fugitive dust emissions are likely confined to mine property.

Not including possible fugitive emissions related to *Coal Processing* is supported by the control efficiencies listed in the *Air and Waste Management Association* (AWMA) manual. The manual lists the control efficiency for coal cleaning as 100%. Therefore, for most of the large coal mining operations in Western Canada, the fugitive dust emissions from Coal Processing would be close to zero. (AWMA 2000)

The dusting associated with coal loading and unloading from process plants is considered to be included under the loading and unloading operations associated with coal mining, Table 4.1. Other coal emissions associated with *Coal Processing* or coal-cleaning are considered beyond the scope of this report and have not been estimated.

4.2 Emission factors - Coal Mines

For emission inventory purposes, provincial and federal governments estimate fugitive dust emissions from mining operations, using the emission factors (EFs) shown in Table 4.1. The NEIPTG Guidebook states that these emission factors were "taken from section 11.9 of AP-42 5th edition (U.S. EPA 1995), and from factors used in previous Environment Canada inventories". (NEIPTG 1999)

The PM_{10} and $PM_{2.5}$ emission factors were derived using data from the EPA SPECIATE software. The scaling factors used for the CAC Inventory 1995 emissions estimates were:

$$PM_{10} = 0.545 \times PART$$

$$PM_{2.5} = 0.33 \times PART$$

Where: PART is the EF for total particulate matter (TPM).

Obviously, the emission factors in Table 4.1 are the generalized EFs that are used to estimate emissions for *Area Sources* in emissions inventories. Their strength is that they allow universal application to any coal mining operation for which yearly quantity of coal mined is know. They can be applied to individual mines or to total provincial production data.

The weakness of the emission factors shown in Table 4.1 is that, other than in a general way, they do not account for individual coal mining operations and the specific parameters at those mines that can influence fugitive coal dust emissions.

Table 4.1 CAC 1995 Inventory Coal Mining – Uncontrolled Emission Factors

Coal Mining Emission Factors	PART	PM_{10}	$PM_{2.5}$
	kg/tonne	kg/tonne	kg/tonne
Mining	0.0130	0.0071	0.0043
Raw Coal Loading – mine	0.0200	0.0109	0.0066
Raw Coal Unloading - mine	0.0330	0.0180	0.0109
Overburden Removal	0.0060	0.0033*	0.00198*
Pile Wind Erosion (t/ha)	0.85		

* Correction made for scaling factor PART = total particulate

The NEIPTG Guidebook (NEIPTG 1999) does not mention dust control techniques or efficiency of dust suppression methods in connection with the coal mining EFs. Therefore, it is assumed that the emission factors and the resulting estimates are for uncontrolled emissions.

As illustrated in Table 4.2, the information presented by the US EPA in the latest version of Table 11.9-2 of AP-42 contains more complicated EFs for coal mining than are currently employed for computing provincial and national emissions for the 1995 CAC Inventory. The EFs in Table 4.2 are clearly labeled by the EPA as uncontrolled emission factors. (EPA 2001-2) However, although these EFs may produce more accurate emission estimates for coal mining, they are intended for application to individual mines where the factors that may influence emissions are known for specific operations.

While data related to these parameters could be obtained for individual Canadian mines, such information is not readily available and is not public knowledge. Considerable resources would be required to assess and report on individual coal mining operations.

The influence of weather on coal mining emissions is also not included or accounted for by the EFs in either Table 4.1 or 4.2. Heavy precipitation and snow cover will likely limit fugitive dust emissions by inhibiting the wind entrainment of coal dust. Since weather conditions and their influence on coal dusting may vary on a day to day or week to week basis, detailed weather recording would be required at or near mine sites in order to judge the influence of local weather on fugitive dusting. A discussion of the potential influence of weather on fugitive coal dust emissions is presented in Section 5.2.3.1.

For this study, the EFs used to compile the 1995 CAC Inventory were used to compute fugitive coal dust emissions for coal mining, Section 4.4.

Table 4.2 US EPA AP-42 Table

(Table 11.9-2 EPA 2001-2)

EMISSION FACTOR EQUATIONS FOR UNCONTROLLED OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES

		Emissions By Particle Size Range (Aerodynamic Diameter)[b,c]				
		Emission Factor Equations		Scaling Factors		
Operation	Material	TSP <30 μm	<15 μm	<10 μm[d]	<2.5 μm/TSP[e]	Units
Blasting f	Coal or Overburden	$0.00022(A)^{1.5}$	ND	0.52[e]	0.03	kg/blast
Truck loading	Coal	$0.580/(M)^{1.2}$	$0.0596/(M)^{0.9}$	0.75	0.019	kg/Mg
Bulldozing	Coal	$35.6\ (s)^{1.2}/(M)^{1.4}$	$8.44\ (s)^{1.5}/(M)^{1.4}$	0.75	0.022	kg/hr
	Overburden	$2.6\ (s)^{1.2}/(M)^{1.3}$	$0.45\ (s)^{1.5}/(M)^{1.4}$	0.75	0.105	kg/hr
Dragline	Overburden	$0.0046\ (d)^{1.1}/(M)^{0.3}$	$0.0029\ (d)^{0.7}/(M)^{0.3}$	0.75	0.017	kg/m 3
Vehicle traffic[g] Grading		$0.0034\ (S)^{2.5}$	$0.0056\ (S)^{2.0}$	0.6	0.031	kg/VKT
Active storage pile[h] (wind erosion and maintenance)	Coal	1.8 u	ND	ND	ND	kg/(hectare)(hr)

Note all symbols < should be < or equal to

VKT = vehicle kilometers traveled. ND = no data. b Particulate matter less than or equal to 30 μm in aerodynamic diameter is sometimes termed "suspendable particulate" and is often used as a surrogate for TSP (total suspended particulate). TSP denotes what is measured by a standard high volume sampler.
c Symbols for equations:
A = horizontal area (m^2), with blasting depth < 21 m. Not for vertical face of a bench.
M = material moisture content (%)
s = material silt content (%)
u = wind speed (m/sec)
d = drop height (m)
W = mean vehicle weight (Mg)
w = mean number of wheels
d Multiply the < 15-μm equation by this fraction to determine emissions, except as noted.
e Multiply the TSP predictive equation by this fraction to determine emissions.
f Blasting factor taken from a reexamination of field test data.
g To estimate emissions from traffic on unpaved surfaces by vehicles such as haul trucks, light-to-medium duty vehicles, or scrapers in the travel mode, see the unpaved road emission factor equation in AP-42 Section 13.2.2

4.3 Fugitive Dust Control - Coal Mines

In general, fugitive dust control at an underground coal mine is more of an occupational health issue for workers than it is an environmental issue. It is therefore beyond the scope of this investigation. However, for surface mining activities coal dust control may include one or more of the following (Note, rail transport fugitive dust control measures at coal mines are addressed separately in Chapter 5.):

- water sprays at appropriate locations
- water and sealant sprays on roads
- covered conveyor systems
- enclosed crushing, cleaning and processing operations
- cyclones and scrubbers at cleaning plants and transfer points
- enclosed or covered storage piles
- enclosed rail load-out facilities

As noted, the emission factors in the NEIPTG Guidebook (NEIPTG 1999) were used to compute fugitive coal dust emissions related to Canadian coal mining operations in 2000. Since no mention is made in that publication as to dust control techniques or efficiency of dust suppression methods, it is assumed that the emission factors and the resulting estimates are for uncontrolled emissions.

If the control efficiency of specific dust control features at specific mines is known, then the EFs could be modified as illustrated in equation 3.2, Chapter 3.

4.4 Emissions Estimates - Coal Mines

As noted, the CAC Inventory methodology as described in the NEIPTG Guidebook (NEIPTG 1999) was used to compute the fugitive coal dust emissions related to Canadian coal mining operations in 2000. As noted above, it is assumed that the emission factors from the NEIPTG Guidebook, Table 4.1, and the resulting estimates are for uncontrolled fugitive coal dust emissions.

The production data for most mines was available for 2000. However, for a number, 1999 data were used. It was felt that for most of these the changes from 1999 to 2000 were likely minor.

For this report, for the coal mining emissions estimates, the following changes were made to the CAC Inventory data and methodology:

- The Quinsam mine in BC is now an underground mine. Formerly it was an open pit surface mine.
- For the coal mining Emission Factors Table 1.9.1 in the Guidebook there appears to be an error in scaled EFs for PM_{10} and $PM_{2.5}$ in Overburden Removal. Using the $PM_{10} = 0.545 \times PART$ and .5 $PM_{2.5} = 0.33 \times PART$ the EF for PM_{10} should be 0.0033 not 0.0031 and $PM_{2.5}$ should be 0.00198 and not 0.0009. The changes were made and the EFs shown in Table 4.1 were used.

Only the 'unloading' segment of surface mining operations group of activities was used to make emissions calculations for the two underground mines in 2000. (Table 4.1)

The uncontrolled fugitive coal dust emissions estimates calculated for Canadian coal mines for 2000 are presented in Table 4.3. Because no data were available related to the size of the storage piles at individual mines, storage pile emissions at mines were not estimated. The sources used for the mine related data used in the calculations are listed in Appendix C.

4.5 Discussion – Fugitive Coal Dust from Coal Mining Operations

The EFs currently used to calculate fugitive coal dust emissions for coal mining operations are well suited for producing general provincial or national estimates. However, it must be recognized that they have their limitations in regard to accuracy in estimating emissions from individual mines. If an agency wishes to obtain more accurate estimates of emissions for a particular mine, it is suggested that the more detailed EFs that are contained in the EPA's AP-42 could be used. However, in order to apply these EFs individual day-to-day operations at a particular mine would have to be recorded for a significant period in order to develop acceptable average or mean values.

For example, to apply the EFs in Table 4.2, one would have to know details such as: the number of blasts per day, the hours that bulldozers were used, the dragline drop heights, the kilometers and trips made by trucks and graders plus the size of storage piles. This information would then be combined with the silt and moisture content of the coal.

Of importance for inventory consideration is the location of most mines in Canada. Most are situated in isolated areas away from populated urban centres. Therefore, it is suggested that for their inventories, agencies may wish to segregate PM_{10} and $PM_{2.5}$ emissions from coal mining from PM_{10} and $PM_{2.5}$ emissions estimates for the other sources that are located in and around urban population centres.

Cautionary notes regarding the emissions estimates in Table 4.3:

- The 'overburden' emissions estimates are likely to include non-coal dust.
- These annual emissions estimates do not account for the likely mitigating effect on fugitive emissions of localized precipitation.
- The emission factors that were used are general averages and therefore the uncertainties associated with the emissions estimates are likely to be high.

Table 4.3 Uncontrolled Fugitive Coal Dust Estimates for Coal Mining Operations for 2000 (Emissions in tonnes)

Use CAC EFs	Prov	Gross#	PART	PM_{10}	$PM_{2.5}$	PART	PM_{10}	$PM_{2.5}$	PART	PM_{10}	$PM_{2.5}$	PART	PM_{10}	$PM_{2.5}$	PART	PM_{10}	$PM_{2.5}$
Mines		**Mt**	**Mining**	**Mining**	**Mining**	Loading	Loading	Loading	**Unload**	**Unload**	**Unload**	OverB	OverB	OverB	**Total**	**Total**	**Total**
Bullmoose	**BC**	2.30	29.9	16.3	9.9	46.0	25.1	15.2	75.9	41.4	25.0	13.8	7.5	4.6	165.6	90.3	54.6
Coal Mountain	**BC**	3.37	43.9	23.9	14.5	67.5	36.8	22.3	111.3	60.7	36.7	20.2	11.0	6.7	242.9	132.4	80.2
Elkview (Balmer)	**BC**	5.14	66.9	36.4	22.1	102.9	56.1	33.9	169.7	92.5	56.0	30.9	16.8	10.2	370.3	201.8	122.2
Fording River	**BC***	12.93	168.0	91.6	55.5	258.5	140.9	85.3	426.6	232.5	140.8	77.6	42.3	25.6	930.7	507.2	307.1
Greenhills	**BC***	5.36	69.7	38.0	23.0	107.2	58.4	35.4	176.8	96.4	58.4	32.2	17.5	10.6	385.8	210.3	127.3
Line Creek	**BC**	4.90	63.7	34.7	21.0	98.0	53.4	32.3	161.7	88.1	53.4	29.4	16.0	9.7	352.8	192.3	116.4
Quintette	**BC**	2.09	27.1	14.8	9.0	41.7	22.7	13.8	68.9	37.5	22.7	12.5	6.8	4.1	150.3	81.9	49.6
Quinsam (UG mine)	**BC**	0.24	**			**			7.9	4.3	2.4	**			7.9	4.3	2.4
Coal Valley	**Alta**	1.84	23.9	13.1	7.9	36.8	20.1	12.2	60.8	33.1	20.1	11.1	6.0	3.6	132.6	72.3	43.8
Genesee	**Alta***	4.32	56.2	30.6	18.5	86.4	47.1	28.5	142.6	77.7	47.0	25.9	14.1	8.6	311.0	169.5	102.6
Gregg River	**Alta**	2.98	38.8	21.1	12.8	59.7	32.5	19.7	98.5	53.7	32.5	17.9	9.8	5.9	214.9	117.1	70.9
Luscar	**Alta**	3.41	44.3	24.2	14.6	68.2	37.2	22.5	112.5	61.3	37.1	20.5	11.1	6.7	245.4	133.8	81.0
Highvale	**Alta**	13.22	171.9	93.7	56.7	264.4	144.1	87.3	436.3	237.8	144.0	79.3	43.2	26.2	952.0	518.8	314.2
Obed	**Alta**	3.78	49.1	26.8	16.2	75.6	41.2	24.9	124.7	68.0	41.2	22.7	12.4	7.5	272.2	148.3	89.8
Paintearth (+Vesta)	**Alta**	3.50	45.5	24.8	15.0	70.0	38.2	23.1	115.5	62.9	38.1	21.0	11.4	6.9	252.0	137.3	83.2
Sheerness (+ Montgomery)	**Alta**	4.00	52.0	28.3	17.2	80.0	43.6	26.4	132.0	71.9	43.6	24.0	13.1	7.9	288.0	157.0	95.0
Smoky River (UG & OP mine)	**Alta***	1.97	25.6	14.0	8.5	39.4	21.5	13.0	65.0	35.4	21.5	11.8	6.4	3.9	141.8	77.3	46.8
Whitewood	**Alta***	2.39	31.0	16.9	10.2	47.7	26.0	15.7	78.7	42.9	26.0	14.3	7.8	4.7	171.7	93.6	56.7
Bienfait	**Sask**	2.00	26.0	14.2	8.6	40.0	21.8	13.2	66.0	36.0	21.8	12.0	6.5	4.0	144.0	78.5	47.5
Boundary Dam/Shand (Utility)	**Sask**	6.50	84.5	46.1	27.9	130.0	70.9	42.9	214.5	116.9	70.8	39.0	21.3	12.9	468.0	255.1	154.4
Costello	**Sask**	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poplar River	**Sask**	4.00	52.0	28.3	17.2	80.0	43.6	26.4	132.0	71.9	43.6	24.0	13.1	7.9	288.0	157.0	95.0
Minto	**NB**	0.24	3.2	1.7	1.0	4.9	2.6	1.6	8.0	4.4	2.6	1.5	0.8	0.5	17.5	9.5	5.8
Prince (UG mine)	**NS**	1.15	**			**			38.0	20.7	12.5	**			38.0	20.7	12.5
Alder Point	**NS**	0.06	0.8	0.4	0.3	1.2	0.7	0.4	2.0	1.1	0.7	0.4	0.2	0.1	4.3	2.4	1.4
Coalburn	**NS**	0.03	0.3	0.2	0.1	0.5	0.3	0.2	0.9	0.5	0.3	0.2	0.1	0.1	1.9	1.0	0.6
Little Pond	**NS**	0.01	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.5	0.3	0.2
Springhill Rail Bed	**NS**	0.01	0.1	0.1	0.0	0.2	0.1	0.1	0.3	0.2	0.1	0.1	0.0	0.0	0.7	0.4	0.2
St. Rose	**NS**	0.03	0.4	0.2	0.1	0.7	0.4	0.2	1.1	0.6	0.4	0.2	0.1	0.1	2.4	1.3	0.8
Stellarton	**NS**	0.20	2.6	1.4	0.9	4.0	2.2	1.3	6.6	3.6	2.2	1.2	0.7	0.4	14.4	7.8	4.8
Total Canada		90.03	1152.3	628.0	380.2	1772.7	966.1	585.0	2970.9	1619.2	980.2	531.8	289.8	175.5	6427.8	3503.1	2120.9

* Used 1999 data ** underground mine #Gross mining production is prorated from marketable coal data UG – Underground mine OP – Open Pit mine Mt = 10^6 tonnes

Chapter 5

Rail Transport
Fugitive Coal Dust Emission and Control

5.1 Rail Transport

As noted in Chapter 1, the shipment of coal by unit coal train in Canada can result in fugitive coal dust emissions en route. Portions of these emissions are likely to be in the PM_{10} and $PM_{2.5}$ range and may contribute to local airshed loadings in the population centres through which the trains transit.

The fugitive coal dust emissions from loaded coal cars can be controlled. The current practice at most of the mines in Alberta and British Columbia, that ship coal by rail over long distances, is to spray the surfaces of the coal load in each car with sealant spray to attempt to control fugitive dusting. (Appendix B)

Coal remaining in 'empty' cars can also contribute to coal dust emissions en route. Coal left in rail cars that are not fully dumped at the end terminals (or that is frozen in the bottom of cars) can be a source of coal dust on the route back to the mine. (Wituschek 86) In British Columbia in 2000, on more than one occasion, 'empty' rail cars in unit trains returning to mines were reported as being sources of heavy fugitive dusting.

5.2 Emission Factors – Rail Transport

As noted, one of the main objectives of this investigation is to attempt to improve fugitive coal dust emissions estimates for coal carried in unit coal trains. However, it is particularly difficult to estimate emissions from an open-top rail car. The additional variables that can effect the emission rate include: (Cope 1986)

Easily measured parameters

- rail car dimensions
- route length
- coal moisture content at start of journey
- coal surface coated at the start of the journey
- the sealant crust remaining at the end of the journey

Less easily measured parameters

- total surface area of coal load each car
- train speed at all points en route
- total surface covered each car en route
- jostling of load and crust on route
- ambient conditions on route: wind speed and direction, precipitation
- the proportion of coal lost at each stage of a journey

Regardless, even if available, it is difficult to incorporate these factors into a readily useable emission factor (EF). (See Section 5.2)

One focus of this study is to quantify fugitive coal dust blown from the unit coal trains that travel through British Columbia on their way to export terminals on the West Coast of Canada. One of the principal objectives was to search for new and/or improved emission factors (EFs) for the transport of coal by rail in Canada with particular emphasis on the EFs for the emissions of PM_{10} and $PM_{2.5}$.

> *Note that unless specific reference is made to 'empty' coal cars, the discussion of EFs related to rail in this report is in reference to 'loaded' rail cars. Empty cars are discussed briefly in Section 5.2.4.2.*

Investigations into fugitive coal dust EFs in the early 1980s found that several researchers had estimated *uncontrolled* emission factors for total particulate matter for coal shipped by unit train. The papers cited in the 1986 Environment Canada report were:

- *In Transit Control of Coal Dust from Unit Trains*, Fisheries and Environment Canada, Technology Development Report, Guarnaschelli, C., EPS-4-PR-&&-1, May 1977;
- *A Study of Coal Dust Contamination of Canadian Cellulose's Watson Island (Prince Rupert) Pulp Mill for the Operation of a Coal Terminal on Ridley Island and Coal Unit Train Access and Egress to the Proposed Terminal*, Beak Consultants, Hardy Associates (1978), Sandwell and Company, Swan Wooster Engineering Company, September 1980; and
- *In-transit Wind Erosion Losses of Coal and Method of Control*, Mining Engineering, USA publication, Nimerick, K.H., and Laflin, G.P., August 1979.

The data presented by these three research teams provided the best information available at the time regarding EFs for unit trains. The conclusion was that: (Cope 1986)

> *When no coal dust control measures were employed, the maximum potential coal losses (for a one way trip of approximately 1100 km over rough terrain during dry conditions through British Columbia to Vancouver) are estimated to be in a range from 0.5% and 3.0 % of the total coal load.*

The distance of 1100 km was chosen as the reference scenario, since it represents the approximate distance over which most mines on the BC/Alberta border must ship to reach coal terminals in Vancouver, Table 5.1.

In conjunction with the field studies in the early 1980s, by Environment Canada and the province of British Columbia, a series of controlled, wind tunnel experiments were funded in an attempt to derive an emission factor for coal train dusting. The data from those experiments revealed: (MH 1983)

> *A range of uncontrolled emission factors that falls within 0.008 kg/t-km to 0.016 kg/t-km (or 0.9% to 1.76% of the total coal load for a distance of 1 100 km) determined by wind tunnel studies in 1983.*

This range for experimental EFs falls within the 0.5% to 3.0% of load that were developed by the earlier researchers.

Since no measured emissions data are available, the provincial and federal governments use emission factors to estimate the total quantity of coal dust emitted by loaded rail cars in Canada. Environment Canada used the EF discussed in Section 5.2.1 to estimate fugitive dusting from coal trains for their last published, 1995, Criteria Air Contaminants (CAC) Inventory. (Deslauriers1999)

Of the provinces and territories, only British Columbia employed an EF that differed from the one used by Environment Canada, Section 5.2.2. A comparison of EFs used for estimating fugitive dust emissions is presented in Table 5.2.

Table 5.1 Approximate Rail Distances for Coal Transport in Canada

Province	Destination	Total Distance
Mines		km
British Columbia		
Bullmoose*	Ridley Island, BC	1180
Coal Mountain*	Thunder Bay, Ontario	2073
Coal Mountain*	Vancouver	1141
Elkview (Balmer)*	Vancouver	1055
Fording River*	Vancouver	1169
Greenhills*	Vancouver	989
Line Creek	Vancouver	1141
Line Creek	Thunder Bay, Ontario	2102
Quintette*	Ridley Island, BC	1250
Alberta		
Coal Valley	Vancouver	1093
Coal Valley	Ridley Island, BC	1381
Coal Valley	Thunder Bay, Ontario	2282
Gregg River	Vancouver	1114
Gregg River	Ridley Island, BC	1408
Gregg River	Thunder Bay, Ontario	2309
Luscar	Vancouver	1108
Luscar	Ridley Island, BC	1404
Luscar	Thunder Bay, Ontario	2305
Obed	Vancouver	958
Obed	Ridley Island, BC	1257
Obed	Thunder Bay, Ontario	2264
Smoky River*	Alberta	1180
Saskatchewan		
Bienfait*	Sask.	58
Bienfait*	Ridley Island, BC	1180
Poplar River*	Sask	20
Nova Scotia		
Prince*	NS	8
Import		
Nfld Import*	Labrador	350

* Indicates estimated distance, other distances from company supplied information.

5.2.1 CAC Inventory Emission Factors

The NEIPTG Guidebook contains a description of the method used by Environment Canada to compile rail coal dust emissions in the 1995 CAC Inventory: (NEIPTG 1999)

> *For coal transportation, emission factors were derived from the quantities of coal transported by rail, the distance traveled on the railroad and the type of containment of the coal (control, closed environment, covered wagon, etc.). Provincial average emission factors were based on the following formula:*

$$EF = 0.1*(0.62*D)^{0.6} \qquad (5.1)$$

Where: EF = the emission factor in kg/tonne of coal transported and
D = the distance travelled by rail cars (km).

The original formula as published in 1991 was $EF = 0.1*(miles)^{0.6}$ kg/tonne. The 0.62 factor was added to allow the distance D to be entered in kilometres and not miles. Equation 5.1 represents a metric conversion of the original formula as published in the:

> *Methods Manual for Estimating Emissions of Common Air Contaminants in Canada*, ORTECH International for Environment Canada, May 1991.

The original formula was developed by SNC/GECO and ORF in 1981. It was designed to allow a distance factor to be incorporated into the basic emission loss equation of 0.1 kg/tonne. The reference is: *A Nationwide Inventory of Antropogenic Sources and Emissions of Primary Fine Particulate Matter*, SNC/GECO Canada Inc. and Ontario Research Foundation, Prepared for Environment Canada, 1981.

As noted in Section 5.2, from the findings of several researchers, the maximum uncontrolled emissions for coal carried at least 1100 km over rough terrain is 0.5% of the load of 100 tonnes or 500kg per car. This factor is the conservative end of the range of emission factors that was derived in three separate studies. Therefore, the 0.1 kg/tonne EF represents a control level of approximately 98%.

However, the Guidebook also claims that the EF in equation 5.1 is not the 'uncontrolled' EF for loaded cars: (NEIPTG 1999)

> *This formula was developed assuming a 75 % particulate control. Assuming that the formula is linear with respect to percent control of particulate and that the percent control in Canada is actually 99 % for rail transport of coal, the formula was adjusted to become:*

$$\text{EF for total particulate PART} = 0.1*(0.62*D)^{0.6} * ((100-99)/(100-75)) \qquad (5.2)$$

> *The provincial average emission factors were calculated using the amount of coal transported by rail, the origin and destination of this coal and the distance of the specific rail destination.*

For over 20 years, for sprayed coal loads in trains, the total crust-retention on loaded rail cars at the end terminals, after a long journey, has been used as a measure of dust control. Therefore, although empirical evidence is limited, the references to the amount of dust control may relate to the quantity of sealant crust-retention at the end terminals. However, to date, such an assumption is not supported by measured data that can establish a one-to-one direct link between crust-retention and dust control percentage. (Section 5.3.2.1)

Therefore, 75% control in the formula may relate to 75% crust-retention at the end terminal. However, the accepted minimum level for dust control, since 1975, has been 85% crust-retention. Lacking empirical evidence to the contrary, the NEIPTG Guidebook may have erred on the side of caution and used a dust control effectiveness of 99%.

Reflecting upon the origins of the CAC EF, and the data behind its creation, it is felt that the following may apply in regard to dust control efficiency for unit coal trains:

- As illustrated in Table 5.2, the basic CAC EF, equation 5.1, appears to correlate to the basic uncontrolled EF of 0.5% of the coal load over a distance of 1100 km; and
- Therefore, contrary to what is stated in the Guidebook, the basic EF, equation 5.1, may be the *uncontrolled* EF for coal dust emission and not the EF at the 75% control point.

Support for accepting the basic CAC EF as the uncontrolled EF comes from recent emissions measurement work preformed for the Norfolk Southern railway. The group that performs the ongoing measurements for the Norfolk Southern considers a loaded coal car with a crust-retention of less than 80% to be an uncontrolled car in regard to its potential for fugitive dust emissions. Therefore, one could assume that an EF based on a 75% crust-retention would be the uncontrolled EF. (SWA 2001)

The contention that the CAC EF represents an uncontrolled EF of 0.5% of the load also seems to be supported by the EF comparison data presented in Table 5.2. For various assumed EFs, the calculations in Table 5.2 attempt to estimate coal dust emissions for a rail car carrying 100 tonnes of coal travelling 1100 km ($\approx$ 700 miles) from a mine to a coal terminal. These are the same parameters that were used for illustration purposes in the 1986 Environment Canada background report on rail car dusting. (Cope 1986)

Scenario #1 in Table 5.2 illustrates the estimated emissions if the CAC EF is assumed to be the uncontrolled EF. The resulting emissions of 0.5015% of the load is strikingly similar to the 0.5% of the load, or the uncontrolled EF used by the BC MELP.

Scenario #4c in Table 5.2 illustrates the estimated emissions if the dust control efficiency is assumed to be 85%. The resulting EF of 0.0752% is again almost the same as the 0.075% employed to produce example calculations for the Environment Canada background report in 1986. Those calculations also assumed 85% control. (Cope 1986)

The difference between the simple 0.5% of the load EF and the EF produced by the CAC equation 5.1 appears to be the slight variation created by the non-linear function represented by equation 5.1.

Regardless, the basic formula used for the CAC inventory calculations is flawed in that it does not take into account the following:

- The moisture content of the coal;
- The wind and/or train speeds;
- The different between coal types with different fines content; and
- The dust control created by precipitation en route.

Moisture Content:

While moisture content is not factored into the equation, it may not vary significantly for a particular mine. If moisture content is felt to be critical, then it could be monitored by mine on yearly basis. The EFs used could then be adjusted by adjusting the overall emission control factor by mine.

Wind Speed:

The combined wind-over velocity that results from ambient wind and train speed is not used as a variable in equation 5.1. However, it may be sufficient to acknowledge that for most train journeys, the combined wind-over velocity is likely sufficient to create airborne dust. As noted in Section 5.2.3.1, over half the trains through the Lower Fraser Valley in January 2000 exceeded the threshold speed for dust entrainment. Therefore, it is likely that when combined with average winds in any particular area that the combined wind-over velocity which is sufficient to cause dust emissions. At present, there is insufficient data available for any in depth analysis of this parameter.

Fines Content:

For most Western Canadian coals, the fines content is likely sufficient to produce dusting. One mine claims that in 2000 their fines content was from 8 to 11 percent. In the 1980s, samples tested by the Alberta Research discovered that 7% of the coal was less than 200 mesh (75 micron). (Cope 86) Therefore, it appears that coal fine content has changed little in 20 years.

Precipitation:

Precipitation is a factor that should be accounted for in the rail coal dust EF. Precipitation is discussed in Section 5.2.3.1 and suggestions for changes to the current techniques for estimating emissions are presented.

Table 5.2 Rail Car Coal Dust Emission Factor Comparison

#	Scenarios 100 tonnes of coal carried in one open top car for 1100 km	The Emission Factor	Distance D	tonnes shipped (approx. 1 railcar)	EF	For Scenario TPM Emissions in tonnes	As a % of 100 tonne Load	or as a multiplication factor x tonnes carried
	CAC Inventory 1995 Basic Formula is 1	CAC EF			**kg/tonne**		**% load**	
1	EF in kg/tonne coal transported =	$0.1 \times (0.62 \times D)^{0.6}$	1100	100	5.015	0.5015	0.5015	0.00501
	where D = distance travelled in km							
2	If 1 assumes 75% control, uncontrolled EF =	$0.1 \times (0.62 \times D)^{0.6} \times (100-0)/(100-75)$	1100	100	20.060	2.0060	2.0060	0.02006
3	Based on 2 then the 99% control EF =	$0.1 \times (0.62 \times D)^{0.6} \times (100-99)/(100-75)$	1100	100	0.201	0.0201	0.0201	0.00020
4a	Assume Scenario 1 is really an uncontrolled EF. Then the 99% control EF =	$0.1 \times (0.62 \times D)^{0.6} \times (100-99)/100$	1100	100	0.050	0.0050	0.0050	0.00005
4b	Same as 4 but assume control is only 90%	$[0.1 \times (0.62 \times D)^{0.6} \times (100-90)/(100)]$	1100	100	0.501	0.0501	0.0501	0.00050
4c	Assume control is only 85%	$[0.1 \times (0.62 \times D)^{0.6} \times (100-85)/(100)]$	1100	100	0.752	0.0752	0.0752	0.00075
	Wind Tunnel EF Range in 1986	**Wind Tunnel Uncontrolled EFs**						
	Experiments found uncontrolled EFs range to be 0.9% to 1.76% of load	EF in % of total load over 1100 km			**t/tonne**			
5a	If uncontrolled EF is 0.9% of load	0.9/100 x tonnes carried	1100	100	0.009	0.9000	0.9000	0.00900
5b	If uncontrolled EF of 1.76% of load	1.76/100 x tonnes carried	1100	100	0.0176	1.7600	1.7600	0.01760
	Environment Canada in 1986	**Assumed Uncontrolled EF is 0.5 to 3% of total coal load**			**t/tonne**			
6	If uncontrolled EF of 0.5% of load	0.5/100 x tonnes carried	1100	100	0.005	0.5000	0.5000	0.00500
7	If uncontrolled EF of 1.0% of load	1.0/100 x tonnes carried	1100	100	0.01	1.0000	1.0000	0.01000
8	If uncontrolled EF of 3.0% of load	3.0/100 x tonnes carried	1100	100	0.03	3.0000	3.0000	0.03000
	BC MELP EF	**EF is 0.05% x total tonnes shipped x % track distance**			**t/tonne**			
9a	Generic uncontrolled EF= 0.5% of load	0.5/100 x tonnes carried	1100	100	0.005	0.5000	0.5000	0.00500
9b	BC used an EF that is the 90% controlled EF	0.05/100 x tonnes shipped x %D for %D=100%	1100	100	0.0005	0.0500	0.0500	0.00050
9c	If assume that there is 99% control	Example 9 x 0.01	1100	100	0.00005	0.0050	0.0050	0.00005
9d	If assume that there is 85% control	Example 9 x 0.15	1100	100	0.00075	0.0750	0.0750	0.00075

The effect of the non-linear CAC EF as presented in equation 5.1 is to produce lower emissions estimates for rail journeys over 1100 km that are produced using a prorated linear function with similar parameters. Also, for journeys of less than 1100 km the CAC EF produces emissions estimates that are higher than a prorated linear function, Table 5.3a.

Table 5.3a Linear versus Non-Linear Rail Dust Emission Factors

For the scenario of 100 tonnes of coal carried in one open top car for 1100 km

	Uncontrolled Emission Factor		Total Distance D (km)	tonnes shipped (approx. 1 rail car)	EF	Total Particulate Emissions in tonnes (PART)
A	**CAC EF** Note: the basic formula is used to estimate emissions for each distance segment				**kg/tonne**	
	EF in kg/tonne coal transported =	$0.1 \times (0.62 \times D)^{0.6}$	2000	100	7.17882	0.7179
	Where D = distance travelled in km		1500	100	6.04073	0.6041
			1100	100	5.01500	0.5015
			500	100	3.12476	0.3125
			250	100	2.06157	0.2062
			100	100	1.18969	0.1190
			72	100	0.97686	0.0977
			50	100	0.78490	0.0785
B	**Uncontrolled BC MELP EF is 0.5% x total tonnes shipped x % track distance**	The 1100 km emissions estimates are prorated by %Distance			**t/tonne**	
	EF = 0.5/100 x tonnes carried	181.8%	2000	100	0.00909	0.9091
		136.4%	1500	100	0.00682	0.6818
	The basic 1100 km scenario ⇒	100.0%	1100	100	0.00500	0.5000
		45.5%	500	100	0.00227	0.2273
		22.7%	250	100	0.00114	0.1136
		9.1%	100	100	0.00045	0.0455
		6.5%	72	100	0.00033	0.0327
		4.5%	50	100	0.00023	0.0227

Example A in Table 5.3a is as applied in the CAC Inventory. It assumes eight distinct rail journeys of the eight different distances shown. In other words, each distance represents a discrete application of the formula.

In the CAC Inventory, the distance segment in each province is used with the CAC formula to calculate an emission factor and emissions for that provincial segment. Those provincial totals would then be added to produce the emissions total for an entire journey. However, it is suggested that this may not be the way the CAC EF should be applied, since it assumes that the emissions in each segment follow the same non-linear pattern.

A different application, and the one forwarded as the recommended technique, would be to use the CAC EF formula to first produce an EF and an emission estimate for an entire journey. Then, instead of using the formula to calculate a separate EF for each segment of the journey, the total emissions for the 1100 km trip would be divided, or prorated, by distance in each province using the simple linear approach used by the BC MELP.

Table 5.3b presents an example chosen from the 1995 CAC Inventory. (Deslauriers 1999) It involves 1.49 million tonnes of coal from one mine shipped approximately 2073 km to Ontario. The difference between the two applications of the formula is subtle, but they produce very different emissions totals.

Table 5.3b Additional Linear vs Non-Linear Rail Dust Emission Factors

For an example scenario of 1.49 million tonnes of coal carried 2073 km

Coal shipped 1.49 Mt	Total	BC	ALTA	SASK	MAN	ONT
Distance (km)	2073	55	495	628	547	348
From CAC Inventory						
EF (kg/tonne)		0.033	0.124	0.143	0.132	0.101
Total Emissions (tonnes)	795	50	185	214	197	150
New Linear Method		**BC**	**ALTA**	**SASK**	**MAN**	**ONT**
Overall EF (kg/tonne)	0.293					
Total Emissions (tonnes)	437	12	104	133	115	73

A quick examination of the emission estimates produced by the two different approaches, Table 5.3b, shows that they produce significantly different emissions estimates. Not only are the estimates for each segment of the journey lower, but the estimated total emissions for the entire 2073 km trip are almost halved.

Other suggestions for revising the CAC EF, in light of these findings, are presented in Section 5.2.5.

The NEIPTG Guidebook offers the following in regard to estimating the emissions of PM_{10} and $PM_{2.5}$: (NEIPTG 1999)

> *The PM_{10} and $PM_{2.5}$ emission factors were derived from the particulate emission factor, using information from the PM CALCULATOR program from the U.S. EPA (SCC 30501101):*
>
> PM_{10} = 1.0 x PART
> $PM_{2.5}$ = 0.92 x PART

However, it was found that the PM Calculator program does not contain a specific SCC for coal rail shipments. While the NEIPTG Guidebook states that the SCC used to ascertain the above fractions was 30501101, this SCC applies to the Cement Industry. The SCC in the PM Calculator for Coal Transfer is 30501011. It is not clear whether the manual contains an error, or that the Cement Industry SCC was used to obtain the PM fractions.

Regardless, both of these particulate fractions appear to be high in relation to the size of the coal particles that are likely to be emitted from coal rail cars in transit. The following is a general overview of the information available on the size characteristics of rail car generated coal dust samples taken in relation to fugitive dusting:

1] An *International Energy Agency* (IEA) report provides a comprehensive picture of coal properties, sources of coal dust emission from loading, unloading, stockpiles and transportation by trucks and trains, methods of coal dust control and coal dust monitoring methods. One conclusion reached was that the nuisance was caused mainly by coarse dust particles. (IEA 1994)

2] From the experiments conducted in connection with the Environment Canada investigations in the 1980s it was concluded that nearly 95% by weight of the particulate collected from loaded coal trains is reported to be larger than 20 microns. (Cope 1986)

Note, the data from the experiments conducted in the 1980s, should only be used as evidence to show a trend that larger particles than PM_{10} in size are emitted. The measurement equipment was used in a non-standard configuration to attempt to assess 'heavy visible' emissions. In general, most of the equipment, particularly the Hi-vol samplers, could not process sufficient sample in the short duration of a unit train event to collect sufficient sample for measurement. Also, since only one or two samplers were used per train, it is possible that smaller particulate could have blown over and been deposited away from the collection sites.

3] A number of Hi-vol and Lo-vol samples collected during a 1983 coal dust study were analyzed by computer controlled scanning electron microscope for size, shape and chemical composition of the particles. The results showed that the majority of particle mass for each sample was in the 5-30 microns size ranges. Similar analysis of metallurgical and thermal coal samples transported during the study period showed that about 20% (by weight) of the former type and less than 5% of the latter type of coal were comprised of particles having a physical diameter less than 2.5 microns. However, 52% of metallurgical coal particles and 68% of thermal coal particles were in the 10-30 microns range. (ESL 1985)

One of the samples collected during a day that featured visible coal dust emissions from trains passing the sampling equipment showed the following size distribution by weight: 20% less than 2.5microns, 41% between 2.5 and 15 microns, and 39% between 15 and 50 microns. (ESL 1985)

These data appear to support a decision to assume that approximately 50% of the emissions are greater than PM_{10} in size.

4] During a follow-up monitoring program in September-October 1984, a dichotomous sampler was used to estimate two size fractions of airborne particulate matter, namely coarse particles of sizes from 2.5 to 15 microns and fine particles of smaller than 2.5 microns in diameter. A Hi-vol sampler was also used to collect particles of less than about 50 microns in sizes. The collected samples were also analyzed for coal content by optical microscopy as well as X-ray fluorescence and flame ionization by two different laboratories. The results indicated that the coal content in the fine particles (< 2.5 microns) was 'minor and relatively insensitive to observed coal dust emissions'. However, the coal content in the coarse particles (2.5-15 microns) was 'high on all days with coal dust emissions regardless of the degree of dusting.' The analysis of Hi-vol samples showed that the coal content, particularly in the 15-50 microns particles, increased sharply for days when there were strong winds and heavy coal dust emissions. (ESL 1986)

The results of these studies should be viewed with caution. The data collected in the early 1980s were for brief track-side experiments that often featured non-standard sampling equipment. Regardless, the results appear to indicate that coarse coal particles, greater than 10 microns in diameter, are emitted from coal cars. Therefore, the scaling factors in the CAC Inventory used for PM_{10} and $PM_{2.5}$, 1.0 times and 0.92 times respectively, appear to be too high. Suggestions for new scaling factors are presented in Section 5.2.4.

5.2.2 British Columbia Emission Factors

As noted in Section 3.1, the British Columbia *Ministry of Environment, Lands and Parks* (MELP) was the only provincial agency to use a railcar dust emission EF different from the one used for the CAC Inventory to calculate emissions. Note: the local agency, the *Greater Vancouver Regional District* (GVRD), also used the BC MELP EFs for rail dusting in the GVRD.

The basic EF used by the province for the BC inventory was: (BCMELP 1999)

TSP = 0.05% x total coal shipped or *0.0005 x total coal shipped (tonnes)* (5.3)

Where: TSP = Total Suspended Particulate

The 1990 GVRD inventory states: (GVRD 1990)

> Remaining Lower Fraser Valley (LFV) sources and all other sources for the rest of the province, were inventoried as follows:
>
> > *Fugitive losses of coal dust were also estimated, based on the tonnage of coal transported by rail through both the Neptune and Roberts Bank Terminals. The percentage loss of load estimate for those fugitive losses was taken as the same (0.05%) as was assumed for the 1985 inventory. The emission factor for coal loss was derived from Environment Canada data (EAG, 1987) and is the same as used in the 1985 inventory at 0.05% of coal shipped.*

A distance factor was applied to the basic formula to develop an EF specific to the Lower Fraser Valley: (BCMELP 1999)

> For the emissions over a stretch of track such as the LFV the EF is:
>
> *TSP = 0.05% x total coal shipped x % of track* (5.4)

Documentation for the 1990 BC inventory for the Province outside the LFV indicates: (Levelton 1993) (GVRD 1994)

> *For coal shipped through the Port of Vancouver, the emission factor was adjusted for the length of track outside the LFV yielding the factor: 0.05 x (1-0.072) = 0.046%. This allows for 7.2% of the track length in the LFV. For the balance of the coal shipped in BC the emission factor used is 0.05%.*
>
> *To allow use of a single base quantity and, thus, simplify the calculation of coal dust emissions, and equivalent overall emission factor of 473-kg/1000 tonne coal shipped was calculated using the base quantities presented previously.*

However, at present, the basic EF used by the BC Government, equation 5.3, is flawed for the same reasons that the CAC EF is flawed. This EF also does not take into account the following:

- The moisture content of the coal.
- The wind and/or train speeds.
- Allowance for different coal types with different fines content.
- Allowance for the dust control created by precipitation en route.

The BC MELP claims that their EF takes into account the dust control provided by the sealants sprayed on the loaded cars by the mines: (Wakelin 2000)

> *This EF is based on the most conservative figure from the EPS report for uncontrolled cars (0.5%), and an assumed control efficiency of the latex sealer of 90%.*

Therefore, if one examines the emissions estimated by the uncontrolled CAC EF (scenario #1, Table 5.2) and the uncontrolled BC MELP EF (scenario 9a, Table 5.2) one will observe that they appear to produce approximately the same result. Similarly for the 90% control EF, scenarios 4b and 9b respectively. Additional discussion of the CAC and BC MELP EFs plus suggestions for improvements is presented in Section 5.2.5.

For their PM_{10} and $PM_{2.5}$ fractions of the total coal particulate emissions, the BC MELP used the following scaling factors: PM_{10} = TSP x 96% $PM_{2.5}$ = TSP x 92% (Wakelin 2000)

The BC MELP has submitted the following in relation to their use of the PM CALCULATOR: (Wakelin 2001)

> Some clarification appears to be required for the reference to the PM CALCULATOR. The U.S. EPA produced a file known as PSD4PM10. This file contains PM_{10} and $PM_{2.5}$ size fractions by SCC. The original publication that contained the basis for the file is:
>
> > *PM10 Emission Factor Listing Developed for Technology Transfer and Airs Source Classification Codes with Documentation*, by E.H. Pechan & Associates, Inc. Durham, NC 27707, EPA Contract No. 86-D0-0120, Revised June 1992.
>
> Application of the PSD4PM10 file to sources in BC originates with work done by SENES and the Air Resources Branch Co-op. SENES was contracted by the GVRD to produce the following report:
>
> > *Visibility and Fine Particulate Emissions Greater Vancouver Regional District and Lower Fraser Valley Summary Report*, by SENES Consultants Limited Vancouver, B.C. in association with Drs. Douw Steyn and Sara Pryor Department of Geography University of British Columbia, February 21, 1994.

For their PM_{10} and $PM_{2.5}$ calculations, the GVRD used the same scaling factor as employed in the CAC calculations, Section 5.2.1. (Sidi 2001) Regardless, the BC MELP and the GVRD scaling, as noted in Section 5.2.1, both appear to be too high. Suggestions for new scaling factors are presented in Section 5.2.4.

5.2.3 Recent Findings Regarding Coal Car Dusting EFs

A search of literature and the Internet was made in an attempt to discover any new information regarding emissions and EFs for moving coal trains. Unfortunately, little new information was discovered. In fact, it would appear that, at present, fugitive coal dusting from unit coal trains is only an issue in British Columbia and the state of Virginia, USA.

Since 1980, because of nuisance dust problems, the monitoring of wind-blown coal dust from coal trains has been attempted in several countries. However, it would appear that once dust-suppression measures were successfully applied and public complaints lessened, the monitoring program was discontinued.

The following sources were checked for references to coal train EFs (other contacts are listed in Appendix C):

> *I] "Revision of Emission factors for AP-42 Section 11.9 Western Surface Coal Mining, Revised Final Report. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Factor and Inventory Group, Research Triangle Park, NC 27711. Prepared by Midwest Research Institute under EPA Contract 68-D2-0159, September 1998."*
>
> > Although AP-42 covers various emission sources associated with coal mining, the shipment of coal by trains is not addressed as a source of dust emission. Also, as noted earlier, although the EPS has assigned

SCC codes to hundreds of industrial sectors, including several in the coal industry, it has not assigned one to the movement of coal by rail.

ii] "National Pollutant Inventory, Emission Estimation Technique Manual for Mining, Version 2.1, Environment Australia, October 11, 2000."

The sources covered in the manual include drilling, blasting, mine power generation (if any), excavators, bulldozers, scrapers, graders, front-end loaders, loading stockpiles, unloading from stockpiles, transfer points, wind erosion, mine transportation by trucks, and loading to trains, but not emissions from the trains.

iii] "Control of coal dust in transit and stockpiles", IEA Coal Research, IEAPER/15, December 1994."

The report provides a comprehensive picture of coal properties, sources of coal dust emission from loading, unloading, stockpiles and transportation by trucks and trains, methods of coal dust control and coal dust monitoring methods. It cites a study* that looked into the correlation between dust emission and nuisance it caused by simultaneous monitoring of dust levels and doing a survey of nearby residents. The conclusion reached was that the nuisance was caused mainly by coarse dust particles. However, no emission factor for coal dust emission is provided in this IEA report.

* "Nuisance from coarse dust", P. Hofschreuder and E. L. M. Vrins. Paper presented at European Aerosol Conference, Oxford, U. K., 1992.

iv] "Coal Particulate Emissions From Rail Cars", Noble, George, et al, Paper presented at A Specialty Conference on Fugitive Dust Issues in the Coal Use Cycle, held by Western Pennsylvania Section of Air Pollution Control Association at Pittsburgh, PA on April 11-13, 1983.

The study was undertaken to evaluate potential environmental impact of coal dust emission from rail cars on the ambient air quality. A Hi-vol sampler was used to collect ambient air samples at a location about 15 m (50 ft.) away from the rail tracks. A total of 12 trains, consisting of 7 exclusively coal cars, 4 trains of mixed coal and freight cars, and 1 with a number of empty coal cars, were samples. Train speeds varied from about 5-32 km/h. (No mention is made about the use of any dust suppressant on the coal cars.)

Statistical analysis was performed with the monitoring data to determine any relationship between variables such as number of coal cars, average train speed, wind speed, rainfall and source of coal. The results do not indicate any direct relationship between coal dust emission and any of the other variables; but it appears that a combination of factors influence the rate of dust emission. Other key findings are:

- the coal dust emission from coal trains ranged from 0.00004 to 0.00373 $\mu g/m^3$-day per coal car, and that from mixed coal and freight trains ranged from 0.00015 to 0.00159 $\mu g/m^3$-day for each car;
- the coal dust emission from 34 empty coal cars was 0.00093 $\mu g/m^3$-day. It appears that emissions from empty cars were nearly the same as that from loaded cars;
- the ambient coal particulate contribution was extremely low, irrespective of whether the train carried coal or not;

- particle size analysis indicated that on average 42% of the total coal particles were greater than 70 μm, and this fraction may represent up to 85%;
- the effect of rain shower on one occasion was observed on the significant reduction in the ambient concentration of coal particulates; and
- re-suspension of accumulated coal particles over time in the vicinity of the rail tracks may play some role in the observed dust emission during the passing of a coal train.

Unfortunately, this study did not produce an emission factor.

Since some of the conclusions reported for the investigation in #iv above seem to run counter to other observations, the following comments on those conclusions are offered:

1] A maximum train speed of 32 km/hr is barely within the emissions threshold for dusting discovered during wind tunnel experiments. More recent data indicate that excessive dusting only occurs at train speeds in excess of 50 km/hr. Were trains in the APCA study going at a speed that would generate sufficient dust for analysis?

2] The study results do not mention the separation diesel particulate from the coal dust collected on Hi-Vol samples? In the 1980s this separation was a major drawback in regard to the quantitative analyses of collected particulate samples. A method was not developed for this separation until 1994. (OAG 1994)

3] It is claimed that on the one day it rained, coal dust was down. However, they conclude that there was no direct link between precipitation and coal dust emissions?

4] Dust measurements were almost as high for non-coal trains? Again, did they separate coal dust from diesel particulate and other non-coal dust on the samples they collected?

Prior to this investigation, the BC MELP contacted agencies in Canada, the USA and internationally regarding new EFs for coal trains. These same agencies were contacted again as a part of this investigation. The BC MELP findings were confirmed. None of the groups contacted have developed an EF for coal trains. The contacts are listed in Appendix A.

The Midwest Research Institute (MRI) in the USA has been responsible for much of the research into fugitive coal dust emission factors for the US EPA. Unfortunately, neither the EPA nor the MRI has published EFs for coal train losses. When asked about EFs for coal trains the following response was received from a MRI researcher: (MRI 2001)

> *In regard to PM lost from coal trains, the wind erosion estimates in AP-42 Section 13.2 would be as applicable as anything because these were measured under steady, high air flows, just like the open surface in railcars. Furthermore, most of the AP-42 database involves coal erosion rather than any other material.*

In BC, several monitoring programs were initiated to address the problem of coal dust from trains carrying coal through the LFV to the Vancouver area. Various monitoring methods were employed to attempt to determine coal dust concentrations, and to a lesser extent the particle sizes of the coal samples. However, no EFs for coal dust were produced. The following contributed to the lack of success:

- the limitations of these monitoring methods;
- the different origins of the coal particles;
- weather conditions; and
- the complexity of apportioning collected particles to their sources.

Even less information is available on the particle size distribution of the coal dust in the collected samples.

Some of the most recent work on coal dust from trains involves the company, *Simpson Weather Associates* (SWA). SWA is working with the Norfolk Southern (NS) railway monitoring coal dust emissions from coal trains in Virginia.

SWA offers a number of systems and services in regard to rail car dusting: (SWA 2001)

- Rail Transport Emission Profiling System (RTEPS)
- Coal Car Load Profiling System (CCLPS)
- Portable LAser for Coal Emission Mapping (PLACEM)
- Evaluation of Chemical Dust Suppressants
- Autonomous control of wet dust suppression systems for coal storage piles (ProControl)
- Seasonally Adjusted Rail Transport Dusting Index (SARTDX)

SWA, for the Norfolk Southern Railway and its operations in Virginia, are involved in a series of coal dust measurement experiments and ongoing dust monitoring from rail cars. They have measured coal dust from rail cars using:

a] Passive Dust Collectors on the cars.
b] Car Weights before and after – buried moisture gauges were used.
c] Scanning Laser device to measure volume in the car.

Of the sources that were studied, the work of SWA with the Norfolk Southern Railway appears most likely to be capable of producing an EF for loaded rail cars. In fact, the data they have collected to date may have revealed EFs, but the data are proprietary and although contacted, neither company forwarded the measurement data that would have produced an EF.

In 1996 the Senate of the State of Virginia passed Joint Resolution # 257 that required the Norfolk Southern Railway to monitor dusting trains en route and to take measures to eliminate dusting. As a result, the Norfolk Southern installed two of *SWA's Track-Side Monitoring* (TSM) systems that automatically photographs dusting trains. Information is downloaded daily by SWA and once per week photos are graded by eye regarding dusting. SWA then informs the mine involved if their trains are dusting. (NS 2001) SWA were recently contacted by the CPR regarding a TSM system for possible installation at HOPE, BC. (SWA 2001)

Of note, SWA, when they monitor and report train dusting for the NS, consider a car with 20% crust loss (or 80% crust-retention) to be uncontrolled. They feel such a loaded coal car will be a *heavy duster* with emissions similar to those of an unsprayed car. (SWA 2001)

This conclusion appears to confirm the findings in Environment Canada's *1986 Recommended Practices*, that 85% crust retention is the *minimum standard* for dust control, and that a much higher level of crust retention is required to significantly reduce emissions. (Wituschek 1986)

5.2.3.1 Weather En Route - Analyses

For coal carried by rail over long distances in open rail cars in unit trains, it is logical to assume that weather conditions en route can influence coal dust emissions:

- High temperatures can contribute to the drying of exposed coal and surface sealant crusts;
- Freezing temperatures can influence the setting of sealant crusts or freeze coal in cars so that it does not all dump out at the end terminal;
- Ambient wind can add to train speed to produce a greater wind-over velocity for dust entrainment;
- Snow and ice may add a dust inhibiting layer to the surface of a coal load or cover loose coal in an empty car; and
- Precipitation as rain can inhibit dust emissions or breakdown and dilute sealant chemicals.

In regard to visible dusting incidents (and likely total emissions as well), it is not just the local weather at the potential emissions location that can influence the severity of the dust emissions episodes. The weather 'up route' of the emissions may also influence the emissions at the point of observation.

The nuisance dusting incidents reported in the spring, summer and fall of 2000 involved unit trains on the route through the Lower Fraser Valley. A total of 27 separate complaints regarding 'heavily' dusting trains were recorded in the area of Hope, BC from May to October 2000. In regard to specific dates, a Hope, BC resident registered one complaint on 12 July 2000 and another citizen in the same area reported on 21 July 2000 that "dusting was still a problem". (See Appendix B)

Weather data were obtained for 2000 from a number of Environment Canada weather stations along the rail route, from the mines near the Alberta/BC border to the port of Vancouver. Weather information from Kamloops (approximately 300 km closer to the coal mines than Hope), Hope and Abbotsford (approximately 80 km closer to Vancouver than Hope), British Columbia was analyzed. Note: these data have not yet undergone Quality Control assessment by Environment Canada. (Brewer 2001)

Maximum Temperature

For the three stations selected, a summary of the temperature data collected in 2000 is listed in Table 5.4.

Table 5.4 Maximum Temperature Readings (Tmax in °C) for 2000

	Kamloops	Max	Max	Tmax	**Hope**	Max	Max	Tmax	**Abbotsford**	Tmax	TMax	Tmax
Month	Average TMax	12-Jul	21-Jul	1 Day	Average TMax	12-Jul	21-Jul	1 Day	Average TMax	12-Jul	21-Jul	1 Day
Jan	-0.9			3.7	3.7			9.3	6.3			10
Feb	3.7			11.1	7.7			11.3	9.6			14.2
Mar	11.4			16.9	10.5			15.9	10.8			15.2
Apr	16.9			22.6	15.6			22.3	15.5			20.3
May	19.5			24.5	16.5			23.7	16.6			23.2
Jun	24.3			32.4	21.5			30.1	21.3			31.1
Jul	27.1	**30.7**	**34.3**	34.3	22.8	**24.7**	**29.7**	29.7	23.1	**24.8**	**30.7**	30.7
Aug	27.1			33.3	22.7			29.6	22.8			29.1
Sep	21.1			25.8	19.4			28.9	20.4			28.3
Oct	13.6			20.2	14.5			20.5	15.7			23.4
Nov	4.5			9.6	7.2			12.5	9.2			14
Dec	-1.0			8	3.3			8.7	5.6			10.3

The maximum temperature data from the three stations indicate that from May to September 2000 the maximum temperatures in all three cities ranged from warm to hot. In Kamloops, on the day of one reported dusting train, the temperature exceeded 30 degrees C. Single day maximums of greater than 30 degrees C were also recorded at each site in May, the month when the most visible dusting complaints were registered in 2000.

For loaded trains, an average temperature of below zero degrees Centigrade in Kamloops in January 2000 could have contributed to coal freezing in cars. On occasion, frozen coal in cars is not dumped at the end terminal. Subsequently on the return journey in the LFV in particular higher temperatures can cause that frozen coal to thaw. That unthawed coal can then be the source of dusting from 'empty' returning coal cars.

In regard to emissions estimates, no method was discovered for integrating the influence of maximum temperature into an emission factor. For nuisance dusting, what can be said is that in the spring and summer of 2000 there were many days in which the maximum temperatures were in a range that would have been conducive to nuisance dusting.

Wind Speed

Prevailing wind and the air movement created by train motion are critical to the coal dust emission rate for trains en route. Local wind plus train generated wind can combine to create complex air-flow patterns over the coal surface which can then entrain fine coal particles. Therefore, the coal surface in a train travelling at a relatively low velocity, may still be exposed to a wind of a much higher 'wind-over' velocity. The resultant wind-over the load will depend upon local wind velocity and direction plus train speed when the train transits a community en route to a coal terminal (or returning).

Episodes of 'heavy' dusting from trains have been recorded from fast trains on still days. Field observations have shown trains travelling in excess of 50 km/h (30 mph) in dry weather can emit significantly more dust than trains travelling at lower speeds in the same conditions. Conversely, field observations in the 1980s also indicated that trains dust at speeds lower than 50 km/hr. (Holmes 1982) (Cope 1986)

Laboratory wind tunnel experiments in the 1980s measured threshold-dusting velocities of 30 to 40 km/h (18 to 25 mph). (Cope 1986) More recent data, gathered by the EPA in regard to wind erosion, show threshold speeds for storage piles of approximately 18 km/hr. (EPA 2001-1).

A recent report appears to confirm that train speed is likely a factor in dusting. In January 2000, the average coal train speed in the LFV was reported as 35.8 km/hr. Therefore, one could conclude that for the communities in the LFV:

- On average, unit coal trains are travelling at a speed near the threshold wind velocity; and
- Over half the trains are travelling in excess of the threshold velocity.

For 2000, the hourly wind data for Hope, BC was averaged for each month. It would appear that the highest averages are in the winter months of January, February and December. In July, in Hope the average wind speed was 12 km/hr and from 12 to 21 July the local average wind speed was 13 km/hr, Table 5.5.

Table 5.5 Wind Measurement Averages - Hope, BC for 2000

2000			Wind	Average	in	km/hr					
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16	15	10	12	11	13	12	12	10	11	10	19
					12-Jul	**11**					
					21-Jul	**11**					
				Average	**12 –21 Jul**	**13**					

The average measured wind in Hope in January 2000 was 16 km/hr in January. If in January 2000, the average coal train speed was 35.8 km/hr as reported, it is quite possible that on most days the two could combine and produce a resultant wind-over the coal load in each car that was in excess of the threshold speed for dust entrainment.

Since the average wind speed in Hope was 10 km/hr or greater from May to October, if one assumes that the average train speed in the spring, summer and fall of 2000 was also approximately 35.8 km/hr, then similar conclusions can be made for those periods. It would seem that on most days the combination of ambient wind and train speed should be capable of producing a wind-over velocity in each car in excess of the threshold speed for dust entrainment.

No emissions factor for rail car dusting that included a wind speed factor was discovered. However, the visible dusting incidents reported in 2000 in Hope, BC indicate that the combined wind-over velocity for those 27 coal trains was sufficient to produce dusting.

Precipitation

The rain, snow and total precipitation records for 2000 for these same three communities in BC were also analyzed. In July and August of 2000 each of the three communities had 20 or more days when the measured precipitation was zero, Table 5.6.

Less than one millimeter of rain fell in Kamloops each month from June to December of 2000. Less than 1.5 millimeters of rain fell in Hope in July and August of 2000. Conversely in May the average recorded rain was greater than 2.5 millimeters and yet more heavily dusting trains were recorded in that month than in any other month in 2000. As noted, Kamloops is approximately 300 km before Hope on the rail line to Vancouver. Therefore, in regard to precipitation, snow could cover or rain could wet the surface of the coal load prior to it reaching Hope.

Close to 2 millimeters of rain were recorded for Abbotsford in July, but on average, July and August were the two driest months in that community in 2000.

However, in 2000, from January to April inclusive, Kamloops had precipitation on eight or fewer days each month, on nine or fewer days for July, August and September and on only four days in November. Precipitation in Abbotsford, Hope and Kamloops on the 12th and 21st of July, 2000, the days when visible dusting was reported, was 0 mm of rain for all three communities.

Table 5.6 Recorded Precipitation - 2000

	Kamloops Rain Average mm	Days when Rain is 0	Days with Snow	Days with Precip	Hope Rain Average mm	Days when Rain is 0	Days with Snow	Days with Precip	Abbotsford Rain Average mm	Days when Rain is 0	Days with Snow	Days with Precip
Jan	0.39	29	8	8	1.01	26	21	21	4.24	7	2	25
Feb	0.21	18	2	8	1.44	18	7	14	3.94	13		16
Mar	1.18	24	1	7	2.26	13	7	20	4.79	12		18
Apr	0.92	24	1	6	1.87	14	6	18	3.65	15		15
May	1.09	17		14	2.57	9		22	5.81	10		20
Jun	0.84	19		11	2.21	14		16	4.31	14		15
Jul	0.96	22		9	1.39	19		12	1.72	24		7
Aug	0.76	25		6	1.23	21		10	1.11	27		4
Sep	0.26	20		9	3.15	15		15	3.81	16		14
Oct	0.32	21		10					4.28	16		15
Nov	0	26	1	4					3.46	19		11
Dec	0	27	15	17					3.58	14	3	17

In an analysis of emission methodology for unpaved road dust for British Columbia, the Emission Factor that was adopted was modified to account for 'precipitation days'.

> *Precipitation days* were defined as days when the rainfall exceeded three millimeters. Also, a snow day was one in which over one centimeter of snow lay on an unpaved road. (Levelton 1999)

With respect to dusting from coal trains, the difficulty with the application of such a factor will be variation in the number of precipitation and snow days in different areas along the 1100 km rail route through British Columbia.

For example, the data in Table 5.7 indicate that the average rain in Kamloops never exceeded three millimeters in any month in 2000 whereas, in Abbotsford the average exceeded three millimeters in every month but July and August or 2000. In Hope, for the nine months of data, the average only exceeded three millimeters in September.

Table 5.7 Precipitation Days and Snow Days in 2000

Abbotsford Rain		Abbotsford Snow		Hope Rain		Hope Snow		Kamloops Rain		Kamloops Snow	
M	Days > 3mm	M	Days > 1 cm	M	Days > 3mm	M	Days > 1 cm	M	Days > 3mm	M	Days > 1 cm
Jan	14	Jan	0	Jan	3	Jan	5	Jan	1	Jan	0
Feb	10	Feb	0	Feb	5	Feb	0	Feb	1	Feb	0
Mar	12	Mar	0	Mar	8	Mar	0	Mar	2	Mar	0
Apr	9	Apr	0	Apr	7	Apr	2	Apr	0	Apr	0
May	17	May	0	May	12	May	0	May	3	May	0
Jun	10	Jun	0	Jun	8	Jun	0	Jun	3	Jun	0
Jul	4	Jul	0	Jul	4	Jul	0	Jul	4	Jul	0
Aug	2	Aug	0	Aug	5	Aug	0	Aug	3	Aug	0
Sep	6	Sep	0	Sep	6	Sep	0	Sep	4	Sep	0
Oct	9	Oct	0					Oct	4	Oct	0
Nov	7	Nov	0					Nov	1	Nov	0
Dec	10	Dec	0					Dec	1	Dec	0
Total	110		0		58		7		27		0

Conclusions Regarding the Influence of Weather in 2000 Near Hope, BC

It would appear that for the section of the coal/rail route that passes through Kamloops, Hope and Abbotsford, British Columbia, that ambient weather conditions on many occasions in 2000 met the criteria that could be capable of producing heavily dusting trains.

There were extended periods of hot weather during the spring and summer months and all three communities experienced extended periods of little or no precipitation. The average wind in Hope, BC in the summer of 2000 did not. However, if the average monthly velocity of greater than 10 km/hr throughout the year were to combine with the train speed the combination could produce a wind-over velocity high enough to exceed the threshold speed for dust entrainment for any given train.

In regard to weather, the dusting conditions in the Hope, BC area during the period from 12 to 21 July, 2000 appear to have been ideal for the generation of dust from any untreated coal surfaces in unit train cars. For the three communities of Kamloops, Hope and Abbotsford, British Columbia, during the middle of July, the time of one specific dust complaint, only very light precipitation was recorded;

- Abbotsford recorded zero precipitation from 10 to 22 July;
- The Hope station recorded only 0.4 mm of rain on two days, 8 and 14 July, in a period from 5 to 21 July; and
- Kamloops only 0.2 mm on 20 July in a period from 9 to 21 July.

5.2.4 Recommended EFs for Rail Transportation of Coal

The literature and personal contact searches undertaken during the course of this study failed to identify any new EFs related to the loss of coal during shipment by train. Therefore it would seem appropriate to reiterate the findings of the 1980s: (MH 1983, Cope 1986)

> *The maximum potential coal losses, for one trip of approximately 1 100 km (700 mi.) over rough terrain during dry conditions, are in a range from 0.5 to 3% of the total coal load. This range for an uncontrolled emission factor is similar to the EF range determined by wind tunnel studies in 1983.*

As noted in Sections 5.2.1 and 5.2.2, if used to estimate emissions in relation to an 1100 km rail journey, the basic uncontrolled emission factors now used for the national CAC Inventory and the BC MELP Inventory are quite similar. Both are within the ranges noted above and appear to be based on the 0.5% of load uncontrolled EF that was discovered in early experiments. Where the two EFs differ is in how they incorporate distance and in what they consider to be the level of dust control achieved en route.

While the BC MELP EF is likely incorrect in the assumption that emissions are uniform over distance travelled, the CAC EF is also likely to be incorrect in the assumption that emissions always follow their non-linear relationship with distance travelled.

Data from the two Coal Terminals in Vancouver indicated that in 2000 approximately 27,462,000 tonnes of coal were exported through that port. Table 5.8 presents a comparison of the two EFs, if used to estimate dust emissions from rail cars for different hypothetical scenarios in relation to those exports. For the same dust control efficiency, the differences between the estimates produced by the two EFs are clearly illustrated. The two techniques produce estimates that are nearly identical for an 1000 km journey; they only differ by 4 tonnes. However, for a 100 km portion of the trip through the Lower Fraser Valley, the BC MELP EF produces a lower total than does the CAC EF, 125 tonnes versus 327 tonnes respectively (assuming that the CAC EF is employed to estimate emissions by distance segment).

However, as noted in Section 5.2.1, using the CAC EF in this manner is likely an incorrect application of the formula. It is suggested that, for the examples illustrated in Table 5.8, the CAC EF should first be used to produce an EF, and an emissions estimate, for the entire trip, in this example 1100 km. Then, it is suggested that those CAC EF generated emissions should be apportioned, or prorated, over the distance segments using the same linear technique as used by the BC MELP. Using the latter approach, since the EFs and emissions estimates for the 1100 km trip are almost identical, it also follows that the emissions apportioned to the 100 km segment would also be nearly identical, see B-Pro and G-LFV examples in Table 5.8.

However, the limitations of the BC MELP EF are also clearly illustrated in Table 5.8. The BC MELP EF, since it was derived in relation to a long rail journey, should only be used for estimating emissions from journeys in the range of 1100 kilometers. Those estimates can then be prorated for shorter segments such as the LFV, as is the present practice of the BC MELP.

However, since the BC MELP EF does not incorporate a distance factor, the application of their EF will produce the same total EF (for the same quantity of coal) regardless of the total distance travelled. Examples H and H-long in Table 5.8 illustrate this contention. While all of the coal shipped to Vancouver in 2000 did travel long distances, there were coal mines in Canada that did ship large quantities of coal by rail over short distances in 2000. When the BC MELP EF is applied for those scenarios, the estimated emissions for such short distances are questionably high. (See Section 5.4)

Conversely for longer distances, example G-long in Table 5.8. G-long illustrates a scenario where the BC MELP EF estimates, for an 1100 km trip, are prorated or extrapolated for a longer 1500 km journey. Used in this manner they produce higher emissions estimates than the CAC EF estimates using the same parameters, see C-long.

Therefore, for estimating emissions on a national basis, it is recommended that the basic CAC EF formula, equation 5.1, be used to represent the uncontrolled emissions for a rail coal journey. However, the use of that formula should be modified. Instead of the current practice of using the formula to produce new estimates for each provincial distance segment, the overall estimate for the total trip should instead be prorated by distance segment. The latter technique is used by the BC MELP to prorate emissions for the LFV.

Table 5.8 Comparison of Different EFs for LFV Emissions in 2000

Scenario	Description	D (km)	Coal Shipped through Vancouver in 2000 (tonnes)	EF	Emissions in tonnes (PART)
	Using the CAC EF			**kg/tonne**	
A	Uncontrolled CAC EF	1100	27,462,000	5.015	137,722
A-LFV	Using a Distance of 100 km for LFV	100	27,462,000	1.190	32,671
A-Pro	Prorate Using Distance of 100 km for LFV	100	27,462,000	0.456	12,520
B	As for 1995 inventory with 99% control	1100	27,462,000	0.201	5,509
B-LFV	Using Distance of 100 km for LFV	100	27,462,000	0.048	1,307
B-Pro	Prorate Using Distance of 100 km for LFV	100	27,462,000	0.018	501
C	99 % control applied to A	1100	27,462,000	0.050	1,377
C-LFV	Using Distance or 100 km for LFV	100	27,462,000	0.012	327
C-Pro	Prorate Using Distance of 100 km for LFV	100	27,462,000	0.005	125
C-long	For a distance of 1500 km	1500	27,462,000	0.060	1,659
	Using the BC MELP EF			**t/tonne**	
E	Generic uncontrolled EF= 0.5% of load	1100	27,462,000	0.005000	137,310
E-LFV	Prorate Using Distance of 100 km for LFV	100	27,462,000	0.000455	12,483
G	If assume that there is 99% control	1100	27,462,000	0.000050	1,373
G-LFV	Prorate Using Distance of 100 km for LFV	100	27,462,000	0.0000045	125
G-long	Prorate for a distance of 1500 km	1500	27,462,000	0.0000682	1,872
H	Use BC MELP EF for entire quantity of coal carried for a short trip of 100 km	100	27,462,000	0.0000500	1,373
H-long	Use BC MELP EF for entire quantity of coal carried for a long trip of 1500 km	1500	27,462,000	0.0000500	1,373

In conclusion, it is recommended that the basic CAC EF be modified using:

- New PM_{10} and $PM_{2.5}$ scaling factors,
- A precipitation factor,
- A linear distance factor to prorate emissions, and
- An adjusted dust control factor of 99%.

Particulate Sizing - PM_{10} and $PM_{2.5}$ Scaling Factors

The different sets of ratios for scaling TPM to PM_{10} and $PM_{2.5}$, as used by BC Environment and by the CAC Inventory, are felt to be too high. Therefore, as suggested by researchers at MRI, the scaling factors used in the Industrial Wind Erosion section 13.2.5.3 of the EPA AP-42 may be more appropriate. (MRI 2001)

AP-42 Chapter 13.2.5 on *Industrial Wind Erosion* lists particle size multipliers that vary with aerodynamic particle size: (EPA 2001-1)

Aerodynamic Particle Size Multipliers for EF equation:			
30 μm	<15 μm	<10 μm	<2.5 μm
1.0	0.6	0.5	0.2

This distribution of particle size within the under 30 micrometer (μm) fraction is comparable to the distributions reported for other fugitive dust sources where wind speed is a factor. A comparison of the Scaling Factors used for comparable operations is presented in Table 5.9.

Recommended PM_{10} and $PM_{2.5}$ Scaling Factors

For this study, the recommended *Scaling Factors* to convert Total Particulate Matter emission estimates to PM_{10} and $PM_{2.5}$ emissions estimates are those assigned by the EPA for wind erosion of storage piles:

$$PM_{10}\ EF = PART\ or\ TSP\ EF \times 0.5 \qquad (5.5)$$

$$PM_{2.5}\ EF = PART\ or\ TSP\ EF \times 0.2 \qquad (5.6)$$

While the scaling factors for wind erosion from stockpiles have been selected for use with rail coal cars, the AP-42 EF for a stationary stockpile that is not subject to vibration is not felt to be appropriate since it does not adequately reflect rail car emissions.

Table 5.9 Comparison of Scaling Factors

Comparable Operation	Scaling factor x TSP		Reference
	PM_{10}	$PM_{2.5}$	
CAC Inventory - Train Dust	1.0	0.92	NEIPTG 1999
BC MELP - Train Dusting	0.96	0.92	BCMELP 1999
CAC Inventory Mining Coal Dust Emissions	0.545	0.33	NEIPTG 2001
Truck loading	0.75	0.019	US EPA[1]
Loading to trains	0.42		Env. Australia[2]
Wind erosion of stockpiles[3]	0.5	0.2	US EPA[4]
Wind erosion of stockpiles	0.5		Env. Australia[2]

1. "Revision of Emission Factors for AP-42 Section 11.9 Western Surface Coal Mining, September 1998, US Environmental Protection Agency."
2. "National Pollutant Inventory, Emission Estimation Technique Manual for Mining, Version 2.1, 11 October, 2000, Environment Australia."
3. Predictive emission factor equation.
4. "AP-42 Section 13.2.5 Miscellaneous Sources, January 1995, US Environmental Protection Agency."

Effect of Weather En Route – Precipitation Factor

It is not a new discovery that weather can influence particulate emissions. In regard to visible coal dusting from trains, the investigations in the 1980s revealed that incidents of 'heavily' dusting trains frequently occurred during periods of hot, dry weather. Conversely, heavy precipitation could act to limit dust emissions. The difficulty is in how to apply precipitation variables to dust emissions estimates? To date, it would appear that no agency has developed an EF for rail transportation that includes a weather qualifier. However, for this study an attempt is made to link the controlling effect of precipitation to dusting.

Recommended Precipitation Factor

Therefore, to account for rain en route, it is suggested that the basic EF be modified using the precipitation factor developed for unpaved road dust emission estimates: (Levelton 1999)

$$\textit{Final EF} = \textit{PART or TSP EF} \times (365-P)/365 \qquad (5.7)$$

Where P = number of precipitation days plus the number of snow days, see Section 5.2.3.1.

The difficulty with the application of this factor is that the number of precipitation days will vary with location over a long rail journey.

Coal Dust Distribution En Route – Distance Factor

In general, most of the EFs used for estimating fugitive dust emissions are meant for macro applications. They are best used to produce national, provincial or regional emissions estimates. By their nature they are general and meant to be used in a general context.

The CAC EF incorporates a rail distance variable. However, it is felt that it should not be used to estimate emissions for each segment of a longer rail journey, as is now the practice for the CAC Inventory. Instead it is suggested that the CAC EF equation should be used to produce an EF, and an emissions estimate, for the entire trip. Subsequently, the total trip EF (or the total emissions estimate) should be prorated for each trip segment using a simple linear function. This is the system that is now employed by the BC MELP to estimate emissions for the LFV. In other words a second distance factor is used related to the distance the coal travels in each segment.

Recommended Distance Factor

First, the Distance for the total trip, D, is used in the CAC uncontrolled EF formula, equation 5.1:

$$EF \text{ for Total Trip} = 0.1*(0.62*D)^{0.6} \qquad (5.1)$$

Where: EF = the emission factor in kg/tonne of coal transported and
D = the total distance travelled by rail cars (km).

Second, the EF is modified using the length of each segment:

$$\textit{Final EF each segment} = \textit{EF for Total Trip} \times (\textit{Segment Distance}/D) \qquad (5.8)$$

Where: Segment Distance = the distance the coal is shipped in km within the segment.

Emission Control Efficiency - Dust Control Factor

As noted in the general discussion of EFs in Chapter 3, one of the basic factors required to modify any uncontrolled emission factor is one that accounts for the efficiency of any emissions control system:

Recommended Dust Control Factor

$$\textit{Final Controlled EF} = \textit{EF} \times (100 - \textit{Control Efficiency})/100 \quad (5.9)$$

Where: Control Efficiency = the % efficacy of the control i.e. if the Control Efficiency is 99% enter 99 in the formula.

Recommended Overall Rail Coal Dust EF

Therefore, the final EF formula recommended for estimating rail coal dust emissions is:

Rail Coal Dust EF (kg/tonne)

$$= 0.1*(0.62*D)^{0.6} \times (365-P)/365 \times (\textit{Segment Distance}/D) \times (100 - \textit{Control Efficiency})/100 \quad (5.10)$$

Where: D = total rail distance (km)
P = number of precipitation days
Segment Distance = distance travelled in a province or region
Control Efficiency = coal dust control efficiency

The PM_{10} and $PM_{2.5}$ PM emissions are then calculated using the scaling factors:

$$PM_{10}\ EF = \textit{Rail Coal Dust EF} \times 0.5 \quad (5.11)$$

$$PM_{2.5}\ EF = \textit{Rail Coal Dust EF} \times 0.2 \quad (5.12)$$

The BC MELP EF and the CAC EF were both used to illustrate emissions estimates for 2000, see Section 5.4.

5.2.4.1 Emission Factors for Dusting from Empty Trains

As noted in Section 1.3, from 1979 to 1984 of over 1600 *empty* unit trains observed in transit, approximately 2% were judged to be 'medium' to 'heavy' dusters in relation to visible coal dust emissions. While these trains are part of the nuisance dusting problem, their contribution to total train dusting on an annual basis is not known. No EFs in relation to total emissions from such trains were found as a result of this investigation.

It is suggested that while dusting from empty cars may create a number of visible, nuisance soiling dusting events during a year, the overall contribution to an annual emission inventory may also be minor. No EFs for empty rail cars are proposed, but the empty train issue deserves study as part of the continued nuisance soiling problems in communities in the Lower Fraser Valley.

5.3 Fugitive Dust Control – Rail Transport

In Western Canada, since 1975 the principal method for controlling fugitive coal dust emissions from rail cars has been to spray sealant chemicals on the surface of each car at the mine site prior to shipment. Other coal dust mitigation techniques that have been suggested, attempted or that are in use are listed in Table 5.10.

Table 5.10 Train Coal Dust Mitigation Techniques

	Technique	Comments
A	**Railway Companies**	
1	Reduce Train Speed	Claimed to be a railway policy in 2000
2	Uniform Design	Both CN and CP are adding new cars to their fleets
3	Group Coal Cars of Similar Design and Height	Car grouping suggested as a policy for railway companies
4	Ban Above Car Loading	Would reduce expose of coal load to high wind and may reduce dusting
5	Aerodynamic Modifications to Cars	May be difficult to retrofit and may not work with different loading systems
6	Buy Property or Homes Affected by Dust	Too many homes are affected for this technique to be practicable
7	Damage Compensation Payments-Yearly Stipend	Not a long term solution
B	**Coal Mining Companies**	
1	Flat Load-Profile	Effective load levelling systems are required at all mines
2	Chemical Sealant Application Systems	Effective sealant spray systems are required at all mines. In addition, backup or secondary sprays systems are also required at all mines
3	Switch Chemical Sealants	The most effective chemical sealants should be used
4	Increase Chemical Sealant Concentrations	If trains are dusting an increase in the sealant concentration may be required
5	Chemical or Water Sprays - En Route	Could be effective, but how, when, where and cost could present significant barriers to their use
6	Hinged Covers	While they could be effective in a new system, there retrofit to existing system is impractical
7	Lift-off Covers	Similar to above, but no functioning fast-load system currently available
8	Roll-Back Covers	Similar to above, but no functioning fast-load system currently available
9	Soft Once-Only Covers	Their retrofit into existing system is likely impractical and they would represent a source of pollution
10	Briquetting	Effectiveness and practicality is unknown at this time
11	Coarse Coal Topping	Attempted but found to be impractical and abandoned
C	**Coal Terminal Operators**	
1	Exterior Car Washing	Once in use at several terminals
2	Interior Car Washing	Suggested for empty car dusting problem
3	Thaw Sheds	In use at several terminals
4	Side Release Agents	Tested in the early 80s results unknown

5.3.1 Environment Canada's 1986 Recommended Practices

A series of studies into the problem of visible train dusting were conducted in the early 1980s. As part of those investigations, train loading and spraying practices were observed at several mines in Alberta and British Columbia from 1979 to 1984. The results of those observations indicated that the frequent occurrence of exposed (non-sealed) coal surfaces in rail cars, that had supposedly been sealed with chemicals, likely resulted from one of more of the following: (Cope 1986)

- Poorly designed spray apparatus;
- Inadequate maintenance procedures;
- Inappropriate sealant concentration;
- Incorrect spray chemicals;
- Inadequate loading, levelling and spray system operator training;
- Poorly functioning load levelling devices; and/or
- Weaknesses inherent in the sealant chemical spray technique.

To improve the control of fugitive coal dust from unit trains, all of the major coal mining companies in Western Canada in 1986 agreed to a number of *Recommended Practices*. The *Coal Dust Control, Recommended Practices for Loading, Unloading and Transporting Coal by Rail* were published by Environment Canada in 1986. (Wituschek 86) It was felt that following the application of these practices, illustrated in Appendix C, that consistent performance from the coal dust control systems could be achieved

5.3.2 Rail Car Dust Control at the Mines - 2000

While improvements have been reported in the coal dust control procedures at certain mines in Western Canada, an information update re the status of dust control equipment at mines was not available. Regardless, the visible dusting incidents reported in 2000 indicate that there are still equipment and procedural problems at certain mines that can lead to dusting trains.

Two examples of problems in relation to dust control were reported in 2000 and 2001:

- In 2001, one unconfirmed report indicated that at least one major coal mine in Western Canada, that shipped coal to Vancouver, was not spraying sealants on its loaded rail cars.
- In 2000 Transport Canada reported that they visited the Roberts Bank coal terminal to inspect the loaded coal cars on trains that had been judged to be *heavily* dusting. They observed nine cars in one train that had mid-load craters. (CTA 2000) Such craters are usually an indication that the level profile in a rail car has been disturbed after levelling and spraying in order to adjust the weight of over-loaded (weight) cars. These disturbed profiles are a known source of heavy fugitive emissions and the *Recommended Practice* for such actions was:

  When load adjustments are made at the mine, the load should be levelled and re-sprayed with sealant prior to departure from the mine site. (Wituschek 1986)

Tables 5.11 and 5.12 illustrate the information that would be required from each mine in order to adequately assess the dust control features and practices at each mine in Western Canada in relation to the *1986 Recommended Practices* for rail car dust control. Unfortunately, the mining companies contacted during the course of this investigation presented little or no information.

5.3.2.1 Crust-Retention at End of Journey

As noted in Section 5.2, since 1975, for sprayed coal loads in trains, the total crust remaining or retained on loaded rail cars at the End Terminals after a long journey has been used as a measure of dust control. The assessment of crust-retention is based upon the visual observation of exposed, non-crusted, coal surfaces when loaded trains arrive at the End Terminals. For the *1986 Recommended Practices*, the mines that ship coal to Vancouver, agreed that: (Wituschek 1986)

> *A minimum acceptable level of dust control is generally achieved under all conditions if the crust-retention of a train is at least 85%. The minimum objective for crust-retention is therefore 85% and should be calculated as a 'train average'.*

Unfortunately, crust-retention is only a crude gauge of dust control performance. One study in 1982 clearly stated that: (Holmes 1982)

> *The 85% crust-retention standard is inadequate since trains achieving a crust-retention level close to this value emit unacceptable levels of fugitive dust during periods of hot, dry weather.*

Also, as noted earlier, the company monitoring coal dusting from trains in Virginia consider that a car with 20% crust loss (or 80% crust-retention) is virtually uncontrolled in regard to dust emissions. (SWA 2001)

To date, a one-to-one link has not been established between crust-retention percentage at the end of a journey and the percentage dust control achieved en route. However, while crust-retention assessment may not provide a direct indication as to dust control efficiency, it can indicate when there are problems with the sealant spray and profile levelling systems at individual mines. Therefore, until another generally approved system is devised for dust control effectiveness assessment, crust-retention assessment is likely to be retained as a method for assessing dust control effectiveness.

5.3.3 Railcar Dust Control - The Railways

Table 5.13 lists the information that would be required from the railway companies in order to assess their current practices versus what was required by the *1986 Recommended Practices*. While little new information was available from the railway companies regarding their dust control procedures, the minutes of the public meeting in September 2000 in Hope, BC, indicated that the CPR stated that they had a *slow down* order in effect for dusting trains.

An industry-wide Action Committee on Coal Dust was formed in 2000. This committee comprises coal producers in BC and Alberta, CN, CP and the port facilities located in the Vancouver region. (Laing 2000) (See Appendix B)

A report of the Action Committee claims that: (Action 2000)

> *The railways reviewed operating procedures with train crews to ensure dusting trains are reported immediately and procedures for proper handling of dusting trains are followed.*

Table 5.11 Train Dust Control – Equipment 2001

Equipment		Sill Clean	Car Profile Load-Level Type	Compact	Adjust Load Backhoe	Re-level	Type of Sealant	Spray System Number or Spray Bars	Re-Spray Facility	Monitor Cones & Mixiing	Freeze Protection	Wind Protect
Mine	Prov.											

Table 5.12 Train Dust Control - Procedures - 2001

Equipment		Spray Systems Training Programs	Malfunction Procedures	Verification Procedures		Spray Cone &Volume	Inspect and Adjust During Car Spraying	Re-spray After Load Adjustment	Re-spray Cars if Required	Records of Spraying
Mine	Prov.			Equipment Function	Levelling					

Table 5.13 Railway - Train Dust Control Procedures

Railway Company	Group Cars of Similar Height	Speed Control Systems at Load-Out Facilities	Reduce Speed of Dusting Trains
CP			Claim a slow down order is in effect for dusting trains.
CN			
BCR			
Imports			
Rail to Vancouver			
Rail to Thunder Bay			

Table 5.14 Coal Terminals - Rail Car Dust Controls – Equipment & Procedures – 2001

Port	Prov	Empty Car Wash Exterior	Empty Car Wash Interior	Waste Water Collection & Treat	Empty Car Air Wash	Empty Car Sealant Spray	Treat Cars for Frozen Coal
Westshore	BC	yes	no	yes	no	no	freeze protection for car spray
Neptune	BC	no	no	yes	no	no	no
Texada	BC						
Ridley	BC						
Thunder Bay	Ont						
Procedures		**Training Programs**	**Equipment Malfunction Procedures**	**Standby Spray Truck for Malfunctions**	**Inspect all Empty Cars**	**Enclosed Rotary Dumper**	**Dump at Maximum Angle**
Westshore	BC					yes	yes
Neptune	BC	yes	yes	yes	no	yes	yes
Texada	BC						
Ridley	BC					no	
Thunder Bay	Ont						

5.3.4 Railcar Dust Control - Terminals

The *empty* railcar dust control procedures, as reported by two End Terminals for 2000, are illustrated in Table 5.14. The procedure of ensuring that their rotary-dumpers are turned to the maximum angle, was not in the *1986 Recommended Practices*. This technique was one of the actions reported by the industry *Action Committee on Coal Dust*. (Action 2000)

One terminal reported that it employs an external sill car wash to clean the rail cars after they are dumped. While this wash should eliminate one source of dust associated with empty cars, it would not remove coal that may be left inside of a car.

5.4 Coal Dust Emissions Estimates
Rail Transport – 2000

Estimates of the fugitive coal dust emissions for rail transport in Canada in 2000 were attempted for coal shipped by rail in 2000. Three sets of estimates have been prepared:

(While the production data for most mines were available for 2000, some 1999 data were used. It was felt that for most cases the changes from 1999 to 2000 were likely minor.)

1] Estimates were made using a CAC Inventory uncontrolled EF that was modified to include a dust control efficiency of 99%. However, the 99% efficiency control was applied differently than was the case for the 1995 CAC Inventory estimates. For this example, it was assumed the basic CAC EF is uncontrolled and not at the 75% level to start. This EF was used to estimate emissions for each provincial distance segment, Tables 5.15a and b.

2] Estimates were made using the CAC Inventory uncontrolled EF and the 99% control as in case 1] above to estimate total trip emissions. Then a linear distance function was used to apportion estimates by province, Tables 5.16a and b.

3] Estimates were made using the BC MELP EF of 0.5% of total throughput but assuming 99% control efficiency for those emissions, Tables 5.17a and b.

While a dust control of 99% may appear high, it is the dust control efficiency currently assumed by Environment Canada for assessing national rail coal dust emissions. It is also supported by the evidence that only just over 1% of the loaded coal trains observed in Hope, BC in 2000 were assessed as 'heavy' emitters in terms of visible dust emissions.

Of the four modifying factors noted in Section 5.2.4, three were used to make these estimates: PM_{10} and $PM_{2.5}$ scaling factors, distance factors and a dust control factor. The use of a precipitation factor is discussed in Section 5.4.1.

Also, for the CAC Inventory related emission calculations, the following changes, related to possible errors in regard to mines, were made:

- Quinsam mine in BC – the coal does not travel by rail, it travels by truck and barge.
- Highvale, Whitewood, Genesee mines in Alberta – coal travels by truck not train.
- Boundary Dam mine in Saskatchewan – coal travels by truck only.
- Poplar River mine in Saskatchewan – while coal does go by train to a power plant, the plant is only 20 km away not 192 km as now used.
- Bienfait mine in Saskatchewan – ships some coal by rail to Ontario for use at power plants near the Lakehead. Therefore there should be rail distances for Sask, Man and Ontario not just 58km for Sask.
- The Prince mine in NS (that closed in November 2001) – shipped to a nearby Power Plant.
- Trenton Power Plant in NS – do not think the coal goes by rail? This should be confirmed.
- Sheerness and Paintearth in Alta mines move coal only short distances by truck to local PPs.

Table 5.15a CAC EF Conventional Rail Dust Emissions Estimates – 2000 – Total Particulate

Total Particulate Emission factors – 99% control **Total Particulate Emissions Estimates –99% control**

Coal by Rail (CAC 1995 EFs) **in kg/tonne** (Using CAC 1995 EFs) **Emissions in Tonnes for 2000**

	Prov	Coal	Dist	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld	Province	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Mines		Mt	km		PART	with	99%	control				Mines		PART	PART	PART	PART	PART	PART	PART
Bullmoose	BC	1.60	1180	0.052								Bullmoose	83.69							
Coal Mountain	BC	2.00	2073	0.008	0.031	0.036	0.033	0.025				Coal Mountain	16.62	62.12	71.65	65.96	50.28			
Coal Mountain#	BC	0.30	1141	0.051								Coal Mountain#	15.38							
Elkview (Balmer)	BC	3.00	1055	0.049								Elkview (Balmer)	146.73							
Fording River*	BC	8.30	1169	0.052								Fording River*	431.72							
Greenhills*	BC	4.20	989	0.047								Greenhills*	197.61							
Line Creek	BC	3.00	1141	0.051								Line Creek	153.79							
Line Creek#	BC	0.50	2102	0.011	0.031	0.036	0.033	0.025				Line Creek#	5.36	15.53	17.91	16.49	12.57			
Quintette	BC	1.00	1250	0.054								Quintette	54.15							
Coal Valley	Alta	0.70	1093	0.041	0.023							Coal Valley	28.74	16.26						
Coal Valley#	Alta	0.20	1381	0.051	0.02							Coal Valley#	10.28	3.96						
Coal Valley#	Alta	0.10	2282		0.035	0.041	0.038	0.017				Coal Valley#		3.52	4.13	3.78	1.75			
Gregg River	Alta	1.50	1114	0.041	0.024							Gregg River	61.58	36.26						
Gregg River#	Alta	0.50	1408	0.052	0.02							Gregg River#	26.15	9.75						
Gregg River#	Alta	0.10	2309		0.041	0.036	0.033	0.025				Gregg River#		4.10	3.58	3.30	2.51			
Luscar	Alta	2.00	1108	0.041	0.024							Luscar	82.11	47.81						
Luscar#	Alta	0.50	1404	0.051	0.021							Luscar#	25.71	10.48						
Luscar#	Alta	0.30	2305		0.036	0.041	0.038	0.017				Luscar#		10.79	12.38	11.35	5.25			
Obed	Alta	1.50	958	0.041	0.016							Obed	61.58	24.54						
Obed#	Alta	0.20	1257	0.051	0.013							Obed#	10.28	2.52						
Obed#	Alta	0.10	2264		0.035	0.041	0.038	0.017				Obed#		3.45	4.13	3.78	1.75			
Smoky River*	Alta	1.80	1180	0.043	0.025							Smoky River*	76.51	45.02						
Bienfait	Sask	1.90	58			0.009						Bienfait			16.30					
Bienfait#	Sask	0.10	1086			0.022	0.033	0.025				Bienfait#			2.23	3.30	2.51			
Poplar River	Sask	4.00	20			0.005						Poplar River			18.12					
Prince	NS	0.98	8							0.003		Prince							2.55	
Nfld Import via Que	Imp	0.05	350						0.018		0.015	Nfld Import via Que						0.89		0.75
Totals =												Canada = 2123.3	1487.99	296.12	150.44	107.96	76.62	0.89	2.55	0.75

* 1999 data # estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

Table 5.15b CAC EF Conventional Rail Dust Emissions Estimates – 2000 - PM_{10} and $PM_{2.5}$

PM_{10} Emissions in tonnes (PM_{10} = PART with 99% control x 0.5)

Province	Prov	BC	Alta	Sask	Man	Ont	Que	NS	Nfld
Mines			PM_{10}	PM_{10}	PM_{10}	PM_{10}	PM_{10}	PM_{10}	PM_{10}
Bullmoose	BC	41.85							
Coal Mountain	BC	8.31	31.06	35.83	32.98	25.14			
Coal Mountain#	BC	7.69							
Elkview (Balmer)	BC	73.36							
Fording River*	BC	215.86							
Greenhills*	BC	98.80							
Line Creek	BC	76.89							
Line Creek#	BC	2.68	7.76	8.96	8.24	6.29			
Quintette	BC	27.07							
Coal Valley	Alta	14.37	8.13						
Coal Valley#	Alta	5.14	1.98						
Coal Valley#	Alta		1.76	2.06	1.89	0.87			
Gregg River	Alta	30.79	18.13						
Gregg River#	Alta	13.08	4.88						
Gregg River#	Alta		2.05	1.79	1.65	1.26			
Luscar	Alta	41.05	23.91						
Luscar#	Alta	12.86	5.24						
Luscar#	Alta		5.39	6.19	5.68	2.62			
Obed	Alta	30.79	12.27						
Obed#	Alta	5.14	1.26						
Obed#	Alta		1.73	2.06	1.89	0.87			
Smoky River*	Alta	38.26	22.51						
Bienfait	Sask			8.15					
Bienfait#	Sask			1.12	1.65	1.26			
Poplar River	Sask			9.06					
Prince	NS							1.27	
Nfld Import - Que	Imp						0.45		0.38
Totals =		744.00	148.06	75.22	53.98	38.31	0.45	1.27	0.38

$PM_{2.5}$ Emissions in tonnes ($PM_{2.5}$ = PART with 99% control x 0.2)

Province	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Mines		$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$
Bullmoose	16.74							
Coal Mountain	3.32	12.42	14.33	13.19	10.06			
Coal Mountain#	3.08							
Elkview (Balmer)	29.35							
Fording River*	86.34							
Greenhills*	39.52							
Line Creek	30.76							
Line Creek#	1.07	3.11	3.58	3.30	2.51			
Quintette	10.83							
Coal Valley	5.75	3.25						
Coal Valley#	2.06	0.79						
Coal Valley#		0.70	0.83	0.76	0.35			
Gregg River	12.32	7.25						
Gregg River#	5.23	1.95						
Gregg River#		0.82	0.72	0.66	0.50			
Luscar	16.42	9.56						
Luscar#	5.14	2.10						
Luscar#		2.16	2.48	2.27	1.05			
Obed	12.32	4.91						
Obed#	2.06	0.50						
Obed#		0.69	0.83	0.76	0.35			
Smoky River*	15.30	9.00						
Bienfait			3.26					
Bienfait#			0.45	0.66	0.50			
Poplar River			3.62					
Prince							0.51	
Nfld Import Que						0.18		0.15
Totals =	297.60	59.22	30.09	21.59	15.32	0.18	0.51	0.15

* 1999 data # estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

Table 5.16a New CAC EF Rail Dust Emissions Estimates – 2000 – Total Particulate

Total Particulate Emissions Estimates - PART with 99% Control

Emissions in Tonnes for 2000

Mine		Coal Mt	Total Distance km	New CAC EF Total Trip Kg/tonne	Emissions Total Trip tonnes	Mine	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Bullmoose	BC	1.60	1180	0.052	83.69	Bullmoose	83.69							
Coal Mountain	BC	2.00	2073	0.073	146.70	Coal Mountain	3.89	35.03	44.44	38.71	24.63			
Coal Mountain#	BC	0.30	1141	0.051	15.38	Coal Mountain#	15.38							
Elkview (Balmer)	BC	3.00	1055	0.049	146.73	Elkview (Balmer)	146.73							
Fording River*	BC	8.30	1169	0.052	431.72	Fording River*	431.72							
Greenhills*	BC	4.20	989	0.047	197.61	Greenhills*	197.61							
Line Creek	BC	3.00	1141	0.051	153.79	Line Creek	153.79							
Line Creek#	BC	0.50	2102	0.074	36.98	Line Creek#	1.48	8.71	11.05	9.62	6.12			
Quintette	BC	1.00	1250	0.054	54.15	Quintette	54.15							
Coal Valley	Alta	0.70	1093	0.050	34.97	Coal Valley	25.21	9.76						
Coal Valley#	Alta	0.20	1381	0.057	11.50	Coal Valley#	9.55	1.95						
Coal Valley#	Alta	0.10	2282	0.078	7.77	Coal Valley#		2.07	2.71	2.34	0.65			
Gregg River	Alta	1.50	1114	0.051	75.80	Gregg River	53.62	22.18						
Gregg River#	Alta	0.50	1408	0.058	29.08	Gregg River#	24.37	4.71						
Gregg River#	Alta	0.10	2309	0.078	7.83	Gregg River#		2.66	2.13	1.85	1.18			
Luscar	Alta	2.00	1108	0.050	100.74	Luscar	71.64	29.09						
Luscar#	Alta	0.50	1404	0.058	29.03	Luscar#	23.71	5.31						
Luscar#	Alta	0.30	2305	0.078	23.45	Luscar#		6.43	8.09	7.00	1.93			
Obed	Alta	1.50	958	0.046	69.24	Obed	56.95	12.29						
Obed#	Alta	0.20	1257	0.054	10.87	Obed#	9.92	0.95						
Obed#	Alta	0.10	2264	0.077	7.73	Obed#		2.02	2.72	2.35	0.65			
Smoky River*		1.80	1180	0.052	94.15	Smoky River*	66.63	27.53						
Bienfait	Sask	1.90	58	0.009	16.30	Bienfait			16.30					
Bienfait#	Sask	0.10	1086	0.052	5.23	Bienfait#			1.26	2.42	1.54			
Poplar River	Sask	4.00	20	0.005	18.12	Poplar River			18.12					
Prince	NS	0.98	8	0.003	2.56	Prince							2.56	
Nfld Import via Que	Imp	0.05	350	0.025	1.25	Nfld Import - Que						0.71		0.53
				Totals =	1812.35	Totals =	1430.03	170.69	106.81	64.30	36.70	0.71	2.56	0.53

* 1999 data # estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

Table 5.16b New CAC EF Rail Dust Emissions Estimates – 2000 – PM_{10} and $PM_{2.5}$

PM_{10} = PART with 99% control x 0.5 scaling factor

Emissions in Tonnes for 2000

Mine		BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Bullmoose	BC	41.85							
Coal Mountain	BC	1.95	17.51	22.22	19.35	12.31			
Coal Mountain#	BC	7.69							
Elkview (Balmer)	BC	73.36							
Fording River*	BC	215.86							
Greenhills*	BC	98.80							
Line Creek	BC	76.89							
Line Creek#	BC	0.74	4.35	5.52	4.81	3.06			
Quintette	BC	27.07							
Coal Valley	Alta	12.61	4.88						
Coal Valley#	Alta	4.77	0.97						
Coal Valley#	Alta		1.04	1.35	1.17	0.32			
Gregg River	Alta	26.81	11.09						
Gregg River#	Alta	12.18	2.35						
Gregg River#	Alta		1.33	1.06	0.93	0.59			
Luscar	Alta	35.82	14.55						
Luscar#	Alta	11.86	2.66						
Luscar#	Alta		3.21	4.04	3.50	0.97			
Obed	Alta	28.48	6.14						
Obed#	Alta	4.96	0.48						
Obed#	Alta		1.01	1.36	1.18	0.32			
Smoky River*		33.31	13.76						
Bienfait	Sask			8.15					
Bienfait#	Sask			0.63	1.21	0.77			
Poplar River	Sask			9.06					
Prince	NS							1.28	
Nfld Import -Que	Imp						0.36		0.27
Totals =		715.01	85.35	53.41	32.15	18.35	0.36	1.28	0.27

$PM_{2.5}$ = PART with 99% control x 0.2 scaling factor

Emissions in Tonnes for 2000

Mine	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Bullmoose	16.74							
Coal Mountain	0.78	7.01	8.89	7.74	4.93			
Coal Mountain#	3.08							
Elkview (Balmer)	29.35							
Fording River*	86.34							
Greenhills*	39.52							
Line Creek	30.76							
Line Creek#	0.30	1.74	2.21	1.92	1.22			
Quintette	10.83							
Coal Valley	5.04	1.95						
Coal Valley#	1.91	0.39						
Coal Valley#		0.41	0.54	0.47	0.13			
Gregg River	10.72	4.44						
Gregg River#	4.87	0.94						
Gregg River#		0.53	0.43	0.37	0.24			
Luscar	14.33	5.82						
Luscar#	4.74	1.06						
Luscar#		1.29	1.62	1.40	0.39			
Obed	11.39	2.46						
Obed#	1.98	0.19						
Obed#		0.40	0.54	0.47	0.13			
Smoky River*	13.33	5.51						
Bienfait			3.26					
Bienfait#			0.25	0.48	0.31			
Poplar River			3.62					
Prince							0.51	
Nfld Import Que						0.14		0.11
Totals =	286.01	34.14	21.36	12.86	7.34	0.14	0.51	0.11

* 1999 data

estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

Table 5.17a New BC MELP EF Rail Dust Emissions Estimates – 2000 – Total Particulate

Total Particulate Emissions Estimates - PART with 99% Control

Emissions in Tonnes for 2000

Mine		Coal Mt	Total Distance km	BC MELP EF Total Trip t/tonne	Emissions Total Trip tonnes	Mine	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
				.5/100*1/100										
Bullmoose	BC	1.60	1180	0.00005	80.00	Bullmoose	80.00							
Coal Mountain	BC	2.00	2073	0.00005	100.00	Coal Mountain	2.65	23.88	30.29	26.39	16.79			
Coal Mountain#	BC	0.30	1141	0.00005	15.00	Coal Mountain#	15.00							
Elkview (Balmer)	BC	3.00	1055	0.00005	150.00	Elkview (Balmer)	150.00							
Fording River*	BC	8.30	1169	0.00005	415.00	Fording River*	415.00							
Greenhills*	BC	4.20	989	0.00005	210.00	Greenhills*	210.00							
Line Creek	BC	3.00	1141	0.00005	150.00	Line Creek	150.00							
Line Creek#	BC	0.50	2102	0.00005	25.00	Line Creek#	1.00	5.89	7.47	6.51	4.14			
Quintette	BC	1.00	1250	0.00005	50.00	Quintette	50.00							
Coal Valley	Alta	0.70	1093	0.00005	35.00	Coal Valley	25.23	9.77						
Coal Valley#	Alta	0.20	1381	0.00005	10.00	Coal Valley#	8.31	1.69						
Coal Valley#	Alta	0.10	2282	0.00005	5.00	Coal Valley#		1.33	1.74	1.51	0.42			
Gregg River	Alta	1.50	1114	0.00005	75.00	Gregg River	53.05	21.95						
Gregg River#	Alta	0.50	1408	0.00005	25.00	Gregg River#	20.95	4.05						
Gregg River#	Alta	0.10	2309	0.00005	5.00	Gregg River#		1.70	1.36	1.18	0.75			
Luscar	Alta	2.00	1108	0.00005	100.00	Luscar	71.12	28.88						
Luscar#	Alta	0.50	1404	0.00005	25.00	Luscar#	20.42	4.58						
Luscar#	Alta	0.30	2305	0.00005	15.00	Luscar#		4.11	5.17	4.48	1.24			
Obed	Alta	1.50	958	0.00005	75.00	Obed	61.69	13.31						
Obed#	Alta	0.20	1257	0.00005	10.00	Obed#	9.12	0.88						
Obed#	Alta	0.10	2264	0.00005	5.00	Obed#		1.31	1.76	1.52	0.42			
Smoky River*		1.80	1180	0.00005	90.00	Smoky River*	63.69	26.31						
Bienfait	Sask	1.90	58	0.00005	95.00	Bienfait			95.00					
Bienfait#	Sask	0.10	1086	0.00005	5.00	Bienfait#			1.21	2.32	1.47			
Poplar River	Sask	4.00	20	0.00005	200.00	Poplar River			200.00					
Prince	NS	0.98	8	0.00005	49.00	Prince							49.00	
Nfld Import via Que	Imp	0.05	350	0.00005	2.47	Nfld Import Que						1.41		1.06
				Totals =	2021.47	Totals =	1407.24	149.63	344.00	43.90	25.23	1.41	49.00	1.06

* 1999 data

estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

Table 5.17b New BC MELP EF Rail Dust Emissions Estimates – 2000 – PM_{10} and $PM_{2.5}$

PM_{10} = PART with 99% control x 0.5 scaling factor

Emissions in Tonnes for 2000

Mine		BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Bullmoose	BC	40.00							
Coal Mountain	BC	1.33	11.94	15.15	13.19	8.39			
Coal Mountain	BC	7.50							
Elkview (Balmer)	BC	75.00							
Fording River*	BC	207.50							
Greenhills*	BC	105.00							
Line Creek	BC	75.00							
Line Creek	BC	0.50	2.94	3.73	3.25	2.07			
Quintette	BC	25.00							
Coal Valley	Alta	12.62	4.88						
Coal Valley	Alta	4.15	0.85						
Coal Valley	Alta		0.67	0.87	0.75	0.21			
Gregg River	Alta	26.53	10.97						
Gregg River	Alta	10.48	2.02						
Gregg River	Alta		0.85	0.68	0.59	0.38			
Luscar	Alta	35.56	14.44						
Luscar	Alta	10.21	2.29						
Luscar	Alta		2.06	2.59	2.24	0.62			
Obed	Alta	30.85	6.65						
Obed	Alta	4.56	0.44						
Obed	Alta		0.65	0.88	0.76	0.21			
Smoky River*		31.84	13.16						
Bienfait	Sask			47.50					
Bienfait	Sask			0.60	1.16	0.74			
Poplar River	Sask			100.00					
Prince	NS							24.50	
Nfld Import	Imp						0.71		0.53
Totals =		703.62	74.82	172.00	21.95	12.61	0.71	24.50	0.53

$PM_{2.5}$ = PART with 99% control x 0.2 scaling factor

Emissions in Tonnes for 2000

Mine	BC	ALTA	SASK	MAN	ONT	Que	NS	Nfld
Bullmoose	16.00							
Coal Mountain	0.53	4.78	6.06	5.28	3.36			
Coal Mountain	3.00							
Elkview (Balmer)	30.00							
Fording River	83.00							
Greenhills	42.00							
Line Creek	30.00							
Line Creek	0.20	1.18	1.49	1.30	0.83			
Quintette	10.00							
Coal Valley	5.05	1.95						
Coal Valley	1.66	0.34						
Coal Valley		0.27	0.35	0.30	0.08			
Gregg River	10.61	4.39						
Gregg River	4.19	0.81						
Gregg River		0.34	0.27	0.24	0.15			
Luscar	14.22	5.78						
Luscar	4.08	0.92						
Luscar		0.82	1.03	0.90	0.25			
Obed	12.34	2.66						
Obed	1.82	0.18						
Obed		0.26	0.35	0.30	0.08			
Smoky River	12.74	5.26						
Bienfait			19.00					
			0.24	0.46	0.29			
Poplar River			40.00					
Prince							9.80	
Nfld Import						0.28		0.21
Totals =	281.45	29.93	68.80	8.78	5.05	0.28	9.80	0.21

* 1999 data

estimate quantity shipped in 2000 & subtract from total shipped to principal terminal

5.4.1 Application of a Precipitation Factor

As noted, the EFs used so far in Section 5.4 do not include a factor that accounts for the influence of weather, notably precipitation and snow, en route. It would be difficult to apply a weather factor that would apply year long to any single long distance rail route in Canada. However, as an example of the potential influence of weather, the Lower Fraser Valley example is used to illustrate the potential impact of applying a precipitation factor to the emission estimates, Table 5.18.

The number of rain and snow days for the three communities of Kamloops, Hope and Abbotsford on the coal rail route to Vancouver were estimated in Table 5.7. These data indicate the variation that is possible in relation to weather. The communities used in this example only span a portion of the route from the mines on the BC/Alberta border to Vancouver. In Abbotsford in 2000 the precipitation for almost one third of the year met the precipitation day criteria whereas in Kamloops that level of precipitation was only recorded on 27 days. In Hope, precipitation records were only available for nine months, but for those nine months the precipitation days were over twice the number recorded in Kamloops for the entire year.

Table 5.18 illustrates the impact on emission estimates of the application of a simple precipitation factor, as illustrated in equation 5.7, Section 5.2.4.

5.5 Discussion – Fugitive Coal Dust Emissions – Rail Transportation

The BC MELP EF for fugitive coal dust emissions employs a set percent emission per tonne carried. However, since it does not incorporate distance, there is a problem with its application to large amounts of coal carried short distances. The BC MELP EF is best suited for estimating emissions that are related to its derivation. That is, coal carried at least 1100 km. For that scenario, the BC MELP EF and the CAC EF provide approximately identical coal dust emissions estimates.

If the modified CAC EF emissions estimates are prorated by segment distance, the provincial or regional segments are similar to those produced by the BC MELP EF. Therefore, since the CAC EF provides what appear to be more reasonable estimates for the dust emissions for coal shipped over short distances, it is recommended.

However, the basic CAC EF, as recommended in this study, has been modified. Unlike the NEIPTG Guidebook recommendation, the basic CAC EF is considered to be the uncontrolled EF and not the 75% control EF.

In addition, as noted, for emission estimates this basic EF should be modified to account for distance, control efficiency, particulate size and precipitation.

Different PM_{10} and $PM_{2.5}$ scaling factors were employed for the estimates in this report. It was felt that the scaling factors currently employed by Environment Canada, GVRD, the BC MELP were too large and overestimated emissions in these two particulate ranges.

There are still no definitive data to directly link the dust control effectiveness of the systems currently employed to suppress rail car dust by the coal mines in Western Canada to a control efficiency percentage. Therefore, for the emissions calculations in this study it was decided to err on the side of caution and choose an efficiency of 99%. This is the same efficiency that is currently used by Environment Canada for their emissions calculations.

While a number of visible dusting events that lead to citizen complaint were registered in 2000, there is also no quantitative data to relate those visible dusting events to overall dust control efficiency. Suffice to say that these visible dusting events confirmed that for 2000 the emissions control effectiveness of the dust suppressant systems used by the mines that ship coal to Vancouver was less than 100%.

While temperature and wind en route can influence dust emissions, no method was discovered for quantifying the effect

Table 5.18 Precipitation Factor Example

Precipitation Factor Final EF = EF x (365-P)/365	Distance D	tonnes shipped through Vancouver in 2000	Basic EF t/tonne	Total Particulate Emissions in tonnes	Abbotsford Rain and Snow Days in 2000	Precipitation Adjusted Emissions Using Abbotsford tonnes	Kamloops Rain and Snow Days in 2000	Precipitation Adjusted Emissions Using Kamloops tonnes
Use BC MOE EF and assume 99% control								
	1100	27,462,000	0.000050	1,373	110	959	27	1272
Prorate Using a Distance of 100km LFV								
	100	27,462,000	0.0000045	125	110	87	27	116

Excerpt from Table 5.7 – Precipitation Days for 2000

12 months data				9 months data				12 months data			
Abbotsford Rain		Abbotsford Snow		Hope Rain		Hope Snow		Kamloops Rain		Kamloops Snow	
Total	110		0		58		7		27		0

Chapter 6

Truck Transport of Coal Fugitive Dust Emission and Control

6.1 Truck Transport

As noted, fugitive coal dust emissions associated with coal by moved by trucks at mine sites and around other coal handling facilities are considered to be incorporated into the coal handling EFs and the estimates for coal mines and Coal Terminals, Chapter 4 and Chapter 8. The truck movements referred to in this Chapter are those associated with the shipment of coal from mine site, or from receiving terminal, to end-user facility by truck in Canada in 2000.

From the data available, it appears that most of the coal carried by trucks in Canada is from the large surface mines in Alberta and Saskatchewan to nearby electric power plants.

As noted in Section 5.4, the 1995 CAC Inventory has listed shipments of coal from several mines as being by train when they are actually shipped by truck. These corrections have been made for the estimates in Section 5.4 and in Table 6.1.

6.2 Emission Factors - Trucks

No provincial or federal agency is presently calculating coal dust emissions from truck transport. For estimates in this Chapter, the CAC EF that was employed for rail was also used for truck transport, Table 6.1 and 6.2. The PM_{10} and $PM_{2.5}$ scaling factors that were used for rail transport were also employed. No attempt was made to produce a precipitation factor.

6.3 Dust Controls - Trucks

The most readily available method for controlling dust from trucks carrying coal would be to cover the load in the truck. Information related to the use of truck covers in Canada for coal shipped in 2000 was not available. Therefore, as per the rail emissions calculations, a control efficiency of 99% was employed as were the same PM_{10} and $PM_{2.5}$ scaling factors.

6.4 Coal Dust Emissions Estimates - Trucks

For 2000, the emissions estimates for trucks carrying coal in each province in Canada are illustrated in Table 6.2. Please note that it was necessary to estimate many of the distances travelled using a map reference.

Because of the limited amount of information available regarding the transport of coal by truck in Canada in 2000, these estimates must be considered as only very rough indications of possible emissions.

Table 6.1 Coal Truck Transportation Emissions – 2000 – Total Particulate

Mines		Coal in 2000 Mt	Destination	Dist	Distance by Truck in km BC	ALTA	SASK	ONT	EFs Using CAC Rail EFs in kg/tonne (assume 99% control of PART) NS	NB	$EF = 0.1x(0.62xD)^{0.6}x(100-99)/100$	CAC EF Total Trip kg/tonne	Emissions Total Trip tonnes
Bullmoose	BC	1.6	Rail Loadout	36	36						Bullmoose	0.006	10.31
Quinsam #	BC	0.24	Comox	50	50						Quinsam	0.008	1.88
Genesee *	Alta	3.60	Local PP	10		10					Genesee	0.003	10.76
Highvale	Alta	13.00	Local PPs	10		10					Highvale	0.003	38.85
Paintearth	Alta	3.50	Local PP	5		5					Paintearth	0.002	6.90
Sheerness	Alta	4.00	Local PP	5		5					Sheerness	0.002	7.89
Whitewood *	Alta	2.30	Local PP	10		10					Whitewood	0.003	6.87
Bienfait #	Sask	0.20	Local Char	5			5				Bienfait	0.002	0.39
Boundary Dam/Shand	Sask	6.50	Local PPs	10			10				Boundary Dam/Shand	0.003	19.42
Minto to Grand Lake	NB	0.12	Grand Lake	35						35	Minto to Grand Lake	0.006	0.77
Minto to Belledune #	NB	0.12	Belledune	270						270	Minto to Belledune	0.022	2.62
Alder Point #	NS	0.06	Coal Yard	40					40		Alder Point	0.007	0.41
Coalburn #	NS	0.03	Local PP	20					20		Coalburn	0.005	0.12
Little Pond	NS	0.01	Local PP	50					50		Little Pond	0.008	0.05
Springhill Rail Bed #	NS	0.01	Local PP	100					100		Springhill Rail Bed	0.012	0.12
St. Rose #	NS	0.03	Local PP	200					200		St. Rose	0.018	0.60
Stellarton #	NS	0.20	Local PP	20					20		Stellarton	0.005	0.91
Imported Coal											**Imported Coal**		
NS Power Corp #	NS	1.2	Lingan PP	20					20		NS Power Corp	0.005	5.44
NS Power Corp #	NS	0.85	Trenton PP	100					100		NS Power Corp	0.012	10.11
Lafarge Canada, NS #	NS	0.035	Kilns	80					80		Lafarge Canada, NS	0.010	0.36
St. Mary's Cement #	Ont	?	Cement	80				80			St. Mary's Cement	0.010	?
											Totals =		124.79

*** 1999 data** **# distances are approximations**

Table 6.2 Emissions Estimates for Coal Transported by Truck – 2000

	PART in tonnes PART with 99% Control						PM_{10} in tonnes PM_{10} = PART with 99% control x 0.5						$PM_{2.5}$ in tonnes $PM_{2.5}$ = PART with 99% control x 0.2					
Originating Mines	**BC**	**Alta**	**Sask**	**Ont**	**NS**	**NB**	**BC**	**Alta**	**Sask**	**Ont**	**NS**	**NB**	**BC**	**Alta**	**Sask**	**Ont**	**NS**	**NB**
British Columbia																		
Bullmoose	10.31						5.2						2.1					
Quinsam	1.88						0.9						0.4					
Alberta																		
Genesee		10.8						5.4						2.2				
Highvale		38.8						19.4						7.8				
Paintearth		6.9						3.5						1.4				
Sheerness		7.9						3.9						1.6				
Whitewood		6.9						3.4						1.4				
Saskatchewan																		
Bienfait			0.4						0.2						0.1			
Boundary Dam/Shand			19.4						9.7						3.9			
New Brunswick																		
Minto to Grand Lake						0.8						0.4						0.2
Minto to Belledune						2.6						1.3						0.5
Nova Scotia												1.7						0.7
Alder Point					0.4						0.2						0.1	
Coalburn					0.1						0.1						0.0	
Little Pond					0.1						0.0						0.0	
Springhill Rail Bed					0.1						0.1						0.0	
St. Rose					0.6						0.3						0.1	
Stellarton					0.9						0.5						0.2	
Coal Imported by																		
Nova Scotia																		
NS Power Corp					5.4						2.7						1.1	
NS Power Corp					10.1						5.1						2.0	
Lafarge Canada, NS					0.4						0.2						0.1	
Ontario																		
St. Mary's Cement				?						?						?		
Totals =	12.20	71.27	19.82	0.00	18.12	3.39	6.10	35.63	9.91	0.00	9.06	3.39	2.44	14.25	3.96	0.00	3.62	1.36

6.5 Discussion – Fugitive Coal Dust – Truck Transportation

The CAC EF for rail emissions was used for providing a first approximation of the potential for fugitive coal dust emissions from coal transported by truck. However, since virtually no recent data was available in regard to transport of coal by truck in Canada, one should not harbour any illusions regarding the accuracy of these emissions estimates. They are rough approximations at best.

Given the origins of the railcar dusting EF, i.e. unit trains carrying coal over a thousand kilometres, it is likely that this EF is not representative of the EF for a single coal truck driven over a relatively short distance. In addition, no information was available regarding the emissions controls used by the various companies involved to limit dusting from their trucks in 2000.

As for coal mines, the large quantities of coal that are moved by truck in Alberta and Saskatchewan, and hence associated dusting, likely occur in areas remote from most large urban populations. Therefore the impact of the fugitive dust emissions from truck transport on those urban populations may be slight.

Chapter 7

Coal Storage Piles
Fugitive Dust Emission and Control

7.1 Coal Storage Piles

In Canada in 2000, coal was likely stored in piles in a host of locations throughout the country. Every mine, transfer facility, Coal Terminal and end-use facility is likely to have at least one storage pile for coal. It is also likely that at each of these many sites, the quantity of coal stored varied throughout the year. An attempt to list the more likely sites for large storage piles in Canada in 2000 was attempted in Table 2.9.

This list did not include the coal mines. All coal mines are likely to store coal in piles at various locations on their mine property. For coal mines, fugitive dust emissions from the associated storage piles may be included in the fugitive coal dust emissions EFs that the EPA developed for coal mining, see Chapter 4.

Inherent in operations that use coal is the maintenance of outdoor storage piles. Because of the need for frequent material transfer into or out of storage, storage piles are often not covered. Dust emissions occur at several points in the storage cycle, such as material loading onto the pile, disturbances by strong wind currents while the coal is in storage and material load-out from the pile. The movement of trucks and loading equipment in the storage pile area is also a source of dust.

Since 1980 complaints regarding nuisance fugitive coal dusting from coal storage piles have been registered in Nova Scotia, Ontario, Manitoba and British Columbia. However, no agency in Canada appears to have made fugitive dust emissions estimates for the storage piles in their region or province.

Because of the many variable involved, and the lack of information regarding coal storage piles in Canada in 2000, emissions from storage piles were not attempted in this investigation.

7.2 Emission Factors - Storage Piles

Despite the paucity of information regarding coal storage in Canada, EFs for estimating fugitive dust emissions are available. The US EPA provides an emission factors for aggregate handling and storage piles in Section 13.2.4 of AP-42.

Aggregate Handling and Storage Piles (EPA 2001-3)

Emissions and Correction Parameters

The quantity of dust emissions from aggregate storage operations varies with the volume of aggregate passing through the storage cycle. Emissions also depend on 3 parameters of the condition of a particular storage pile: age of the pile, moisture content, and proportion of aggregate fines.

Predictive Emission Factor Equations

Total dust emissions from aggregate storage piles result from several distinct source activities within the storage cycle:

1. Loading of aggregate onto storage piles (batch or continuous drop operations).
2. Equipment traffic in storage area.
3. Wind erosion of pile surfaces and ground areas around piles.
4. Loadout of aggregate for shipment or for return to the process stream (batch or continuous drop operations).

Either adding aggregate material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation.

The quantity of particulate emissions generated by either type of drop operation, per tonne of material transferred, may be estimated using the following empirical expression:

$$EF = k \times (0.0016) \times (U/2.2)^{1.3} / (M/2)^{1.4} \text{ (kg/megagram) (6.1)}$$

Where:
EF = emission factor
k = particle size multiplier (dimensionless)
U = mean wind speed, meters per second (m/s) (miles per hour [mph])
M = material moisture content (%)
The particle size multiplier in the equation, k, varies with aerodynamic particle size range, as follows:

Aerodynamic Particle Size Multiplier (k)				
<30 µm	<15 µm	<10 µm	<5 µm	< 2.5 µm
0.74	0.48	0.35	0.20	0.11

The AP-42 reference on *Emission Factor Equations for Uncontrolled Open Dust Sources at Western Surface Coal Mines* Table 11.9-2 (Metric Units) has an active storage pile EF for wind erosion and maintenance: (EPA 2001-2)

EF for active coal storage pile = 1.8 u in kg/(hectare)(hr) (6.2)

Where u = wind speed (m/sec)

Unfortunately, the detail regarding the storage of coal in Canada at the various locations that would have allowed the application of even a simple formula, such as represented by equation 6.2, was not available. The application of equation 6.2 would require hourly wind readings plus dimensions for each coal pile in Canada in order to apply this factor with any accuracy.

7.3 Dust Control – Storage Piles

One of the best ways to control fugitive dusting from the storage of coal would be to enclose the pile. However, most coal storage piles in Canada are uncovered. The conventional methods for controlling dusting related to these uncovered piles include:

- fixed water spray towers
- water sprays on conveyors, stacker-reclaimers and other drop points
- sealant sprays for long term piles
- pile orientation with respect to wind
- limiting the angle of repose and height of piles
- mobile truck sprays,
- wind fences, and
- the cessation of all operations in high winds

The dust control equipment and practices at two of the large Coal Terminals in Vancouver are listed in Table 7.1. One coal end-use company, Stelco Inc., provided the following information in connection with the control of dust using coal storage pile management at their facilities: (See Table 7.1) (Stelco 2001)

> *Throughout the shipping season, coal received is both consumed in our ovens and stockpiled against the coming winter. The coals are moved to stock using "belly pan" earthmovers, which build low, compacted stockpiles. Lake Erie Steel maintains three stockpiles and Hilton Works maintains four. After the last coal has been received, these stockpiles are surface sealed. The piles are opened and reclaimed on the lee side of the prevailing winds. By early spring, we would have completely consumed all coal stockpiled the previous year. Throughout the season, coal received is both consumed and stockpiled against the coming winter.*

Table 7.1 lists possible dust control measures for storage piles at end-user facilities and terminals for operations other than for just coal trains. Unfortunately, information was only received from four facilities for 2000. A list of the information that would be required for a thorough assessment of fugitive dusting and control for storage piles is presented in Appendix B.

7.4 Coal Dust Emissions Estimates – Storage Piles

Lacking sufficient data regarding operating parameters, local weather conditions or quantities in regard to storage piles in Canada, no attempt was made to estimate emissions. An attempt was made to estimate emissions at Coal Terminals, for this one sector a crude attempt was made to estimate dusting in relation to the storage piles at those facilities, see Chapter 8.

7.5 Discussion – Fugitive Coal Dust Emissions – Storage Piles

The operations in relation to coal storage piles are many and varied and they frequently produce fugitive dust emissions. The variables involved in estimating those emissions are also numerous. Because of a lack of information, emissions from storage piles were not attempted in this study. However, if data related to specific storage piles were collected, there are emission factors available for estimating fugitive dust emissions.

At present, the various contaminant inventories in Canada estimate fugitive coal dust emissions for coal mining and coal rail transportation, but they do not include emissions from coal storage piles. However, most coal mining operations are remote from heavily populated areas, and although coal may be transported through heavily populated areas such as Vancouver, the bulk of the emissions from coal trains are likely to also be in more remote areas. In contrast, many coal storage piles are located near populated areas and yet emissions for these sources are not estimated.

It is suggested that regional, provincial and/or national agencies may wish to investigate the possibility of gathering the data that would be required to estimate emissions from the coal storage piles located in or near large urban areas. It is recommended that emissions from storage piles in or close to major urban centres be included in emissions inventories.

Table 7.1 Dust Control Storage Piles

Dust Control Storage Piles and Handling 2001

Control System / Possible Storage Piles	Prov	# Piles	Max Pile Capacity	Water Spray Towers	Sealant Sprays	Pile Orientation	Pile Wind Fences	Water Truck	Stop Operations High Wind	Sprays on Conveyors	Sprays Stacker-Reclaimer	Other
Westshore	BC		2.5 Mt	119	roads/piles			fleet		yes	yes	integrated control system
Neptune	BC			yes		SW-NE		yes	yes			
Stelco, Hamilton	Ont	4			piles				work lee side			low compact piles
Stelco, Lake Erie	Ont	3			piles				work lee side			low compact piles

Chapter 8

Coal Terminals
Fugitive Dust Emission and Control

8.1 Coal Terminals

For this report, the term *Coal Terminals* is used in reference to the large coal handling facilities that receive coal (mostly Canadian coal) by rail and transship millions of tons of that coal each year, principally for export purposes. In 2000, there were four such *Coal Terminals* in operation in Canada:

- The *Thunder Bay Terminals Ltd.* facility in Thunder Bay, Ontario;
- The *Neptune Bulk Terminals (Canada) Ltd.* facility in the inner harbor, Vancouver, BC;
- The *Westshore Terminals Ltd.* facility at Roberts Bank near Vancouver, BC; and
- The *Ridley Terminals Inc.* facility in Prince Rupert, BC.

In 2000, a quantity of coal was moved through the *International Pier*, in Cape Breton, Nova Scotia, and millions of tons of coal were transshipped through port facilities in Ontario. Most of the latter coal was destined for the *Ontario Power Generation* power plants. However, these operations are considered to be coal received at *end-use* facilities and not coal terminal operations in the sense of the four noted above. Fugitive coal dust emissions estimates related to these port facilities are included in Table 8.2, but little is known about the details of these operations.

Coal Terminal Operations

Coal Terminals by their nature are active sources of fugitive dust. The Coal Terminals are designed to handle large quantities of coal every day. Many receive and unload coal from several, 100-car unit trains each day. The four Coal Terminals noted above all employ a rail loop that encircles most of the terminal and the storage piles. In 2000, each of the four Coal Terminals in Canada employed the rotary-dumping technique for unloading coal. This technique involves the near inversion of the car (while still coupled to the rest of the train) to release the coal.

In general, conveyor belts are used to move coal from the rotary-dumping facility to the storage pile, and at any one time a significant quantity of coal is usually in storage in a number of piles on the Coal Terminal property.

While in storage the coal in the pile may be disturbed as the pile is increased in size, rearranged, levelled, reconfigured, or decreased in size. The terminal may employ bulldozers or other 'earth moving' equipment to rearrange coal in the piles.

The Coal Terminals generally employ a *stacker-reclaimer* to do just that, stack coal on the pile after it is unloaded from rail cars (ships may also be loaded directly at some terminals) or reclaim the coal from storage piles for ship loading. Coal moves to and from the stacker-reclaimer via conveyor. At the ship-loading end, the coal is usually added to the ship using a large telescopic loading nozzle that can be lowered into the hold.

The activities or operations at a large *Coal Terminal* that can lead to the generation of fugitive coal dust include:

a] The rotary-dumping of the loaded coal cars,
b] Moving coal to and from the storage piles,
c] Loading to and reclaiming coal from storage piles
d] Pile handling operations - levelling and rearranging of storage piles,
e] Wind-blown dust from inactive storage piles, and
f] The loading of coal into vessels.

Coal dust may also be blown from loaded and empty unit trains while operating on the property, but this source is felt to be insignificant in comparison to the dusting potential of the other activities.

For 2000, the emissions from Coal Terminal operations are considered in regard to the operations noted above.

8.2 Emission Factors - Coal Terminals

Estimating emissions from Coal Terminals is difficult. The difficulty arises not because there is any particular mystery related to fugitive emissions from the activities at Coal Terminals, but because of the day-to-day variation in the activities and the parameters that may affect emissions, such as weather.

One approach to estimating emissions from a coal terminal would be to treat the facility as a 'black box' or a 'bubble'. Rather than focusing upon the individual operations at a coal terminal, one could measure airborne coal dust emissions at a number or points around the perimeter of the facility for a prolonged period during a variety of weather conditions. One could then attempt to generate an average EF for that coal terminal.

At various times over the last 20 years, government agencies in British Columbia have monitored coal dust emissions around the Coal Terminals in the province. However, it appears that no emission factors have resulted from that measurement activity.

Therefore, the alternative approach to estimating emissions from Coal Terminals is to attempt to isolate the various activities at the terminals and estimate emissions using average EFs for each of those activities. The average EFs for the various activities can then be combined with activity information in an attempt to estimate emissions.

Unfortunately, an investigation of the sources of fugitive coal dust EFs was unable to discover any average EFs that were specific to coal terminal operations.

Also, as noted, the activities and operations at a large Coal Terminal can vary significantly from day to day, therefore, the level of fugitive coal dust emissions can also vary significantly from day to day. The number of trains on a specific day, whether a vessel is being loaded, the alteration of storage piles, along with the weather conditions, are all important in relation to the magnitude of fugitive dust emissions.

To accurately estimate emissions, the detailed activity information related to the daily (or weekly or monthly) operations at the four Coal Terminals in Canada for 2000 would be required. Unfortunately these statistics were not readily available, and resources did not

allow for their collection. While the representatives for the two major coal terminals in the Vancouver area did provide annual throughput data, they did not supply the detailed information that would be required for a thorough application of average EFs.

The *Air and Waste Management Association* (AWMA) produces an air pollution manual that contains fugitive dust emission factors for coal operations. While there is no section specific to Coal Terminals, the Coal Processing section has EFs that "are considered to include...coal-handling facilities". (AWMA 2000)

The AWMA EFs that could be applied to fugitive coal dust emissions at a Coal Terminal are illustrated in Table 8.1 along with the EFs used in this study to estimate emissions.

Table 8.1 Fugitive Dust Emission Factors - Coal Handling - Total Particulate

Activity	Uncontrolled AWMA EF*	Uncontrolled AWMA EF metric	Uncontrolled EF used in study	Controlled EF used in study
	lb/ton	kg/tonne	kg/tonne	kg/tonne
Unloading				
Truck	0.02	0.01		
Railcar rotary dumped	0.4	0.2	0.2	**dumper enclosed** 0.002 **dumper open** 0.1
Transfer and Conveying	0.2	0.1	0.1	0.001
Loading to pile	0.08	0.04	0.04	0.008
Vehicular traffic or levelling and rearranging of piles	0.16	0.08	0.04	0.008
Loading out or reclaiming	0.1	0.05	0.05	0.01
Storage Pile wind erosion	0.09	0.045		
Assume only 1/30 of coal is stored			0.0015	0.0003
Loading				
Truck	0.02	0.01		
Railcar	0.4	0.2		
Barge	0.4	0.2		
Ship			0.01	0.0025
Terminal Composite EF enclosed dumper			**uncontrolled** 0.4415	**controlled** 0.0318
Terminal Composite EF open dumper			**uncontrolled** 0.4415	**controlled** 0.1298

* EFs from the AWMA (AWMA 2000)

Unfortunately, while the AWMA EFs purport to apply to all coal-handling operations, their application to the operations at Coal Terminals is not entirely clear. The EFs for each of the activities at a Coal Terminal are discussed below.

a] The rotary-dumping of the loaded coal cars.
In 2000, the four Coal Terminals in Canada employed rotary-dumpers to unload unit trains. The Ridley Terminals Inc. facility in Prince Rupert, BC was the only one of the four Coal Terminals not to enclose its rotary-dumper. The enclosed rotary-dumper facilities usually employ bag-houses filtering systems to control coal dust emissions. It is assumed that the Ridley Island Coal Terminal does not enclose its rotary-dumper, because fugitive emissions are limited by the frequent precipitation in the area.

The emissions associated with an enclosed railcar dumper, where the coal dust emissions are controlled by a bag-house or similar device, are felt to be beyond the scope of this report, which is intended to focus on wind-blown fugitive emissions from exposed coal surfaces. Once enclosed and controlled, these emissions are no longer truly fugitive, and the emissions from such operations should be governed by regional or provincial permit. Regardless, for completeness, an attempt has been made to include potential dumping emissions in the overall EF for a Coal Terminal.

The AWMA lists a railcar unloading fugitive dust EF that is 20 times as great as that for unloading a truck, 0.2 kg/tonne for railcars as compared to 0.01 kg/tonne for trucks. It is unclear why the difference should be so great? Granted the railcar is inverted or nearly inverted when unloaded, but the load carrier in most dumping trucks is also raised to nearly 90 degrees to unload. Also, dumping trucks frequently bang, or otherwise agitate their load carriers, in order to release all of the coal. Therefore, it would seem that the truck unloading operations should generate a similar level of fugitive coal dust.

The AWMA manual does not provide details for selecting either of these unloading EFs. However, it may be that truck unloading is associated with raw coal and the railcar unloading with thermally dried coal. The latter has a higher fines content than the raw coal and is likely to have a greater dusting potential.

For this study, the AWMA EF for railcar unloading has been employed. A dust control efficiency of 99%, as recommended by the AWMA for an enclosed rotary-dumper equipped with a fabric filter has also been used.

The **uncontrolled** EF for **railcar dumping** used in this study: 0.2 kg/tonne
The **controlled** EF for **railcar dumping - enclosed dumper** used in this study:
0.2 kg/tonne x (100-99)/100 = 0.002 kg/tonne

Since they employ enclosed rotary-dumpers, this controlled EF is used to estimate emissions for the two Coal Terminals in Vancouver and the Thunder terminal.

However, for the Ridley Island Coal Terminal, the dumper is not enclosed. Regardless, the effect of the heavy precipitation in the area is assumed to be the same as the control efficiency from 'watering', 50%, as assigned in the AWMA manual.
Therefore, the **controlled** EF used for **railcar dumping - open dumper** is:
0.2 kg/tonne x (100-50)/100 = 0.1 kg/tonne

Since little is known of the coal unloading operations at other ports in Canada, the Ridley Island EF has been used to estimate emissions for these operations, Table 8.2.

b] The movement of coal to and from storage piles.
In general, the conveyor systems that move coal from the railcar unloading facilities to the storage piles, and from piles to ships are covered. The systems are covered to limit dust emissions. Most of the terminals also employ water sprays at the transfer points at the end of the conveyors to limit emissions as the coal is dumped onto the piles.

The AWMA provides an EF for transfer and conveying. This EF is subsequently modified for the control offered by covering the conveyors. However, it is not known if the various terminals enclose their transfer points and how they control dust at those transfer points. Some transfer points are enclosed and some employ water sprays. It is not known if they vent enclosures to fabric filter systems. However, what is known is that during extreme wind conditions some of the Coal Terminals cease operations.

Therefore, the AWMA uncontrolled EF for conveying is used, and to err on the side of caution, a control efficiency of 99% is employed. The AWMA manual assigns a 99% dust control efficiency to conveying with an enclosure vented to a bag filter.

The **uncontrolled** EF for **transfer and conveying** used in this study: 0.1 kg/tonne
The **controlled** EF for **transfer and conveying** used in this study:
0.1 kg/tonne x (100-99)/100 = 0.001 kg/tonne

c] Loading to and reclaiming coal from storage piles
As far as could be ascertained, all of the Coal Terminals employ bucket-wheel stacker-reclaimers to load coal onto their storage piles and to reclaim the coal for ship loading.

The AWMA manual provides separate EFs for loading and reclaiming. The manual also provides a control efficiency of 80% for a bucket-wheel reclaimer. However, since none of the controls noted for loading, in the AWMA manual, appear to apply directly to the Canadian Coal Terminals, the 80% control efficiency is used in this study for both loading and reclaiming,

The **uncontrolled** EF for **loading to piles** used in this study: 0.04 kg/tonne
The **controlled** EF for **loading to piles** used in this study:
0.04 kg/tonne x (100-80)/100 = 0.008 kg/tonne

The AWMA manual contains and EF for reclaiming that is slightly higher than the EF for loading. A control of 80% as listed in the manual for a bucket-wheel reclaimer has been used.

The **uncontrolled** EF for **reclaiming from piles** used in this study: 0.05 kg/tonne
The **controlled** EF for **reclaiming from piles** used in this study:
0.05 kg/tonne x (100-80)/100 = 0.01 kg/tonne

d] Pile handling operations - levelling and rearranging of storage piles
Operations on storage piles are a likely source of fugitive dust. After coal is loaded onto a pile, it may be subjected to a number of 'handling operations'. Depending upon the conditions at the time of handling, all of these are likely to generate emissions.

The only EF listed in the AWMA manual that may relate to these activities is titled *Vehicular Traffic*. While there may be some vehicular traffic near the piles at a Coal Terminal, they would likely be kept to a minimum. This is unlike the vehicular traffic associated with Coal Processing (the title of the chapter in the AWMA manual), since large trucks and coal movers will move coal to the Processing Plant, and the unwanted remnants away, on a near continuous basis. Therefore, the AWMA uncontrolled EF for vehicular traffic has been halved to err on the side of caution.

Also, the AWMA manual does not list controls specific to vehicular traffic or to storage pile handling operations. The large Coal Terminals all employ a considerable array of fixed and mobile water spray systems. These would likely be used to dampen any emissions from pile handling operations. Also, the operations are likely to be terminated in extreme wind conditions. Therefore, again to err on the side of caution, a control efficiency of 80% has been used for these operations.

The **uncontrolled** EF for **vehicular traffic and pile handling operations**
used in this study: 0.04 kg/tonne
The **controlled** EF for **vehicular traffic and pile handling operations**
used in this study: 0.04 kg/tonne x (100-80)/100 = 0.008 kg/tonne

e] Wind-blown dust from storage piles.
Coal storage piles are storage piles whether they are located at a mine, end-use facility or at a Coal Terminal. The wind-blown emissions from storage piles at Coal Terminals could not be estimated using the complex EFs listed in Chapter 7, because of the lack of information regarding those piles and the day-to-day weather conditions.

The storage pile wind erosion EF in the AWMA manual is simplistic and as such can only render an extremely crude estimate of storage pile emissions. However, in order to provide a more complete emissions estimate for Coal Terminals, estimates have been attempted using this EF.

The controlled EF for wind erosion from storage piles from the AWMA manual is used for this study. However, the AWMA manual does not supply a control efficiency for the most common dust control technique used for storage piles, wet suppression. Watering is only noted as a control technique in truck and railcar unloading. However, the crude application in the unloading situation is not comparable to the complex set of water tower sprays and mobile sprays that are used at most terminals.

Wet suppression with chemicals is noted, but this technique is generally only applied for long term, undisturbed storage. For example, Stelco Inc. indicated that they used sealant sprays on their long term piles.

The AWMA manual also does not provide factors for the control of dusting related to pile orientation, working only the lee side of the pile, stopping operations in high wind, and the restriction of pile height. All of these are used in connection with storage piles in Canada.

Therefore, in order to err on the side of caution, a dust control efficiency of 80% has been applied for wind erosion from storage piles.

However, not all of the coal throughput at a terminal in one year is in storage at any one time. Therefore, using the factor forwarded by the Greater Vancouver Regional District (GVRD), it has been assumed that 1/30th of the annual coal throughput is in storage at any one time. (Der 2001)

The **uncontrolled** EF for **wind erosion from storage piles** used in this study:
0.045 x 1/30 = 0.0015 kg/tonne
The **controlled** EF for **wind erosion from storage piles** used in this study:
0.0015 kg/tonne x (100-80)/100 = 0.0003 kg/tonne

f] The loading of coal into vessels.
As noted Coal Terminals generally employ a stacker-reclaimer to reclaim the coal for ship loading. Coal moves from the stacker-reclaimer to the ship via conveyor. In general, the conveyors are covered, the transfer point may be covered by a water spray and the loading nozzle for the vessel is telescopic and can extend into the hold.

While the AWMA manual provides an EF for barge loading, it does not provide one for ship loading. As far as could be determined, no barges were loaded at Canadian Coal Terminals in 2000.

No indication is given in the manual as to whether the barge considered for the EF is flat with a pile of coal on the deck or enclosed like a ship's hold. Also, the EF used by the AWMA for barge loading is the same as for railcar loading. This seems highly improbable. Most railcars are loaded under a silo, while the loading nozzle may extend into the railcar it is not the same as a ship loading nozzle that usually extends deep into the ships hold to load.

Therefore, to err on the side of caution, once again, the lower EF for truck loading has been applied for ship loading. For the controlled EF, the control efficiency of 75% for telescopic chutes from the AWMA manual is used.

The **uncontrolled** EF for **ship loading** used in this study: 0.01 kg/tonne
The **controlled** EF for **ship loading** used in this study:
0.01 kg/tonne x (100-75)/100 = 0.0025 kg/tonne

Composite EF Used for Emissions Estimates - Coal Terminals

A composite EF has been used to estimate emissions from Coal Terminals. It combines the EFs for rotary-dumping of the loaded coal cars, conveying coal to and from the storage piles, loading to and reclaiming coal from storage piles, pile handling operations, wind-blown dust from inactive storage piles, and the loading of coal into ships. The EFs from each of the operations have been added to produce the composite. This is felt justified, since the operations are largely independent.

The **overall** or **composite uncontrolled** EF for total particulate (PART) for Coal Terminals used in this study: 0.4415 kg/tonne (8.1)

The **overall** or **composite controlled** EF for total particulate (PART) for Coal Terminals, **dumper enclosed,** used in this study: 0.0318 kg/tonne (8.2)

The **overall** or **composite controlled** EF for total particulate (PART) for Coal Terminals **dumper not enclosed,** used in this study: 0.1298 kg/tonne (8.3)

For the processed coal as received by the terminals, the same **scaling factors** for **PM_{10}** and **$PM_{2.5}$** that was used for rail transport were also employed for Coal Terminals:

PM_{10} Scaling factor is PART EF x 0.5

EF for PM_{10} = PART x 0.5 x terminal throughput per year in kg/tonne (8.4)

$PM_{2.5}$ Scaling factor is PART EF x 0.2

EF for $PM_{2.5}$ = PART x 0.2 x terminal throughput per year in kg/tonne (8.5)

Table 8.2 Emissions Estimates for Coal Terminal Operations - 2000

				Controlled Emissions		
Coal Terminal	**Location**	**Prov**	**2000 Throughput tonnes**	**PART tonnes**	**PM_{10} tonnes**	**$PM_{2.5}$ tonnes**
Westshore	Roberts Bank**	BC	22,500,000	715.5	357.8	143.1
Neptune	Vancouver**	BC	4,962,000	157.8	78.9	31.6
Texada	Texada Island	BC	0	0.0	0.0	0.0
Ridley *	Prince Rupert***	BC	6,000,000	778.8	389.4	155.8
Thunder Bay *	Thunder Bay**	Ont	1,830,000	58.2	29.1	11.6
	Total Emissions =			**1710.3**	**855.1**	**342.1**
Transship Coal	**To**					
Comox	Vancouver***	BC	240,000	31.2	15.6	6.2
Vancouver	LFV***	BC	240,000	31.2	15.6	6.2
Import Terminals						
Ontario #	***	Ont	15,511,828	2013.4	1006.7	402.7
Quebec #	***	Que	847,043	109.9	55.0	22.0
NB	***	NB	1,022,070	132.7	66.3	26.5
NS	***	NS	2,085,000	270.6	135.3	54.1

* 1999 data # 1998 data ** used enclosed dumper EF ***used open dumper EF

8.3 Dust Controls - Coal Terminals

The dust controls employed at the four Coal Terminals in Canada in 2000 included:

- **Unloading Unit Trains**
  - Enclosed rotary-dumpers with dust control systems
- **Moving Coal to and from Storage Piles**
  - Covered conveyors
  - Water sprays at transfer points
- **Loading to and Reclaiming coal from Storage Piles**
  - Water spray towers
  - Water trucks with sprays
  - Stop operations in high winds
  - Use of stacker-reclaimers
  - Water sprays at transfer points
- **Levelling, Rearranging and Retrieving coal from Storage Piles**
  - Water spray towers
  - Water trucks with sprays
  - Stop operations in high winds
  - Pile orientation
- **Wind-blown Dust from Inactive Storage Piles**
  - Water spray towers
  - Chemical sealants
  - Pile orientation and configuration
  - Wind fences
  - Water trucks with sprays
  - Stop operations in high winds
- **The Loading of Vessels**
  - Telescopic ship loader
  - Water sprays at transfer points
  - Enclosed transfer points
  - Stop operations in high winds

Details as to all of the control systems used at the four Coal Terminals were not available. The two Coal Terminals in operation in the Vancouver area in 2000 forwarded the dust control systems that they employed at their terminal, see Table 7.1. Many of the dust controls at Coal Terminals are discussed in Section 7.3 for Storage Piles.

8.4 Emissions - Coal Terminals

For this study, rough estimates of the potential fugitive dust emissions related to the Coal Terminal have been made using the composite EFs presented in Section 8.2. These EFs were combined with the annual throughput data for each facility. The emissions estimates for Coal Terminal operations in Canada in 2000 are presented in Table 8.2.

8.5 Discussion – Fugitive Coal Dust – Coal Terminals

The emissions estimates listed in table 8.2 for Coal Terminals are only very rough estimates and are used to illustrate the potential for emissions.

Precipitation was used as a control factor to develop the open-dumper controlled EF. However, in general, weather has not been accounted for in these emission estimates. Most of the Coal Terminals are located in areas where the piles, the coal handling to and from the piles and the loading of ships will likely be exposed to high winds.

Chapter 9

Fugitive Coal Dust Emissions Trends 1985 to 2020

Fugitive coal dust emissions have been estimated for 2000, but what are the future trends? Projections are considered necessary in light of a study in the 1980s that predicted an almost explosive growth in the amount of coal that would be processed through the Port of Vancouver to year 2020.

The growth surrogate used was coal throughput at the *Port of Vancouver*. Data was obtained for 1985 and 1996 and extrapolated to the years 1997 to 2020. The projections that were originally used are: (Levelton 1999-2)

year	1000's tonnes
1985	20,163
1990	24,042
1995	26,500
2000	37,658
2005	49,568
2010	61,478
2015	73,388
2020	85,928

These predictions from the 1980s now seem very optimistic. For example, in 2000 the throughput for Westshore and Neptune terminals was 27,462,000. This total is similar to what was predicted for 1995 and over 10,000,000 tonnes short of the prediction for 2000.

The 1995 CAC Inventory listed the annual clean coal production in Canada for 1990 to 1995, Table 9.1. (Deslauriers 1999) These data reveal a decline in production in 1992 and a growth of slightly over 9.5% from 1990 to 1995.

Table 9.1 Clean Coal Production in Canada 1990 to 1995 (Deslauriers 1999)

Provinces and Territories	1990	1991	1992	1993	1994	1995
	10^6 tonnes	10^6 tonnes	10^6 tonnes	10^6 tonnes	10^6 tonnes	10^6 tonnes
Newfoundland	0	0	0	0	0	0
Prince Edward Island	0	0	0	0	0	0
Nova Scotia	3.416	4.138	4.486	3.647	3.509	2.444
New Brunswick	0.548	0.498	0.399	0.389	0.332	0.263
Quebec	0	0	0	0	0	0
Ontario	0	0	0	0	0	0
Manitoba	0	0	0	0	0	0
Saskatchewan	9.407	8.981	10.027	10.045	10.685	10.740
Alberta	30.405	32.554	33.528	34.319	35.675	37.119
British Columbia	24.556	24.962	16.922	20.629	22.608	24.350
Yukon	0	0	0	0	0	0
NWT	0	0	0	0	0	0
Canada	68.331	71.134	65.361	69.029	72.808	74.916

From 1995 CAC Inventory Calculations (Statistics Canada #45-002)

A more recent forecast of coal consumption in Canada until 2020 was obtained from by *Natural Resources Canada* (NRCan), Table 9.2. (NRCan 2001) These data show a decline in coal consumption in Canada from 2000 to 2020. Therefore, unless exports increase dramatically in the next 20 years, it would appear that the predictions for coal production from the 1980s were very high.

Table 9.2 Forecast of Coal Consumption in Canada*

Coal Consumption	1998	2000	2005	2010	2020
	10^6 tonnes	10^6 tonnes	10^6 tonnes	10^6 tonnes	10^6 tonnes
Ontario - Total Consumption including imports	17.2	13.7	13.8	11.6	2.7
Ontario - Import	15.7	12.4	12.5	10.4	2.1
Alberta	26.0	23.9	23.5	23.7	24.8
British Columbia	0.1	0.1	0.1	0.1	0.1
Saskatchewan	9.8	9.9	9.9	9.9	9.8
Quebec Import	0.7	1.0	1.1	1.1	1.2
New Brunswick - Total Consumption including imports	1.4	2.0	2.0	2.0	0.1
New Brunswick - Import	1.2	1.7	1.7	1.7	0.0
Nova Scotia	2.7	3.1	3.1	3.0	0.1
Manitoba	0.2	0.0	0.0	0.0	0.0
Canada - Total Consumption including imports	**58.1**	**53.8**	**53.5**	**51.3**	**38.7**
Canada - Total Import	**18.2**	**15.8**	**16.0**	**13.8**	**3.3**
Consumption Canadian Coal only	**40.0**	**38.0**	**37.6**	**37.5**	**35.5**

* (NRCan 2001)

Fugitive coal dust emissions projections for all coal in Canada were not attempted. However, to show the changes in emissions, estimates from dusting coal trains were attempted for the different quantity of coal shipped via Coal Terminals in Vancouver for 1985, 1990, 1995 and 2000, Table 9.3. Emissions were estimated using the CAC EF as recommended in Chapter 5 and the following coal throughput in tonnes:

1985	1990	1995	2000
19,624,000	24,042,000	26,500,000	27,462,000

Table 9.3 Coal Rail Fugitive Dust Emissions Estimates Lower Fraser Valley 1985 to 2000

	Total Trip km	LFV km	Coal Throughput tonnes	CAC EF Total Trip kg/tonne	Total Particulate Emissions Total Trip tonnes	Total Particulate Emissions LFV tonnes	Total Particulate Emissions LFV tonnes	PM_{10} Emissions LFV tonnes	$PM_{2.5}$ Emissions LFV tonnes
Year							Adjusted Precip *	Adjusted Precip *	Adjusted Precip *
1985	1100	100	19.624	0.0501	984.14	89.47	62.50	31.25	12.50
1990	1100	100	24.042	0.0501	1205.71	109.61	76.58	38.29	15.32
1995	1100	100	26.500	0.0501	1328.97	120.82	84.41	42.20	16.88
2000	1100	100	27.462	0.0501	1377.22	125.20	87.47	43.73	17.49

* The precipitation and snow days for Abbotsford were used

Chapter 10

Recommendations & Uncertainty

10.1 Coal Dusting Monitoring Program from Unit Trains for Establishing Emission Factors

A comprehensive en route dust-monitoring program is suggested in order to establish a more accurate dust emission profile and/or emission factor for coal trains that ship coal through ports in the Vancouver area. Besides other objectives, the program should be designed to monitor TSP, PM_{10} and $PM_{2.5}$ emission levels from coal trains, as well as wind speed, precipitation and temperature during monitoring.

It is suggested that this study also attempt to estimate how railway coal dust emissions disperse with distance along a prolonged rail journey, and how far different size particles are likely to spread from the rail line after being emitted from the rail cars.

In order to gather empirical data in regard to dust emissions control, detailed records of dust suppressants use at the mines plus the washing of coal cars at the terminals should also be maintained and coordinated with the train dust monitoring program plus any crust-retention measurement data. The data gathered should be used to assess whether there is a direct relationship between emissions control and crust-retention percentage. (See Appendix B)

10.2 Coal Dust Emissions from Trucks

The emission factors and emission estimates for dust blown from trucks, as presented in this report, can only be described as rough speculation. Very little information was available regarding the movement of coal by truck in Canada in 2000. In areas were emissions from coal trucks may be of concern, particularly in Alberta and Saskatchewan, agencies may wish to investigate and gather data related to those operations.

10.3 Coal Storage Piles and Coal Terminals

Agencies should attempt to gather the information that is needed to accurately estimate emissions for the coal storage piles in their areas of responsibility. Emission factors for storage piles are available, but they cannot be applied without detailed information regarding the storage piles and the activities related to them. Similarly for Coal Terminals, more detailed information related to their operations is required before accurate emissions estimates are possible.

Since many storage piles and Coal Terminal operations are located in or near large urban population centres, agencies may wish to concentrate their efforts regarding fugitive coal dust emissions estimates on these two areas. Unlike emissions related to coal mines, and most of the emissions related to coal trains, the dust emissions from storage piles and coal terminals may have a more immediate impact on urban populations.

10.4 Coal Mining Fugitive Dust Emissions

While fine particulate emissions at coal mines may have serious implications for employees at the mines, in general their impact on urban ambient air sheds is likely minor. Most coal mining operations in Canada are located in remote areas far from populated urban areas and much of the fugitive dust that is generated by mining operations is likely deposited on or near mining company property.

Therefore, there is the danger that fugitive particulate emission from coal mines, if added to provincial or national totals, may give a distorted view of the exposure of the majority of the population to those fine particulates. Therefore, those preparing inventories may wish to consider the listing of these emissions separate from other urban TPM, PM_{10} and $PM_{2.5}$ emissions totals.

10.5 The Influence of Weather on Fugitive Dust Emissions

There seems little doubt that heavy rain and snow will have an inhibiting effect on fugitive dust emissions. However, additional study is required to determine whether the rain and snow day assumptions for unpaved road dust, as assumed in this study, do apply to coal dust emissions or whether new criteria are required.

Wind speed is a factor in fugitive dust emissions regardless of source. However, while it is difficult to apply a wind speed factor to thousands of moving unit trains each year, wind speed can be applied to emissions from storage piles.

10.6 Uncertainties in Emission Factors

The emission factors and estimates of coal dust losses from trains have been based on investigations that range from theoretical estimates and wind tunnel experiments to actual field measurements at locations of nuisance dust complaints. Because of the combination of factors which influences coal dust emission from an open source moving over a long distance through different weather conditions, none of the EFs available to date appear to be able to yield coal dust particulate emission estimates with a high degree of certainty.

The uncontrolled emission factor used in this report for coal dust emission from trains is considered to be the best that can presently be derived from the information available. However, the inherent uncertainty in the emission estimates will remain high.

The emission factors for coal mine operations are the most established of the EFs used in this report. However, as noted, the EFs and emissions estimates for trucks and Coal Terminals are only intended to present a rough estimate of emissions for these two areas. The uncertainties for the truck and Coal Terminal emission estimates, presented in this report, are very high.

REFERENCES

Action Committee, *Report of the Action Committee on Coal Dusting*, 30 August, 2000 *and Letter from Burdenie, J., Action Committee on Coal Dust, to Administrator, District of Delta*, 12 September, 2000
AMEE, *Best Practices Booklet for Fugitive Dusting,* Environment Australia, from Internet site www.ameef.com.au/publicat/bpem/dust.htm, March 2001
AWMA, *Air Pollution Engineering Manual*, Air and Waste Management Association, 2000
BCMELP, *Personal communications from Linda Vanderhoek*, Ministry of Environment, Lands and Parks, Region 2, 14 March, 2001
BCMELP, *1995 British Columbia Emissions Inventory of Common Air Contaminants and Greenhouse Gases,* B. C. Ministry of Environment, Lands and Parks, Air Resources Branch, http://www.elp.gov.bc.ca/epd/epdpa/ar/airquality/inventory/sub-index.html, May 1999
Coal Association of Canada, Internet website, www.coal.ca, March 2001
CN, *Canadian National internet site,* http://www.cn.ca/productsservices/coal/en_KFCoalEquipment.shtml, March 2001
Cope, D., et al, *Report on the Emission and Control of Fugitive Coal Dust from Coal Trains*, Environment Canada, Regional Program Report 86-11, April 1986
Cope, D., *Fugitive Dusting from Bulk Commodity Storage and Handling at Canadian Ports and Harbours,* Internal memorandum to Environment Canada Regions, Industrial Programs Branch, 2 November, 1988
CPR, *Canadian Pacific Railway Company, Investor Fact Book*, December 2000 & letter General Manager, Safety & Regulatory Affairs to I. Spear, CTA, PRC0025, 31 August, 2000
CTA, *Complaint Regarding Coal Dusting from Railway Trains in the Hope Area of BC.,* Letter I. Spear to Distribution, Canadian Transportation Agency, R8030/H5, 5 October, 2000
Der, K., Communication K. Der, GVRD to PDB, Environment Canada, 19 July 2001
Deslauriers, M., et al, *Canadian Emissions Inventory of Criteria Air Contaminants (1995)*, Draft, Environment Canada, EPS, May 1999
Deslauriers, M., *Canadian Emissions Inventory of Criteria Air Contaminants (1990)*, Environment Canada, EPS 5/AP/7E, December 1995
Dofasco, Coal Use Information, Email From: Vasudha, S. to D. Cope, 15 March, 2001
Brewer, R., *Weather Data for Selected Stations, Email Communication*, Environment Canada, Suite 700 - 1200 West 73rd Avenue, Vancouver, BC, 22 March 2001
EPA, *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, http://www.epa.gov/ttn/chief/ap42/,* March 2001
EPA, *AP 42 Section 13.2.5 on Industrial Wind Erosion*, epa.gov/ttn/chief/ap42/ch13/final/c13s02-5.pdf1, 5 March 2001-1
EPA, *AP42 Table 11.9-2 (Metric Units). Emission Factor Equations Uncontrolled Open Dust Sources At Western Surface Coal Mines*, http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s09.pdf 12 March 2001-2
EPA, *AP 42 13.2.4 Aggregate Handling And Storage Piles,* http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s02-4.pdf, March 2001-3
ESL, *Testing and Evaluation of Methods for Collection and Analysis of Coal Dust from Unit Trains (1983 Study),* ESL Environmental Sciences Ltd., December 1985
ESL, *Testing and Evaluation of Methods for Collection and Analysis of Coal Dust From Unit Trains (1984 Study),* Prepared for Environment Canada and BC Ministry of Environment, by ESL Environmental Sciences Ltd., March 1986
GVRD, *Personal communications from Bob Cochlan*, Air Quality Department, Greater Vancouver Regional District, 15 March, 2001
GVRD, *Emission Inventory Appendix C - 1990 Inventory of Mobile Sources*, Greater Vancouver Regional District, July 14, 1993 Revised February 1994
GVRD, *1985 Lower Mainland Emission Inventory, Greater Vancouver Regional District*, D: Mobile Sources, Volume 2: Methodology, 1990

REFERENCES (continued)

Holmes, J., et al, *Report of a Field Study, Coal Train Sealant Spray Performance Evaluation August 1981*, Environment Canada, January 1982.
Hope, District of, *Letter P. Taylor, Chief Administration Officer, District of Hope, to D. Cope*, 2 April 2001
IEA, *Control of Coal Dust in Transit and in Stockpiles,* IEA Coal research, and *Nuisance from Coarse Dust*, P. Hofschreuder and E. L. M. Vrins. Paper presented at European Aerosol Conference, Oxford, U. K., 1992, IEAPER/15, December 1994
Laing, B., *Letter to Mr. and Mrs. D. Webster of Hope BC*, Canadian Pacific Railway, 18 October, 2000
Levelton, *1990 Air Emissions Inventory for the Province of British Columbia Outside the Lower Fraser Valley: Mobile Sources*, Prepared for: B.C. Ministry of Environment, Lands and Parks, by B.H. Levelton & Associates Ltd., July 1993
Levelton Engineering Ltd., and Midwest Research Institute, *Road Dust Estimation Methodology, Phase 2, BC Outside the Lower Fraser Valley,* for NEIPTG (EPWG) 498-0612, 29 April 1999
Levelton Engineering Ltd., *Forecast and Backcast of 1995 BC Area and Mobile Source Emission Inventory (Outside the LFV),* for BC MELP, 498-0169, 15 January 1999-2
Luscar, *From Luscar Ltd. Website*, http://www.luscar.com/, 9 March, 2001
MH, *Testing of Emission factors – Fugitive Coal Dust from Unit trains (A Laboratory Evaluation)*, Prepared for Environment Canada, by Morrison, Hershfield (MH) Ltd., June 1983
MRI, *Emails to D. Cope*, Midwest Research Institute, March 2001
NEIPTG, *1995 Criteria Contaminants Emissions Inventory Guidebook (First Draft)*, National Emissions Inventory and Projections Task Group (now EPWG), March 1999
Newhook, J., et al, *AirCare On-Road Program: First Year Results*, GVRD, March 2000
NB, *New Brunswick Coal Production and Imports*, Email from Griggs, J, DNRE/MRNE, Government of New Brunswick, 3 April, 2001
NS, *Telephone conversation, Doug Cope to Gibson Barbee, Norfolk Southern Corporation* http://www.nscorp.com/nscorp/html/coal/index.html, March 2001
NS, *Annual Report to the Joint Subcommittee Studying Measures to Reduce Emissions from Coal-Carrying Railroad Cars per Senate Resolution number 257*, submitted by Norfolk Southern Railway Company, January 2001-1
NS Power Corp, *Coal Use by Plant in 2000 Imports and Domestic*, Email from J.K. Keeping and T. Kumanan. Nova Scotia Power Corp., March 2001
NRCan, *Email from Analysis and Modeling Division*, Energy Policy Branch, Natural Resources Canada, hlabib@nrcan.gc.ca, 20 March, 2001
OAG, *A Method for Detection of Diesel Soot and Coal in Dust Samples*, Organic Analysis Group for Environment Canada, PR 95-04, January 1994
ORTECH, *Methods Manual for Estimating Emissions of Common Air Contaminants in Canada*, for Environment Canada by ORTECH International, May 1991
Sidi, S., *Email Sidi, S., GVRD to Cope, D.*, 9 April 2001
SWA, *Telephone Conversation Doug Cope to Dave Emmitt, Simpson Weather Associates* - SWA Fugitive Coal Dust Control - www.swa.com/coal/, 12 March, 2001
Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada* (QRESD) #57-003
Stelco, *Letter P. Redyhough to D. Cope*, Stelco Inc. Raw Materials Department, 21 March 2001
Ternan, G., *CBDC International Pier, Sydney, N.S.,* Memo to J. Kozak, Atlantic Region, Environment Canada, 15 September 1987
Wakelin, T., *Email Wakelin, T., BC MELP, to Lane, D., BC Mining Assoc.*, 4 January 2000
Wakelin, T., *Email Wakelin, T., BC MELP, to Cope, D.*, 11 April 2001
Wituschek, E., Cope, D., *Coal Dust Control, Recommended Practices for Loading, Unloading and Transporting Coal by Rail*, Environment Canada, Regional Report 86-17, April 1986

Appendix A
Information Sources

Table A.1 Agencies Contacted Regarding Coal Train EFs

Agency	Contact Person	Comments
US EPA	Tom Pace (919) 541-5634 pace.tom@epa.gov	Doubts EPA will have anything.
US EPA	Bill Kuykendal (919) 541-5372 kuykendal.bill@epa.gov	No EF. EPA exposure profiling technique may be the closest to estimating dust from rail cars. Recommends Dr. Chat Cowherd of Midwest Research Institute (MRI). Check also with individual States to see if any local work done.
US EPA	Ron Myers (919) 541-5407 myers.ron@epa.gov	No EF. Recommends adapting coal pile EF. Adapt AP-42 EF.
MRI	Greg Muleski (819) 753-7600 Ext. 1596 Chat Cowherd (816) 753-7600 Ext. 1585	Suggest using AP-42, Sec. 11.9 Western Surface Coal Mining, Fugitive Dust EFs and modify for trains. Not aware of any jurisdiction quantifying coal train dust emission. Some work might have been done on wind erosion related to coal trains in South Africa.
CTA	Bill Aird (819) 953-9924	Only anecdotal evidence of train emissions.
Wisconsin DEQ	Mike Warren (307) 672-6457	No EF.
W. Virginia OAQ	Dave Porter (304) 926-3647	No EF.
Kentucky DAQ	Martin Luther (502) 573-3382	No EF.
Pennsylvania DEP, Bur. AQ	Dean Van Orden (717) 787-9495	No EF. Check with Penn. Coal Association.
Illinois EPA, Bur. Air	Don Sutton (217) 782-7326	No EF.
Ohio EPA	Tom Velalis (614) 644-4837	No EF.
Texas NRCC	Skip Clark (512) 239-1000	No EF.
Pennsylvania Coal Association	(717) 233-7909	No EF.
EP Authority, Victoria, Australia	Rhonda Boyle Rhonda.boyle@epa.vic.gov.au	No EF.
EP Authority, New South Wales, Australia	Elizabeth Davidson Davidson@epa.nsw.gov.au	No EF.

Table A.2 Sources of Year 2000 Detailed Information

Information Sources	Information Supplied	Contact
BC Mining Association - website	Links to various mines in BC	www.mining.bc.ca/relatedlinks.html
BC Mining Association - Grasley	Informed that the Association does not support this data gathering exercise	Lorne Grasley
Coal Association of Canada - website	Detailed mine production information for 1998 for CA mines	www.coal.ca
Coal Association HQ - Edmonton	Provided 1999 production data by CA registered mine	Marge Martin <martin@coal.ca>
Mines		
Fording Coal - website	Details regarding each mine - no production data	www.fording.ca
Luscar Coal - website	Details regarding each mine plus production data	www.luscar.com
Luscar Coal HQ	Contacted - to provide data	JOANNE_MILLER@LUSCAR.COM
Mines in NS - Government of NS	Production by mine in 2000	HENNICEW@gov.ns.ca
Mines in NB - NB Energy Dept.	Production, import and use in 2000 + Power Plant use	NB Energy Dept John.Griggs@gnb.ca
Mines in Alberta - Govt. of Alberta	1998 and 1999 coal production data	Khalid Jamil - Alberta Energy and Utilities Board
Smoky River Alta mine	Shipped Neptune 2000, Westshore backed out of buy, all equip for sale on net	Lederer, Neptune - intequip.com/news.asp

Table A.2 Sources of Year 2000 Detailed Information (continued)

Information Sources	Information Supplied	Contact
Railways		
BCR	Information on BCR train sets and cars in 2000	DermodyG@bcrail.com
CNR - website	Little information	www.cn.ca
CP - website	Little information	www.cp.ca/cp/e/index.htm
CP Ken McGuire	Supplied 2000 Annual Report with rail car fleet information	Ken_McGuire@cpr.ca
Norfolk Southern	Information on Coal Monitoring	Gibson Barbee
Terminals		
GVRD	Contacts at Neptune and Westshore	Kelly Der
Neptune Terminals	Sent total throughput in 2000 plus dust controls	Frid Lederer FLederer@NBTCL.bc.ca
Westshore Terminals - website	Operational details, equipment and dust controls	http://www.westshore.com/
Westshore Terminals	Sent total throughput in 2000 plus dust controls	David Crook DCROOK@Westshore.com
Ridley Terminals Inc. from CA	1999 data	Coal Association of Canada
Thunder Bay Terminals Ltd. from CA	1999 data	Coal Association of Canada
End-Users		
Stelco	Use data for 2 steel plants for 2000 plus storage pile control info	Paul Readyhough
Dofasco	Their coal use in 2000 import and Canadian	vasudha_seth@dofasco.ca
NS Power Corp	Coal use by plant in 2000 imports and Domestic	J.K. Keeping & tom.kumanan@nspower.ca
Ontario Power Generation website	Number of power plants and power generation	http://www.ontariopowergeneration.com/
Ontario Power Generation 1998 Progress Report	Total coal used in 1998, prorate from 1999 GWh each plant	www.opg.com/environmental/SEDrpt.pdf
Imports		
EC Newfoundland District Office	1998, 1999, 2000 coal to Iron Ore Company in Labrador	Charles MacLean charles.maclean@ec.gc.ca

Table A.3 Sources of General Year 2000 Information

General Information	Information Supplied	Contact
EIA on Canada re Energy	General information on Canadian Energy use	http://www.eia.doe.gov/cabs/canada.html
World Coal Institute	Links to some Canadian Mines	http://www.wci-coal.com/linkscoal.htm
Canadian Transportation Agency	Minutes meeting 20 Sep 2000	Bill Aird
Environment Canada (EC) PDB	Guidebook and 1995 EFs and Emissions Estimates	C. Vezina
EC Regions		
Pacific and BC	coal dust complaints for BC and recent history re dusting	D. Poon
Atlantic	General info mines in NB and NS	G. Terman &Andre.Gauthier@EC.GC.CA
Ontario	contacts with provincial government	S. Humphrey
Western	contacts with provincial government	D. Woo
Quebec	general info Quebec imports	A. Gosselin
Ontario Govt.	Can not respond - OPG contacts only	S. Wond
Provincial Governments		
BC Govt.	Contact data and BC estimates	Tony Wakelin
BC Govt.	General Mining History Information	Gordon.Ford@gems4.gov.bc.ca
Alberta Govt.	1998 and 1999 coal production data	Khalid Jamil of the Alberta Energy and Utilities Board
Alberta Govt. - Environment	contacts	Brian Hudson Energy- Randy M. Dobko Environment
Alberta Energy & Utilities Board website	power plant capacities in MW	http://www.eub.gov.ab.ca/
Saskatchewan Power Corp	Power plant capacities in MW	http://www.saskpower.com
Manitoba - Environment Department	coal use by plant in 2000	Manitoba Env Dept cmoche@env.gov.mb.ca
Statistics Canada	For Quebec - General total end use by industrial sector 1999	QRESD 1999
Statistics Canada	1998 import and consumption data	from Coal Association
States		
Virginia	Annual report on coal dusting from Norfolk Southern Railway	Tom Jennings, Dept. of Environmental Quality
Weather Data		
Environment Canada	Data for 2000 BC weather stations	Roxanne.Brewer@ec.gc.ca
Crust Monitoring		
Associate Research	Information on crust retention	Claudio Guarnaschelli
Coal Dust Complaints		
Alberta Govt.	No complaints to repor	Dave.Slubik@gov.ab.ca
District of Hope	Package of information	P. Taylor, Chief Admin. Officer
Coal Dust Monitoring		
Simpson Weather Associates, Inc. Virginia	Detailed information on train dust monitoring system May have data that would yield and EF but data are proprietary.	www.swa.com/coal/

Table A.4 Associations or Companies Contacted that did Not Supply Information

Company or Association	Status of Information	Contact
Mines		
BC Mining Association	Association does not support this data gathering exercise	Lorne Grasley
Fording Coal	No data supplied	dermot_lane@fording.ca
Luscar Coal		
Luscar - Manager Line Creek Mine	No data supplied	lloyd_metz@Luscar.com
Luscar - Line Creek mine.	No data supplied	John Van Den Brock
Luscar Obed Mine	Dust control info to be sent - none received	Ms. Saundra
Teck - website	Only general company information	www.teck.com
Teck Corp HQ Vancouver	Asked that I send request, but No data supplied	E. Evans for Mike Lipkewich Senior VP Mining, eevans@teckcorp.com
Teck - Bullmoose Mine	No response to Email	F. Duperreault
Teck - Quintette Mine	No response to Email	K. Sharman
Quinsam Coal - mine	Spoke to and sent Email request, No data supplied	Dave Selent dhs35@hotmail.com
Railways		
CNR	No response	Bryan Vaughan bryan.vaughan@cn.caSchoor schoor@cn.ca
End-Users		
Ontario Power Generation (Ontario Hydro)	Email to 3 contact persons – no response	lois.wallace@ontariopowergeneration.com
	Anne Douglas, Lois Wallace, Bill Perks	
Terminals		
Thunder Bay Terminals	Email to their contact person – no response	Paul Kennedy port@baynet.net
Ridley Island Terminals	Email to their contact person – no response	klindenberger@rti.ca

Appendix B
Nuisance Coal Dusting from Unit trains

B.1 Introduction

Nuisance soiling from windblown coal dust has been a particular problem in relation to coal blown from loaded rail cars that travel from the Alberta and BC border area to Vancouver. In 2000, federal and provincial agencies reopened investigations into the nuisance soiling problems related to fugitive dusting from unit coal trains. Once again various agencies had received complaints regarding nuisance soiling from coal dust associated with unit trains that transit through communities in the Lower Fraser Valley (LFV) of British Columbia from Hope to Vancouver.

While visible dusting incidents cannot be quantitatively linked to overall dust control efficiency, visible dust events confirm that in 2000 the emissions control effectiveness of the dust suppressant systems used by certain mines that ship coal to Vancouver was less than 100%.

This appendix provides an overview and an update of the situation in regard to nuisance soiling from coal blown from rail cars in Western Canada for 2000.

B.2 Unit Coal Train Nuisance Dusting Complaints in British Columbia

In British Columbia, nuisance dusting from coal trains has been a source of citizen complaint since 1974. More recently, according to officials with the Canadian Pacific Railway (CPR), there were incidents of dusting in 1994 and sporadically from 1994 to 2000. (CTA 2000)

> *The CPR typically received only a couple of sporadic complaints per year, usually in early summer and usually from residents in the Agassiz and Kent regions.*

Similar dust complaints from residents in the area of Flood, BC were received by Canadian National (CN) in the early to mid-1990s.

In 1999 Transport Canada officials attended a 'town hall' meeting in Yale, BC (north of Hope) to discuss coal dusting from unit trains with local citizens, and the Canadian Transportation Agency (CTA) reported that unit trains from mines in Alberta and BC were dusting in 2000 (CTA 2000)

Complaints regarding dusting trains in British Columbia returned in earnest during the spring and summer of 2000. From May to August 2000, a series of complaints were received regarding dusting from loaded and empty unit coal trains in the Flood-Hope/Kent areas in the Fraser Valley. From May to October 2000, 27 trains were reported as dusting in the Flood-Hope area of British Columbia. These complaints culminated in a meeting in Hope, BC on September 20, 2000 (See Section B.5) involving residents, mining companies, rail companies and concerned agencies from all levels of government. (MELP 2001) (Hope 2001)

B.3 General History
Coal Train Dusting in Western Canada

Wind blown fugitive coal dust can result in nuisance soiling complaints in connection with any one of the operations in the process that takes coal from mine to end-user. However, dusting from unit coal trains is a principle focus of this report.

In Canada, most coal is mined in Western Canada in Saskatchewan, Alberta and British Columbia. While the majority of Saskatchewan coal is consumed within the province, approximately one quarter of the coal mined in Alberta and virtually all of the coal mined in BC is exported. In order to reach the export terminals, three of the largest of which are on the West Coast, that export coal is shipped by rail.

Coal is shipped by rail in Western Canada in 'unit trains' of approximately 100 open top rail cars. This coal is highly friable and has a high percentage of fines, 20% less than 60 mesh (250 micron) plus 7% less than 200 mesh (75 micron) in some samples. (Cope 1986) The quantity of fine coal in bulk coal shipments is important because loose, exposed fine coal in an open-top rail car is susceptible to wind entrainment.

The rail corridors to Vancouver from coal fields in Northwest Alberta and the Southeast BC pass through many small communities. However, coal dust nuisance complaints appear to be concentrated in the section of that corridor from Hope to Vancouver in British Columbia.

The area from Hope to Vancouver appears particularly prone to fugitive dusting. This section of the trip is near the end of the long rail journey from mine to terminal. By this point in the trip, many of the surface coatings sealing the fine coal on the loaded rail cars may have fractured or broken as a result of atmospheric drying, vibration and shock on route. Much of the terrain along this section of the route is also flat and trains may travel at or near the maximum allowable tract speed of 80 km/hr. In addition, high ambient crosswinds combine with train generated wind to create high turbulent dust-entraining air currents over coal cars. (Cope 1986)

In the early 1970s, federal and provincial environment agencies received complaints regarding wind blown coal dust from unit trains from citizens residing in communities along the coal/rail corridor in the Lower Fraser Valley (LFV). Following initial investigations into those dusting complaints, all of the major coal producers in Western Canada recognized chemical sealants as the most practical method of controlling in transit dusting. In 1975, all of the coal producers that shipped coal by rail to Vancouver commenced spraying the coal loaded in their rail cars with sealants. (Cope 1986)

While the spraying achieved success initially, by 1979 unit train coal dust complaints in the LFV were sufficient to reopen investigations. From 1979 to 1984 over 2200 loaded coal trains were observed in transit near the town of Agassiz, BC. With respect to their visible dust emissions, these trains were graded using the purely subjective designations: heavy, medium and light. Of those trains, 359 or over 16% were judged to be emitting some level of visible dust. At the higher end of the range, 198 trains or approximately 9% were judged to be emitting either 'medium' or 'heavy' levels of visible dust. Trains with

this level of dust emission in that community are know to give rise to nuisance soiling and citizen complaints. (Cope 1986)

Also, from 1979 to 1984 over 1600 unit trains returning to the mines, 'empty' trains, were monitored for visible coal dust emissions at the same site in Agassiz, BC. Of those empty trains, 66 were judged to have some level of visible dust and 35 of those, or approximately 2% were judged to be emitting either 'medium' or 'heavy' levels of visible dust.

From 1979 to 1984, standard high-volume sampler measurements of *Total Suspended Particulate* (TSP) from a provincial air monitoring station located 100 meters from the railway tracks in Agassiz, BC were below the annual maximum 'acceptable' standard of 70 $\mu gm/m^3$. However, occasional excursions of the measurement of TSP to the 24-hour maximum acceptable level of 120 $\mu gm/m^3$ were recorded. (Cope 1986) No measurements or assessment as to the emission of particulate in the PM_{10} and $PM_{2.5}$ range were made during those investigations.

In the early 1980s, the inconsistent performance of chemical spray systems at certain coal mines was considered the cause of the majority of the severely dusting trains. In 1984, a number of the coal mines that shipped coal via this route listed the following as reasons for inconsistent dust control performance for their sprayed trains: (Cope 1986)

- spray equipment malfunction,
- spray system freeze-up, and
- inexperienced personnel operating equipment at two new mines.

At that time, at least one West Coast coal terminal employed a water spray to clean coal from the outside of their cars once they had been dumped. The coal terminal cited the breakdown of the car wash as a possible reason for an increase in dusting 'empty' trains.

As a result of their investigations, Environment Canada in 1986 published a set of *Recommended Practices* for improving the control of fugitive coal dust from unit trains. These recommendations included suggestions for improvements in dust control practices at both the mines and end terminals. They also included recommendations for the railway companies. (Wituschek 86) (See Appendix C)

It was felt that the thorough application of these techniques and *Recommended Practices* would achieve more consistent performances from the various coal dust control measures.

During the 1990s, it appeared that the problems associated with nuisance coal dusting from unit trains had abated. As noted, the CPR reported incidents of dusting in 1994 and sporadically from 1994 to 2000. For the CPR it would appear that during the 1990s, nuisance dusting was confined to one or two complaints per year, usually in early summer and usually from residents in the Agassiz and Kent regions. (CPR 2000)

CN reported that during a two-year period in the mid-1990s dust complaints were received from residents in the area of Flood. CN conducted an investigation and they

claim that the mining companies involved took remedial action to 'help contain coal particles'. (CPR 2000)

In 1999 Transport Canada officials attended a 'town hall' meeting in Yale, BC (north of Hope) to discuss coal dusting from unit trains with local citizens, and the Canadian Transportation Agency (CTA) reported that unit trains from mines in Alberta and BC were dusting in 2000. (CTA 2000) However, in the spring, summer and fall of 2000, the number of dusting coal trains transiting the Lower Fraser Valley appeared to increase dramatically. (See Section B.4)

One difficulty with finding a permanent solution to the rail coal dusting problem is the issue of jurisdiction. While the railways may come under federal jurisdiction, the mines that ship the coal are under provincial jurisdiction.

In connection with the most recent rail dust complaints in 2000, the Canadian Transportation Agency attempted to take control of the situation and assume responsibility for the control of rail car coal dusting. On 7 December 2000, a federal court ruled that the Canadian Transportation Agency did not have jurisdiction in the matter. The issue of jurisdiction remains unresolved.

B.4 Coal by Rail - The Nuisance Dusting Issue in 2000

As noted above, complaints regarding dusting from coal trains once again became an issue in British Columbia in 2000. The 27 dusting incidents reported in the Flood-Hope area in 2000 were reported from May through October, Table B.1. (Hope 2001)

Table B.1 Dusting Coal Trains Reported Flood-Hope Area - 2000

Month	May	June	July	August	September	October
# of Dusting Trains Reported	2	9	8	5	2	1

The number of incidents in the spring and summer of 2000 was considered significant enough for federal and provincial agencies to reopen investigations into fugitive dusting from unit coal trains.

The CPR felt that one possible reason for increased nuisance dusting in the Hope area in 2000 was because of a change of routing by the CPR: (CPR 2000)

> *In January 2000, CPR began operating trains westbound over the CN track west of Kamloops under an infrastructure sharing arrangement that also sees CN trains operate eastbound over the CPR track. Consequently, CPR trains are operating through the Flood area for the first time.*

At a 'town hall' meeting in Hope, BC in September 2000, federal agency, provincial environment department, coal mining, and railway officials attempted to address citizen concerns regarding unit train coal dust emissions. At that meeting a number of issues were raised in conjunction with the issue of coal dust from unit trains. (CTA 2000) Comments regarding those issues, in regard to the dusting experiences in BC during the early 1980s are presented in Section B.5.

However, the dusting incidents in 2000 should be put in context. The 27 reported incidents of dusting trains in the Flood-Hope area were only a fraction of the unit coal trains that would have transited the area in that year. As reported by the industry in August 2000, "six to seven trains per day are required to move the coal to export". (Action 2000) Assuming that this refers to full trains only, if returning empty trains are then included, presumably 12 to 14 coal related unit trains could have been in transit through the Flood-Hope area every day. (Action 2000)

While the precise number of trains that carried coal in through the Flood-Hope was not available, Table B.2 attempts to relate the dusting incidents to the loaded coal train activity during the spring, summer and fall months of 2000.

As noted, observations of loaded trains near Agassiz, BC from 1979 to 1984 revealed that approximately 9% were judged to be emitting either 'medium' or 'heavy' levels of visible dust. (Cope 1986)

No other visible dusting incidents were recorded or registered with government agencies in 2000. Therefore, if one were to assume an equal number of trains for the remaining six months of 2000, the percentage of dusting trains would drop to just over 1% for 2000.

Table B.2 Relating Dusting Trains to Total Loaded Trains

Month	Days	Loaded Trains per month*	Recorded Dusting Trains	% Dusting
May	31	186	2	1.1
June	30	180	9	5.0
July	31	186	8	4.3
August	31	186	5	2.7
September	30	180	2	1.1
October	31	186	1	0.5
		1104	27	2.4

* assume 6 loaded trains per day

Therefore, the data available for 2000 appear to indicate that the situation in regard trains judged as 'heavy' emitters of visible dust has improved since the early 1980s. During June 2000 when the reported incidents of heavily dusting trains was highest, the rate of dusting trains was only approximately half what it was 20 years earlier.

Unfortunately, while situation regarding heavily dusting loaded unit coal trains appears to have improved, sufficient nuisance dusting occurred in 2000 to generate complaints from the public.

B.4.1 Recent Actions - Government Agencies

As noted, one of the difficulties that government agencies have encountered in attempting to address the issue of citizen complaints regarding nuisance coal dusting is jurisdiction. In the 1980s Environment Canada took the lead in regard to the coal dust issue, but while recommendations for improving dust control were prepared, that agency did not have the power to enforce any of the changes or improvements listed in those recommendations.

With the renewed concern regarding the number of heavily dusting trains in 2000, complaints regarding dusting were filed with the Canadian Transportation Agency (CTA) by residents of the Flood-Hope area of BC. In response, the CTA convened the 'town hall' meeting in September of 2000 in Hope, BC that brought together most of the stakeholders. In October 2000 the CTA issued the official minutes of that meeting. (See Section B.5) However, in March of 2001 the CTA reported that:

> *The Agency lost jurisdiction to investigate and determine complaints such as noise, vibrations, pollution, etc. resulting from rail operations per a Federal Court Ruling dated December 7/2000.*

However, while the CTA lost jurisdictional rights, it does not appear that the federal court indicated which government agency did have jurisdiction in this matter.

This investigation into emissions for fugitive coal dust in Canada is funded by the Canadian Council of Ministers of the Environment (CCME). As such it would appear that all provinces have an interest in the issue of fugitive coal dusting and wish to determine the extent of the problem by improving their estimates of total emissions.

While the situation, both historic and at present, in respect to nuisance dusting from trains is described in this report, the principal objective is to provide an analysis of total dust emissions for 2000. A resolution of the nuisance dusting issue is beyond the scope of this investigation.

B.4.2 Recent Actions - Coal Mines, Railways and Terminals

In 2000 the coal mine, railway and coal terminal companies most directly involved in the transport of coal in the Lower Fraser Valley formed an *Action Committee on Coal Dusting*. This industry-wide committee comprises the coal producers in BC and Alberta, the CN and CP railways, and the coal terminals located in the Vancouver region. The Action Committee was formed to coordinate industry-wide efforts to control coal dust during rail transport. The Action Committee comprises two working groups: the *Technical Working Group* and the *Community Relations Working Group*. (Laing 2000)

The Action Committee on Coal Dust identified five major items that required their immediate attention: (Laing 2000)

Complaint Protocol

A toll-free complaint line was established and a process was put in place for quickly tracing reported trains to their source for immediate corrective measures and for root-cause analysis.

The Complaint Process links the complaint line directly to CPR Operations who then identify the train and relay the complaint to either the mine (for loaded trains) or the port (for empty trains). The mine or port then relays their analysis of the problem and corrective actions to the Community Relations Working Group who then contact the person making the complaint.

Accountability to the Public

The plan is for an independent external auditor to conduct an audit of coal-dust control practices across the coal transport chain in accordance with the Environment Canada Guidelines published in 1986. The results of this audit will be reported to the public.

Monitoring of Early Detection

The Action Committee is investigating available monitoring technology and, if feasible, will install and test and automated coal-dust monitoring system to record and report levels of dust generated by passing loaded and empty coal trains.

Mandatory check points for all coal train crews will be established along the route to visibly assess the level of dusting for both loaded and empty coal trains.

Performance Reporting

The Action Committee is developing a reporting process to evaluate the coal industry's performance in meeting its dust-control objectives. The Community Relations Working Group will work with community representative to develop a reporting format that meets the public's needs.

Stakeholder Involvement

The Action Committee plans to work with the public, local governments and government agencies on a regular consultative basis.

Committee Actions to Date

The Report of the industry Action Committee on Coal Dusting, issued on 30 August, 2000, claimed that since industry officials were made aware of increased coal dusting, the mines have undertaken the following steps: (Action 2000)

1. Each mine performed a complete spray system check to ensure all components were functioning properly. These checks have been and will continue to be completed on a daily basis by operating personnel. Issues identified during system checks are and will continue to be resolved before train loading commences.

2. Each mine reviewed operational practices and objectives with all crew supervisors. Supervisors conducted and will continue to conduct checks at the loadout and associated facilities during every train loading. Appropriate employees involved in loading trains reviewed their procedures and practices to ensure they are applied consistently. Operations management reaffirmed with appropriate personnel that the contents of all railcars must be properly coated with suppressant before trains are allowed to leave the mine site.

3. The railways reviewed operating procedures with train crews to ensure dusting trains are reported immediately and procedures for proper handling of dusting trains are followed.

The coal companies are also reported to have made adjustments to the concentration and/or amount of dust suppressant applied to railcars to improve dust suppression. In conjunction with these adjustments, the industry increased the frequency of crust-retention monitoring at the port to gather more detailed data on crust retention performance.

In summary, to combat the coal dust issue, the mines, railways and terminals have:

- Investigated the complaint,
- Thoroughly reviewed coal dust control guidelines, processes and procedures,
- Optimized (and will continue to optimize) the amount and concentration of suppressant used to reduce coal dust,
- Formed an Action Committee to coordinate industry efforts for immediate and long-term dust control,
- Established a communication process for complaints which ensures a prompt response, and
- Increased monitoring of crust retention now and into the future.

In their letter of 18 October 2000, the Action Committee also added that: (Laing 2000)

- The ports have already implemented changes to ensure that coal cars are being unloaded at the maximum angle of rotation to minimize the potential for coal carry-back in the empty cars.
- A third party will be retained to monitor empty trains for coal carry-back at Westshore Terminals, while Neptune Bulk Terminals will continue to monitor empty trains visually and by videotape.

B.5 Discussion Related to Public Meeting Hope, BC on 20 September, 2000

Based upon experience with the nuisance dusting issue from coal shipped by rail in British Columbia in the 1980s, the authors offer the following comments *in Italics* in regard to the issues raised and reported in the minutes of the 20 September 2000 meeting in Hope, BC. That meeting was attended by: provincial government and federal government agency representatives, coal mine personnel, railway company personnel, coal terminal officials and members of the general public. The Canadian Transportation Agency convened the meeting and published the minutes. (CTA 2000)

General Comments - Related to Canadian Transport Agency Minutes of 20 September 2000 Meeting in Hope, BC Related to Fugitive Dust from Coal Trains

Many at the meeting seemed to be viewing the coal dusting from trains in the region from Hope to Vancouver as a new issue that needs to be studied in depth before action can be taken. It is not a new issue. Heavily dusting trains were a problem in 1973. The mines began effective train spraying and agreed to the 85% crust retention standard in 1975. There were few or no complaints for 5 years until 1979 when heavily dusting trains once again became a problem. From 1979 to 1984 of over 2000 trains that were observed, approximately 10 percent were considered medium to heavy dusters and created nuisance pollution. (Cope 1986)

Regarding Statements from Coal Mine Representatives

a] "Objective of the mines it to achieve 85% retention of crust...empirically that retention should prevent dusting"

NO *– the Recommended Practices clearly state that 85% retention is the 'minimum acceptable level of dust control' – 85% retention will not 'eliminate' dusting. The original report clearly states that 85% crust- retention should 'eliminate' heavily dusting trains, not all dusting. Mining companies originally agreed to the 85% crust-retention standard in 1975.* (Wituschek 86)

b] "Mines only apply suppressant at the same rate based on the Environment Canada report findings."

NO *– at no time do the reports or Recommended Practices issued in 1986 list rates or concentrations of suppressants.*

c] "Covers for cars are too expensive and technical difficulty due to loading and rotary dumping."

NO *– whether they are too expensive when prorated over time remains to be proven, however, they may be too expensive to retrofit into and existing system. However, automated cover systems do work. In 1984, the near flawless operation of an automated cover system was witnessed including loading at a mine and the rotary dumping at a power plant in the Dakotas.* (Cope 1986)

d] "Since being made aware of the dusting issue, the mines have taken actions to prevent dusting"

They have been aware of dusting complaints since 1974? All of the measures recently listed by the mines should have been in place and in operation since 1975. The mines agreed to spray cars in 1974.

Statements by Railway Companies

"Re-issued bulleting instructing crews to report dusting trains"

But did the railway companies re-issue the bulletin instructing the crews to slow down those trains as agreed to in the Recommended Practices?

Statements by Other Government Departmental Experiences

Transport Canada

"Note that dusting trains are limited to 25 mph speed limit to reduce continued dusting"

How often in 2000 did trains reduce speed and was it effective?

BC Environment Department

"Need to re-evaluate procedures in 1986 Federal DOE report as equipment and suppressants have changed since the report was issued"

While a review is needed, the question is did the mines change equipment to make dusting worse? Or, in other words, why and when did they change? If from 1986 to 2000 their dust suppressant systems worked (few complaints?) then why did they change? If new mines or owners are on then scene, why did they not incorporate the successful designs?

Canadian Transportation Agency

"Want a permanent solution not just resolution of dusting issue in summer 2000"

The truly permanent solution would be to add an automated cover system to every unit coal train operating in western Canada.

"Crew reporting of dusters has improved"

The question is improved from what and since when? Trains have been dusting heavily and there have been nuisance complaints since 1974.

"Slower speed for dusters can minimize dusting"

While this may be the case, the question remains, how frequently do trains slow down to prevent dusting and does it work? Since there were heavily dusting trains reported in 2000, either they did not slow down when dusting or slowing down did not work?

B.6 Recommendations

The following are suggested for improving estimates of fugitive coal dust emissions in Canada and for ameliorating the nuisance dusting problems for coal trains.

B.6.1 Recommendations Designed To Assist in Resolution of Nuisance Fugitive Dusting Problems

For British Columbia, in relation to the nuisance-dusting problem related to rail transport, a trackside monitoring system could be used in the communities most affected. This system could relate incidents of significant fugitive dusting to the mine of origin. The dust monitoring system could also be used to attempt to establish more accurate emissions factors and control efficiency data for rail coal movement in Western Canada.

Railcar dust control efficiency is difficult to assess. While crust-retention on railcars has been used for over 20 years to assess dust control on loaded rail cars, more conclusive empirical data to support a direct link between crust-retention percentage and dust control efficiency is still required.

Inter-linked Monitoring Programs

The current monitoring programs for crust-retention at coal terminals should also be inter-linked to the suggested en route system for monitoring dusting trains. It should also be combined with the public complaint feedback system established by the joint-industry Action Committee on Coal Dust. This system allows dusting train complaints to be linked to the mines of origin and any problems related to sealant spray systems.

This type of en route monitoring program is now in place in Virginia in the USA. Two automated Trackside Monitors are used to acquire information on dusting trains. (NS 2001-1)

It is important to note that this monitoring system should be designed to include coal imported into Canada from mines in the United States. As noted in Chapter 2, in 2000 at least one of the terminals in the Vancouver area experimented with the transshipment of export coal from mines in the Powder River Basin of the USA. While the future of these shipments is unknown, so is the nature of the rail car dust control measures that may or may not be used at the mines in the USA.

Comprehensive Survey of Fugitive Dust Control Techniques at Coal Mines

Considering the long history of fugitive dusting and related nuisance dusting complaints in regard to coal rail dusting, a comprehensive survey of the fugitive dust control techniques at each mine is required. This survey should be linked to the dust monitoring surveys noted above and an attempt should be made to discover why the nuisance dust problem has yet to be fully resolved.

An annual survey of the dust control equipment and procedures at each mine that ships coal by rail may be required in order to assess changes from year to year.

B.6.2 Information Requirements

Unfortunately, during the course of this investigation, most of the coal industry sources that were contacted for information did not respond, or did not supply the information requested. For a more accurate assessment of fugitive coal dusting, and the state of the dust control procedures used for controlling dust from unit trains, and storage piles in Canada in 2000, Tables B.3 to B.6 would have to be completed. While mines and associations were contacted during this investigation for this information, response was minimal.

Table B.3 Train Dust Control – Equipment 2001

Equipment		Sill Clean	Car Profile Load-Level Type	Compact	Adjust Load Backhoe	Re-level	Type of Sealant	Spray System Number or Spray Bars	Re-Spray Facility	Monitor Cones & Mixiing	Freeze Protection	Wind Protect
Mine	**Prov.**											
Bullmoose	BC											
Coal Mountain	BC											
Elkview (Balmer)	BC											
Fording River	BC											
Greenhills	BC											
Line Creek	BC											
Quintette – closed 2000	BC											
Coal Valley	**Alta**											
Gregg River – closed 2000	**Alta**											
Luscar	**Alta**											
Obed	**Alta**											
Smoky River – closed 2000?	**Alta**											
Bienfait	**Sask**											
Poplar River	**Sask**											
Prince	**NS**											
Nfld Import via Que	Que											
Transshipment												
Powder River Basin, Mon	**RB-BC**											
Powder River Basin,Wyo	**RB-BC**											
Powder River Basin	**TB-Ont**											

Table B.4 Train Dust Control - Procedures - 2001

Equipment		Spray Systems Training Programs	Malfunction Procedures	Verification Procedures		Spray Conc &Volume	Inspect and Adjust During Car Spraying	Re-spray After Load Adjustment	Re-spray Cars if Required	Records of Spraying
Mine	Prov.			Equipment Function	Levelling					
Bullmoose	BC									
Coal Mountain	BC									
Elkview (Balmer)	BC									
Fording River	BC									
Greenhills	BC									
Line Creek	BC									
Quintette – closed 2000	BC									
Coal Valley	**Alta**									
Gregg River – closed 2000	**Alta**									
Luscar	**Alta**									
Obed	**Alta**									
Smoky River – closed 2000?	**Alta**									
Bienfait	**Sask**									
Poplar River	**Sask**									
Minto	NB									
Prince	**NS**									
Nfld Import via Que	Que									
Transshipment										
Powder River Basin, Mon	**RB-BC**									
Powder River Basin,Wyo	**RB-BC**									
Powder River Basin	**TB-Ont**									

Table B.5 Dust Control Storage Piles

Dust Control Storage Piles and Handling 2001

Control System Possible Storage Piles	Prov	# Piles	Max Pile Capacity	Water Spray Towers	Sealant Sprays	Pile Orientation	Pile Wind Fences	Water Truck	Stop Operations High Wind	Sprays on Conveyors	Sprays Stacker-Reclaimer	Other
Westshore	BC		2.5 Mt	119	roads/piles			fleet		yes	yes	integrated control system
Neptune	BC			yes		SW-NE		yes	yes			
Ridley, Prince Rupert	BC											
Cement Plants LFV	BC											
Comox	BC											
Texada Island	BC											
Battle River PP	Alta											
Genesee PP	Alta											
Keephills PP	Alta											
Sheerness PP	Alta											
Sundance PP	Alta											
Wabamun PP	Alta											
Brandon PP	Man											
Selkirk PP	Man											
Belledune PP	NB											
Grand Lake PP	NB											
Iron Ore Coy, Nfld	Nfld											
North Star Cement	Nfld											
Auld Cove, S of Canso	NS											
Domestic Coal Yard	NS											
Halifax, NS	NS											
International Pier, CB	NS											
Lafarge, Brookfield	NS											
Lingan PP	NS											
Point Aconi PP	NS											
Point Tupper PP	NS											
Trenton PP	NS											

Table B.5 Dust Control Storage Piles (continued)

Dust Control Storage Piles and Handling 2001

Control System / Possible Storage Piles	Prov	# Piles	Max Pile Capacity	Pile Water Sprays	Sealant Sprays	Pile Orientation	Pile Wind Fences	Water Truck	Stop Operations High Wind	Sprays on Conveyors	Sprays Stacker-Reclaimer	Other
St. Mary's Cement	Ont											
Atikokan PP	Ont											
Dofasco, Hamilton	Ont											
Lakeview Power Plant	Ont											
Lambton Power Plant	Ont											
Nanticoke Power Plant	Ont											
Port Stanley	Ont											
Sarnia	Ont											
Stelco, Hamilton	Ont	4			piles				work lee side			low compact piles
Stelco, Lake Eric	Ont	3			piles				work lee side			low compact piles
Thunder Bay	Ont											
Thunder Bay PP	Ont											
Sept. Iles for Nfld	Que											
Montreal	Que											
Bienfait Char	Sask											
Boundary Dam PP	Sask											
Poplar River PP	Sask											
Shand PP	Sask											

Table B.6 Railway - Train Dust Control Procedures

Railway Company	Group Cars of Similar Height	Speed Control Systems at Load-Out Facilities	Reduce Speed of Dusting Trains
CP			Claim a slow down order is in effect for dusting trains.
CN			
BCR			
Imports			
Rail to Vancouver			
Rail to Thunder Bay			

Appendix C

Coal Dust Control, Recommended Practices for Loading, Unloading and Transporting Coal by Rail *(Wituschek 1986)*

In general, the estimate of total dust released was not the issue. The Recommended Practices were intended to address nuisance dusting and their control, and not the estimation of total dust released by unit coal trains. These *Recommended Practices* underwent a page by page review and agreement by every major coal producer in Western Canada and the Coal Association prior to publication.

Table C-1 Recommended Design Practices – 1986

Design Recommendations for Load-Out Facilities

The optimum design criteria for loading, levelling and spraying systems are presented below. Some of these criteria may not apply where it is demonstrated that satisfactory control is being achieved. In general, each load out facility should be designed to:

- Achieve a uniform flat surface profile along the full length and width of all loaded rail cars, using either properly designed loading chutes or separate levelling devices;
- Provide a device to remove loose coal from the rail car sills using either sill sweeping devices incorporated as part of the load out station or a separate mechanism located before the chemical spraying station;
- Provide a chemical application spraying system consisting of primary and secondary spray units, each equipped with its own pumping unit, discharge piping, flow meter and spray header. The secondary spray unit should be located a sufficient distance from the primary unit to allow the identification of problem cars and to facilitate re-spraying. At facilities where only one spray header is used, trains should be backed up and re-sprayed if improperly sprayed the first time;
- Employ spray patterns that achieve complete and uniform coverage over all areas of the load surface within a car, regardless of the train speed through the load out;
- Provide freeze protection for effective operation during cold weather periods;
- Use spray nozzles compatible with the chemical requirements of the chemical solution and applied pressure;
- Provide wind screens to prevent spray pattern distortion at sites where high winds prevail;
- Provide a compressed air supply to clear blocked nozzles;
- Provide adequate mixing in the tanks where batch solutions are mixed;
- Provide a sufficient volume of mixed solution to spray a complete train when batch mixing systems are used;
- Provide automatic low level sensor and audible alarm on the solution storage tank for batch mixing systems or on the chemical storage tank for in-line mixing systems:
- Provide a flow metering device on the piping to the spray header to record flow rates and total volumes applied to each train; and
- Provide variable flow to the spray header in order to apply more solution volume to the end slopes in relation to the center flat section of the load profile.

Design Recommendations for Empty Rail Car Cleaning Facilities

Where there is a coal dust problem from empty trains, each terminal should provide an exterior rail car cleaning facility designed to remove loose coal deposited on the external car surfaces.

Water washing systems should have:

- Adequate system pressure and spray pattern to reach all exterior surfaces of the car;
- A self-draining system for the piping and spray headers to prevent freezing in cold weather operation;
- A wash water collection pad at the spray station to collect the wash water for recycling; and
- A wastewater treatment facility to meet local requirements-for suspended solid removal before discharging to the receiving environment.

Air cleaning systems should provide:

- Adequate system pressure and air jet pattern capable of reaching all exterior surfaces of the car;

- An enclosure for the rail car cleaning system. The enclosure should be equipped with an adequate air exhaust system; and
- A high efficiency emission control system on the air exhaust from the cleaning station capable of meeting the air pollution control requirements of local regulatory authorities.

Table C-2 Recommended Operating Practices – 1986

Load-Out Facilities

As a general requirement, the coal producers should plan and implement training programs for company employees assigned to the loading, levelling and spraying operations and emphasize the importance of proper system operations for achieving coal dust control. Training in environmental control could be integrated with other employee training programs such as technical and safety programs. Proper maintenance of load levelling equipment, sill cleaning devices and spraying equipment is essential. A comprehensive schedule of preventive maintenance of these systems should be implemented and an adequate supply of chemicals, spray nozzles and other essentials should be kept in stock. Each mine should develop a set of procedures to be followed in the event of equipment malfunction during the load out operation in order to avoid the possibility of poorly sprayed cars leaving the mine.

Operating procedures should include the following main features:

- Verify the proper operation of all equipment when loading the first cars, in particular the operations of the load-leveller or compactor, sill sweeper and chemical spray system;
- When load adjustments are made at the mine, the load should be levelled and re-sprayed with sealant prior to departure from the mine site;
- Verify the concentration and volume of the chemical solution before spraying a train for batch mix systems, and pump flow rates and settings for in-line mixing systems;
- Ensure that an appropriate volume of mixed solution is applied to each car;
- Inspect and adjust, if required, the operation of the system during the spraying of the first few cars;
- Re-spray any improperly sprayed cars; and
- Maintain records of solution concentration and volume for each train, including notes on system malfunctions, profile problems or other deficiencies.

While research and development are encouraged, proposed changes in chemical sealants should be first reviewed by the senior operating employees responsible for dust control operations and then approved for testing and/or routine use.

Coal Terminal - Empty Car Cleaning Facility

- Personnel involved with the operation and maintenance of the car cleaning system should be formally trained and advised on environmental requirements;
- Equipment malfunctions should be corrected immediately. Standby truck mounted spray systems, normally used at terminals to control fugitive coal pile emissions, should be used to used to wash rail cars in case of malfunctions in the car cleaning system; and
- Trains should be visually inspected and cleared by a designated employee prior to departing the terminal

Coal Train Operations

- Railway companies should provide coal train sets consisting of cars of uniform height when practical. Where cars of different height must be used within a train set, cars of similar height should be grouped together;
- Locomotive speed control systems at load out facilities should be maintained operational to ensure proper loading of coal; and
- In the event of heavy dust emissions from loaded or empty trains, train crews should be instructed to reduce the train speed to prevent dust emissions through communities where coal dust impacts are of concern.

FUGITIVE COAL DUST:

AN OLD PROBLEM DEMANDING NEW SOLUTIONS

G. D. Emmitt, Ph.D.
Simpson Weather Associates, Inc.
809 E. Jefferson Street
Charlottesville, Va. 22902
USA

Telephone: 804-979-3571
Fax: 804-979-5599
E-mail: gde@thunder.swa.com

Abstract

Declining public tolerance of the nuisance aspects of fugitive coal dust together with the increasing dustiness of the coal products being marketed have presented operators of coal terminals with a situation that demands improved and/or new control measures. The response of railroads and port facilities in the Commonwealth of Virginia to increased pressure to be good corporate neighbors was to invest in the development of new dust control strategies and technologies. A discussion of these new initiatives is presented within the context of an integrated dust mitigation program.

1.0 Introduction

Swirling black clouds of coal dust lofted by the gust front of an approaching thunderstorm can ruin the day for the operator of a coal transshipment facility. Perhaps no air quality standards are exceeded, but the "blow-out" provides a visual suggestion to neighboring businesses and homeowners that, perhaps, some of their housekeeping costs should be underwritten by the offending coal terminal(s). As the air quality regulations for particulate shift away from TSP to PM-2.5 and/or PM-10, some of the nuisance aspects of fugitive dust emissions shift, in some jurisdictions, to remediation through the civil courts.

An increasingly fine grained coal product, the typically windy conditions of port facilities, and a rising intolerance of pollution trespass by neighboring property owners all combine to put increased pressure on coal handling facility owners to go beyond what it takes to just meet the regulated air quality standards. The coal mining and transportation businesses in the Commonwealth of Virginia have responded to regulatory and political pressure in ways that can serve as blueprints for others involved in similar situations. Several new operating practices and technologies have been developed that demonstrate the industry's willingness and capability to be good corporate neighbors.

As consultant to several major coal marketers and transporters, Simpson Weather Associates, Inc. (SWA) has been involved with developing innovative programs and technologies to meet air quality standards and to reduce the nuisance of fugitive coal dust and its impact on individuals and businesses located in close proximity to rail corridors, ground storage areas or shiploaders. By "nuisance" we mean, in general, emissions of odors, particulate, noise, light etc. that fall below the allowable thresholds set by

regulatory agencies but are still considered to be sufficient to cause economic losses or inconveniences. In the case of fugitive coal dust emissions, nuisance usually denotes soiling as opposed to any health or biological insults.

The technologies and programs that are described in this article have been developed by SWA with funding from transportation partners including a railroad and two marine coal terminals (Dominion Terminal Associates and Pier IX of Newport News, Va.). These ideas include a Trackside Monitor (TSM), a Rail Transport Emissions Profiling System (RTEPS), a Coal Car Load Profiling System (CCLPS), ProControl, and a Portable Laser for Coal Emission Mapping (PLACEM).

2.0 Fugitive dusting from mine to ship

From the perspective of the port facility operations, their primary concerns are associated with fugitive emissions while the coal is in port. Emissions during loadout and rail transport are usually of secondary interest. However, the way in which the coal is handled and treated prior to its arrival in port can have effects on its "behavior" while being dumped, stored and reclaimed.

The following discussion of a suite of fugitive coal dust control programs and technologies is presented within the context of a common mine-to-ship scenario. The coal being marketed has gone through a processing plant where it is crushed, washed and thermally dried. The coal is loaded into railcars with a flood loader equipped with a spray bar and load profiling "plow". The train then travels 500 miles to port at speeds up to 50 mph. The rail corridor passes through many towns and cities that have experienced train traffic for many decades. The port facility is located in a generally industrial area but is in close proximity to residential and commercial dwellings, some of which were built long after the coal facility was in operation. The coal is unloaded using rotary dumpers and transferred to 60-80 foot high piles. After several days, the coal is reclaimed for loading into ships or barges for transport to its final destination.

The two properties of coal that we focus upon are its dustiness and its moisture content. Moisture content effects the handling characteristics, the BTU value and, for some coals, the potential for spontaneous combustion. A high bulk moisture content upon arrival in port may reduce the dustiness during stackout but may also set the piles up for sloughing or complete collapse after a lengthy period of rain. Low moisture content usually results in a dust problem through the entire transportation process. SWA's approach to all dust control projects joins the issues of moisture management and dust suppression.

3.0 Integrated approach to fugitive dust control

3.1 Selective treatment

Since dust control in port begins with dust control at the loadout facility near the mine, a program to spray the tops of loaded rail cars has been instituted. Not all coal products have the same potential to dust. In fact, the same coal's dusting potential may vary from season to season. Therefore the use of chemical dust control agents at the loadout facilities is based upon both laboratory and field evaluations of individual coals. In the laboratory, a wind tunnel is used to establish a dusting index called the Seasonally Adjusted Rail Transport Dusting Index (SARTDX). Each tested coal is ranked in terms of its dustiness relative to a reference coal. The reference coal is one that was the subject of an extensive series of experiments over a protracted period of time.

The laboratory classification of a coal is sometimes followed by a field test that involves the use of the Rail Transport Emission Profile System (RTEPS). RTEPS is a collection of active and passive instruments that are mounted on the rear of coal cars, providing one second data on all factors related to the stress (e.g. wind, rain, radiation, train speed) and the response (e.g. dusting, load redistribution, load settling) of the coal during transit. A railcar loaded with treated coal and equipped with the RTEPS is shown in Figure 1.

3.2 Providing timely feedback

As part of an agreement between the railroads and the State, monitors have been set up within the rail corridor to monitor the performance of the dust control prescriptions and the voluntary participation by the mines. A permanent TrackSide Monitor (TSM) was installed "uptrack" about 50 miles from port in a location where the trains tend to move at track speeds of 35-45 mph. A picture of the TSM is provided in Figure 2. The TSM includes a Realtime Aerosol Monitors (RAM), a weather station, a laser transmissometer, an Automatic Equipment Identification (AEI) transponder reader, and a video camera. Data from the TSM are uploaded to the consultant's main computers once per day, where the data is analyzed and reports on the performance of the treated and untreated loads passing that site are sent to the railroad for disposition.

In response to the clustering of some complaints on dust from railcars, a mobile version of the TSM was built and deployed. This version of the TSM not only provides very site specific dusting data but also visible evidence that the railroad is working on a local level to reduce the incidences of severe dusting events.

While the TSMs provide reliable evidence of dusting coal loads, they have an inherent limitation. The weather conditions and the speed of the train as it passes the TSM site must be conducive to dusting to consider the absence of a dusting signal as evidence of a non-dusting coal shipment. Also, the TSMs do not provide data for estimating the amount of coal lost to wind erosion during the entire rail trip. Thus, after extensive field studies to measure the tons ($$)/car loss of material during transit, a Coal Car Load Profiling System (CCLPS) was developed. CCLPS uses a scanning laser suspended over moving railcars to generate a 3-D mapping of the load top (Figure 3). Using an algorithm based on the field data, the volumetric changes to the load during transit can be estimated and the performance of the treatment applied at the mines evaluated. Currently the CCLPs resides in port for special diagnostic studies.

3.3 Fugitive dust control during stackout and reclaiming

If the treatment at the mine is successful, the coals then arrive in port resistant to dust emissions until they are unloaded in the rotary dumper. Given a treatment that addressed moisture uptake/loss as well as dust suppression, the coals should have also maintained moisture contents close to what they were during loadout. The case we are describing here is a port facility that employs the standard set of Best Available Control Technology (BACT) throughout the rotary dumping, belt transfer, stackout and pile forming. That is, the rotary dumper is enclosed, transfer belts are covered, scrappers are used to reduce "carryback", water sprays are used to wet down the working areas and water cannons are available for wetting down the storage piles. An example of the use of water cannons on storage piles is presented in Figure 4. The same BACT dust control measures apply to the reclaiming and shiploading activities.

In addition to the visual monitoring of yard activities, several RAMs have been installed to provide feedback to the operators of the stacker/reclaimers, bulldozers and maintenance vehicles. These RAMs can detect very low levels of particulate concentrations and, when combined with the wind data, not only provide the facility operators with an alert, but also suggest a likely cause of any higher than background dust signal. Monthly statistics derived from the log of alerts serve to focus enhanced dust prevention measures.

The in situ nature of the RAMs limits their usefulness to those times when the wind carries the dust plumes to them. Using a CO^2 laser, a prototype for a Portable Laser for Coal Emission Mapping

(PLACEM) was developed and demonstrated by Pier IX Terminals. The laser transmits a beam of infrared light which is then scattered by particles suspended in the air. A portion of the light is scattered back to a detector, which is co-located with the transmitter; the more particulate, the stronger the backscatter signal. .By scanning the entire coal facility several times per minute, the PLACEM builds a "climatology" of dust emission sites and activities. This then helps the facility owners to prioritize their investment in improvements to the dust control program. PLACEM is not yet in full operation.

3.4 Reducing emissions from storage piles

After the coal is in piles, the surface of the pile becomes the focus of dust suppression measures regardless of the internal (bulk) moisture content. The usual options for dust control of coal storage piles are topical treatments with a binder applied using a tanktruck or the use of water applied with an array of water cannons. The binders tend to be expensive and given the mean time between pile disturbances, are usually reserved for the problematic coals or extremely stressful situations. In Virginia, the scheduling of the cannons is the focal issue when both the effectiveness and the optimal use of water are considered. The State worked together with two coal terminals to develop a rational and objective basis for activating the water cannons. Antecedent weather, current weather and a 12-hour weather forecast were used to compute the wind erosion and drying stresses on the piles and prescribe a preventative application of water. The algorithm for scheduling the water cannons became known as the "K-factor".

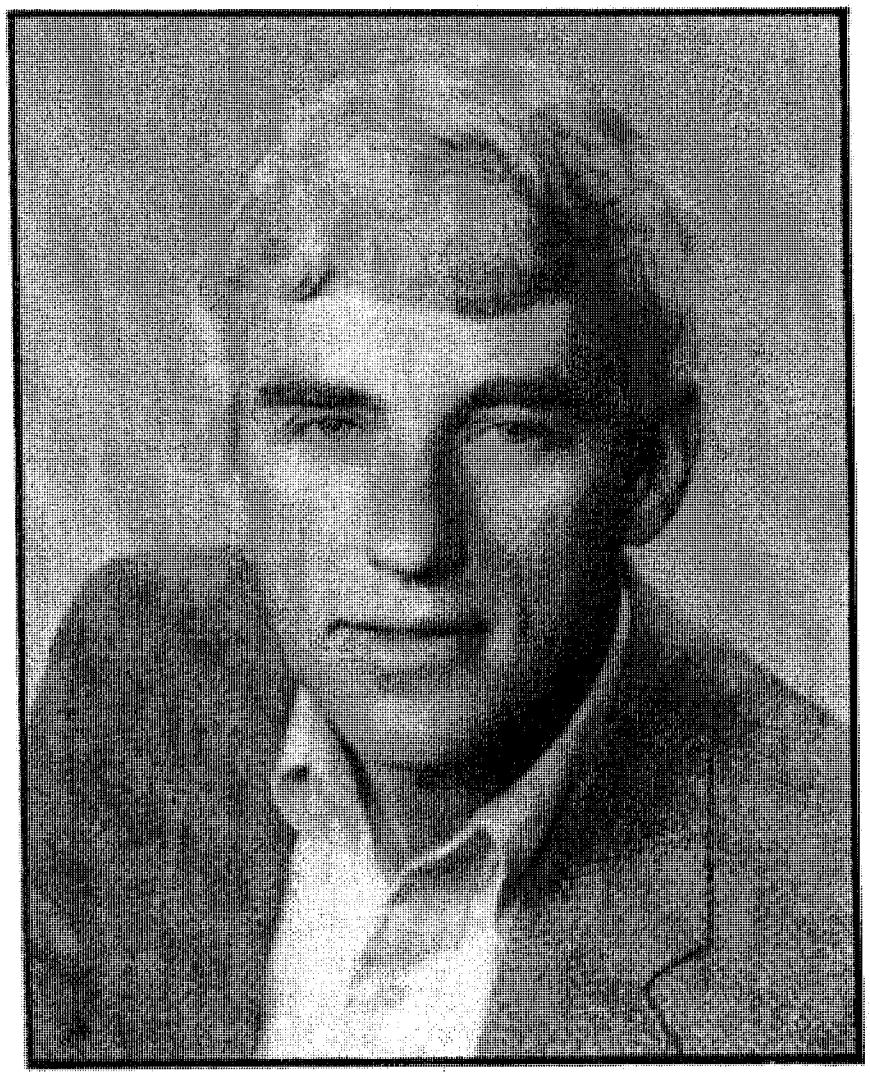
The logic of the "K-factor" has been combined into a more comprehensive package of software tools called ProControl. ProControl displays the weather data and dust monitor signals, schedules the cannons according to the "K-factor", and maintains records of interest to the State as well as the facility operators. Currently ProContol is being modified to include warnings of conditions favorable to the physical collapse of specific coal piles due to excessive moisture retention. Figure 5 provides an example of the weather and other advisory information displayed on the main screen of ProControl.

3.5 Documenting success and good faith effort

Having made significant investments in meeting imposed air quality standards and self-imposed "good neighbor" goals, the railroads and port terminals become involved in the dilemma of deciding whether or not to document the performance of their efforts. Usually there is the required TSP or PM-10 monitor with reports to the regulatory bodies. As Figure 6 shows, improvements can be seen in the long term statistics of many observations (180J is located just across a terminal's property line; Hampton is a regional monitoring site). Going beyond the conventional monitoring obligation raises the issue of recording emissions in ways that may be misinterpreted in adversarial situations. On the other hand, the data collected by RAMs or dustfall samplers can be used to show good faith effort, improved control, and identify specific targets for further investment that may be more cost effective than blind application of a control measure to the whole operation. The decision to collect data as part of a self-imposed dust control enhancement program must take into consideration many issues that will vary greatly from one terminal to another.

4 Conclusions

Taking extra steps beyond the required measures to meet air quality standards can involve significant costs and carries the risk of raising unreasonable expectations of the coal transportation industry. However, with the public's decreasing tolerance for the nuisances they associate with coal dust, there is political, legal and economic wisdom in demonstrating a good faith effort. Also, while not discussed above, there are some tangible benefits to the railroads and terminals. These cost savings may include reduced contamination of rail ballast with coal dust, reduced revenues due to loss of material, and reduced costs of cleanup of roadways and other work areas.



5 About the Author

Dr. George Emmitt is President and Senior Scientist with Simpson Weather Associates. His degrees are in Physics and Environmental/Atmospheric Sciences. His work with the coal transportation sector has been an opportunity to combine ongoing basic research in lasers for observing the earth's atmosphere and his experience with conventional observations and numerical models in solving practical problems.

6 Enquiries directory

Simpson Weather Associates, Inc.
809 E. Jefferson Street
Charlottesville, Va. USA
22902

Telephone: 804-979-3571
Fax: 804-979-5599
e-mail: gde@thunder.swa.com
Web Site: http://cyclone.swa.com

7 Captions

Figure 1: Railcar loaded with coal that has been groomed with a rake/plow and sprayed with a binder. The instruments attached to the rear sill of the coal car are part of the RTEPS.

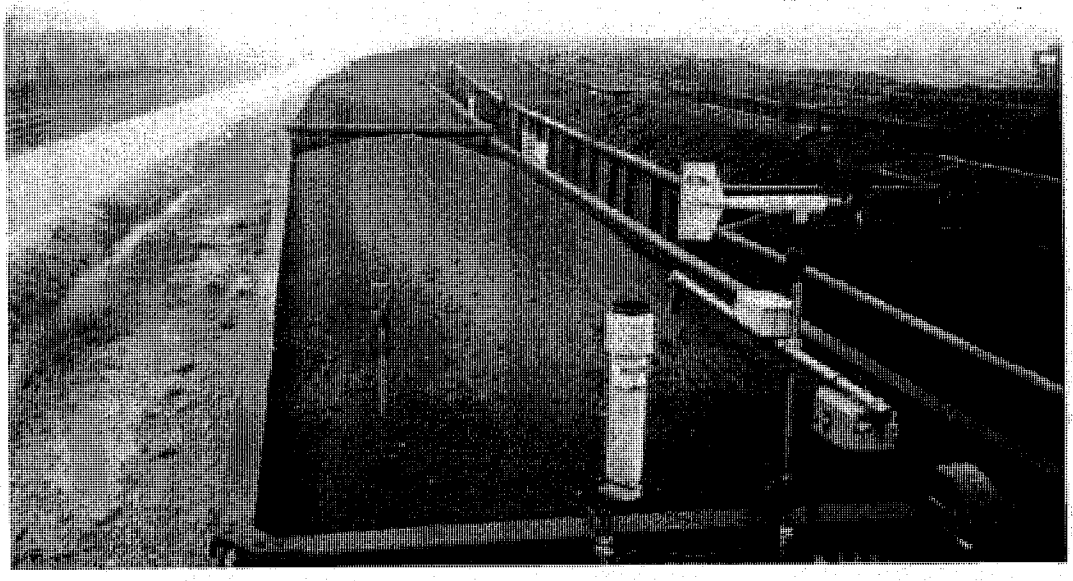
Figure 2: TSM site for monitoring the emissions from passing trains. The tower on the far right of the figure holds a laser that is focused on a detector mounted on the main tower (at left) and the intake for a RAM. All other instruments are located on the left side of the track.

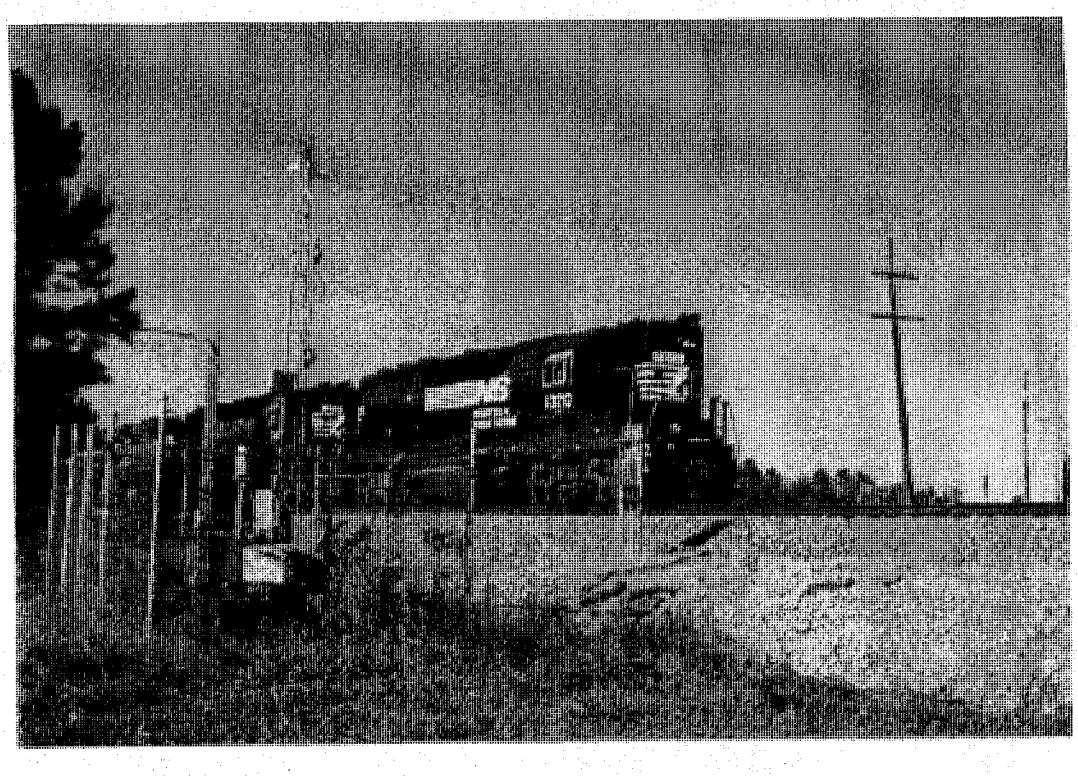
Figure 3: An example of a 3-D mapping using CCLPS of the top of a load of coal after it arrived in port. The white area denotes an area where the binder has been lost during transit.

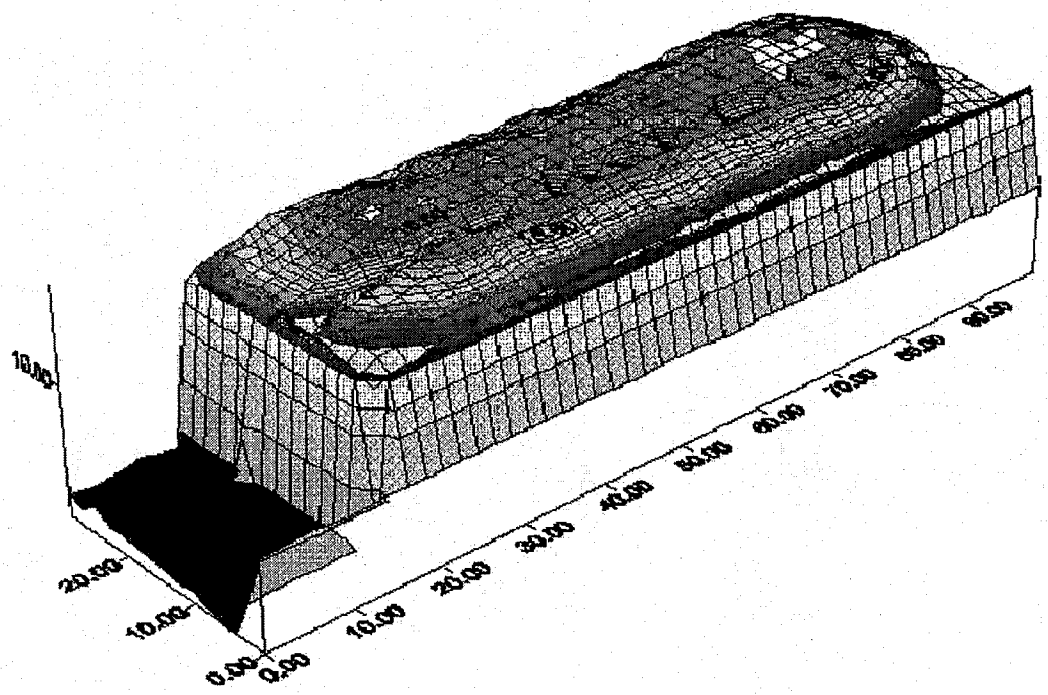
Figure 4: Water cannons being used to wet coal storage piles in Newport News, Virginia. ProControl schedules the activation of the cannons based upon the weather and coal type.

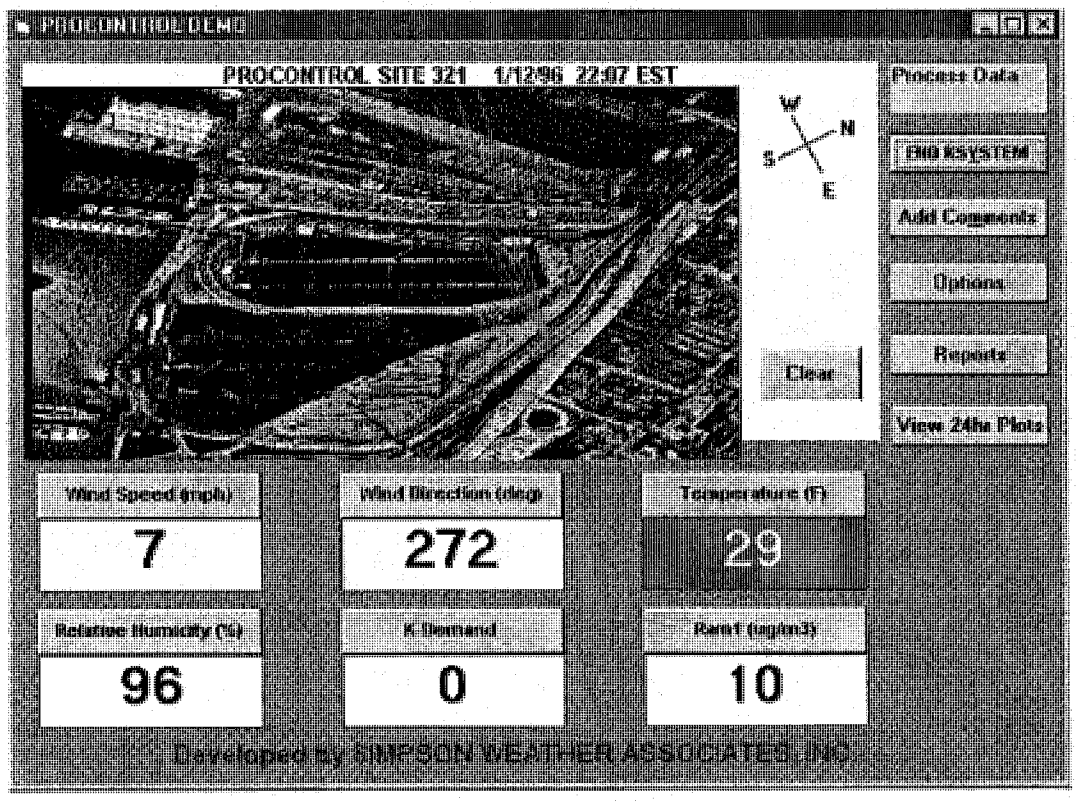
Figure 5: Example of the information presented on to the facility operators by the Pro Control system. The fan of lines focused on a point in the lower right of the image denote the suspected area containing the source of a detected dust event.

Figure 6: The decrease in the PM-10 concentrations after 199? Is coincident with steady improvement in the coal terminals' execution of their dust control programs. Note that the annual averages are well below the allowable limit of 50 micrograms/meter^3.

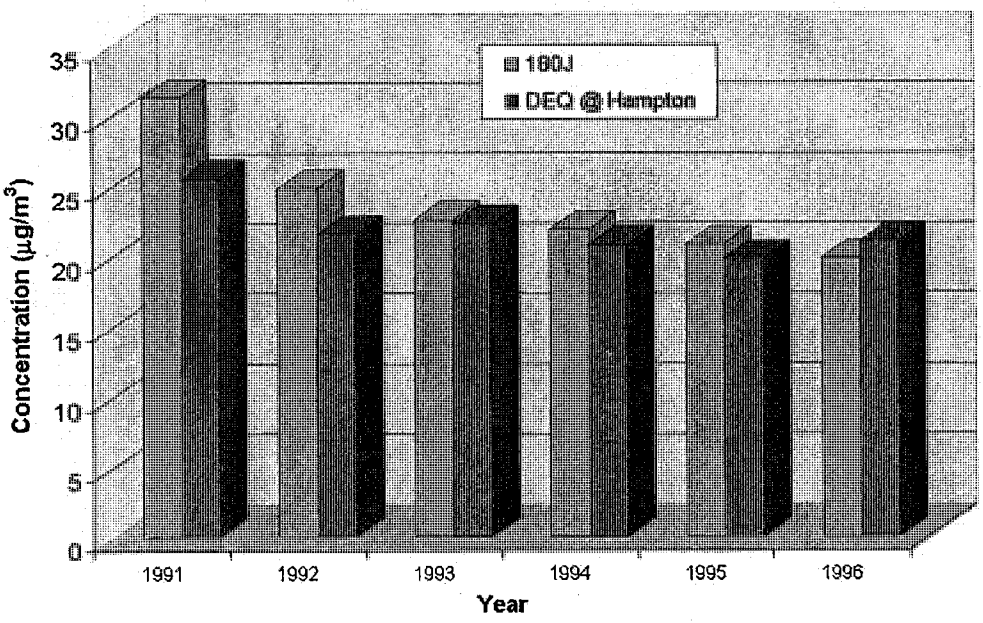





10.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00



PM-10 Yearly Concentration Averages



E. CALVIN

PROCEEDINGS
for the
Seventh Annual

ENVIRONMENT VIRGINIA '96
SYMPOSIUM

A TWO-DAY CONFERENCE
ON
ENVIRONMENTAL MANAGEMENT
AND POLLUTION PREVENTION

APRIL 11-12, 1996

Cameron Hall at Virginia Military Institute
Lexington, Virginia

Presented by
the Virginia Department of Environmental Quality
and VMI Research Laboratories, Inc.

PROCONTROL: AUTOMATED FUGITIVE DUST CONTROL SYSTEM

George D. Emmitt
Linnea S. Wood
Edward M. Calvin
Steven Greco
Simpson Weather Associates, Inc.
Charlottesville, Virginia

ABSTRACT

In the early 1980's, two new export coal terminals were built in Newport News, VA. Unlike the older terminals in the area which kept the coal in rail cars until ship loading, these newer facilities store the coal temporarily in 50-100,000 ton piles. Located on the north banks of the James River, the coal terminals are exposed to southerly winds, winds that blow from the river, across the coal storage area and into the adjacent community and business district. The terminals, working together with the Virginia Department of Environmental Quality (DEQ) and Simpson Weather Associates, developed a methodology and technology that has significantly reduced dust emissions. The 'K-factor' approach that resulted from this cooperative effort has now become one component of a more comprehensive dust control/monitoring system called PROCONTROL. A description of the basic system, its performance over the past few years and some recent enhancements will be presented using computer-generated demonstrations.

INTRODUCTION

A challenge facing many facilities that handle large quantities of coal (e.g., coal trans-shipment facilities, electric utilities, steel mills) is that of controlling fugitive coal dust emissions originating from coal piles, rail cars, rotary dumpers, conveyor belts, yard traffic, maintenance activities, etc.. Concerns associated with fugitive coal dust emissions issues fall into three broad categories: 1) compliance with regulatory emission standards; 2) public relations and corporate image; and 3) economics. Clearly, a facility must be in compliance with all Federal and State regulatory emission standards to conduct operations . Even when all emission standards are met, a facility may still receive complaints from the general public (residential and/or corporate) regarding "nuisance" dust. In these instances, the facility must weigh its options carefully and make crucial decisions which require balancing its desires to be a good neighbor against the economic realities of the marketplace.

As noted by Doll and Calvin (1994), 'Economic control of particulate emissions' can be defined as meeting the requirements of external factors such as air quality standards while also minimizing: 1) the capital and operating cost of the control system; and 2) the reduction of the value or loss of the material being handled. In most ground storage cases, the monetary value of the material leaving a site as fugitive dust is significantly less than the cost of preventing its loss. This is true because, although fugitive emissions can be controlled, they are by their nature difficult to conomically manage and control. With a wide range of designed to respond to changing weather, coal, and operating conditions.

Manually controlled spray systems have been used to combat fugitive dust emissions. This type of approach, however, is not an optimal solution to the fugitive dust problem. As an example, a water spray system operated only when dust is visible will not control nighttime emissions or fine-particle emissions which are not easily detected visually. Another typical method is to spray water just as strong winds arrive. This strategy usually results in much of the water being blown away from its target area. A third method is to run the water sprays at preset intervals which, in principle, will usually result in over-control, i.e., reduce the market value of the coal without an offsetting advantage.

The application of chemical binders and surfactants can also be used to control fugitive dust emissions. Although this type of chemical treatment is effective soon after an initial application, the chemicals often lose their effectiveness over time as a function of wet/dry and freeze/thaw cycles, physical handling, and chemical breakdown. The lifetime of a binder application to a coal storage pile may only be (depending on weather

conditions and type of coal, among other factors) a matter of a day or so before reclaiming or further stackout necessitates retreatment.

Assuming the choice of water spray (instead of chemicals) for fugitive dust control, a facility must also consider the potential reduction in value of coal due to the higher moisture content resulting from over-spraying. As an example, assume that a dust control water spray system operated at a coal handling facility increased the moisture content of the treated coal piles by, on average, one percent. If there is a moisture penalty deduction from the sale price of the coal, there can be a significant loss of revenue. For a 1% moisture penalty deduction of $0.24 per ton, this would translate to an annual loss of $640,000 for a company which ships about two million tons of coal a year. This example points out the important and complex balance that must be reached between controlling dust emissions and the economic management of moisture/product quality.

THE K-SYSTEM

In 1984, the Commonwealth of Virginia's Department of Environmental Quality (DEQ), together with Simpson Weather Associates (SWA) and two Newport News, Virginia coal terminals, responded to public complaints of dust problems near the coal terminals. These complaints were registered despite initial efforts of the terminals to control dust emissions by using manually activated "rainbirds" to spray the coal piles. The manual efforts, however, were often taken after emissions had started, and frequently in wind conditions which rendered the spraying ineffective. Both the DEQ and the terminals recognized the need to develop autonomous control for the operation of water cannons to reduce fugitive dust emissions from coal storage piles. A product of this cooperative effort was the K-SYSTEM which is now considered the Best Available Control Technology (BACT) by the Commonwealth of Virginia and is required under terms of the terminals operating permits.

The K-SYSTEM is an autonomous scheduler used for activating arrays of water cannons to control fugitive dust emissions. The K-SYSTEM is based on an index called the K-factor which is used to determine when and how much water should be sprayed on coal piles to control fugitive dust emissions. The K-factor is an empirically derived quantity based on physical and statistical relationships between environmental conditions and the potential for wind generated dust emissions from coal piles. The K-factor is computed as follows:

$$K = (WS*T/RH)\ (p/u)$$

where WS, T, RH, p, and u represent hourly measurements of, respectively, wind speed (mph), temperature (degrees F), relative humidity (%), air density, and air viscosity of the air. The measurements of these variables are taken at a height (20-50 feet) above the top of nearby coal piles.

The K-SYSTEM coded logic incorporates equations representing the site's 'normal' uncontrolled emissions. 'Normal' uncontrolled conditions represent the mean day-to-day potential emissions uncomplicated by weather events such as precipitation, fog, frontal passages, etc. The K-system also involves the concept of a stable pile. A stable pile condition exists when one spray cycle reduces emissions in accordance with the percent reduction per cycle formulated into the program. Rain in excess of 0.025 inches is an example of a super stable condition. After a rain of this magnitude, the emission rate of the piles will return to stable conditions at a predetermined rate in accordance with the value of the K-factor and the elapsed hours. If water suppression is not activated, the piles are considered unstable and prone to emissions.

The K-SYSTEM software also contains logic that adjusts the K-factor for rain and freeze effects to define the need for water to be sprayed by the computer-controlled suppression system. Based on the K-factor (where higher values imply higher dusting potential), the computer-controlled K-SYSTEM will initiate one of the following actions:

1) no spraying required;
2) the spraying of a 'Demand cycle' to suppress the predicted dust emissions;
3) the spraying of one 'assurance cycle' at 0300, 0700, 1100 and 1300 if no other cycles have been run;
4) continuous spraying to recover from freeze events or in anticipation of high winds.

The suppression system used must have the capability to administer 0.025 inches of water per hour per site. The program uses three cycles when the K-factor is very high (high emissions)in order to reduce emissions and maintain stability. If this capability is not met, high K-factor values over time may cause the coal piles to slump and possibly blow out. In addition, the three cycle mode is necessary to administer the heavy pre-wetting needed to hold the piles before a pending freeze period (during which the water in the spraying system may freeze up and become unavailable for controlling emissions). At the end of such a freeze period, three cycles per hour is also needed to bring the level of pile stability back to a target value.

The K-SYSTEM can be implemented at almost any location. However, the primary hurdle to adapting this system to other sites lacking sufficient dust monitoring data is the formulation of equations to represent the new site's normal uncontrolled emission rate. This can be accomplished for sites other than the original coal terminals using the following necessary information:

1) standard modeling equations
2) configuration and area of coal storage area
3) one year of complete weather data

Once the system is in place, the accuracy of the modeling equations can be verified or modified with normal emission data.

PRO-CONTROL

The basic K-SYSTEM equations and instructions have been packaged by SWA into a computer program called PROCONTROL. This system was initially installed in the Newport News terminals in 1986. In addition to the basic K-factor logic described above, PROCONTROL provides the facility operators with information regarding the status of the weather instruments, water spray equipment, expected changes in the weather (e.g., freezes, thunderstorms, wind shifts, extended dry periods, etc.), status of coal handling equipment and dust crossing the fence line. The primary components of PROCONTROL are shown in Figure 1. The sensors included on the meteorological tower measure the following parameters: temperature, relative humidity, wind speed and direction, precipitation, and steel surface temperature.

The K-SYSTEM, as required in the State of Virginia, does not use any inputs from real-time dust monitoring equipment although the value of timely feedback on the performance of a dust control system is critical to the success of a low dust tolerance operation. However, PROCONTROL is designed to include the input of a recently developed monitoring strategy which uses Real-Time Aerosol Monitors (RAMs) to provide a reasonable check on the efficiency of dust control efforts. These data provide real-time and continuous evidence of the magnitude of the dusting within a selected area and help quantify the improvements achieved through the dust control program.

The PROCONTROL provides the following general functions:

1) Monitors the local weather and computes the drying potential (Figure 2) for the surface of coal piles.
2) Provides 12 hour weather forecast (Figure 3) to schedule special treatments such as manual application of chemical tarps, super-spraying prior to a freeze, or tiedown of equipment in anticipation of a major storm.
3) Automatically activates a network of water sprays for a prescribed period of time.
4) Issues visual and audible alarms for pre-set weather or real-time dust monitor conditions.
5) Performs end-of day calculations of estimated coal contribution to TSP at specified monitoring sites.
6) Archives data and operator comments for future reference and review by regulatory agencies.

SUMMARY

The K-SYSTEM has, in one form or another, been implemented at the Newport News, VA coal terminals since 1986, two years after operation began. Therefore, it is difficult to establish a statistically significant 'before' and 'after' comparison. However, the Virginia DEQ has judged the dust control effectiveness to be on the order of 90%. There are several observations that are consistent with this level of control:

1) There have been no violations (PM-10 concentrations) since 1987;
2) There has been a general decline in the annual average PM-10 concentrations at a nearby monitoring site (Figure 4); and
3) There has been a significant reduction in the number and intensity of visual dust events.

Additional benefits of using the K-SYSTEM include the reduction of potable water consumption, reduced manpower and equipment costs associated with 'last second' applications of surface binders to problem piles, and the redirection of personnel resources to handle exceptions not adequately covered by the automated decision system.

ACKNOWLEDGMENTS

The authors wish to acknowledge the input from Mr. John Stewart of the Virginia Department of Environmental Quality and personnel at both Dominion Terminal Associates and Pier IX terminals.

REFERENCES

1. Doll, E.R. and E.M. Calvin, 1994: PLACEM and PROCONTROL: New tools for fugitive dust control at coal handling facilities. Paper presented at the COAL PREP '94 Meeting, Lexington, KY, May.

PROCONTROL - PLUS COMPONENT DIAGRAM

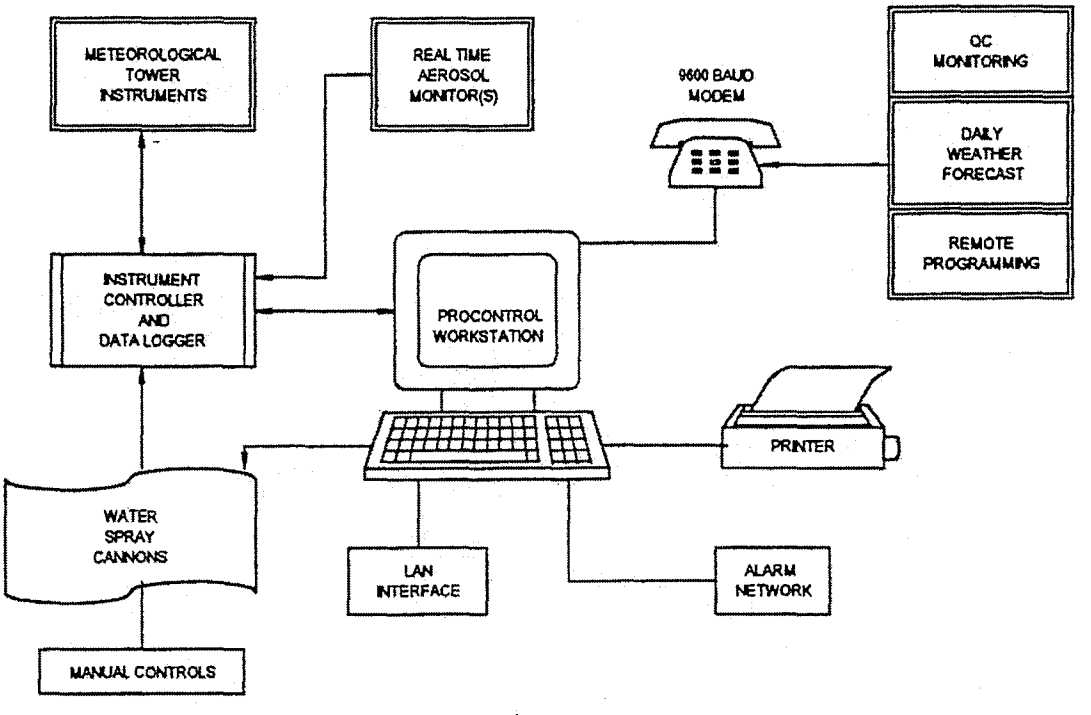


Figure 1. Component Diagram of PROCONTROL

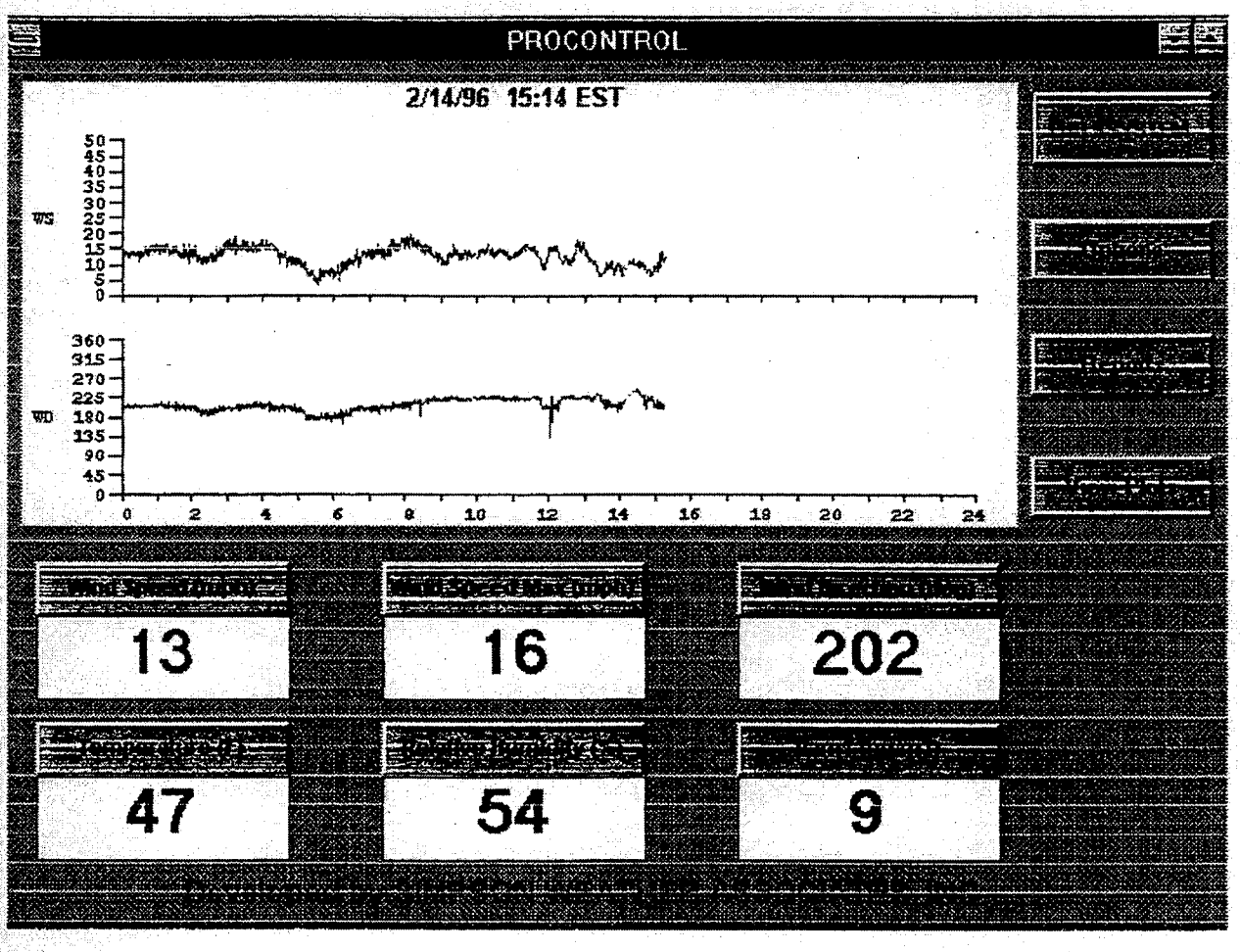


Figure 2. Main Panel for PROCONTROL Workstation Display

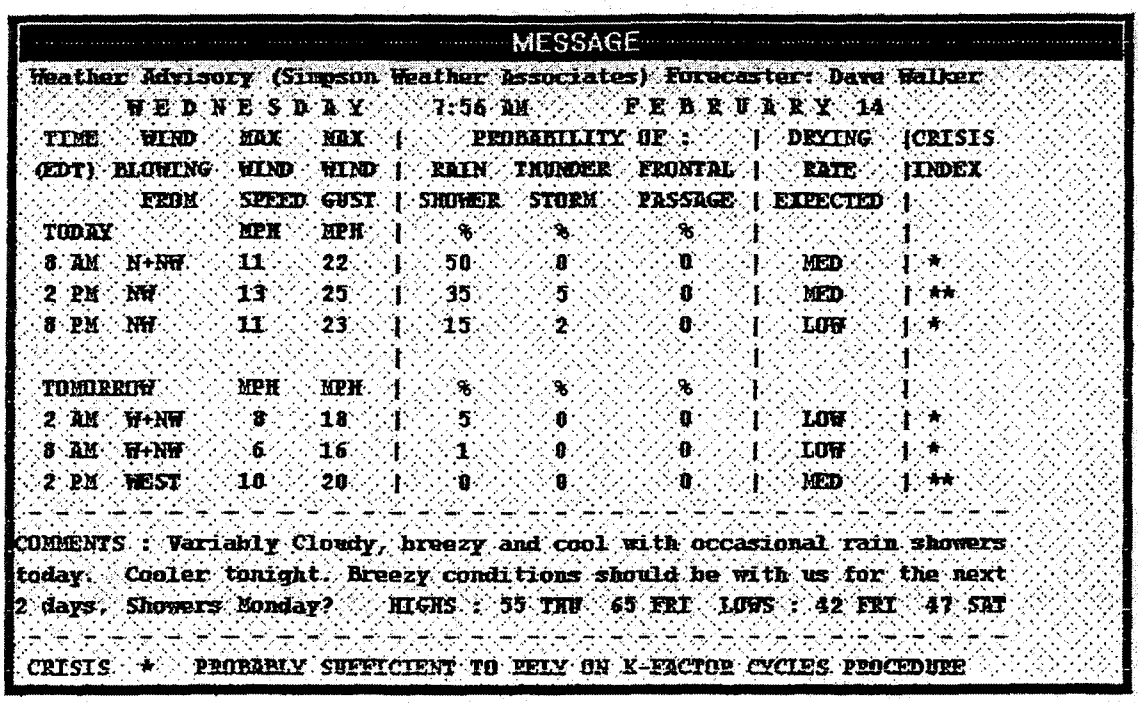


Figure 3. Sample of Twice Per Day Weather Forecast Coded for Interpretation of PROCONTROL Software

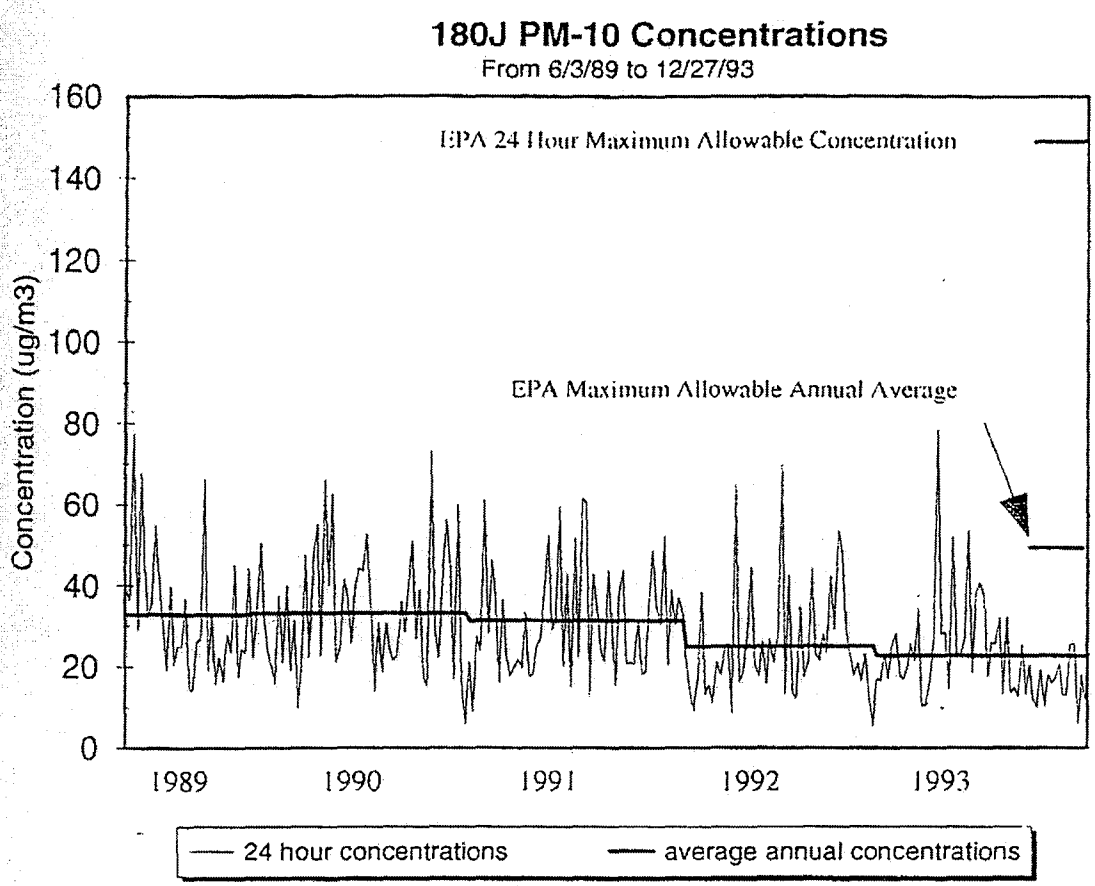


Figure 4. PM-10 Concentrations Within 300 Yards of Newport News Terminals Between 6/23/89 and 12/27/93

E. CALVIN

PROCEEDINGS
for the
Seventh Annual

ENVIRONMENT VIRGINIA '96
SYMPOSIUM

A TWO-DAY CONFERENCE
ON
ENVIRONMENTAL MANAGEMENT
AND POLLUTION PREVENTION

APRIL 11-12, 1996

Cameron Hall at Virginia Military Institute
Lexington, Virginia

Presented by
the Virginia Department of Environmental Quality
and VMI Research Laboratories, Inc.

MINIMIZING GROUNDWATER CONSUMPTION FOR REQUIRED FUGITIVE DUST CONTROL PROGRAMS

George D. Emmitt
Executive Vice President/Senior Scientist
Simpson Weather Associates, Inc.
Charlottesville, Virginia

ABSTRACT

Control of fugitive dust emissions from coal ground storage facilities, in most cases, involves the use of water, applied with fixed and/or mobile water spray cannons. Based upon experience at Virginia coal transshipment facilities, the Department of Environmental Quality (DEQ) has issued operating permits that require the use of ~ 8 gallons of water per throughput ton of coal. A facility, with throughput of 20-40 million tons puts a rather large demand on municipal water supplies or local aquifers. In either case, there are incentives to minimize the need for such water. Recycling of dust control water and the capture/storage of rainfall are two options available to reduce the demand on potable water supplies.

Simpson Weather Associates (SWA) has developed and applied a full Water Budget Model (WBM) for designing and operating a fugitive dust control system at a coal ground storage facility. The model uses 30 years of hourly weather data to simulate a model facility's impact on fugitive dust management, storm water management, water treatment, and water discharge. The model yields optimum settling pond size and water retention schemes to

1) minimize groundwater demand;
2) minimize discharge to streams during a 25+ year storm;
3) meet dust control permit requirements during extended droughts; and
4) minimize suspension of operations due to insufficient water supply or local flooding.

INTRODUCTION

A common strategy for suppressing fugitive dust emissions from an industrial complex is to use water sprays delivered by tank trucks, in situ spray bars or elevated water cannons. In the case of the ground storage of coal, the water required to maintain dust control can be significant, on the order of several 100 million gallons of water per year. Both existing and proposed ground storage facilities for coal in Virginia are required by the DEQ to employ water (plus surfactants in some cases) to assure compliance with air quality standards for particulates. The quantities of water needed to meet the permit requirements can represent a significant demand on potable water, whether it is supplied via municipality water mains or from dedicated wells.

In addition to reducing the annual consumption of potable water, facility operators are concerned with designing water holding/treatment ponds that will be adequate for dry period (low rainfall) operations as well as sufficient for the retention of major storm water runoffs. A Water Budget Model (WBM) has been developed to provide the basis for sizing the water delivery, retention, treatment and discharge components of the dust control/storm water runoff system at a large coal ground storage facility.

THE WATER BUDGET MODEL

A general flow diagram of the Water Budget Model is illustrated in Figure 1. The primary assumptions made by the model are that water is needed for:

1) dust control during coal handling, in particular, at the rotary dumper, stacker/reclaimer and loadout silos;
2) dust control for piles;
3) the cleaning of storage pads, vehicles and roadways;

4) fire control; and
5) incidental human consumption, cleaning, etc.

It is further taken that:

1) saline water is not acceptable;
2) municipal or other public water is not available;
3) rainwater will be captured and stored;
4) a portion of the water used in dust control will be recycled; and
5) ground water will be the source of "make-up" water.

The following discussion of the WBM is based upon a hypothetical design of a facility with a ground storage capacity of 4 million tons, an average working storage of 2.5 million tons, and an annual throughput of 40 million tons.

The WBM was run using three different weather scenarios - a typical year, a design storm and a design drought. The "typical year" data was obtained from a meteorological tower located in Newport News, VA. The criteria for spraying the coal piles was taken to be the K-system required by the Virginia DEQ and described in Emmitt et al. (1996).

A second simulation was done using a design storm of 7.6 inches in 24-hours based upon climatological data from the official NOAA National Weather Service (NWS) station at Norfolk International Airport. This design storm has a return interval of 25 years.

A third water budget was run for a 90-day drought during the months of May, June and July. While there is no official engineering "design drought" for a coal handling facility, it is critical to design the water supply system to handle an extended dry period.

Water Demands

The primary demands for water include the spraying of the coal during its unloading and loading (inline dust control), the spraying of the piles of coal using the K-system (Emmitt et al., 1996), the wetting of roadways and the cleaning of equipment.

Inline Dust Control

It was assumed that water was used in the rotary dumpers to form a curtain spray to contain fugitive emissions during dumping. Based upon experience at Virginia terminals, a nominal water requirement is .75 gal/ton of coal handled. The curtain sprays are operated in a fashion to optimize capture and reuse of the spray water. It is estimated that at least 33% of the spray water can be captured and returned to the water supply pond.

In recognition that some of the incoming coal will require additional water (plus surfactant) to control emissions during stackout, inline sprays (.75 gal/ton) are provided at two more locations. In reclaiming the coal, additional wetting capability (.75 gal/ton) is provided at three selected transfer points.

Based upon a throughput of 40 million tons per year, the reprocessing* of 4 million tons per year and assuming the estimated annual maximum water requirement, the inline dust control, (INLINE) was computed to be 195 million gallons per year (MGY) (assuming all coal is treated with water at all six spray points).

The actual amount of water added to any given coal shipment may vary, depending upon several factors. First, real-time dust monitors at the dumper and other transfer points serve to identify coals that need water for dust control. Second, the amount of water needed to achieve a targeted level of dust control may depend upon the use and effectiveness of a wetting agent (surfactant). In the absence of sufficient data, a very conservative estimate was made: on the average only 50% of the inline spray capacity would used on the total coal processed.

A further reduction of the "inline" demand is realized when weather conditions are incorporated into the dust control system. Based upon weather data taken from Norfolk, VA, there are approximately 100-120 days per year with rainfalls greater than .10 inch. According to hourly data, it rains 6 out of 24 hours on days with rain and thus no spray water would be needed during that time.

Combining these reduction factors the expected inline water requirements for a typical year was calculated by the simulation model to be 71 MGY.

Coal Pile Dust Control

Control of fugitive dust emissions from the coal piles represents the largest demand for water. Sizing the water supply/delivery system depends primarily upon the estimated water requirements for fugitive dust control during extended dry periods.

In estimating the average annual water demand for dust control from coal piles we have made several assumptions:

- the objective of the pile spray system is to deliver an average of .02" of water in one spray cycle to the surface area of each pile and the surrounding pad area. The value of .02" is based upon amounts found acceptable by the DEQ for coal storage facilities in the Norfolk area,

- except for very extreme (crisis) cases each pile will be sprayed, at most, once per hour, and

- a minimum of 4 spray cycles will be used each day except when it is raining, the temperature is below freezing, or it is foggy.

While we recognize that it may be possible to reduce the water demand by discriminating between coals of different dust potential or between used and unused portions of the storage pad, a maximum treatment is computed and used as a "reference". The amount of water required for a reference spray cycle (assuming no overlapping in coverage) is 84,025 gals/cycle.

To estimate the spray water required during a typical year we have considered the following factors:

- number of hours in a year during which its is raining, below freezing, foggy or snow covered; and

- the number of cycles that would be required under a current DEQ permit. Thirty year's worth of hourly meteorological data obtained locally are used.

To determine the number of water spray cycles that are required for dust control, one cannot use average climate statistics. Instead, hourly weather data must be used to simulate the sequence of demand for dust control. Based upon 30 years of recorded hourly data, the K-system operations were simulated and the average water required to treat the piles was estimated to be 160 MGY.

Road Sprays

The pile spraying system was assumed to cover the primary yard traffic routes and thus no additional water was needed for road surfaces. It was further assumed that any frequently used road not wetted by the coal pile spray system would be paved and cleaned periodically with a spray truck.

Wash Water

A value of 6% (based upon experience) of pile spray water required was used to estimate the amount of water needed per day to clean roadways, vehicles, and other equipment. It was further assumed that with the exception

of the roadways, this cleaning would take place where the water would be recaptured for recycling. A recycle factor of 75% was assumed as a best guess.

Water Supplies

Groundwater should not be the primary source for meeting the demands of a coal storage facility. The annual average and daily maximum amounts of required ground water are the net results of a water budget study and are therefore discussed in Section 3. It is advantageous to find alternative water supplies and ways of increasing the efficiency of water usage.

Rainfall

Rainfall represents a significant source of water if properly captured and stored. Not only can rainfall be stored but it also negates the need for other water usage during and immediately after rain events.

Our estimates of rainwater available for capture are based upon the following:

48.5" (4.0') of rain per year

capture areas
- pad - 6.8×10^6 ft^2
- inbound loop (includes pad) - 19.3×10^6 ft^2
- outbound loop - $10.3 \times 10^6 \times$ ft^2

runoff factor (% of incident water)
- bare ground - 25%
- pad - 95%
- coal piles - 73%

The total amount of rain water runoff potential (gals):

loop area (w/o pad)		171.3 MGY
pad (30% open)		57.5 MGY
coal piles		103.0 MGY
	Total	331.8 MGY

While the amount of rain water potentially available for dust control exceeds the estimated water demands, not all of that water survives evaporation or can be stored. In our simulation we have made the conservative assumption that only if it rains more than 0.25 inches within a 24-hour period will there be any runoff from the pad and piles that is actually available for capture. In other words, 0.25 inches of rain is lost to pooling on tops of piles, inhibited flow in drainage ditches and evaporation.

The model facility has perimeter ditches. These ditches carry water from the non-pad areas into the storage ponds. However, only under very heavy rain conditions should there be significant return from those ditches. The amount of water from these ditches that can actually be captured for use in the dust control system will depend upon the antecedent conditions of the soil and the pond levels at the time of the rainfall event. This potential water supply is not incorporated into the WBM at this time.

Coal Pile Flow Through

This is the most difficult term in the water budget to assess. It also has the potential of being a significant source of water. By "coal water yield" we include any water that exits the pile from the bottom. This water could be

coal moisture that was imported with the coal or it could be some of the rain or spray water that infiltrated and flowed through the pile.

Using soil analogies (sand/silt) we can only make a very rough estimate of what this term might be. If the coal looses 1% weight due to gravitational drainage, then there is ~100 MGY available for retention. Based upon laboratory experiments, we estimate that the infiltration water (from rain) is released by the pile within 24 hours.

There is significant uncertainty in these estimates. There is the likelihood that much of the drainage would occur during non-rainy periods and would therefore evaporate before getting to the retention pond. We have assumed that 75% of the leachate will evaporate before being captured. The total flow through is reported primarily for water chemistry computations.

Recycled Water

Not all of the water sprayed on or toward the coal is absorbed. This is particularly true for the in-line dust control at the rotary dumper and loadout silos. Some of this water can be captured and recycled. The exact amount depends on the design of the dust control system. For the model facility we have assumed that 33% of the rotary dumper water and 75% of the water used to clean pads and vehicles can be recycled. All other inline spraying should be absorbed by the coal and effect the desired dust control.

WATER BUDGET RESULTS

All of the factors and budget components discussed in the preceding sections have been incorporated into the Water Budget Model. Thirty individual years of operation were simulated producing time series such as the one for 1974 shown in Figure 2. The model was also run for 2 design situations, the results for which follow.

Typical Year

A plot of the daily water demand during a 'typical year' for dust control and the groundwater requirements to maintain pond levels is provided in Figure 3. A summary of the water budget for this typical year follows:

Kilogallons of water associated with:	
Inline dust control	71099
Pile dust control (2668 cycles)	26491
Wash water	13589
Total water demand	311179
Captured rain water	113108
Recycled control water	14885
Pile flow through water	121440
Evaporation	99962
Total surface supply	149470
Groundwater required	161581
Total water supply	311051
Discharge required	819
Total rainfall (inches)	48.47

From this simulation we see that with a facility designed to use storm runoff, pile drainage and recycling of dust suppression water can meet nearly 48% of its water needs without use of fresh water from the ground supply. Given the limited capacity for storage of storm runoff, approximately ~1 MGY must be discharged. However, even this amount of "lost" water can be reduced by using the storage pads (with a berm) as a surge pond during heavy rains.

A Year With a 90-day Drought

In this simulation (Figure 4) we have used the same data used in the typical year case but have zeroed the rain for 90 consecutive days and have kept the minimum number of pile spray cycles per day at 4.

Kilogallons of water associated with:	
Inline dust control	72205
Pile dust control (2813 cycles)	238807
Wash water	14328
Total water demand	325340
Captured rain water	77804
Recycled control water	15512
Pile flow through water	115088
Evaporation	95119
Total surface supply	113205
Groundwater required	211187
Total water supply	324392
Discharge required	0
Total rainfall (inches)	33.72

It is clear from the table above that the demand for water only increased 14 MG for the year (section 4.1) but the groundwater requirement increased by nearly 50 MG, due to the extended absence of rainfall.

SUMMARY

A water budget model has been developed and applied to a 'model' coal ground storage facility to provide the basis for designing the dust control water supply system and predicting the discharge of treated water. A properly designed facility can provide nearly 50% of its water requirements through the capture of rainwater, and the recycling of dust control water, combined with adequate sizing of retention and treatment ponds.

ACKNOWLEDGMENT

A portion of the development of the WBM was made possible through support from the Norfolk Southern Corporation.

REFERENCES

Emmitt, G.D., L.S. Wood, E.M. Calvin and S. Greco, 1996: PROCONTROL: Automated fugitive dust control system. Paper to be presented at the Environment Virginia '96 Meeting, Lexington, VA, April.

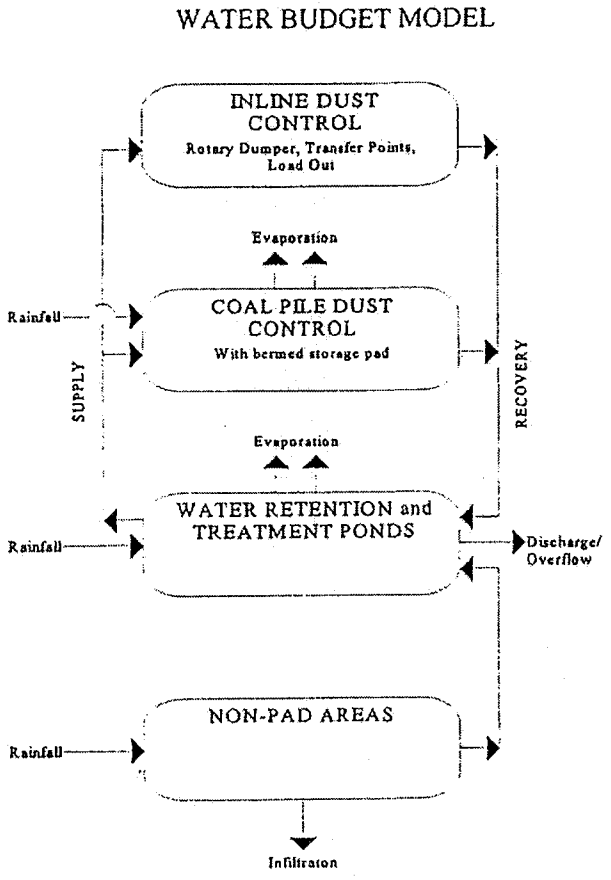


Figure 1. Flow Diagram for Water Model Budget

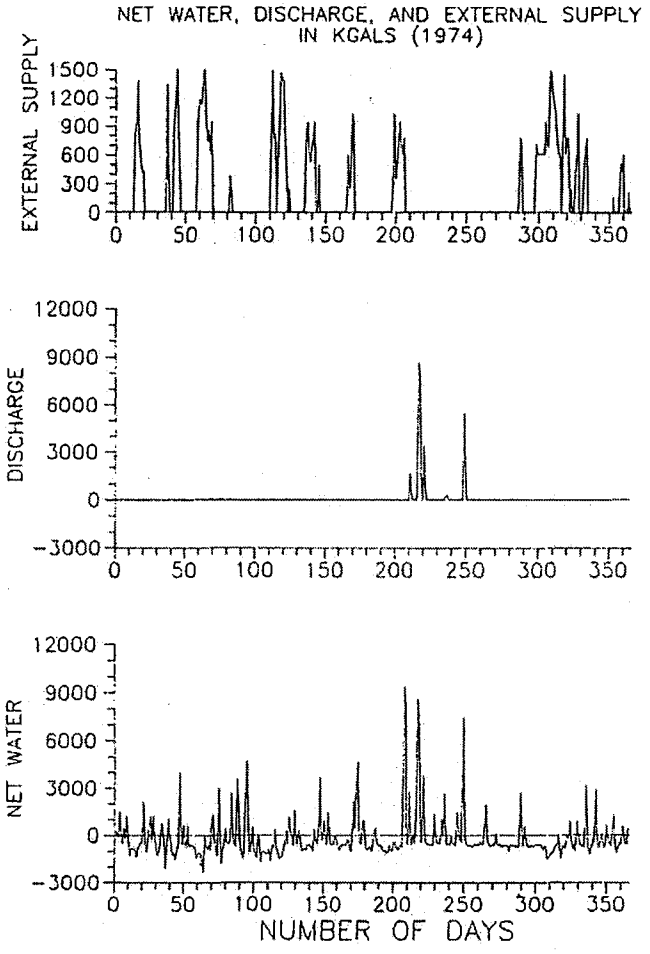


Figure 2. Example of One Year's WBM Simulation of the Model Coal Handling Facility

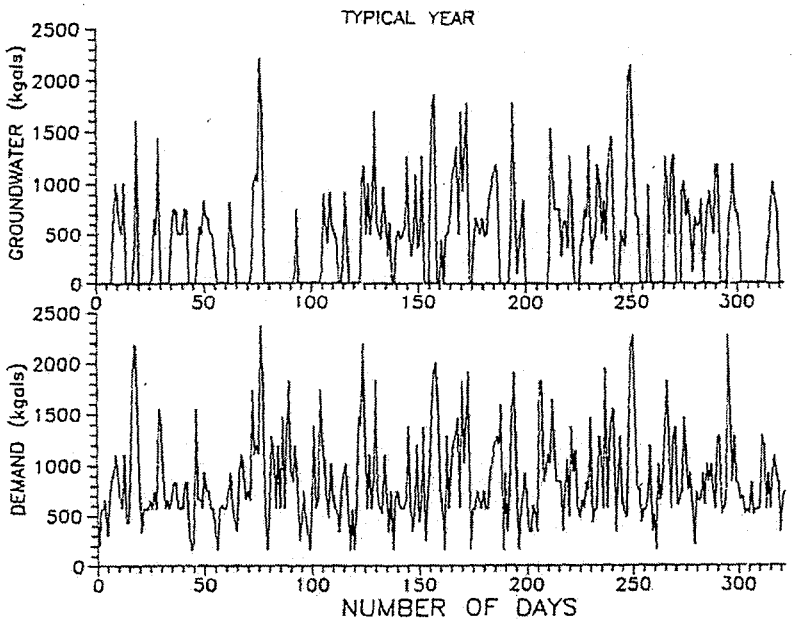


Figure 3. DEMAND (Dust Control) and GROUNDWATER (Municipal Supply)

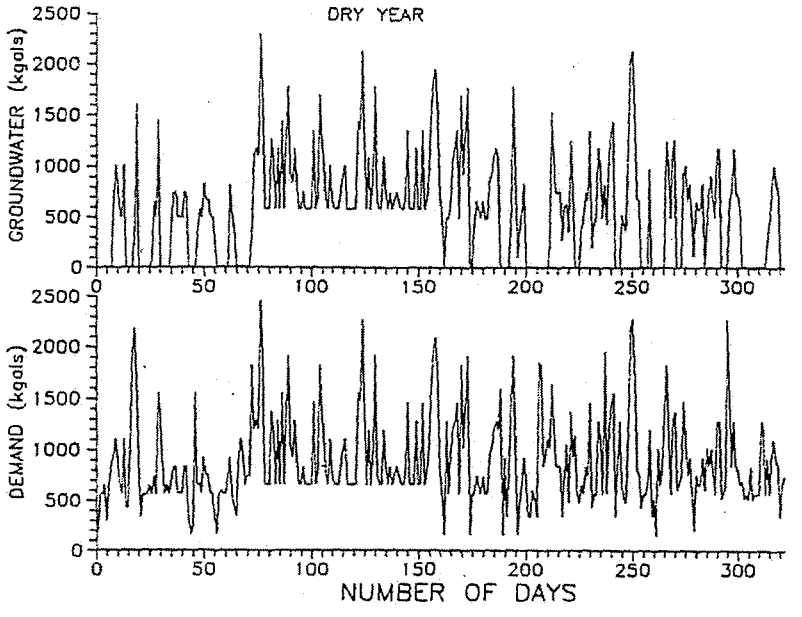


Figure 4. Same as Figure 3 Except a 90-Day Dry Period is Included

IN-TRANSIT CONTROL OF COAL DUST

FROM UNIT TRAINS

by

Claudio Guarnaschelli, Ph.D., P.Eng.

Environmental Protection Service

Fisheries and Environment Canada

Report Number EPS 4-PR-77-1

May, 1977

ABSTRACT

Effectiveness of chemical binders in controlling coal dust emanating from unit trains was investigated and monitored during 1974 and 1975. The parameters investigated included loading profile, type of chemical binder and spraying technique. A flat loading profile provided maximum retention of binder crust and simplicity of spray application. Oil products were the most effective binders. Almost equally effective were the oil and asphalt emulsions. Latex type chemicals formed brittle crusts that were easily fractured by torsional movement of the cars. A combination of simultaneous flooding and spraying was the most effective technique applied during the study. Coal trains from four mines were monitored for crust retention by measuring the percentage of crust cover remaining over the total car surface when the unit trains reached the terminals. Coverages of up to 95% were obtained; however, the crust coverages which most frequently occurred varied from 86% to 90%, 76% to 80%, 81% to 85% and 61% to 65%, depending on loading profile, type and concentration of chemical binder.

RÉSUMÉ

En 1974 et 1975, on a étudié et contrôlé l'efficacité de certains liants chimiques à éliminer la poussière de charbon se dégageant des trains intégraux. Les paramètres examinés comprenaient le profil de charge, le type de liant chimique et la technique d'arrosage. Le profil plat donnait à la croûte de liant une résistance maximale en même temps qu'il simplifiait l'application. Les produits huileux se sont révélés les liants les plus efficaces et les émulsions d'asphalte ont donné des résultats presque aussi valables. Les produits chimiques à base de latex formaient une croûte cassante que le mouvement de torsion des wagons brisait facilement. C'est le procédé combinant un jet de saturation et l'arrosage superficiel qui s'est révélé le plus efficace. En contrôlant les trains provenant de quatre mines, les techniciens ont mesuré l'adhésion de la croûte qui s'exprime en pourcentage de celle-ci demeurée intacte lorsque le train arrive à destination. Ils ont ainsi mesuré des couches protectrices intactes atteignant 95 p. 100 de la surface. Toutefois, les croûtes superficielles le plus souvent observées ont varié de 86 à 90 p. 100, de 76 à 80 p. 100, de 81 à 85 p. 100 et de 61 à 65 p. 100 en fonction du profil de la charge ainsi que du type et de la concentration du liant chimique.

ACKNOWLEDGEMENTS

The author of this report wishes to express his appreciation for the considerable assistance received from the members of the project committee: Mr. L.J. Cherene, Manager of Environmental Services, Kaiser Resources Ltd.; Mr. D.J. di Biasio, Staff Assistant, Fording Coal Limited; and Mr. W. Mummery, Assistant Superintendent, Canadian Pacific Rail.

Recognition is also given to B.H. Levelton and Associates Ltd. for their assistance during the monitoring program, and to numerous staff of the mining companies who provided invaluable technical advice.

Specialized technical assistance was also freely given by staff of other Federal agencies, particularly Mr. Sam Payne of the Canadian Transport Commission for his monitoring work, and by my colleagues in the Environmental Protection Service.

TABLE OF CONTENTS

		PAGE
1	CONCLUSIONS	1
2	INTRODUCTION	3
	2.1 Objectives	3
	2.2 Environmental Concerns	3
	2.3 Coal Transportation in the Study Area	4
3	THE STUDY PROGRAMME	5
	3.1 Phase I - Planning and Preliminary Field Investigations	5
	3.2 Phase II - Extension of Field Investigations to Complete Unit Trains	6
4	COAL LOSSES BY WIND FROM UNTREATED CARS	6
5	LOADING PROFILE	7
	5.1 Effects on Crust Retention During Transit	7
	5.2 Influence of Loading Method	8
6	CHEMICAL BINDERS EVALUATED IN PHASE I	8
	6.1 Oil and Emulsion Test Results and Comments	10
	6.2 Other Binding Products, Test Results and Comments	10
7	SPRAYING METHODS	11
8	SPRAYING REQUIREMENTS	12
9	PHASE II FIELD MONITORING	13
	9.1 Coal Shipments	13
	9.2 Loading Profiles	13
	9.3 Measurements of Surface Coverage	14

TABLE OF CONTENTS (Continued)

		PAGE
10	PHASE II MONITORING RESULTS	15
	10.1 Crust Retention Calculations	15
	10.2 Crust Retention on Front and Rear Surface Slopes	16
11	NEW LOADING TECHNIQUES AND CHEMICAL PRODUCTS FOR COAL DUST CONTROL	16
12	REFERENCES	17
TABLES		18-35
FIGURES		36-44
PLATES		45-54

LIST OF TABLES

TABLE NO.	TITLE	PAGE
1	Movement of Coal to British Columbia Terminals During 1973	18
2	Visual Observation Form - Phase I	19
3	Test Results and Summary: Coal Spray 100	20
4	Test Results and Summary: Reclamation Oil	21
5	Test Results and Summary: Dust Suppressant 100	22
6	Test Results and Summary: Dust Suppressant 200	23
7	Test Results and Summary: Dowell M167	24
8	Test Results and Summary: Lignin Derivatives	25
9	Test Results and Summary: Aquatain	26
10	Test Results and Summary: Alchem 63026	27
11	Rating and Acceptability of Chemical Binders Based on Comparison Tests of Best Performances (Derived from Tables 3 to 10)	28
12	Number of Trains and Cars Monitored During Phase II Field Work	29
13	Mine B - Cover Remaining on Coal on Arrival at Terminal (Percent of Total Surface)	30

LIST OF TABLES

TABLE NO.	TITLE	PAGE
14	Mine C - Cover Remaining on Coal on Arrival at Terminal (Percent of Total Surface)	31
15	Mine A - Cover Remaining on Coal on Arrival at Terminal (Percent of Total Surface)	33
16	Mine D - Cover Remaining on Coal on Arrival at Terminal (Percent of Total Surface)	34
17	Frequency of Coverage on Front and Rear Slopes	35

LIST OF FIGURES AND PLATES

FIGURE NO.	TITLE	PAGE
1	Regional Distribution of Complaints During 1972 - 1973	36
2	Coal Losses at High Speeds	37
3	Comparative Screen Analysis of British Columbia and Alberta Coals	38
4	Typical Coal Car Surface Dimensions	39
5	Coal Car Coating Inspection Form	40
6	Distribution of Cover Remaining on Total Surface of Coal Cars	41
7	Distribution of Cover Remaining on Front and Rear Slopes - Mine A	42
8	Distribution of Cover Remaining on Front and Rear Slopes - Mine B	43
9	Distribution of Cover Remaining on Front and Rear Slopes - Mine C	44

PLATE NO.	TITLE	PAGE
1	Coal Losses in Transit	45
2	Incomplete Coverage of Slopes	45

LIST OF FIGURES AND PLATES (Continued)

PLATE NO.	TITLE	PAGE
3	Untreated Car Showing Pools of Water and Coarse Coal	46
4	Preferential Wind Erosion of Untreated Car	46
5	Original Loading Method	47
6	Formation of Undesirable Slopes	47
7	Hand Application of Asphalt Emulsion	48
8	Car in Plate 7 at Kamloops	48
9	Car in Plate 7 at Westshore Terminals	48
10	Uniform Surface Cover	49
11	Close-up Showing Penetration of Binder	49
12	Well Protected Front-end Surface	49
13	Preferential Spraying Pattern of a Well Prepared Surface	50
14	End Spraying	50
15	Additional Water Sprays to Increase Penetration of Binder	50
16	Modified Loading Method	51

LIST OF FIGURES AND PLATES (Continued)

PLATE NO.	TITLE	PAGE
17	Combination of Flooding and Spraying	51
18	Properly Loaded and Sprayed Surface	51
19	Effective Spraying on an Uneven Profile	52
20	Limited Crust Failure of Sloped Area in Car in Plate 19	52
21 to 24	Typical Field Work Photographs Taken by B.H. Levelton and Associates in the Phase II Study	53 & 54

IN-TRANSIT CONTROL OF COAL DUST FROM UNIT TRAINS

1 CONCLUSIONS

(a) Results of the field studies proved that some chemical binders offered an immediate and satisfactory solution to controlling coal dust emanation from en route unit trains.

(b) Coal Spray 100 and Reclamation Oil were the most effective products used to control dust, principally because their regenerative properties were capable of sustaining a cohesive crustal cover which overcame surface cracks caused by torsional stresses of moving rail cars.

(c) Oil emulsion (DS200) and asphalt emulsions (DS100) produced 85% crustal coverage, which met acceptable government and operating mining company criteria.

(d) Properly formulated latex binders used on horizontal surfaces were as effective as oil emulsions, but on sloped surfaces they were less efficient.

(e) The Study Committee had postulated that crustal deficiencies on irregular coal surface profiles may be overcome if increased spraying on sloped surfaces was applied by an improved spraying method. The field test and observed results did not substantiate this theory, particularly in the case of latex products. These compounds are brittle after the curing period and do not re-polymerize on the surface of the coal cars.

(f) Complete dust control depends on a spraying technique which provides complete and controllable spreading of the binder, adequate quantities and concentrations of applied

chemical (gallons/car), the use of acceptable and readily available chemicals to the mining industry, and loading techniques which form flat loading profiles.

(g) Extensive monitoring confirmed that when latex products are used, crustal retentions of 85% can be readily achieved if the coal surface configuration is a central horizontal plane bounded by limited sloped ends. Crustal retention can be increased to 95%, if the front-end slope is made level with the horizontal central portion.

2 INTRODUCTION

2.1 Objectives

The study was designed to evaluate chemical methods of eliminating or minimizing wind dispersion of coal dust from open-top rail cars during transportation of coal from mine sites to terminal storage areas. Dust control techniques were to be tested and developed which would be economically acceptable and readily adaptable by mining and railway companies. In addition, the establishment of sound, proven control technology would become available to legislators as guidelines in formulating any necessary environmental control regulations.

2.2 Environmental Concerns

The clouds of wind-blown dust that emanate from moving trains are receiving considerable attention as an environmental issue in many countries. In Canada, concern about the air-borne transport and deposition of coal dust has been expressed by the public as numerous complaints to railway companies, operating mines, municipalities, Members of Parliament and government agencies. Supportive evidence in newspaper articles has also highlighted the pollution aspects.

Figure 1 illustrates the geographical range and monthly frequency distribution of complaints in the study area of British Columbia during 1972 - 1973. The peak of complaints during March to May, possibly reflects the public's tendency to object prior to the onset of the summer outdoor season, a time when their awareness of air-borne dust becomes more acute. Also, moisture deficient coal transported during dry months has lower compaction rates and is more susceptible to wind dispersion than during the wetter months of fall and winter. Evidence of this was observed following compaction tests* on a unit train where only 58% of total compaction had occurred after transportation of 180 miles.

---

*Kaiser Resources, Internal Report

Physically, coal is black, nontransparent and relatively lightweight. In populated areas its black colour soils houses, swimming pools, terraces and clothing. The nontransparency creates highway hazards by reducing visibility, while its lower density makes it readily airborne and capable of being carried further than common silicate dust.

From a chemical viewpoint, coal mined in Western Canada has not been demonstrated to be acutely toxic to salmonids. Bioassays conducted by B.C. Research proved that liquid extracts from East Kootenay coal are acutely nontoxic to fish.(1)

Pollution by coal dust, then appears to be confined to some aesthetic values and to physical hindrance where excessive quantities of coal are deposited.

2.3 Coal Transportation in the Study Area

Coal is transported to British Columbia terminals by Canadian National Railways (CNR) and by Canadian Pacific Rail (CPR). CNR moves coal from two major mines located in Alberta (McIntyre Mines Limited and Cardinal River Coal) to Neptune Terminals Ltd. in North Vancouver. CPR transports coal from the East Kootenay (Kaiser Resources Ltd. and Fording Coal Ltd.) to Westshore Terminal, the superport at Roberts Bank in the Municipality of Delta.

Figure 1 shows the major coal mine locations and railway routes to the Vancouver terminals. During 1973, 11,303,539 short tons of coal were transported over the railway system, 8.3 million tons by CPR and approximately 3 million by CNR. Table 1 details the coal movements to British Columbia terminals during 1973. Future coal industry development will greatly increase the tonnages transported, particularly from the northeastern area of British Columbia. Such development will emphasize the need for effective en route coal dust control.

3 THE STUDY PROGRAMME

In February 1974, a committee of representatives from Kaiser Resources Ltd., Fording Coal Ltd., Canadian Pacific Rail and the Federal Government formulated a study and test programme to determine the relative effectiveness of available chemical binders as an immediate solution to the problem of coal dust control on moving unit trains.

3.1 Phase I - Planning and Preliminary Field Investigations (During 1974)

(a) Planning involved technical and logistic considerations to determine the following:

- The most economical and effective location to apply chemical spraying.
- The minimum number of rail cars per train required to obtain a conclusive test programme.
- The number and types of tests to be conducted to obtain base data for Phase II.
- Allocation of test sites, based on in-transit settling characteristics, where tests would be carried out.
- What test evaluation procedures and criteria would yield reliable data.
- Preliminary screening and assessment of available chemical products to be used in the field test work.

(b) Field Work

Initially, spraying locations other than the mine sites at Fort Steele, were considered to evaluate the possible advantages of spraying after coal compaction had taken place. Eventually all trains were sprayed at the mine sites (Kaiser and Fording) to avoid all pollution problems.

Each chemical product was tested on a maximum of five cars, with each car selected on the basis of representative profile and location at, or near, the head-end of the train, to avoid possible accumulation of coal dust escaping from other cars. Binding performance at the departure point, at Kamloops, and at the Vancouver terminal was recorded by each committee member on a Visual Observation Form (see Table 2). The final rating for each series of tests reflecting the opinion of the total group was recorded on Tables 3 to 10.

3.2 Phase II - Extension of Field Investigations to Complete Unit Trains

In order to confirm the test results and analyses obtained in the limited (five cars per train) Phase I work, B.H. Levelton and Associates Ltd. were contracted by Environment Canada to carry out control tests on complete unit trains during the period August 28th to September 30th, 1975. A synopsis of Levelton's report entitled, "Measurement of Crust Remaining on the Surface of Coal Cars on Arrival at Dumping Terminals - Results of Monitoring 30 Trains", is presented in Sections 9 and 10 of this report.

4 COAL LOSSES BY WIND FROM UNTREATED CARS

Early in the study it became evident that the loading profile, that is, the geometrical configuration of the exposed surface of the coal, had a large influence on the coal lost in transit (Plate 1). Beshketo[2] reported heavy losses of coal at high train speeds. According to his data, the best "hood" height, based on car capacity and winds losses, is 200 mm (8") above the sill of the coal cars (Figure 2). He observed that 6 mm of coal was lost at 60 km/h (40 mph) and 13 mm (1/2") lost at 100 km/h (approx 60 mph). A parallel study on dust losses from mineral concentrates was carried out by Schwartz.[5] He observed

that losses from concentrates were up to 2.1% for speeds up to 60 mph.

Screen analyses of the various coals transported to British Columbia terminals are presented in Figure 3. Even though the coal from Alberta is somewhat coarser than the coal from British Columbia, both types readily become airborne at low speeds.

Exact measurements of coal losses during transportation were difficult to determine with a high degree of confidence. Some problems experienced during the study included: inconsistencies in weigh scale calibration, variations of existing moisture content of the coal, addition of flying debris deposited in cars en route, and the inclusions of rain and/or snow. Thus calculations of coal lost en route as a measurable difference between car weight at the departure point and its weight at the terminal were somewhat unreliable.

Previous studies[2 and 3] suggest losses in the order of 1.5 tons/car or 1.5% for a 100-ton car capacity. Even if we assume that losses of western coal are only 0.5% or 1/2 ton/car per 700 mile journey, it is relatively easy to justify a reasonable expenditure to keep coal in the cars and, at the same time, reduce public concern over pollution.

In economic terms, prevention of the assumed Western Canada coal losses represent a saying, based on $60/ton of $30/car or over $3 million annually.

5 LOADING PROFILE

5.1 Effects on Crust Retention During Transit

Loading profiles had a profound influence on crust retention (Plates 1, 2). A surface particle is affected by the vertical force of gravity and by horizontal forces of linear and centrifugal acceleration

and/or deceleration. The magnitude of each component depends on whether the particle rests on a horizontal surface or on an inclined plane and on the resistance to shear offered by the substrate. Furthermore, if the independent particle is chemically bound to other surface particles, the strength of the chemical bond is an additional force that increases the particle's resistance to sliding.

During the field tests it was soon realized that a totally flat surface would produce the most desirable profile (Plates 3, 4). Coverage of the flat portion of the car never presented a serious problem, suggesting that the effects of acceleration and deceleration of the train were negligible compared to the resistance offered by the substrate. The only evidence of failure was the appearance of surface cracks induced by torsional and vibrational stresses to which the cars were subjected during transportation.

5.2 Influence of Loading Method

In practice, the operation of a single loading chute always produced a sloped end at each end of the car (Plates 5, 6). On these slopes, the larger the horizontal component of the opposing force the more stable the system became. At the natural angle of repose where all forces were in balance, any minor disturbance due to acceleration or deceleration of the cars was sufficient to cause failure. To increase crust stability the angle of repose would be decreased at least by the expected maximum acceleration or deceleration of the cars. If this cannot be achieved, then, the strength of the chemical bond within the binder must accommodate the impact of these accelerations plus any torsional or vibrational components.

6. CHEMICAL BINDERS EVALUATED IN PHASE I

A chemical spray is more effective if it shows an affinity for the material on which it is sprayed and if the product (eg. coal) does

not slump after the application (Plate 10). Coal readily absorbs oils without any prior surface treatment (lipophilic property) but repels water (hydrophobic property). In the case of emulsions, where water is the continuous phase, wetting of the surface can occur only if the surface has been pretreated with a solution containing a surface-active agent, or if there are sufficient quantities of a fast acting surfactant within the formulation.

Papic and McIntyre[4] tested 83 surfactants to evaluate their ability to improve the wetting of coal by water. Their findings showed that nonionic surfactants of the alkyl-phenylpolyethoxy ether type were the best wetting agents.

During the study the following chemical binding products, with or without the addition of specific surfactants, were tested:

(a) Dowel M167, a latex product by Dowell of Canada.

(b) Alchem 63026, a latex product by Alchem Limited.

(c) Dust Suppressant 100, an asphalt emulsion produced and marketed by Pounder Emulsions Limited.

(d) Dust Suppressant 200, an emulsified petroleum residue produced and marketed by Pounder Emulsions Limited.

(e) Acquatain, a product marketed by Whitlock Construction.

(f) Lignin Derivatives, an experimental product by Cominco.

(g) Coal Spray 100, an oil preparation by Imperial Oil Limited.

(h) Reclamation Oil, a product tested by Cominco.

6.1 Oil and Emulsion Test Results and Comments

Oil sprays and emulsions were the most effective binders (Plates 7, 8, 9). The success of the binders was attributed to the production of a flexible crust, high viscosity and an inherent ability to regenerate their surface. In other words, the stability of the product prevented the formation of a rigid crust by reacting neither with the coal particles nor with the atmosphere. The cohesive forces of the oil phase were enhanced by the lipophilic character of the coal which facilitated spreading of the oil on the coal surface. In this case the oil-coated particles adhered to each other forming a porous and oozy top layer. The same mechanism was operative in regenerating the top layer of the crust whenever a surface crack was produced by vibrational and/or torsional movement of the cars or by settling of the coal. The oils and emulsions were the only products to display this regenerative property.

Some of the disadvantages of using oils included the adverse effects on rubber conveyor belts and the possibility of washing residual oil and/or additives into adjacent water bodies.

Tables 3, 4, 5 and 6 present a summary of the detailed analysis and results of oil and emulsion tests obtained by each participant and previously recorded on Visual Observation Forms - Phase I (See Table 2).

Table 3 shows results for Coal Spray 100; Table 4, Reclamation Oil; Table 5, Dust Suppressant 100; and Table 6, Dust Suppressant 200.

Table 11 is an overall summary based on the best tests from the above tables, and includes the rating and the degree of acceptability of all the products.

6.2 Other Binding Products, Test Results and Comments

The main disadvantage of latex is its brittle crust. Vibra-

tional and torsional movements cracked the surface polymer and patches of polymerized latex were easily removed or displaced by wind (Plate 2). Adherence of the crust to the substrate was minimal, and therefore, the best retention occurred on horizontal surfaces (Plates 10, 11, 12). Because the well polymerized and chemically stable crust of latex products is not water soluble, leaching is unlikely to take place, and therefore, pollution of adjacent water bodies will not occur.

Lignin derivatives, which are strong wetting agents, formed a thick crust which will dissolve readily in water. Following excess rainfall, the lignin derivatives were transported into the bulk of the coal in the cars, and the remaining washed unconsolidated coal behaved as untreated coal in that coal dust became airborne.

Tables 7, 8, 9 and 10 present a summary of the detailed analysis and results of latex and Lignin Derivatives products obtained by each participant and previously recorded on Visual Observation Forms - Phase I (see Table 2). Table 7 shows results for Dowell M167; Table 8, Lignin Derivatives; Table 9, Aquatain; and Table 10, Alchem 63026. Table 11 is a summary based on the best tests from the above tables, and includes the rating and the degree of acceptability of all the products.

7 SPRAYING METHODS

The difficulties of retaining a crust on the surface slopes necessitated an investigation of spraying techniques. Two mechanical techniques were tried: (a) preferential spraying, and (b) a combination of flooding and spraying.

Preferential spraying is the uneven application of chemical binders to different parts of the exposed surface (Plates 13, 14, 15). The slopes were sprayed more than the horizontal surfaces. This technique has been used with moderate success and will continue to be applied when fast and complete wetting can be achieved without binder run-off.

To increase binder retention on slopes, Fording Coal Ltd. devised a penetration-spray system designed to achieve not only maximum penetration and thickness but also an adequate surface coverage (Plates 17, 18). The system employs an oscillating spray bar equipped with nozzles capable of open-orifice discharge and fan spraying. The open-orifice discharges are designed to prevent run-off of the emulsion and the formation of a thick crust by increasing binder penetration. The fan sprays are designed to provide a more uniform and adequate coverage of the surface layer. Using this system, Fording Coal Ltd. demonstrated that undesirable slopes could be stabilized almost entirely (Plates 19, 20).

8 SPRAYING REQUIREMENTS

The major coal companies operating in Western Canada, in direct response to public concern about the coal dust pollution problem and their agreement with the findings of this report, volunteered to apply reasonable measures to control the coal dust emanating from moving trains. As of July 1, 1974, all major mining companies sprayed every train leaving their property.

Unfortunately, not all of the chemical binders offered adequate protection. Industrial and Federal representatives agreed that the single parameter that best describes the effectiveness of the various chemical binders is the residual surface coverage measured at the terminals. Assuming that coal dust originates uniformly from every part of the exposed surface, then effective surface coverage is the only parameter that is directly proportional to the coal dust generated in transit.

The mining companies agreed with the standards presented in Phase I of this report that a minimum of 85% of the surface would be covered immediately and furthermore, that a 90% coverage should be achieved by October 1975.

9 PHASE II FIELD MONITORING

Sections 9 and 10 present a synopsis of the B.H. Levelton and Associates' study. The spraying techniques and methods of crust retention observation and recording were founded on the basis of the Phase I work. In the Levelton study, the range of tests were extended to include complete unit train protection and to assess the coverage resulting from mine optimization of chemical binder required to produce an 85% cover. Table 12 shows the number of trains and cars monitored.

9.1 Coal Shipments

All unit trains originating from western mines consist of open-top rail cars, but the size of cars varies not only between the two major railway companies but also within the same company.

The most common car size used by CP Rail is 48-ft long, 12-ft high and 10-ft wide. Cars from CN Railway are 50-ft long, 10-ft high and 10-ft wide.

Unit trains from Alberta to Vancouver cover a distance of approximately 700 miles at a maximum speed of 45 mph. Coal trains from British Columbia cover approximately the same distance but are allowed to travel at 50 mph.

9.2 Loading Profiles

The total surface profile of the coal cars comprized three distinct sections: a front slope, a central flat area and a rear slope. Typical longitudinal profiles showing slope lengths, slope angles, flat lengths and cross-sectional profiles are shown in Figure 4. The total exposed area, therefore, is comprised of the area along the two slopes plus the flat area.

9.3 Measurements of Surface Coverage

Initially, the areas of both front and rear slopes and the levelled area in the centre were measured in several cars from each of four mining companies. Later, a "trained observer" was exposed repeatedly to measured and observed sections of the cars in order to eliminate unnecessary measurements and costly slow-down procedures at the terminals. Measured and estimated percentages of the front slope, middle surface and rear slope were recorded on a pre-printed "Coal Car Coating Inspection" form (See Figure 5). From these individual area measurements, the extent of crustal cover remaining intact at the Vancouver terminal was calculated as a percentage of the total original coal surface. At the same time, a summary sheet was prepared. This summary included data on:

- Terminal
- Coal origin
- Train number
- Times train left origin and arrived at terminal
- Binder used
- Weather during treatment, during transit and during observation
- Number and location (in train) of cars inspected
- Nature of crust cracks, crust loss and crust character
- Abnormalities in profile
- Special observations
- Percent coverage
- Percent coverage on total coal surface.

In addition, colour photographs were taken of about 220 coal cars. See Plates 21 to 24 for typical photographic recordings.

10 PHASE II MONITORING RESULTS

10.1 Crust Retention Calculations

The number of cars and their respective coverage expressed in percent of total surface area have been tabulated for each mine in Tables 13, 14, 15 and 16. These data have been rearranged below to show the frequency distribution for total cover remaining as a percentage of coal cars inspected.

COVER REMAINING (%)	MINE B (%)	MINE C (%)	MINE A (%)	COVER REMAINING (%)	MINE D (%)
0-50	2.6	6.6	0	0-40	5.0
51-55	0.5	0.9	0	41-45	7.5
56-60	1.0	1.0	1.2	46-50	7.5
61-65	2.1	2.4	0	51-55	22.5
66-70	1.0	9.0	2.5	56-60	25.0
71-75	10.0	14.2	9.9	61-65	25.0
76-80	11.6	18.4	14.8	66-71	7.5
81-85	21.6	16.5	30.9		
86-90	26.3	17.0	21.0		
91-95	17.9	10.4	19.8		
95-100	5.3	3.3	0		

The frequency distribution of total cover remaining is shown graphically in Figure 6. The most frequently occurring coverage within a 5% interval is 86-90% for Mine B, 76-80% for Mine C, 81-85% for Mine A and 61-65% for Mine D.

10.2 Crust Retention on Front and Rear Surface Slopes

The percentage of cover remaining on front and rear slopes for coal shipped from Mines A, B, C and D and is tabulated in Table 17. This frequency distribution has been plotted for 10% intervals in Figures 7, 8, and 9. The most effective coverage observed resulted from levelling the front slope of the cars at the loading site of Mine B. Levelling increased surface crust retention by an average of 40% when compared to Mines A and C.

11 NEW LOADING TECHNIQUES AND CHEMICAL PRODUCTS FOR COAL DUST CONTROL

Since September 1976 all coal mines shipping to British Columbia terminals have adopted a modified method of loading and spraying unit trains.

New and more capable loading (eg. Plate 16) chutes have improved the loading profile, increased dust control and have reduced considerably the total loading time for the unit train. In addition, the operator can more effectively control the total tonnage carried by each car thus fewer variations in the total carrying capacity occur when cars are loaded to the allowable limit. The net result is a substantial saving of time and money.

Encouraged by the potential savings in coal losses and by required environmental controls, many companies in the U.S.A. and Canada are developing new chemical products to equal or better the performance of the products tested in this report.

Coverages approaching 100% can be expected by the end of the 1970's.

12 REFERENCES

1. Report 2382 - Coal Dust Study - Roberts Bank, B.C. Research, Vancouver, B.C.

2. V.K. Beshketo, "How to Reduce the Loss of Coal when Transported at High Speeds", Zheleznodorozhni Transport, p. 27, October 1964.

3. G.H. Denton et al, "Minimization of In-transit Windage Losses of Olga Low Volatile Coal", 1972 Coal Show, American Mining Congress, Cleveland, Ohio.

4. M.M. Papic and A.D. McIntyre, "Surface Active Agents in Coal Dust Abatement", p. 85, Coal Age, June 1973.

5. P.L. Schwartz, "Innovations in Railroad Transportation of Mineral Products", Paper presented at the Second International Symposium on Transport and Handling of Minerals, Rotterdam, Netherlands, October 1-6, 1973.

TABLE 1

MOVEMENT OF COAL TO BRITISH COLUMBIA TERMINALS DURING 1973

SHIPPER*	FROM	TO	COAL TRANSPORTED (Short Tons)
CPR	Elkview	Delta	4,847,530
CPR	Fording	Delta	2,464,740
CPR	Coleman	Port Moody	867,497
CPR	Canmore	Port Moody	200,249
CNR	Winniandy	Vancouver	1,658,251
CNR	Luscar	Vancouver	1,265,272

* CPR - Canadian Pacific Railway
  CNR - Canadian National Railway

TABLE 2

Coherex Wilco

VISUAL OBSERVATION FORM - PHASE I

Participant _____ Spraying date _____
Product tested _____ Spraying location _____
Test No. _____ Type of coal _____
Train No. _____ Test rated by _____

Car No. / Parameter		Weather	General Crust Appearance	Crust	Binder Penetration (inches)		Condition of Pines		Remarks
					Top	Sides	Crust	Cracks	
_____	origin								
conc.____	en route								
vol.____	terminal								
_____	origin								
conc.____	en route								
vol.____	terminal								
_____	origin								
conc.____	en route								
vol.____	terminal								
_____	origin								
conc.____	en route								
vol.____	terminal								
_____	origin								
conc.____	en route								
vol.____	terminal								

LEGEND:

(H) homogeneous (F) friable (U) unconsolidated
(C) crushed (B) brittle (C) consolidated
(P) patchy (T) tough
(N) nodulized

TABLE 3

Imp Oil Ltd

TEST RESULTS AND SUMMARY: COAL SPRAY 100

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Kaiser	20	100	Good coverage up to 30 gal/car.
	30	100	
	45	100	Excellent coverage above 45
	60	100	
	70	100	gal/car.
Foraing	40	100	Very homogeneous coverage. Some
	50	100	
	60	100	evidence of blowing. Good
	70	100	
	80	100	results.

TABLE 4

TEST RESULTS AND SUMMARY: RECLAMATION OIL

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Fording	25	100	Good coverage on slopes.
Fording	50	100	Very good. Minor exposure of ends.
Fording	30	100	Soft crust. Good ends.
Fording	30	100	Good coverage. Minor exposure of ends.

TABLE 5

TEST RESULTS AND SUMMARY: DUST SUPPRESSANT 100

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Ft. Steele	70	30	Good crust. Fair results.
Ft. Steele	75	15	Tough crust. Poor spraying. Good results.
Ft. Steele	45	25	Good crust. Good results.
Ft. Steele	70	10	Brittle to tough crust. Evidence of blowing.
Kaiser	50	5	Homogeneous, brittle to tough. Good coverage.
Kaiser	120	15	Fair to good. Evidence of blowing.
Kaiser	50	25	Good crust. Excellent results.
Fording	50	15	Homogeneous crust. Ends blown. Poor to fair results.
Fording	50	15	Homogeneous crust. Ends blown. Poor to fair results.
Fording	108	10	Homogeneous, poor slopes.
Fording	62	15	Consolidated crust. Slopes partly exposed.

TABLE 6 Dust Sup. 200

TEST RESULTS AND SUMMARY: DUST SUPPRESSANT 200

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Fording	90	15	Homogeneous crust. Exposed ends.
Fording	60	15	Soft crust. Minor exposure of ends.
Fording	50	15	Good coverage on improved profiles.

TABLE 7

TEST RESULTS AND SUMMARY: DOWELL M167

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Ft. Steele	24	9.0	Friable to brittle crust. Fair.
Ft. Steele	60	10.0	End erosion by wind. Fair.
Ft. Steele	25	5.0	Friable crust. Poor penetration.
Ft. Steele	42	5.0	Thicker crust. Fair to good.
Ft. Steele	43	5.0	Patchy. Wind erosion. Poor.
Kaiser	65	7.5	Good coverage. Fair to good results.
Kaiser	40	7.5	Good appearance. Good results.
Kaiser	40	10.0	Brittle to tough crust. Fair.
Fording	40	7.5	Rain had detrimental effect. Poor.
Fording	55	7.5	Brittle crust. Fair results.
Fording	60	5.0	Friable crust. Wind erosion. Poor.

TABLE 8

TEST RESULTS AND SUMMARY: LIGNIN DERIVATIVES

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Fording	50	8	Crust thickness up to 3".
Fording	60	8	Evidence of blowing at both
Fording	70	8	ends. Fair results.
Fording	80	8	
Fording	72	8	Brittle crust. Poor ends.
Fording	80	8	Fair coverage on slopes.
Fording	60	8	Excessive exposure on poor profile.

TABLE 9

TEST RESULTS AND SUMMARY: AQUATAIN

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Ft. Steele	32	12.5	Weak, friable crust. Slopes exposed.
Ft. Steele	45	14.2	Friable crust. Wind erosion. Poor.
Ft. Steele	18	20.0	Patchy, friable crust. Poor.
Ft. Steele	40	14.3	Patchy crust. Ends eroded.
Ft. Steele	40	33.0	Evidence of blowing. Poor.
Kaiser	32	Not reported	Thin, friable. Poor results.
Kaiser	36		Improved crust. Poor to fair.
Kaiser	23		Friable crust. Poor to fair.
Fording	73	6.6	Homogeneous thin crust. Fair.
Fording	60	6.6	Sides blown. Poor results.
Fording	60	6.6	Thin and friable crust. Ends eroded.

TABLE 10

TEST RESULTS AND SUMMARY: ALCHEM 63026

SPRAYING LOCATION (Mine Site)	VOLUME (Gal.)	CONCENTRATION (%)	REMARKS
Ft. Steele	27	7.2	Friable, inadequate coverage. Poor.
Ft. Steele	27	5.4	Thin crust, excessive wind erosion. Poor.
Ft. Steele	26	3.8	Extremely poor. Little or no crust.
Ft. Steele	27	3.0	Much evidence of blowing. Poor.
Ft. Steele	30	1.6	Poor results on poor profiles.
Kaiser	27	3.8	Thin, friable crust. Much blowing.
Kaiser	27	11.0	Improved crust. Still unacceptable.
Fording	30	4.0	Patchy, friable crust. Poor.
Fording	40	10.0	Slight improvement. Still very patchy.
Fording	26	6.2	Thin and friable. Poor.

TABLE 11

RATING AND ACCEPTABILITY OF CHEMICAL BINDERS
BASED ON COMPARISON TESTS OF BEST PERFORMANCES

(Derived from Tables 3 to 10)

BINDER	VOLUME (Gal.)	CONCENTRATION (%)	GALS/CAR	RATING	ACCEPTABILITY
Coal Spray 100	45	100.0	45.0	1	Best performance on
Reclamation Oil	50	100.0	50.0	2	all profiles.
DS 100	50	25.0	12.5	3	Effective on flat pro-
DS 200	50	15.0	7.5	4	files and slopes.
Dowell M167	65	7.5	4.9	5	Effective on flat
Lignin Derivative	60	8.0	4.8	6	profiles.
Acquatain	73	6.6	4.8	7	Unacceptable.
Alchem 63026	40	10.0	4.0	8	

TABLE 12

NUMBER OF TRAINS AND CARS MONITORED DURING PHASE II FIELD WORK

SOURCE	NO. OF TRAINS	TOTAL CARS	CARS/TRAIN (Average)	LOCATION IN TRAIN
Kaiser	12	211	17.6	Front 3 trains Centre 4 Rear 4 All cars 1
Fording	10	215	21.5	Front 6 trains Centre 1 Rear 2 All cars 1
Luscar	4	79	19.7	Front 1 train Centre 1 Rear 2
McIntyre	4	42	20.0 (2 trains) 1.0 (2 trains)	

TABLE 13

MINE B

COVER REMAINING ON COAL ON ARRIVAL AT TERMINAL (PERCENT OF TOTAL SURFACE)

TRAIN	432	434	436	444**	446**	448**	450	457	460	463	468	TOTAL
DATE	Aug 31	SEP 3	4	7	9	10	11	15	17	18	19	
NO CARS	10	18	20	20	13	28	20	20	20	20	2	211
LOCATION	R	C	C	C	R	All	F	C	F	F	R	
WEATHER	CI	OW	SW	SW	SW	SW	SW	R	SW	SW	SW	
COAL							WET	WET	WET			
PERCENT												
98		5[a]										5
97												
96		5										5
95		5							4			9
94										2		2
93								2	3	1		6
92		1						1		4		6
91		1		1					1	8		11
90			1	3		3	2		5	1		15
89			1	2				1	1			5
88			5	1	1		1	1	1	2		12
87						2		4				6
86			3	2	1		2	2	1	1		12
85			2	4		1	2	3	1		2	15
84			3	1	1		1					6
83					1	2		1				4
82			1		1	3	2	1				8
81			1		2	1	2	2				8
80				1		2			2	1		7
79					2							2
78					1	1	1					3
77						1	2					3
76	1			1	2		3					7
75				1		4	1		1			7
74	1					4	1					
73												
72			2			2						4
71	1					1						2
70					1							1
69												
68				1								1
	(63) 1	(50) 1	(65) 1	(65) 1		(63) 1	(63) 1					
	(59) 1						(60) 1					
	(54) 1											
	(39) 1											
	(38) 1											
	(36) 1											
	(23) 1											

**Binder is "modified" latex.

Footnote: a. The number of cars with percentage cover as shown.

TABLE 14

MINE C

COVER REMAINING ON COAL ON ARRIVAL AT TERMINAL (PERCENT OF TOTAL SURFACE)

TRAIN	821249	821254	821257	821261	821262	821263	821269	821270	821271	821273	Total
DATE	Aug 29	Sept 1	Sept 5	Sept 8	Sept 9	Sept 9	Sep 16	Sep 16	Sep 17	Sep 19	
NO. CARS	44	24	22	20		22	22	24	25	12	
LOCATION	All	F	F	F*	F	F*	F*	R	R	C	
WEATHER	SW	OW	SW	SW	SW	SW	OW	OW	SW	SW	
COAL											
PERCENT											
97	1										1
96	1		2						2		5
95									1		1
94	6								1		7
93	4								2		6
92	1								2		3
91	3							1	1		5
90	1		1					1	1		4
89	3		1	1					1		6
88	3						1	1	4		9
87	2					2		2	3		9
86	1			1		1		2	2	1	8
85	1		1	1		3	1	1		1	9
84	2						1	2			5
83	1	1	2				1	2	1	1	9
82			1			2		1			4
81			1	2		2	1	1	1		8
80				2		3		1			6
79	2	1	2	1				2		1	9
78	3	2	1	1		2	1			1	11
77	1		1	2			1				5
76	2	1				2				3	8
75						1	2		1	2	6
74	2			1			1	1		1	6
73	2		2	2		1	1				8
72		1		1		1	1	1			5
71			1			1	1	1		1	5
70			1			1	1				3
69		1	1	1			1				4
68		2	1				4				7
67		3					1				4

PART INSPECTED WAS NOT COATED

*Night train

SW = Sunny and warm; OW = Overcast and warm; Cl = Cloudy
R = Rain. F = Front; R = Rear; C = Centre.

TABLE 14 (CONTINUED)

MINE C

COVER REMAINING ON COAL ON ARRIVAL AT TERMINAL (PERCENT OF TOTAL SURFACE)

TRAIN	821249	821254	821257	821261	821262	821263	821269	821270	821271	821273	Total
DATE	Aug 29	Sept 1	Sept 5	Sept 8	Sept 9	Sept 9	Sep 16	Sep 16	Sep 17	Sep 19	
NO. CARS	44	24	22	20		22	22	24	25	12	
LOCATION	All	F	F	F*	F	F*	F*	R	R	C	
WEATHER	SW	OW	SW	SW	SW	SW	OW	OW	SW	SW	
COAL											
				(66) 1			(65) 1	(65) 1			
							(64) 1				
								(63) 1			
				(62) 1							
	(59) 1	(60) 1	(60) 1								
		(57) 1									
		(55) 1									
		(53) 1									
								(48) 1			
		(43) 1									
		(39) 1									
									(38) 1		
			(36) 1	(36) 1							
				(35) 1							
		(29) 1									
		(23) 1									
								(21) 1			
		(20) 1	(20) 1								
		(0) 2									

*Night Train.

TABLE 15

MINE A

COVER REMAINING ON COAL ON ARRIVAL AT TERMINAL (PERCENT OF TOTAL SURFACE)

TRAIN	L151*	L154	L158	L160	TOTAL
DATE	Aug 28	Sept 3	Sep 14	Sep 16	
NO. CARS	19	20	20	20	
LOCATION		C	R	R	
WEATHER	R	SW	SW	SW	
COAL					
PERCENT					
94				1	1
93	1	1	1	3	6
92				4	4
91			1	3	4
90		1		3	4
89	1			4	5
88					
87	1	1			2
86	2	1	3		6
85	2			1	3
84		4	3	1	8
83		3			3
82	3	1	5		9
81	1	1			2
80			1		1
79	1				1
78	1	2	2		5
77	1		1		2
76		1	2		3
75	1	2			3
74					
73		1			1
72	3	1			4
71					
70					
69					
			1		1

*Night train.

TABLE 16

MINE D

COVER REMAINING ON COAL ON ARRIVAL AT TERMINAL (PERCENT OF TOTAL SURFACE)

TRAIN	M380	M381*	M388	M389	TOTAL
DATE	Sep 9	Sep 10	Sep 22	Sep 23	
NO. CARS	18	22	1	1	
LOCATION	F	F-W			
WEATHER	SW	SW			
COAL					
PERCENT					
71	1				1
70		1			1
69		1			1
68					
67					
66					
65					
64	1	1			2
63	3	1			4
62	1				1
61	1	1			2
60				1	1
59	1	2			3
58		2			2
57	2	1			3
56	2				2
55		1			1
54	1				1
53	2	1			3
52	1	1			2
51		2			2
50		1			1
49	1		1		2
48					
47	1				1
46					
45		1			1
44					
43		1			1
42		1			1
30		1			1
0					1

*Night train

TABLE 17

FREQUENCY OF COVERAGE ON

FRONT AND REAR SLOPES

Percent Cover	Kaiser		Luscar		Fording	
	Front	Rear	Front	Rear	Front	Rear
0	1	16	1	13	9	10
5	-	2	-	-	1	-
10	2	14	1	4	19	3
15	-	-	-	1	1	-
20	2	10	1	5	13	6
25	-	5	3	-	3	-
30	-	9	10	4	15	14
35	1	6	1	1	2	-
40	-	18	6	10	23	23
45	-	1	1	1	-	1
50	8	14	16	21	20	32
55	-	1	2	-	-	2
60	5	14	14	14	34	31
65	-	1	2	3	-	3
70	4	11	12	1	27	11
75	1	7	3	2	5	10
80	13	18	4	2	16	18
85	9	9	-	-	2	10
90	42	15	1	1	10	13
95	14	9	-	-	6	15
95+	6	3	-	-	-	9
100	22	8	-	-	-	2

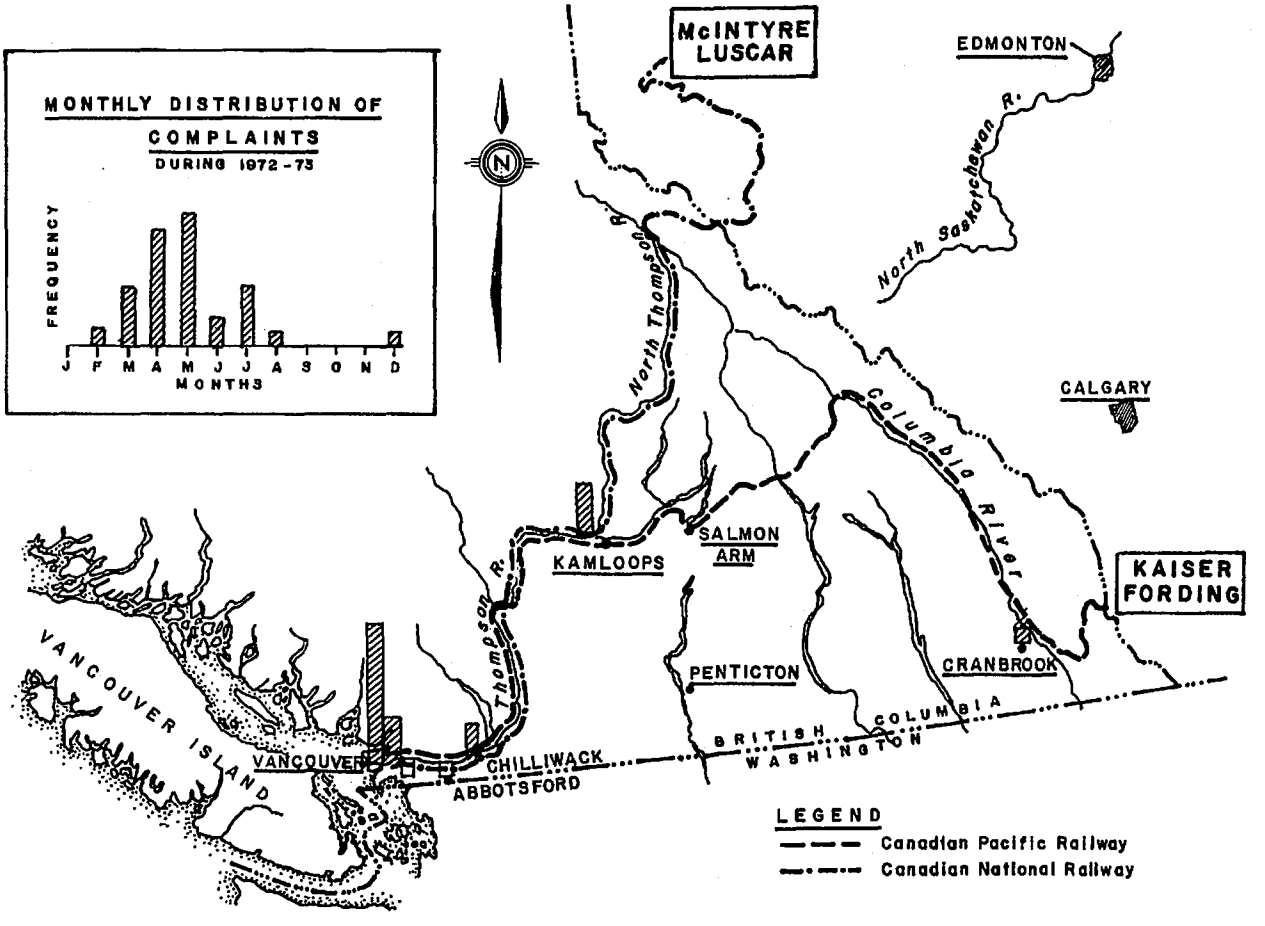


FIGURE 1 REGIONAL DISTRIBUTION OF COMPLAINTS DURING 1972 - 1973

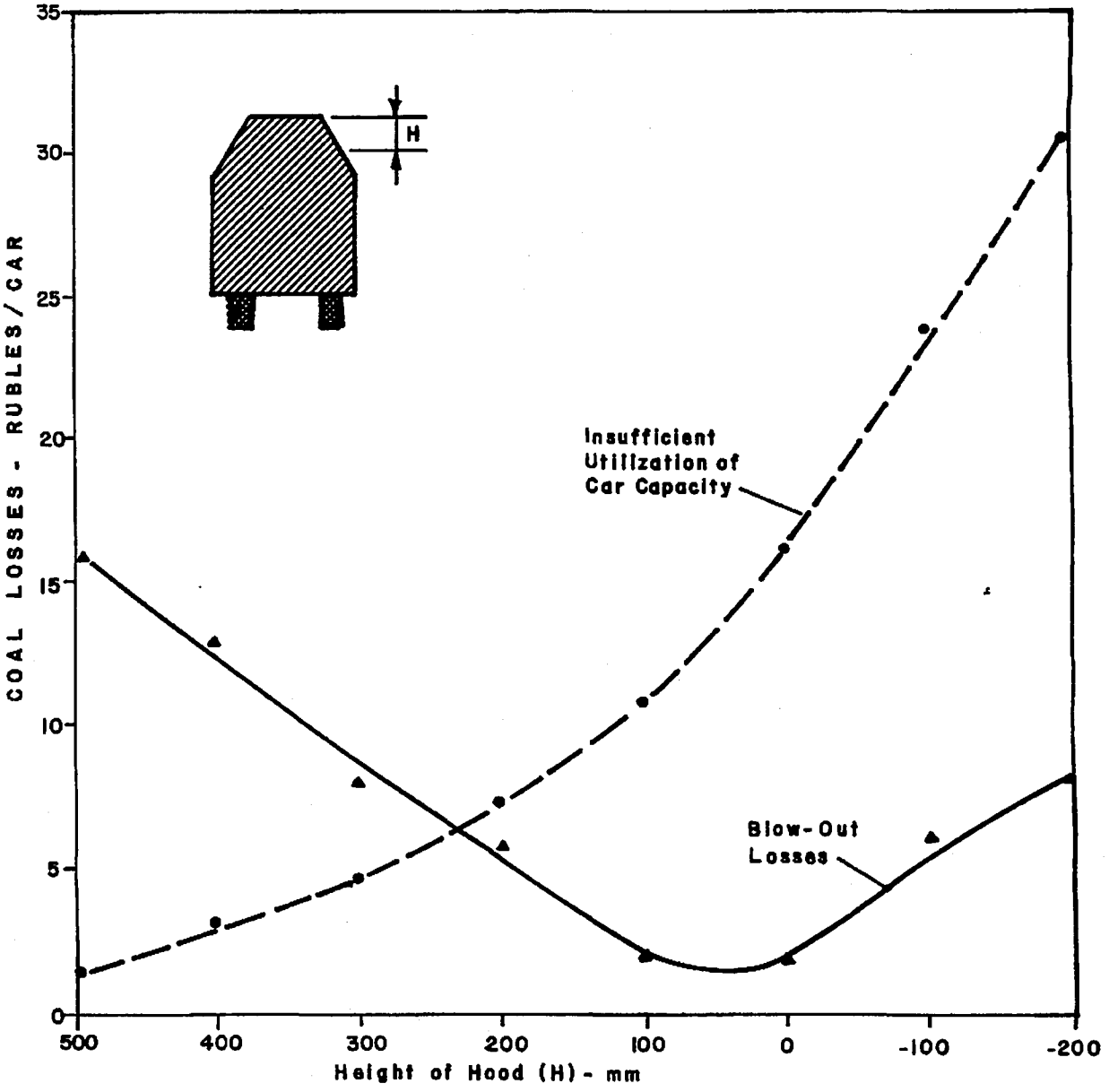


FIGURE 2 COAL LOSSES OF HIGH SPEEDS
(After V.K. Beshketo)

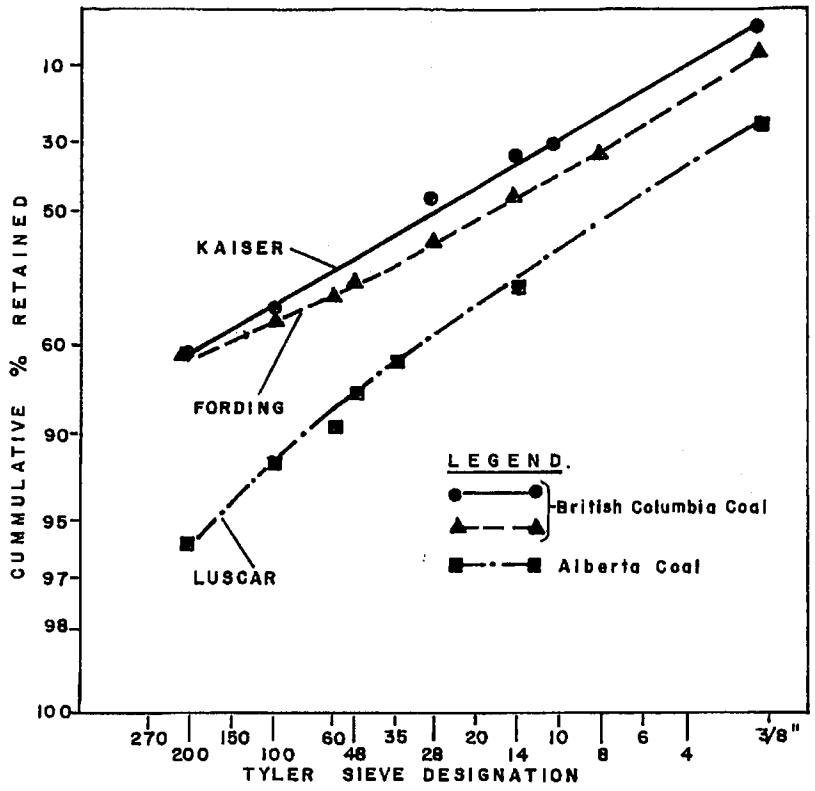


FIGURE 3 COMPARATIVE SCREEN ANALYSIS OF BRITISH COLUMBIA AND ALBERTA COALS

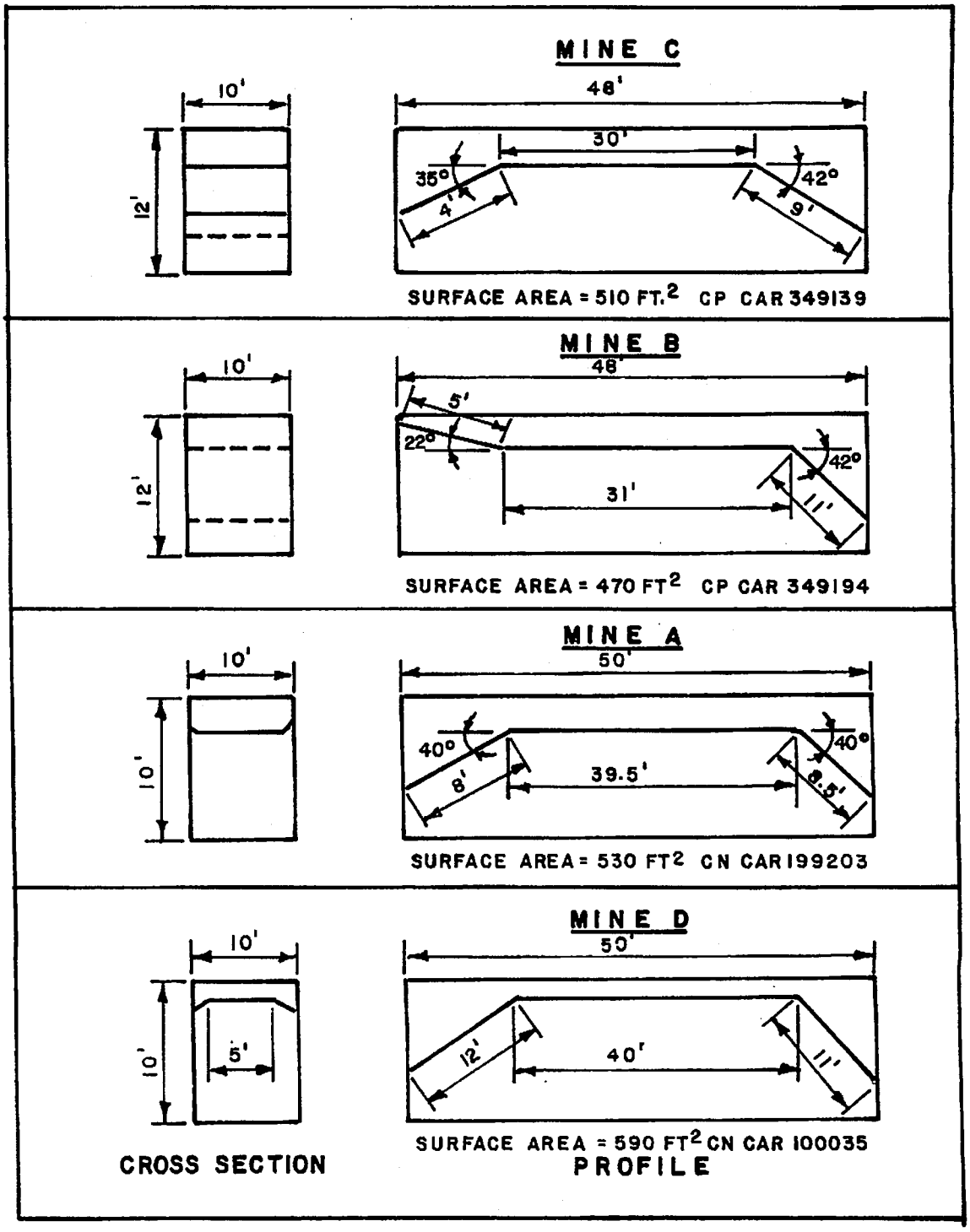


FIGURE 4 TYPICAL COAL CAR SURFACE DIMENSIONS - (From Levelton & Associates Ltd.)

B. H. LEVELTON & ASSOCIATES LTD. 1755 WEST 4TH., VANCOUVER, B.C. V6J 1M2 PHONE 736-6516

COAL CAR COATING INSPECTION

Terminal _____ Date Treated _____ Origin _____

Photo No. _____ CP/CN Train No. _____

Inspector _____ Date Examined _____ Car No. _____

Time _____ Binder _____

Weather - During Treatment _____ During Trip _____ On Arrival _____

	FRONT	FLAT	REAR	TOTAL
% Coverage				
Condition				
Dust Escapement Evidence				
Crust Flexibility				
Crust Thickness				
Crust Failure Nature and Prevalence				
Incomplete Coverage				

Terminal _____ Date Treated _____ Origin _____

Photo No. _____ CP/CN Train No. _____

Inspector _____ Date Examined _____ Car No. _____

Time _____ Binder _____

Weather - During Treatment _____ During Trip _____ On Arrival _____

	FRONT	FLAT	REAR	TOTAL
% Coverage				
Condition				
Dust Escapement Evidence				
Crust Flexibility				
Crust Thickness				
Crust Failure Nature and Prevalence				
Incomplete Coverage				

FIGURE 5

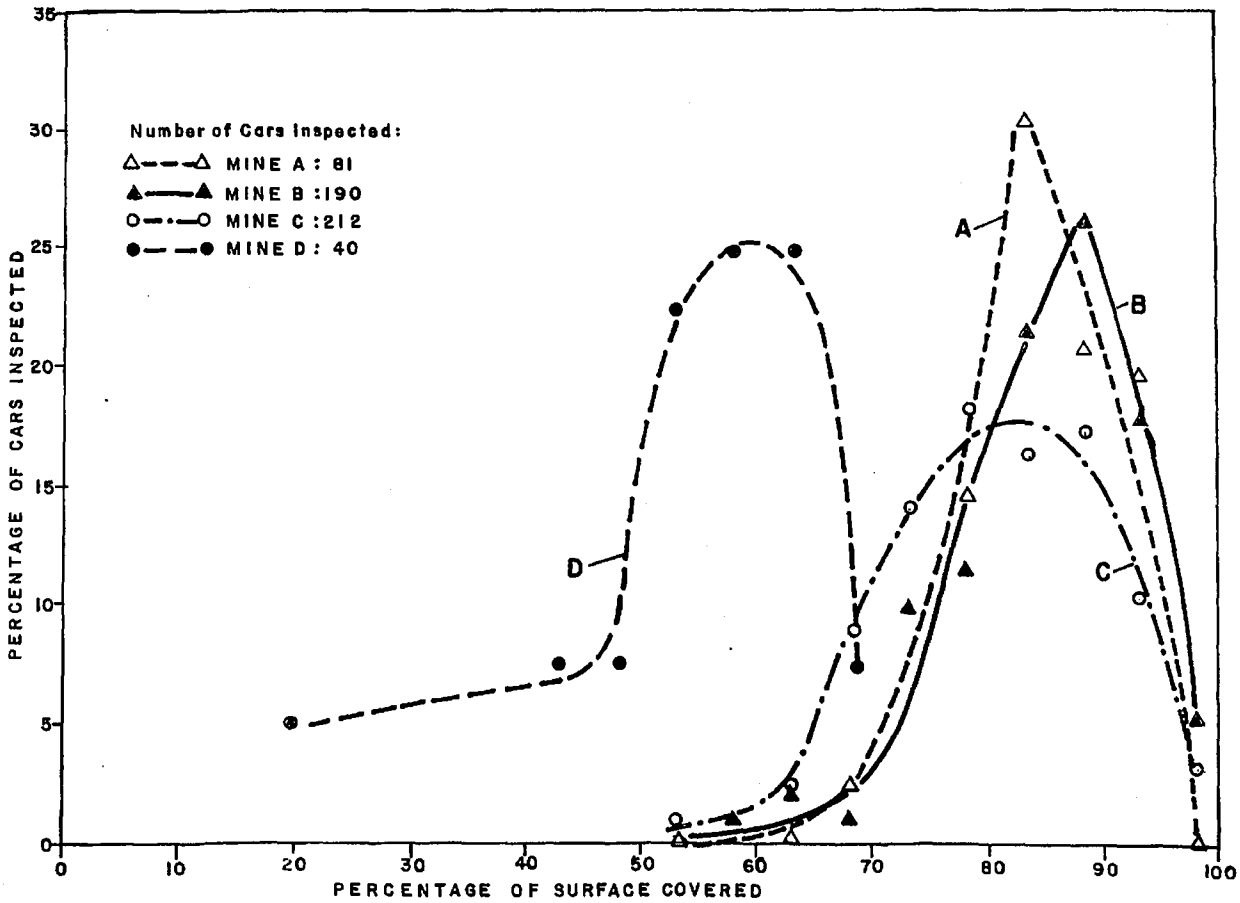


FIGURE 6 DISTRIBUTION OF COVER REMAINING ON TOTAL SURFACE OF COAL CARS

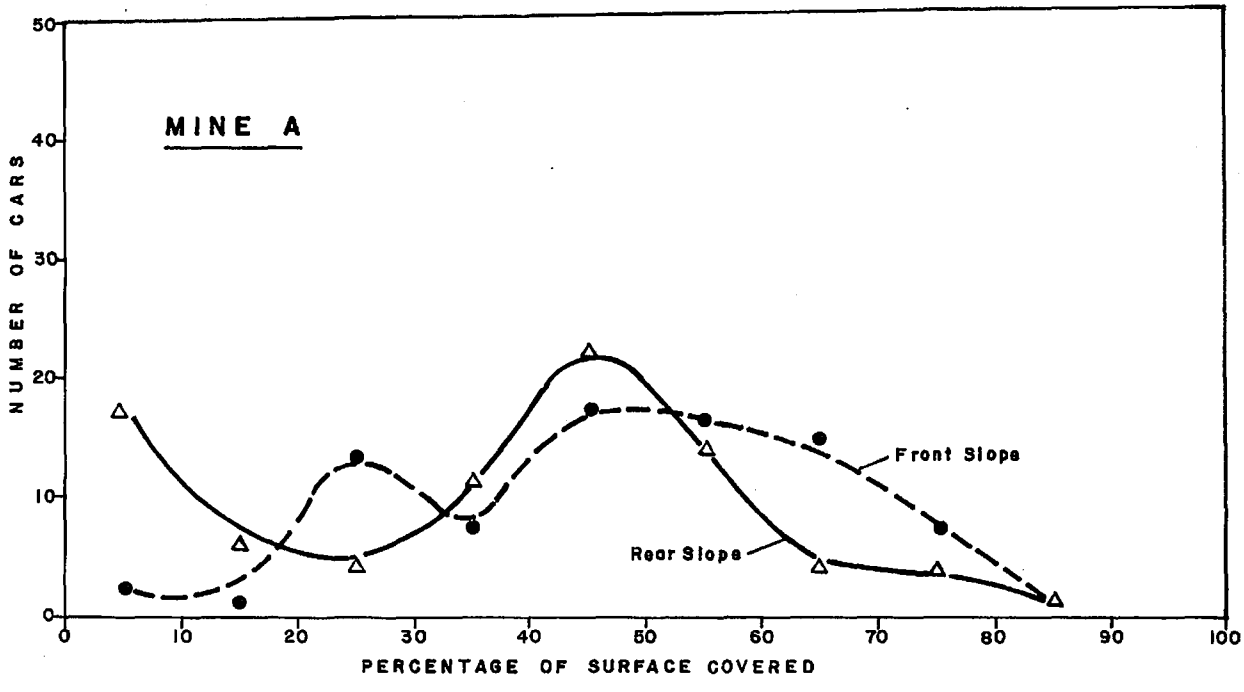


FIGURE 7 DISTRIBUTION OF COVER REMAINING ON FRONT AND REAR SLOPES

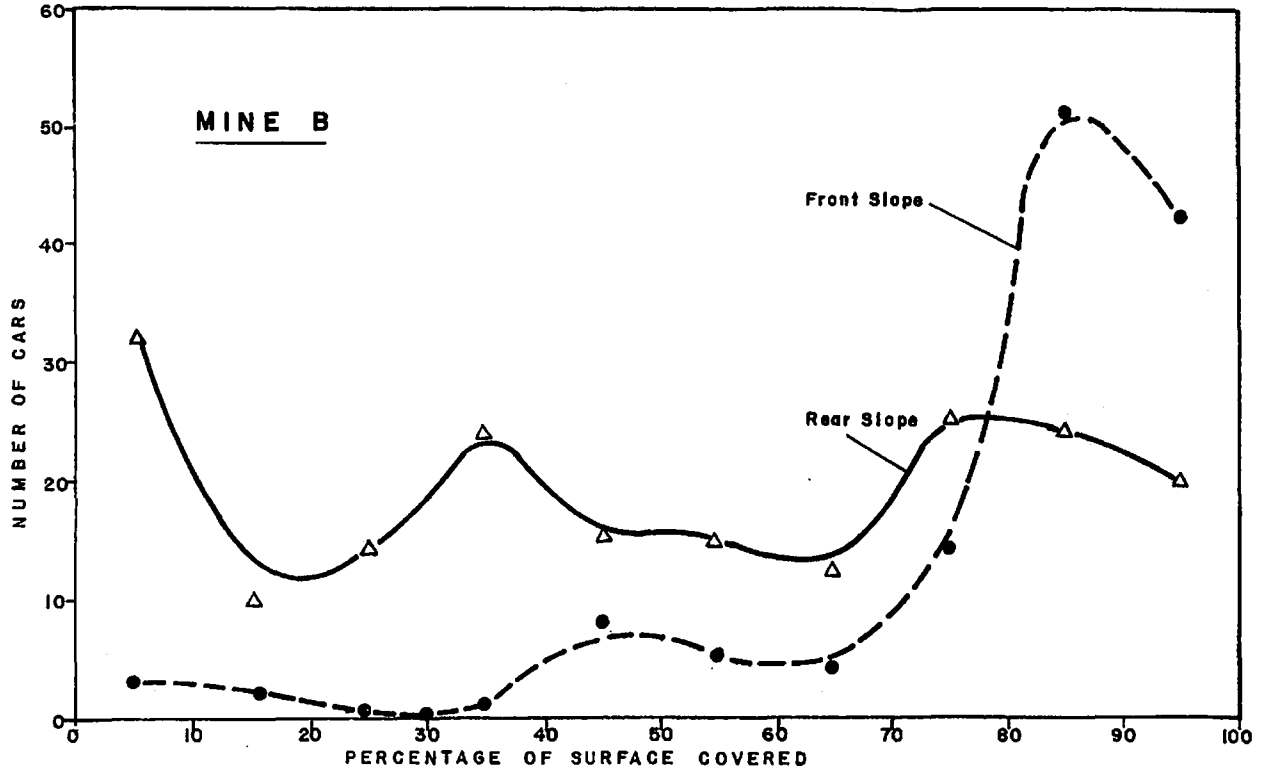


FIGURE 8 DISTRIBUTION OF COVER REMAINING ON FRONT AND REAR SLOPES

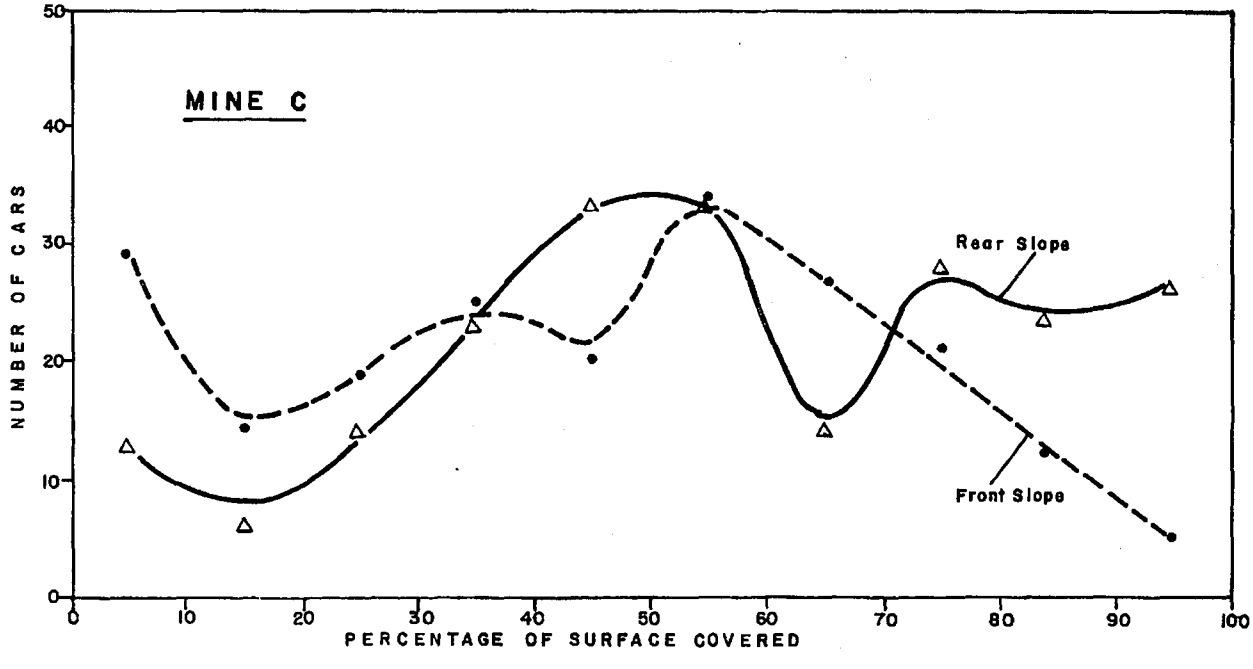


FIGURE 9 DISTRIBUTION OF COVER REMAINING ON FRONT AND REAR SLOPES

PLATE NO. 1: COAL LOSSES IN TRANSIT

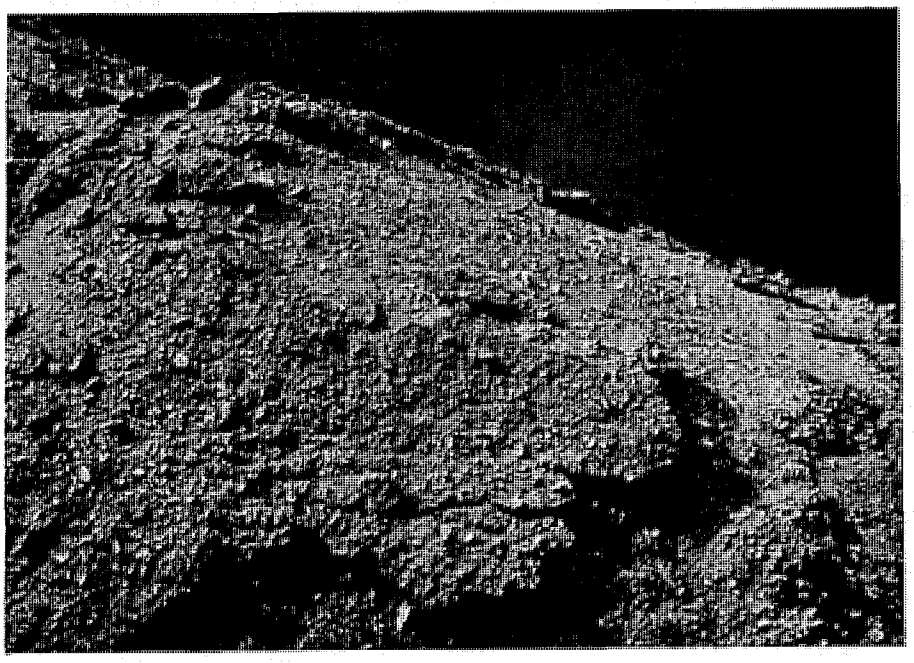


PLATE NO. 2: INCOMPLETE COVERAGE OF SLOPES

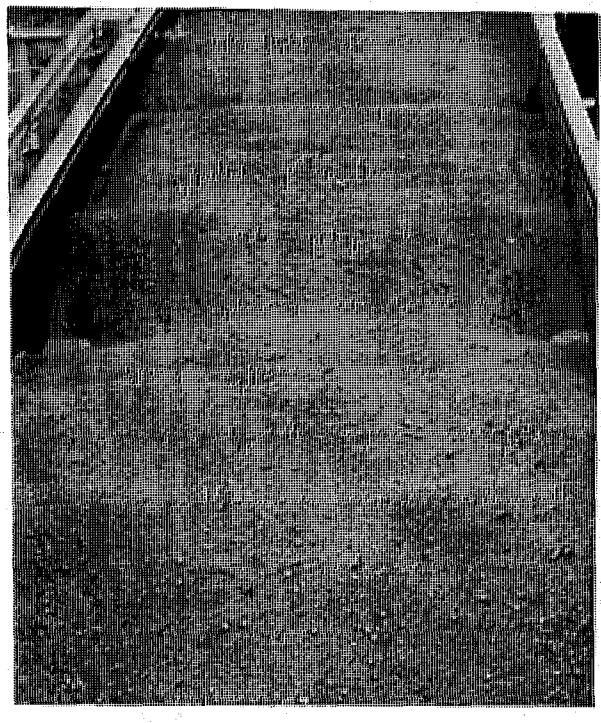
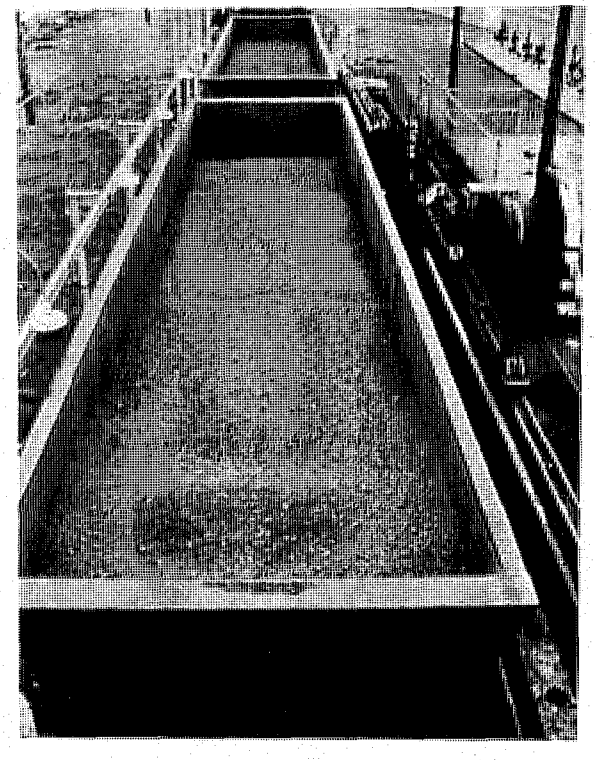


PLATE NO.3: UNTREATED CAR SHOWING POOLS OF WATER AND COARSE COAL

PLATE NO.4: PREFERENTIAL WIND EROSION OF UNTREATED CAR



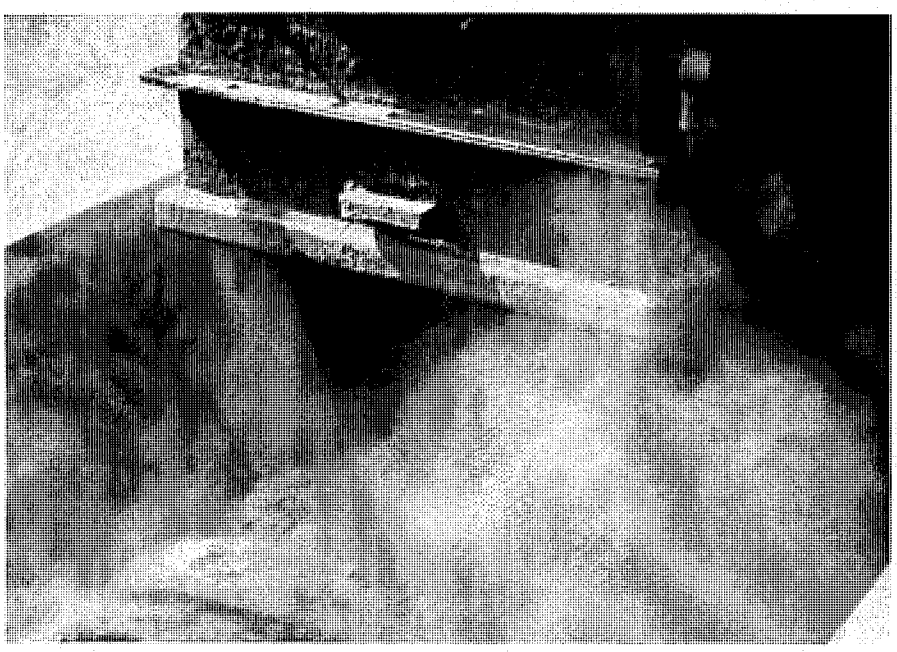


PLATE NO.5: ORIGINAL LOADING METHOD

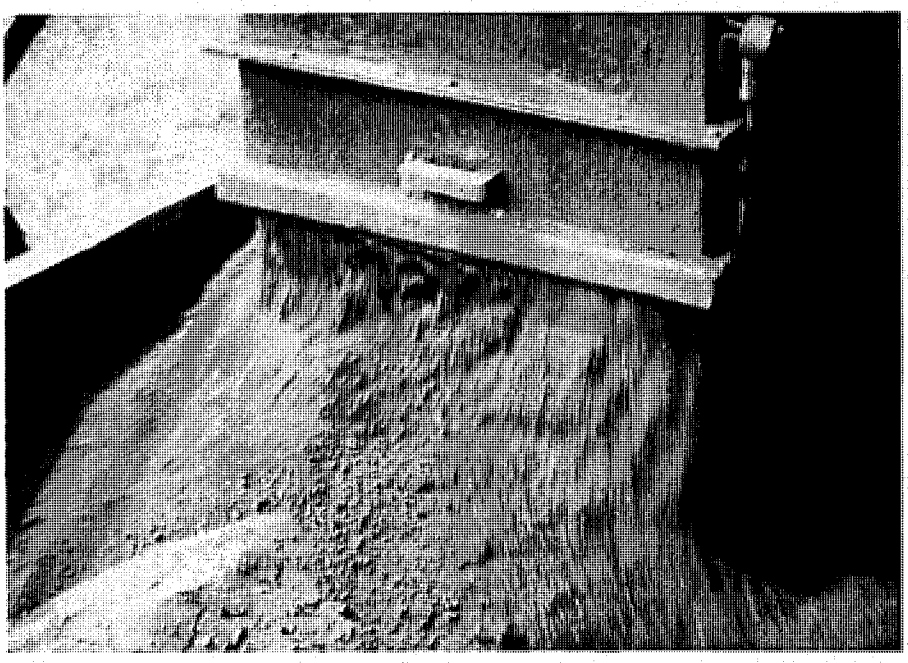


PLATE NO.6: FORMATION OF UNDESIRABLE SLOPES

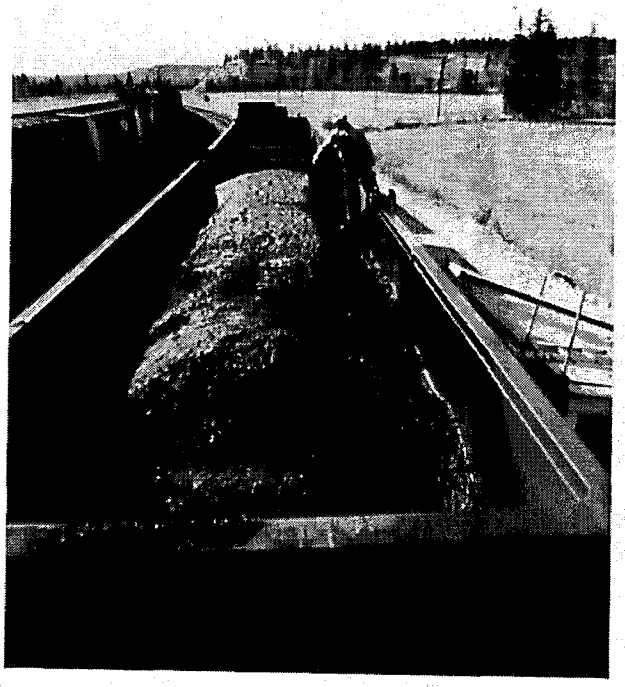
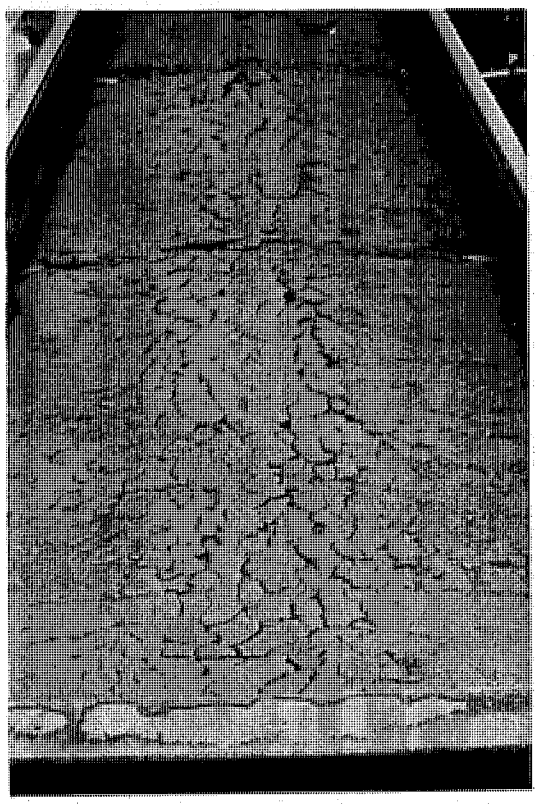


PLATE NO.7: HAND APPLICATION OF ASPHALT EMULSION

PLATE NO.8: CAR IN PLATE 7 AT KAMLOOPS

PLATE NO.9: CAR IN PLATE 7 AT WESTSHORE TERMINALS



❮ PLATE NO.10: UNIFORM SURFACE COVER

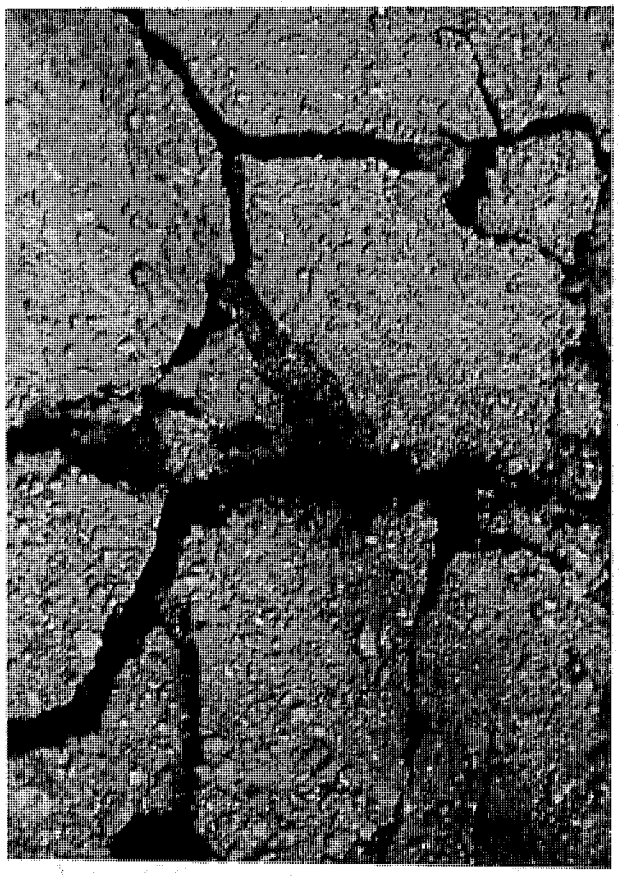
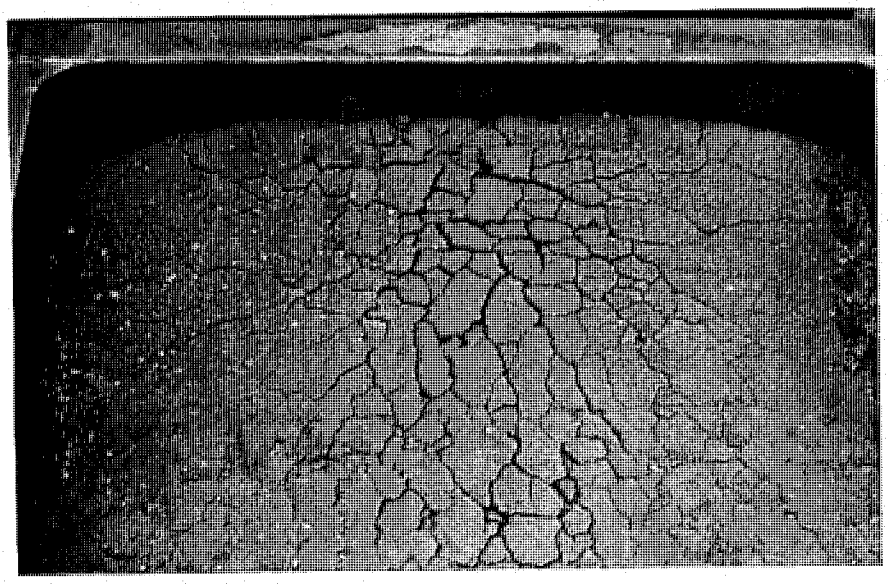


PLATE NO.11: CLOSE-UP SHOWING PENETRATION OF BINDER ❯



❮ PLATE NO.12: WELL PROTECTED FRONT-END SURFACE

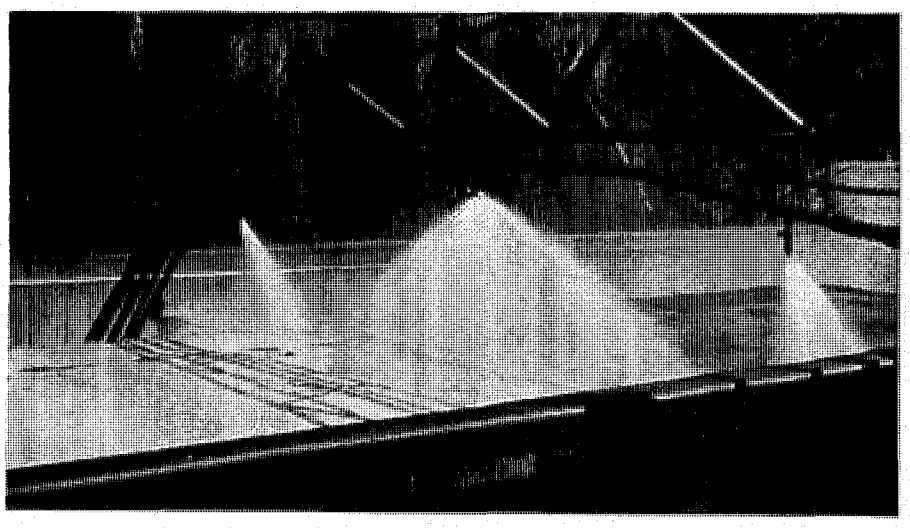


PLATE NO.13: PREFERENTIAL SPRAYING PATTERN OF A WELL PREPARED SURFACE

PLATE NO.14: END SPRAYING

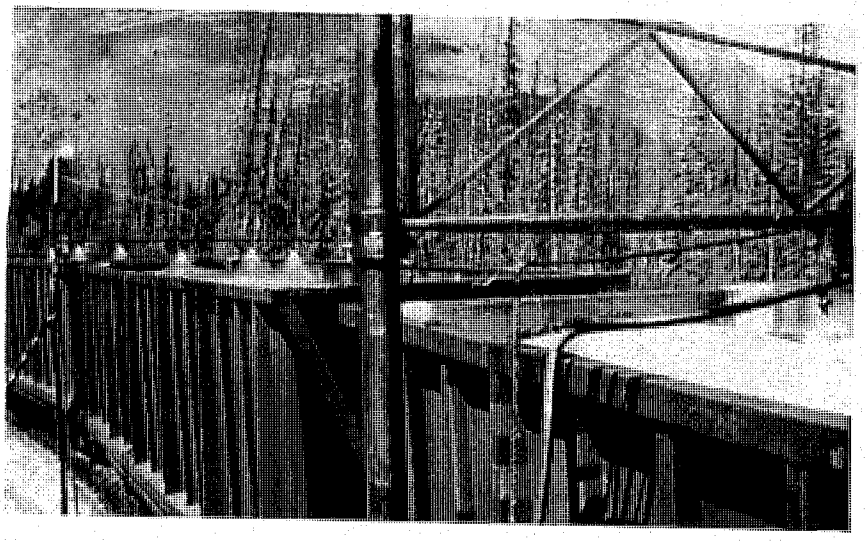


PLATE NO.15: ADDITIONAL WATER SPRAYS TO INCREASE PENETRATION OF BINDER

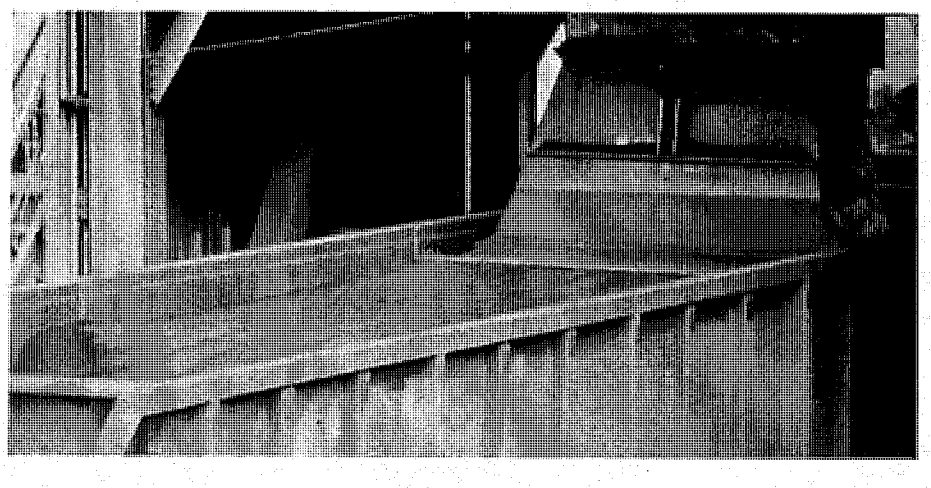
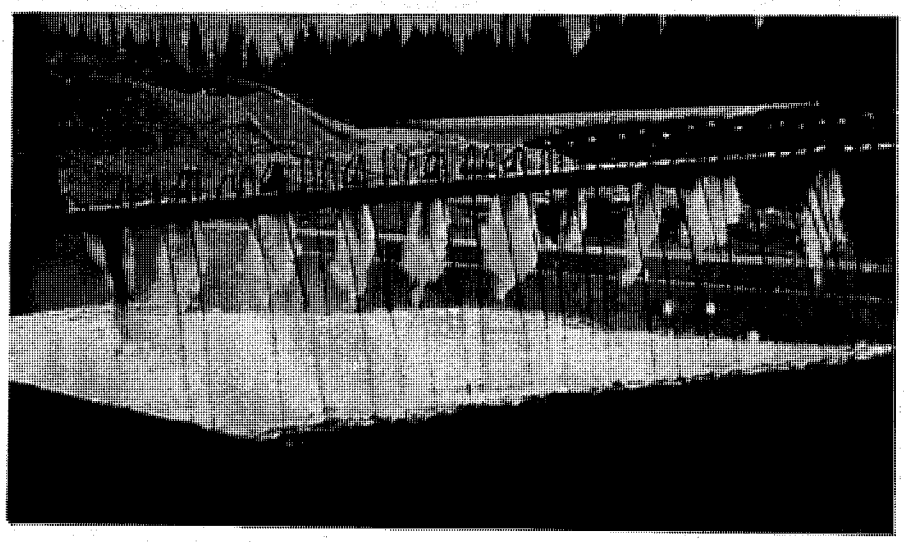


PLATE NO. 16: MODIFIED LOADING METHOD

PLATE NO. 17: COMBINATION OF FLOODING AND SPRAYING



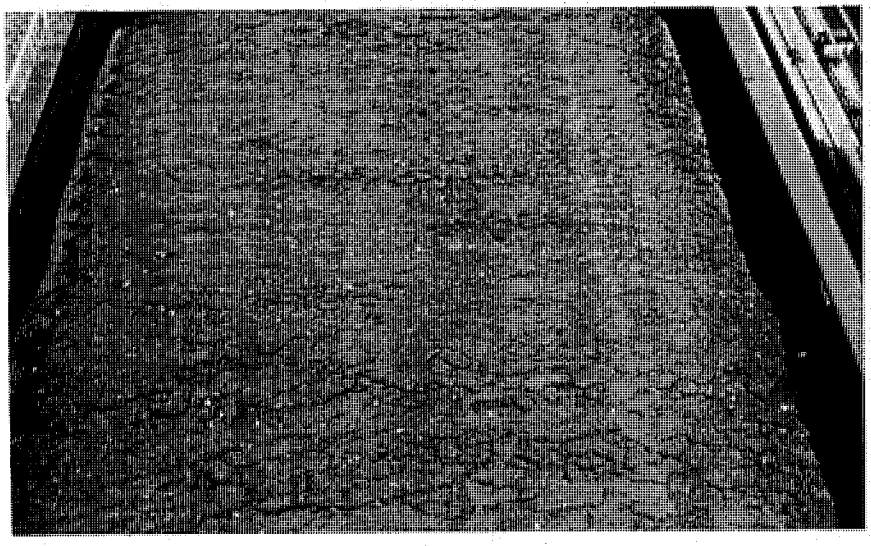


PLATE NO. 18: PROPERLY LOADED AND SPRAYED SURFACE

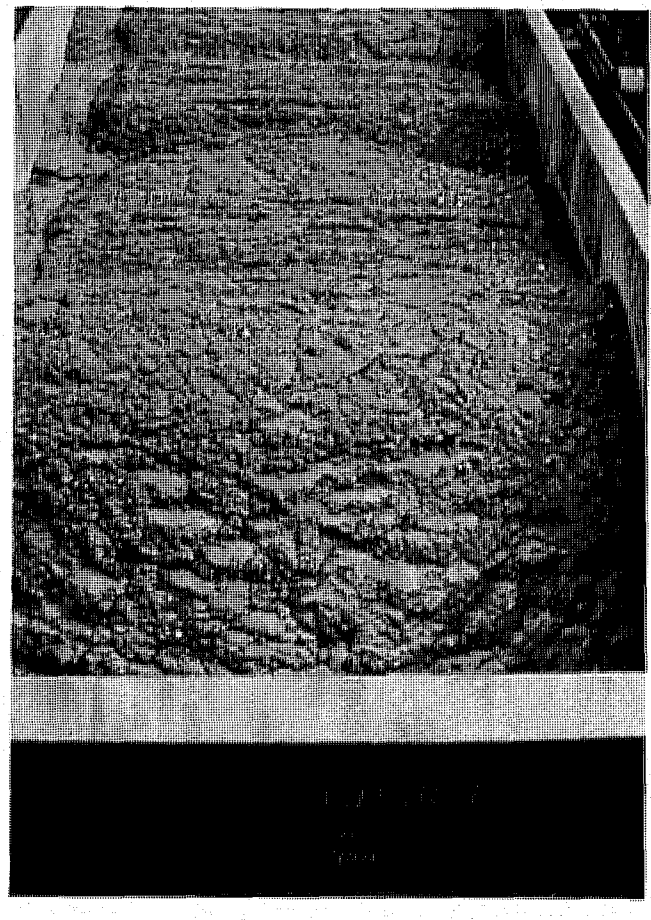
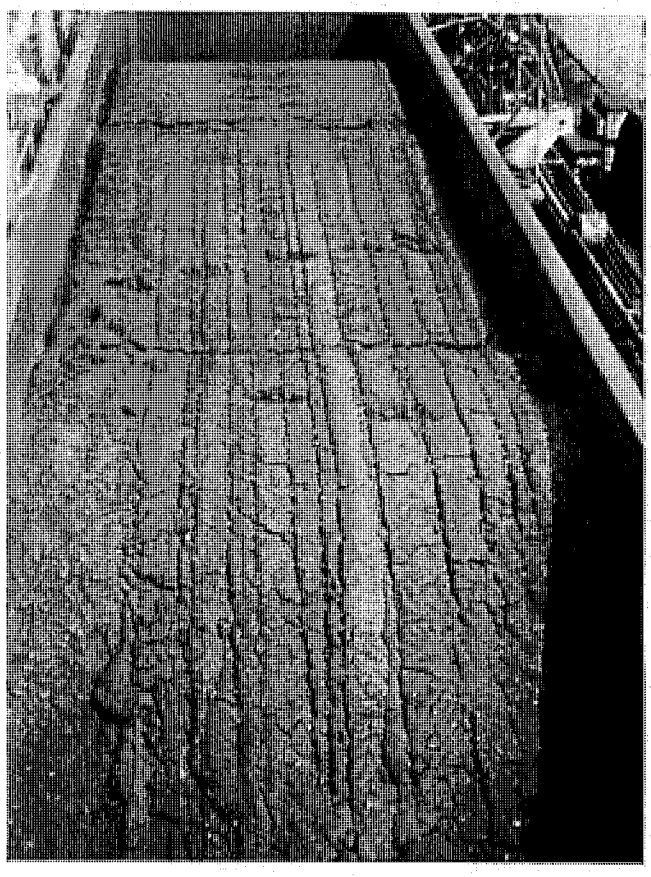


PLATE NO. 19:
EFFECTIVE SPRAYING
ON AN UNEVEN PROFILE

PLATE NO. 20: LIMITED CRUST FAILURE OF SLOPED AREA
IN CAR IN PLATE 19

PLATE 21: SLIDE 434-2
MINE B
CAR 349498
DATE SEPT. 3, 1975
COVERAGE 95%

PLATE 22: SLIDE 254-1
MINE C
CAR 351620
DATE Sept. 2, 1975
COVERAGE 70%



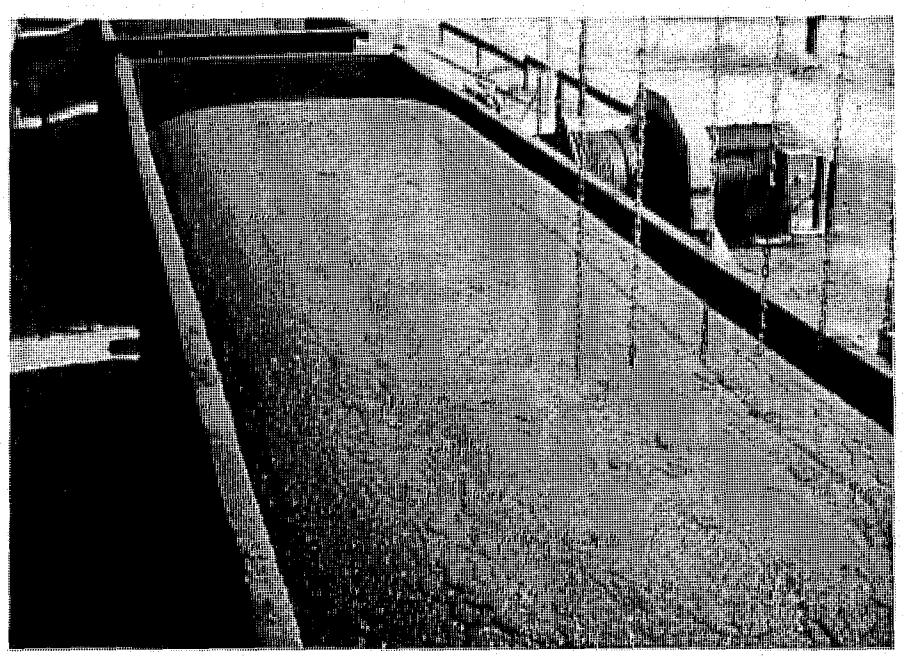


PLATE 23:
SLIDE L154-1
MINE A
CAR 199013
DATE SEPT. 3, 1975
COVERAGE 95%

PLATE 24:
SLIDE M280-10
MINE D
CAR 100945
DATE SEPT. 9,1975
COVEERAGE 80%

CERTIFICATE OF SERVICE

I hereby certify that on this 5th day of August, 2010, I caused a copy of the foregoing to be served on the following Parties of Record by first class mail, postage prepaid:

Mr. Eric Von Salzen
McLeod, Watkinson & Miller
One Massachusetts Avenue, NW, Suite 800
Washington, DC 20001
evonsalzen@mwmlaw.com

Counsel for Arkansas Electric Cooperative Corporation

Mr. Joe Rebein
Shook, Hardy & Bacon LLP
2555 Grand Blvd.
Kansas City, Missouri 64108-2613
jrebein@shb.com

Counsel for Union Pacific Railroad Company

Ms. Sandra L. Brown
Thompson Hine LLP
1920 N Street, NW, Suite 800
Washington, DC 20036
Sandra.Brown@ThompsonHine.com

Counsel for Ameren Energy Fuels and Services Company and Texas Municipal Power Agency

Mr. Kelvin J. Dowd
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
kjd@sloverandloftus.com

Counsel for Consumers Energy Company

Mr. John H. LeSeur
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
jhl@sloverandloftus.com

Counsel for Western Coal Traffic League

Mr. C. Michael Loftus
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036-3003
cml@sloverandloftus.com

Counsel for Concerned Captive Coal Shippers

Mr. Michael F. McBride
Van Ness Feldman, PC
1050 Thomas Jefferson Street, NW
Suite 700
Washington, DC 20007-3877
mfm@vnf.com

Counsel for American Public Power Association, Edison Electric Institute, and National Rural Electric Cooperative Association

Mr. G. Paul Moates
Sidley Austin LLP
1501 K Street, NW
Washington, DC 20005
pmoates@sidley.com

Counsel for Norfolk Southern Railway Company

Mr. Frank J. Pergolizzi
Slover & Loftus LLP
1224 Seventeenth Street, NW
Washington, DC 20036
fjp@sloverandloftus.com

Counsel for Entergy Arkansas, Inc., Entergy Gulf States Louisiana, LLC, and Entergy Services, Inc.

Mr. Paul Samuel Smith
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Room W94-316 C-30
Washington, DC 20590
paul.smith@dot.gov

Mr. Thomas W. Wilcox
GKG Law, PC
Canal Square
1054 Thirty-First Street, NW, Suite 200
Washington, DC 20007-4492
twilcox@gkglaw.com

Counsel for National Coal Transportation Association and TUCO Inc.

Mr. Charles A. Stedman
L.E. Peabody & Associates, Inc.
1501 Duke Street, Suite 200
Alexandria, Virginia 22314

Mr. Paul R. Hitchcock
Associate General Counsel
CSX Transportation, Inc.
500 Water Street, J-150
Jacksonville, Florida 32202
Paul_Hitchcock@CSX.com

Kathryn J. Gainey

LAXT

November 30, 2010

Ted Sturdevant, Director
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
ted.sturdevant@ecy.wa.gov

Sally Toteff, Southwest Region Director
Department of Ecology
P.O. Box 47775
Olympia, WA 98504-7775
stot461@ecy.wa.gov

Department of Ecology
Water Quality Program
Attn: Joyce Smith
P.O. Box 47696
Olympia, WA 98504-7696
josm461@ecy.wa.gov
Fax: (360) 407-6426

RE: Millennium Bulk Logistics Longview Coal Export Terminal; Public Comments on Notice of Intent for a Construction Stormwater General Permit and SEPA Compliance.

Dear Director Sturdevant, Ms. Toteff, and Ms. Smith,

Millennium Bulk Logistics ("Millennium") is planning to operate a massive outdoor coal storage and export terminal on the banks of the Columbia River at the Chinook Ventures facility in Longview, Washington. Columbia Riverkeeper, Climate Solutions, Sierra Club, and the Washington Environmental Council submit the following comments on Millennium's Notice of Intent ("NOI") for a Construction Stormwater General Permit ("CSWGP") and State Environmental Policy Act ("SEPA"), RCW 43.21C *et seq.*, compliance. Our organizations appreciate the Department of Ecology's commitment to clean water and healthy ecosystems. We

recognize the time and effort Ecology expended on this complex facility during the aluminum smelter curtailment and the Chinook Ventures enforcement actions. We request that the Department continue to take a leadership role and carefully analyze the full impact of the new proposed use.

Millennium's plans call for soil disturbing activities in excess of 70 acres and associated stormwater runoff to the Consolidated Diking Improving District Ditches, or "Longview Ditches," and the Columbia River. The Longview Ditches are 303(d) listed for turbidity, fecal coliform, and dissolved oxygen and Ecology has not prepared any Total Maximum Daily Loads ("TMDLs") for these pollutants. Under the Ninth Circuit's 2007 *Friends of Pinto Creek v. U.S. EPA* decision, the Clean Water Act prohibits new discharges of 303(d) listed pollutants to the Longview Ditches.

Even if a TMDL existed, Ecology should deny Millennium's CSWGP application and require that the company apply for an individual NPDES permit. Neither the 2005 nor draft 2010 CSWGP are designed to protect water quality from a facility like the Chinook Ventures site. As the Department is well aware, soils and groundwater at this industrial property are contaminated with fluoride, cyanide and polycyclic aromatic hydrocarbons (PAHs). The property is currently subject to a Model Toxics Control Act ("MTCA"), RCW 70.105D *et seq.*, Agreed Order. Most recently, Ecology conducted a series of compliance investigations and issued multiple enforcement orders against Chinook Ventures for air, land, and water quality violations. Simply put, the combined impact of pollution caused by over sixty years of aluminum smelting and Chinook Ventures now notorious environmental record render the general permit's one-size-fits-all approach completely inadequate to protect public health, aquatic life, and water quality.[1]

Finally, Ecology must require an Environmental Impact Statement ("EIS") to assess the direct, indirect, and cumulative impacts of this massive coal export terminal. From climate change to the coal dust emissions associated with coal transport and storage, this permit application raises issues of state-wide significance. Cowlitz County recently approved Millennium's Shoreline Substantial Development Permit and an inadequate SEPA analysis that, among other things, failed to consider the impacts of authoring a 5.7 million ton per year coal export terminal on the Columbia River. Before taking any action on Millennium's CSWGP application, Ecology must prepare a complete SEPA review, including an EIS.

For the reasons explained below, Ecology should: (1) deny Millennium's CSWGP application; and (2) require an Environmental Impact Statement before proceeding with any permitting for this coal export terminal.

[1]Regardless of the Department's understandable interest in seeing Chinook Ventures sell its lease, the CSWGP application raises serious water quality issues that should be assessed independent of any sale.

I. Ecology Should Deny Millennium's Construction Stormwater Permit Application or, at a minimum, Require an Individual NPDES Permit.

Millennium's proposed construction activities will disturb over 73 acres, significantly increasing the risk that historic pollution from aluminum smelting and more recent pollution from Chinook Ventures' operations could be discharged during construction activities. Columbia Riverkeeper, Climate Solutions, Washington Environmental Council and the Sierra Club urges Ecology to deny Millennium's application because it violates 40 C.F.R. § 122.4. Even if TMDLs existed for the Longview ditches, a CSWGP is inappropriate because it is not tailored to the significant contamination at the former Reynolds Aluminum site.

A. Millennium's proposed construction stormwater discharges to a 303(d) listed waterbody would violate the prohibitions of 40 C.F.R. § 122.4.

The Clean Water Act prohibits issuing a NPDES permit to a new discharger if the discharge will contribute to the violation of water quality standards that resulted in the inclusion of the receiving waters on the 303(d) list, unless both requirements of 40 C.F.R §§ 122.44(i)(l) and (2) are satisfied. *Friends of Pinto Creek v. EPA*, 504 F.3d 1007, 1012 (9th Cir. 2007).[2] Millennium's construction stormwater activities will discharge pollutants into the Longview Ditches, which are 303(d) listed for fecal coliform, turbidity, and dissolved oxygen. Based on Ecology's online 303(d) mapping tool, it is unclear if the particular segment of the Longview Ditches that Millennium will discharge to is included on the 303(d) list.

Pollutants that are likely to be present in construction stormwater discharges include turbidity, suspended and settleable solids, pathogens, metals, organic compounds, and nutrients. 74 Fed. Reg. 62996, 63010 – 011 (Dec. 1, 2009). Therefore, Ecology must abide by the prohibition of 40 C.F.R. § 122.4 with respect to discharges from construction stormwater to the Longview Ditches. To date Ecology has not issued, and EPA has not approved, TMDLs for the Longview Ditches. Consequently, the Clean Water Act prohibits a new or expanded discharge of 303(d) listed pollutants to this impaired waterbody.

In *Friends of Pinto Creek*, the Ninth Circuit explained that 40 C.F.R. § 122.4 prohibits new discharges of pollutants of concern to 303(d) listed waterbodies unless "a TMDL has been performed and the owner or operator demonstrates that *before the close of the comment period* two conditions are met, which will assure that the impaired waters will be brought into compliance with applicable water quality standards." *Friends of Pinto Creek*, 504 F.3d at 1012 (emphasis in original). The Ninth Circuit explained that "[t]he plain language of this exception to the prohibited discharge by a new source provides that the exception does not apply unless the new source can demonstrate that, under the TMDL, the plan is designed to bring the waters into compliance with the applicable water quality standards." *Id.* As a result, Ecology may not issue

[2]The Puget Soundkeeper Alliance submitted detailed comments on the draft 2010 CSWGP, which explained why Schedule 1.E. fails to comply with the Ninth Circuit's *Friends of Pinto Creek* decision.

NPDES permit coverage for Millennium's proposed construction stormwater discharges to a 303(d) listed waterway unless Ecology determines that no pollutant of concern will be discharged. However, the overwhelming science on pollution associated with stormwater from construction sites—and Ecology's acknowledgement of this science in the Draft 2010 CSWGP Fact Sheet—weighs strongly against issuing Millennium coverage under the CSWGP. *See* Draft 2010 CSWGP Fact Sheet at 7 ("Pollutants expected in the stormwater discharge from construction activity include sediment (that is, suspended solids, turbidity, etc.), pH, phosphorous, and petroleum products."); *id.* at 8 ("The suspended solids may affect biological functions, such as the ability of submerged aquatic vegetation to receive light and the ability of fish gills to absorb dissolved oxygen.").

B. Historic Contamination at the former Reynolds Metals Site Warrants Requiring an Individual Construction Stormwater Permit.

Even if Ecology had issued TMDLs for the Longview Ditches, a CSWGP is not appropriate for this highly contaminated industrial property. As an initial matter, soil and groundwater at the former Reynolds Metals Company ("Reynolds") site is contaminated with hazardous substances. Reynolds produced aluminum and aluminum based products at the site for nearly sixty (60) years. The site is currently subject to an Agreed Order between Northwest Alloys, Chinook Ventures, and Ecology. The Agreed Order states:

> Studies done at the Site in 2002 and 2003 show contamination is located at two closed industrial landfills, three closed waste ponds, one closed potliner storage area and a closed RCRA waste pile. Ground water found beneath portions of the Site has elevated levels of sulfate, fluoride and cyanide.
>
> Initial studies of soil and ground water at the Site find levels of free cyanide above Model Toxics Control Act (MTCA) cleanup standards. Levels of fluoride are above MTCA ground water levels.

Agreed Order at 3, ¶¶ 9 – 10.

Fluoride, cyanide, and PAHs found at the site are "hazardous substances" as defined in RCW 70.105D.020(7). The Agreed Order states: "Based on the presence of these hazardous substances at the Site and all factors known to the Department, there is a release or threatened release of hazardous substances from the facility, as defined at RCW 70.105D.020(19)." Agreed Order at 4 § III ¶ 4.

Notably, the CSWGP does not require additional monitoring, best management practices, or stormwater treatment to address historic pollutants that may enter the Longview Ditches and the Columbia River. In addition, the CSWGP does not impose numeric effluent limits or, at a minimum, benchmarks for fluoride, cyanide, PAHs and other pollutants associated with the historic aluminum plant operations or Chinook Ventures recent operations.

The Clean Water Act, and in turn Ecology's 2005 CSWGP and Draft 2010 CSWGP, anticipate that the general permit approach will not protect water quality in all circumstances. In turn, both the 2005 and Draft 2010 CSWGP authorize Ecology to develop individual permits to protect our state's rivers, streams, and lakes. The 2005 Construction Stormwater General Permit, Schedule 1.D., states:

> The *Director* may require any *discharger* to apply for and obtain coverage under an individual permit or another more specific general permit. Such alternative coverage will be required when Ecology determines that this general permit does not provide adequate assurance that *water quality* will be protected; or there is a reasonable potential for the project to cause or contribute to a violation of water quality standards.

(emphasis in original). According to Ecology's website, the agency intends to issue the new CSWGP on December 1, 2010. *See* Ecology' Construction Stormwater Website at http://www.ecy.wa.gov/programs/wq/stormwater/construction/. The 2010 Draft Construction Stormwater General Permit, Schedule 1.E., "Limitations on Coverage," states:

> The Director may require any discharger to apply for and obtain coverage under an individual permit or another more specific general permit. Such alternative coverage will be required when Ecology determines that this CSWGP does not provide adequate assurance that water quality will be protected; or there is reasonable potential for the project to cause or contribute to a violation of water quality standards.

Thus, both the 2005 and Draft 2010 CSWGP empower Ecology to require that dischargers obtain an individual permit when the CSWGP: (1) does not provide adequate assurance that water quality will be protected; or (2) when Ecology determines that there is a reasonable potential for the construction project to cause or contribute to a violation of water quality standards.

Unlike the 2005 CSWGP application, the Draft 2010 CSWGP application requires that applicants disclose the construction site's history and soil contamination. *See* Draft 2010 CSWGP Application at 2, § V (requiring that CSWGP applicants disclose existing site conditions, including information on whether contaminated soils are present on the site, whether the site boundaries include contaminated groundwater, and whether "any contaminated soils will be disturbed" or whether "any contaminated groundwater [will] be discharged due to the proposed construction activity"). In addition, the new CSWGP application requires that applicants explain "in detail the locations, contaminants, and concentrations, and pollution prevention and/or treatment BMPs proposed to control the discharge of soil/groundwater contaminants." *Id.* Ecology's decision to require this information in the new application reflects the connection between historic site contamination, soil disturbance, and pollution associated with stormwater from construction sites. *See* Draft 2010 CSWGP Fact Sheet at 9 ("Historical contamination or natural soil conditions may contribute other pollutants to stormwater. Examples may include pesticides, metals (arsenic, lead, etc.), polychlorinated biphenyls (PCBs), or petroleum."). This critical information on historic site contamination will

inform the Department's decision on whether to invoke Schedule 1.E. for CSWGP applicants starting December 1, 2010.

Because Millennium submitted the 2005 CSWGP application, Ecology has not had the benefit of reviewing historic site contamination at the Chinook Ventures site. Even if this information had been submitted, the 2010 CSWGP fails to ensure that a highly contaminated property like the Chinook Ventures site will not cause or contribute to water quality violations. Based on the site's historic soil and groundwater contamination alone, an individual NPDES permit is warranted.

C. Recent industrial operations support issuing an individual permit to protect the Columbia River from pollution associated with Chinook Ventures' management of the facility.

In addition to historic soil contamination, Chinook Ventures' unlawful management of the facility raises serious questions about the potential for stormwater contamination from soil disturbing activities. Since 2006, Chinook Ventures operated the site as a bulk materials handling facility without first obtaining a NPDES permit to cover these industrial activities.[3] Ecology's files on Chinook Ventures document numerous illicit activities that must be considered in the context of this CSWGP application. Of particular significance, Ecology has issued at least three enforcement orders against Chinook Ventures for violating multiple state environmental laws. The Department must assess whether Chinook Ventures' activities at the site could have caused soil contamination that Millennium's construction activities will expose to stormwater, the Longview Ditches, and the Columbia River.

Ecology's inspection reports and enforcement orders against Chinook Ventures counsel against issuing the CSWGP. In particular, Ecology's inspections identified multiple air, land, and water quality violations that range from storing dangerous wastes (spent potliner)[4] outdoors to rerouting stormwater outfalls to land application of unpermitted substances. It is highly probable that Chinook Ventures' unlawful activities contaminated the facility.

---

[3]Chinook Ventures' failure to obtain a NPDES permit and other Clean Water Act violations are the subject of a pending lawsuit, *Columbia Riverkeeper v. Chinook Ventures*, case no. 09-5707 (W.D. Wash). The facility currently operates under a NPDES permit issued in 1990 for an aluminum smelting facility. Ecology modified the permit in 1992 and 2002 to cover an aluminum smelting facility in curtailment. The Clean Water Act, 33 U.S.C. § 1342(b)(1)(B), authorizes delegated states to issue NPDES permits "for fixed terms not exceeding five years."

[4]The former aluminum smelter "operated 876 pots to produce molten aluminum. Each pot consisted of a steel shell, electrical bus bar conductor, and an anode/ore storage superstructure. The pots were lined with a carbon material known as potliner. Potliner removed from pots is known as spent potliner ("SPL"). SPL is listed as a dangerous waste (K088) and subject to the Washington State Dangerous Waste (DW) Regulations (Chapter 173-303)." Ecology Order No. 6422.

Ecology's enforcement orders against Chinook Ventures make a compelling case for requiring an individual NPDES application. Ecology's Notice of Penalty No. 6421 (Mar. 9, 2009) states:

> Over the last several years, Ecology has received numerous complaints about the Chinook Ventures facility. During site visits (April 5, 2006, December 28, 2006, April 11, 2007, and October 17, 2007), Ecology discovered that Chinook had begun operating a flat storage and transport facility that received petroleum coke, coke, coal, cement, alumina, fly ash, and furnace slag by marine vessels and rail, and transports the materials off-site by rail, truck and ship.

Notice of Penalty No. 6421 at 1. The Order goes on to state:

> Ecology issued Air Order No. 2728 AQ05 in 2006 which allowed Chinook to operate equipment to size and crush SPL [spent potliner] and anode material in buildings with emission controls. The order required that all activities be conducted under controlled conditions as a *temporary source* for a period of not more than one year.
>
> Ecology conducted two unannounced site inspections in 2007 (April 11 and October 17). During these inspections, Ecology observed Chinook operating anode sizing and crushing equipment in buildings that had no emissions controls. Despite discussions with Chinook management and staff following the April 2007 inspection and in the intervening months, in October 2007, Ecology found Chinook sizing and crushing anodes again without air pollution controls. They have also continued this operation beyond the one-year deadline for a temporary source.
>
> In addition to the air quality violations noted during these inspections, Ecology also observed a number of water quality violations. Inspectors found Chinook storing waste materials outside without adequate pollution prevention controls, materials being spilled during loading and unloading operations and begin tracked through the site, and poor housekeeping on-site and at the pier, all of which were potentially impacting stormwater runoff and water quality in the Columbia River.

Notice of Penalty No. 6421 at 1 – 2 (emphasis in original).

The Department of Ecology's 2009 fines failed to stop illegal pollution at Chinook Ventures. Ecology's 2010 inspections chronicle additional, unlawful water quality and land management activities. On October 8, 2010, Ecology issued Order No. 8027 for violations of Chinook Ventures' Dangerous Waste Management Facility Post-Closure Plan (WAD 057068561) and National Pollutant Discharge Elimination System (NPDES) Permit (No. WA 00000806). According to the Order, in March 2010 Chinook Ventures' new environmental manager "revealed that stormwater from the drainage ditch system near the Black Mud Pond [a

dangerous waste management facility] and Industrial Landfill was once again being routed to the plants' NPDES Outfall 005."

In addition to Ecology's inspections, a petroleum coke spill in February 2010 prompted a private investigation and report by Marine Systems, Inc. The report states:

> Much of the smelter and associated infrastructure has been cannibalized by Chinook partly as agreed for the cleanup of the site, but also for scrapping to raise cash, and for re-use and conversion into components of the new long multi-leg conveyor system, reverser trip and ship loader for the petcoke business built without permits, engineering or inspection . . . Evidence abounds of sloppy and un-permitted handling of wastes, poor and unsafe working conditions, and conversion of the former engineered and permitted waste treatment system into an un-permitted and un-maintained waste *distribution* system that has intensified rather than reduced the complexity of the cleanup and remediation the site will require to return to safe and beneficial use . . . .

Marine Systems Inc. Report (Apr. 22, 2010) at 3. Together, Ecology's inspections and private investigations demonstrate that soil disturbing activities at this facility warrant the review and oversight that a CSWGP does not afford.

By orders of magnitude, the CSWGP application is far less rigorous than an individual NPDES application. Typically, the rationale for this less rigorous, general permit approach is the intermittent nature of the stormwater discharges and the common BMPs that construction sites can use to reduce erosion, turbidity, and total suspended solids. The typical rationale does not hold up for the Chinook Ventures property. Given Chinook Ventures' atypical and illegal management of dangerous wastes and other materials, the more rigorous individual permit application process will provide critical information on soil contamination and ensure that water quality is protected.

II. Ecology Should Assume Lead Agency Status and Prepare an Environmental Impact Statement for the 5.7 Million ton/year Coal Export Terminal.

Based on the nature, size, and environmental impacts associated with coal transport and export, we have urged from the outset that Ecology take lead-agency status or, at a minimum, that Cowlitz County require a comprehensive Environmental Impact Statement. On November 23, 2010 Cowlitz County issued Millennium's Substantial Shoreline Development Permit and associated Modified Mitigated Determination of Nonsignificance ("MMDNS"). The MMDNS fails to account for the coal export terminal's direct impacts on human health and the environment, particularly along the rail transport route outside of Cowlitz County, and the indirect impacts on climate change. By this reference, we incorporates pubic comments submitted to Cowlitz County by Earthjustice on behalf of Climate Solutions, Columbia Riverkeeper, Sierra Club, and the Washington Environmental Council. *See* Ex. A, B, C, D, and E. We urge Ecology to consider these comments on Millennium's SEPA compliance.

Based on Cowlitz County's inadequate SEPA review, Ecology should exercise its authority under WAC 197-11-600(3)(a) and assume lead agency status. Specifically, WAC 197-11-600(3)(a), "When to use existing environmental documents," states:

> Any agency acting on the same proposal shall use an environmental document unchanged, except in the following cases:
>
> (a) For DNSs, an agency with jurisdiction is *dissatisfied with the DNS*, in which case it *may assume lead agency status* (WAC 197-11-340(2)(e) and 197-11-948).

(emphasis added). Given the state-wide significance of climate change and coal dust emissions, Ecology should assume lead agency status and require that Millennium prepare an Environmental Impact Statement. For perspective, five million tons of coal per year will generate approximately 10 million tons of carbon dioxide annually—roughly equivalent to the emissions of two million U.S. cars, or about 10% of Washington State's total carbon emissions. It is about the same total amount of coal that the TransAlta coal-fired power plant in Centralia, Washington uses every year. Cowlitz County's wholesale failure to account for climate change is an end-run around SEPA's requirements and contrary to Governor Gregoire's Executive Order on climate change.

Millennium's coal export terminal requires, at minimum, a one mile-long train of open coal cars traveling across Washington and along the Columbia River every day. Cowlitz County attempted to address the significant and widespread impacts of coal dust emissions from the coal transport and terminal operations. We urge Ecology to carefully assess the adequacy of these MMDNS conditions. At first blush, the MMDNS appears to mitigate coal dust emissions with conditions that address rail car loading techniques and coal dust monitoring along the transport route. Upon further scrutiny, Ecology should reject the MMDNS because the conditions: (1) are highly discretionary; (2) do not require proven methods that can significantly reduce coal dust emissions (*i.e.*, covered rail cars, mandatory use of dust suppressants); and (3) hinge on "enforcement" by a party with a serious financial stake in west coast coal export: Burlington Northern Santa Fe ("BNSF"). For the reasons explained in Earthjustice's November 15, 2010 letter, Ecology should assume lead agency status and require an EIS before proceeding with any permits for Millennium's facility.

III. Millennium's CSWGP Application was Premature because Cowlitz County's SEPA Review was not "Final" at the Time Millennium Submitted the Application.

Aside from the reasons explained above, Ecology cannot issue Millennium's CSWGP because of procedural errors in the application. First, Millennium's Notice of Intent ("NOI") was incomplete at the time it applied for the CSWGP. Section VI of the NOI, "State Environmental Policy Act (SEPA)," states: "The Notice of Intent (NOI) is incomplete and cannot

be approved until the applicable SEPA requirements under Chapter 197-11 WAC are met." Millennium's October 22, 2010 NOI failed to meet the NOI SEPA requirements.

Specifically, Millennium's October 22nd application incorrectly stated that Cowlitz County had issued a "final" SEPA determination. In fact, on October 22nd, Cowlitz County's MDNS was not "final." *See* WAC 197-11-390(3) ("Regardless of any appeals, a DS or DNS issued by the responsible official may be considered final for purposes of other agencies' planning and decision making unless subsequently changed, reversed, or withdrawn."); WAC 197-11-340 (describing DNS process). The public comment period on Cowlitz County's preliminary SEPA determination was still pending when Millennium submitted the NOI. The preliminary nature of the MDNS determination was confirmed on November 9, 2010 when Cowlitz County issued a *Modified* Mitigated Determination of Nonsignificance ("MMDNS"). The MMDNS responded to public comments, added conditions, and modified proposed conditions. Under WAC 197-11-390(3), a DS or DNS is not considered "final" if it is subsequently "changed, reversed or withdrawn." In the case of Millennium's initial MDNS, Cowlitz County later changed and modified its preliminary finding. Thus, the Notice of Intent was incomplete at the time Millennium advertised the public notice and public comment deadlines. Ecology must require that Millennium submit a new, accurate NOI and publish a new public notice and associated public comment deadlines.

Second, contrary to its response in the CSWGP application, Millennium did not "own or control" the Chinook Ventures site on the date it submitted the application. Moreover, were Ecology to issue Millennium permit coverage, it is entirely unclear if Millennium would meet the CSWGP definition of "owner" or "operator" today. *See* Millennium's CSWGP Application (Oct. 22, 2010). The Draft 2010 CSWGP defines as "operator" as:

> [A]ny party associated with a construction project meets either of the following two criteria:
>
> - The party has operational control over construction plans and specifications, including the ability to make modifications to those plans and specifications; or
> - The party has day-to-day operational control of those activities at a project that are necessary to ensure compliance with a SWPPP for the site or other permit conditions (e.g., they are authorized to direct workers at a site to carry out activities required by the SWPPP or comply with other permit conditions).

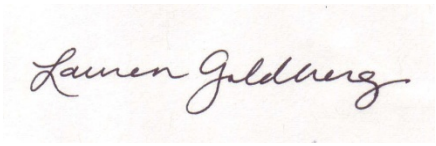
Draft 2010 CSWGP at 47; *see also* 2005 CSWGP at 42 (defining "operator"). According to Ecology's November 2010 website updates, Millennium had not acquired the Chinook Ventures' property on October 22, 2010, and a sale is still pending. Millennium's application and publicly available information do not support a finding of operational control or site ownership.

Based on these procedural errors alone, Ecology should deny Millennium's CSWGP application at this time.

IV. Conclusion.

For the reasons explained above and in SEPA comments to Cowlitz County, Columbia Riverkeeper, Climate Solutions, Sierra Club, and the Washington Environmental Council urge Ecology to deny Millennium's CSWGP application. We greatly appreciate Ecology's commitment to carefully reviewing new industrial projects such as the Millennium coal export terminal. Given the complexity of the issues raised in this comment, we are requesting a meeting with the Department to discuss these issues and, more generally, coal export terminals in Washington State. Please contact me at your earliest convenience to arrange a meeting with representatives from the coalition.

Sincerely,



Lauren Goldberg
Staff Attorney, Columbia Riverkeeper
lauren@columbiariverkeeper.org
541-965-0985
On behalf of Climate Solutions, Columbia Riverkeeper, Sierra Club, and Washington Environmental Council

cc: *(Letter via email only)*

Governor Chris Gregoire
Jay Manning, Chief of Staff
Governor's Office
(jay.manning@gov.wa.gov)

Keith Phillips
Governor's Office
(keith.phillips@gov.wa.gov)

Alan Bogner
Office of Regulatory Assistance
(alan.bogner@ora.wa.gov)

Josh Baldi
Department of Ecology
(jbal461@ecy.wa.gov)

Janice Adair
Washington Department of Ecology
(jada461@ecy.wa.gov)

Kim Wigfield
Washington Department of Ecology
(kim.wigfield@ecy.wa.gov)

Judy Schweiters
Washington Department of Ecology
(judith.schweiters@ecy.wa.gov)

Rogers Weed
Washington Department of Commerce, Director
(rogersw@cted.wa.gov)

Tony Usibelli
Washington Department of Commerce
(tonyu@cted.wa.gov)

Phil Anderson, Director
Washington Department of Fish and Wildlife
(director@dfw.wa.gov)

Dave Howe
Washington Department of Fish & Wildlife
(david.howe@dfw.wa.gov)

Steve West
Washington Department of Fish & Wildlife
(steve.west@dfw.wa.gov)

Brian Larsen
Washington Department of Natural Resources
(brian.larsen@dnr.wa.gov)

Denise Wilhem
Washington Department of Natural Resources
(denise.wilhelm@dnr.wa.gov)

Bridget Moran
Washington Department of Natural Resources
(bridget.moran@dnr.wa.gov)

Edie Gilliss
Washington Department of Natural Resources
(edie.gilliss@dnr.wa.gov)

Heath Packard
Washington Department of Natural Resources
(heath.packard@dnr.wa.gov)

Siri Nelson
U.S. Army Corps of Engineers
(siri.c.nelson@usace.army.mil)

David Marten
U.S. Army Corps of Engineers
(david.j.martin@usace.army.mil)

Danette Guy
U.S. Army Corps of Engineers
(danette.l.guy@usace.army.mil)

Dan Guy
National Marine Fisheries Service
(dan.guy@noaa.gov)

Steve Landino
National Marine Fisheries Service
(steven.landino@noaa.gov)

Mike Wojtowicz, Director
Department of Building & Planning
Cowlitz County
(wojtowiczm@co.cowlitz.wa.us)

Chris Bischoff
Cowlitz Co. Environmental Health Manager

(bischoffc@co.cowlitz.wa.us)

Air Pollution and Greenhouse Gas Emissions from Ships

James E. McCarthy
Specialist in Environmental Policy

December 23, 2009

Congressional Research Service
7-5700
www.crs.gov
RL34548

CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

This report provides information regarding pollution from ships and port facilities; discusses some of the measures being implemented and considered by local, state, and federal regulatory agencies; discusses the efforts to strengthen Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL); and describes legislation in Congress to control emissions from ships, as well as efforts in Congress to address the applicability of proposed EPA regulations to ships on the Great Lakes.

As pollution from cars, trucks, and land-based stationary sources has been more tightly controlled over the last 40 years, the contribution of ships and port operations to air pollution in port cities has become more important. In the same period, foreign trade has grown dramatically; thus, pollution from shipping and port operations is growing as a percentage of total emissions. In many cities, ships are now among the largest sources of air pollution. As Congress and the Administration turn their attention to climate change, there is also a growing recognition that marine vessels are an important source of greenhouse gas (GHG) emissions.

Controlling these sources of both conventional and greenhouse gas pollutants is complicated by the fact that most ocean-going ships are not registered in the United States and may not even purchase the fuel they are using here. Thus, controlling such pollution would seem to lend itself to an international approach. Such efforts have been slow to yield results: in 1997, the United States and most countries signed an international agreement known as MARPOL Annex VI, setting extremely modest controls on air pollution from ships, but the agreement did not enter into force until 2005, and the United States did not enact legislation to implement it until July 21, 2008 (P.L. 110-280). Negotiations to strengthen Annex VI accelerated in 2008, however, and amendments that will strengthen its provisions have received preliminary approval. Discussions regarding GHG emissions have also begun, although without results to date.

While awaiting congressional action and international agreement, the Environmental Protection Agency (EPA), port cities, and states have begun to act on their own. This report discusses a number of these efforts, including EPA measures that will require cleaner fuels and will greatly strengthen emission standards, and measures being implemented in California to reduce pollution from ships and ports.

In the current Congress, greenhouse gas emissions from ships are addressed in H.R. 2454, the Waxman-Markey climate change bill. As passed by the House, the bill would direct EPA to establish emission standards for nonroad vehicles and engines (a category that includes ships), by December 31, 2012.

In other action, Congress added a provision to the FY2010 EPA appropriation (P.L. 111-88) that prohibits FY2010 funds being used to implement cleaner fuel requirements as they apply to Great Lakes ships. Accompanying report language directs EPA to develop provisions to establish waivers of the low sulfur fuel requirements for Great Lakes ships if the fuel is not available or in cases of serious economic hardship.

Contents

Introduction 1
MARPOL Annex VI 3
Provisions of Annex VI 3
Implementing Legislation (P.L. 110-280) 4
Amendments to Annex VI 4
EPA Regulations for Ocean-Going Ships 5
Category 3 Engines and Fuels 5
Reaction to the New Standards 7
Costs and Benefits of the Proposed Standards 8
Great Lakes Ships 8
Category 1 and 2 Engines 11
California Emission Reduction Measures 11
Low Sulfur Fuels 12
Emission Controls 12
Alternative Power 13
Grants 13
Greenhouse Gases 15
International Efforts to Address GHGs 15
Shipping vs. Other Transport Modes 16
Measures to Reduce Ships' GHG Emissions 16
Conclusion 17

Figures

Figure 1. U.S. Ports and Nonattainment Areas 2
Figure 2. Area Proposed for Emission Control Area (ECA) Designation 7
Figure 3. Potential Ambient Reductions of Fine Particulates ($PM_{2.5}$) from Proposed U.S. ECA, in 2020 9

Contacts

Author Contact Information 18

Introduction

Over the last 40 years, air quality in the United States has improved substantially. Since the passage of the Clean Air Act in 1970, annual emissions of the six most widespread ("criteria") air pollutants have declined 180 million tons (59%), despite major increases in population, motor vehicle miles traveled, and economic activity.[1]

Emissions from shipping are a major exception to these trends. Although emission controls have reduced pollution from new cars and trucks by more than 90%, most ocean-going ships operate without any pollution controls at all. New and remanufactured engines on tug boats, ferries, and other smaller ships are subject to emission controls beginning in 2008 and 2009, but most existing engines in vessels of these types remain uncontrolled.

Pollution from ships is also affected by the fuel they use. Marine vessels other than oceangoing ships have been required to use cleaner fuels, but ocean-going ships generally use bunker fuel, a fuel that contains a high level of contaminants: the average fuel used by oceangoing ships contains 27,000 parts per million (ppm) sulfur, for example—almost 2,000 times as much as would be allowed in trucks operating on U.S. roads.

In the Los Angeles-Long Beach area—which is both the nation's busiest port[2] and the nation's most polluted area[3]—the problem is particularly acute. According to the South Coast [L.A.-Long Beach] Air Quality Management District (AQMD):

- Oceangoing vessels are among the largest sources of nitrogen oxides (NOx) in the area, emitting more NOx than all power plants and refineries in the South Coast air basin combined. NOx reacts with volatile organic compounds in the atmosphere to produce ozone/smog.
- 70% of the area's emissions of sulfur dioxide (SO_2) come from ships. These emissions need to be cut by over 90%, according to the AQMD, if the area is to attain the national air quality standard for particulates by the 2014 deadline.
- Particulates from marine vessels also create significant cancer risks; more than 700 premature deaths are caused in the Los Angeles area annually by these emissions, according to the AQMD.[4]

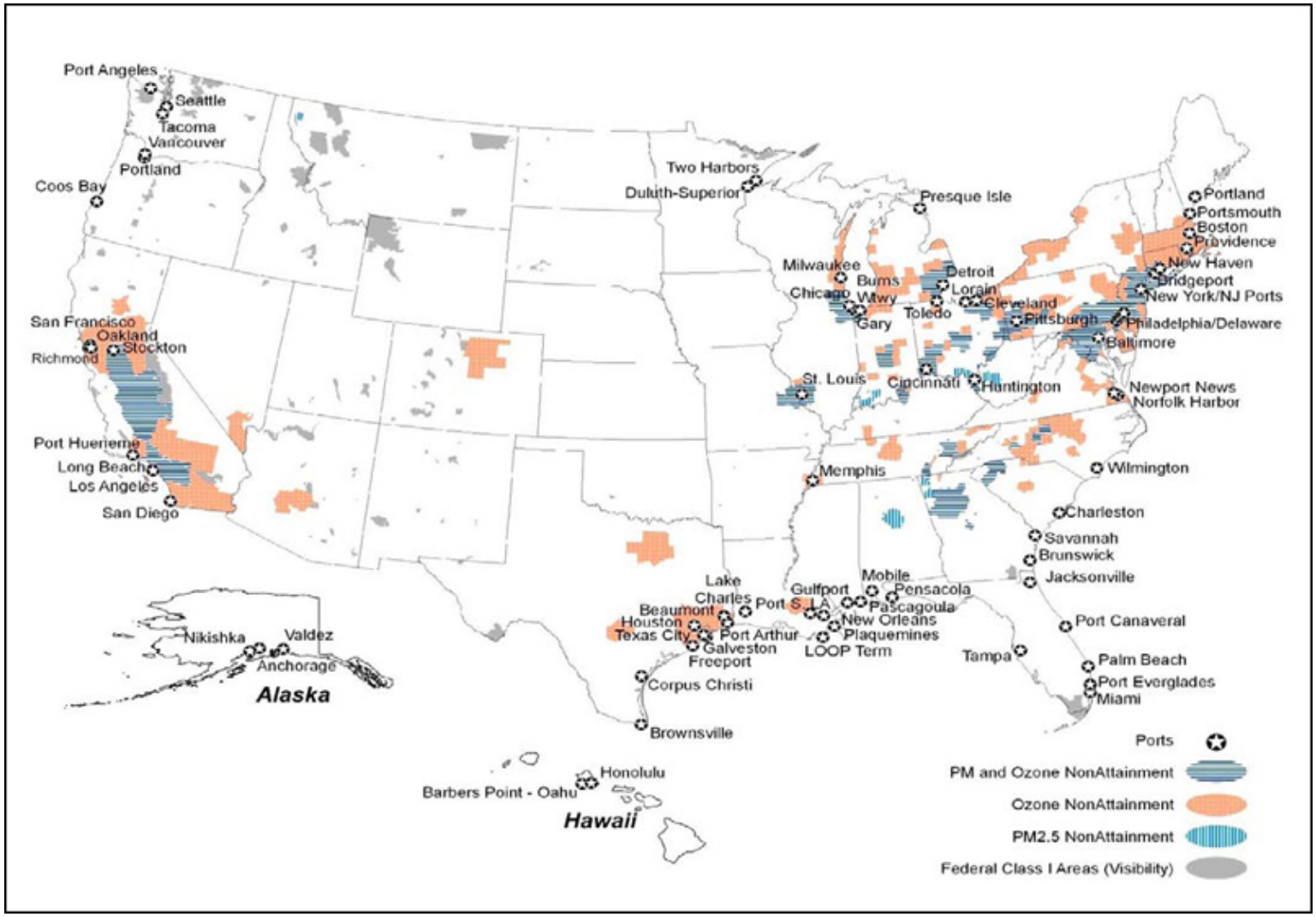
[1] See U.S. EPA, "Air Emissions Summary Through 2005," at http://www.epa.gov/air/airtrends/2006/emissions_summary_2005.html, updated with data from 2008 in U.S. EPA, "Air Quality Trends," at http://www.epa.gov/airtrends/aqtrends.html#comparison. The six criteria pollutants are ozone, particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead.

[2] According to the *Wall Street Journal*, Los Angeles and Long Beach ranked number 1 and number 2 in the value of cargo handled, with a combined total exceeding $248.5 billion in 2003-2004. The port of New York and New Jersey ranked third with $132.4 billion. See "The Busiest U.S. Ports," March 9, 2006, at http://americanfuture.net/?p=1447.

[3] The Los Angeles South Coast Air Basin is the only area that EPA considers to be a "Severe 17" nonattainment area for ozone. The area also has the highest readings in the country for fine particulates ($PM_{2.5}$), and is among only 8 areas classified as "Serious" nonattainment areas for larger particles (PM_{10}). See U.S. EPA, "Green Book," at http://www.epa.gov/oar/oaqps/greenbk/index.html.

[4] See testimony of Barry R. Wallerstein, Executive Officer, South Coast Air Quality Management District, at "Legislative Hearing on the Marine Vessel Emissions Reduction Act of 2007, S. 1499," U.S. Senate, Committee on Environment and Public Works, February 14, 2008, p. 1.

Figure 1. U.S. Ports and Nonattainment Areas



Source: U.S. EPA, March 2009. Nonattainment areas are areas are areas where concentrations of pollution exceed National Ambient Air Quality Standards. Ozone and $PM_{2.5}$ are the pollutants that most commonly exceed the standards. $PM_{2.5}$ refers to particulate matter with a diameter less than or equal to 2.5 micrometers, often referred to as "fine particles."

While the Los Angeles-Long Beach area may be the most extreme example, the problem is not limited to L.A. or to California. According to the Environmental Protection Agency (EPA), more than 40 U.S. ports nationwide are located in "nonattainment" areas[5] for ozone, fine particulates, or both (**Figure 1**).[6] In addition, according to EPA, "... the problem is not limited to port areas alone. Santa Barbara County, which has no commercial ports, estimates that by 2020, 67 percent of its NOx inventory will come from shipping traffic transiting the California coast.... "[7]

Oceangoing ships are perhaps the largest source of port emissions, but they are not the only source. Ports make use of tug boats to guide ships entering and leaving the harbor. Ports make connections to land-based transportation networks, such as railroads, and they generally operate large truck terminals. Ships at rest in the port need a source of power, which often comes from running auxiliary engines. And, in many cases, a harbor is served by substantial local boat or barge traffic, sometimes including ferry service. Thus, addressing the sources of pollution in a port may require a multi-faceted approach.

MARPOL Annex VI

Pollution from ships (not only air pollution, but pollution of all kinds) is governed by the International Convention for the Prevention of Pollution from Ships, first negotiated through the International Maritime Organization (IMO) in 1973. The Convention, known as MARPOL (for "MARine POLlution") 73/78 (the dates referring to the 1973 Convention and its 1978 amendments), applies to all ships of the flag states that have ratified it. About 150 countries, representing over 98.7% of world shipping tonnage, have done so. The Convention also applies to ships of non-signatory states while they are operating in waters under the jurisdiction of parties to MARPOL. Six annexes to MARPOL 73/78 cover various sources of pollution from ships (oil, noxious liquids, sewage, garbage, etc.) and provide an overarching framework for implementation.

Provisions of Annex VI

Annex VI of the Convention, which was adopted in 1997 but did not enter into force until 2005, addresses the Prevention of Air Pollution from Ships. In its 1997 form, the annex represented a small first step toward controlling such pollution, particularly if one compares it to pollution controls that the United States and other developed countries impose on land-based sources. Annex VI:

- limits the sulfur content of the fuel used in oceangoing ships (bunker fuel) to 4.5% (45,000 parts per million (ppm)). By comparison, highway diesel fuel in the United States is limited to 15 ppm;

[5] That is, areas where air quality is worse than the health-based standard for ozone, particulates, or both.

[6] Testimony of Bryan Wood-Thomas, U.S. EPA, Office of Transportation and Air Quality, at "Legislative Hearing on the Marine Vessel Emissions Reduction Act of 2007, S. 1499," U.S. Senate, Committee on Environment and Public Works, February 14, 2008, p. 2.

[7] Ibid.

- allows special sulfur oxide (SOx) Emission Control Areas (currently the Baltic Sea, the North Sea, and the English Channel), where the sulfur content of fuel is limited to 1.5% (15,000 ppm) or SOx emissions are limited;
- limits NOx emissions from new engines and engines that have undergone major conversions to a range of 9.8-17.0 grams per kilowatt-hour (g/kwh), depending on the rated engine speed. By comparison, power plants in the eastern United States are limited to 0.45-0.73 g/kwh;
- allows the regulation of emissions of volatile organic compounds (VOCs) from tankers by parties to Annex VI in their ports and terminals;
- prohibits emissions of ozone-depleting substances;
- prohibits the incineration on ships of polychlorinated biphenyls (PCBs, a class of toxic chemicals widely used in electrical transformers until the 1970s). In the United States, PCB production and use were banned in 1976, and disposal has been strictly regulated since then; and
- prohibits the incineration of garbage containing more than traces of heavy metals and of refined petroleum products containing halogen compounds.

Implementing Legislation (P.L. 110-280)

- The United States is a party to MARPOL 73/78 and most of its annexes, but did not enact legislation to implement Annex VI until the summer of 2008. The Senate gave its consent to ratification of Annex VI on April 7, 2006,[8] but Congress needed to enact implementing legislation before the United States could submit the instrument of ratification. The House passed H.R. 802 to implement the annex on March 26, 2007. The Senate passed the bill, with an amendment, June 26, 2008, and the House agreed to the Senate amendment July 8, 2008. The President signed the bill July 21, 2008 (P.L. 110-280).

The Annex VI standards apply to: any oceangoing vessel that is registered in the United States; ships of any registry in ports, shipyards, terminals, or the internal waters of the United States; ships of any registry bound for or departing from the United States, while they are located in the navigable waters of the United States or designated emission control areas; and ships bearing the flag of any country that has ratified Annex VI traveling through U.S. waters or designated emission control areas, even if they are not bound for or departing from a U.S. destination. To the extent consistent with international law, the Annex also applies to any other ship in the U.S. exclusive economic zone.

Amendments to Annex VI

The United States has participated in negotiations to strengthen Annex VI, and more stringent limits on both fuels and emissions were approved by the IMO, October 10, 2008:

[8] The Senate consented to ratification through Treaty Document 108-7.

- The new limits cut the allowable sulfur content of bunker fuel to 3.5% (35,000 ppm) starting January 1, 2012, with a further drop to 0.5% (5,000 ppm) on January 1, 2020. This provision will have little effect prior to 2020, since bunker fuel currently averages 27,000 ppm sulfur, substantially cleaner than the 2012 requirements.
- New limits will also apply in Sulfur Emission Control Areas—currently the Baltic Sea, North Sea, and English Channel, but potentially including other areas. Sulfur content in those areas, currently capped at 1.5% (15,000 ppm), will be capped at 1.0% (10,000 ppm) effective July 1, 2010, and 0.10% (1,000 ppm) effective January 1, 2015.
- IMO also agreed to reductions in nitrogen oxide (NOx) emissions from marine engines, with the new standards to be phased in. For engines installed on ships constructed after January 1, 2011, but before 2016, NOx limits would be reduced about 20% to a range of 7.7 to 14.4 grams per kilowatt-hour, depending on the rated engine speed. For engines installed on ships constructed after January 1, 2016, the limits would be reduced about 80%, to a range of 2.0 to 3.4 g/kWh while ships are operating in designated emission control areas. Outside emission control areas, the prior limit (7.7 to 14.4 g/kWh) would apply.[9]

EPA Regulations for Ocean-Going Ships

Before Congress enacted the Annex VI implementing legislation in 2008, EPA had already promulgated regulations under the Clean Air Act that were as stringent as the 1997 Annex VI standards, and shipping companies were already generally meeting the standards. In addition, the agency has promulgated standards for smaller engines.

EPA groups ship engines in three categories. The largest of these engines—the main engines on oceangoing ships—are diesel engines with a per-cylinder displacement at or above 30 liters. These are referred to as "Category 3" or "C3" engines. Category 1 and 2 engines (those smaller than 7 liters per cylinder, and those from 7 to 30 liters per cylinder, respectively), are used in boats or smaller ships—tugs, ferries, some Great Lakes freighters, fishing boats, and recreational boats, for example.

Category 3 Engines and Fuels

EPA began addressing emissions from Category 3 engines about a decade ago, and two steps the agency took in 2009 will significantly strengthen its regulations. But it is important to bear three factors in mind, as one considers the potential impact of the new regulations. First, the new EPA emission standards will only apply to engines installed on vessels flagged or registered in the United States. In 2007, only 6.7% of the world's ocean-going ships (and only 1.2%, if measured by carrying capacity) were registered in the United States.[10] Thus, EPA's emission standards for

[9] "International Maritime Panel Sets Limits on Ships' Sulfur, Nitrogen Oxide Emissions," *Daily Environment Report*, October 14, 2008, p. A-6. For a copy of Annex VI as revised by the October 10, 2008 agreement, see the IMO website at http://www.imo.org/includes/blastDataOnly.asp/data_id%3D23760/176%2858%29.pdf.

[10] United Nations Conference on Trade and Development, *Review of Maritime Transport 2007*, p. 36, at http://www.unctad.org/en/docs/rmt2007_en.pdf.

C3 engines by themselves (i.e., apart from the similar Annex VI rules) will have little effect on the overall level of pollution from ocean-going ships. Second, when the more stringent requirements do take effect, they will apply only to new and remanufactured engines, so improvements resulting from the standards will be gradual. Third, EPA will be able to achieve more substantial emission reductions through standards for marine fuel. These will affect emissions from both new and existing engines, and from both U.S.- and foreign-flagged ships. The new C3 standards will require substantially cleaner fuel, a point to which we will return after describing the existing and proposed rules in more detail.

Current C3 engine standards were promulgated February 28, 2003, and went into effect in 2004.[11] These standards mirrored the relatively lenient requirements of Annex VI, adopted by the IMO in 1997. In October 1999, EPA also established a voluntary certification program so that engine manufacturers could show that their new engines were compliant with Annex VI. EPA believes that all marine Category 3 diesel engines sold in the United States since January 1, 2000, have met Annex VI requirements.

When the 2003 standards were promulgated, EPA set itself a deadline of April 2007 to promulgate stronger standards for C3 engines. EPA subsequently reset this deadline to December 2009: the Administrator signed new regulations December 18. Thus, 2009 has seen several developments that will strengthen emission standards for ships and expand the use of cleaner fuels. The new standards are in line with the Annex VI amendments that were negotiated in 2008. EPA has also proposed to add U.S. waters to those areas designated as Emission Control Areas under the annex. Specifically:

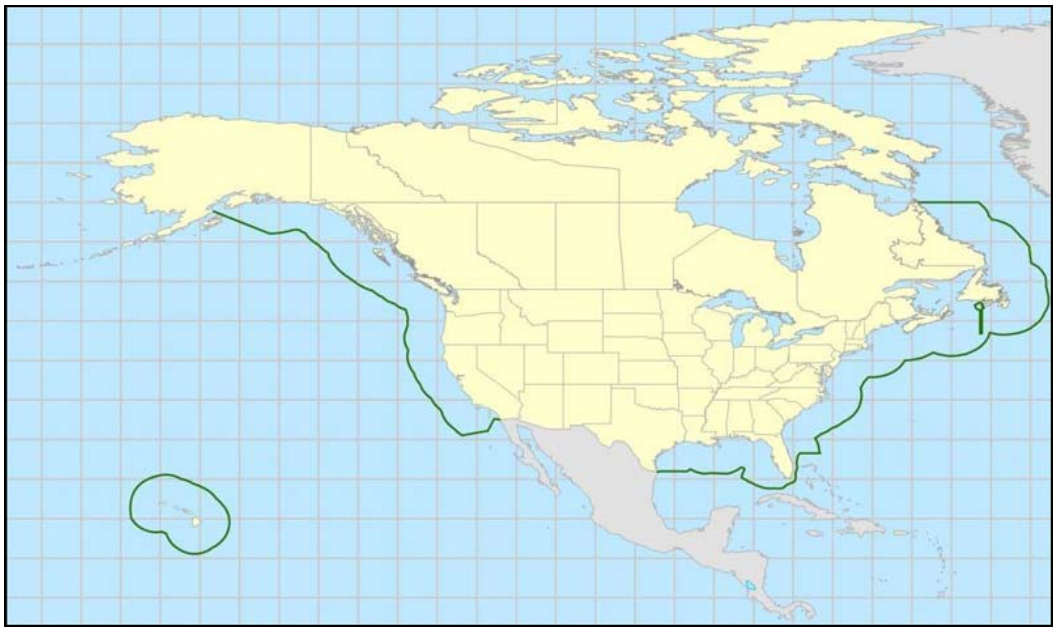
- On March 27, 2009, EPA proposed that the entire U.S. coastline except portions of Alaska be designated by the IMO as an Emission Control Area (ECA), subject to the lower sulfur limits in bunker fuel discussed above. As shown in **Figure 2**, the proposed ECA includes the entire coastline of the contiguous 48 states, Southeastern Alaska, and the main Hawaiian Islands, extending to a distance of 200 nautical miles from shore. EPA anticipates that this amendment will be adopted at the next IMO Marine Environment Protection Committee meeting (MEPC 60) which is scheduled for March 2010. Adoption of the ECA will set sulfur limits of 10,000 ppm as early as August 2012, and 1,000 ppm effective January 1, 2015.
- On July 1, 2009, EPA proposed regulations that will strengthen emission standards for new C3 marine engines and will implement the low sulfur fuel requirements that apply in ECAs starting in 2015. These regulations were finalized, with relatively minor changes on December 18, 2009.[12] New marine engines will be required to meet these standards in two phases: Tier 2, which would apply to new engines beginning in 2011, would require "more efficient use of current engine technologies, including engine timing, engine cooling, and advanced computer controls," resulting in a 15% to 25% reduction in NOx emissions, compared to Tier 1 standards; Tier 3, effective in 2016, would reduce

[11] 68 *Federal Register* 9746, February 28, 2003.

[12] The proposal appeared in the *Federal Register* August 28, 2009: "Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder," 74 *Federal Register* 44442. The final regulations had not yet appeared in the *Federal Register* as of this writing, but a pre-publication copy, as signed by the Administrator on December 18, can be found at http://www.epa.gov/otaq/oceanvessels.htm#regs.

NOx emissions from new engines 80% below current standards through the application of aftertreatment technology such as selective catalytic reduction (SCR), a technology now widely used at electric power plants.

Figure 2. Area Proposed for Emission Control Area (ECA) Designation



Source: U.S. EPA

Reaction to the New Standards

In general, the Category 3 engine standards and the ECA proposal have been supported by the shipping industry and by environmental groups.[13] The World Shipping Council (WSC), whose member companies carry over 90% of the United States' international containerized ocean cargo, in its comments on the C3 standards, stated, "... the WSC and its members fully support the proposal to codify and adopt these standards as proposed in the current rulemaking," although they went on to suggest a number of clarifications and technical improvements.[14] Regarding the ECA proposal, a spokesman for the Pacific Marine Shipping Association was quoted as saying, "We've been waiting for this a long time. We're pleased to see everything moving forward as planned."[15]

[13] See "Industry, Environmental Groups Offer Praise for EPA Proposal to Limit Ship Emissions," *Daily Environment Report*, August 5, 2009, p. A-5. Also see "U.S., Canada Propose Areas for Large Cuts in Emissions from Oceangoing Ships," *Daily Environment Report*, March 31, 2009, p. A-5.

[14] See "Comments of the World Shipping Council Submitted on September 28, 2009 to the U.S. Environmental Protection Agency in the Matter of Proposed Rule, Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder," Docket Number: EPA-HQ-OAR-2007-0121, at http://www.regulations.gov/search/Regs/home.html#docketDetail?R=EPA-HQ-OAR-2007-0121.

[15] T.L. Garrett, Vice President, Pacific Marine Shipping Association, as quoted in "U.S., Canada Propose Areas for Large Cuts in Emissions from Oceangoing Ships," *Daily Environment Report*, March 31, 2009, p. A-5.

The Clean Air Task Force, and 34 other environmental organizations stated, "EPA's proposed C3 Marine Engine rule is a substantial step in the right direction."[16] They would have liked to see the proposed emission standards strengthened to cover all new ships travelling in U.S. waters, no matter where they are registered, and would have liked stronger standards for NOx and particulate matter from the existing fleet of ships. Environmental groups also support the ECA/fuel sulfur proposal, although they would like to see it expanded to include Alaska's Arctic waters.

Costs and Benefits of the Proposed Standards

EPA estimates that the benefits of its new regulations for C3 engines and fuel will outweigh the costs by at least 30 to 1. The benefits include annually preventing between 12,000 and 31,000 premature deaths, 1,500,000 work days lost, and 9,600,000 minor restricted activity days, which the agency values at between $99 billion and $270 billion annually.[17] The reductions in pollution, shown in **Figure 3**, are greatest near the coasts, but more modest reductions would extend a substantial distance inland, according to EPA modeling.

The agency's estimated cost of the proposals is approximately $1.85 billion in 2020, increasing to $3.11 billion in 2030. Of the 2020 costs, nearly 89% are attributable to the use of lower-sulfur fuel in the proposed ECA. These costs are substantial, but they will be spread over such a huge volume of traded goods that they may be little noticed. According to the agency:

> These costs are expected to be completely passed on to the consumers of ocean transportation. The impacts of these costs on society are estimated to be minimal, resulting in a small increase in the goods transported. For example, EPA estimates it will result in an increase of about $0.01 for a pair of tennis shoes, and about $0.03 for a bushel of grain.[18]

Great Lakes Ships

Perhaps the most controversial aspect of the ECA and Category 3 rules was their proposed application to the large ships that ply the Great Lakes. The Great Lakes would be included in the proposed ECA and, therefore, ships operating on the lakes would be required to burn low sulfur fuels under the ECA proposal.

More than 100 U.S.- and Canadian-flagged cargo ships operate on the Great Lakes. These ships generally carry bulk cargoes, including iron ore, coal, limestone, agricultural products, and rock salt. The associations that represent the U.S. and Canadian ship owners estimate that they carry as much as 150 million tons of cargo annually.[19]

---

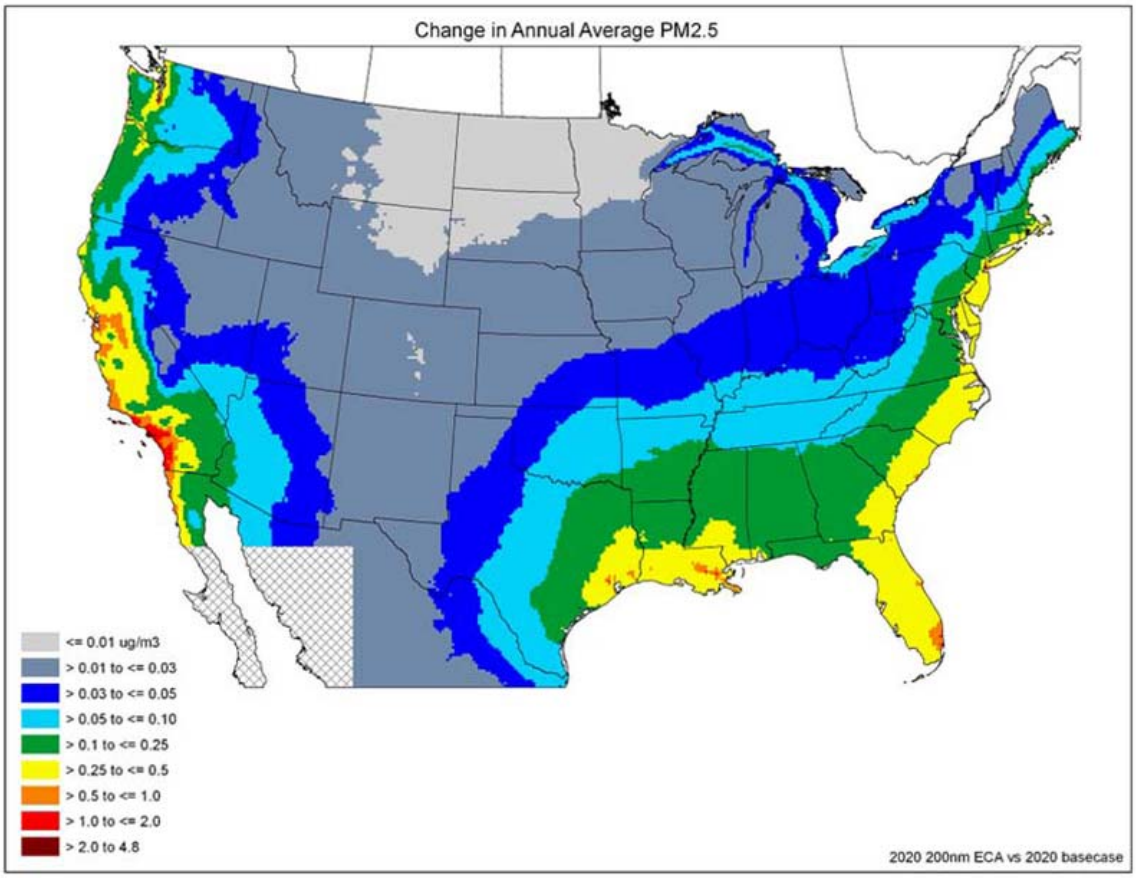
[16] Clean Air Task Force et al., "Comments on Proposed Large Marine Diesel Engine Rule," September 28, 2009, p. 30, Docket Number: EPA-HQ-OAR-2007-0121at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480a3df87.

[17] U.S. EPA, "Regulatory Announcement: EPA Proposal for Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," June 2009, at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09029.htm#4.

[18] U.S. EPA, Office of Transportation and Air Quality, "EPA Proposal for Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," Fact Sheet, p. 4, at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09029.pdf.

[19] The Lake Carriers' Association represents 18 American companies that operate 55 vessels on the Great Lakes. These (continued...)

Figure 3. Potential Ambient Reductions of Fine Particulates ($PM_{2.5}$) from Proposed U.S. ECA, in 2020



Source: U.S. EPA

Many of these ships are old. The Lake Carriers' Association (LCA) identified one U.S.-flagged vessel built in 1906 and 17 others built between 1929 and 1960 that are still in operation. Thirteen of these ships have powerplants that were designed to burn heavy residual fuel. According to the LCA,

> It is theoretically possible to switch the fuel supply system for the boilers to distillate fuel. However, it would require modifications including new fuel pumps, bypass of the fuel heating systems, new burners and burner tips, and possibly new air diffusers. A number of upgrades to the automation system would also have to have been done to ensure the proper air to fuel ratio and that the fuel cut off valves are sufficient to ensure that absolutely no diesel fuel enters the boiler in the off position.[20]

(...continued)

vessels can carry as much as 115 million tons of cargo in a given year, according to the association. The Canadian Shipowners Association represents the owners of 68 Canadian vessels with an annual volume of over 62 million metric tons in 2008, slightly more than half of which were carried between Canada and the United States. See their respective comments on the proposed Category 3 rule at http://www.regulations.gov, Docket Number: EPA-HQ-OAR-2007-0121.

[20] Comments of the Lake Carriers' Association on the proposed Category 3 rule, September 28, 2009, p. 4, at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480a3e004.

LCA estimated the cost of converting these 13 steamers' powerplants to run on diesel fuel or of converting them to self-unloading barges powered by tugs to be $20 million to $27 million each. Another 13 vessels were identified by LCA as facing significant impacts because of higher fuel prices, even though they are able to safely burn low sulfur distillate fuel.

The case made by the Lake Carriers Association and other industry commenters that older Great Lakes ships will face significant impacts appears not to have been considered by EPA when it proposed the ECA and C3 regulations. The Category 3 Regulatory Impact Analysis did indicate, however, that switching from residual fuel to lower sulfur distillate would increase costs borne by shipping companies $145 per tonne of fuel, or 44%.[21] For ocean-going ships, this cost increase is not as great as it might seem, since they operate in an ECA only a small percentage of the time and can burn dirtier fuel outside of ECAs. Great Lakes ships, however, operate in the proposed ECA 100% of the time, and thus would face a greater increase in costs.[22]

The Great Lakes shipping companies made a sufficiently persuasive case that Congress addressed their concerns. Section 442 of H.R. 2996, the FY2010 appropriations for Interior, Environment, and Related Agencies, signed by the President, October 30, 2009 (P.L. 111-88), provides that:

> None of the funds made available for the Environmental Protection Agency in this Act may be expended by the Administrator of the Environmental Protection Agency to issue a final rule that includes fuel sulfur standards applicable to existing steamships that operate exclusively within the Great Lakes, and their connecting and tributary waters.

This prohibition applies only to the period covered by the appropriation, i.e., FY2010. But language in the accompanying Conference Report (H.Rept. 111-316), states that EPA has received comments detailing significant negative economic impacts for carriers that operate Category 3 engine vessels exclusively within the Great Lakes, and the report adds:

> Because of these economic impacts, EPA should include waiver provisions similar to those in other EPA rules in the final rule—one to waive the 10,000 ppm sulfur standard for Great Lakes Category 3 diesel engine vessels that burn residual fuel if EPA determines that 10,000 ppm residual fuel is not available; and one to waive fuel requirements for an owner/operator of a Great Lakes Category 3 diesel engine vessel based upon a showing of serious economic hardship. It is important that EPA structure such a waiver provision similar to the other fuels rules, where parties can apply for and receive a waiver in sufficient time prior to the implementation of the requirements. Finally, EPA should perform a study and issue a report

[21] U.S. EPA, Office of Transportation and Air Quality, "Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines," June 2009, p. 5-58, available at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420d09002.pdf. The RIA found no substantial increase, however, for ships switching from distillate fuel to lower sulfur distillate fuel. For this group, the additional fuel cost was less than $1.00 per barrel, about 2 cents a gallon.

[22] How this cost increase would affect the shipping companies and their customers is a different question. The ships have a large cost advantage over other modes of transportation because they use significantly less fuel per ton-mile: according to the Army Corps of Engineers, Great Lakes carriers use 90% less fuel per ton-mile than trucks, and 66% less than trains. The Corps estimated that Great Lakes shipping annually saves its customers $3.6 billion in transportation costs compared to the next least expensive mode of transportation. Furthermore, the low sulfur fuel requirements for shipping companies are not happening in a vacuum. Both trucks and trains also face lower sulfur fuel requirements: in both cases, the sulfur limit will be 15 parts per million, as compared to the 1,000 ppm allowed on ships in the proposed ECA. Thus, although Great Lakes ships would undoubtedly incur costs to comply with the C3 and ECA proposals, higher costs would not necessarily eliminate the huge cost advantage they hold over competing modes of transportation. Rather, the impacts on them will depend on the degree to which they can pass on higher costs to their customers and the ability of those customers to do the same, a question that was not analyzed in EPA's RIA.

> within six months that evaluates the economic impact of the final rule on Great Lakes carriers.[23]

The final C3 rule provides the two Great Lakes waivers discussed in the report language.

Category 1 and 2 Engines

Category 1 and 2 engines (those smaller than 7 liters per cylinder, and those from 7 to 30 liters per cylinder, respectively), are used in boats or ships that operate in U.S. waters—tugs, ferries, smaller Great Lakes freighters, fishing boats, and recreational boats, for example—virtually all of which are registered in the United States. While smaller than Category 3 engines, these engines are still rather large: they generate at least 800 horsepower.

EPA is further along in regulating the emissions of these categories, as compared to Category 3. Regulations that will reduce emissions of NOx from new or remanufactured engines by 24% and emissions of particulates by 12% when fully implemented, were promulgated in 1999 and began taking effect between 2004 and 2007. More stringent standards were promulgated May 6, 2008, and will take effect between now and 2014.[24] The final 2014 standards will require ultra low sulfur diesel fuel (15 ppm sulfur) and high efficiency catalytic emission controls capable of reducing particulate matter emissions by 90% and NOx emissions by 80%, along with "sizeable reductions" of hydrocarbon, carbon monoxide, and air toxic emissions, according to EPA.[25]

As with the new Category 3 regulations, EPA estimates that benefits of the May 2008 rule will substantially exceed the costs of compliance – in this case, by a figure of at least 9 to 1. The principal benefits that the agency estimated are health benefits: a reduction of between 1,150 and 1,400 premature deaths, 120,000 work days lost, and approximately 1,000,000 minor restricted-activity days annually. The agency estimates that these benefits will be worth between $8.4 billion and $11 billion in 2030, whereas the annual social costs will be approximately $740 million in that year. The impact of these costs on society is expected to be manageable, with the price of marine transportation services estimated to increase by about 1.1%.[26]

California Emission Reduction Measures

California, being more adversely affected than most other areas, has also played a leadership role in identifying and implementing emission reduction measures applicable to shipping. The state has focused on port activities, in addition to fuel and emission standards for marine vessels. California's measures fall into four categories: (1) requiring the use of lower sulfur fuel; (2) requiring emission controls on harbor vessels and shore-side equipment; (3) providing alternative

[23] U.S. Congress, House, "Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010," Conference Report to Accompany H.R. 2996, October 28, 2009, pp. 109-110.

[24] 73 *Federal Register* 25097, May 6, 2008.

[25] For information, see U.S. EPA, Office of Transportation and Air Quality, "Diesel Boats and Ships," at http://www.epa.gov/oms/marine.htm.

[26] For additional information, see the EPA Regulatory Impact Analysis at http://www.epa.gov/otaq/regs/nonroad/420r08001a.pdf.

(electric) power to ships while they are docked at marine terminals; and (4) providing grants for the re-powering of harbor craft and short-haul trucks with cleaner engines.

Low Sulfur Fuels

The California Air Resources Board (CARB), at a July 24, 2008, meeting, approved regulations that required both U.S.- and foreign-flagged vessels sailing within 24 miles of its coast to use low sulfur fuels in both main and auxiliary engines beginning July 1, 2009. Compliant fuels are marine diesel oil with 5,000 ppm or less sulfur or marine gas oil with 15,000 ppm or less sulfur. In January 2012, sulfur in both types of fuel will be limited to 1,000 ppm. The rules replace low sulfur fuel requirements that the state implemented in 2007, but which were overturned by the U.S. Court of Appeals for the Ninth Circuit in February 2008.[27] The original rules would have set a 1,000 ppm limit two years earlier, in 2010.

Emission Controls

California has, in general, led the nation in imposing more stringent requirements on diesel engines. In addition, the ports of Los Angeles and Long Beach have developed procedures to require that trucks serving the ports will be replaced by newer, less-emitting models. According to a description of the ports' plan:

> ... all pre-1989 trucks will be barred from entering the ports' terminals beginning Oct. 1 [2008]. Effective Jan. 1, 2010, all 1989-1993 trucks and any 1994-2003 trucks without certified pollution control equipment will be banned. By Jan. 1, 2012, all trucks entering the port must meet the 2007 federal standard for heavy-duty diesel trucks....
>
> A $35 gate fee for each 20-foot container unit that passes through the port will generate funds to help underwrite subsidies to upgrade and replace trucks.[28]

The Port of Los Angeles estimates that truck emissions have been reduced about 70% since October 1, 2008, as a result of these requirements.[29]

In addition, CARB has adopted regulations for harbor craft, including ferries, tugboats, and tow boats, which will require the replacement of unregulated engines beginning in 2009, and will

[27] Pacific Merchant Marine Ass'n v. Goldstene, 517 F.3d 1108 (9th Cir. 2008). The court held that the state's Marine Vessel Rules were preempted by the federal Clean Air Act because the regulations set emission standards for marine engines without California having received a waiver from EPA to do so. California has since asked EPA for a waiver to enforce the original rules, in addition to developing the rules applying only to fuels. If the waiver is granted, the original (2007) requirements would be enforced. See "California Air Board Seeks Federal Waiver to Enforce Ship Auxiliary Engine Rules," *Daily Environment Report*, May 13, 2008, p. A-1. See also, CARB, "Advisory on Plans to Implement a Proposed ARB Regulation on Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels," October 2008, at http://www.arb.ca.gov/ports/marinevess/documents/advisory1008.pdf.

[28] "Los Angeles Harbor Commission Approves Program to Replace Older Diesel Trucks," *Daily Environment Report*, March 24, 2008, p. A-9.

[29] "January 1, 2010 Truck Restrictions Will Bring More Clean Trucks to Port of Los Angeles, Continue to Reduce Harmful Air Emissions," Port of Los Angeles News Release, December 4, 2009, at http://www.portoflosangeles.org/newsroom/2009_releases/news_120409_ctp_truck_ban.asp.

accelerate the adoption of EPA's Category 1 and Category 2 marine engine pollution controls. These rules became effective November 19, 2008.[30]

Alternative Power

In June 2004, the Port of Los Angeles opened the world's first Alternative Maritime Power (AMP) terminal for container ships, where cargo ships can plug in to power instead of operating auxiliary engines to generate electricity while at berth. The electrification project was the result of a lawsuit brought by the Natural Resources Defense Council and other groups, who sued the city claiming it failed to fully weigh air quality and other environmental impacts of a new container terminal. As a result of the suit, a state appeals court halted work on the terminal in October 2002, and Los Angeles subsequently agreed to electrify the terminal to cut diesel emissions while ships are at docks, among other measures.[31] A second terminal was outfitted with AMP capability in 2005. To encourage shippers to use the AMP facilities, in December 2004, the Los Angeles Board of Harbor Commissioners passed a policy resolution to help each existing Port customer underwrite the cost of building or retrofitting their first container or cruise ship to run on electrical power when docked, a cost estimated at $320,000-$830,000 per vessel.[32] Cruise ship terminals in San Francisco and Seattle are also implementing AMP, and CARB obtained final approval of regulations to require the use of AMP at the state's six largest ports, in December 2008.[33]

Grants

CARB, the Ports of Los Angeles and Long Beach, and the South Coast Air Quality Management District also intend to provide substantial amounts of financial support for the replacement of older, high-emitting engines and the conversion to lower emitting power sources. CARB awarded $247 million in FY2007-FY2008 funds for "goods movement emission reduction" projects (about $137 million of which was designated for ports); another $250 million was appropriated in FY2008-FY2009, and a third cycle of $250 million was appropriated in the FY2009-FY2010 state budget. According to CARB, most requests for the funds came from trucking companies, which would replace older engines or trucks with new models that reduce emissions as much as 90%.[34]

---

[30] Information on these regulations can be found at http://www.arb.ca.gov/regact/2007/chc07/chc07.htm.

[31] Natural Resources Defense Council v. City of Los Angeles, 126 Cal. Rptr. 2d 615 (Cal. App. 2002).

[32] See Port of Los Angeles, "Alternative Marine Power," at http://www.portoflosangeles.org/environment/alt_maritime_power.asp. Also see "Alternative Maritime Power "Off and Running," presented by Eric Caris, at http://www.ffca2006.com/documents/presentations/marine/Eric%20Caris.pdf.

[33] See California Air Resources Board, "Rulemaking to Consider Adoption of Proposed Regulations to Reduce Emissions from Diesel Auxiliary Engines on Ocean-Going Vessels While at Berth at a California Port," at http://www.arb.ca.gov/regact/2007/shorepwr07/shorepwr07.htm. The December 2008 regulation will require container vessels, passenger vessels, and reefers (refrigerated ships for perishable cargo) to reduce on-board power generation 50% by 2014, 70% by 2017, and 80% by 2020. Tankers, vehicle carriers, and bulk and general cargo ships are not affected by the regulation.

[34] See CARB, "Emissions Reduction Plan for Ports and Goods Movement in California: *Update on Implementation*," Staff Presentation, Air Resources Board Meeting , Oakland, CA, April 24, 2008 at ftp://ftp.arb.ca.gov/carbis/board/books/2008/042408/08-4-7pres.pdf.

In February 2009, CARB noted that state funding for bond programs had been suspended, pending "effective resolution of the current fiscal year budget crisis and a restoration of the state's ability to access the bond market." This affected FY2007-FY2008 funds awarded to local agencies under the Goods Movement Program, as well as the FY2008-FY2009 funds that had not yet been awarded.[35] Some funding has since been freed up, but a Department of Finance directive prohibited CARB from making allocations for the second and third installments ($250 million each) appropriated for this program.

In addition to the CARB funding, the ports of Los Angeles and Long Beach, as noted earlier, will provide subsidies for truck and engine replacement from a fund generated by a $35 to $70 per container fee. The grants will provide $20,000 for the cost of each truck compliant with EPA's 2007 emission standards used by port concessionaires. The ports began distributing $44 million in incentive checks in December 2008, for the first 2,200 low-emission trucks purchased under the program.[36]

These grants have also experienced funding problems. The per-container fees that are to fund the system were to have been collected beginning in November 2008, but implementation was delayed by the Federal Maritime Commission (FMC), which maintained that the ports' program (referred to as the PortCheck Agreement) is anti-competitive and interferes with interstate commerce. FMC delayed implementation of the fees by requiring two 45-day review periods. These actions delayed the start of fee collection until February 18, 2009.[37]

The Port of Los Angeles is also collaborating with the South Coast Air Quality Management District to provide up to $100,000 for each natural gas (LNG or CNG) truck purchased by port concessionaires and up to 80% of the cost of electric trucks. This has led to the purchase of more than 400 alternate fuel trucks. About 8.5% of the cargo moves at the port were being made by these alternative fuel trucks as of October 2009.[38]

Besides state and local funding, U.S. EPA has become a source of funds for diesel emission reductions at ports. The stimulus package (the American Recovery and Reinvestment Act of 2009, P.L. 111-5) contained $300 million for diesel emission reduction grants. This money may be used for purposes authorized under Title VII, Subtitle G of the Energy Policy Act of 2005 (P.L. 109-58), including retrofit of diesel trucks, marine engines, and cargo handling equipment, not only in California, but in other states as well. Of the first $156 million awarded, at least $29

[35] Although funds are appropriated to ARB as part of the state's budget process, ARB must obtain the cash through the Pooled Money Investment Board. See CARB, "Prop 1B/Goods Movement Update" (e-mail to listserve on February 4, 2009), at http://www.arb.ca.gov/bonds/gmbond/docs/2_4_2009_email_update_to_listserv.pdf. Additional information was provided on July 1 at http://www.arb.ca.gov/bonds/gmbond/docs/july_2009_semi_annual_report_to_dof.pdf.

[36] "Port of Los Angeles Begins Estimated $44 Million Pay-Out Process to Clean Truck Program Concessionaires that Applied for Port's 2007-Compliant Incentive Program," Press Release, December 23, 2008, at http://www.portoflosangeles.org/environment/ctp.asp.

[37] Trucking interests also sued the ports to prevent implementation of PortCheck, focusing on the mechanism it uses (i.e., its requirement that truckers be concessionaires of the ports and submit to numerous administrative, financial, training, maintenance, and insurance requirements, in addition to using cleaner trucks). See American Trucking Ass'ns Inc. v. City of Los Angeles, C.D. Cal., No. 08-4920. In April 2009, the U.S. District Court for the Central District of California blocked the ports of Los Angeles and Long Beach from enforcing the concessionaire requirements of the PortCheck program on the grounds that they interfered with interstate commerce. The Port of Long Beach subsequently settled with the trucking associations. See "Port of Long Beach, Calif., Settles Lawsuit Over Clean-Truck Program," *Daily Environment Report*, October 22, 2009, p. A-3.

[38] http://www.portoflosangeles.org/CTP/CTP_Cargo_Move_Analysis.pdf

million went for diesel reduction activities at ports, including $8 million to California ports. There is an additional $60 million in diesel emission reduction grant money in P.L. 111-88, the Fiscal Year 2010 Interior, Environment, and Related Agencies Appropriation, signed by the President October 30, 2009.

Greenhouse Gases

Ships are also an important source of greenhouse gas (GHG) pollutants. Although there is a wide range of estimates, the International Maritime Organization's consensus is that international shipping emitted 843 million metric tonnes of carbon dioxide, 2.7% of global CO_2 emissions in 2007. Including domestic shipping and fishing vessels larger than 100 gross tonnes, the amount would increase to 1.019 billion tonnes, 3.3% of global emissions.[39] At these levels, only five countries (the United States, China, Russia, India, and Japan) account for a higher percentage of the world total of CO_2 emissions.[40]

In addition to the CO_2 emissions, the low quality fuel (bunker fuel) that ships use and the absence of pollution controls result in significant emissions of black carbon and nitrogen oxides, which also contribute to climate change. The refrigerants used on ships (hydrofluorcarbons and perfluorocarbons—HFCs and PFCs) are also potent greenhouse gases when released to the atmosphere. Thus, the total impact of ships on climate may be somewhat greater than 3%.

International Efforts to Address GHGs

For the most part, these emissions occur in international waters, and the sources are vessels not registered in the United States. Addressing the emissions, therefore, is likely to require international agreement. On the international level, however, there has been disagreement over who should take responsibility to abate GHG emissions. Rather than cover these emissions under the Kyoto Protocol, nations agreed to look to the IMO for sector-specific provisions to reduce GHG emissions from shipping.[41] The IMO's Marine Environment Protection Committee has begun negotiations on the issue, and has stated that the issue is "high on the Committee's agenda." Thus far, however, it has agreed only on voluntary guidelines on ship design and operational efficiency, while continuing to discuss market-based instruments to reduce GHG emissions.[42] Some in the industry, including shipping industry associations from several European countries, have suggested applying a cap-and-trade scheme to shipping's GHG emissions. At U.N.-sponsored climate negotiations, on the other hand, there has been talk of imposing a tax on bunker fuel.[43]

---

[39] International Maritime Organization, *Updated Study on Greenhouse Gas Emissions from Ships*, Executive Summary of Phase 1 Report, 1st September 2008, p. 5 at regserver.unfccc.int/seors/attachment/file_storage/6ep77qqvcujba7k.doc. Both estimates exclude emissions from naval vessels. Cited below as "IMO 2008 Update."

[40] Oceana, *Shipping Impacts on Climate: A Source with Solutions*, p. 2, at http://www.oceana.org/fileadmin/oceana/uploads/Climate_Change/Oceana_Shipping_Report.pdf.

[41] Under the UN Framework Convention on Climate Change, emissions from internationally used fuels (both ships and aviation) are calculated by countries but reported separately from national emissions, such as those subject to the United Nations Kyoto Protocol.

[42] For information on IMO discussions, see http://www.imo.org/Environment/mainframe.asp?topic_id=1737.

[43] "U.N. Climate Talks Consider Carbon Tax on Air, Sea Transport; Progress on Draft Text," *Daily Environment Report*, October 7, 2009, p. A-14.

As with many other sectors, the European Union has been a driving force in getting international consideration of controlling the shipping sector's GHG emissions. The EU has considered adding the shipping industry to its cap-and-trade system, the EU Emissions Trading Scheme (ETS), but for now is deferring to the IMO. Approving a broad package of climate measures on December 17, 2008, the European Parliament left shipping out of the package, pending the outcome of the IMO discussions. Satu Hassi, a Finnish lawmaker from the Parliament's Green Group, who oversaw negotiations on emission reduction targets for non-ETS sectors, was quoted as saying the "EU will act unilaterally" should IMO discussions not produce sufficient results.[44]

Shipping vs. Other Transport Modes

Ocean-going ships are already by far the most efficient means of goods movement. As noted by the United Nations Conference on Trade and Development (UNCTAD):

> While in absolute terms GHG emissions from international shipping are significant, in relative terms maritime transport – in particular where larger ships are used – surpasses other modes of transport in terms of fuel efficiency and climate friendliness. On a per ton kilometre (km) basis and depending on ship sizes, CO_2 emissions from shipping are lower than emissions from other modes. For example, emissions from rail could be 3 to 4 times higher than emissions from tankers, while emissions from road and air transport could, respectively, be 5 to 150 times and 54 to 150 times higher. Equally, in terms of fuel consumption (kilowatt (kW)/ton/km), a container ship (3,700 twenty-foot equivalent units (TEUs)), for instance, is estimated to consume on average 77 times less energy than a freight aircraft (Boeing 747-400), about 7 times less than a heavy truck and about 3 times less than rail.[45]

But, in general, shipping does not compete with other modes of transport. Only in a small number of cases involving high value or perishable commodities, or relatively short distances between countries that also have land links, are mode shifts between shipping and air, truck, or rail transport possible. Ships move more than 80% of the volume of international trade, and are likely to continue doing so. As the overall volume of trade grows, GHG emissions from shipping are projected to be 2.4 to 3 times the current level by 2050 unless control measures are adopted.[46]

Measures to Reduce Ships' GHG Emissions

A number of measures might be taken to reduce the shipping sector's GHG emissions. One of the more common suggestions is that ships operate at lower speeds. The IMO's 2000 study of GHG emissions from ships concluded that a 10% reduction in speed would result in a 23.3% reduction in emissions.[47] Slowing speeds is not without problems. According to the 2000 IMO report:

---

[44] "European Parliament Gives Final Approval to Far-Reaching Climate Protection Strategy," *Daily Environment Report*, December 18, 2008, p. A-1.

[45] "Maritime Transport and the Climate Change Challenge," Note by the UNCTAD Secretariat, 9 December 2008, prepared for the Multi-Year Expert Meeting on Transport and Trade Facilitation, Geneva, Switzerland, 16-18 February 2009, at http://www.unctad.org/en/docs/cimem1d2_en.pdf.

[46] IMO 2008 Update, op. cit., p. 5.

[47] Norwegian Marine Technology Research Institute – MARINTEK et al., for the International Maritime Organization (IMO), *Study of Greenhouse Gas Emissions from Ships*, March 2000, p. 17, at http://unfccc.int/files/methods_and_science/emissions_from_intl_transport/application/pdf/imoghgmain.pdf. This one measure (slow steaming) dwarfed the potential of any of the other technical and operational measures examined in the IMO study: in (continued...)

> For most ship engines, running at reduced speed / slow steaming may ... cause problems. Such problems may be vibrations (critical RPM of engine / shaft) and accelerating sooting in the exhausted gas channel. Sooting problems are normally coincident with incomplete combustion and increasing GHG emission per fuel unit consumed. For ships permanently operating at slow speed, however, engine modifications / de-rating may be a solution.[48]

In addition, of course, cargo owners may consider the lost time in reaching the ship's destination to be more valuable than the fuel and GHG savings. Thus, in a competitive market with low fuel costs, ship owners will tend to offer as swift a service as they can safely provide.

Nevertheless, it is possible without changes in technology or fuels to achieve significant GHG emission reductions, and shipping companies have begun to implement slow steaming policies to reduce their emissions. A.P. Moller – Maersk Group, the world's largest container shipper, for example, reports that it reduced fuel consumption in its transport group 6% in 2008 compared to the fuel used for the same level of business activity in 2007. In addition to slow steaming, the company has implemented waste heat recovery systems on 32 ships, has installed software in containers to reduce energy consumption for cooling, and has developed a voyage planning program to identify the most fuel-efficient routes, and a "just in time" steady running strategy that minimizes engine loads.[49]

Cleaner fuels and emission controls could also lower emissions, particularly if one focuses on emissions of black carbon and nitrogen oxides. Like slow steaming, these could be implemented without the need to replace ship engines or the ships themselves.

The use of alternative power in ports may also reduce GHG emissions, if the shore power is derived from low-carbon sources such as natural gas, or no-carbon sources (hydropower, wind, solar, or nuclear).

New ships may be able to reduce emissions further through better hull design, more efficient propulsion, and propeller coatings, among other options. A detailed discussion of options (in the context of Navy ships) is provided in CRS Report RL33360, *Navy Ship Propulsion Technologies: Options for Reducing Oil Use—Background for Congress*, by Ronald O'Rourke

Conclusion

As pollution from cars, trucks, and land-based stationary sources has been more tightly controlled over the last 40 years, the contribution of ships and port operations to air pollution in port cities has become more important. Simultaneously, foreign trade has grown dramatically, adding to the burden of pollution from these sources. Thus, pollution from ships and the port operations that serve them is now among the most important sources of sulfur oxides, nitrogen oxides, particulates, and other pollutants in numerous U.S. cities.

(...continued)

the short term (10 years), it accounted for nearly 60% of the total reductions identified; over a 20-year horizon, it still accounted for 43% of potential reductions.

[48] Ibid., p. 91.

[49] *Preparing for the Future*, A.P. Moller – Maersk Group's Health, Safety, Security and Environment Report 2008, p. 30, at http://media.maersk.com/da/PressReleases/2009/Documents/Maersk%20HSSE%202008_Final.pdf.

Controlling these sources of pollution is complicated by the fact that most oceangoing ships are registered in foreign countries. As a result, initial efforts at control were focused on international negotiations through the IMO, which established a basic structure (MARPOL Annex VI) that appears likely to be the basis of more stringent future controls. Negotiating, ratifying, and implementing MARPOL agreements has been time-consuming, but now has resulted in significant levels of regulation that will gradually be implemented over the next six years. EPA and state and local agencies (particularly those in California) have also begun to address pollution from ships using the Clean Air Act and comparable state authorities.

Not all pollution from marine vessels comes from foreign ships. Smaller craft, such as ferries, tugboats, and fishing boats do tend to be registered in the United States, and are thus more amenable to control. Even for these smaller craft, the technical issues can be complex, as the vessels include a wide variety of engine sizes and ship configurations. Safety also poses important considerations, as ships must be able to depend on their sources of power in what may be extreme weather conditions and while dealing with a variety of navigational hazards. A particular issue has arisen regarding Great Lakes freighters, many of which were built more than 50 years ago, and might face significant costs in upgrading to burn cleaner fuel. The FY2010 appropriation for EPA has prohibited the expenditure of funds in this fiscal year to issue final fuel sulfur standards applicable to existing steamships operating exclusively within the Great Lakes, and accompanying report language states that EPA should develop waiver provisions available to these ships.

Because ships and port operations are now such significant sources of air pollution, and because of the importance of shipping to the national and world economy, implementation of the emissions regulations for ships and ports, including the cleaner fuels requirements, may continue to be of interest to Congress. In addition, ships are a large and growing source of greenhouse gas emissions; how and whether to regulate these emissions are the subject of IMO discussions and are a small part of the larger debate over legislation to address climate change.

Congress has begun efforts to address these problems, by enacting legislation to implement MARPOL Annex VI in July 2008. But this is likely to be just the start of Congressional attention to air pollution from ships. Action at the state level, in the courts, and at U.S. EPA will continue to bring the issue to Congress's attention, with numerous opportunities for oversight and legislation.

Author Contact Information

James E. McCarthy
Specialist in Environmental Policy
jmccarthy@crs.loc.gov, 7-7225

An Overview of Potential Economic Costs to Washington of a Business-As-Usual Approach to Climate Change

A Report from
The Program on Climate Economics,
Climate Leadership Initiative,
Institute for a Sustainable Environment,
University of Oregon

Prepared by Ernie Niemi (CLI Fellow and
Member of Economic Steering Committee)
and Staff from ECONorthwest

With Assistance from
Members of the Program on
Economics' Steering Committee

February 17, 2009

ECONorthwest
ECONOMICS • FINANCE • PLANNING

AUTHORSHIP AND CONTACT INFORMATION

The Program on Climate Economics of the Climate Leadership Initiative (CLI), Institute for a Sustainable Environment, at the University of Oregon, sponsors research on the potential economic consequences and benefits of climate mitigation, preparation and economic development policies. This report is part of that effort. It calculates some of the potential costs that families, businesses, and communities in Washington might expect in the next several decades if Washington, the U.S., and countries around the world were to continue their activities in a business-as-usual manner, i.e. without effective steps to reign in greenhouse gas emissions (GHGs) or to prepare for and adapt to changes in climate that past and future emissions of GHG will bring about.

The work of the CLI Program on Climate Economics is supported by a steering committee of academic and private economists from across the West and nation. Steering committee members provide overall guidance for the program, may be contracted to produce or contribute to economic assessments, and, serve as peer reviewers. Current members of the Steering Committee are:

Katie Baird, *U. of Washington, Tacoma*
Randall A. Bluffstone, *Portland State U.*
Trudy Ann Cameron, *U. of Oregon*
Bonnie G. Colby, *U. of Arizona*
Peter Dorman, *Evergreen State College*
Kristine M. Grimsrud, *U. of New Mexico*
Hart Hodges, *Western Washington U.*
Don Negri, *Willamette U.*
Andrew Plantinga, *Oregon State U.*
W. Douglass Shaw, *Texas A&M U.*
William Barnes, *U. of Portland*
Gardner Brown, *U. of Washington*
Janie Chermak, *U. of New Mexico*
Paul N. Courant, *U. of Michigan*
David Ervin, *Portland State U.*
Joel Hamilton, *U. of Idaho*
Daniel Huppert, *U. of Washington*
Ernie Niemi, *CLI Fellow & ECONorthwest*
Michael J. Scott, *PNW National Laboratory*

This report was prepared by Ernie Niemi, a CLI Fellow and member of the Program on Climate Economics' Steering Committee, along with Mark Buckley, Cleo Neculae, and Sarah Reich of ECONorthwest. We gratefully acknowledge the assistance of Katie Baird, Randall Bluffstone, Gardner Brown, Bonnie Colby, Bob Doppelt, Peter Dorman, Kristine Grimsrud, Joel Hamilton, Hart Hodges, Andrew Plantinga, and Michael Scott, for their comments on an earlier version of our manuscript. The assistance from others notwithstanding, ECONorthwest is solely responsible for this report and its content.

For more information, please contact:

Bob Doppelt, Director
Climate Leadership Initiative
Institute for a Sustainable Environment
University of Oregon
bdoppelt@uoregon.edu

Ernie Niemi, Senior Economist and
Policy Analyst with ECONorthwest,
and CLI Fellow
niemi@eugene.econw.com

I. INTRODUCTION AND SUMMARY

Extensive research shows that Washington and other western states already have experienced noticeable changes in climate and predicts that more change will occur in the future.[1] Much of this change is having and will continue to have negative economic consequences. Some negative effects are readily recognized: warmer stream temperatures during summer stressing salmon and trout populations, prolonged drought destroying farmers' crops, and rapidly growing insect populations attacking trees. In response, families, businesses, and communities are considering actions that would reduce the emissions of carbon dioxide and other greenhouse gases (GHGs) that contribute to climate change. Amid all this activity, many have concluded that such actions should not be undertaken because their costs are too great. They reach this conclusion, however, without first seeing what the costs would be of not taking these actions and allowing climate change to continue unabated.

Until now, attempts to describe the costs of climate change have produced results that are too abstract to matter to most citizens. Some have estimated the global costs, but what does this mean to an average family in Washington? Others have looked at the costs that will materialize over the next several centuries, but what does that mean to people making decisions today? A few have attempted to describe the net costs of taking this or that action, but undermined their efforts by focusing mostly on describing the action and not providing a full, easily understandable description of the consequences of not taking it.

The first step toward filling the gap was taken a few years ago by the Climate Leadership Initiative at the University of Oregon, which produced the first climate economic report for the State of Washington, *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities*.[2] The study used information available at that time. The current report builds on that assessment and additional data available today. It illustrates some of the potential costs Washington's families, businesses, and communities might incur over the next several decades if Washington, other states, the U.S., and other countries were to extend a business-as-usual approach to climate change. Under this approach, we assume behaviors do not change and the emissions of carbon

---

[1] *See*, for example, the assessments of climate science and other reports prepared by the U.S. Climate Science Program: http://www.climatescience.gov, and the reports of the Intergovernmental Panel on Climate Change: http://www.ipcc.ch.

[2] Washington Economic Steering Committee and the Climate Leadership Initiative, Institute for a Sustainable Environment, University of Oregon. 2006. *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities.* November. Retrieved December 19, 2008, from http://www.ecy.wa.gov/climatechange/economic_impacts.htm. The Institute produced a similar assessment of the impacts of climate change for the State of Oregon. *See,* Resource Innovations, Institute for a Sustainable Environment, University of Oregon. 2005. *The Economic Impacts of Climate Change in Oregon: A Preliminary Assessment.* October. Retrieved December 19, 2008, from http://climlead.uoregon.edu/publicationspress/Consensus_report.pdf

dioxide and other greenhouse gases would continue to grow at rates similar to those seen during recent years, leading to increases in global temperature such as those depicted in the high-emission scenarios described by the U.S. Climate Science Program, the Intergovernmental Panel on Climate Change (IPCC), and others.

We take this approach with full recognition that it does not address all the potentially important effects of climate change on Washington's economy. Moderate warming might have some positive economic effects for some Washingtonians, by boosting the output of some farmers, for example, or allowing some recreational activities to occur earlier in the spring and later in the autumn. Many of the most serious economic consequences of a business-as-usual approach to climate change will occur elsewhere, or beyond the next several decades, but still are important to today's Washingtonians. As people in Washington become more familiar with the prospect of changes in climate they likely will take actions to mitigate the harm. All these concerns must be considered to have a complete picture of how climate change will affect Washington's economy. This report provides only one piece of the picture: the potential gross costs that might materialize in this state over the next several decades, if societies here and elsewhere fail to address climate change by proceeding in a business-as-usual manner.

To facilitate better understanding of our findings, we place each potential cost in a setting familiar to today's Washingtonians, assuming that families, businesses, and communities will behave in the future essentially the same as they do today and that future prices relative to budgets will be essentially the same as today's. That is, we assume that families, farms, and businesses will continue to go about their activities in a business-as-usual manner. Families will continue with consumption patterns similar to those of today, businesses will continue to produce products similar to their current ones, and communities will follow current behaviors to organize land-use, transportation, and other activities. In short, we provide an estimate of costs that might materialize if climate change is not reined in, not a forecast of how things will actually unfold.

We anticipate that the information in this report will help families, businesses, and communities better understand the nature of the economic threats that climate change poses over the next several decades. We emphasize, however, that the scope of this report is limited. It illustrates only some of the potential costs that might materialize if Washington, other states, the U.S., and other countries were to fail to address climate change by carrying on in a business-as-usual manner. Insufficient data currently exist, however, for us to account for all the potential costs. Hence, we encourage the reader to bear in mind that Washingtonians face substantial, multi-faceted costs in addition to those we describe here, both during the next several decades and beyond.

Our analysis is structured as follows: in Section II, we present a conceptual framework for describing the potential negative economic effects of climate change. In Sections III and IV, we apply the framework and calculate 18 different types of potential costs. We divide these costs into two broad categories: the costs

produced by the effects of climate change, and the costs generated by some of the business-as-usual activities that contribute to climate change. In Section V, we discuss the potential implications for Washington's households.

The 19 costs we describe are already observable. Over time, they will be exacerbated by potential changes in temperature, precipitation and other climate characteristics, or by climate-related changes in the state's ecosystems. The extent of the anticipated climate change is closely related to increases in the atmospheric concentration of carbon dioxide, which was about 260 to 280 parts per million (ppm) before the Industrial Revolution and has risen to about 385 ppm today. Under our business-as-usual assumptions, the concentration would rise to about 400 ppm by 2020, 500 ppm by 2040, and 800 ppm by 2080.[3] At these concentrations, climate modeling indicates that average global surface temperature could rise by more than 5°C (9°F) above pre-industrial levels by the end of this century (during the past century, the temperature rose 0.74°C (1.33°F), mostly in the past three decades).

Economic costs would arise from undesirable changes in climate, ecosystems, or both. Higher temperatures would increase the incidence of heat-related health problems, for example, and ecosystem changes would reduce summertime stream flows. These and similar changes would impose economic costs on Washington's families, businesses, and communities. In addition, Washingtonians would incur costs as they engage in practices that contribute to climate change, such as consuming electricity generated by burning coal and continuing with technologies and practices that waste energy. For each type of cost, we describe the mechanism that produces it, as well as the assumptions, data, and steps we take to calculate it.

Figure 1 summarizes our findings, aggregating the 18 different costs into 9 categories. By 2020, these costs total $3.8 billion per year. The major components of climate-change costs are potential health-related costs of about $1.3 billion per year, potential reductions in salmon populations, with a value of $530 million per year, and energy costs of about $220 million. In addition, continuing with the activities that contribute to climate change potentially would cost Washingtonians almost $1.4 billion per year in missed opportunities to implement energy-efficiency programs and about $19 million per year in health costs from burning coal. The combined total annual costs would increase with time, more than three-fold by 2080.

If spread evenly, Washington's households, on average, could incur annual costs of $1,250 per year by 2020. Of this amount, $540 relate to expenditures on energy,

---

[3] These increases correspond to the A1FI scenario used by the Intergovernmental Panel on Climate Change (IPCC). The IPCC applies the label, business as usual, to another scenario, A2, but, since its development, it has understated the actual, business-as-usual emissions of greenhouse gases. Hence, we use the A1FI scenario, which we believe more closely represents the trajectory of emissions in a business-as-usual world. *See*, IPCC. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/.

Figure 1. Potential Economic Costs in Washington Under a Business-as-Usual Approach to Climate Change, 2020, 2040, and 2080 (dollars per year)

Potential Cost	2020	2040	2080
Costs of Climate Change			
Increased Energy-Related Costs	$222 million	$623 million	$1.5 million
Reduced Salmon Populations	$531 million	$1.4 billion	$3.0 billion
Increased Coastal and Storm Damage	$72 million	$150 million	$352 million
Reduced Food Production	$35 million	$64 million	$364 million
Increased Wildland Fire Costs	$102 million	$208 million	$462 million
Increased Health-Related Costs	$1.3 billion	$2.2 billion	$4.4 billion
Lost Recreation Opportunities	$75 million	$210 million	$612 million
Subtotal for Costs of Climate Change	*$2.3 billion*	*$4.9 billion*	*$10.7 billion*
Additional Costs from Business-as-Usual (BAU) Activities that Contribute to Climate Change			
Inefficient Consumption of Energy	$1.4 billion	$1.6 billion	$2.2 billion
Increased Health Costs from Coal-Fired Emissions	$19 million	$23 million	$31 million
Subtotal for Costs from BAU Activities	*$1.4 billion*	*$1.6 billion*	*$2.2 billion*
TOTAL	**$3.8 billion**	**$6.5 billion**	**$12.9 billion**
Average Cost per Household per Year	$1,250	$1,800	$2,750

Source: ECONorthwest.

Notes: These numbers illustrate different types of annual costs Washingtonians potentially would incur if society were to continue with a business-as-usual approach to climate change. There may be overlap between the values for some of the different types of costs. Nonetheless, adding the different types of costs probably seriously understates the total potential cost of climate change because the table excludes many additional types of climate-related costs that Washingtonians would incur under a business-as-usual approach. The numbers do not indicate the net effect of climate change, as they do not represent a forecast of how the economy will respond to the different effects of climate change, or account for potential economic benefits that might materialize from moderate warming and other changes in climate.

$440 relate to health-care costs, and $180 to the adverse effects of climate change on salmon populations. These costs are not negligible. The 2020 average of $1,250 represents more than 2 percent of the current median household income in Washington. Analogously, the potential costs in 2040 represent more than 3 percent of median household income and those in 2080 more than 5 percent of the income that half of the households in Washington earn in a year.

We recognize that families, businesses, and communities in Washington may be able to offset or mitigate some of the potential costs in the near term by taking advantage of the potential economic benefits of climate change, such as increased production of some crops or reduced expenditures on heating, that might accompany moderate climate warming. Our aim, however, is not to describe this potential adjustment but to describe the potential consequences if such adjustments are not realized. Further investigation is required to determine the extent of these opportunities, but current evidence suggests they will not fully

Figure 2. Some Potential Economic Costs Not Incorporated in this Report

Potential Unquantified Cost
Reduced productivity of nearshore marine environments
Increased cooling costs for commercial and industrial businesses
Increased costs for air conditioning and refrigeration in transportation
Increased costs to cope with greater variability in weather conditions
Increased pumping costs to replace surface water with groundwater for irrigation
Increased regulatory costs for protecting additional threatened and endangered species
Increased management costs for controlling invasive species
Increased costs associated with flood and wind damage from more frequent and intense storms
Reduced value of certain crops, such as tree fruits and nursery stock
Increased costs associated with agricultural pests and diseases related to climate change
Increased costs associated with fish and wildlife diseases related to climate change
Reduced value of certain crops due to water stress
Increased costs for families and businesses that move in response to climate change
Reduced productivity of rangelands
Increased health care costs related to expanded range of tropical and sub-tropical diseases
Increased health care costs related to increased incidence of water- and food-borne diseases
Reduced recreation opportunities due to increased wildland fires
Reduced boating and other recreation opportunities due to decreased streamflows
Increased costs to bring warmer streams into compliance with water-quality standards
Increased insurance costs for storms, fires, sea-level rise and other effects of climate change

Source: ECONorthwest

offset the costs likely to materialize with large increases in atmospheric concentrations of GHGs.

Similarly, we recognize that there may be some overlap among our cost estimates and, hence, double counting when they are summed. We're confident, however, that the potential costs that are not included in the calculations more than offset the double-counts, if any, and that the total potential costs of a business-as-usual approach to climate change are larger—perhaps far larger—than the amounts shown in Figure 1.

Some of these additional costs likely would materialize inside Washington over the next several decades. Figure 2 summarizes some of these additional costs, for which we were unable to find adequate documentation to quantify in this report.

Far greater costs might materialize elsewhere or in future centuries, the result of a business-as-usual approach to climate change over the next few decades. If temperatures rise to the maximum levels predicted under the business-as-usual

scenario, billions of people in less-developed countries likely would endure increased thirst and starvation, thousands of species would face extinction, sea levels would rise several meters. and vast areas of the oceans could become essentially barren. To the extent that these distant effects matter to today's Washingtonians, the potential costs would be far greater than we indicate.

II. CONCEPTUAL FRAMEWORK

This analysis is concerned with the climate-related economic costs families, businesses, and communities in Washington might incur over the next several decades under a business-as-usual approach to climate change. This approach has two major assumptions. One is that Washington, other states, the U.S., and other countries will not take effective actions to rein in emissions of greenhouse gases (GHGs) and continue to engage in activities that drive climate change. We use the A1FI scenario described by the Intergovernmental Panel on Climate Change (IPCC) to represent the future evolution of emissions and atmospheric concentrations for GHGs, as it seems to trace most closely the recent trends in emissions.[4]

The other major assumption we make in this analysis is that Washington's households, businesses, and communities will continue to engage in behaviors and adopt technologies similar to those of today. This assumption has several strengths. It reflects the social and economic inertia that arises, for example, insofar as there exists a large amount of residential, commercial-industrial, and public capital built with little or no regard for climate change, and modifying or replacing it likely will take considerable time. It also facilitates both the analysis and the communication of our findings. Limited by time and money, we lacked the ability to construct a scenario of how Washingtonians will behave over the next 10, 30, and 70 years that is both more suitable and understandable than the scenario we used, which assumes that, absent major effort to rein in climate change, most families, businesses, and communities will try to continue doing tomorrow what they are doing today.

These assumptions yield illustrations of costs that might materialize if business-as-usual activities continue, but fall far short of a worst-case depiction of what the costs of climate change might be. Numerous recent reports of scientific studies, not represented in the most recent assessment of climate prospects by the IPCC from 2007, signal a growing probability that emissions of GHGs and average surface temperatures might rise faster than previously anticipated. Other studies signal a growing probability that, whatever the increase in emissions and temperatures, the effects of climate change will be more severe. Forests will die more rapidly, oceans will become less productive, ice sheets will melt more rapidly, epidemics of disease and pests will spread more quickly, and more. At the same time, meaningful progress on efforts to rein in the global emissions of GHGs has been slow, and many in the state continue to oppose proposals to

[4] A recent analysis by the MIT Joint Program on the Science and Policy of Global Change confirms our choice of using IPCC's A1FI scenario to represent business-as-usual conditions. Its analysis of uncertainties in emissions, the climate-system's sensitivity to emissions, and the economy predicts a high probability of warming at levels that correspond to the likely range of the A1FI scenario. *See* Sokolov, A.P., P.H. Stone, C.E. Forest, R. Prinn, et al. 2009. *Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters.* Report No. 169. January.

reduce GHG emissions here or to prepare for climate changes that cannot be avoided.

In the following sections we first provide an overview of climate-related risks, and then describe ways in which climate change might impose economic harm on this state. We then outline the specific steps we have taken to produce the illustrations of specific types of potential economic harm that we present in Sections III and IV.

A. Overview of Climate-Related Risks

Rapidly accelerating emissions of carbon dioxide, methane, and other GHGs since the beginning of the 20th century have increased the average global temperature by about 0.74°C (1.33°F), and altered precipitation patterns.[5] These changes in climate have had and will continue to have negative effects on the well being of current and future generations of humans.[6] These effects are expected to worsen at an increasing rate as atmospheric concentrations of GHGs increase and global temperatures rise even further.[7] Figure 3 illustrates, briefly and incompletely, the potential impacts of each incremental increase in average global temperature.

Based on this evidence, many have concluded that society should aim to rein in emissions of GHGs so the rise in temperature does not exceed 2°C (3.6°F). There is considerable uncertainty underlying such conclusions, however. As we understand the scientific reports, this uncertainty suggests that the economic risks associated with the smaller increases in temperature (and, hence, with the lower levels of emissions of GHGs) are higher than they first appear, insofar as:

- ***Once set in motion, the processes of climate change cannot easily be reversed, if at all.*** Temperatures will continue to rise in response to GHGs

[5] Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/

[6] *See*, for example, Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/. Some believe climate change is important not only for what it does for humans, but for its effects on the environment, apart from people. They suggest economics should consider those values, and there are good arguments for doing so. There similarly are good reasons for considering spiritual and other measures of the value of climate change that lie outside the direct purview of economics. Here, however, we focus on the economic connections between climate change and people. We do so not just to keep our task from becoming intractable but also because this relationship underlies many, if not most, of the motivation for human actions to restrict emissions of greenhouse gases and to prepare for unavoidable changes in climate. We take a broad view, though, of the ways in which climate change might affect the economic dimensions of human standards of living and quality of life.

[7] Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/; Lynas, M. 2008. *Six Degrees: Our Future on a Hotter Planet.* New York: National Geographic Society; Stern, N. 2006. *The Economics of Climate Change: The Stern Review*. Cambridge, United Kingdom: Cambridge University Press. Retrieved October 30, 2006, from http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Figure 3. Potential Impacts of Incremental Increases in Average Global Temperature

1°C (1.8°F)	Increased potential for prolonged drought, converting some parts of the American West to sandy deserts, on a scale much larger than the 1930s Dustbowl.
2°C (3.6°F)	Small mountain glaciers will disappear and mountain snowpack diminish, as will stream flows dependent on snow melt. Large areas of the oceans will become too acidic for organisms with calcium carbonate shells, and for many species of plankton, the basis of the marine food chain. Onset of irreversible melting of the Greenland ice sheet would raise sea levels by about seven meters. Heat waves similar to the most extreme in recent history likely would occur every year in many places. About one-third of all species around the globe may be driven to extinction. Increased risk of hunger for many communities, especially in Africa and Asia.
3°C (5.4°F)	An increase of this magnitude could be a tipping point that causes climate change to become uncontrollable. The middle areas of North America likely would become deserts. Extreme weather, such as hurricanes, may become more intense, doubling damage costs in the U.S. Millions, perhaps billions may face famine from extreme drought, flooding, and insect infestations. Perhaps 50 percent of species face extinction.
4°C (7.2°F)	The West Antarctic ice sheet may collapse and raise sea levels another five meters. Crop yields likely would continue to fall in many regions. Significant shortages of water may affect more than a billion people, as some areas may see runoff increase by one-third. Perhaps 50 percent of species face extinction. Conditions typical of the Sahara Desert probably will materialize across southern Europe.
5°C (9.0°F)	Entire regions of the Earth might see major declines in crop production and ecosystems unable to maintain their current form. Forest fires, droughts, flooding, and heat waves will increase in intensity. Increasing probability of abrupt, large-scale shifts in the climate system, e.g., tropical conditions, may materialize in Arctic regions. Rising sea level threatens major coastal cities.
6°C (10.8°F)	The Earth would experience climate conditions associated with a period, about 250 million years ago, that saw perhaps 95 percent of all species go extinct.

Source: ECONorthwest, adapted from Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/; Lynas, M. 2008. *Six Degrees: Our Future on a Hotter Planet*. New York: National Geographic Society; and Stern, N. 2006. *The Economics of Climate Change: The Stern Review*. Cambridge, United Kingdom: Cambridge University Press. Retrieved October 30, 2006, from http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_ climate_change/stern_review_report.cfm; and

already in the atmosphere, and additional GHG emissions will only reinforce the momentum. There may be no corrective actions available to arrest or reverse some of the processes, and their ecological and economic consequences, once they have been triggered.

- ***Some major impacts of climate change are occurring faster than anticipated.*** Sea ice in the Arctic Ocean is melting at rates unforeseen by the IPCC in its 2007 integrated assessment of climate-related research through the early part of 2007.[8] The melting of the sea ice means that solar energy that the ice would reflect now will be absorbed by open water,

[8] Stroeve, J., M. Holland, W. Meir, T. et al. 2007. "Arctic Sea Ice Decline: Faster than Forecast." *Geophysical Research Letters* 34: L09501, doi:10.1029/2007GL029703.

further accelerating increases in temperature. Some ice structures in the Antarctic Peninsula also are melting faster than expected.[9] The global sea level has been rising faster than expected, and recent analyses conclude during this century it will rise twice as much as IPCC predicted in 2007.[10] The processes that enable the oceans and other elements of the global ecosystem to remove GHGs from the atmosphere are slowing down faster than anticipated.[11] Trees in the U.S. and Canada are dying at unforeseen rates, so that some forests, rather than increasing their removal of carbon dioxide from the atmosphere, are contributing the greenhouse gas to the atmosphere.[12]

- ***Recent research suggests that, for a given concentration of GHGs in the atmosphere, the temperature will rise higher than previously anticipated.*** The 2007 report of the IPCC, for example, reported that, if carbon dioxide concentrations were to stabilize in the range of 350 to 400 ppm, warming likely would stabilize within the range of 2°C to 2.4°C (3.6°F to 4.3°F), but it warned that larger temperature increases might occur.[13] Research not represented in the IPCC report looks more directly at the possibility that temperatures will increase faster than expected. The authors of one recent paper find that, if carbon dioxide concentrations stabilize at 450 ppm (or higher) there is a substantial probability that the increase in temperature will rise to 6°C (10.8°F).[14]
- ***The atmospheric concentration of GHGs has been rising faster than expected.***[15] The acceleration stems from faster than expected burning of

---

[9] Pritchard, H.D. and D.G. Vaughan. 2007. "Widespread Acceleration of Tidewater Glaciers on the Antarctic Peninsula." *Journal of Geophysical Research* 112: F03S29.

[10] Rahmstorf, S., et al. 2007. "Recent Climate Observations Compared to Projections." *Science* 316(5825): 709; and Rohling, E.J., et al. 2008. "High Rates of Sea-Level Rise During the Last Interglacial Period." *Nature Geoscience* 1: 38-42.

[11] Le Quéré, C., et al. 2007. "Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change." *Science* 316(5832): 1735-1738.

[12] Van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, et al. 2009. "Widespread Increase of Tree Mortality Rates in the Western United States." *Science*. 323:521-524. January 23; and Kurz, W.A., C.C. Dymond, G. Stinson, G.J. Rampley, et al. 2009. "Mountain Pine Beetle and Forest Carbon Feedback to Climate Change." *Nature*. 452:987-990. April 24.

[13] Solomon, S., D. Qin, M. Manning, M. Marquis, et al. (eds.). 2007. *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change Working Group I. New York: Cambridge University Press. An average global temperature increase of 2°C to 2.4°C (3.6°F to 4.3°F) would mean higher temperature increases over land and in some regions. Scientists anticipate that the increase in temperatures over land will be larger than the global average increase, perhaps as great as two times larger, because land absorbs more heat than the oceans.

[14] Hansen, J., et al. 2008. "Target Atmospheric CO_2: Where Should Humanity Aim?" Retrieved January 14, 2009, from http://www.columbia.edu/~jeh1/2008/TargetCO2_ 20080407.pdf

[15] Raupach, M.R., et al. 2007. "Global and Regional Drivers of Accelerating CO_2 Emissions." *Proceedings of the National Academy of Sciences* 104(24): 10288-10293.

fossil fuels for electricity, transportation and other purposes, but also from other contributing factors, such as a slowing in oceanic absorption of carbon dioxide and unexpected releases of methane, a potent GHG, trapped in soils.[16] Several authorities have warned of the potential consequences. The authors of one study of past changes in climate concluded, for example, that warmer temperatures likely would accelerate the emission of GHGs into the atmosphere, and "promote warming by an extra 15 to 78 percent on a century scale" relative to the projections presented by the IPCC.[17]

- ***Leading researchers are urgently calling for faster and steeper curtailment of GHG emissions to prevent catastrophic damage from climate change.*** The International Energy Agency has observed that, given the recent rapid increases in the burning of fossil fuels, the average global temperature will rise 6°C (10.8°F) unless there is a quick and rigorous change in policy.[18] The head of Britain's Met Office recently warned that, if emissions keep rising, the average temperature could increase by more than 5°C (9°F) by the end of the century.[19] Some scientists conclude that, to sustain climatic and ecological conditions similar to those that have existed during the development of human civilization, society must do more than just arrest growth in the atmospheric concentration of GHGs, it will have to be reduce them below the current level, with the concentration of carbon dioxide falling to no more than 350 ppm within the next several decades.[20]

Not all of these (and many related) impacts would occur immediately. There is considerable uncertainty about how long it would take for some of the impacts to materialize, but some of the most extreme impacts likely would not materialize

---

[16] Park, G.-H., K. Lee, and P. Tishchenko. 2008. "Sudden, Considerable Reduction in Recent Uptake of Anthropogenic CO_2 by the East/Japan Sea." *Geophysical Research Letters* 35: L23611, .; Le Quéré, C., M. Raupach, P. Ciais, T. Conway, et al. 2008. "Carbon Budget 2007." Global Carbon Project. Retrieved January 6, 2009, from http://www.globalcarbonproject.org/carbontrends/index.htm; and Canadell, J.G., C. Le Quéré, M.R. Raupach, C. B. Field, et al. 2007. "Contributions to Accelerating Atmospheric CO_2 Growth from Economic Activity, Carbon Intensity, and Efficiency of Natural Sinks." *Proceedings of the National Academy of Science* 104 (47): 18899-18870. For additional references, see http://www.globalcarbonproject.org/carbontrends/index.htm#References.

[17] Scheffer, M., V. Brovkin, and P.M. Cox. 2006. "Positive Feedback between Global Warming and Atmospheric CO_2 Concentration Inferred from Past Climate Change." *Geophysical Research Letters* 33, L10702, DOI: 10.1029/2005GL025044.

[18] International Energy Agency. 2008. *Energy Technology Perspectives: Scenarios and Strategies to 2050, Executive Summary*. Retrieved January 15, 2009, from http://www.iea.org/Textbase/npsum/ETP2008SUM.pdf

[19] Pope, V. 2008. "Met Office Warn of 'Catastrophic Rise' in Temperature." *(London) Times Online.* December 19. Retrieved January 14, 2009, from http://www.timesonline.co.uk/tol/news/environment/article5371682.ece

[20] Hansen, J., et al. 2008. "Target Atmospheric CO_2: Where Should Humanity Aim?" Retrieved January 14, 2009, from http://www.columbia.edu/~jeh1/2008/TargetCO2_ 20080407.pdf

for decades or centuries. This delay does not, however, mean that the far-distant impacts have no economic relevance today. Decisions now that affect the atmospheric concentration of GHGs may set in motion climate-relate processes that lead to irreversible consequences. Moreover, current Washington residents may have strong feelings, and thus realize a marked reduction in their economic well-being, knowing that today's decisions might have catastrophic consequences for future generations.

Having recognized the importance of these more distant and extreme effects, we now set them aside, and focus on the task at hand: describing the business-as-usual potential harm of climate change for families, businesses, and communities in Washington over the next several decades. In the next section we describe the general mechanisms through which such harm can materialize in this context.

B. Climate Change and the Economy

Figure 4 illustrates some of the potential changes in climate expected over the next two decades. The top two maps depict the average annual temperature (left) and heat waves (right), and the bottom two maps depict the annual average precipitation (left) and extreme precipitation (right) expected by about 2030, relative to conditions in about 1990, under a middle-of-the-road scenario regarding future emissions of GHGs and their impacts. These anticipated changes point toward some of the ways that climate change can impose harm on the western states. The lower left map, for example, shows that the southwestern region can expect reductions—marked reductions in some areas—in precipitation, while some of the northern parts of the region likely will see precipitation increase. Individually and together, these maps indicate the potential for some or all in the region to realize economic harm through any number of mechanisms: increased droughts and floods, higher air-conditioning costs to cope with higher temperatures, higher incidence of morbidity and mortality for those without access to air conditioning, more frequent wildfires, loss of habitat for important species—the list is perhaps without end.[21] Moreover, under a business-as-usual scenario, the physical changes depicted in Figure 4, and thus the resulting economic impacts, would likely be magnified.

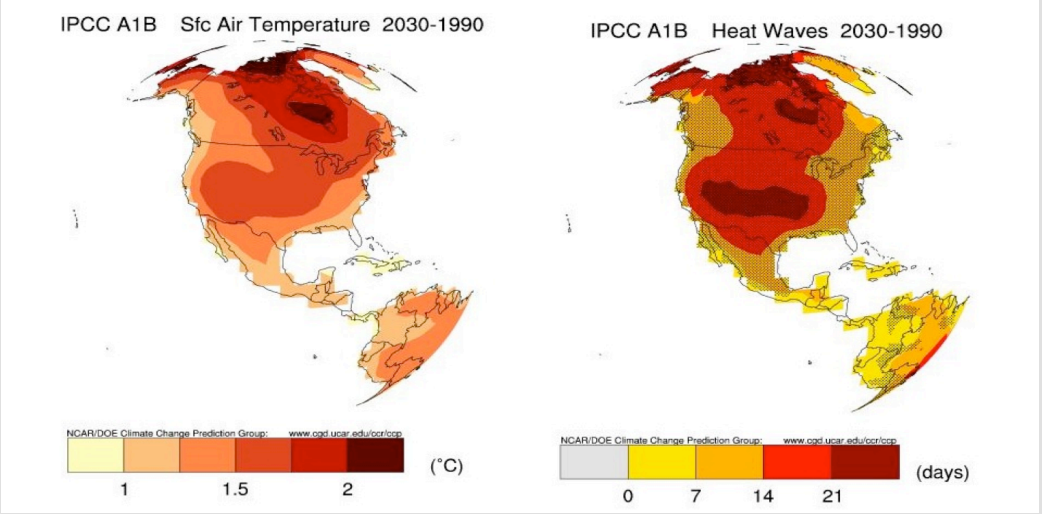
To provide some structure for thinking about the different ways in which climate changes can produce economic harm, Figure 5 identifies different types of change that can generate harm and the different ways in which harm might materialize. In some cases, the harm can originate directly from a change in the climate itself, through changes in temperature, precipitations, or storms and other extreme events. An increase in heat waves, for example, might increase the incidence of heat-related human illness and death,[22] high temperatures plus

---

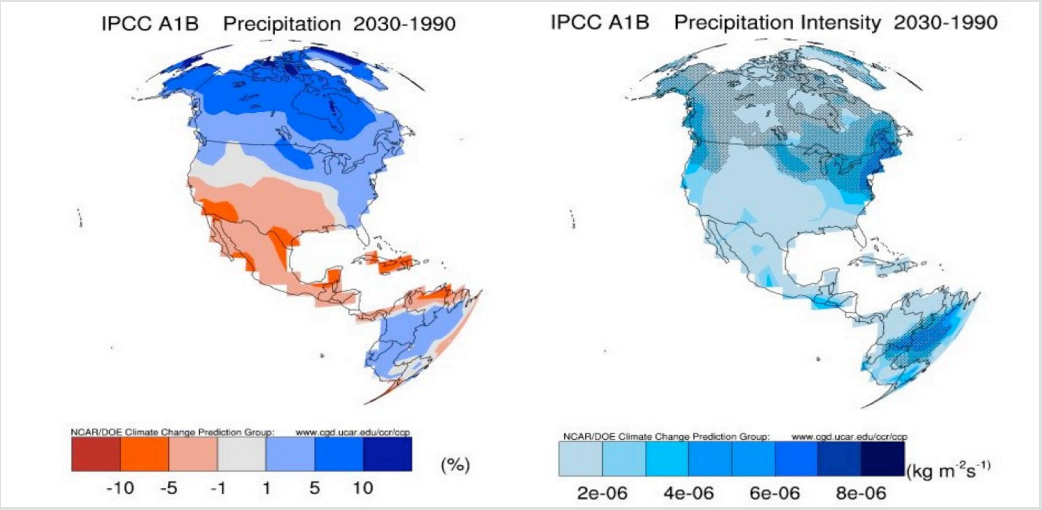
[21] We understand that the results from the temperature models generally are more robust than the results from the precipitation models. Nonetheless, most models generally support the expectations indicated by the lower left map in Figure 4.

[22] *See*, for example, Kalkstein, L.S. and J.S. Greene. 2007. *An Analysis of Potential Heat-Related Mortality Increases in U.S. Cities under a Business-as-Usual Climate Change Scenario.* Environment America. September 6. Retrieved January 13, 2008, from http://www.environmentamerica.org/uploads/Js/tF/JstFE5oHrsQJi5ifIA931Q/Heat-Mortality_Report_.pdf

Figure 4. Expected Changes in Annual Temperature, Heat Waves …



… Annual Precipitation and Extreme Precipitation, 2030 Relative to 1990



Source: Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes; An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_gallery_test/

Note: Please refer to the original source for definitions and descriptions of units displayed in each figure.

reduced precipitation might reduce the productivity of crops that wither under drought conditions,[23] and higher flooding from more severe storms might damage property, disrupt commerce, and take lives.[24]

---

[23] *See*, for example, Hatfield, J., et al. 2008. "Agriculture." *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States.* U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington D.C., USA.

In other cases, climate change indirectly diminishes well-being by inducing changes in ecosystems or social systems. Warmer temperatures have been associated, for example, with ecosystem changes, such as epidemic outbreaks of insects that kill pine trees and reduce the productivity of the timber industry,[25] rises in sea level that erode ocean-front property and increase the cost of maintaining coastal homes and highways,[26] and contractions of fish habitat that diminish salmon populations and eliminate opportunities for recreational fishing.[27] Climate-related changes in social systems that can diminish economic well-being might arise if families and businesses conclude they must move to avoid the effects of climate change, or if the costs of climate change fall disproportionately on poor families and communities, diminishing their prospects for climbing out of poverty.

The bottom of Figure 5 illustrates that climate-related economic harm can occur in several ways. This summary illustrates each mechanism in greater detail:

- ***Reduction in human health and other constituents of quality of life.***

  Hotter temperatures can increase human mortality; reductions in stream flows can reduce boating, fishing, and other recreational opportunities.

- ***Reduction in the value of assets or in the level of income.***

  Increased flooding from climate-related storms can reduce the value of exposed properties and disrupt employment for workers at commercial and industrial enterprises in low-lying areas.

- ***Increase in climate-related expenditures and, hence, decrease in income available for other purposes.***

  Households, businesses, and government are likely to increase spending on health-related issues in response to higher temperatures, leaving less money for discretionary household spending, business investment and profits, and government services.

---

[24] *See,* for example, Munich Re Group. 2008. *Catastrophe Figures for 2008 Confirm that Climate Agreement is Urgently Needed*. December 29. Retrieved January 16, 2009, from http://www.munichre.com/ en/press/press_releases/2008/2008_12_29_press_release.aspx

[25] *See*, for example, Carroll, A., S. Taylor, J. Regniere, and L. Safranyik. 2004. "Effects of Climate Change on Range Expansion by the Mountain Pine Beetle in British Columbia." In T.L. Shore, J.E. Brooks, and J.E. Stone, (eds.) *Mountain Pine Beetle Symposium: Challenges and Solutions*. October 30-31, 2003, Kelowna, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Information Report BC-X-399. Pp. 223-232.

[26] *See*, for example, Mote, P., A. Petersen, S. Reeder, et al. 2008. *Sea Level Rise in the Coastal Waters of Washington State.* University of Washington Climate Impacts Group and the Washington Department of Ecology. January.

[27] *See*, for example, United States Environmental Protection Agency. 1995. *Ecological Impacts from Climate Change: An Economic Analysis of Freshwater Recreational Fishing*. EPA Report No. 220-R-95-004. April.

Figure 5. Changes in Climate Can Have Negative Effects on the Economy Over the Next Several Decades

Changes in Climate…

Higher Temperatures
Increases in short- and long-run temperatures.

Changes in Precipitation
Decreases or increases in snow or rain, and shifts in seasonal precipitation patterns.

Increases in Extreme Events
More frequent or more severe storms, droughts, heat waves.

Climate-Related Changes in Ecosystems
Losses of habitat for species of concern, increases in undesired species (diseases and pests), reductions in ecosystems' ability to produce desired goods and services.

Climate-Related Changes in Social Systems
Increases in climate-related expenditures, behaviors, and institutions, including migrations of population and economic activity away from areas facing high climate-related risks.

…can lead to… Economic Harm

Economic Costs
Reductions in the value of goods and services available to society.

Negative Economic Impacts
Reductions in jobs, income, and related variables.

Increases in Risk and Uncertainty
Risk: Higher probability that harmful events will materialize in the future, or that harmful events will become more severe, or both.

Uncertainty: Diminished ability to anticipate the future.

Increases in Unprecedented Economic Conditions
Information costs, adaptation costs, and increased economic impacts.

Increases in Undesirable Distribution of Economic Well-Being
The effects of climate change accrue in a manner people consider to be unfair and inappropriate.

- *Reduction in the value of goods and services derived from the ecosystem.*

  Changes in climate can diminish an ecosystem's ability to provide valuable goods and services, such as those illustrated in Figure 5. The reduced supply of ecosystem goods and services can reduce the quality of life in a community and increase costs for families, businesses, and governments.

- ***Loss of employment or reduction in employment opportunities.***

  Workers may be harmed when climate-related events, such as floods or wildland fires, cause them to lose their jobs and incomes. The indirect effects of climate change also may lead to similar outcomes, as businesses move away from areas affected by drought to areas with greater availability of water.

- ***Increase in risk or uncertainty about future economic conditions.***

  All else equal, the economic well-being of most families, businesses, and communities is diminished when they experience higher risk, i.e., a higher probability of having bad things happen to them, and greater uncertainty about the probability that such events will occur. The prospect of climate change increases both.

- ***Increase in unprecedented economic conditions.***

  Preparation for and adaptation to new conditions will generate new costs that were not necessary to address similar concerns in the past. Climatic, environmental, and economic variations in the past provide reference for families, businesses and communities to anticipate impacts and adapt their activities. Insofar as climate change generates conditions not experienced in the past, preparation and adaptation will be more costly in terms of requiring new information, institutions, infrastructure, and behaviors.

- ***Undesirable shift in the distribution of wealth, income, and other indicators of economic well-being.***

  Many Americans may experience harm when climate change, or changes in ecosystems and social systems that stem from it, generate economic benefits for one group while imposing costs on another, especially if the latter is poor or otherwise disadvantaged. Similar harm may occur if changes in climate cause the extinction of species or the loss of notable landscapes and other natural resources so they will not be available to future generations.

Washingtonians potentially will incur additional costs not as a result of changes in climate but from activities that contribute to climate change. We examine two of these. One is the cost households and businesses would incur by continuing with technologies and behaviors that inefficiently use energy, even though more-efficient alternatives are available at little or no cost. The other is the health-related cost individuals and families would incur by being exposed to harmful pollutants produced by burning coal to produce electricity.

The analysis we present in Section III focuses on the potential economic costs of changes in climate, ecosystems, and social systems. Washingtonians potentially will incur additional costs not as a result of changes in climate but from activities that contribute to climate change. We examine two of these in Section IV. One is the cost households and businesses would incur by continuing with technologies and behaviors that inefficiently use energy, even though more-efficient alternatives are available at little or no cost. The other is the health-related cost

individuals and families would incur by being exposed to harmful pollutants produced by burning coal to produce electricity. In the following section, we describe our analytical approach to quantifying these costs.

C. Calculating the Business-As-Usual Potential Economic Harm

Our objective is to illustrate the potential economic harm to families, business, and communities in Washington over the next several decades under conditions likely to materialize if society continues to conduct its affairs without an effective program to rein in GHGs. We call this the business-as-usual potential economic harm.

The reasoning underlying the calculation is straightforward. We begin with a credible, quantitative estimate of a climate-related potential worsening in some factor (public health, agricultural production, energy costs, etc.) that contributes to the economic well being of families, businesses, or communities in Washington. We then multiply this times a credible estimate of the per-unit value of the factor. The product is an initial estimate of the potential harm per year.

We complete our calculations by adjusting the initial estimate to represent business-as-usual expectations for three target years: 2020, 2040, and 2080. This adjustment may have three steps. First, if the literature provides estimates of the quantitative impact of climate change for years other than a target year (2020, 2040, or 2080), we linearly interpolate to get a value for a target year when it falls between two values available from the literature, or linearly extrapolate when it falls outside them. For example, the maps in Figure 3 show expected changes in climate from 1990 to 2030. If we were to use the underlying data for our calculation, we would interpolate to find the expected change in 2020, and extrapolate to find the expected change in 2040 and 2080. The values would be 70, 125, and 225 percent of the 1990 to 2030 change. We anticipate that linear interpolative and extrapolative adjustments likely understate and overstate the impact in the target year, respectively, as the underlying climate relationships apparently are nonlinear.

Second, we adjust the initial estimate to account for business-as-usual conditions. This adjustment is required because most of the studies that offer a quantitative estimate of the impact of future climate change employ a scenario of emissions, temperature, and climate that assumes business-as-usual behaviors will not continue (i.e., society begins to act to rein in emissions). Other studies employ middle-of-the-road assumptions about the sensitivity of temperature and climate to GHG emissions, and thus potentially underestimate the possible effects of climate change. Accordingly, we adjust our initial estimate of the potential harm to reflect more closely what it would be under a business-as-usual scenario, based on differences among scenario assumptions of CO_2 concentrations in a given time period. For this exercise, we employ Scenario A1FI, as represented by

Figure 6. Adjustment Factors for Estimating the Business-As-Usual Impacts of Climate Change from Initial Estimates Based on Other Scenarios

Adjustment to A1FI from…	2020	2040	2080
A1B	0.9929	1.0265	1.2311
A2	1.0000	1.0286	1.1447
B1	1.0121	1.0886	1.4879
B2	1.0221	1.1126	1.4293
IS92a	1.0048	1.0611	1.2825

Source: ECONorthwest, with data from IPCC. 2008. *Carbon Dioxide: Projected Emissions and Concentrations*. Retrieved on January 16, 2009, from http://www.ipcc-data.org/ddc_co2.html

the IPCC.[28] We anticipate that using this scenario may still understate the potential harm under business-as-usual conditions, as actual emissions in recent years have exceeded the level embedded in the scenario, and recent research suggests the climate and ecosystem may be more sensitive than previously anticipated to increases in greenhouse gases. Figure 6 lists the adjustment factors applicable to the calculations we present in Section III. As Figure 6 shows, the differences between A1FI and the other emission scenarios are fairly small for 2020 and 2040 but they increase substantially by 2080.

Third, we adjust for anticipated changes in population. This adjustment is appropriate, for example, when a study estimates the future impact of higher temperatures on human morbidity, expressed as a change in the death rate per hundred-thousand population. We adjust the population of Washington, assuming it will experience population growth at the rates estimated by the state through 2030, and for the nation as a whole by the Bureau of Census after 2030.[29]

The product of these steps is a representation of the potential future cost in Washington over the next several decades if the global society should extend a business-as-usual approach to addressing issues associated with climate change. We anticipate that our results will provide a useful introduction to the potential economic consequences of climate change, at a spatial and temporal scale that is useful for many Washingtonians. We also anticipate that our results will provide a useful basis for future investigations to describe these other facets of the economic consequences of climate change:

---

[28] IPCC, Data Distribution Centre. 2008. "Carbon Dioxide: Projected Emissions and Concentrations." December 5. Retrieved January 22, 2009, from http://www.ipcc-data.org/ddc_co2.html

[29] U.S. Department of Commerce, Census Bureau, Population Division. 2000. *Annual Projections of the Total Resident Population as of July 1: Middle, Lowest, Highest, and Zero International Migration Series, 1999 to 2100*. February 14. Retrieved January 16, 2009, from http://www.census.gov/population/projections/nation/summary/np-t1.txt

- A full assessment of all the potential near-term costs in this region, encompassing the many costs that are too poorly understood to describe today.
- An assessment of the potential costs that might materialize outside this region and beyond the next several decades.
- An estimate of the present expected value of the overall potential cost of climate change, reflecting the many alternative ways in which climate change might play out and the probability that each will occur.
- A comparison of the potential costs and benefits associated with different levels of GHG emissions, actions to rein in emissions, or actions to prepare for and adjust to changes in climate that cannot be avoided.
- An estimate of the costs associated with continued dependence on foreign oil, including payments to foreign countries.
- A forecast of what the economy will look like in the future. Such a product would require information about all the potential costs and benefits of climate change, the climate-related actions society might take, and the probabilities associated with different potential outcomes.

Some of the potential costs, called market costs, would materialize as reductions in cash: lower disposable incomes for households, net revenues for businesses, and financial resources for communities. Increased expenditures to cope with climate-related illness, for example, would lower household incomes, while reductions in workers' productivity could also reduce business earnings and public tax revenues. Other potential costs, called non-market costs, would not have an immediate cash effect on incomes, earnings, and public finance. Much of the cost associated with potential reductions in salmon populations, for example, reflects the public's desire to ensure that salmon will be available for future generations to enjoy. Both market and non-market costs are important.

This analysis does not capture all likely costs of climate change for Washington. Insufficient data are available to provide estimates for all of the potential effects scientists have identified, not to mention other effects not yet identified. In addition, Washingtonians likely will experience costs that materialize beyond the state's border: as climate change leads to damage from heat waves, droughts, and storms elsewhere in the country and the world, for example, tax dollars and voluntary contributions will flow out of the state to provide assistance. Today's Washingtonians also will incur some costs from manifestations of climate change that would occur beyond this century. Many Washingtonians strongly want to pass to future generations the beaches, salmon populations, and skiing opportunities that exist today, for example, and will experience reductions in economic well-being should climate change make this unlikely, if not impossible. For all these reasons, we are confident that the actual potential costs of climate change in Washington are larger than the amounts we have calculated.

III. The Potential Economic Costs Associated with the Effects of Climate Change

In this section we present our illustrative calculations of the business-as-usual, potential economic costs to families, businesses, and families in Washington of climate change over the next several decades. In Section IV, we present another set of costs resulting from activities associated with the business-as-usual pathway that contribute to climate change. For each type of cost in this section and in Section IV, we present this information:

Description: We provide a short description of the potential cost, and the change(s) in climate, ecosystems, or social systems that likely will generate it. To facilitate the presentation, we organize the potential costs into these categories:

A. Energy
B. Fish and Wildlife
C. Flood and Storm Damage
D. Food Production
E. Forest and Range Production
F. Recreation
G. Public Health

Assumptions, Data, and Calculation: We describe our assumptions, identify the information we use to quantify the business-as-usual potential cost and estimate its economic value, and demonstrate how we make the calculation.

Results: We report each potential annual cost under a business-as-usual scenario in 2020, 2040, and 2080. Our findings represent the costs expressed in today's dollars, that Washingtonians potentially would bear if they, in concert with others around the world, do not take meaningful action and climate change occurs as represented by the A1FI scenario from the IPCC.

We anticipate that our results generally understate the potential economic costs climate change would impose on Washingtonians if they and the residents of other states and nations continue in a business-as-usual manner. The degree of understatement increases the further one looks into the future. As atmospheric concentrations of GHGs increase, it becomes increasingly likely that higher temperatures will trigger processes that bring about even faster change in climate and initiate irreversible changes in ecosystems and social systems.

We recognize that families, businesses, and communities in Washington may be able to offset or mitigate some of the potential costs in the near term by taking advantage of the potential economic benefits of climate change, such as increased production of some crops or reduced expenditures on heating, that might accompany moderate climate warming. Our aim, however, is not to describe this potential adjustment but to describe the potential consequences if such adjustments are not realized. Further investigation is required to determine the extent of these opportunities, but current evidence suggests they will not fully offset the costs likely to materialize with large increases in atmospheric

concentrations of GHGs. Similarly, adaptation opportunities may not offset the costs of small increases, or even the costs of increases that already have occurred. In sum, our results do not represent a forecast of what will happen, but a description of what might happen. We do not present a forecast because doing so would inject into the calculations many variables about which little is known, at odds with our objective to provide results that are defensible, comprehensible, and useful.

A. Energy

1. Reduced Hydropower Generation

Description

Climate models indicate that changes in the Pacific Northwest's climate likely will cause runoff to increase in winter and decrease in summer, reducing value of hydropower produced by the region's hydroelectric facilities. This reduction in value would ensue due to a mismatch between energy demand, which will increase in summer, and hydropower supplies, which would be lower at the same time.

Assumptions, Data, and Calculation

We apply the findings of a recent regional assessment, which concludes that climate-related changes in streamflow could reduce the annual average production of the hydropower system in the Pacific Northwest by 664 megawatts (MW) in 2020, and 2,033 MW in 2040. We assume the trend will continue and extrapolate to estimate the potential effect in 2080. We estimate Washington's share of the potential reduction in productive capacity to be 355 MW by 2020, 1,100 MW by 2040, and 2,150 MW by 2080, assuming that its current share of production will persist. We estimate the value of the reduction in the production of energy assuming the forgone generation otherwise would have produced electrical energy year-round and applying $48.25 per MW-hour as the estimated bulk electricity price.[a]

Results

Potential Value of Reduction in Hydropower Generation

2020	2040	2080
$150 million	$473 million	$1.12 billion

Source: ECONorthwest

References and Notes

[a] Northwest Power and Conservation Council. 2005. *The Fifth Northwest Electric Power and Conservation Plan; Appendix N*. Retrieved on December 12, 2008, from http://www.nwcouncil.org/energy/ powerplan/5/Default.htm

2. Increased Energy Consumption for Residential Indoor Air Cooling

Description

Higher temperatures during summer months will induce residential consumers to spend more money on air conditioning, decreasing the amount they can spend on other things.

Assumptions, Data, and Calculation

A regional assessment concludes that average July-August temperatures will increase 2.9°C (5.2°F) by 2040, and the associated increases in air conditioning will increase average regional residential demand for energy from the power system by about 200 megawatts (MW).[a] We linearly interpolate to estimate the increase in 2020 and extrapolate to estimate the increase in 2080. Assuming that Washington's 2000 share of regional consumption in 2000 will extend into the future, the additional average demand will be about 47 MW by 2020, 110 MW by 2040, and 280 MW by 2080. We use the average monthly residential prices in Washington between 1990 and 2008 for July and August to estimate consumers' additional cooling costs.[b]

Results

Potential Value of Increased Energy Costs for Air Conditioning

2020	2040	2080
$28 million	$65 million	$164 million

Source: ECONorthwest

This calculation does not include additional expenditures for commercial or industrial consumers, which we expect to be small relative to the potential increase in Washingtonians' home electricity bills.

References and Notes

[a] Northwest Power and Conservation Council. 2005. *The Fifth Northwest Electric Power and Conservation Plan; Appendix N*. Retrieved on December 12, 2008, from http://www.nwcouncil.org/energy/ powerplan/5/Default.htm

[b] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector* (Form EIA-826). Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_ revenue.xls.

3. Increased Energy Loss During Transmission

Description

Higher temperatures during climate-related heat waves will increase the amount of energy lost during electricity-transmission lines. During heat waves, the resistance of overloaded transmission lines increases, causing the grid to convert more electricity into heat, which wastes energy.[a]

Assumptions, Data, and Calculation

We assume summertime consumption of electricity in 2008 will increase in accord with the rate projected by the Energy Information Administration for Washington.[b] We apply a middle-of-the-road estimate of the potential growth in heat-wave days from 1990 to 2030;[c] linearly interpolate and extrapolate to estimate the number of additional days in 2020, 2040, and 2080; and adjust the numbers to estimate what the impact would be under a business-as-usual scenario of climate change. If the additional transmission-line losses during a heat-wave day equal about one-quarter of the electricity being transmitted,[a] the annual losses would total 678,000 MW-hours by 2020, 1.3 million MW-hours by 2040, and 3.75 million MW-hours by 2080. We assume the average summertime wholesale price of electricity, $65 per MW-hour in 2008 dollars, will apply in the future.[d]

Results

Potential Value of Energy Lost in Transmission During Heat Waves

2020	2040	2080
$44 million	$85 million	$241 million

Source: ECONorthwest

References and Notes

[a] Ackerman, F. and E.A. Stanton. 2008. *The Cost of Climate Change: What We'll Pay If Global Warming Continues Unchecked.* Natural Resources Defense Council. May. Retrieved January 20, 2009, from http://www.nrdc.org/globalwarming/cost/cost.pdf

[b] Energy Information Administration. 2008. *EERE State Activities and Partnerships: Electric Power and Renewable Energy in Washington*. Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=WA

[c] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes: An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_ gallery_test/

[d] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector* (Form EIA-826). Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_ revenue.xls

4. Other Potential Costs of Climate Change Related to Energy

Description

Climate change undoubtedly will affect other parts of Washington's energy system but there is little research to substantiate the magnitude of these impacts. For instance, a recent report showed that industry may increase its energy consumption on days with high temperatures, people may consume higher amounts of gasoline due to increased use of air conditioning in their cars, and trucks that transport perishables may increase their fuel use to refrigerate their cargoes. Equally uncertain is how much farmers' energy demand will increase on hot days when they ramp up irrigation to maintain soil moisture.[a] Other potential costs include damages to electricity-transmission equipment during floods and storms, which are expected to become more frequent and intense because of climate change[b] and costs associated with an increased probability of blackouts. A study by researchers at Los Alamos National Laboratory found that an increase in air temperature of 1.5°C (2.7°F) would increase the probability of a blackout occurring from 1 time per year to 8-10 times per year. The researchers estimated economic loss associated with this increased probability at 1 percent of gross state product.[c]

References and Notes

[a] Scott, M.J. and Y.J. Huang. 2007. "Effects of Climate Change in Energy Use in the United States." In Wilbanks, T.J., V. Bhatt, D.E. Bilello (eds.). *Effects of Climate Change on Energy Production and Use in the United States.* A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research.

[b] Bull, S.R., D.E. Bilello, J. Eckmann, et al. 2007. "Effects of Climate Change on Energy Production and Distribution in the United States." In Wilbanks, T.J., V. Bhatt, D.E. Bilello (eds.). *Effects of Climate Change on Energy Production and Use in the United States.* A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research.

[c] Personal communication with Gary Geernaert, Director, Institute of Geophysics and Planetary Physics, Los Alamos National Laboratory. February 6, 2009.

B. Fish and Wildlife

1. Reduced Salmon Habitat and Populations

Description

Warmer stream temperatures resulting from increased global temperatures reduce the amount of habitat that can viably support salmon, reducing salmon populations.

Assumptions, Data, and Calculation

We assume salmon populations will decline proportionate to expected losses of suitable aquatic habitat. An assessment of stream temperatures under an A2 emissions scenario indicates increased warming might reduce salmon habitat in Washington by 5, 13, and 22 percent by 2030, 2060, and 2090, respectively.[a] We interpolate and adjust the percentages to reflect the potential changes in 2020, 2040, and 2080, as well as the A1FI scenario. To determine the value of the loss of salmon, we rely on a study of Washingtonian's willingness to pay for changes in the size of anadromous fish runs.[b] The methodology in this study was vetted and adopted by a panel of economists for Washington State's Columbia River Initiative, who recommended that "any reliable estimates of impacts on salmon and steelhead should be assigned values based upon the methodology."[c] Using results from Layton et al., we derive the value Washingtonians place on the potential loss of salmon populations in Washington in 2020, 2040, and 2080, adjusting for growth in households over time.

Results

Potential Value of Reduced Salmon Populations

2020	2040	2080
$531 million	$1.4 billion	$3 billion

Source: ECONorthwest

These results are based on an analysis of the value of increasing salmon stocks, which diminishes as fish populations become more robust. Climate change impacts reduce stocks, which should lead to an increasing, rather than decreasing value as salmon become more rare. Consequently, these estimates likely understate the value of salmon losses. The results also probably understate the total impact of climate change on salmon populations, because they overlook stresses from potential changes in ocean conditions, climate-related increases in disease, and reduced effectiveness of habitat restoration efforts, among other effects.[d] They also may not fully account for ecosystem goods and services other than salmon that would be lost as changes in climate affect salmon habitat.

References and Notes

[a] O'Neal, K. 2002. *Effects of Global Warming on Trout and Salmon in U.S. Streams.* Defenders of Wildlife and Natural Resources Defense Council. May.

[b] Layton, D.F., G.M. Brown, and M.L. Plummer. 1999. *Valuing Multiple Programs to Improve Fish Popu*lations. April. Retrieved January 24, 2009, from http://www.econ.washington.edu/user/gbrown/valmultiprog.pdf

[c] Huppert, D., G. Green, W. Beyers et al. 2004. *Economics of Columbia River Initiative*. Washington Department of Ecology and CRI Economics Advisory Committee. January 12.

[d] *See*, for example, Battin, J., M.W. Wiley, M.H. Ruckelshaus et al. 2007. "Projected Impacts of Climate Change on Salmon Habitat Restoration." *Proceedings of the National Academy of Sciences* 104 (16): 6720-6725. Retrieved January 23, 2009, from http://www.pnas.org/content/104/16/6720.full.pdf+html; Independent Scientific Advisory Board. 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. ISAB Climate Change Report ISAB 2007-2. Northwest Power and Conservation Council. May 11; and Richter, A. and S.A. Kolmes. 2005. "Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest." *Reviews in Fisheries Science* 13: 23-49.

2. Other Potential Costs Related to Impacts of Climate Change on Fish and Wildlife

Description

Increased temperatures and changes in precipitation are likely to impact many species, other than salmon in Washington. Scientists have found evidence that climate change can result in changes in species' range, abundance, phenology (timing of an event, such as migration), morphology and physiology, and community composition, biotic interactions and behavior.[a] Many of these impacts on populations and ecosystems would potentially result in economic harm. For example, sea level rise, changes in ocean currents, and increases in ocean acidity are likely to impact the species and ecological communities in Washington's coastal and near-shore environments, including coastal wetlands and rocky intertidal areas. Disruptions in these ecosystems could adversely affect Washington's commercial and recreation fishing industries.[b] Temperature increases also are likely to disrupt montane ecosystems, particularly those associated with glaciers and snowpack. Some invasive species and pests, which have historically been limited by temperature or moisture, may be able to expand their range and pose new threats to native populations of fish and wildlife.[c] Data are not available, however, to allow us to estimate the costs associated with these and other potential fish and wildlife-related impacts.

References and Notes

[a] Root, T.L. and S.H. Schneider. 2002. "Climate Change: Overview and Implications for Wildlife." In S.H. Schneider and T.L. Root (eds.). *Wildlife Responses to Climate Change: North American Case Studies*. Island Press: Washington D.C.

[b] Stanford, E. 2002. "Community Responses to Climate Change: Links Between Temperature and Keystone Predation in a Rocky Intertidal System." In S.H. Schneider and T.L. Root (eds.). *Wildlife Responses to Climate Change: North American Case Studies*. Island Press: Washington D.C.

[c] Janetos, A.C. 2008. "Chapter 5: Biodiversity." In Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

C. Flood and Storm Damage

1. Costs Related to Sea-Level Rise

Description

Rising global temperature leads to increased sea levels, which will inundate valuable property and structures.

Assumptions, Data, and Calculation

No direct estimates of the value of coastal property damage due to sea-level rise exist for Washington, so we apply estimates for California.[a,b] After adjusting for differences in general coastline length, median home value, and coastal population density, the potential damage for Washington in 2070 would be $74 million per year, under the A2 scenario for future emissions and climate change.[c] Hence, we linearly interpolate and extrapolate to obtain estimates for 2020, 2040, and 2080, and adjust to represent the A1FI scenario.

Results

Potential Value of Property Damage from Sea Level Rise

2020	2040	2080
$21 million	$44 million	$97 million

Source: ECONorthwest

These results embody considerable uncertainty, as there exists no direct measurement of the potential damage from climate-related increases in sea level and storm surges. We do not adjust for the current tectonic trend of uplift for northwestern Olympic peninsula, subsidence for south Puget Sound, and little noticeable movement for the rest of Washington coastline.[d] The estimate does not account for the interactive effects of higher sea levels and increased storm surges that would further increase damages. Sea-level rise and increased storm surges would generate increased risk of flood and storm damage for inland areas reached by the tides such as downtown Olympia, Tacoma, Seattle, and other urban areas.

References and Notes

[a] Neumann, J., D. Hudgens, J. Herr, and J. Kassakian. 2003. "Market Impacts of Sea Level Rise on California Coasts." 2003. Appendix XIII in Wilson, T., L. Williams, J. Smith, and R. Mendelsohn, *Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy*. Consultant report 500-03-058CF to the Public Interest Energy Research Program, California Energy Commission.

[b] Kahrl, R. and D. Roland-Holst. 2008. *California Climate Risk and Response.* Research Paper No. 08102801. University of California. November. Retrieved January 23, 2009, from http://are.berkeley.edu/~dwrh/CERES_Web/Docs/California%20Climate%20Risk%20and%20Response.pdf.

[c] Washington's general coastline is 19 percent as long as California's, its 2000 median home value was 80 percent, and its 2008 coastal population density is 50 percent. National Oceanic and

Atmospheric Administration. 2004. *Population Trends Along the Coastal United States: 1980-2008.*Retrieved February 6, 2009, from http://oceanservice.noaa.gov/programs/mb/supp_cstl_population.html.

[d] Mote P., Petersen A., Reeder S., Shipman H., and Whitely-Binder L. 2008. *Sea Level Rise in the Coastal Waters of Washington State.* A report by the University of Washington Climate Impacts Group and the Washington Department of Oceanography.

2. Costs Related to Extreme Weather Events

Description

Climate change is expected to increase storm severity and the frequency of extreme storm events, including high winds, flooding, lightning and fire. Storm events will have direct property-damage effects, as well as increased storm-related injuries and fatalities.[a]

Assumptions, Data, and Calculation

The National Oceanic and Atmospheric Administration's National Weather Service and National Climatic Data Center collect information on fatalities, injuries, property damage, and crop damage resulting from extreme weather events, including weather-influenced wildfires.[b] The U.S. Climate Change Science Program provides rough estimates for increases in extreme weather events, including an increase in frequency of extreme precipitation events by 2.5 times under the A1B scenario by 2100. Wildfire forecasts for the west follow similar increases rates with two to five times the acreage burnt at the end of the 20th century by late in the 21st century.[c] Using the average total property and crop damage estimates from 1996 to 2007, we linearly interpolate an increase in these impacts 2.5 times by 2100 for 2020, 2040 and 2080, and adjust for the A1FI scenario. We do not monetize fatalities and injuries, but the increase by 2080 would be 20 fatalities and 58 injuries due to extreme weather events. These include heat-related effects that are further described in the *Public Health* section below.

Results

Potential Value of Property and Crop Damage from Extreme Weather Events

2020	2040	2080
$51 million	$106 million	$255 million

Source: ECONorthwest

References and Notes

[a] U.S. Climate Change Science Program. 2008. Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. In Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple and W.L. Murray (eds.). *Weather and Climate Extremes in a Changing Climate.* Synthesis and Assessment Product 3.3. Washington, DC.

[b] Consistent damage cost estimates are available from 1996-2007. National Weather Service and National Climatic Data Center. 1996-2008. "Summary of Hazardous Weather Fatalities, Injuries and Damage Costs by State." *Natural Hazard Statistics.* Accessed February 3, 2009 from http://www.weather.gov/os/hazstats.shtml#. Adjusted to 2008 dollars.

[c] Mckenzie, D., Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

3. Other Potential Costs from Climate-Related Sea-Level Rise and Extreme Weather

Description

The combined impact of multiple storm and ocean effects from climate change is likely to be greater than the sum of the individual impacts, as interactions increase severity. Similarly, damages from storm events tend to increase relative to storm severity more than linearly.[a] Thresholds exist in current infrastructure designed to protect property and people from storm impacts.

Sea-level rise and extreme weather events will impact natural structures and functions and the resulting ecosystem services communities rely upon. Storm events increase erosion, create landslides, damage forests and habitat, and injure wildlife.

References and Notes

[a] U.S. Climate Change Science Program. 2008. "Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands." In Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple and W.L. Murray (eds.). *Weather and Climate Extremes in a Changing Climate.* Washington, DC.

D. Food Production

1. Reduced Beef Production

Description

Higher temperatures slow the rate of growth for beef cattle and reduce the production and sales of ranches and feedlots.

Assumptions, Data, and Calculation

We assume ranchers and feedlot operators will continue the practices of 2007 and that prices will remain at 2007 levels, which produced sales of $732 million.[a] We also assume that the temperature increases accompanying a doubling of carbon dioxide emissions would increase the time required for a cow to reach finished weight in a feedlot in the western United States by 2.5 percent; a tripling might increase the time by 15 percent.[b] The potential harm equals the value of annual beef production times the percentage loss of production from climate change, adjusted to reflect potential doubling of carbon dioxide emissions by 2040 and tripling by 2080, under scenario A1FI.

Results

Potential Value of Reduced Beef Production

2020	2040	2080
$11.6 million	$18.3 million	$91.5 million

Source: ECONorthwest

Potential losses would be greater if ranchers tried to expand their production, so that higher temperatures would affect the maturation of a larger number of animals. Also, additional beef production losses, especially for range-fed cattle, may occur as range productivity declines with increasing temperatures and reduced water availability during summer months.[c]

References and Notes

[a] United States Department of Agriculture, National Agricultural Statistics Service. 2008. *Meat Animals Production, Disposition, and Income: 2007 Summary*. April.

[b] Frank, K.L. 2001. *Potential Effects of Climate Change on Warm Season Voluntary Feed Intake and Associated Production of Confined Livestock in the United States*. Masters of Science Thesis. Kansas State University, Manhattan. As cited in Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

[c] Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

2. Reduced Wheat Production

Description

Temperatures above 5°C (9°F) reduce the yields of winter wheat production.

Assumptions, Data, and Calculation

We assume farmers will continue with the practices that produced the 2007 crop and that prices will remain at 2007 levels, which produced a crop worth about $822 million.[a] We apply the results of a study that indicates wheat production in eastern Washington will decline by approximately 20 percent with a 5°C (9°F) increase in global mean temperature, and an atmospheric carbon-dioxide concentration of 365 ppm.[b] We extrapolate and adjust this finding to estimate the potential reduction in production under the A1FI scenario in 2080, the only one of our target years that would experience a temperature increase of at least 5°C (9°F). The potential harm equals the value of the potential reduction in wheat production.

Results

Potential Value of Reduced Wheat Production

2020	2040	2080
--	--	$164 million

Source: ECONorthwest

We do not include costs for 2020 and 2040, because reduced wheat production does not occur until temperatures reach approximately 5°C (9°F). This magnitude of temperature increase is not expected to occur in the A1FI scenario until the later part of the 21st century.

References and Notes

[a] U.S. Department of Agriculture, National Agricultural Statistics Service. 2008. *U.S. & All States Data – Winter Wheat* [2007, Value of Production, All Winter Wheat, Washington].

[b] Brown, R.A. and N.J. Rosenberg. 1999. "Climate Change Impacts on the Potential Productivity of Corn and Winter Wheat in their Primary United States Growing Regions." *Climatic Change* 41: 73-107. Although the authors hold carbon dioxide concentrations constant to control for any so-called fertilization effect, in which higher concentrations of CO_2 accelerate plant growth, they conclude that even at concentrations of carbon dioxide at 750 ppm, a 5°C (9°F) increase in temperature causes wheat yields to decline.

3. Reduced Agricultural Output in the Yakima Basin

Description

Decreased summer water supplies negatively impact irrigated agriculture in the Yakima basin, that comprises a great number of high-value crops.

Assumptions, Data, and Calculation

A recent study of the impact of climate change on the irrigated agriculture in the Yakima Valley found that water shortages in spring and summer reduce the crop yields by $66 million by 2060.[a] The results were modeled under a scenario similar to A1B, with temperature increases of 2°C (3.6°F) and CO_2 concentrations of 560 ppm, assuming no adaptation other than early planting. We linearly interpolate and extrapolate to estimate these losses in 2020, 2040, and 2080 and adjust the numbers to estimate what the impact would be under a business-as-usual approach to climate change. The authors of the study recognize that their results are probably underestimates since the analysis does not account for damages to fruit trees and grape vines from low-water years that carry over into the future.

Results

Potential Value of Reduced Agricultural Output in the Yakima Basin

2020	2040	2080
$23 million	$46 million	$108 million

Source: ECONorthwest

References and Notes

[a] Scott, M.J., L.W. Vail, C. Stöckle, and A. Kemanian. No date. *Climate Change Impact on Agriculture in the Yakima Valley, Washington State.* Battelle Pacific Northwest Division. Working Paper.

4. Other Potential Costs from the Effects of Climate Change on Food Production

Description

Changes in precipitation and temperature are likely to impact Washington's agricultural industry in ways other than those reported above. For example, higher temperatures may reduce the yield or cease production altogether in some regions of some additional crops, such as grapes, apples, cherries, and potatoes. Changes in temperature may also increase the occurrence of pests and plant diseases, requiring famers to expend more resources on pest and disease management.[a] Increased evaptranspiration and reduced availability water supplies may lead to reductions in yield for a variety of crops due to water stress. Insufficient data are available, however, to allow us to estimate the costs associated with these and other potential food-production-related impacts.

References and Notes

[a] Hatfield, J.L. 2008. "Chapter 2: Agriculture." In Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

E. Forest and Range Production

1. Lost Forest Assets from Wildland Fires

Description

Wildland fires become more frequent and severe as climate change increases temperatures and aridity, and accelerates tree mortality from insects and disease. When forests burn, they lose their ability to produce many goods and services, but data are available only to estimate the loss assuming the forest would be managed to produce timber.

Assumptions, Data, and Calculation

Projections for climate-related changes in temperature and precipitation suggest that, relative to the 20th century, wildfires in Washington will burn 50 percent more acreage per year by 2020 and double the acreage by 2040.[a] On average, 73,000 acres of federal land burned annually from 1988 to 1999.[b] We assume that, if non-federal lands burned at the same rate, the average would have been 166,000 acres. State and federal land make up 63 percent of all forestland in Washington.[c] A 50 percent increase in acreage burned by 2020 would be a marginal increase of 84,000 acres, and a 100 percent increase by 2040 would be a marginal increase of 166,000 acres. We assume the value of lost goods and services when a forest burns is at least $1,000 per acre, a general estimate for the value of lost timber.[d] We use the projected increase in burn rates for the A2 scenario, which we linearly extrapolate for A1FI and 2080.

Results

Potential Value of Lost Forest Assets from Increased Forest Fires

2020	2040	2080
$84 million	$171 million	$380 million

Source: ECONorthwest

These results do not include the value of ecosystem services distinct from the production of timber that would be lost with increased forest fires. The loss of structures to fire is included under extreme weather events because the data are collected by the National Weather Service and aggregated with other weather-related structural losses.

References and Notes

[a] Mckenzie, D. Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

[b] Climate Leadership Initiative, Institute for a Sustainable Environment, University of Oregon. 2006. *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities.* Retrieved February 6, 2009, from http://www.ecy.wa.gov/climatechange/economic_impacts.htm

[c] National Association of State Foresters. *2006 State Forestry Statistics.* http://www.stateforesters.org/files/2006%20State%20Forestry%20Statistics-Web-Final.pdf

[d] Titus, J.G. 1992. "The Costs of Climate Change to the United States." In: Majumdar, S.K., L.S. Kalkstein, B. Yarnal, E.W. Miller, and L.M. Rosenfeld (eds). *Global Climate Change: Implications, Challenges, and Mitigation Measures*. Pennsylvania Academy of Sciences.

2. Increased Control Expenditures Related to Wildland Fire

Description

Wildfires become more frequent and severe as climate change increases temperatures and aridity, and accelerates tree mortality from insects and disease. As wildland fires become more widespread Washingtonians will incur additional fire-control costs.

Assumptions, Data, and Calculation

Projections for forests in Washington based on temperature and precipitation suggest that wildland fires will impact 50 percent more acreage than during the 20th century by 2020 and a doubling by 2040.[a] We assume suppression costs will increase proportional to acres burned, fire suppression costs will increase as well, or alternatively.[b] We base our calculation on these rates and historical expenditures.[c]

Results

Potential Value of Increased Control Expenditures for Wildland Fires

2020	2040	2080
$18 million	$37 million	$82 million

Source: ECONorthwest

References and Notes

[a] Mckenzie, D. Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

[b] National Association of State Foresters. *2006 State Forestry Statistics.* http://www.stateforesters.org/files/2006%20State%20Forestry%20Statistics-Web-Final.pdf

[c] Climate Leadership Initiative, Institute for a Sustainable Environment, University of Oregon. 2006. *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities.* Retrieved February 6, 2009, from http://www.ecy.wa.gov/climatechange/economic_impacts.htm

3. Other Potential Costs from the Effects of Climate Change on Forests and Range

Description

Numerous studies based on climate forecasts as well as impacts already occurring indicate that climate change is likely to increase the forest damages resulting from disease and pests such as the mountain pine beetle. Mountain pine beetle populations are historically held in check by cold winters. As the frequency of cold winters decreases, the mountain pine beetle's exponential growth rate goes unfettered and leads to rapid and widespread tree mortality, as seen throughout the western United States and Canada.[a] The mountain pine beetle is now beginning to show a potential to jump to non-pine species after locally exhausting the supply of pines. Mountain pine beetles could conceivably impact the majority of remaining forest in Washington. Mountain pine beetles can interact with other effects that stress forests in Washington such as increased temperatures and decreased soil moisture to hasten tree mortality.[b]

Lost forest will lead to lost ecosystem services for Washintonians, such as water filtration, water storage and air filtration. The City of Portland, Oregon avoids purchasing a $200 million filtration treatment system for its water supply by protecting 102 square miles of its watershed. This equates to an avoided cost benefit of $3,000 per acre for water filtration services.[c] We do not make an estimate of the total value of ecosystem services lost with forest loss because there currently are not equivalent identifications of demand for the state of Washington as a whole. While the forest value from Portland is likely high for most forest in Washington, it is a value for only one ecosystem service, and as the population grows, demand for these services will increase as well.

References and Notes

[a] Carroll, A.L., J. Régnière, J.A. Logan et al. 2006. *Impacts of Climate Change on Range Expansion by the Mountain Pine Beetle*. Working Paper No. 2006-14. Canadian Forest Service, Natural Resources Canada, Pacific Forestry Centre. Retrieved May 18, 2007, from http://mpb.cfs.nrcan.gc.ca/research/projects/1-02_e.html

[b] van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, et al. 2009. "Widespread Increase of Tree Mortality Rates in the Western United States." *Science* 323: 5913.

[c] ECONorthwest, with data from the Portland Water Bureau, http://www.portlandonline.com/water/index.cfm?c=29784; and Krieger, D. 2001. *Economic Value of Forest Ecosystem Services: A Review*. The Wilderness Society.

F. Public Health

1. Increased Low-Altitude Ozone

Description

Increased temperatures favor the production of low-altitude ozone, which negatively impacts the health of humans that live in urban areas and creates costs associated with increased rates of morbidity, premature mortality, and lost worker productivity.[a]

Assumptions, Data, and Calculation of Mortality

We apply findings from an assessment of the A2 scenario, which indicate elevated ozone levels related to climate change could increase nonaccidental mortality by 0.27 percent by 2050.[b] We linearly interpolate and extrapolate to estimate the effects in 2020, 2040, and 2080, then adjust for higher temperatures expected in the A1FI scenario. We assume that, absent climate change, nonaccidental mortality would rise proportional to future increases in Washington's metropolitan population and estimate that the higher ozone concentrations would increase annual mortality by 56 deaths in 2020, 128 in 2040, and more than 335 in 2080.[c] We estimate the value of the additional premature deaths using EPA's current estimate of the value of a statistical life.[d]

To calculate the potential costs of increased morbidity we rely on the results of an employee survey, that estimated expenditures associated with conditions, such as allergies, asthma, and other respiratory affections, incurred by employees, including those who do not suffer from the particular condition.[e] Using these results, we first estimate what the costs would be absent climate change by assuming that current costs of hospitalization for conditions related to ozone in metropolitan areas will increase proportionate to expected growth in Washington's labor force. We then apply the results from a study that concluded current hospitalization costs related to high ozone concentrations in California might triple under the A2 scenario,[f] and make adjustments to reflect the higher temperatures expected under the A1FI scenario. The results represent the potential increases in medical costs for 2020, 2040, and 2080.

To estimate the value of increases in lost productivity as more workers become ill from climate-related increases in ozone concentrations, we rely on the findings of the same employee survey[e] and first assume that, absent climate change, current levels of lost productivity in metropolitan areas would grow proportional to expected growth in Washington's labor force. We then apply the results of a study that estimated the productivity losses in California related to ozone could increase 62 percent under the A2 scenario,[f] and make adjustments to reflect the higher temperatures expected under the A1FI scenario. The results represent the potential increases in workers' lost productivity for 2020, 2040, and 2080.

Results

Potential Health-Related Costs from Increased Low-Altitude Ozone

2020	2040	2080
Value of Premature Deaths		
$388 million	$882 million	$2.3 billion
Value of Increased Morbidity		
$70 million	$86 million	$126 million
Value of Lost Productivity		
$731 million	$892 million	$1.3 billion
TOTAL		
$1.2 billion	$1.9 billion	$3.7 billion

Source: ECONorthwest

The calculation of increased morbidity costs does not account for costs that would occur outside a hospital (in-patient or emergency room) or for the effects of higher ozone concentrations on all sensitive groups, like children and elderly.

A newly released assessment of the impacts of climate change in Washington by the Climate Impacts Group similarly finds that higher temperatures will lead to increased ozone concentrations, which in turn will result in increased mortality in the state. The report's forecast is higher than our estimates giving us confidence that probably the impacts of climate-induced increases in ozone concentrations will be at least equal to those we calculate above. The assessment also does not estimate increased costs of morbidity and lost productivity related to higher ozone levels.[g]

EPA's value of statistical life represents the value that people, on average, are willing to pay to avoid premature mortality from exposure to harm, be it pollution, accidents, etc. Researchers have argued that a more appropriate measure to value a life is the willingness to accept fatal consequences of exposure to harm. This value is usually higher than the willingness to pay.[h] This means that the total value of increased mortality from high ozone concentrations, that we estimate above, understate the actual value society places on deaths froom climate change.

References and Notes

[a] Ebi, K.L., J. Balbus, P.L. Kinney et al. 2008. "Effects of Global Change on Human Health." In J.L. Gamble, ed., *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems.* Washington, D.C.: U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency. Retrieved December 23, 2008, from http://www.climatescience.gov/Library/sap/sap4-6/final-report/sap4-6-final-all.pdf.

[b] Bell, M.L., R. Goldberg, C. Hogrefe et al. 2007. "Climate Change, Ambient Ozone, and Health in 50 U.S. Cities." *Climatic Change* 82: 61-76.

[c] Washington State Department of Health, Center for Health Statistics. 2006. *Death Data. Table A1: Age-Adjusted Mortality Rates and Life Expectancy by Sex for Residents.* Retrieved on January 6, 2009, from http://www.doh.wa.gov/EHSPHL/CHS/chs-data/death/dea_VD.htm; Office of Financial Management. 2008. *Annual April 1 Population and Components of Population Change: 1990 to 2030*. Retrieved on January 6, 2009, from http://www.ofm.wa.gov/pop/stfc/stfc2008/stfc2008 components.xls; and Office of Financial Management. 2007. *Washington State County Growth Management Population Projections: 2000 to 2030.* Retrieved on January 13, 2009, from http://www.ofm.wa.gov/pop/gma/gmhsingle.xls

[d] Borenstein, S. 2008. *American Life Worth Less Today.* July 10. Associated Press. Retrieved on December 23, 2008, from http://www.huffingtonpost.com/2008/07/10/american-life-worth-less_n_112030.html

[e] Goetzel, R.Z., S.R. Long, R.J. Ozminkowski et al. 2004. "Health, Absence, Disability, and Presenteeism Cost Estimates of Certain Physical and Mental Health Conditions Affecting U.S. Employers." *Journal of Occupational and Environmental Medicine* 46: 398-412.

[f] Kahrl, F. and D. Roland-Holst. 2008. *California Climate Risk and Response*. Department of Agricultural and Resource Economics, University of California Berkeley. November. Retrieved January 7, 2009, from http://are.berkeley.edu/~dwrh/CERES_Web/Docs/California%20Climate %20Risk%20and%20Response.pdf.

[g] Jackson, J.E., M.G. Yost, C. Karr, et al. 2009. "Public Health Impacts of Climate Change in Washington State: Projected Mortality Risks Due to Heat Events and Air Pollution." In *Washington Climate Change Impacts Assessment.* Climate Impacts Group. Retrieved February 11, 2009, from http://cses.washington.edu/cig/files/waccia/wacciafullreport.pdf

[h] *See*, for example, Guria, J., J. Leung, M. Jones-Lee, and G. Loomes. 2005. "The Willingness to Accept Value of Statistical Life Relative to the Willingness to Pay Value: Evidence and Policy Implications." *Environmental and Resource Economics* 32: 113-127.

2. Increased Heat Waves

Description

Additional heat waves (days with temperatures consistently above a threshold specific to different geographic areas) are expected to increase mortality rates and medical costs of those already suffering from cardiovascular, cerebrovascular, and respiratory diseases.[a] They also will reduce work productivity, household productivity, and the value of leisure time.

Assumptions, Data, and Calculation

We apply to the entire Washington state the results of a recent study, which estimated climate-related heat waves would cause an additional 14 deaths in Portland, Oregon, by 2055 under the A2 scenario,[b] and make adjustments to estimate the number of additional deaths in 2020, 2040, and 2080 under the A1FI scenario. We estimate the value of the additional premature deaths using EPA's current estimate of the value of a statistical life.[c]

To calculate additional medical and other costs, we multiplied Washington's expected future populations times the per capita daily costs for hospitalization, emergency-room visits, and follow-up medical costs during the 2006 heat wave in California.[d] We estimate the additional climate-related costs by applying the results of a study that projected Washington would experience an additional 14 heat-wave days by 2030 under the A1B scenario[e] and making adjustments to estimate the number of additional deaths in 2020, 2040, and 2080 under the A1FI scenario.

Results

Potential Value of Health-Related and Other Costs of Heat Waves

2020	2040	2080
Value of Premature Deaths		
$114 million	$263 million	$618 million
Value of Increased-Medical Care Costs		
$15 million	$31 million	$86 million
Value of Other Costs		
$1 million	$3 million	$8 million
TOTAL		
$130 million	$297 million	$712 million

Source: ECONorthwest

Heat-wave statistics show they cause more deaths than all other natural disasters in the US. Death certificates systematically fail to represent high temperatures as the death cause during heat waves, however, and a full accounting would increase the mortality numbers, perhaps by 54 percent.[f]

Recently the Climate Impacts Group of the University of Washington released anassessment of the impacts of climate change in Washington. The authors similarly find that higher temperatures will lead to increased heat waves, which in turn will result in increased mortality in the state. The report's forecast is higher than our estimates giving us confidence that probably the impacts of climate-induced heat waves will be at least equal to those we calculate above. The assessment also does not estimate increased costs of morbidity and lost productivity related to higher ozone levels.[g]

EPA's value of statistical life represents the value that people, on average, are willing to pay to avoid premature mortality from exposure to harm, be it pollution, accidents, etc. Researchers have argued that a more appropriate measure to value a life is the willingness to accept fatal consequences of exposure to harm. This value is usually higher than the willingness to pay.[h] This means that the total value of increased mortality from high ozone concentrations, that we estimate above, understate the actual value society places on deaths froom climate change.

References and Notes

[a] Knowlton, K., M. Rotkin-Ellman, G. King et al. 2009. "The 2006 California Heat Waves: Impacts on Hospitalizations and Emergency Department Visits." *Environmental Health Perspectives* 117: 61-67.

[b] Kalkstein, L.S. and J.S. Greene. 2007. *An Analysis of Potential Heat-Related Mortality Increases in U.S. Cities under a Business-as-Usual Climate Change Scenario*. Environment America. September 6. Retrieved January 13, 2008, from http://www.environmentamerica.org/uploads/Js/tF/JstFE5oHrsQJi5ifIA931Q/Heat-Mortality_Report_.pdf.

[c] Borenstein, S. 2008. *American Life Worth Less Today.* July 10. Associated Press. Retrieved on December 23, 3008, from http://www.huffingtonpost.com/2008/07/10/american-life-worth-less_n_112030.html

[d] Srinivasan, T. 2008. *Cost of Excess Hospitalization and Emergency Department Visits for the 2006 California Heat Wave*. Natural Resources Defense Council. August 28. Retrieved January 11, 2009, from http://docs.nrdc.org/health/files/hea_08082601a.pdf.

[e] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes: An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_gallery_test/.

[f] Luber, G.E. and C.A. Sanchez. 2006. "Heat-Related Deaths—United States, 1999-2003." *Morbidity and Mortality Weekly Report* 55 (29): 796-798. Retrieved January 13, 2009, from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5529a2.htm

[g] Jackson, J.E., M.G. Yost, C. Karr, et al. 2009. "Public Health Impacts of Climate Change in Washington State: Projected Mortality Risks Due to Heat Events and Air Pollution." In *Washington Climate Change Impacts Assessment.* Climate Impacts Group. Retrieved February 11, 2009, from http://cses.washington.edu/cig/files/waccia/wacciafullreport.pdf

[h] *See*, for example, Guria, J., J. Leung, M. Jones-Lee, and G. Loomes. 2005. "The Willingness to Accept Value of Statistical Life Relative to the Willingness to Pay Value: Evidence and Policy Implications." *Environmental and Resource Economics* 32: 113-127.

3. Other Potential Costs from the Efffects of Climate Change on Human Health

Description

Impacts of climate change on human health are not restricted to those caused by high levels of ozone or heat. Studies have shown that climate change will make wider areas hospitable to vectors that produce diseases, such as the West Nile virus, encephalitis, and Lyme disease. At the same time, water- and food-borne diseases likely will increase in incidence and cases of *Giardia, salmonellosis, E. coli* will become more frequent.[a]

We have found no data to quantify these future impacts associated with climate change but the lack of quantifiable information does not mean that the value is zero.

References and Notes

[a] Ebi, K.L., J. Balbus, P.L. Kinney et al. 2008. "Effects of Global Change on Human Health." In J.L. Gamble, ed., *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems.* Washington, D.C.: U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency. Retrieved December 23, 2008, from http://www.climatescience.gov/Library/sap/sap4-6/final-report/sap4-6-final-all.pdf.

G. Recreation

1. Reduced Opportunities for Snow-Related Recreation

Description

Higher temperatures reduce snowfall and accumulation, shortening the ski season, degrading skiing conditions, and reducing the value associated with the ski industry.

Assumptions, Data, and Calculation

We assume that, absent climate change, downhill skiing participation would grow from the 2006 ski season level, 2,137,930 skier-days,[a] at the same rate as the general population is expected to grow, and that the average expenditures and consumer surplus per skier day would remain at $70[b] and $28[c] per day, respectively. We assume that the ski season will shrink 14 percent by 2020 and 30 percent by 2040,[d] based on a temperature increase rate associated with business-as-usual emissions. We assume the number of user-days, expenditures, and consumer surplus shrinks proportionately. We linearly extrapolate to estimate the reductions for 2080. The potential harm equals the number of user-days times the expenditures and consumer surplus per day times the percentage loss of recreation opportunity from climate change.

Results

Potential Value of Reduced Downhill Skiing Recreation

2020	2040	2080
$35.5 million	$90.6 million	$247 million

Source: ECONorthwest

Industry officials suggest that once the snow-recreation season is shortened to the extent indicated for 2080, snow-related recreation businesses, and the downhill skiing businesses in particular, likely would not be viable and would close.[e]

References and Notes

[a] Washington State Parks. 2007. *Market and Economics Analysis for the Mt. Spokane Ski and Snowboard Park Master Facilities Plan.* April.

[b] Berry, M. 2008. *Overview of the U.S. Ski Industry.* National Ski Areas Association. June 27.

[c] Loomis, J. and J. Crespi. 1999. "Estimated Effects of Climate Change on Selected Outdoor Recreation Activities in the United States." In Mendelsohn, R. and J. Neumann (eds.). *The Impact of Climate Change on the United States Economy.* Cambridge University Press: Cambridge, UK.

[d] Casola, J.H., J.E. Kay, A.K. Snover et al. 2005. *Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture.* Climate Impacts Group, University of Washington, Seattle

[e] Zimmerman, G., C. O'Brady, and B. Hurlbutt. 2006. *Climate Change: Modeling a Warmer Rockies and Assessing the Implications.* The 2006 Colorado College State of the Rockies Report Card.

2. Reduced Opportunities for Cold-Water Angling

Description

Increased stream temperatures reduce the amount of habitat that can viably support salmon, reducing the contribution of cold-water angling to the economy.

Assumptions, Data, and Calculation

We assume the value of cold-water angling will decline proportionate to expected losses of aquatic habitat for salmon and trout. An assessment of the A2 emissions scenario indicates increased warming might reduce salmon habitat in Washington by 5, 13, and 22 percent by 2030, 2060, and 2090, respectively.[a] We interpolate and adjust the percentages to reflect the A1FI scenario, and apply them to 3,526,000,[b] the number of stream-based angling days in Washington in 2006, to estimate the reductions in angling in 2020, 2040, and 2080. We adjust for population growth in 2020, 2040, and 2080 and value the reductions applying the estimated consumer surplus and expenditures per salmon-angler per day: $140[c] and $118,[b] respectively.

Results

Potential Value of Reduced Cold-Water Angling

2020	2040	2080
$35.7 million	$107 million	$356 million

Source: ECONorthwest

These results may overstate the potential harm by applying values associated with salmon angling to trout angling. They probably underestimate the total harm from climate change, insofar as it also might lead to degraded ocean conditions, increased incidence of disease, and other factors that would affect future salmon and trout populations.[d]

References and Notes

[a] O'Neal, K. 2002. *Effects of Global Warming on Trout and Salmon in U.S. Streams.* Defenders of Wildlife and Natural Resources Defense Council. May.

[b] U.S. Fish and Wildlife Service. 2008. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Washington.* Report No. FHW/06-WA. April.

[c] Ransom, M.M. 2001. *Economic Impacts of Salmon Fishing.* U.S. Department of Agriculture, Natural Resources Conservation Service. February 12.

[d] Battin, J., M.W. Wiley, M.H. Ruckelshaus, et al. 2007. "Projected Impacts of Climate Change on Salmon Habitat Restoration." *Proceedings of the National Academy of Sciences of the United States of America* 104 (16): 6720-6725. from http://www.pnas.org/content/104/16/6720.full.pdf+html; Independent Scientific Advisory Board. 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. ISAB Climate Change Report ISAB 2007-2. Pacific Northwest Power and Conservation Council. May 11; and Richter, A. and S.A. Kolmes. 2005. "Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest." *Reviews in Fisheries Science* 13: 23-49.

3. Reduced Opportunities for Reservoir Recreation

Description

Increased temperatures and changes in precipitation are predicted to affect the way the Columbia River reservoir system is operated, reducing water levels and opportunities for reservoir recreation in some years on Lake Roosevelt, which is formed by Grand Coulee Dam.

Assumptions, Data, and Calculation

We assume the value of reservoir recreation on Lake Roosevelt will decline proportionate to the expected loss of years in which storage levels are sufficient to support summer recreation. Reservoir reliability decreased from baseline levels in response to climate change, as modeled under a scenario similar to the B1 scenario, by 2 percent in 2020, 5 percent in 2040, and 2 percent in 2080.[a] We adjust the percentages to reflect the A1FI scenario, and apply them to 1,804,000,[b] the average number of reservoir-recreation days for Lake Roosevelt between 1987 and 1993. We adjust for population growth in 2020, 2040, and 2080, and value the reductions applying the estimated consumer surplus per recreation day: $72.[c]

Results

Potential Value of Reduced Reservoir Recreation

2020	2040	2080
$3.8 million	$12.2 million	$8.8 million

Source: ECONorthwest

References and Notes

[a] Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier. 2004. "Mitigating the Effects of Climate Change on the Water Resources of the Columbia River Basin." *Climatic Change* 62: 233-256.

[b] U.S. Army Corps of Engineers, North Pacific Division. 1995. *Columbia River System Operation Review: Final Environmental Impact Statement.* Appendix J: Recreation. Report No. DOE/EIS-0170. November.

[c] U.S. Army Corps of Engineers, North Pacific Division. 1995. *Columbia River System Operation Review: Final Environmental Impact Statement.* Appendix O: Economic and Social Impact. Report No. DOE/EIS-0170. November.

4. Other Potential Costs from the Effects of Climate Change on Recreation

Description

Increased wildland fires will potentially reduce recreation opportunities during summer months. Forest closures during wildland fire events and exceptionally dry, high-risk fire seasons may limit the area, and thus opportunities, available for activities, such as hiking, mountain biking, wildlife watching, and scenic driving. Post-fire landscapes may provide more limited or lower-quality recreation experiences.[a,b]

Low water levels in streams, especially in late summer, may also reduce some water-related recreation opportunities, such as river rafting and kayaking. As peak flows shift earlier in the season due to earlier snowmelt, they may not longer overlap with the summer season in which many people enjoy river recreation. Lower flows during peak summer months may limit boating on certain stretches of river and lower the quality of the recreation experience.[c]

Though insufficient data are available to quantify these impacts, research elsewhere suggests that they have the potential to reduce the value (expenditures and consumer surplus) of forest-based and water-related recreation in Washington.

References and Notes

[a] Starbuck, C.M., R.P. Berrens, and M. McKee. 2006. "Simulating Changes in Forest Recreation Demand and Associated Economic Impacts Due to Fire and Fuels Management Activities." *Forest Policy and Economics* 8: 52-66.

[b] Scott, D., G. Wall, and G. McBoyle. 2005. "Chapter 7: Climate Change and Tourism and Recreation in North America: Exploring Regional Risks and Opportunities." In C. M. Hall and J. Higham (eds.) *Tourism, Recreation and Climate Change. Aspects of Tourism.* Clevedon: Channel View Publications.

[c] Mickelson, K.E., and A.F. Hamlet. 2008. "Effects of Climate Change on White-Water Recreation on the Salmon River, Idaho." American Geophysical Union, Fall Meeting.

IV. The Potential Economic Costs Associated with Activities that Contribute to Climate Change

In this section, we describe costs that are produced by activities associated with the business-as-usual pathway that contribute to climate change. Although these are not costs resulting directly from the effects of climate change *per se*, they represent important sources of economic harm society incurs by proceeding with business-as-usual activities.

A. Wasteful Use of Energy

Description

Consumers incur costs by using technologies and behaviors that are less efficient in their use of energy than available substitutes.

Assumptions, Data, and Calculation

We assume Washington's consumption of electricity and natural gas in 2007[a] will increase at rates estimated by the Energy Information Administration[b] for Washington and use percentages reported by several studies[c] to estimate the amount of energy Washingtonians will waste by not implementing cost-effective programs and technologies to increase energy efficiency. We estimate the value of the expenditures on wasted energy using recent average prices.[d]

Results

Potential Value of Wasted Electricity and Natural Gas

2020	2040	2080
$1.41 billion	$1.64 billion	$2.22 billion

Source: ECONorthwest

References and Notes

[a] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector (Form EIA-826)*. Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls; and Energy Information Administration. 2008. *Washington Natural Gas Consumption by End Use: 2002-2007*. Retrieved January 28, 2009, from http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_SWA_a.htm.

[b] Energy Information Administration. 2008. *EERE State Activities and Partnerships: Electric Power and Renewable Energy in Washington*. Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=WA

[c] Nadel, S., A. Shipley, R.N. Elliott. 2004. *The Technical, Economic and Achievable Potential for Energy Efficiency in the U.S.-A Meta Analysis of Different Studies*. American Council for an Energy-Efficient Economy.

[d] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector (Form EIA-826)*. Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls; and Energy Information Administration. 2008. *Washington Natural Gas Prices: 2002-2007*. Retrieved from http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_SWA_a.htm

B. Emissions from the Generation of Coal-Fired Electricity

Description

Burning coal to generate electricity in Washington will impose health-related spillover costs on Washingtonians, i.e., costs not reflected in the price of the electricity.

Assumptions, Data, and Calculation

The TransAlta Centralia Coal Plant, Washington's only coal-fired power plant, which has a generating capacity of 1,404 megawatts (MW), emitted about 2,000 metric tons of sulfur dioxide and 8,000 metric tons of nitrogen oxide in 2006.[a] The health-related externality costs associated with these pollutants are $2,556 per ton for sulfur dioxide, $1,505 per ton for nitrogen oxides.[b] We assume that, in a business-as-usual future, emissions would continue at these rates and that coal-fired electricity generation in Washington would grow at the expected rate for total electricity consumption, 0.8 percent per year.[c] The potential harm is the sum of the cost of the health-related spillover costs for the three pollutants.

Results

Potential Value of Health-Related Spillover Costs of Coal-Fired Electricity

2020	2040	2080
$19.2 million	$22.5 million	$30.7 million

Source: ECONorthwest

These results likely underestimate the total health-related spillover costs associated with coal-fired electricity generation, insofar as they do not include other harmful pollutants, such as particulate matter, mercury, volatile organic compounds, and carbon monoxide.

References and Notes

[a] Energy Information Administration. 2008. *U.S. Electric Power Industry Estimated Emissions (EIA-767 and EIA 906).* Retrieved January 23, 2009, from http://tonto.eia.doe.gov/state/SEP_MoreEnviron.cfm.

[b] Northwest Environmental Defense Center. 2008. "Breakdown of PGE Boardman Pollution." *PGE Boardman Coal-Fired Power Plant.* Retrieved January 23, 2009, from http://www.lclark.edu/org/nedc/pge.html.

[c] Matthews, H.S. and L.B. Lave. 2000. "Applications of Environmental Valuation for Determining Externality Costs." *Environmental Science and Technology.* 34 (8) 1390-1395. Values converted to equivalent 2008 dollars.

[d] U.S. Department of Energy, Energy Efficiency and Renewable Energy. 2008. *Electricity Power and Renewable Energy in Washington.* Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=WA

V. POTENTIAL ECONOMIC COSTS PER HOUSEHOLD

The preceding sections illustrate some specific types of potential economic costs Washingtonians as a whole would face if Washington, other states, the U.S., and other nations adopt a business-as-usual approach to climate change. Here, we scale down our findings to illustrate the potential costs per household.

In 2005, Washington had 2.45 million households.[30] We assume this number will grow at the same rates projected for Washington's population through 2030 and at the rates projected for the U.S. population from 2030 until 2080, reaching 3.0 million in 2020, 3.56 million in 2040, and 4.70 million in 2080. Dividing these numbers into the estimates of statewide potential costs from the preceding section for each of these years yields the per-household costs shown in Figure 7. These costs are not negligible; based on the median income of a household in Washington in the 2005-2007 period,[31] these costs represent 2 percent of household earnings in 2020, 3 percent in 2040, and 5 percent in 2080.

[30] U.S. Census Bureau. 2006. "Selected Social Characteristics: Washington." *2005 American Community Survey*. Retrieved January 30, 2009, from http://www.census.gov/acs/www/Area%20Sheets/Area%20Sheet%20WA.doc.

[31] U.S. Census Bureau. No date. "Washington-Fact Sheet – American FactFinder." *2005-2007 American Community Survey*. Retrieved January 26, 2009, from http://factfinder.census.gov/

Figure 7. Potential Economic Costs Per Household in Washington Under a Business-As-Usual Approach to Climate Change, 2020, 2040, and 2080 (Dollars per Year)

Potential Cost	2020	2040	2080
Costs of Climate Change			
Increased Energy-Related Costs	$74	$175	$319
Reduced Salmon Populations	$177	$393	$638
Increased Coastal Damage	$24	$42	$75
Reduced Food Production	$12	$18	$77
Increased Wildland Fire Costs	$34	$58	$98
Increased Health-Related Costs	$433	$618	$936
Lost Recreation Opportunities	$25	$59	$130
Subtotal for Costs of Climate Change	*$779*	*$1,363*	*$2,275*
Additional Costs from Business-as-Usual (BAU) Activities that Contribute to Climate Change			
Inefficient Consumption of Energy	$466	$449	$468
Increased Health Costs from Coal-Fired Emissions	$6	$6	$7
Subtotal for Costs from BAU Activities	*$473*	*$456*	*$475*
Average Cost per Household per Year	**$1,252**	**$1,819**	**$2,750**

Source: ECONorthwest.

Notes: These numbers illustrate different types of annual cost Washingtonians potentially would incur if society were to continue with a business-as-usual approach to climate change. There may be overlap between the values for some of the different types of cost. Nonetheless, adding the different types of costs probably seriously understates the total potential cost of climate change because the table excludes many additional types of climate-related costs that Washingtonians would incur under a business-as-usual approach. The numbers do not indicate the net effect of climate change, as they do not represent a forecast of how the economy will respond to the different effects of climate change, or account for potential economic benefits that might materialize from moderate warming and other changes in climate.

ENCLOSURE

Washington State Department of Ecology's Comments on Public Notice of Permit Application for Coyote Island Terminals LLC; US COE Number NWP-2012-56

1. There are Numerous Coal Export Proposals Pending in Oregon and Washington:

Coyote Island Terminals seeks to ship coal from locations in Oregon to overseas markets. The proposal would entail the coal traveling by train from the Powder River Basin to the Port of Morrow, then loaded onto barges and traveling on the Columbia River to Port Westward. At Port Westward, the coal would then be loaded onto Panamax vessels and shipped to Asia. At full build-out, the facility proposes to annually ship 8.8 million tons of coal.

There are permit applications pending for three other coal export facilities in the Pacific Northwest. SSA Marine has submitted an application for a coal export facility in Whatcom County, Washington at Cherry Point, with annual export of 48 million tons at full build-out. Millennium Bulk Logistics (a subsidiary of Ambre Energy, like Coyote Island Terminals) has submitted an application for a coal export facility in Longview, Washington with annual export capacity of 44 million tons at full build-out. A dredging permit at Coos Bay, Oregon is currently under appeal, with expectations that the dredging will accommodate a coal export facility with approximate annual export capacity of 10 million tons. All of these facilities would entail transport of coal by train from the Powder River Basin to their Oregon and Washington locations, followed by shipment overseas to Asian markets. There are also two other permit applications expected at two separate sites at the Port of St. Helens, Oregon and Hoquiam, Washington.

2. The National Environmental Policy Act (NEPA) Requires Consideration of Cumulative Impacts:

We believe that NEPA provides a helpful and instructive process for and requires consideration of cumulative impacts. In 40 C.F.R. §1508.7, the Council on Environmental Quality (CEQ) has defined cumulative impacts as:

> "The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions."

In 1997, CEQ issued comprehensive guidance on cumulative impacts analysis under NEPA.[1] In its guidance, CEQ notes that: "The range of actions that must be considered includes not only the project proposal, but all connected and similar actions that could contribute to cumulative effects." "Similar actions" are defined in 40 C.F.R. §1508.25(3) as "reasonably foreseeable or proposed agency actions [with] similarities that provide a basis for evaluating the environmental consequences together, such as common timing or geography." According to CEQ, "the goal of cumulative effects analysis, like that of NEPA itself, is to inject environmental considerations into the planning process as early as needed to improve decisions."

Cumulative impacts result from geographic and temporal crowding of environmental disturbances. In Table 1-2 of its guidance, CEQ enunciates and describes eight principles of cumulative impacts analysis. In setting forth these principles, CEQ recognizes that: "[i]ndividual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time" and that "repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects."

In Table 2-1 of its guidance, CEQ poses seven questions to assist federal agencies in identifying potential cumulative impacts. In the present situation, two questions are particularly relevant: (1) "Is the proposed action one of several similar past, present, or future actions in the same geographic area?" and (2) Do other activities (whether governmental or private) in the region have environmental effects similar to those of the proposed action?"

Like CEQ, courts have recognized the need for cumulative impacts analysis under NEPA. It is also helpful to look at what the courts have said about federal agency responsibility in doing cumulative impacts analyses. In the important cumulative impacts case of *Kleppe v. Sierra Club*, 427 U.S. 390(1976), the Supreme Court stated: "[W]hen several proposals for coal-related actions that will have cumulative or synergistic environmental impact upon a region are pending concurrently before an agency, their environmental consequences must be considered together." And in 2004, the Ninth Circuit Court acknowledged that NEPA requires a federal agency to analyze the cumulative impacts of non-federal actions even if the federal agency has no control over those actions, and that in order to justify the need for a cumulative impacts analysis, it is enough to identify the *potential* for cumulative impacts, not that such impacts will necessarily occur. *Resources Limited, Inc. v. Robertson*, 35 F.3d 1300, 1306 (9th Cir. 2004).

Several cases have also specifically addressed the responsibility of the Army Corps of Engineers to consider cumulative impacts in the context of NEPA. For example, in *Te-Moak Tribe of Western Shoshone v. Dep't of Interior*, 608 F.3d 592 (9th Cir. 2010), the Ninth Circuit Court concluded that the Corps was required to take a hard look at increased vessel traffic associated

[1] Considering Cumulative Effects Under the National Environmental Policy Act, Council on Environmental Quality, January 1997, *available at* http://ceq.hss.doe.gov/nepa/ccenepa/ccenepa.htm.

with a new dock at BP's Washington State oil refinery, including consideration of cumulative impacts of the dock when combined with existing and proposed future projects. The District Court of Wyoming concluded in a 2005 case that, before issuing a §404 permit under the Clean Water Act, the Corps was required to consider all cumulative impacts to the "natural and physical environment" rather than confine its analysis to wetlands impacts. *Wyoming Outdoor Council v. US Army Corps of Engineers*, 351 F.Supp. 2d 1232, 1241 (D. Wyo. 2005). In a case involving a NEPA determination for multiple casinos on the Mississippi coast, the D.C. District Court concluded that cumulative impacts alone can constitute grounds for an EIS under NEPA. *Friends of the Earth v. US Army Corps of Engineers*, 109 F.Supp. 2d 30, 42-43 (D. D.C. 2000).

The Coyote Island Terminals' proposal could result in potential environmental impacts of considerable importance. This potential is magnified when considered cumulatively along with impacts from other similar projects in the region. Areas of concern that merit a hard look, at a minimum, include:

- Increased vessel traffic on the Columbia River, including navigational and maritime safety concerns
- Protection of water quality, including increased risk of spills in the Columbia River
- Coal dust emissions at the facility and during product transit
- Emissions of other air pollutants, including diesel particulate and greenhouse gases
- Increased rail traffic, including railroad capacity, increased noise, and delay times for emergency vehicles at rail crossings

Some of these impacts are addressed in more detail below.

3. Cumulative Impacts to the Columbia River System have the Potential to Be Significant:

As noted above, multiple new coal terminals are currently proposed along the river that would increase vessel traffic, would increase risks to maritime safety and environmental protection. Infrastructure concerns such as anchorages, fuel transport, and pilot availability should be addressed as they affect the level of risk presented by an increase in vessel traffic. Facility and vessel operations need to be described in more detail to determine the full level of impacts. However, using the Public Notice for Permit Application as our source of information, we have determined, at a minimum, that the following issues should be considered in an EIS.
We have also identified some areas where more information is needed.

For background, in 2010, the number of vessels entering the Columbia River bound for Washington or Oregon ports, was 1,467 cargo vessels and 116 tank ships. At maximum capacity under the Port of Morrow proposal, there would be 156 more cargo ships. Additionally, 1,248 more barge trips would substantially increase barge traffic upriver. Thus, for this project alone, there would be an 11% increase in cargo vessel traffic and an even more significant increase in barge traffic upriver. The cumulative impact from all the planned coal projects would be even

greater. This sizable increase cannot simply be folded into the current infrastructure or operational processes on the Columbia River. In addition, the Columbia River system is a confined river system with multiple ports, a breaking coastal bar at the entrance, and no federal vessel traffic system, all of which increase the potential for risk. Vessel impacts from this project (singly and cumulatively) could be significant and should be analyzed.

The coal is proposed to travel by barge from the Port of Morrow to Port Westward. However, very little information was provided on the plan for Port Westward operations or structures. No information is provided on the enclosed transloading barge or its operations. No information is provided on how the barges and ship will be secured while at Port Westward. If Coyote Island Terminals proposes to use the current World War II-era dock in the area, additional studies and surveys should be conducted to verify the stability of the structure for the proposed operations and depths. If permanent anchors will be utilized, additional information is needed on how these will be installed and used. The environmental impacts of the various options should be considered.

Assuming the enclosed transloading barge will remain in one place, information on how the vessel will be fueled and what vessel emissions will be released should be provided and analyzed. Depending on the operations, the barge may have office or living spaces onboard, so there should be information on how the sewage and gray water will be discharged.

A description of how the coal will be transported from the barge to the vessel is missing. If the system is not fully enclosed, the potential for releases of coal dust exists. Also, how will the coal dust that is collected be handled? And at the Port of Morrow, will the conveyor system be fully or partially enclosed? How will coal dust be controlled there? The environmental impacts associated with coal dust should be considered.

Oil spill risk should also be considered. Will oil be stored on site to fuel tugs? As no land-side facility is proposed, in the case of a spill, where will spill response equipment be located? Will barge personnel be trained in spill response and booming operations? Oil spill response equipment, personnel and training need to be better described.

There are also navigational concerns that should be considered. First, navigation concerns should be addressed for Port Westward due to the narrow width of the river at that location and the nearness of the navigational channel. The significant increase in barge traffic from the Port of Morrow to Port Westward must pass through several locks and transit along a depth-constrained channel with areas of potential shoaling. What are the proposed lengths, beams and depths of the barges? How will the increase in barge traffic be managed to prevent near-misses or groundings? Safety factors should be considered, such as requiring the use of Automatic Identification System (AIS) on board each tug and tow and improved AIS monitoring capability for the upriver portion of the Columbia River. These potential impacts should be analyzed in an EIS.

4. Increased Rail Traffic Could Result in Potential Environmental Impacts:

The Public Notice states that there will be eleven coal trains traveling weekly to the Port of Morrow at full build-out. Ecology assumes that the trains will be making round trips. Thus, it appears that this proposal would result in 22 additional train trips to and from the proposed facility, or slightly over 3 trips per day. We understand that the trains will travel on BNSF tracks from the Powder River Basin, traveling through Spokane, and then continuing southwest through Washington until crossing the border in the south to Oregon.

The trains associated with at least two of the other proposed facilities are expected to travel this same route in Washington. Those proposals at full build-out could result in approximately 18 daily trips (Gateway) and 16 daily trips (Millennium Bulk). Thus, a minimum of 37 coal trains might daily transit the same route. The rail traffic from some of the other proposals may also travel the same route, further adding to the potential for environmental impacts of increased traffic.

In 2006, the Washington State Transportation Commission published a Statewide Rail Capacity and System Needs Study.[2] The study shows a rail system that is at, or over, capacity in several critical areas along the rail line. Specific to the present proposal, Figure 3 in the study shows that rail capacity is constrained along much of the BNSF route from Sandpoint to Oregon and is congested in the Spokane area. Figure 4 in the study shows Spokane as a "choke point" in the rail system. Rail capacity issues are an important challenge for this proposed project, especially when considered cumulatively with the other proposals.

The increase in coal train traffic also presents the potential for other environmental impacts of concern. For example, coal dust is known to be emitted from uncovered coal cars during transit. The length and number of trains could result in longer wait times at at-grade crossings for emergency personnel and members of the traveling public. Increased trains could result in noise impacts and increased air emissions, including diesel particulate emissions. The potential for these and other types of impacts have not gone unnoticed by communities located along this corridor. Many are expressing strong concerns about the potential for significant environmental impacts that could occur from the cumulative impacts of these proposals. These communities' concerns and these potential impacts should be considered in an EIS for the proposal.

5. The Corps' Regulations and NEPA Require Consideration of Both Direct and Indirect Impacts that would be Proximately Caused by a Proposal:

Some of the impacts identified in this letter, such as those associated with facility operations, are direct impacts of the project. Some of the impacts, such as those arising from increased vessel

[2] The study can be found at http://www.wstc.wa.gov/Rail/RailFinalReport.pdf.

and rail traffic, may be more properly described as "indirect" impacts, which CEQ defines in 40 C.F.R. §1508.8(b) as those impacts "which are caused by the action and are later or farther removed in distance, but are still reasonably foreseeable." Both direct and indirect impacts must be considered under NEPA.

All impacts which are "proximately caused" by the proposal under consideration should be analyzed in a NEPA document. In *Dep't of Transp. v. Public Citizen,* 541 U.S. 752 (2004), the Supreme Court defined proximate cause as "a reasonably close causal relationship between the environmental effect and the alleged cause." Consistent with this standard, courts have required federal agencies to take a hard look at indirect impacts that would be proximately caused by a proposal, even if those impacts are well outside of the immediate vicinity of the proposal and/or are further removed in time from the proposal itself. For example, the Ninth Circuit Court held that BLM needed to look at the indirect impacts of transporting and processing refractory ore prior to making permit decisions on a mine proposal. *South Fork Band Council of Western Shoshone v. Dep't of Interior*, 588 F.3d 718, 725-26 (2009).

Corps' regulations define the scope of what the Corps considers under NEPA. Typically, the Corps focuses its analysis on "impacts of the specific activity requiring a permit and those portions of the entire project over which the district engineer has sufficient control and responsibility to warrant federal review." 33 C.F.R. Part 325, App. B §7(b). In urging the Corps to look at cumulative impacts associated with increased vessel and rail traffic, Ecology notes that it is not asking the Corps to expand the scope of its NEPA analysis beyond what is required under the Corps' regulations. Rather, vessel and rail impacts are indirect impacts that are expected to be proximately caused by the proposal that is pending before the Corps. For that reason, those impacts are appropriately considered in an EIS.

6. Conclusion:

Because of the confluence of several coal export proposals in the Oregon-Washington region, it is imperative that a federal agency consider the cumulative impacts of these proposals. In fact, in 40 C.F.R. §1508.25(a)(3), CEQ authorizes agencies to analyze similar actions in the same EIS, and notes that an agency "should do so when the best way to assess adequately the combined impacts of similar actions or reasonable alternatives to such actions is to treat them in a single impact statement."

Should the Corps decline to do this broader cumulative impact analysis as part of a single EIS, it is still imperative that agencies making permit decisions on individual projects consider the direct, indirect, and cumulative impacts of those decisions.

Protecting American Health from Global Shipping Pollution

ESTABLISHING AN EMISSION CONTROL AREA IN U.S. WATERS

e
ENVIRONMENTAL DEFENSE FUND
finding the ways that work

AMERICAN LUNG ASSOCIATION®

pscleanair.org
Puget Sound Clean Air Agency

NACAA
national association of clean air agencies

Protecting American Health from Global Shipping Pollution

ESTABLISHING AN EMISSION CONTROL AREA IN U.S. WATERS

AUTHORS

Janea Scott

Hilary Sinnamon

Acknowledgments
We would like to thank the following people for their contributions and insight in developing this report: Vickie Patton, Dennis McLerran, Ramon Alvarez, Cal Baier-Anderson, John Balbus, Bill Becker, Paul Billings, Elena Craft and Nancy Kruger. We very much appreciate all of your invaluable help.

Environmental Defense Fund
Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

American Lung Association
Now in its second century, the American Lung Association is the leading organization working to save lives by improving lung health and preventing lung disease. With your generous support, the American Lung Association is "Fighting for Air" through research, education and advocacy.

National Association of Clean Air Agencies
The National Association of Clean Air Agencies (NACAA) comprises the air pollution control agencies in 53 states and territories and over 165 metropolitan areas across the country. NACAA's members have primary responsibility for ensuring that everyone in our nation breathes clean, healthful air.

Puget Sound Clean Air Agency
The Puget Sound Clean Air Agency is the regional air quality agency for the area including the major container ports of Seattle and Tacoma, Washington. We work together to clean the air we breathe and protect our climate through education, incentives and enforcement.

Cover photo: Ocean-going ship at the port of Los Angeles. Photo by Janea Scott.

©2009 Environmental Defense Fund

The complete report is available online at www.edf.org.

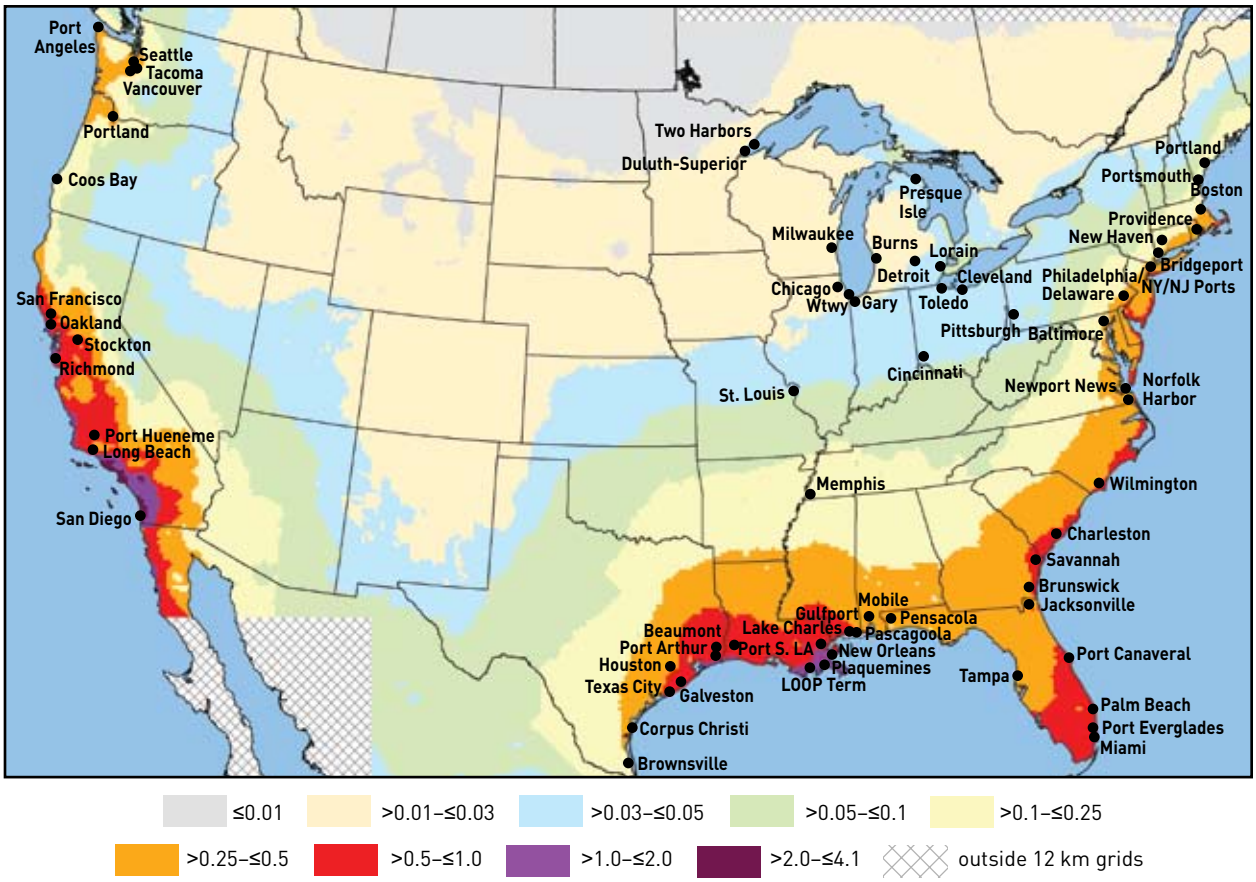
Executive summary

The United States Government can chart a course to achieve healthier air for the millions of Americans impacted by the emissions from ocean-going ships by applying to the International Maritime Organization (IMO) for an Emission Control Area (ECA)—an area where stricter pollution limits apply. Ocean-going ships, sometimes referred to as Category 3 ships, are the largest ships on the water and include container ships, tankers, cruise ships, and bulk carriers. These large vessels travel all over the world, making international shipping a significant factor in U.S. port traffic and emissions. In fact, 90% of ship calls on U.S. ports are made by foreign-flagged vessels. Ocean-going ships impact air quality in U.S. coastal cities and ports and even send pollution hundreds of miles inland.

The American Lung Association (ALA), Environmental Defense Fund (EDF), the National Association of Clean Air Agencies (NACAA), and the Puget Sound Clean Air Agency (PSCAA) strongly support the leadership of the United States Government to fully implement the pollution limits available under international

FIGURE 1

An Emission Control Area for the United States would dramatically reduce particulate pollution from ocean-going ships by 2020 (change in annual concentration µg/m^3)



Difference in annual average SMAT $PM_{2.5}$ (µg/m^3)—2020ce-2020ce—200nm. Source: Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9..

law to reduce harmful marine air pollution. We also respectfully request that the IMO promptly act on the United States ECA application, and give it full consideration at the July 2009 meeting of the IMO Marine Environment Protection Committee (MEPC 59). As Figure 1 illustrates, prompt action to establish an ECA for the United States will secure vital clean air protections for millions of Americans.

- This map depicts the estimated reductions in annual concentrations of harmful particulate pollution in 2020 if the United States establishes an ECA to cover the nation's entire Exclusive Economic Zone, which generally extends a distance of 200 nautical miles from the coast. About 87 million Americans live in port areas that are not meeting basic federal public health standards.

- The Environmental Protection Agency's early estimates indicate the benefits of an ECA would be about 5 times larger than that of the recently finalized commercial ships and locomotives rule.[1]

- ECAs require fuel to be over 60% cleaner than the global average by 2010 and 96% cleaner in 2015, resulting in emissions reductions far greater and faster than by baseline global standards.

- Establishing an ECA for the United States would reduce smog-forming oxides of nitrogen (NO_x) emissions by 80% from existing engine emission levels, particulate pollution (PM) by 85% and sulfur oxides (SO_x) by 95%.

- Estimated 2020 particulate concentration reductions in the United States as a result of an ECA are as high as 4.1 $\mu g/m^3$ (micrograms per cubic meter) in some of the most impacted port areas.

- In some metropolitan areas, like Houston, the expected reductions could mean the difference between meeting and not meeting the health-based federal clean air standards.[2]

Healthier air on deck

The International Maritime Organization has charted a course for deep reductions in air pollution from ships

The IMO, established under the purview of the United Nations, is responsible for coordinating with member nations to establish international pollution standards for ocean-going ships. Annex VI of the International Convention for the Prevention of Marine Pollution from Ships (MARPOL) treaty contains the clean air provisions that apply to all signatory nations. The United States became a party to this treaty in 2008. Annex VI consists of two sets of emissions standards: (1) global standards that apply to all ships arriving at, and departing from, countries that are party to the MARPOL treaty; and (2) more rigorous geographically-based standards that apply in specially designated areas called Emission Control Areas (ECAs).

In October 2008, the IMO updated Annex VI of the MARPOL treaty to be more protective. The new standards require modest global reductions in oxides of nitrogen (NO_x), particulate pollution (PM), and sulfur oxides (SO_x) pollution. They also put in place the framework for more rigorous reductions to be made in ECAs, those areas hardest hit by shipping pollution. We support the U.S. application to the IMO for ECA designation in order to enforce these rigorous standards on all international ships that enter the area.[3] The global and ECA emission control standards are as follows:

NO_x emission control standards

- 20% NO_x reduction beginning in 2011 for new engines.
- 15 to 20% NO_x reduction beginning in 2011 for existing engines.
- **Within an ECA:** 80% NO_x reduction beginning in 2016 for new engines.

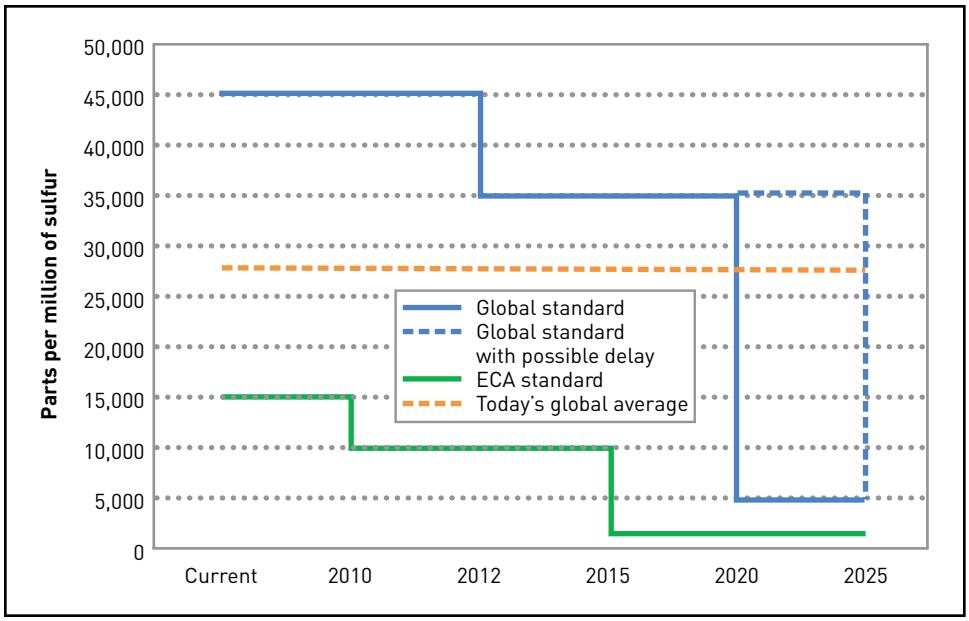
These NO_x standards are based on advanced emission control technology, including selective catalytic reduction (SCR).[4] SCR is a commonly used technology to reduce NOx emissions in all varieties of diesel engines, and has been successfully installed in over 300 marine vessels.[5]

Fuel quality standards

- Beginning in 2012, global sulfur fuel levels will drop from the current standard of 45,000 parts per million (ppm) to 35,000 ppm. However, the current global average is about 27,000 ppm.[6]
- Global sulfur limits will drop to 5,000 ppm in January 2020. However, this deadline may be delayed to 2025 pending a review in 2018 of the availability of the cleaner fuel.
- **Within an ECA:** Sulfur limits will drop from the current standard of 15,000 ppm to 10,000 ppm in August 2010 and to 1,000 ppm in January 2015.[7]

The IMO's action to improve fuel quality is essential because ocean-going ships are currently powered by residual fuel, which is some of the dirtiest fuel on earth.

FIGURE 2
Global sulfur requirements for ocean-going ship fuel under new IMO rule



Source: IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008.

Residual fuel has a high content of ash, metals, nitrogen, and sulfur that result in high SO_x and PM emissions. Since SO_x emissions are directly related to the concentration of sulfur in the fuel, reducing the sulfur in fuels, as required by the IMO, also reduces SO_x emissions.[8] Fortunately, most ship engines that are designed to run on residual fuel are also capable of burning cleaner low sulfur distillate fuel. As a result, no significant ship changes or upgrades are necessary to burn cleaner fuel,[9] so the cleaner fuel required in an ECA can be used immediately.

Figure 2 illustrates the far greater reduction in fuel sulfur content in ECAs compared to the baseline global standards. While the new global standards require ship fuel to reduce sulfur limits to 35,000 ppm in 2012, this will have minimal impact because the global average fuel sulfur level is 27,000 ppm. More significant reductions will be achieved in 2020, when the global standard drops to 5,000 ppm—this is an 80% reduction from the global average. However, this 2020 deadline may be delayed to 2025 pending a review in 2018 of the availability of the cleaner fuel.

In contrast to the global standards, ECAs require fuel to be over 60% cleaner than the global average in 2010 and 96% cleaner in 2015, reducing more pollution far more quickly than under the baseline global standards. Sulfur levels in a U.S. ECA would not drop to 10,000 ppm until 2012[10] and EPA has confirmed that the lower sulfur fuel required will be available at that time.[11]

When fully implemented in the United States, the ECA requirements for engines and fuel would reduce NO_x emissions by 80% from current levels, PM by 85% and SO_x by 95%.[12] These reductions will provide clean air benefits to communities from coast to coast.

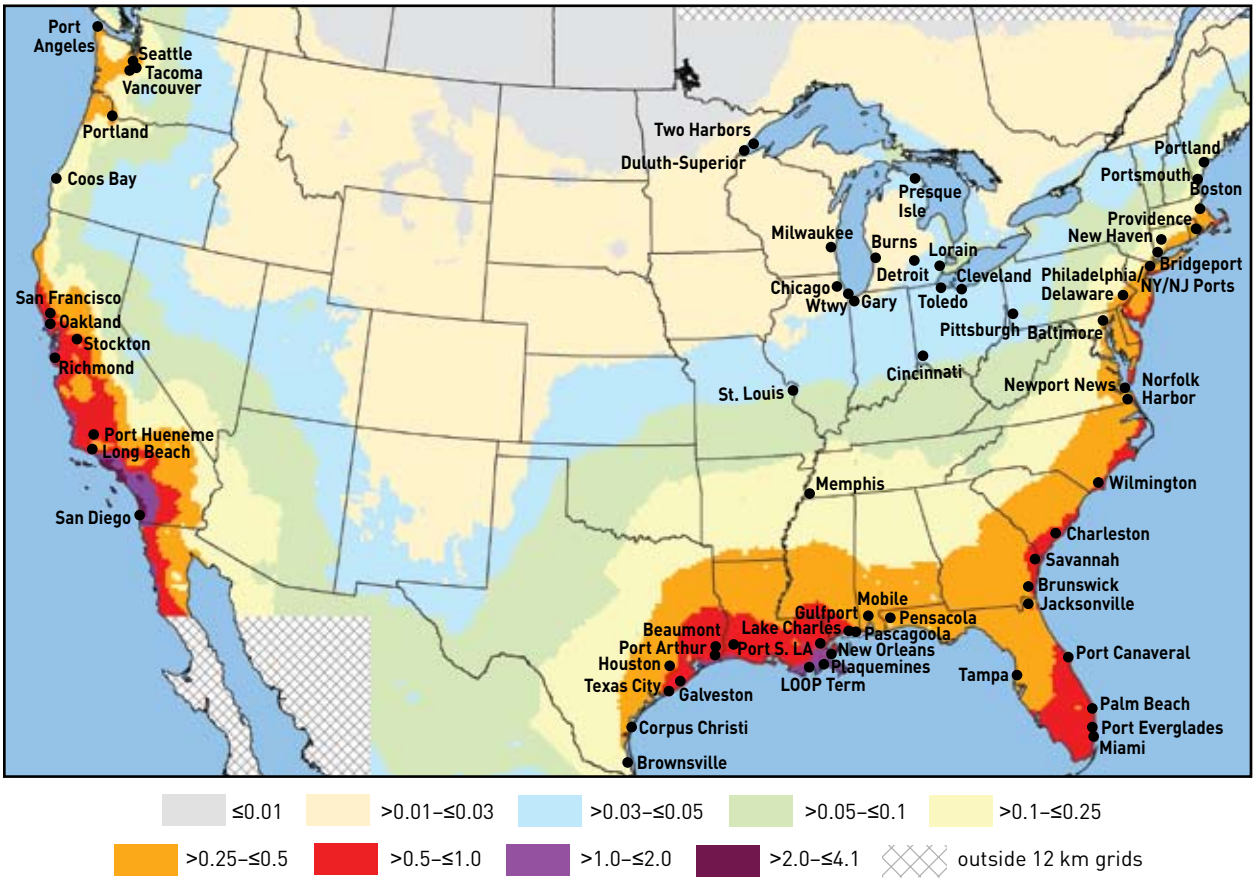
Securing an Emission Control Area for the United States will have a striking impact on air quality across our nation

Diesel exhaust, like that emitted from ocean-going ships, is among the most dangerous and pervasive sources of air pollution. The constituents of diesel exhaust include particulate matter (PM), implicated in a host of respiratory problems and thousands of premature deaths every year; smog-forming oxides of nitrogen (NO_x); sulfur dioxide (SO_2), which forms harmful fine particles and falls back to earth as acid rain; and a noxious brew of toxic chemicals that together pose a cancer risk greater than that of any other air pollutant. Shipping-related PM emissions contribute to approximately 60,000 global deaths annually, with impacts concentrated in coastal regions on major trade routes.[13] The U.S. Environmental Protection Agency (EPA) estimated that in 2001, ocean-going ships emitted:

- more than 54,000 tons of fine particulate matter, which is equivalent to the pollution from 117 coal-fired power plants.[14]
- approximately 745,000 tons of smog-forming NO_x pollution—comparable to the NO_x emissions from more than *800 million* of today's new cars,[15] and

FIGURE 3

Estimated reductions in annual PM concentrations from U.S. ECA in 2020 (ug/m^3)



Difference in annual average SMAT $PM_{2.5}$ (µg/m^3)—2020ce-2020ce—200nm. Source: Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9.

- around 450,000 tons of SO_2, which is more than 40% of the total SO_2 from the U.S. transportation sector.[16] This percentage is due mainly to the low grade residual fuel ocean-going ships use. Residual fuel is the tar-like product left behind after all the lighter petroleum is refined from crude oil and is so viscous that it requires heating before it can be burned.[17]

The diesel air pollution from ocean-going ships has been under regulated. In the past two decades, EPA has set rigorous emission standards for nearly all other mobile sources of diesel, including highway trucks and buses, nonroad sources such as construction equipment, locomotives and smaller commercial ships. Securing an ECA for the United States will put in place rigorous standards for ocean-going ships that are more comparable to the standards set for other diesel sources. Establishing an ECA that covers the nation's entire Exclusive Economic Zone will result in significantly greater emissions reductions than the IMO baseline global standards and will provide much needed air quality improvements across the nation, particularly in densely populated coastal areas.

Figure 3 depicts the air quality benefits the United States could secure by implementing an ECA for the entire coastline of the mainland United States. Figure 3 speaks loudly and clearly: *Every state* in the lower 48 would see an improvement in air quality if large ocean-going ships in U.S. waters met the rigorous pollution control standards that would be required in an ECA—even states that are landlocked. Particulate pollution reductions, represented in annual average concentrations, range from 0.01 to 0.1 $\mu g/m^3$ (micrograms per cubic meter) in the middle of the country up to 4.1 ug/m^3 in some of the hardest hit coastal and port areas. These reductions will translate into significant health benefits across the nation. Additionally, in some metropolitan areas, like Houston, the expected reductions could mean the difference between meeting and not meeting the health-based federal clean air standards.[18]

Given the enormous clean air and public health benefits to be gained from strong emission standards for ocean-going ships, the IMO should promptly act on the U.S. application to establish an ECA.

IMO approval of U.S. Emission Control Area will clear the way for healthier air

When countries apply to the IMO for an ECA designation, they must demonstrate a need to prevent, reduce and control emissions of SO_x, PM, and/or NO_x from ships. The United States has a compelling case for ECA designation. These contaminants are major contributors to unhealthy air pollution in the United States, especially the harmful levels of particulate pollution and ground-level ozone in many communities.

More than half of all Americans live in communities out of compliance with the federal health-based standards for ozone and particulate pollution.[19] And millions live near U.S. port cities that are especially hard hit by shipping pollution. EPA estimates that 87 million Americans live in port areas that are not meeting basic federal health standards.[20]

An ECA application submitted by the United States this spring will be considered by the IMO at the July 2009 meeting of the Marine Environment Protection Com-

mittee (MEPC 59). The IMO will then vote on the U.S. application in 2010. If accepted, the ECA designation will go into effect in 2012.[21] We respectfully urge the IMO to approve the ECA designation for the United States. The need for these clean air measures is clear and convincing.

Pollution from ocean-going ships in U.S. waters impacts public health and revered ecosystems

The large ocean-going ships that travel along U.S. coastlines and dock at our nation's ports deliver considerable amounts of pollution in addition to the goods they bring. Much of the pollution from these large vessels is concentrated in ports and the densely populated metropolitan areas near ports that, in almost every instance, already suffer from unhealthy air.

The health effects of diesel emissions in general are well documented. Diesel air pollution adds to cancer risk all around the United States. In many places, diesel emissions create the greatest contribution to cancer risk from air pollution. For example, in the Seattle area, diesel soot accounts for somewhere between 70% and 85% of the total cancer risk from all air toxics.[22] And in the South Coast Air Basin, which includes Los Angeles, diesel exhaust contributes about 84% of the cancer risk from air toxics.[23]

In addition, because diesel emissions are a complex mixture of chemicals, exposure to this pollution contributes to a wide range of non-cancer health risks, including pulmonary disease, cardiovascular effects, neurotoxicity, low birth weight in infants, premature births, congenital abnormalities and elevated infant mortality rates.[24]

Particulate matter

Particulate matter can aggravate respiratory conditions such as asthma and chronic bronchitis and has been associated with cardiac arrhythmias (heartbeat irregularities), heart attacks and premature deaths. People with diabetes, heart or lung disease, the elderly and children are at highest risk from exposure to particulate pollution.[25]

A recent study calculated that, worldwide, shipping-related PM emissions contribute to approximately 60,000 deaths annually, with impacts concentrated in coastal regions on major trade routes.[26] The study also predicted that under the regulations in place before the amendments to Annex VI were passed in October 2008, and with the expected growth in shipping activity, annual deaths could increase 40% by 2012, increasing the number of deaths associated with shipping pollution to 84,000 every year.[27]

NOx and ozone

Oxides of nitrogen transform into aerosol particulates and also combine with volatile organic compounds in the presence of sunlight to form smog, or ground-level ozone. High ozone levels cause acute respiratory problems, aggravated asthma, decreased lung function, inflammation of lung tissue, an increase in hospital admissions and emergency room visits for respiratory causes, and crop damage. Children with asthma are among those most at risk. Ozone also is associated with premature

death.[28] The national health-based standard for ozone was strengthened in March 2008 to be more protective than the 1997 standard.

Environmental impacts

Pollution from ocean-going ships impacts our environment, in addition to impacting public health. The same fine particles that can be breathed deep into the lungs adversely affecting human health also cause the haze that pollutes scenic vistas in national parks and wilderness areas and creates "brown clouds" in our urban centers.

The constituents of diesel exhaust also contribute to the acid rain that continues to harm sensitive ecosystems across the United States. Acid rain occurs when pollutants like SO_2 and NO_x react with water, oxygen, and other chemicals in the atmosphere to form various acidic compounds. The result is a mild solution of sulfuric acid and nitric acid.[29] When this acid falls back to the earth, it harms our nation's revered ecosystems–causing acidification of lakes and streams and contributing to the damage of trees, like red spruce trees, at high elevations and many sensitive forest soils.[30]

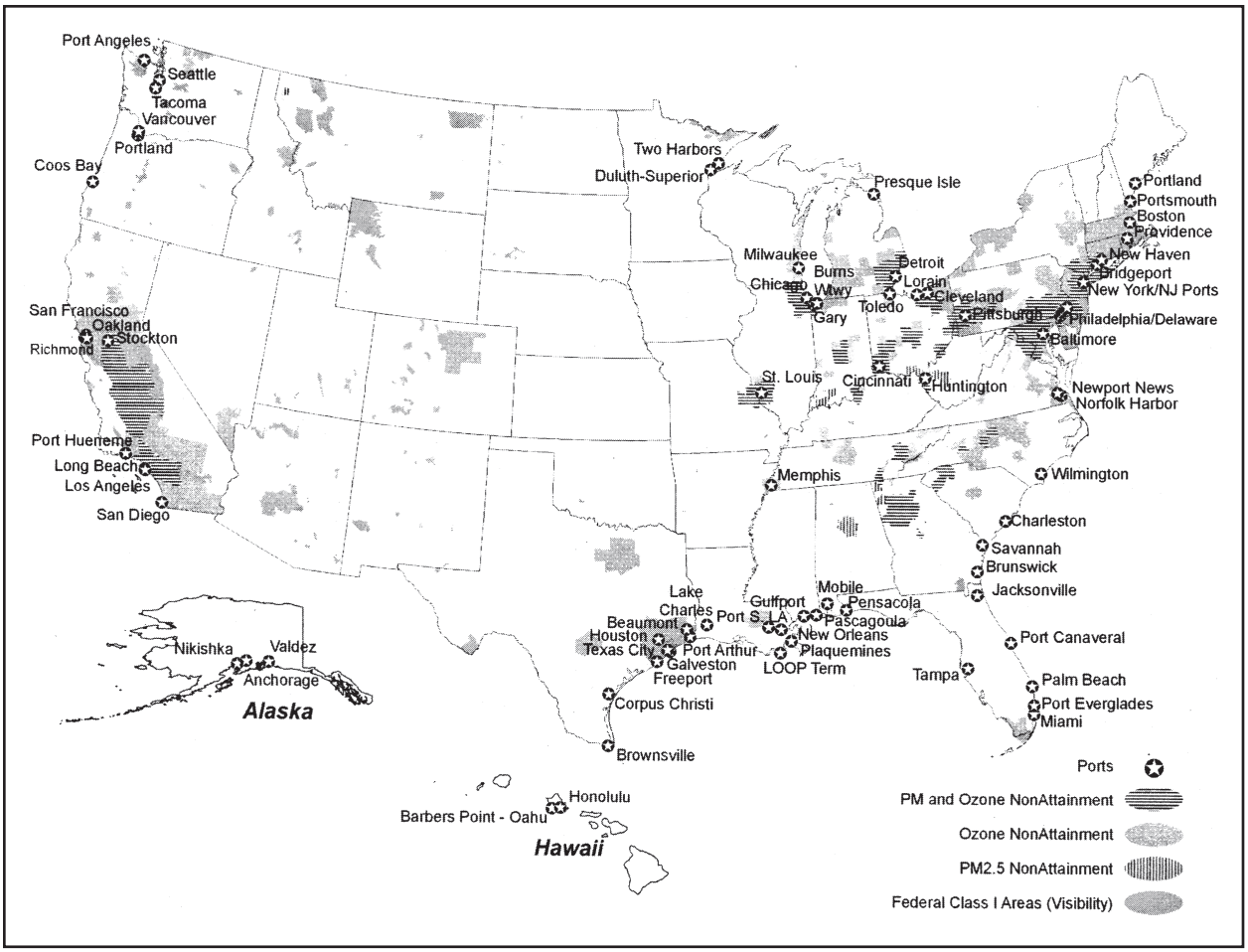
Pollution from ocean-going vessels also contributes to global climate change. In 2006, in U.S. waters alone, these vessels emitted about 55.6 million metric tons of CO_2.[31] Additionally, ocean-going ships contribute about 1.7% of global black carbon emissions every year.[32] Black carbon refers to the solar-absorbing component of soot, which is released during the combustion process, and is another potent global warming pollutant.[33] Studies show that black carbon triggers snow and ice melting, and contributes to Arctic warming.[34] And in some places, including the Alaska region, shipping can contribute an additional 40% to atmospheric concentrations of black carbon.[35] Further, black carbon from shipping could have disproportionate effects on air quality near port areas because of the intensity of shipping in these areas.[36]

Timely reductions in PM and NO_x from ocean-going ships will help states protect human health and achieve cleaner air

Approximately 88 million people nationwide either live in counties that do not meet the 1997 federal air quality standards for fine particles, or their counties contribute to violations elsewhere.[37] About 132 million people live in counties that violate the 1997 eight-hour federal air quality standard for ozone.[38] These standards have recently been updated to be more protective, so the number of people living in communities that violate federal air quality standards will increase.[39]

Ocean-going ships are a major source of harmful fine particles, and their emissions also contribute to harmful smog levels. In Figure 4, EPA identifies 40 ports that are currently located in nonattainment areas. EPA estimates that some 87 million Americans live in these port areas that are not meeting basic federal public health standards for ground-level ozone and particulate pollution.[40] This map, however, is not based on recent updates strengthening the public health-based standards for fine particulate matter and ozone, so air quality problems in U.S. port areas are likely to be more widespread than this map indicates. For example, both the Port of Seattle and

FIGURE 4
Air quality problems are widespread especially in U.S. port areas



Source: Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69528.

Port of Tacoma areas are within a region that is in violation of the new federal ozone standards based on data for Summer 2008.

As illustrated in Figure 1 previously, reducing pollution from these ships will help every state in the nation improve its air quality.

Conclusion: Establishing an Emission Control Area for the United States will dramatically reduce marine shipping pollution and protect public health

The United States has the opportunity to join an international emissions control program that would reduce shipping pollution along U.S. coastlines, at U.S. ports and indeed, in every state in the continental United States. Participation in the ECA program would result in SO_x reductions of approximately 98% and NO_x reductions of up to 80% from each new ship. Prompt action by the IMO can secure healthier air for millions of Americans.

ALA, EDF, NACAA, and PSCAA support the United States' application for a U.S. ECA and respectfully recommend that the IMO promptly approve the application.

Ocean-going vessels from all over the world dock at over 100 U.S. ports. EPA estimates that some 87 million Americans live in port areas that do not meet basic federal public health standards for ground-level ozone and particulate pollution.[41] Fortunately, a pivotal opportunity is on deck to achieve significant reductions in the pollution from ocean-going ships. With U.S. leadership in requesting the establishment of an Emission Control Area, and IMO approval, the nation will be sailing more smoothly towards healthier air.

Notes

[1] Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9.

[2] Based on Texas Commission on Environmental Quality data for the Clinton C403/C304/AH113 monitor, generated at http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo.pl?cams=403. These data show the yearly average for $PM_{2.5}$ concentrations as 15 $\mu g/m^3$ in 2005, 16 $\mu g/m^3$ in 2006, 15 $\mu g/m^3$ in 2007, and 13 $\mu g/m^3$ in 2008—the 2008 data, however, is still under review. The three-year average for 2005–2007 is 15.33 $\mu g/m^3$ which is just above the current annual fine particle standard at 15 $\mu g/m^3$ and the three-year average for 2006–2008 is 14.7 $\mu g/m^3$ which is just below the current standard. The reductions from 0.25 to 1.0$\mu g/m^3$, expected from establishing an ECA, could help the Houston metropolitan region attain or maintain the current health-based federal clean air standard of 15$\mu g/m^3$ for fine particulates.

[3] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[4] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[5] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,539.

[6] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[7] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[8] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[9] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[10] "Given the MARPOL amendment acceptance process and the lead time specified in the regulations, an ECA submitted [by late March or early April] could be expected to enter into force as early as August 2012." EPA Regulatory Update, *Frequently Asked Questions about the Emission Control Area Application Process.* EPA-420-F-09-001, January 2009.

[11] EPA Regulatory Update, "Frequently Asked Questions about the Emission Control Area Application Process," EPA420-F-09-001; January 2009. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09001.pdf

[12] EPA Program Announcement, "International Maritime Organization Adopts Program to Control Air Emissions from Ocean-going Vessels," EPA420-F-08-033; October 2008. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f08033.pdf

[13] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

[14] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546. Power plant comparisons are based on 0.25lb/MWh of $PM_{2.5}$ and 4.22 lb/MWh of NO_x for power plants, which are the averages for existing coal plants in the western U.S. Also assumes a typical power plant unit has 500MW capacity and 85% utilization rate.

[15] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546. Calculations based on Tier 2 NOx emissions standard (0.07g NOx/mile) for highway vehicles and 12,000 vehicle miles/year. Bureau of Automotive Repair, Engineering and Research Branch, State of California, "Methodology for Calculating Vehicle Miles Traveled (VMT)," September 30, 2000, Report 2000-06, available at http://www.epa.gov/otaq/regs/im/vmt.pdf

[16] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546.

[17] http://www.atsdr.cdc.gov/toxprofiles/tp123-c3.pdf

[18] Based on Texas Commission on Environmental Quality data for the Clinton C403/C304/AH113 monitor, generated at http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo.pl?cams=403. These data show the yearly average for $PM_{2.5}$ concentrations as 15 $\mu g/m^3$ in 2005, 16 $\mu g/m^3$ in 2006, 15 $\mu g/m^3$ in 2007, and 13 $\mu g/m^3$ in 2008—the 2008 data, however, is still under review. The three-year average for 2005–2007 is 15.33 $\mu g/m^3$ which is just above the current annual fine particle standard at 15 $\mu g/m^3$ and the three-year average for 2006–2008 is 14.7 $\mu g/m^3$ which is just below the current standard. The reductions from 0.25 to 1.0$\mu g/m^3$, expected from establishing an ECA, could help the Houston metropolitan region attain or maintain the current health-based federal clean air standard of 15$\mu g/m^3$ for fine particulates.

[19] $PM_{2.5}$: http://www.epa.gov/oar/oaqps/greenbk/qnsum.html, web resource, last accessed February 13, 2009. Ozone: http://www.epa.gov/oar/oaqps/greenbk/gnsum.html, web resource, last accessed February 13, 2009.

[20] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships,* October 10,2008. http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308.

[21] EPA Regulatory Update, "Frequently Asked Questions about the Emission Control Area Application Process," EPA420-F-09-001; January 2009. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09001.pdf.

[22] Puget Sound Clean Air Agency, "Final Report: Puget Sound Air Toxics Evaluation," October 2003. http://www.pscleanair.org/airq/basics/psate_final.pdf

[23] South Coast Air Quality Management District, "Final Report: MATES III," September 2008. http://www.aqmd.gov/prdas/matesIII/MATESIIIFinalReportSept2008.html

[24] Krivoshto IN, Richards JR, Albertson TE, Derlet RW. 2008. The Toxicity of Diesel Exhaust: Implications for Primary Care. J Am Board Fam Med. 21:55– 62.

[25] American Lung Association, Facts About Particle Pollution, April 2008. http://www.lungusa2.org/sota/SOTA08__PMFacts.pdf.

[26] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

[27] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

[28] Jerrett, M. et al. 2009. Long-term ozone exposure and mortality. N Engl J Med 360;11. Bell ML, Peng RD, Dominici F. 2006. The exposure-response curve for ozone and risk of mortality and the adequacy of current ozone regulations. Environ Health Perspect. 114(4):532-536. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. 2004. Ozone and short-term mortality in 95 US urban communities, 1987-2000. JAMA. 292(19):2372-2378. Levy JI, Chemerynski SM, Sarnat JA. 2005. Ozone exposure and mortality: an empiric bayes metaregression analysis," Epidemiol. 16(4):458-468.

[29] http://www.epa.gov/acidrain/what/index.html, web resource, last accessed September 18, 2008

[30] http://www.epa.gov/acidrain/effects/index.html, web resource, last accessed September 18, 2008

[31] Regulating Greenhouse Gas Emissions Under the Clean Air Act; Proposed Rule (July 30, 2008) 73 Fed. Reg. 44354 at 44466

[32] Ramanathan, V. and G. Carmichael (2008) Global and Regional Climate Changes due to Black Carbon, Nature Geoscience. May be accessed online at: http://www-ramanathan.ucsd.edu/publications/Ram_Carmichael-NatGeo1-221.pdf

[33] Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815

[34] Ramanathan, V. and G. Carmichael (2008) Global and Regional Climate Changes due to Black Carbon, Nature Geoscience. May be accessed online at: http://www-ramanathan.ucsd.edu/publications/Ram_Carmichael-NatGeo1-221.pdf Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815 Flanner, M. G., C. S. Zender, J. T. Randerson, and P. J. Rasch (2007), Present-day climate forcing and response from black carbon in snow, J. Geophys. Res., 112, D11202, doi:10.1029/2006JD008003.

[35] Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815

[36] Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815

[37] http://www.epa.gov/pmdesignations/2006standards/documents/2008-12-22/factsheet.htm $PM_{2.5}$: http://www.epa.gov/oar/oaqps/greenbk/qnsum.html, web resource, last accessed February 13, 2009

[38] Ozone: http://www.epa.gov/oar/oaqps/greenbk/gnsum.html, web resource, last accessed February 13, 2009

[39] Ozone: National Ambient Air Quality Standards for Ozone; Final Rule, published March 27, 2008. 73 Fed. Reg. 16436. May be accessed on the web at: http://www.epa.gov/fedrgstr/EPA-AIR/2008/March/Day-27/a5645.pdf, last accessed March 10, 2009. Particulate Matter: National Ambient Air Quality Standards for Particulate Matter; Final Rule, published October 17, 2006. 71 Fed. Reg. 61144. May be accessed on the web at: http://www.epa.gov/ttn/naaqs/standards/pm/data/fr20061017.pdf, last accessed March 10, 2009.

[40] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships*, October 10, 2008. May be accessed online at http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308

[41] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships*, October 10, 2008. May be accessed online at http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308

ESTUARY HABITAT MOA

MEMORANDUM OF AGREEMENT
ON COLUMBIA RIVER ESTUARY HABITAT ACTIONS
BETWEEN THE STATE OF WASHINGTON,
THE BONNEVILLE POWER ADMINISTRATION,
THE U.S. ARMY CORPS OF ENGINEERS, AND
THE U.S. BUREAU OF RECLAMATION

SEPTEMBER 2009

TABLE OF CONTENTS

Section **Page**

I. **INTRODUCTION** 1

II. **BIOLOGICAL OPINION COMMITMENTS** 2

III. **ESTUARY HABITAT COMMITMENTS** 2
- A. Biological Value of Estuary Habitat Projects 2
- B. Overall Increased Estuary Commitments--$40.5 million 3
- C. Funding for Estuary Habitat Improvements 4
  - C.1 General Principles: 4
  - C.2 BPA Funding for Estuary Habitat Actions 5
  - C.3. Corps Funding for Estuary Habitat Actions 6
  - C.4. Estuary RM&E Funding 7
  - C.5. Contingency 7
- D. General Provisions For All Projects 8
- E. Council and ISRP Review 9
- F. Replacement Projects 9
  - F.1. General Principles: 9
  - F.2. Replacement Projects: 10
- G. Adaptive Management 10
  - G.2. New Information/Changed Circumstances 10
  - G.3. Additional Work and Funding 11
- H. Inflation and Budget Matters 11
  - H.1. Inflation 11
  - H.2. Expense Planning versus Actuals, and Project-Year Budgets 11
  - H.3. Budget Management 11
  - H.4. Costs of environmental and regulatory reviews 12

IV. **LITIGATION, GOOD FAITH, DISPUTE RESOLUTION AND OTHER PROVISIONS** 13
- A. Effects on Litigation 13
- B. Good Faith Implementation and Support 13
- C. Changed Circumstances, Renegotiation/Modification, Withdrawal 14
- D. Dispute Resolution 15
  - D.1. Negotiation 15
  - D.2. Mediation 16
- E. Modification 16

V. **MISCELLANEOUS PROVISIONS** 16
- A. Term of Agreement 16
- B. Relationship Between This Agreement and Implementing Intergovernmental Agreements 16
- C. Applicable Law 16
- D. Authority 17

E. Effective Date & Counterparts 17
F. Binding Effect 17
G. No Third Party Beneficiaries 17
H. Entire Agreement 17
I. Waiver, Force Majeure, Availability of Funds 17
J. Notice 18
K. List of Attachments 19

MEMORANDUM OF AGREEMENT
ON COLUMBIA RIVER ESTUARY HABITAT ACTIONS
BETWEEN THE STATE OF WASHINGTON, THE BONNEVILLE POWER ADMINISTRATION, THE U.S. ARMY CORPS OF ENGINEERS, AND THE U.S. BUREAU OF RECLAMATION

I. INTRODUCTION

This agreement for estuary habitat actions ("Estuary MOA" or "Agreement") confirms joint commitments of the Bonneville Power Administration ("BPA"), the U.S. Army Corps of Engineers ("Corps") the U.S. Bureau of Reclamation ("Reclamation") (collectively, "Action Agencies") and the State of Washington ("Washington" or "State") (collectively, the "Parties") regarding habitat actions to be undertaken to conserve salmon and steelhead through improvement of conditions in the Columbia River estuary, consistent with the Lower Columbia River Recovery plan,[1] the Estuary Recovery Plan Module, and the 2008 Biological Opinions ("BiOps") for the Federal Columbia River Power System ("FCRPS")[2] and Upper Snake Projects ("Upper Snake"),[3]and the Harvest BiOp.[4]

The Parties have also initiated good faith negotiations of a comprehensive long-term Memorandum of Agreement ("long-term Agreement" or "long-term MOA") to address issues associated with the effects of the FCRPS and Reclamation's Upper Snake Projects, on the fish and wildlife resources of the Columbia River Basin, including implementation of 2008 Biological Opinion for the FCRPS and Upper Snake Projects. This Estuary MOA is not intended to constrain or otherwise limit the scope of Parties' negotiations concerning a long-term Agreement. In particular, the Parties recognize that the Action Agencies' commitments in this Estuary MOA are part of their broader commitments to implement all-H actions to mitigate federal hydropower effects, consistent with the 2008 BiOps under the Endangered Species Act ("ESA") and the Pacific Northwest Electric Power Planning and Conservation Act ("Northwest Power Act" or "NPA").

[1] Lower Columbia River Salmon Recovery and Fish and Wildlife Subbasin Plan, issued by the Lower Columbia Fish Recovery Board on December 15, 2004, and adopted as an interim recovery plan for the Washington portion of the ESU recovery plan in February 2006 by NOAA Fisheries.
[2] For purposes of this Agreement, the FCRPS comprises 14 Federal multipurpose hydropower projects. The 12 projects operated and maintained by the Corps are: Bonneville, the Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak dams. Reclamation operates and maintains the following FCRPS projects: Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee Dam.
[3] For purposes of this Agreement, the Upper Snake River Projects (Upper Snake) are Minidoka, Palisades, Michaud Flats, Ririe, Little Wood River, Boise, Lucky Peak, Mann Creek, Owyhee, Vale, Burnt River and Baker.
[4] Consultation on Treaty Indian and Non-Indian Fisheries in the Columbia River Basin Subject to the 2008-2017 *U.S. v. Oregon* Management Agreement, issued by NOAA Fisheries on May 5, 2008.

II. BIOLOGICAL OPINION COMMITMENTS

The Parties reaffirm their position that the FCRPS and Upper Snake BiOps (including hydro operation, configuration, and water management provisions) satisfy ESA requirements during their terms. This includes the overarching hydro performance standards, supported by adaptive management, as set out in the BiOps and Biological Assessment.[5]

In implementing this Estuary MOA, the Parties commit to collaborate within the framework of the FCRPS BiOp. This includes annual reporting and comprehensive evaluations (including consideration of population and evolutionarily significant unit ["ESU"] status) in 2013 and 2016, all-H diagnosis, and identification of modified actions and contingencies.

III. ESTUARY HABITAT COMMITMENTS

A. Biological Value of Estuary Habitat Projects

The Parties agree that projects to protect, improve, and restore estuary habitat will yield important biological benefits. The Columbia River estuary represents one of three major environments supporting the life cycle of Columbia Basin salmon and steelhead. All of these salmon and steelhead stocks spend time in the estuary before migrating to the ocean. The Columbia River estuary has been significantly altered and degraded by human activities, and innumerable scientific studies and communications from notable regional scientists confirm that protection and restoration of this habitat will yield biological benefits for all listed salmonids in the Columbia River Basin. In addition, by improving ecological conditions and processes, the estuary habitat actions under this Agreement will also benefit numerous other fish and wildlife species that rely on estuary habitat at some point in their lifecycle. This includes non-listed salmon and steelhead, smelt (eulachon, whitebait, surf, night, and longfin), sea-run cutthroat trout, Pacific lamprey, and green and white sturgeon, among others. Enhancement of wetlands and riparian areas also provide important habitat for a variety of birds, including bald eagle, peregrine falcon and a variety of waterfowl species.

The actions being undertaken by the Parties in the estuary (including on the ground actions and research, monitoring and evaluation) support the estimated ESU survival benefits of 6% and 9% (for stream type and ocean type fish, respectively) over the term of the FCRPS BiOp. Although this Estuary MOA is not required under the 2008 FCRPS

[5] The hydro performance standards referenced here, as well as hydro targets and metrics, are described in the Main Report, Section 2.1.2.2 of the Action Agencies' August 2007 FCRPS Biological Assessment (FCRPS BA), pages 2-3 through 2-6, and the FCRPS BiOp at RM&E Strategy 2 (Hydro) and RPA 52 (pages 72-76 of 98). The adaptive management referenced here, including reporting and diagnosis, are described in Section 2.1 of the FCRPS BA, with population/ESU progress monitoring addressed in RM&E Strategy 1 (Status Monitoring) and RPAs 50 and 51 (pages 69-71 of 98).

BiOp, the additional $4.5 million annually of funding and actions provided under this Agreement will aid in the achievement of these benefits. The Parties are committed to using the estuary research, monitoring, and evaluation actions in the BiOp, in conjunction with the 2013 and 2016 comprehensive evaluations, to confirm the achievement of these benefits by 2018 within the framework of the FCRPS BiOp.

B. Overall Increased Estuary Commitments--$40.5 million

As a result of the mutual commitments between BPA, the Corps, and Washington described below, the Action Agencies will be providing an increase in funding for all estuary habitat actions of approximately $40.5 million over the nine year term of this MOA, summarized as follows:

	Pre-Estuary MOA			**With this Estuary MOA**			
Annual Planning Budgets ($ million)							
	Habitat	RM&E	Estuary Total	Habitat	RM&E	Estuary Total	Increased Habitat Funding
BPA	3.5			5.3			1.8
Corps	2.0			4.7			2.7
BPA & Corps Combined		6.6			6.6		
Sub-Total	5.5	6.6	**12.1**	10.0	6.6	**16.6**	**4.5**
Nine-Year Total ($ million)							
BPA & Corps Combined	49.5	59.4	**108.9**	90.0	59.4	**149.4**	**40.5**

****

Actual dollars figures will be higher, because these figures
do not include the 2.5% inflation adjustment for BPA commitments.

This MOA addresses the additional funding from BPA and the Corps for estuary habitat projects of $4.5 million annually committed to Washington. The remaining $5.5 million combined BPA and Corps commitments for estuary habitat projects, which began prior to this MOA, will continue to be utilized with other governmental and non-governmental entities in Oregon and Washington, including the Lower Columbia River Estuary Partnership ("LCREP"). The $6.6 million annually for estuary research, monitoring, and evaluation ("RM&E") will similarly be utilized with governmental and non-governmental entities.[6]

[6] There is an additional $1.2 million (annual) from system-wide RM&E activities benefitting the estuary that is not included in the table above; RM&E amounts may vary to reflect changes in scope over time.

Any funds provided to Washington or the Estuary Partnership through the stimulus packages under the American Recovery and Reinvestment Act of 2009 or other subsequent Acts, may provide additional biological benefits, but will not affect the funding commitments in this Agreement.

C. Funding for Estuary Habitat Improvements

C.1 General Principles:

- For purposes of this Agreement, the Columbia River estuary is defined as the area from the mouth of the Columbia River, including the plume, upstream to the limit of tidal influence (including tidally influenced areas of tributaries) at Bonneville Dam at River Mile 146.
- Estuary habitat projects funded under this Estuary MOA are linked to biological benefits based on limiting factors for ESA-listed fish at the ESU level. Estimated survival benefits based on habitat improvements will be determined for each project utilizing the process and methodology specified in the FCRPS BiOp. See Attachments 1 and 2. (Attachment 1 is the spreadsheet showing projects and estimated planning budgets; Attachment 2 provides brief project narratives, ESUs and limiting factors being addressed, and estimated survival benefits of the actions).
- Washington, acting through the Washington Department of Fish and Wildlife ("WDFW"), will either sponsor or coordinate the projects or actions funded under this Agreement for the benefit of salmon and steelhead in support of the FCRPS BiOp, consistent with the Northwest Power and Conservation Council's ("Council") Fish and Wildlife Program implementation in Washington. WDFW will coordinate the projects with the Lower Columbia Fish Recovery Board ("LCFRB"), and LCREP (which includes the State of Oregon), and other estuary action partners of the Action Agencies.
- The Parties endorse the National Oceanic and Atmospheric Administration ("NOAA")-modified LCREP ecosystem criteria[7] for estuary habitat projects (Attachment 3), and will apply these criteria (subject to any subsequent modifications made by NOAA in coordination with LCREP to reflect results of RM&E) in the process of selecting projects for this MOA.
- Projects funded under this Agreement are consistent with subbasin plans now included in the Council's Program and ESA recovery plans. More specific linkages to these plans will be documented as a function of the BPA contracting process.
- Projects may be modified by mutual agreement over time based on biological priorities, feasibility, science review comments, or based on results in habitat and survival improvements.

[7] NOAA modified the broader LCREP ecosystem criteria to more specifically address ESA-listed salmon and steelhead.

- Parties agree to report the results of implementation of this MOA through the annual reporting process under the FCRPS BiOp.
- The Parties acknowledge that there may be multiple projects in various phases of planning, design, and construction in any given year. The Parties agree to meet annually to discuss which projects will receive funding in that fiscal year for the Corps projects addressed in this MOA.

C.2 BPA Funding for Estuary Habitat Actions

- New Funding: BPA is committing to an increase of $1.8 million per year of estuary habitat funding beginning in fiscal year 2010. These funds will be utilized by Washington to:
    - Provide the cost share for projects to be submitted to the Corps pursuant to the Water Resource Development Act of 2000 ("WRDA 2000") Section 536, Lower Columbia River and Tillamook Bay Ecosystem Restoration, Oregon and Washington (see description below);
    - Provide cost-share for restoration of shoreline and shallow water habitat to benefit salmon and steelhead in the estuary under the Corps' Beneficial Use of Dredge Material program;
    - Address any planning and development and operation and maintenance costs for Corps projects addressed in this MOA; and
    - Fund other estuary habitat projects as mutually agreed.

- The BPA funding will be available for (in priority order):
    - Non-federal cost share for Corps projects under this MOA;
    - To cover operation O&M costs (O&M) for Corps projects under this MOA; and
    - Additional estuary habitat projects.

- Up to 20% percent of the BPA funds will be available per year for "transaction costs" which means costs to develop proposed projects, identify willing project sponsors, coordinate and develop the basic elements of these proposals, initiate and respond to science review and otherwise plan for project implementation.

- In order to reflect the heavier emphasis on initial planning steps in the first two years of the MOA, BPA will execute an umbrella contract with Washington's designated implementing agencies, providing up to $250 thousand each year for transaction costs.
    - Upon completion of planning, development and execution of partnering agreements for estuary projects for implementation under this Agreement, any additional transaction costs (if any) will transition from the umbrella contract to the Corps projects addressed in this Agreement.
    - The Parties will cooperate with the Corps to ensure that costs incurred prior to the start of the Corps' processes are to perform tasks needed to develop a proposal that addresses provisions of the Corps' authorities.

- The Parties also agree to cooperate to minimize these transaction costs to maximize available funds for the non-federal cost share and leveraging Corps appropriations for Corps projects under this Agreement.

- Of the $1.8 million commitment, $1.3 million is based on the Corps' commitment, below, to assume some of BPA's estuary RM&E commitments. The remaining $0.5 million commitment will be added to the Fish and Wildlife Program budget. However, the Parties share a preference that the 0.5 million per year will be funded from within BPA's existing Fish and Wildlife Program, and will cooperate in good faith to seek that outcome.

C.3. Corps Funding for Estuary Habitat Actions

- Under this Agreement the Corps will seek a $2.7 million annual increase in federal appropriations for the Corps 536 Program. This is based on the increase from BPA available to the State of Washington to cost share in increased estuary habitat work.[8] Two existing Corps authorities to create estuarine habitat are Section 536 of the WRDA 2000 ("536 Program") and Section 204 of the WRDA of 1992 (Beneficial Use of Dredge Material)("Section 204 Program").

- Under Section 536 (WRDA 2000), the Corps can construct ecosystem restoration projects for the lower Columbia River estuary to protect, monitor and restore fish habitat. This authority requires a non-Federal cost share sponsorship, in which the sponsor pays 35% and the Corps is responsible for 65% of the total costs to plan and construct the projects. The non-Federal sponsor (or local sponsor) is responsible for all lands, easement and rights-of-ways, of which value will be credited toward the local (non-Federal) cost- share. In addition, the local sponsor is responsible for all future operation and maintenance costs. (See Attachment 4 for more details of this authority and a flow chart for the Section 536 process.)

- A feasibility study to formulate an estuary habitat project under the Corps' 536 Program is cost shared equally (50 percent/50 percent) between the Corps of Engineers and the non-Federal sponsor. One hundred percent of the non-Federal share may be contributed as in-kind products or services. The feasibility study results in recommendations for the design and construction of the habitat actions, and identifies the responsibilities of the Federal and non-Federal sponsor during design and construction.

[8] Corps funds are subject to annual appropriations. The Corps, through its Northwestern Division, will request and work to obtain appropriations sufficient to fund its commitments under this Estuary MOA, and will keep the Parties apprised of the status of its appropriations request. The other Parties will support the Corps' efforts to obtain this funding. BPA will maintain its $1.8 million estuary habitat commitment even if the increased appropriations request is not immediately successful, provided the Corps continues to use best efforts to obtain the increased appropriations.

- Under Section 204 (WRDA 1992), the Corps can cost share with willing local sponsors the incremental costs above the least cost Federal standard to create estuarine habitat (beneficial use) from material dredged for a federal navigation project. Incremental costs could result from increased distances to disposal site, requiring different equipment or special handling/rehandling techniques or additional features to help stabilize dredged material at a placement site. The Corps will pay 75% of the incremental costs and the sponsor is required to pay the remaining 25%.

- The Corps will consult with Washington to ensure that Corps projects and related RM&E implemented under these authorities will contribute to the objectives of this Agreement, including projects (or types of projects) identified for funding.

C.4. Estuary RM&E Funding.

- The Corps and BPA currently fund approximately $6.6 million annually of RM&E in the estuary to support implementation of the FCRPS BiOp. (*See II.B. above).*
- As part of its commitments to implement the Reasonable and Prudent Alternative (RPA) actions of the 2008 FCRPS BiOp, the Corps and BPA are funding RM&E (RPA actions 58- 61). Under this Estuary MOA, the Corps agrees to fund up to $1.3 million annually of the on-going RM&E work through its Columbia River Fish Mitigation Project ("CRFM") starting in Fiscal Year 2010, through the duration of this MOA. This work will include the study of "Historic Habitat Food Web Linkages" (NOAA and others) and the "Ecology of Juvenile Salmon in Tidal Freshwater in the Vicinity of the Sandy River Delta" (Pacific Northwest National Lab).
- In regional coordination processes, WDFW will support these estuary RM&E actions for priority funding under the CRFM.
- This shift in funding will not change the commitment by the Corps and BPA to implement the estuary RM&E. Any changes in scope for the two RM&E projects identified above will be coordinated and mutually agreed by the Corps and BPA.
- With the Corps' commitment to fund through CRFM up to $1.3 million in RM&E commitments that had been provided by BPA, BPA will provide an equivalent amount, $1.3 million, to Washington to serve as the matching cost share from Washington or other entities in Washington (as project sponsor) to the Corps, for habitat work in the estuary.

C.5. Contingency

If, despite its best efforts, Washington does not identify sufficient viable estuary habitat projects to utilize all 536 Program funds contemplated in this Estuary MOA for two consecutive years, the Parties agree that the Corps and BPA may seek additional project sponsors, for projects in Washington or Oregon, to utilize the available appropriations and the 'freed' cost share funds provided by BPA.

D. General Provisions For All Projects

D.1. All projects funded pursuant to this Agreement shall:

- Be consistent with the Council's Program (including sub-basin plans), as amended, otherwise compliant with the NPA's science and other review processes; applicable ESA recovery plans; and applicable data management protocols adopted by the Action Agencies.
- Be consistent with BPA's then applicable policies, including but not limited to BPA's *in lieu* policy and BPA's capital policy.
- Report results annually (including ongoing agreed upon monitoring and evaluation) via PISCES and/or other appropriate databases.
- Remain in substantive compliance with any applicable implementing project contract terms, including but not limited to 536 Program or Section 204 WRDA partnering agreements.
- Be subject to any necessary permits and approvals for actions on federal lands.

D.2. In addition, Washington shall:

- Provide estimated habitat and survival benefits from the project to listed salmon and steelhead based on key limiting factors and determined using the process and methodology specified in RPA 37 of the FCRPS BiOp, in cooperation with the Corps and BPA;
- Prior to implementation, bring projects through the expert regional technical group process prescribed in RPA 37 to confirm projected benefits and, in the event that there are differences between the results of the expert panel process and Washington's original benefit estimate, the Parties will reconcile the difference and develop final benefits through technical collaboration;[9] and
- Support and defend these estimates of habitat and survival benefits with available and relevant scientific, policy, and legal information.

D.3. The Parties will coordinate their RM&E projects with each other and with regional RM&E processes (particularly those needed to ensure consistency with the FCRPS BiOp RM&E framework), as appropriate and agreed to among the Parties.

D.4. For actions on federal lands, Washington will consult with the federal land managers, and discuss necessary permits and approvals.

D.5. For projects where the State of Washington is a sponsor, before project approval, the Parties will meet to discuss and address projected operation and maintenance requirements and any potential liability exposure arising from project implementation. Operation and maintenance costs may be paid for as agreed by the Parties, on a project-

[9] BPA and the Corps will provide assistance to WDFW for technical support in the expert regional technical group process, on request.

by-project basis, from the BPA portion of the funding in this MOA. Risk management issues will also be discussed and addressed by the Parties as needed, prior to project selection.

E. Council and ISRP Review

E.1. As described in Section III.C.1, above, projects funded by BPA pursuant to this Agreement shall be consistent with the Council's Program and follow the NPA's science and other review processes.

E.2**.** The Parties recognize that the Council's Program is a maturing program, which through several decades of implementation has established a continuing framework for mitigating the impacts of hydroelectric development in the Columbia River Basin. The Parties acknowledge that nothing in this Agreement precludes any Party from making recommendations to the Council about modifications to the Council or ISRP review processes to facilitate project implementation under this Agreement or generally. The guidelines for ISRP review developed by the Council in consultation with the ISRP, BPA, and the Accord parties, for review of the Columbia Basin Fish Accords projects will be used for review of the projects under this Estuary MOA. Washington will ensure that any needed ISRP science review is timely and occurs before a project partnering agreement is drafted to implement a project under the Corps' Programs. If the ISRP review process cannot accommodate the timing requirements for Corps projects funded under this Estuary MOA, the Parties may propose a programmatic approach for ISRP review to the Council.

F. Replacement Projects

F.1. General Principles:

- The Parties agree that a project identified in this Agreement may not ultimately be implemented or completed due to a variety of possible factors, including but not limited to:
    - Problems arising during regulatory compliance (e.g., ESA consultation, National Environmental Policy Act ("NEPA"), the (Washington) State Environmental Policy Act ("SEPA"), National Historic Preservation Act ("NHPA") review, Clean Water Act permit compliance, etc);
    - The project does not meet BPA's *in lieu* policy or does not meet BPA's capital policy;
    - New information regarding the biological benefits of the project (e.g., new information indicating a different implementation action is of higher priority, or monitoring or evaluation indicates the project is not producing its anticipated benefits);
    - Changed circumstances (e.g., completion of the original project or inability to implement the project due to environmental conditions); or

- Substantive non-compliance with the implementing contract, including but not limited to the Corps' 536 Program or Section 204 WRDA partnering agreements.

- Should a project not be implemented due to one or more of the above factors, the Action Agency and WDFW, in consultation with the LCFRB, LCREP, NOAA Fisheries, and other estuary action partners of the Action Agencies, will promptly negotiate a replacement project.

F.2. Replacement Projects:

- A replacement project(s) should be the same or similar to the project(s) it replaces in terms of target species, limiting factor, mitigation approach, geographic area and/or subbasin and biological benefits.
- A replacement project(s) should have the same or similar planning budget as the project(s) it replaces (less any expenditures made for the original project(s)). Such budget must address carry-forward funding whose amount and calculation will be subject to the Parties' mutual agreement.

G. Adaptive Management

In the implementation of this MOA, the Parties will work together on an adaptive management basis, consistent with the FCRPS BA and the collaborative framework of the FCRPS BiOp, including but not limited to the following:

G.1. Regular Feedback and Review

The Parties will meet at least annually to review implementation of this Estuary MOA and its progress, and to discuss actions needed to maintain or improve steady implementation and to attain the predicted biological benefits of the Agreement.

G.2. New Information/Changed Circumstances

In addition to project-specific adaptation through replacement project(s) described above, the Parties may mutually agree to adaptively manage this shared implementation portfolio on a more programmatic scale based on new information or changed circumstances. For example, if during implementation of this MOA, new information or changed circumstances indicate the habitat focus of this MOA is no longer the most effective type of activity to meet the estuary performance standards the Parties can, if mutually agreed, shift the BPA commitments in this MOA to a different programmatic approach.

G.3. Additional Work and Funding

As part of the comprehensive evaluations in 2013 and 2016, the Parties will review results under this Agreement and will determine whether additional work is needed to achieve ESU survival benefits of 6% and 9% (for stream type and ocean type Chinook, respectively) within the framework of the FCRPS BiOp. Based on this review, if additional work is needed to achieve these benefits, the Parties will discuss whether the Action Agencies should seek and commit additional actions or funding.

H. Inflation and Budget Matters

H.1. Inflation

Beginning in fiscal year 2011, BPA will provide an annual inflation adjustment of 2.5 percent. In implementing this provision, BPA will add the inflation adjustment, compounded, to expense budgets beginning in 2011, but will not subsequently adjust project budgets as the schedule of that work changes.

H.2. Expense Planning versus Actuals, and Project-Year Budgets

H.2.a. BPA will plan to contract at the full amounts described in this Estuary MOA. Due to a variety of factors outside of BPA's control, however, BPA's actual expenditures may be less. (Historically, the average difference between BPA's planned expenditures for implementing the expense component of its Council Fish and Wildlife Program, and BPA's actual spending—what BPA is invoiced and pays under individual implementing contracts—is about 7%; that is, BPA plans to expend 100 dollars, but it will be invoiced and pay 93 dollars). When under-spending occurs, funding can be made available in other years and for other projects by mutual agreement per Section III.H.3, below. If total BPA expense spending under this Agreement is less than 93% of the planned amount in any one year, BPA, the Corps, and Washington will meet to discuss possible actions to remove the impediments to achieving the Agreement's full implementation and spending.

H.2.b. BPA's financial commitments and project budgets identified in Attachment 1 are described in fiscal-year terms, but BPA fish and wildlife program contracts are not necessarily aligned to the fiscal year (FY). As a result, the expense budgets in Attachment 1 will be interpreted as project-year (PY) budgets. This means that the project (as implemented through a BPA-issued contract or contracts) can start anytime during the federal fiscal year (Oct 1 – Sep. 30) and use that PY budget for the full implementation period (usually one year).

H.3. Budget Management

Washington may request an adjustment of the PY budget (through requests for transfers, reschedules, or preschedules) for any individual project so long as the Agreement level

planning budget--the roll up of the individual project-year budgets--does not exceed 120% of the original planning budgets after the inflation adjustment (see Attachment 1).

Transfers of budgets between projects may be allowed through mutual agreement so long as the transfer is consistent with the Agreement-level budget cap (above), and BPA and Washington mutually agree on the revised focus. (BPA will not likely agree to a budget transfer that moves dollars away from habitat work or other on-the-ground work.)

If Washington is able to complete work below a project budget, leaving obligated funds unspent for a project when the contract is closed, those funds will be made available to Washington for re-allocation if mutually agreed by BPA. Through mutual agreement those unspent funds may be rescheduled to the same project or transferred to another Agreement project so long as the adjustment is consistent with the Agreement-level budget cap.

In addition, BPA and Washington may, by mutual agreement, adjust the 120% cap for those projects that involve the acquisition of interests in land or water from willing sellers, to accommodate the uncertainties of negotiations with sellers. In order to exceed the 120 percent cap for such circumstances, Washington shall give BPA at least six months notice of the potential need for such an extension, and provided further that BPA may decline to make the adjustment to avoid a "bow wave" of spending in any given year, or towards the end of this MOA's terms, or on any other reasonable ground, including consideration of how any such adjustments would affect cost-share opportunities with the Corps' 536 Program under this MOA.

H.4. Costs of environmental and regulatory reviews

In order to implement the projects identified in this Agreement, BPA, the Corps and/or Washington may need to undertake a variety of environmental and regulatory reviews, including, but not limited to those under NEPA, the NHPA, the ESA, and the Clean Water Act. Unless otherwise mutually agreed, the costs of these review processes will be taken out of the funding commitments of this Agreement, regardless of whether Washington or BPA undertakes the work. Thus, for example, if an Environmental Assessment or an Environmental Impact Statement under NEPA is needed for one or more projects, the costs of that work will be subtracted from the relevant budget under this Agreement. The Parties agree to coordinate in advance on budgeting for these environmental and regulatory reviews.

IV. LITIGATION, GOOD FAITH, DISPUTE RESOLUTION AND OTHER PROVISIONS

A. Effects on Litigation

The Parties will discuss the appropriate means of alerting the district court in *NWF v. NMFS* of this Agreement (if needed) and will undertake any agreed-upon approach.

B. Good Faith Implementation and Support

Best effort good-faith implementation and support of this Estuary MOA is the general duty to which all Parties agree to be bound. Nonetheless, the Parties understand that from time to time questions or concerns may arise regarding a Party's compliance with the terms of this Agreement. In furtherance of the continuing duty of good faith, each Party agrees that the following specific actions or efforts will be carried out:

B.1. On a continuing basis, each Party will take steps to ensure that all levels of its government/institution is made aware of the existence of this Agreement and the specific commitments and obligations herein, and emphasize the importance of meeting them.

B.2. Each Party will designate a person to be initially and chiefly responsible for coordinating internal questions regarding compliance with the Agreement.

B.3. Each Party will make best efforts to consult with other Parties prior to taking any action that could reasonably be interpreted as inconsistent with any part of this Agreement. To assist in this, the Parties will designate initial contact points. The formality and nature of the consultation will likely vary depending circumstances. The initial contact points are initially charged with attempting to agree on what form of consultation is required. In some instances, the contact between initial contact points may suffice for the consultation, while in others, they may need to recommend additional steps. The Parties agree that consultations should be as informal and with the least amount of process necessary to ensure that the Parties are fulfilling the good-faith obligation to implement and support the Agreement.

B.4. If a Party believes that another Party has taken action that is contrary to the terms of the Agreement, or may take such action, it has the option of a raising a point of concern with other Parties asking for a consultation to clarify or redress the matter. The Parties will endeavor to agree upon any actions that may be required to redress the point of concern. If after raising a point of concern and having a consultation the Parties are unable to agree that the matter has been satisfactorily resolved, any Party may take remedial actions as it deems appropriate, so long as those remedial actions do not violate the terms of the Agreement.

C. Changed Circumstances, Renegotiation/Modification, Withdrawal

C.1. The Parties acknowledge that NOAA Fisheries has issued a final BiOp for the FCRPS as of May 5, 2008, and that there is litigation regarding this BiOp.

C.2. If any court, regardless of appeal, finds that the FCRPS or the Upper Snake Project BiOp or agency action is arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law, and subsequently remands either BiOp to NOAA Fisheries, this Agreement shall remain in force, subject to the provisions of this Section IV.C.2. If any court, regardless of appeal, finds that either BiOp or agency action is arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law, the Parties will seek to preserve this Estuary MOA, and will meet promptly to determine the appropriate response as described below:

(a) In the event that a portion(s) of this Agreement is in direct conflict with the court order or resulting amended BiOp, the Parties shall meet and agree on an appropriate amendment to that section, or, if such amendment is not possible under the terms of the court order or resulting amended BiOp, then a substitute provision shall be negotiated by the Parties.

(b) If the court-ordered FCRPS operations or resulting amended BiOp require additional actions that are either financially material to an Action Agency or that materially constrain the Corps or Reclamation from meeting FCRPS purposes, Section IV.C.3 shall apply.

(c) The Parties will participate in any court-ordered process or remand consultation in concert with Sections IV.B and IV.C.

(d) The Parties intend that determinations of materiality will only be made in cases of great consequence.

C.3. In the event of the occurrence of any of the material effects in Section C.2, or in the event of material non-compliance with the Agreement not resolved by dispute resolution, the affected Party or Parties shall notify the other Parties immediately and identify why the event is considered material. The Parties shall utilize dispute resolution if there is a disagreement as to whether the event is material. In addition, prior to any withdrawal, the Parties shall first make a good faith effort to renegotiate mutually agreeable modifications to the Agreement. If renegotiation is not successful, the affected Party may notify the other Parties in writing of its intent to withdraw by a date certain. If renegotiation is not successful, at the time the withdrawal is effective, all funding commitments and/or other covenants made by the withdrawing Party cease, and the withdrawing Party shall have no further rights or obligations pursuant to the Agreement. A withdrawing Party reserves any existing legal rights under applicable statutes, including all arguments and defenses,

and this Agreement cannot be used as an admission or evidence in support of or against any such argument or defense.

C.4. The provisions of this Agreement authorizing renegotiation, dispute resolution, withdrawal, or challenge in appropriate forums provide the sole remedies available to the Parties for remedying changed circumstances or disputes arising out of or relating to implementation of this Agreement.

C.5. Any Party may withdraw or request renegotiation for reasons other than those enumerated above subject, however, to the provisions in Section IV.C.3.

C.6. If one Party withdraws from the Agreement, any other Party has the option to withdraw as well, with prior notice.

C.7. Savings. Notwithstanding Section IV.C.3, in the event of withdrawal, BPA will continue providing funding for projects necessary for support of FCRPS BiOp commitments (as determined by the Action Agencies), and may provide funding for other on-going projects or programs that the Parties mutually agree are important to continue.

D. Dispute Resolution

D.1. Negotiation

1.a. The Parties shall attempt in good faith to resolve any dispute arising out of or relating to implementation of this Estuary MOA in accordance with this section prior to administrative, judicial or other formal dispute resolution procedures. The purpose of this Section IV.D.1 is to provide the Parties an opportunity to fully and candidly discuss and resolve disputes without the expense, risk and delay of a formal dispute resolution.

1.b. If the Parties are unable to resolve the dispute through informal dispute resolution, then the dispute shall be elevated to negotiating between executives and/or officials who have authority to settle the controversy and who are at a higher level of management than the person with direct responsibility for administration of this Agreement. All reasonable requests for information made by one Party to the other will be honored, with the Action Agencies treating "reasonable" within the context of what would be released under the Freedom of Information Act.

1.c. In the event a dispute over material non-compliance with the Agreement has not been resolved by negotiation, the affected Party may seek to withdraw, without further renegotiation, in accordance with Section IV.C.3, and may pursue any other remedy provided by law.

D.2. Mediation

In the event the dispute has not been resolved by negotiation as provided herein, the disputing Parties may agree to participate in mediation, using a mutually agreed upon mediator. To the extent that the disputing Parties seeking mediation do not already include all Parties to this Agreement, the disputing Parties shall notify the other Parties to this Agreement of the mediation. The mediator will not render a decision, but will assist the disputing Parties in reaching a mutually satisfactory agreement. The disputing Parties agree to share equally the costs of the mediation.

E. Modification

The Parties by mutual agreement may modify the terms of this Estuary MOA. Any such modification shall be in writing signed by all Parties.

V. MISCELLANEOUS PROVISIONS

A. Term of Agreement

The term of this Estuary MOA will extend from its effective date through midnight on September 30, 2018, unless amended by mutual agreement of the Parties.

B. Relationship Between This Agreement and Implementing Intergovernmental Agreements

The Parties will enter into separate and discrete intergovernmental agreements to implement this Estuary MOA. Once issued, those intergovernmental agreements will govern all activities addressed in those agreements. For example, the provisions of this MOA regarding changed circumstances, renegotiation and withdrawal (Section IV.C) would not govern disputes in a Corps partnering agreement or BPA contract. Similarly, if a Party were to withdraw from this MOA pursuant to Section IV.C, this would not automatically terminate any implementing intergovernmental agreements; any decision to terminate an implementing intergovernmental agreement would be pursuant to that agreement's termination provisions.

C. Applicable Law

All activities undertaken pursuant to this Agreement must be in compliance with all applicable laws and regulations. No provision of this Agreement will be interpreted or constitute a commitment or requirement that the Action Agencies or Washington take action in contravention of law, including the APA, ESA, CWA, NEPA, Federal Advisory Committee Act, Information Quality Act, or any other procedural or substantive law or

regulation. Federal law shall govern the implementation of this Agreement and any action to enforce its terms.

D. Authority

Each Party to this Agreement represents and acknowledges that it has full legal authority to execute this Agreement.

E. Effective Date & Counterparts

The effective date of this Agreement shall be the date of execution by the last Party to provide an authorized signature to this Agreement. This Agreement may be executed in counterparts, each of which is deemed to be an executed original even if all signatures do not appear on the same counterpart. Facsimile and photo copies of this Agreement will have the same force and effect as an original.

F. Binding Effect

This Agreement shall be binding on the Parties and their assigns and successors. Each Party may seek dispute resolution in accordance with Section IV.D, or to withdraw in accordance with Section IV.C.3 if the dispute is not resolved.

G. No Third Party Beneficiaries

No third party beneficiaries are intended by this Agreement.

H. Entire Agreement

All previous communications between the Parties, either verbal or written, with reference to the subject matter of this Agreement are superseded, and this Agreement duly accepted and approved constitutes the entire Agreement between the Parties.

I. Waiver, *Force Majeure*, Availability of Funds

I.1. The failure of any Party to require strict performance of any provision of this Agreement or a Party's waiver of performance shall not be a waiver of any future performance of or a Party's right to require strict performance in the future**.**

I.2. No Party shall be required to perform due to any cause beyond its control. This may include, but is not limited to fire, flood, terrorism, strike or other labor disruption, act of God or riot. The Party whose performance is affected by a *force majeure* will notify the other Parties as soon as practicable of its inability to perform, and will make all reasonable efforts to promptly resume performance once the *force majeure* is eliminated.

If the force majeure cannot be eliminated or addressed, the Party may consider withdrawal pursuant to Section IV.C.3.

I.3. The actions of the Corps and Reclamation set forth in this Agreement are subject to the availability of appropriated funds. Nothing in this Agreement shall be construed to require the obligation or disbursement of funds in violation of the Anti-Deficiency Act.

J. Notice

J.1. Any notice permitted or required by the Good Faith provisions of this Agreement, Section IV.B, may be transmitted by e-mail or telephone to a Party's initial contact points, as that person is defined pursuant to the Good Faith provisions.

J.2. All other notices permitted or required by this Agreement shall be in writing, delivered personally to the persons listed below, or shall be deemed given five (5) days after deposit in the United States mail, addressed as follows, or at such other address as any Party may from time to time specify to the other Parties in writing. Notices may be delivered by facsimile or other electronic means, provided that they are also delivered personally or by mail. The addresses listed below can be modified at any time through written notification to the other Parties.

Notices to BPA should be sent to:

Vice President, Environment Fish & Wildlife
Mail Stop KE-4
Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208-3621

Notices to the U.S. Army Corps of Engineers should be sent to:

U.S. Army Corps of Engineers, Northwestern Division
Chief, Planning, Environmental Resources and Fish Policy Support Division
1125 NW Couch Street
Suite 500
P.O. Box 2870
Portland, OR 97208-2870

Notices to the U.S. Bureau of Reclamation should be sent to:

Deputy Regional Director
Bureau of Reclamation
Pacific Northwest Region
1150 N. Curtis Rd., Suite 100
Boise, ID 83706

Notices to the State of Washington should be sent to:

Southwest Regional Director
Washington Department of Fish and Wildlife
2108 Grand Boulevard
Vancouver, WA 98661

K. List of Attachments

Attachment 1—Excel spreadsheet showing projects and funding commitments
Attachment 2—Narrative description of projects, and benefits to ESUs
Attachment 3—LCREP ecosystem criteria
Attachment 4—Corps 536 Program Authority & Flow Chart

SIGNATURES

/s/ *Stephen J. Wright* *[Sept. 16, 2009]*

Stephen J. Wright — Date
Administrator and Chief Executive Officer
Bonneville Power Administration

/s/ *William Rapp* *16 Sept. 2009*

William E. Rapp, P.E. — Date
Brigadier General, US Army
Division Commander

/s/ *J. William McDonald* *Sept. 16, 2009*

J. William McDonald — Date
Regional Director
U.S. Bureau of Reclamation
Pacific Northwest Region

/s/ *Christine Gregoire* *9/16/09*

Christine O. Gregoire — Date
Governor
State of Washington

/s/ *Phil Anderson* *9-16-09*

Phil Anderson — Date
Director
Washington Department of Fish and Wildlife

ATTACHMENT 1 **ESTUARY HABITAT PROJECTS**

#	PROJECT TITLE	Estimated Cost (2009 Dollars)	2010	2011	2012-2018	TOTAL
	Total BPA+Corps Budget Target (Not including 2.5% Inflation on BPA $1.8M annual commitment)		$ 4,500,000	$ 4,500,000	$ 31,500,000	$ 40,500,000
	WDFW Umbrella project -- WDFW Component	$160,000 / Year	$ 160,000	$ 160,000		$ 320,000
	Lower Columbia Fish Recovery Board (LCFRB) Component	$90,000 / Year	$ 90,000	$ 90,000		$ 180,000
1	**Abernathy Tidal Restoration**	$450,000	$450,000			$ 450,000
2	**Hump-Fisher Island Restoration**	$800,000	$800,000			$ 800,000
3	**Cottonwood/Howard Island Tidal Channel Connection**	$1,100,000	$700,000	$ 400,000		$ 1,100,000
4	**Lower Kalama Tidal Restoration**	$550,000	$550,000			$ 550,000
5	**Acquisition of Chaney Parcel at Wood's Landing and Restoration of Chum Salmon Spawning Tributary**	$1,850,000	$950,000	$ 900,000		$ 1,850,000
6	**Post Office Lake Wetland Restoration**	$1,350,000	$800,000	$ 550,000		$ 1,350,000
	Budget for other Projects, selected from menu, including but not limited to the following, which will be further scoped beginning in FY 10:			$ 2,400,000	$ 31,500,000	$ 33,900,000
7	**Germany Tidal Restoration**	$930,000				
8	**Paradise Point Wetland Enhancement**	$700,000				
9	**Austin Point LWD Complexing**	$350,000				
10	**Elochoman Tidal Restoration**	$600,000				
11	**Willow Grove Tidal Restoration**	To Be Determined				
12	**Shillapoo Wildlife Area - Feasibility of Setback Levees**	To Be Determined				
13	**Duncan Creek Fish Passage Restoration**	To Be Determined				
14	**Lower Washougal Delta Habitat Complexing**	~$200,000				
15	**Lower Kalama Delta Habitat Complexing**	~$400,000				
16	**Chinook River Estuary Restoration**	To Be Determined				
17	**Lower Cowlitz Tidal Restoration**	~ $6 million (rough)				
18	**Coweeman River Tidal Restoration**	To Be Determined				
19	**Lewis River Acquisition**	To Be Determined				
20	**Port of Kalama Off-channel Wetland Enhancement**	To Be Determined				
21	**Barlowe Point Beach Nourishment**	To Be Determined				
		Totals:	$ 4,500,000	$ 4,500,000	$ 31,500,000	$ 40,500,000

ATTACHMENT 2

WDFW Estuary MOA Preliminary Habitat Project List Notes:

Preliminary Project List: The projects identified in this list are derived from a variety of sources, including the Lower Columbia Fish Recovery Board (LCFRB), Lower Columbia River Estuary Partnership (LCREP), U.S. Army Corps of Engineers (USACE), Washington Department of Fish and Wildlife (WDFW), and other entities. This project list will be adjusted over time depending on feasibility, emerging priorities and opportunities, and landowner and community support.

Landowner Support and Coordination: Landowner and community support is recognized as critical to the long term success of Estuary Habitat MOA implementation. No project will be implemented without first securing necessary landowner and community support, and required agreements.

Estimated Project Benefits: Salmon and steelhead survival benefits are determined in accordance with the guidance and procedures outlined in "Estimated Benefits of Federal Agency Habitat Projects in the Lower Columbia River and Estuary" (FCRPS BA, Attachment B.2.2.). In summary, each project is first scored in terms of two criteria: certainty of success and potential benefits (0=low, 5=high). Then each project is linked to a related recovery action from the Estuary Recovery Plan Module, and evaluated for its contribution to implementation of that action, using survival improvement targets from the Module. This results in estimated survival units gained by the action, allocated to ocean- and stream-type juveniles. Project benefits identified in this table are considered preliminary, and will be refined by the expert technical group in accordance with Reasonable and Prudent Alternative (RPA) 37 (FCRPS Biological Opinion, 2008).

Project Coordination: As described in Section C.1 of the Estuary Habitat MOA, WDFW will sponsor or coordinate projects proposed under the agreement. WDFW will coordinate with the Lower Columbia Fish Recovery Board (LCFRB), Lower Columbia River Estuary Partnership (LCREP) and other action partners as needed to ensure efficient and effective implementation of the MOA.

Table 1 Preliminary WDFW Estuary MOA Project Benefits and Survival Unit Summary [1]

	Washington MOA Project	Certainty of Success	Potential Benefit	Total	Estuary Module Sub-Action	Total Possible Survival Units by Sub-Action		Preliminary Estimated Survival Units By Project		Notes[5]
						Ocean	Stream	Ocean	Stream	
1	Abernathy Tidal Restoration	4	3	12	CRE-1.4	2	2	0.06	0.06	Intensively Monitored Watershed (IMW) Treatment Plan identifies two projects in the tidal reaches of Abernathy Cr (1A and 2A). The projects would enhance a minimum of 500' of off-channel habitat and 2200' of mainstem through engineered log jam construction, large woody material placement, riparian enhancement, and floodplain reconnection. Conceptua designs have been completed for these projects. Explore opportunities for creation of chum spawning habitat. **Project Site Acres 22**
2	Fisher - Hump Island Restoration	4	5	20	CRE-1.4	2	2	0.12	0.12	Modify dredged material to improve flushing flows within the Hump - Fisher Island embayment; plant additional riparian vegetation (Hump Island); revegetate meadow on Fish Island (5-10 acres); remove piling add LWD. **Project Site Acres 337**
					CRE-6	0.3	0.15	0.1	0.03	
3	Cottonwood Howard Island Tidal Channel Connection	3	5	15	CRE-10.1	15	6	0.15	0.05	Reconnect and construct backwater channels. **Project Site Acres 400**
4	Lower Kalama Tidal Restoration	5	4	20	CRE-1.4	2	2	0.1	0.1	Lower Columbia Fish Enhancement Group (LCFEG) recently completed a Lower Kalama Off-channel Habitat Assessment that identified five projects in the tidal reaches of the Kalama. Three of these scored in the fundable range when subjected to the LCFRB criteria (KRL 0.1, KRR 0.7, and KRL 1.4). These projects would create or enhance existing off-channel habitat. Conceptual designs and cost estimates have been completed for KRR 0.7. Explore opportunities for creation of chum spawning habitat. **Project Site Acres 32 34 2 12**
					CRE-10.1	10	4	0.12	0.05	
5	Acquisition of Two Alternative Parcels at Wood's Landing Columbia Springs and Restoration of Chum Salmon Spawning Tributary or Channel	4	3	12	CRE-9.1	1	0.5	0.2	0.05	Acquire one of two possible properties in the vicinity of the genetically distinct I-205 spawning population of chum salmon, and restore tributary spawning habitat either by: **OPTION A** - Acquire the 2.29 acre Chaney property located just downriver of the Wood's Landing Columbia River chum salmon spawning site -- that can be combined with existing conservation easements to result in a combined restoration area of 13.0 acres. This parcel contains the last unprotected habitat for "I-205 population" of chum salmon. Site also has Native American cultural and educational values and a functioning riverine wildlife community; or, **OPTION B** - Acquire the 5.5 acre Egan Property and construct a 1400' long by 6' wide engineered spawning channel using natural springs and th WDFW Vancouver Hatchery as a water source. A conceptual design and preliminary feasibility study have been completed on this alternative. This site has high educational potential since it is adjacent to the Columbia Springs educational facility. **Project Site Acres 13.0 (Chaney Woods Landing) or 5.5 (Egan parcel).**
					CRE-9.3	8	3	0.24	0.03	

	Washington MOA Project	Certainty of Success	Potential Benefit	Total	Estuary Module Sub-Action	Total Possible Survival Units by Sub-Action		Preliminary Estimated Survival Units By Project		Notes[5]
						Ocean	Stream	Ocean	Stream	
6	Post Office Lake	4	4	16	CRE-1.4	2	2	0.18	0.18	This project will restore hydrologic connection from the Post Office Lake floodplain wetland with the estuary while protecting privately owned farmland. The objective is to re-establish access and improve wetland function to approximately 80 acres of shallow water habitat for juvenile salmonids. **Project Site Acres □ 80**
					CRE-10.1	10	4	0.15	0.05	
7	Germany Tidal Restoration	4	3	12	CRE-1.4	2	2	0.06	0.06	IMW Treatment Plan identifies two projects in the tidal reaches of Germany Creek (2A, 2B, 2C). The projects would enhance a minimum of 600' of mainstem habitat, stabilize 350' of eroding bank, and enhance a minimum of 7 acreas of riparian area. Conceptual designs have been completed for these projects. Explore opportunities for creation of chum spawning habitat. **Project Site Acres □ 75**
8	Paradise Point Wetland Enhancement	5	4	20	CRE-1.4	2	2	0.08	0.08	Restore and enhance approximately 1000 lineal feet of side channel habitats within a tidally influenced forested□emergent□scrub-shrub wetland complex; construct mainstem LWD structures to increase juvenile rearing and adult holding habitat during low tributary flows, low Columbia River flows, and periods of low tide; and investigate opportunites for creation of chum spawning habitat. Restoration would compliment conservation banking efforts on Morgan Property, at the North Fork Lewis River mouth. **Project Site Acres □ 60**
					CRE-10.1	10	4	0.15	0.07	
					CRE-15.3	1.5	0.7	0.05	0.02	
9	Austin Point LWD Complexing	4	4	16	CRE 1.4	2	2	0.07	0.07	Restore riparian habitat and construct ELJs on the right bank of the North Fork Lewis River at the confluence with the Columbia River, to provide instream cover and complexity, and cold-water refuge for outmigrating salmonids. Restoration would compliment conservation banking efforts on Morgan Property, at the North Fork Lewis River mouth, across from project site; investigate options for off-channel habitat creation other WDFW lands in project vicinity. **Project Site Acres □ 71**
10	Elochoman Tidal Restoration	3	5	15	CRE-1.4	2	2	0.06	0.06	CLT was funded to purchase 200 acres of high quality intertidal forested riparian and wetland habitat along the Elochoman River and Elochoman Slough. The property is adjacent to the JBH Refuge and 210 acres already owned by CLT on Nelson Creek. The property includes over 7000 of off channel habitat. Potential restoration activities on the property include culvert removal, tidegate removal, road abandonment, invasive treatment, and riparian enhancement. **Project Site Acres □ 200**
					CRE-10.1	10	4	0.15	0.05	
					CRE-10.2	3	1.2	0.05	0.01	
					CRE-15.3	1.5	0.7	0.05	0.02	
11	Willow Grove Tidal Restoration	3	5	15	CRE-1.4	2	2	0.06	0.06	CLT has recently purchased over 200 acres of intertidal wetland and off-channel habitat along the Columbia River and Coal Creek. Potential restoration activities include restoration of native wetland communities, invasive control, and enhancing the hydrologic connection of the site to the mainstem, possibly via Fisher slough. **Project Site Acres □ 312**
					CRE-10.1	10	4	0.15	0.05	
					CRE-15.3	1.5	0.7	0.05	0.01	

	Washington MOA Project	Certainty of Success	Potential Benefit	Total	Estuary Module Sub-Action	Total Possible Survival Units by Sub-Action		Preliminary Estimated Survival Units By Project		Notes[5]
						Ocean	Stream	Ocean	Stream	
12	Shillapoo Wildlife Area Floodplain Reconnection	NA	NA	NA	NA	0.0	0.0	0.0	0.0	Investigate the potential for providing fish passage to re-connect historical floodplain wetland habitats at Shillapoo Wildlife Area. Restoration actions will focus on restoring hydrology to existing water bodies, providing physical access for juvenile salmonids, reducing elevated temperatures, and managing pisciverous fish species. Project requires further scoping prior to assessing survival units. **Project Site Acres 900**
13	Duncan Creek Fish Passage Restoration	3	3	9	CRE-10.2	3	1.2	0.03	0.1	Modify existing dam and outlet structure and construct a backwater elevation control berm roughened channel to improve steelhead, coho and chum passage during Columbia River low flow periods.**Project Site Acres 2**
14	Lower Washougal Delta Habitat Complexing	4	4	16	CRE-1.4	2	2	0.06	0.06	Construct ELJs on the Lower Washougal river delta at the Columbia River confluence to provide instream cover and complexity, and cold-water refuge for outmigrating juvenile salmonids an migrating adults. **Project Site Acres 10**
15	Lower Kalama Delta Habitat Complexing	3	4	12	CRE-1.4	2	2	0.06	0.06	Construct ELJs on the Lower Kalama river delta at the Columbia River confluence to provide instream cover, complexity and holding; cold-water refuge for outmigrating juvenile salmonids and migrating adults; and to reduce predation by pinnepeds during low flow conditions. Investigate options for channel realignment.**Project Site Acres 5**
16	Chinook River Estuary Feasibility Restoration[4]	2	5	10	CRE-10.1	10	4	0.15	0.05	Enhance tidal inundation of the historic Chinook River estuary through creation of a community adaptive management strategy. WDFW along with several partners have replaced the failing tide-gates with two new gates that have the ability to be mechanically opened and closed. The new gates provide increased flood protection to Chinook Valley landowners and provide an important management tool in improving the health and productivity of the Chinook River estuary. Through modeling and monitoring efforts WDFW will work with several adaptive management strategies to increase the tidal fluctuation to approximately 500 acres in the Chinook River estuary.**Project Site Acres 500**
					CRE-10.2	3	1.2	0.03	0.01	
					CRE-10.3	2	0.8	0.03	0.01	
17	Lower Cowlitz River Tidal Restoration	3	3	9	CRE-1.4	2	2	0.05	0.05	The Lower Cowlitz River and Floodplain Habitat Restoration Project Siting and Design report identifies 6 potential projects in the tidal reaches of the Lower Cowlitz and Coweeman Rivers (1.0L, 0.5R, C3.5R, C4.0B, 3.0L, 4.5R). These projects include removal of dredge material, riparian enhancement, side channel creation and or enhancement, riprap removal, and LWD placement. (Note: when scored by LCFRB, these projects did not all fall within the fundable range, but out-of-basin estuary benefits were not included at that time). Opportunities exist for beneficial use of dredged materials. **Project Site Acres 226**
					CRE-6.2	0.3	0.15	0.08	0.01	

	Washington MOA Project	Certainty of Success	Potential Benefit	Total	Estuary Module Sub-Action	Total Possible Survival Units by Sub-Action		Preliminary Estimated Survival Units By Project		Notes[5]
						Ocean	Stream	Ocean	Stream	
18	Coweeman River Tidal Restoration	4	3	12	CRE-1.4	2	2	0.06	0.06	The Lower Cowlitz River and Floodplain Habitat Restoration Project Siting and Design report identifies 6 potential projects in the tidal reaches of the Lower Cowlitz and Coweeman Rivers (1.0L, 0.5R, C3.5R, C4.0B, 3.0L, 4.5R). These projects include removal of dredge material, riparian enhancement, side channel creation and/or enhancement, riprap removal, and LWD placement. (Note: when scored by LCFRB, these projects did not all fall within the fundable range, but out-of-basin estuary benefits were not included at that time). Opportunities for beneficial use of dredged materials. **Project Site Acres - 71**
					CRE-6.2	0.3	0.15	0.08	0.01	
19	Lewis River Acquisition and Restoration	4	4	16	CRE-1.3	2	2	0.1	0.1	Clark Co. is proposing to acquire a large parcel of floodplain forest along the left bank of the mainstem Lewis near Mud Lake. This property also has potential for future side channel and floodplain reconnection, as well as lacustrine habitat restoration. Acquisition and restoration would compliment conservation banking efforts on Morgan Property, at the North Fork Lewis River mouth. **Project Site Acres - 154**
					CRE-1.4	2	2	0.08	0.08	
					CRE-9.3	8	3	0.15	0.03	
					CRE-10.3	2	0.8	0.06	0.01	
					CRE-15.3	1.5	0.7	0.05	0.01	
20	Port of Kalama Off-channel Wetland Enhancement	5	5	25	CRE-1.4	2	2	0.06	0.06	Restore and enhance tidal slough and channel habitats at the Port of Kalama's Northport mitigation site and WDFW ownership; remove or modify pile structures. **Project Site Acres - 157**
					CRE-8.2	6	6	0.03	0.03	
					CRE-10.1	10	4	0.12	0.05	
					CRE-15.3	1.5	7	0.05	0.01	
21	Barlowe Point Beach Nourishment	4 if public ownership, 2 if private	2	4 to 8	12.1	0.2	0.1	0.02	0.01	Contour beach profile through beach nourishment to reduce fish stranding (Note: should be associated with subsequent effectiveness monitoring). **Project Site Acres - 21**
							Total:	**3.75**	**2.09**	

Washington MOA Project	Certainty of Success	Potential Benefit	Total	Estuary Module Sub-Action	Total Possible Survival Units by Sub-Action		Preliminary Estimated Survival Units By Project		Notes[5]
					Ocean	Stream	Ocean	Stream	

ESU Type	Project Contribution Totals	Estuary Survival Benefit (x .2)
Ocean	3.75	0.75
Stream	2.09	0.418

[1]Salmon and steelhead survival benefits are determined in accordance with the guidance and procedures outlined in Estimated Benefits of Federal Agency Habitat Projects in the Lower Columbia River and Estuary (FCRPS BA, Attachment B.2.2). Project benefits identified in this table are considered preliminary, and will be refined by the expert regional technical group in accordance with Reasonable and Prudent Alternative (RPA) 37 (FCRPS Biological Opinion, 2008).

[2]This project received survival benefits as a construction project in the 2008 baseline portfolio (2000 - 2006).

[3]This project is a feasibility study therefore no survival benefits were assigned.

[4]This project received acquistion survival benefits and restoration survival benefits in the 2008 BiOp (CRE-10.3).

[5]Project acreage refers to total project site. Actual acreage of restorated habitat will be determined during final project development.

ATTACHMENT 3

Lower Columbia River Estuary Partnership

Criteria for Identifying and Prioritizing Habitat Protection and Restoration Projects on the Lower Columbia River and Estuary*

Modified by NOAA to be more ESA specific

Ecosystem Criteria

1) Habitat Connectivity

This criterion recognizes that habitat connectivity is a landscape level concept. It emphasizes linkages between habitat areas that provide a variety of functions ESA-listed salmonids at various stages of their life cycle (juvenile, yearling, and adult) and that gradual alteration of landscapes through natural succession and retrogression allow species that require a variety of habitat components to disperse and survive. In the Lower Columbia, historic changes have limited or cut off listed salmonids' access to resources needed for their development and migration. Specific emphasis on species with narrow ecological requirements such as salmonids will be prioritized. Upland habitat areas adjacent to drainage ways, existing protected/restored sites, and areas offering diverse habitat types, function, and successional stages should also be considered.

2) Areas of Historic Habitat Type Loss

Land use activities such as diking, filling, pile dike field development, and shoreline hardening have removed many of the shallow, peripheral wetlands along the Lower Columbia, isolating the river from its floodplain. This criterion recognizes that historic wetland types such as emergent and forested wetlands that are particularly important for salmonids, have been greatly diminished. These habitats promote networks of physical complexity such as shallow, dendritic channels and backwater sloughs. NMFS' Northwest Fisheries Science Center has emphasized the need to connect historic habitats that have been disconnected from the mainstem system that are important to ESA-listed salmonids.

3) Improvement in Ecosystem Function

This criterion acknowledges that some restoration actions can result in greater enhancement of ecosystem functions than others. This criterion emphasizes that location of a project may in some cases be more important than size of the project. This is especially the case for dike removal projects that can open backwater habitat back up for salmonid access. This criterion also emphasizes the need to closely evaluate the quality and long-term sustainability of the project.

4) Adequate Size and Shape

Size refers to reach length and the size of the potential habitat within a reach. In general, larger size enhances habitat stability, increases the number of salmonid species that can potentially use the site, makes it easier to find by migratory species such as salmonids, and increases within-habitat complexity.

5) Level of Complexity

This criterion refers to the number and interspersion of different types of habitats within a given restoration reach or area. As the number of habitats increase, so do the number of salmonid species that can occupy an area, and the number of functions supported by an area. Higher complexity potentially results in higher biodiversity. It is recognized that some restoration efforts, such as a chum channel, may not strive for habitat complexity.

6) Accessibility For Target Species

Accessibility refers to unencumbered access by Columbia River for ESA-listed salmonid species that utilize estuary habitat Projects that allow or enhance access of these species to important habitats would potentially enhance the feeding, rearing, and refuge functions of the site are preferred. This criterion acknowledges the need to restore habitat for those threatened and endangered species, whose populations are at precariously low numbers and who might benefit from improved near-shore habitat conditions.

ATTACHMENT 4

-=

SEC. 536. LOWER COLUMBIA RIVER AND TILLAMOOK BAY ECOSYSTEM RESTORATION, OREGON AND WASHINGTON.

(a) IN GENERAL- The Secretary shall conduct studies and ecosystem restoration projects for the lower Columbia River and Tillamook Bay estuaries, Oregon and Washington.

(b) USE OF MANAGEMENT PLANS-

(1) LOWER COLUMBIA RIVER ESTUARY-

(A) IN GENERAL- In carrying out ecosystem restoration projects under this section, the Secretary shall use as a guide the Lower Columbia River estuary program's comprehensive conservation and management plan developed under section 320 of the Federal Water Pollution Control Act (33 U.S.C. 1330).

(B) CONSULTATION- The Secretary shall carry out ecosystem restoration projects under this section for the lower Columbia River estuary in consultation with the Governors of the States of Oregon and Washington and the heads of appropriate Indian tribes, the Environmental Protection Agency, the United States Fish and Wildlife Service, the National Marine Fisheries Service, and the Forest Service.

(2) TILLAMOOK BAY ESTUARY-

(A) IN GENERAL- In carrying out ecosystem restoration projects under this section, the Secretary shall use as a guide the Tillamook Bay national estuary project's comprehensive conservation and management plan developed under section 320 of the Federal Water Pollution Control Act (33 U.S.C. 1330).

(B) CONSULTATION- The Secretary shall carry out ecosystem restoration projects under this section for the Tillamook Bay estuary in consultation with the Governor of the State of Oregon and the heads of appropriate Indian tribes, the Environmental Protection Agency, the United States Fish and Wildlife Service, the National Marine Fisheries Service, and the Forest Service.

(c) AUTHORIZED ACTIVITIES-

(1) IN GENERAL- In carrying out ecosystem restoration projects under this section, the Secretary shall undertake activities necessary to protect, monitor, and restore fish and wildlife habitat.

(2) LIMITATIONS- The Secretary may not carry out any activity under this section that adversely affects--

(A) the water-related needs of the lower Columbia River estuary or the Tillamook Bay estuary, including navigation, recreation, and water supply needs; or

(B) private property rights.

(d) PRIORITY- In determining the priority of projects to be carried out under this section, the Secretary shall consult with the Implementation Committee of the Lower Columbia River Estuary

Program and the Performance Partnership Council of the Tillamook Bay National Estuary Project, and shall consider the recommendations of such entities.

(e) COST-SHARING REQUIREMENTS-

(1) STUDIES- Studies conducted under this section shall be subject to cost sharing in accordance with section 105 of the Water Resources Development Act of 1986 (33 U.S.C. 2215).

(2) ECOSYSTEM RESTORATION PROJECTS-

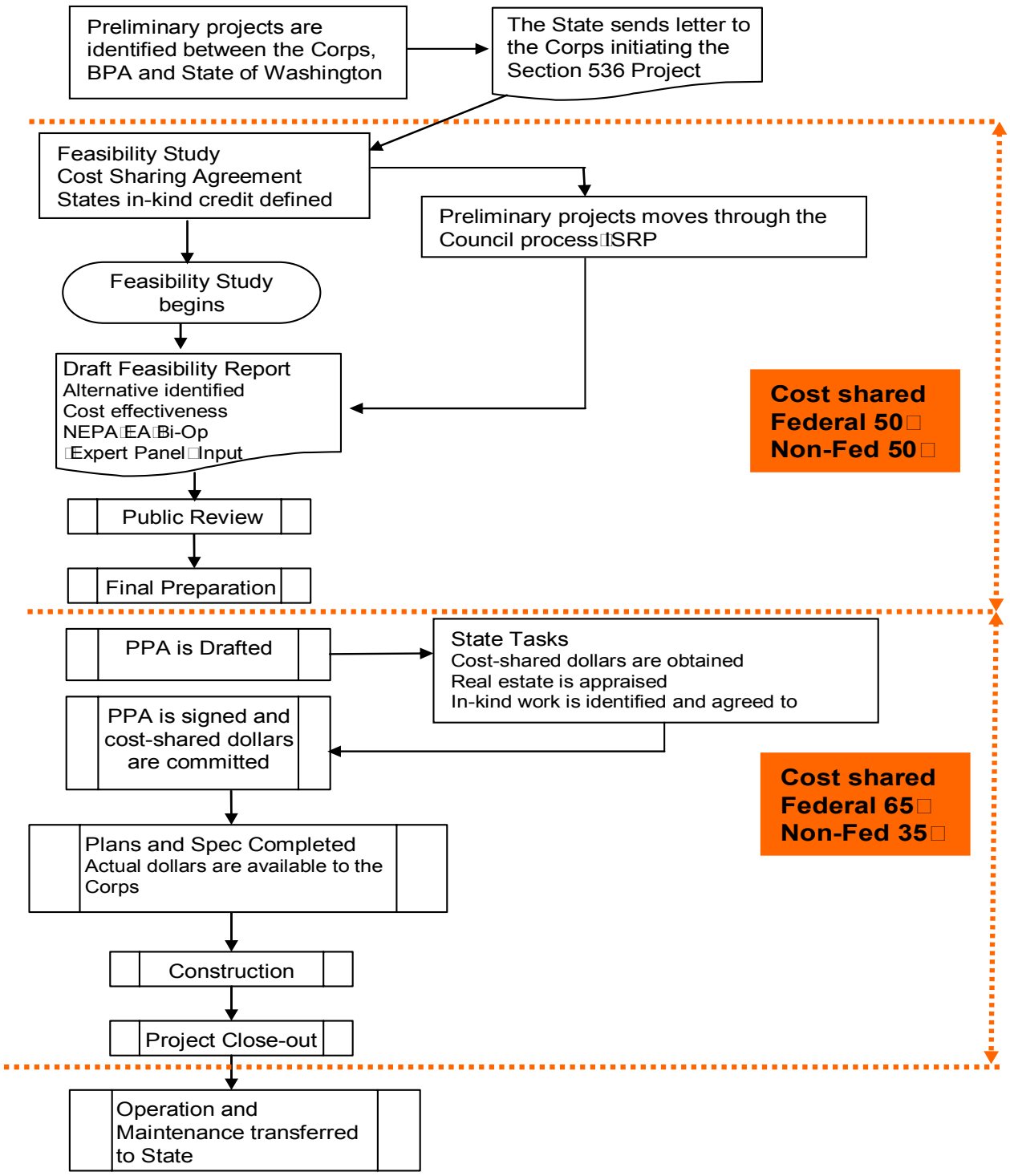
(A) IN GENERAL- Non-Federal interests shall pay 35 percent of the cost of any ecosystem restoration project carried out under this section.

(B) ITEMS PROVIDED BY NON-FEDERAL INTERESTS- Non-Federal interests shall provide all land, easements, rights-of-way, dredged material disposal areas, and relocations necessary for ecosystem restoration projects to be carried out under this section. The value of such land, easements, rights-of-way, dredged material disposal areas, and relocations shall be credited toward the payment required under this paragraph.

(C) IN-KIND CONTRIBUTIONS- Not more than 50 percent of the non-Federal share required under this subsection may be satisfied by the provision of in-kind services.

(3) OPERATION AND MAINTENANCE- Non-Federal interests shall be responsible for all costs associated with operating, maintaining, replacing, repairing, and rehabilitating all projects carried out under this section.

(4) FEDERAL LANDS- Notwithstanding any other provision of this subsection, the Federal share of the cost of a project carried out under this section on Federal lands shall be 100 percent, including costs of operation and maintenance.


Preliminary projects are identified between the Corps, BPA and State of Washington
The State sends letter to the Corps initiating the Section 536 Project
Feasibility Study
Cost Sharing Agreement
States in-kind credit defined
Preliminary projects moves through the Council process ISRP
Feasibility Study begins
Draft Feasibility Report
Alternative identified
Cost effectiveness
NEPA EA Bi-Op
Expert Panel Input
Cost shared
Federal 50
Non-Fed 50
Public Review
Final Preparation
PPA is Drafted
State Tasks
Cost-shared dollars are obtained
Real estate is appraised
In-kind work is identified and agreed to
PPA is signed and cost-shared dollars are committed
Cost shared
Federal 65
Non-Fed 35
Plans and Spec Completed
Actual dollars are available to the Corps
Construction
Project Close-out
Operation and Maintenance transferred to State

Characterization of Particulate Matter (PM_{10}) in Roda, Virginia

Viney P. Aneja *
Department of Marine, Earth, and Atmospheric Sciences
North Carolina State University
Raleigh, NC 27695-8208

*Corresponding Author:
(919) 515-7808 Telephone
(919) 515-7802 Fax
VINEY_ANEJA@NCSU.edu

Table of Contents

List of Tables i

List of Figures ii

Disclaimer and Acknowledgements iii

Executive Summary iv

I. Introduction
Background and Purpose 1

II. Experimental Approach
Sampling and Analysis 2

III. Results and Discussions 12

IV. Summary and Conclusions 18

V. Recommendations 18

References 19

List of Appendices 19

A. Analysis of the legal authority of the Air Board and DEQ/DAQ
B. Statements of Roda residents Ronnie Willis and Nell Campbell
C. Complaints filed by Willis and Campbell with DMME
D. Appalachia Town Ordinance No. 2009-1
E. Report of Dr. Dudley F. Rochester
F. CV of Dr. Viney P. Aneja
G. Particulate Matter (PM_{10}) and Meteorological Sampling
H. PM_{10} sample mass and chemical analysis

Image on cover portrays coal trucks traveling through Roda, Virginia

List of Tables

Table 1: Inorganic Analysis of PM_{10} collected on quartz filter at the Roda, VA, Site (Campbell) for sample collected on August 7, 2008. The analysis was performed by ERG, Inc. based on compendium method IO – 3.5

Table 2: Inorganic Analysis of PM_{10} collected on quartz filter at the Roda, VA, Site (Willis) for sample collected on August 7, 2008. The analysis was performed by ERG, Inc. based on compendium method IO – 3.5

List of Figures

Figure 1: Location of Roda, Virginia

Figure 2: PM_{10} 24-hour concentration sampler and meteorological station at the Willis site in Roda, VA during August 2008

Figure 3: Calibration of PM_{10} 24-hour concentration sampler at the Willis site in Roda, VA during August 2008

Figure 4: PM_{10} 24-hour concentration sampler at the Campbell site in Roda, VA during August 2008

Figure 5: Measurements of PM_{10} 24-hour concentration at the Cambell site in Roda, VA during August 2008

Figure 6: Measurements of PM_{10} 24-hour concentration at the Willis site in Roda, VA during August 2008

Disclaimer and Acknowledgements

We acknowledge support from Southern Appalachia Mountain Stewards (SAMS)* and the Sierra Club.** We greatly appreciate the time and interest of the many volunteers, scientists, interest groups, and graduate students (Ms. Megan Gore, Mr. William Blinn, and Mr. Ian Rumsey) who assisted us, and shared their knowledge and expertise in the development of the report.

This report contains preliminary results associated with PM_{10} measurements. These data should assist the coal mining facilities, the Virginia Air Resources Control Board, and the Virginia Department of Environmental Quality in developing future plans to help the residents of the community and to ensure the protection of public health according to Virginia and U.S. Environmental Protection Agency air quality standards.

* SAMS, a Virginia non-stock membership corporation based in Appalachia, Virginia, is an organization of concerned community members and their allies who are working to stop the destruction of Appalachian communities by surface coal mining, to improve the quality of life in the region, and to help rebuild sustainable communities.

** Sierra Club is a national nonprofit corporation with more than 1.3 million members and supporters nationwide and more than 16,000 members who reside in Virginia and belong to its Virginia Chapter. Sierra Club is dedicated to exploring, enjoying, and protecting the wild places of the Earth; to practicing and promoting the responsible use of the Earth's resources and ecosystems; to educating and enlisting humanity to protect and restore the quality of the natural and human environment; and to using all lawful means to carry out these objectives. Sierra Club's concerns encompass the exploration, enjoyment and protection of mountains, forests and streams in Virginia.

Executive Summary

This report is intended to inform the Virginia Air Pollution Control Board (Air Board) and the Department of Environmental Quality (DEQ) of the dust problem in Roda and other similarly affected communities in Virginia's coalfields and to urge the Air Board and DEQ to take action to reduce this threat to human health and welfare.

Preliminary air sampling (Particulate Matter i.e. PM_{10}, and meteorological measurements) was conducted for a period of approximately two weeks during early August 2008 in the unincorporated community of Roda, Virginia, at two locations (about a mile apart along Roda Road (Route 685) in Wise County, Virginia). For the purposes of this study (a combination of logistics, resource, and characterization of PM) we sited the PM samplers near the road to ascertain the micro exposure from the road. The results revealed high levels of PM_{10}, (average value of 24-hour mass concentration, and +/- 1 SD at the Campbell Site = 250.2 +/- 135.0 micrograms/m^3; and at the Willis Site = 138.4 +/- 62.9 micrograms/m^3 respectively). The 24 hour U.S. national ambient air quality standard for PM_{10} is 150 micrograms/m^3. Ten out of twelve samples taken from the Campbell site revealed levels of PM_{10} above the national standard, including one sample that was more than three times the national standard. Six out of twelve samples taken from the Willis site revealed levels of PM_{10} above the national standard (*see* figures 5 and 6). The impacts of PM_{10} have decreased substantially in the Eastern United States over approximately the last 30 years. Roda, however, continues to see significant impacts of PM_{10} that are substantially larger than those observed in major cities in the Eastern United States. Elemental analysis for samples collected on Quartz filter paper (on one randomly selected day) at both the sites revealed the presence of antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium (group of metals common to the US EPA National Ambient Air Toxics Stations program).

Many communities in the coalfields of southwest Virginia suffer from high dust levels caused by coal mining operations hauling coal by truck along roads that pass through residential areas. Many Roda residents suffer from a variety of respiratory ailments that may be linked to or exacerbated by the high dust levels. These residents also report that the dust has made their lives uncomfortable; they are unable to sit on their porches, have to restrict the amount of time they spend outdoors, and have to spend many hours each week contending with daily coatings of dust that cover the exteriors and interiors of their homes.

A separate letter attached to this report as Appendix A (signed by attorneys Walton Morris and Aaron Isherwood) describes the legal authority of the Air Board and DEQ to take action to remedy the dust problem in the coalfields of southwest Virginia. The letter concludes that the Air Board and DEQ have the authority to issue a special order directing the individuals and corporations that cause coal and other materials to be hauled through Roda to take reasonable precautions to prevent particulate matter from becoming airborne, as well as the authority to conduct their own investigation of the dust problem.

I. Introduction: Background and Purpose

The unincorporated communities of Roda and Osaka consist of approximately ninety homes along Roda Road (Route 685) in Wise County, Virginia (36º57'47" N, 82º50'00" W) (Figure 1). Roda Road is a narrow, public road that branches off of Virginia State Route 78 and terminates approximately four miles from where it begins, at the entrance to several surface and underground coal mining operations, which haul coal by truck along Roda Road. The houses in this area are located very close to the road – most a mere 10 or 20 feet away. There are currently nine active surface mining permits with entrances at the end of the road. These mining operations cause heavy trucks to travel on Roda Road; Roda and Osaka residents advise that, while truck traffic varies, there are often at least ten trucks every hour for up to twenty hours per day passing through their communities. These trucks represent the overwhelming majority of traffic on Roda Road; the road otherwise is used almost exclusively by local residents, their families and friends, and by school buses. The trucks carry coal and other materials away from the mining operations.

The trucks frequently track coal, mud, and other debris away from the mine sites and onto the road. When this mud dries it turns to dust, which is then released into the air by the passage of other vehicles. Fugitive dust, including coal fines, is also released directly from the trucks themselves. This dust coats the homes and property of the residents, and is thought to cause respiratory and other health problems (including sinus problems, asthma and emphysema). The dust diminishes the quality of life of local residents and interferes with their use and enjoyment of their property.

The residents of Roda, including Ronnie Willis and Nell Campbell, have filed multiple complaints with the Department of Mines, Minerals, and Energy (DMME) regarding the dust problem. In these complaints, the residents describe their problems with mud tracked onto Roda Road by coal trucks, and with the dust that covers their homes and property (*see* Appendix C). DMME has most frequently responded to these complaints by stating that the mining agency does not have jurisdiction over dust from public roads. In the few instances where DMME has taken action, the agency issued notices of violation to the mine operators for the operators' failure to maintain permitted

haulroads. Any reductions in dust brought about by such agency action have been temporary, and the dust has always returned.

The Town Council of Appalachia, Virginia (an incorporated municipality located within a few miles of Roda) has taken some action in response to complaints by local residents, but the Council's authority is limited. In February 2009 the Council passed a local ordinance regulating the mining of coal and other minerals within the town boundaries (Appendix D). The Council passed this ordinance after recognizing "the need to control, regulate, and limit the mining of coal and other minerals within its boundaries . . . in order to protect the health, safety, welfare and properties of its citizens." Perhaps the most direct effect of coal mining on local residents is the impact of the coal trucks and the dust that they spread. The town's legal authority to address the coal dust problems, however, is quite limited; accordingly, there is an urgent and compelling need for the Air Board and DEQ to take further action. The authority of the Air Board and DEQ to take action to remedy the dust problem in southwest Virginia is analyzed in Appendix A.

Eventually, local residents sought the assistance of Southern Appalachian Mountain Stewards and Sierra Club to address the persistent dust problems. Particulate matter (PM_{10}) sampling was conducted outside the homes of two Roda residents who have each lived in Roda almost fifty years—Ronnie Willis, a retired underground coal miner, and Nell Campbell, a 91-year-old woman. Statements from Mr. Willis and Ms. Campbell describing more fully their situations and the challenges posed to them by the dust are included in Appendix B.

II. Experimental Approach: Sampling and Analysis

The experimental sites (about one mile apart) are located in Roda, Virginia, in the southwestern region of the state where the majority of Virginia's coal mines are located. Observed high dust levels are the result of coal mining operations hauling coal by truck along roads that pass through residential areas. The locations of the PM samplers were selected in order to represent micro to middle scale environments (i.e. exposure that represents scales of up to 100 to 500 meters respectively). These scales are representative of the exposure of the residents in Roda. For the purposes of this study (a combination of

logistics, resource, and characterization of PM) we sited the PM samplers near the road to ascertain the micro exposure from the road (Figure 2). As Figure 2 illustrates, the area is predominantly covered with vegetation (e.g. trees, brush, grass, etc.). One should therefore expect low concentrations of coarse particles ($PM_{10-2.5}$) without any other emissions impacts. One should expect PM_{10} to be very low, and $PM_{2.5}$ to dominate in the Eastern US (US EPA 2005).

A. Particulate Matter Samplers

Two (2) Andersen/GMW Model GUV-16H High Volume air samplers equipped with PM_{10} size selective inlets were employed to collect ambient particulate matter with an effective aerodynamic size of less than 10 microns (PM_{10}) (Figures 2 and 4) (Appendix G). The field sampling was performed in accordance with U.S. EPA's "Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere" (40 CFR Part 50 Appendix J). The samplers were obtained from Cherokee Instruments, Inc., Fuquay Varina, NC 27526. The samplers were provided with volumetric flow controllers for constant flow control, a Dickson circular chart recorder for historical trend of volumetric flow through the sampler, and a mechanical timer and elapsed time indicator for total sampling time indication. Most of the samples were collected onto 8-inch x 10-inch fiber glass filters (glass microfiber filters Whatman Model # EPM 2000). However on one day (determined randomly) an 8-inch x 10-inch quartz fiber filter (Whatman Grade QMA Quartz Filters) was used. All the filters were pre-tared and numbered. The filters were obtained from Eastern Research Group, Inc. Laboratories in Research Triangle Park, NC.

The functionality and calibration of the particulate samplers were verified immediately prior to the field effort at Cherokee Instruments' service center in Fuquay Varina, North Carolina. The instrumentation was then transported to the field location and setup, calibrated and operated onsite at two locations (Site Willis and Site Campbell) in accordance with the manufacturer's specifications and USEPA methodology.

All calibrations were conducted using a High Volume Air Sampler Calibration Kit, Model Andersen/GMW Veriflow (Figure 3). The calibration kit included a calibrated orifice transfer standard that was referenced to a spirometer as well as an 8-inch x 10-

inch mounting plate adapter and water slack tube manometer. The Veriflow orifice is capable of providing various pressure drops across the sampler flow controller in order to simulate particulate matter loading onto the filter. Calibrations were performed on each sampler at site conditions prior to collection of the first sample at each location. These calibrations included volumetric flow verification through the sampler via comparison of the calibrated orifice results to the volumetric flow controller lookup tables.

B. Meteorological Sampler

One (1) Met One Model Automet portable weather station equipped with an onboard data logger was employed to measure and record site weather conditions at one site (Willis site) during the entire measurement period (Figure 2). The meteorological sampler was obtained from Cherokee Instruments, Inc., Fuquay Varina, NC 27526. The meteorological station measured continuously the following: wind speed, wind direction, temperature, and barometric pressure and relative humidity. All sensors were mounted on a portable tripod with telescoping mast such that meteorological data could be obtained at a height of 5- to 10-ft above grade. All the data was collected in real-time and averaged/stored at 15-minute data intervals using the onboard data logger.

The functionality and calibration of the meteorological sensors were verified immediately prior to the field effort at Cherokee Instruments service center in Fuquay Varina, North Carolina. Verification of the individual sensors functionality was accomplished using constant RPM motor, compass, reference thermocouple and local airport barometric pressure. The instrumentation was then transported to the field location and setup and operated onsite at one location (Site Willis) in accordance with the manufacturer's specifications and USEPA methodology. On site calibrations were not performed for the meteorological instruments.

C. Filter Analysis: Gravimetric Analysis, and Inorganic Analysis

High Volume (Hi Vol) 8/10 inch fiberglass filters were analyzed to determine mass. Quartz Hi Vol 8/10 inch filters were analyzed for mass and a group of metals common to the EPA National Ambient Air Toxics Stations program. Appendix H provides a list of the samples received in this project and is listed in the "Analytical

Report for Samples." Results and reporting/detection limits are provided in the "Gravimetric Measurement and Inorganics by Compendium Method IO-3.5" data tables (Appendix H; including a cover page, 3 pages of narrative, 21 pages of filter mass data, and inorganic analysis results). The filter time of exposure data and the total ambient air volume sampled were recorded on the chain of custody ("COC") forms. The ERG LIMS tracking numbers for this study are 8081414 and 8090908. Samples were stored after receipt at ambient temperature in an environmentally controlled room prior to analysis. Inorganic analysis was performed according to ERG's NELAC certification. A copy of the COCs for this sample set is provided in Appendix H. Samples were delivered to ERG on 08/08/08. Samples were equilibrated in an environmentally controlled balance room prior to analysis.

Gravimetric measurements were performed with a Satorius LA 120S equipped with a large area weighing chamber. Calibration was checked with NIST Class S weights. Ambient filters were equilibrated for 24 hours under balance room conditions prior to weighing. Tare weights were recorded prior to filter media shipment and use. Sample plus filter tare weights were measured after 24-hour equilibration under environmentally controlled balance room conditions. Initial and final weights were recorded and entered into the ERG LIMS for subsequent review and reporting. Samples were handled and analyzed in conformity with to 40 CFR 50, Appendix J, Section 9.16 - 9.17.

A 4"x 1" portion was cut from the exposed filter after final filter mass had been determined gravimetrically. This portion of filter was extracted initially in 4% nitric acid via sonication for a total of 90 minutes, followed by the addition 15mL of water and sonicated again for an additional 90 minutes. The extract was analyzed by ICP-MS. The analysis was completed using the manufacturer software.

Analyses were performed on the ELAN 9000 ICP/MS manufactured by Perkin Elmer Corporation. The instrument consists of an inductively coupled plasma source, ion optics, a quadrupole spectrometer, a computer that controls the instrument, data acquisition, and data handling (ELAN Software SCIEX, Version 3.0), a printer, an autosampler (AS-93plus) and a recirculator. The quadrupole

mass spectrometer has a mass range of 2 to 270 atomic mass units (amu). Inorganic analysis followed the requirements in EPA Compendium Method IO-3.5.

D. Inorganic Quality Control

A summary of the quality control requirements that were met except as flagged for inorganic analysis is provided in Table 1 in Appendix H. Standard method quality control includes:

- Method Spikes and Method Spike Duplicates, one per sample batch. The method spikes and method spike duplicates are controlled within <25% RPD of the target values. If the spikes are outside of these limits, calibration and extraction volumes are checked. If no calibration or calculation error is found the samples are re-extracted and reanalyzed.
- Performance Evaluation (PE) Samples from a secondary source. PE samples are prepared and analyzed in the same way as field samples.
- Blanks including:
    - 1) A method blank (MB) that contains all the reagents in the sample preparation procedure. Blanks are prepared and analyzed as a sample to determine the background levels from the instrument.
    - 2) A rinse blank consists of 2% nitric acid in DI water. The rinse blank is used to flush the system between standards and samples. The results must be below the MDL.
    - Initial calibration blanks (ICB) are analyzed immediately following the high standard verification. The absolute value of the instrument response must be less than the method detection limit. Samples results for analyses less than 5 times the amount of the blank are flagged or analysis is repeated.
    - Continuing calibration blanks (CCB) are analyzed following each continuing calibration verification sample. The acceptance criteria for the CCB are the same as the ICB.

- Laboratory Control Spike (LCS) prepared from a secondary source of calibration standards and analyze with each sample batch. The results must be within 80-120% RPD of actual values.

Figure 1: Location of Roda, Virginia

Figure 2: **PM_{10} 24-hour concentration sampler and meteorological station at the Willis site in Roda, VA during August 2008**

Figure 3: **Calibration of PM_{10} 24-hour concentration sampler at the Willis site in Roda, VA during August 2008**

Figure 4: **PM_{10} 24-hour concentration sampler at the Campbell site in Roda, VA during August 2008**

III. Results and Discussions

Ambient particulate matter (PM_{10}) results from direct particle emissions (e.g. carbon, soil dust, etc.). However, fine particulate matter ($PM_{2.5}$) may also be secondary particles (i.e. generated by atmospheric reactions of precursor gas emissions). Particles typically remain in the atmosphere for days to a few weeks, depending on their size and the rates at which they are removed from the atmosphere, for example by dry and wet deposition processes. Particulate matter in any given area may originate locally or from sources hundreds to thousands of kilometers away. Fine PM may also be formed during atmospheric transport from precursor gases originating from sources locally or far away.

The amount of particulate matter (PM_{10}) airborne in Roda on a 24-hour basis exceeds the level of the National Ambient Air Quality Standard for PM_{10} during the sampling period. PM_{10} was sampled at two locations in Roda over the course of about two weeks in early August 2008. The U.S. Environmental Protection Agency (EPA) daily (i.e. 24 hours) concentration limit for PM_{10} is 150 $\mu g/m^3$. Air sampling revealed daily concentrations of PM_{10} that exceeded 150 $\mu g/m^3$ on ten out of twelve days at one location (Figure 5) (Site Campbell), and six out of twelve days at another location (Figure 6) (Site Willis). On one of these days the recorded daily concentration of PM_{10} at the Campbell sampling site was more than three times the national standard, at 469.7 $\mu g/m^3$. The impacts of PM_{10} have decreased substantially in the Eastern United States over approximately the last 30 years. Roda, however, continues to see significant impacts of PM_{10} that are substantially larger than those observed in major cities in the Eastern United States.

Elevated levels of particulate matter have been associated with significant negative effects on human health. A report prepared by Dr. Dudley F. Rochester for the Virginia State Advisory Board – Air Pollution in November 2006 concluded that "fine particulate matter causes significant morbidity (asthma and other respiratory diseases, heart disease and stroke) and premature mortality (adult and infant)." The report also concluded that "[i]nterventions that lower air concentrations of . . . particulate matter are associated with reductions in respiratory illness and overall death rate" (Appendix E).

On one randomly selected day, Quartz Hi Vol 8/10 inch filters were exposed and analyzed for mass and a group of metals common to the EPA National Ambient Air

Toxics Stations program. Sampling from both sites revealed the presence of antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium (Tables 1 and 2). PM is typically composed of a complex mixture of chemicals, a mixture strongly dependent on source characteristics. All of the metals listed above as present in the samples from Roda are known to be present in coal (Finkelman, R.B., 1995).

The dust problem in Roda and surrounding communities in southwest Virginia is significant. We urge the Virginia Air Pollution Control Board and the Virginia Department of Environmental Quality to address this problem by enforcing state air quality standards and by requiring the operators of coal facilities to employ practices that will prevent dust from being released from trucks and other sources, and that will prevent mud and dust from being tracked onto public roads.

Figure 5: Measurements of PM_{10} 24-hour concentration at the Campbell site in Roda, VA during August 2008

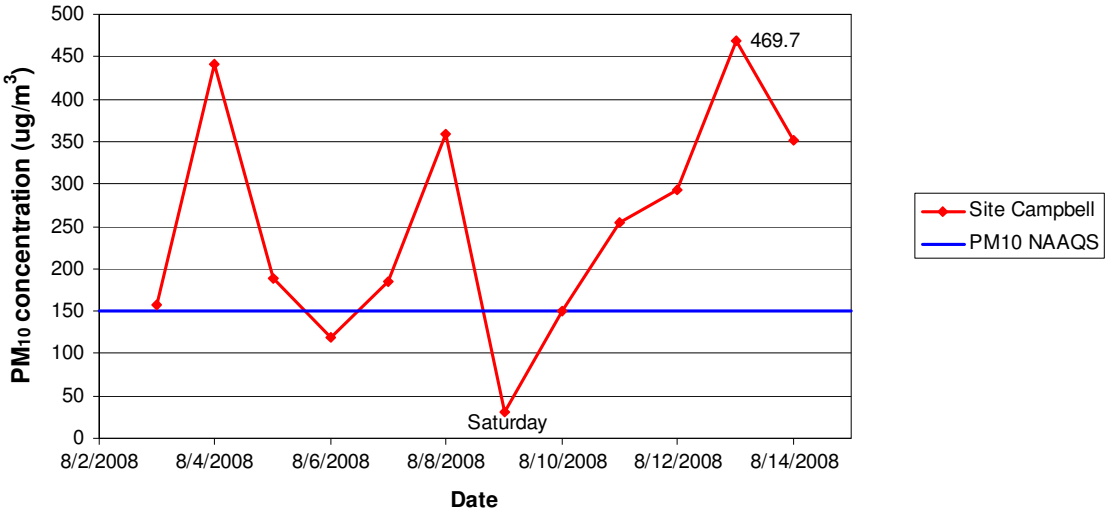


Figure 6: Measurements of PM_{10} 24-hour concentration at the Willis site in Roda, VA during August 2008

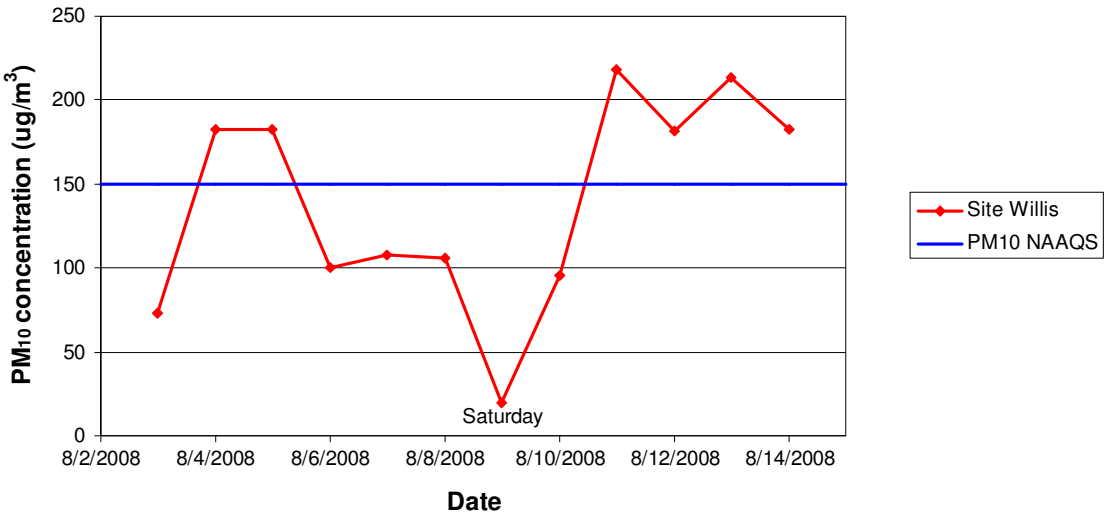


Table 1: Inorganic Analysis of PM_{10} collected on quartz filter at the Roda, VA, Site (Campbell) for sample collected on August 7, 2008. The analysis was performed by ERG, Inc. based on compendium method IO – 3.5

Analyte	PM_{10} Mass concentration collected on the quartz filter paper (ng/m^3)	Time of exposure (h)	Normalized 24h-Mass concentration (ng/m^3)*	Calculated 8h-Mass concentration ($\mu g/m^3$)	ASTDR Standard ($\mu g/m^3$)**	Carcinogens annual ave. (mg/m^3)***	Inhalation Unit Risk ($\mu g/m^3$)****
Antimony	1.83	23.67	1.856	0.000619	0.5	-	-
Arsenic	0.958	23.67	0.971	0.000324	10.0	$2.3x10^{-7}$	$4.3x10^{-3}$
Beryllium	0.067	23.67	0.068	0.000023	2.0	$4.1x10^{-6}$	-
Cadmium	0.263	23.67	0.267	0.000089	5.0	$5.5x10^{-5}$	$1.83x10^{-3}$
Chromium	2.74	23.67	2.778	0.000926	0.5	-	-
Cobalt	0.915	23.67	0.928	0.000309	0.1	-	-
Lead	3.9	23.67	3.954	0.001318	1.5	-	-
Manganese	34.1	23.67	34.575	0.011525	5.0	-	-
Mercury	0.14	23.67	0.142	0.000047	0.1	-	-
Nickel	3.04	23.67	3.082	0.001027	1.0	-	-
Selenium	0.614	23.67	0.623	0.000208	0.2	-	-
PM_{10} Mass	183.432	23.67	185.99	62.0	-	-	-

Volumetric flow rate of ambient air through the quartz filter paper 40 ft^3/min
*** PM_{10} Mass collected on the filter normalized to 24 hour exposure**
****ATSDR - Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/toxprofiles/phs4.html). Values based on 8-hour exposure.**
*****North Carolina Department of Environment and Natural Resources – Division of Air Quality – Acceptable Ambient Level (AAL) for toxic air pollutants** (http://daq.state.nc.us/toxics/haps-taps/haps-taps-lookup.shtml)
******US Environmental Protection Agency – Integrated Risk Information System (IRIS)** (http://cfpub.epa.gov/ncea/iris/index.cfm)

Table 2: Inorganic Analysis of PM_{10} collected on quartz filter at the Roda, VA, Site (Willis) for sample collected on August 7, 2008. The analysis was performed by ERG, Inc. based on compendium method IO – 3.5

Analyte	PM_{10} Mass concentration collected on the quartz filter paper (ng/m^3)	Time of exposure (h)	Normalized 24h-Mass concentration (ng/m^3)*	Calculated 8h-Mass concentration ($\mu g/m^3$)	ASTDR Standard ($\mu g/m^3$)**	Carcinogens annual ave. (mg/m^3)***	Inhalation Unit Risk ($\mu g/m^3$)****
Antimony	1.810	23.5	1.849	0.000616	0.5	-	-
Arsenic	0.720	23.5	0.735	0.000245	10.0	2.3x10-7	4.3x10-3
Beryllium	0.041	23.5	0.042	0.000014	2.0	4.1x10-6	-
Cadmium	0.090	23.5	0.092	0.000031	5.0	5.5x10-5	1.83x10-3
Chromium	3.100	23.5	3.166	0.001055	0.5	-	-
Cobalt	0.970	23.5	0.991	0.000330	0.1	-	-
Lead	3.320	23.5	3.391	0.001130	1.5	-	-
Manganese	19.400	23.5	19.813	0.006604	5.0	-	-
Mercury	0.972	23.5	0.993	0.000331	0.1	-	-
Nickel	14.300	23.5	14.604	0.004868	1.0	-	-
Selenium	0.580	23.5	0.592	0.000197	0.2	-	-
PM_{10} Mass	96.853	23.5	98.914	32.971	-	-	-

Volumetric flow rate of ambient air through the quartz filter paper 40 ft^3/min
*** PM_{10} Mass collected on the filter normalized to 24 hour exposure**
****ATSDR - Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/toxprofiles/phs4.html). Values based on 8-hour exposure.**
*****North Carolina Department of Environment and Natural Resources – Division of Air Quality – Acceptable Ambient Level (AAL) for toxic air pollutants** (http://daq.state.nc.us/toxics/haps-taps/haps-taps-lookup.shtml)
******US Environmental Protection Agency – Integrated Risk Information System (IRIS)** (http://cfpub.epa.gov/ncea/iris/index.cfm)

IV. Summary and Conclusions

Roda and the surrounding communities in southwest Virginia face a significant threat from dust generated and transported by coal trucks. Limited preliminary air quality sampling undertaken in Roda in early August 2008 using standard US EPA measurements protocols revealed the presence of particulate matter (PM_{10}) in amounts (24 hour PM_{10} mass concentration) up to three times the national ambient air quality standard. A considerable and growing body of evidence shows an association between adverse health effects and the exposure to ambient levels of PM. Epidemiological studies of large populations have frequently shown a statistical association between elevated levels of PM mass (PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$) and adverse health effects (McMurry *et al*., 2004).

V. Recommendations

We recommend that the Virginia Air Pollution Control Board and Virginia Department of Environmental Quality take immediate action to address the dust conditions in southwest Virginia. These actions may include but need not be limited to: (1) conducting additional air quality measurements and modeling studies; (2) meeting with residents of affected communities; and (3) requiring mining facilities that contribute to the dust problem, including those that cause coal and other materials to be hauled through Roda to implement reasonable precautions to control fugitive dust. These reasonable precautions include, but are not limited to: (1) installing and operating truck washes; (2) installing rumble strips at the exits of all mining facilities to remove mud and dust from vehicles before they enter public roads; and (3) identifying and using alternate haul routes that bypass residential communities. The Air Board and DEQ should also take any additional steps that they see as necessary to implement best management practices for controlling dust emissions in the region. The authority of the Air Board and DEQ to take these actions is described in Appendix A.

References

Finkelman, R.B. 1995. Modes of Occurrence of Environmentally-Sensitive Trace Elements in Coal. In: D.J. Swaine. and F.Goodarzi (Eds.), *Environmental Aspects of Trace Elements in Coal* (p. 25) New York: Springer.

McMurry, P., M. Shepherd, and J. Vickery. 2004. "Particulate Matter Science for Policy Makers", Cambridge University Press, New York.

US EPA, 2005. www.epa.gov/ttnnaaqs/standards/pm/s_pm_cr_sp.html.

List of Appendices

A. Analysis of the legal authority of the Air Board and DEQ/DAQ
B. Statements of Roda residents Ronnie Willis and Nell Campbell
C. Complaints filed by Willis and Campbell with DMME
D. Appalachia Town Ordinance No. 2009-1
E. Report of Dr. Dudley F. Rochester
F. CV of Dr. Viney P. Aneja
G. Particulate Matter (PM_{10}) and Meteorological Sampling
H. PM_{10} sample mass and chemical analysis

Appendix A:

Analysis of the legal authority of the Air Board and DEQ/DAQ

Virginia State Air Pollution Control Board
629 East Main Street
P.O. Box 1105
Richmond, VA 23218

Virginia Department of Environmental Quality,
Division of Air Quality
629 East Main Street
P.O. Box 1105
Richmond, VA 23218

April 17, 2009

Re: Legal Authority of the Virginia State Air Pollution Control Board and the Virginia Department of Environmental Quality's Division of Air Quality to Investigate and Take Action to Remedy the Dust Problem in Southwest Virginia

Dear Sirs and Madams:

As described in more detail in the attached report, the communities of southwest Virginia suffer from the chronic and persistent presence of dust generated by coal mining operations. One aspect of the problem occurs as a result of the operation of large trucks that haul coal through residential areas. Dust from coal trucks creates and exacerbates serious health problems among residents, and interferes with their use and enjoyment of their property. The Sierra Club and the Southern Appalachia Mountain Stewards ("SAMS") present the information in this report to the Virginia State Air Pollution Control Board ("the Board") and the Virginia Department of Environmental Quality Division of Air Quality ("DEQ/DAQ") to inform the Board and DEQ/DAQ about the dust problem and to urge the Board and DEQ/DAQ to take prompt action to address and remedy this situation.

Virginia's air quality statutes grant the Board broad powers to promulgate regulations, conduct inspections, take enforcement action including the issuance of special orders, and otherwise regulate emissions of pollutants into the outdoor atmosphere. Va. Code §§ 10.1-1301, -1306 through -1309.1, -1316, -1322.01. Virginia's statutes empower the Executive Director of DEQ to exercise such authority as granted to him by statute or delegated to him by regulation. These powers include authority similar to that of the Board to conduct inspections and take enforcement action. Va. Code § 10.1-1322, -1322.01; 9 V.A.C. § 5-170-50, -120, -180.

We hereby request that the Board and DEQ/DAQ exercise their authority and take action to remedy the dust situation in Roda and other similarly affected communities in Virginia's coalfields. The primary source of the dust plaguing these communities is trucks hauling coal from mining operations. There are nine permitted mining operations above Roda alone that hire trucks to haul coal through that community. The Virginia Department of Mines, Minerals and Energy, Division of Mined Land Reclamation has consistently refused to regulate the truck traffic and dust emissions, even in response to citizen complaints. (*See* Appendix G). The dust problem in the coalfields of southwest Virginia includes violations of standards and limitations contained within federal and Virginia air quality statutes and regulations, and therefore falls under the authority of the Board and DEQ/DAQ.

I. Ongoing violations of federal and Virginia air quality statutes and regulations

The federal Clean Air Act ("CAA") requires the U.S. Environmental Protection Agency ("EPA") to set National Ambient Air Quality Standards ("NAAQS") for pollutants considered harmful to public health and welfare. 42 U.S.C. § 7409(b). EPA has set a 24-hour national ambient air quality standard ("NAAQS") for "particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers" ("PM-10") of 150 micrograms per cubic meter. 40 C.F.R. § 50.6. As discussed in more detail in the attached report, Sierra Club and SAMS have recorded levels of PM-10 in the unincorporated community of Roda that are greater than three times the NAAQS. Roda, therefore, is beset by air pollution which is or may be injurious to human health, welfare or safety.

Virginia's State Implementation Plan ("SIP"), promulgated by the Board to implement the CAA in Virginia and approved by the EPA, also places limits on the emission of particulate matter. *See* 42 U.S.C. §§ 7604(a)(1)(A), 7604(f)(4); 40 C.F.R. §§ 52.2420 to 52.2465. The Virginia SIP's standard for fugitive dust states that "[d]uring the construction, modification or operation phase of a stationary source or any other building, structure, facility or installation, no owner or other person shall cause or permit any materials or property to be handled, transported, stored, used, constructed, altered, repaired or demolished without taking reasonable precautions to prevent particulate

matter from becoming airborne." 9 V.A.C. 5-50-90. *See also* 9 V.A.C. 5-50-60, 9 V.A.C. 5-50-70(C).

Each of the mine operators that hire trucks to haul coal through Roda (see Figure 1) causes or permits coal and other materials to be transported by truck from its mining facilities without taking reasonable precautions to prevent particulate matter from becoming airborne, in violation of 9 VAC 5-50-90. These trucks cause particulate matter to become airborne by releasing dust and coal fines from their beds and by tracking mud and coal fines onto public roads where the mud dries and is kicked up as dust by additional trucks. Among the reasonable precautions that each mine operator could take, but does not, are (1) the installation and operation of truck washes, (2) the installation of rumble strips at the exits of all mining facilities to remove mud and dust from vehicles before they enter public roads, and (3) the identification and use of alternate haul routes that bypass residential communities. By failing to take these reasonable precautions, each mine operator has allowed the coal trucks traveling through these communities to release into the atmosphere fugitive dust that contains particulate matter in concentrations that exceed the NAAQS for PM-10.

II. Requested Actions:

Because these violations are ongoing, and because the coal dust problem persists in communities across southwest Virginia, the Board and DEQ/DAQ should, at a minimum, take the following actions:

A. Issue a special order requiring coal operators in Roda to cease and desist from permitting or causing dust pollution

The Board is authorized by statute to "issue special orders to . . . owners who are permitting or causing air pollution as defined by § 10.1-1300, to cease and desist from such pollution." Va. Code § 10.1-1309(i). "Air pollution" is defined as "the presence in the outdoor atmosphere of one or more substances which are or may be injurious to human health, welfare or safety, to animal or plant life, or to property, or which unreasonably interfere with the enjoyment by the people of life or property." Va. Code § 10.1-1300. The Board is also authorized by statute to "issue special orders to . . . owners

who have contravened duly adopted and promulgated air quality standards and policies, to cease such contravention and to comply with air quality standards and policies." Va. Code § 10.1-1309(iv).

As described above, the operation of coal trucks in Roda causes air pollution in the form of levels of particulate matter that exceed the national health-based standard for PM-10. In addition, the coal mining operations near Roda have contravened Virginia's fugitive dust standard by failing to take reasonable precautions to prevent particulate matter, including coal and other dust, from becoming airborne. The Board and DEQ/DAQ should initiate the procedures to issue a special order to the companies that cause or permit coal and other materials to be transported by truck from the mining facilities without taking reasonable precautions to prevent particulate matter from becoming airborne. *See* Va. Code § 10.1-1309. These companies include the operators who hold the nine active surface mining permits for mining operations located above Roda (see Figure 1), as well as any other companies – including the operators of coal preparation plants and other receiving facilities – that hire trucks to haul coal along Roda Road/State Route 685 or otherwise contribute to the dust problem. These companies are permitting or causing air pollution as defined under federal and Virginia law (*see* Va. Code § 10.1-1309(i)), and are contravening Virginia's duly adopted and promulgated fugitive dust limitation (*see* Va. Code § 10.1-1309(iv)). The special order should instruct these companies to cease and desist all hauling operations – including the operations of trucking companies and other sub-contractors – unless and until the companies can demonstrate that they are taking reasonable precautions to prevent particulate matter from becoming airborne from the trucks, the roads, or any other sources.

Figure 1: Mine operators with active surface mining permits near Roda, VA

Mine operator	**VCSMCRA permit(s)**
Maggard Branch Coal, LLC	1201828, 1201890, 1201945, 1201972
Nine Mile Spur, LLC	1101990
A&G Coal Corporation	1101914, 1101917
Nally & Hamilton Enterprises, Inc.	1101820, 1701819

B. Conduct an investigation of the dust problem in the coalfields of southwest Virginia

The Board is directed by statute to:

> make, or cause to be made, such investigations and inspections and do such other things as are reasonably necessary to carry out the provisions of this chapter . . . including the achievement and maintenance of such levels of air quality as will protect human health, welfare and safety and to the greatest degree practicable prevent injury to plant and animal life and property and which will foster the comfort and convenience of the people of the Commonwealth and their enjoyment of life and property and which will promote the economic and social development of the Commonwealth and facilitate enjoyment of its attractions.

Va. Code § 10.1-1306.

The statements from local residents included in Appendix F of the attached report illustrate the threat to human health and to "the comfort and convenience of the people of the Commonwealth and their enjoyment of life and property" posed by the pervasive dust that coal trucks generate. The air quality sampling conducted in Roda and described in detail in the attached report demonstrates that levels of particulate matter in Roda are consistently above the national health-based standard (NAAQS) for PM-10.

Because the sampling conducted by SAMS and Sierra Club was restricted to Roda and covered a limited twelve-day time period, we urge the Board and DEQ/DAQ to undertake a thorough investigation of dust and particulate matter across southwest Virginia. Sampling should focus on areas most directly affected by dust from coal trucks, including communities located in areas where mining or coal preparation or loading facilities are active and where coal truck traffic is heavy. As part of such an investigation, SAMS and Sierra Club urge the Board members and/or DEQ/DAQ staff to meet with local residents who are suffering from excessive dust levels in order to learn more about their predicaments. SAMS and Sierra Club would be pleased to arrange such a meeting.

The Board and DEQ/DAQ should then take appropriate action, based on the results of this investigation, necessary to protect human health, welfare and safety. Such action may include promulgating additional regulations to limit the release of dust from

coal trucks, and issuing special orders to the companies responsible for the release of dust from coal trucks.

III. Conclusion

The Board and DEQ/DAQ have the authority to remedy the dangerous dust situation faced by the residents of Roda and other communities in southwest Virginia. We hope that the Board and DEQ/DAQ will recognize the seriousness of the dust problem and take prompt action to address it. Otherwise, Sierra Club and SAMS will consider taking direct legal action against those individuals and corporations responsible for causing the release of dangerous levels of dust in Roda and the surrounding communities.

Sincerely,

Walton D. Morris, Jr.
Morris Law Office, P.C.

Aaron Isherwood
Senior Staff Attorney
Sierra Club

Appendix B:

Statements of Roda residents Ronnie Willis and Nell Campbell

TESTIMONY OF RONNIE C. WILLIS

I currently live at 1712 Roda Road, Appalachia, Virginia, 24216, and have lived here for approximately 47 years. I was born in this hollow 70 years ago and have lived here most of my life. I am a retired coal miner and worked in the area's underground mines for 28 years.

My home is adjacent to Roda Road, and trucks hauling coal from the surrounding mines to the processing facility in Stonega, VA and elsewhere drive by my house at all hours of the day. They often come through late at night and wake me up. My home is only about 20 feet from the road and, as a result, I am subjected to noise and dust from this incessant coal truck traffic. The trucks are often speeding; they drive much faster than the speed limit of 35 miles/hour.

The amount of coal mining in this area has increased significantly over the last decade and consequently, so has the amount of coal truck traffic and dust. Previously, mining operations were not conducted near peoples' homes and communities, and the mining was mostly underground as opposed to the destructive forms of surface mining that are used today.

From August 3 to August 14, 2008, I had dust monitoring equipment installed on my property. A scientist analyzed the air and found the dust levels to be above acceptable levels for human health. I am very concerned that the coal dust coming off the haul trucks is harming my health. I have been diagnosed with emphysema and black lung and the coal dust exacerbates my condition. I used to go for walks along the road but had to stop because the coal dust was getting into my eyes and burning them terribly. I am also concerned about being hit by speeding coal trucks. Sometimes the trucks pass each other, which I believe is very dangerous on such a narrow road.

I am hardly ever able to enjoy sitting on my front porch with family and friends because the dust from the trucks is so bad. I used to sit on the front porch every morning and drink coffee; it upsets me that I can no longer engage in this pleasant pastime. On the rare days that I do get to sit there, I have to dust off the chairs first on account of all the coal dust that collects on them. I also cannot hang clothes out to dry on the line because doing so would defeat the purpose

of washing them to begin with. I cannot even open my windows because the dust is so bad. I opened my windows only a few times last spring after first sticking filters in them to trap the coal dust.

The coal companies do little to minimize the dust and, as a result, my home is filthy all of the time. I have a pressure washer which I use several times a year to wash off my porch. I don't wash my siding or windows as much because it would be useless. Each time I clean them, they are covered in dust again in a matter of days. I would like to be able to relax and enjoy my home more.

For the past 6 years, I have been vacuuming the coal dust in my house and labeling and dating the vacuum bags to document the continuous presence of coal dust inside my home. I also save my furnace filters and label and date them because they too demonstrate that coal dust is persistently in my home. Each month I have to change the furnace filter because it gets clogged with coal dust mixed with other kinds of fugitive dust.

In March 2005 I called the Department of Mines, Minerals, and Energy (DMME) to make a complaint about mud deposited on my driveway by coal trucks traveling down the road. I was told by DMME that they had no jurisdiction to require the coal companies to remove the mud from my driveway. I called DMME again in July 2005 to make another complaint about the noise and dust from speeding coal trucks. I told DMME that the coal trucks did not slow down during my wife's funeral, even when I helped carry her casket to the hearse. They did not show any respect for my wife. I suggested several things that the coal companies could do to correct the dust problem, including trucking the coal around an old strip bench in front of my house, installing truck washers, installing a sprinkler system to wet down the road, and making the trucks maintain a safe speed limit of 15 mph. Again DMME told me that they could not do anything because they only have jurisdiction over the haul roads.

After years of requests, the Virginia Department of Transportation finally built a ditch on the other side of the road from my house, which helps collect mud and dust. Street cleaning

machines periodically vacuum up some of this dust and wet the road, but this provides only partial and infrequent relief.

A better solution would be to hose off the truck bodies and wheels to remove the dust and mud before they are allowed to drive through town. About 4 years ago, the Virginia Department of Mines, Minerals and Energy (DMME) collected about $35,000 in fines from some coal companies for permit violations. DMME asked the community for suggestions on how to use the money to reduce the coal dust problem. We requested a truck washer but have only received years of excuses for why it hasn't been built. I believe a washer would drastically improve conditions in the community.

I also believe that speed bumps would improve the dust problem because it would slow the trucks down and reduce the amount of dried mud and dust that gets stirred up into the air by the trucks. A third way the coal companies could reduce the problem is by using a different route – a nearby haul road built in the 1950's or 60's – which would enable them to bypass traveling through Roda, Osaka, and Stonega altogether. This would likely require only minor road improvements along this alternate route.

Ever since Carl Ramey, a friend of mine and a respected member of the community, challenged a coal company for conducting mining operations too close to his home and was told to stop harassing the coal company and ordered to pay their attorney fees, a lot of people in the community are afraid to challenge the coal companies that are harming our health and wellbeing. But I am not afraid to stand up for myself and my community. I want the mining companies to be held accountable for the coal dust problem they are creating, which is harming the quality of life and health of local residents including myself. I want the coal companies and DMME to take actions to rectify the problem, such as operating a truck washer, installing speed bumps, cleaning the road more frequently, or avoiding Roda Road altogether by using an alternate haul route.

I've thought about moving several times, but each time decided that home wouldn't be home if it were anywhere else. I wish to live in my home in Roda for the rest of my life. I know

all my neighbors and enjoy the community spirit I feel here. I am 70 years old and not getting any younger; I do not want to move and start over somewhere else.

I also know firsthand how difficult it would be to sell my home. I also owned a house across the road from mine and it took me 3 years to sell it, finally to a family member. I invested a great deal of time and money into remodeling the home and believe I sold it for less than I could have if the coal trucks didn't haul through the community and pollute the air. I believe I faced difficulty selling it because prospective buyers did not wish to live in a community full of coal dust and diesel fumes. I thus believe that the coal dust problem has decreased the value of my home. If air conditions do not improve, I would consider moving away to escape the dust if a coal company offered to buy my home for a fair market price or moved me to another home in the area. But no mining company has offered to buy me out or relocate me.

By: Ronnie C Willis
Ronnie C. Willis

Date: 4-15-09

TESTIMONY OF NELL CAMPBELL

I currently live at 1482 Roda Road, Appalachia, Virginia, 24216. I am 91 years old and have lived in this house here for about 50 years. This place feels like home to me.

My home is located very near Roda Road, and a lot of trucks hauling coal come by my house all the time. I don't know how many there would be a day but once I told my girls, "I looked out my blinds, and there was six coal trucks lined up in each direction. They couldn't pass each other. They had to stop."

The dust coming off of the trucks is a problem. The well-being of the community has been diminished. You know it can't be good for anyone's health to breathe coal dust. From August 3 to August 14, 2008, I had a dust monitor installed on my property. A scientist analyzed the air and found the dust to be at levels that are unsafe for human health. I am very concerned that the coal dust coming off the haul trucks is harming my health.

The community has been deprived of its use of the outdoors. We used to have coffee with our neighbors out on the porch and sometimes on my neighbors' porches. That's not been possible for the last five years because of the dust. There is practically no such thing as sitting on your porch now. But I do go outside on my back porch on Sunday now to sit because the trucks aren't around – the noise and the dust die down for at least that one day.

For about five years now, I have been unable to go outside because the coal dust is unbearable. My grandchildren would come visit pretty often until a year ago when they moved away, but when they would visit they couldn't play outside for all the dirt and dust. The little children can't get out and play in the yard because it is too dusty. When driving through New Town [which is ¼ to ½ mile before you get to Roda from Appalachia], you could see little children playing outside all the time but now you don't see any children. I also worry about the children's safety. It's just too dangerous for the children because of the coal truck traffic. Children come through my yard to go to the school bus and I don't care because it's just too

dangerous for the children to be walking along the road. I won't be here all these years but the children will.

For the last couple of years, I haven't been physically able to work in my flower garden, but before that the dust outside kept me from working in my flower garden. I used to work outside all the time. Our community used to be a happy community but you hardly see anyone anymore. Everyone stays in their houses because of the dust. When I go out now to go to the store, I go out and get in the car, that's it.

What they're doing makes our home worthless. If you wanted to sell it, someone would come and look, they'd see all this dust and dirt, and think they wouldn't want their family to live here. You can clean it up tonight and it's dirty again in the morning. Last year, my neighbor Ronnie Willis came and washed my house down with his pressure washer, but it didn't stay clean long. I used to enjoy being outside. Before the dust became such a problem, you could just use the water hose to wash off the porch and it would stay clean for a pretty good while. Now you could do it today and do it again in the morning and really you wouldn't be able to pay the water bill.

There was talk in the community for awhile about the coal companies making us move. I could go live with my daughters but I want to stay home. There were hints of them buying us out. But with what they'd give you for your property; you couldn't go anywhere and buy a home worth having.

I think it would be better for the community if we could solve the dust problems. I called the Department of Mines, Minerals, and Energy in March 2004 to make a complaint about mud tracked onto the road in front of my house by the coal trucks. The mud was so bad I couldn't even get to my mailbox. One of the coal companies did come down and wash off the road in front of my house and put gravel in front of my driveway. I don't believe anything more was done by the Department or the companies to prevent more problems from happening in the future. I didn't feel that the agency responded adequately. It would be great if there was something more the companies could do to keep the trucks from carrying all this dust into the

communities. Maybe then we could return to the outdoors, to sit outside, and the truck drivers could still keep their jobs. I hate to see anyone lose their job and I don't think anyone has to lose their job. I just want the coal companies to keep the dust levels down so our community has a safe place to live.

BY: Nell Campbell

Nell Campbell

DATE: 04/15/2009

Appendix C:

Complaints filed by Willis and Campbell with DMME

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COMPLAINT INVESTIGATION

OFFICE USE ONLY
COPIED TO:
___ Complainant
___ Company
___ P.R. Manager
___ Technical Section
___ Other (specify)

COMPLAINT NO.	INVESTIGATION NO.	PERMIT NO.	DATE/TIME RECEIVED	DATE OF REPORT
0500060	5197 (RDS0004538)	1101914	3/18/05 04:00 PM	3/23/05

COMPLAINANT NAME, ADDRESS, PHONE	COMPANY/PERMITTEE NAME, ADDRESS, PHONE
Willis, Ronnie 1712 Roda Road Appalachia, VA 24216 (H) (276)565-3421	A & G COAL CORPORATION P. O. BOX 1010 WISE, VA 24293 (276)328-3421

LOCATION	COUNTY(S)	WISE
Roda		

COMPLAINT STATUS/DATE	COMPLAINT TYPE	INVESTIGATION TYPE
RESOLVED 3/21/05	HAULROAD	INITIAL CLOSE OUT

ENFORCEMENT			
TYPE OF ACTION	ACTION NUMBER	COMPLAINANT NOTIFIED	REQUEST TO ACCOMPANY
		3/31/2005 12:50 PM	NO

ATTACHMENT(S): 2
Photographs, Map

COMMENTS FROM:		
COMPLAINANT	Willis, Ronnie	3/18/2005
COMPANY OFFICIAL	Jerry Hamilton	3/21/05 10:15 AM
INVESTIGATOR/SIGNATURE	STANLEY, RANDY	

COMPLAINANT'S COMMENTS	Willis, Ronnie	3/18/2005

The complainant called to say that mud from coal trucks traveling down SR 685 have caused mud to be deposited on his driveway.

COMPANY OFFICIAL'S COMMENTS	Jerry Hamilton	3/21/05 10:15 AM

I met with Jerry Hamilton on March 21, 2005 to discuss this situation. Mr. Hamilton said he met with the complainant on Friday, March 18, 2005. The complaint was in regard to mud on the complainant's driveway. Mr. Hamilton said that he told the complainant he would get with Virginia Department of Transportation (VDOT) to see if they would spread gravel on the shoulders of the state highway if A & G provided the gravel. Mr. Hamilton said that the complainant wanted him to place gravel on his driveway but that due to liability concerns A & G could not do this. He said that A & G would also provide a stockpile of gravel for public use below the rail road crossing near the complainant's house. Mr. Hamilton said that he met today at 9:00am with VDOT Road Supervisor Eddie Westmoreland. He said they discussed repairing the shoulders of SR 685 from the end of state maintenance to the confluence of Mudlick Creek and Callahan Creek. Mr. Westmoreland said that VDOT would also place gravel on other driveways where possible. A & G will provide gravel for surfacing as directed by VDOT. Mr. Hamilton said that he would replenish public use stockpiles as they became depleted. Material will be disposed of on A & G Coal Corp PN 1101914. Mr. Hamilton said that he would continue to work on this problem.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COPY: 5197

COMPLAINT INVESTIGATION

INVESTIGATOR'S DESCRIPTION, COMMENTS, AND RECOMMENDATIONS	STANLEY, RANDY

I conducted this complaint investigation for DMLR Inspector Eddie Varner. The lower portion of the haulroad on PN 1101914 that connects to SR 685 is paved and was in good condition at this time. Inspector Eddie Varner advised the complainant when he spoke with him on Friday, March 18, 2005 that DMME had no jurisdiction to require removal of mud from his driveway. No violations were cited and this complaint investigation is hereby closed out.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COPY: 5197

COMPLAINT INVESTIGATION

In accordance with 4 VAC 25-130-842.15 of the Virginia Coal Surface Mining Reclamation Regulations (Review of Decision not to Inspect or Enforce):

(a) Any person who is or may be adversely affected by a coal exploration or surface coal mining and reclamation operation may ask the Director to review informally an authorized representative's decision not to inspect or take appropriate enforcement action with respect to any violation alleged by that person in a request for an inspection under ' 4 VAC 25-130-842.12. The request for review shall be in writing and include a statement of how the person is or may be adversely affected and why the decision merits review.

(b) The Division shall conduct the review and inform the person, in writing, of the results of the review within 30 days of his receipt of the request. The person alleged to be in violation shall also be given a copy of the results of the review.

(c) Informal review under this Section shall not affect any rights which a citizen may have to formal review under Section 45.1-249 of the Act[1], or a citizen's right to file suit pursuant to Section 45.1-246.1 of the Act.

(d) Any person who requested a review of a decision not to inspect or enforce under this Section and who is or may be adversely affected by any determination made under Subsection (b) of this Section may request review of that determination by filing an application for formal review and request for hearing under the **Virginia Administrative Process Act** Section **2.2-4000A** et seq of the Code of Virginia.

A request for a review of the complaint investigation and/or for a formal hearing should be addressed to the attention of the:

Hearings Coordinator
Division of Mined Land Reclamation
P. O. Drawer 900
Big Stone Gap, Virginia 24219

[1] Virginia Coal Surface Mining Control and Reclamation Act of 1979, as amended.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COMPLAINT INVESTIGATION

OFFICE USE ONLY
COPIED TO:
___ Complainant
___ Company
___ P.R. Manager
___ Technical Section
___ Other (specify)

COMPLAINT NO.	INVESTIGATION NO.	PERMIT NO.	DATE/TIME RECEIVED	DATE OF REPORT
0500120	5281 (CEV0004324)	1101914	7/1/05 09:50 AM	7/1/05

COMPLAINANT NAME, ADDRESS, PHONE	COMPANY/PERMITTEE NAME, ADDRESS, PHONE
Willis, Ronnie 1712 Roda Road Appalachia, VA 24216 (H) (276)565-3421	A & G COAL CORPORATION P. O. BOX 1010 WISE, VA 24293 (276)328-3421

LOCATION	COUNTY(S)	WISE
Roda		

COMPLAINT STATUS/DATE	COMPLAINT TYPE	INVESTIGATION TYPE
RESOLVED 7/1/05	HAULROAD NOISE	INITIAL CLOSE OUT

ENFORCEMENT			
TYPE OF ACTION	ACTION NUMBER	COMPLAINANT NOTIFIED	REQUEST TO ACCOMPANY
		7/1/2005 02:45 PM	NO

ATTACHMENT(S): 2
Photos

COMMENTS FROM:		
COMPLAINANT	Willis, Ronnie	7/1/2005 10:25 AM
COMPANY OFFICIAL	Jerry Hamilton	7/1/05 03:00 PM
INVESTIGATOR/SIGNATURE	VARNER, CHARLES	

COMPLAINANT'S COMMENTS	Willis, Ronnie	7/1/2005 10:25 AM

I am calling to complain about the speeding coal trucks coming by my house and the excessive noise they make. The dust problem is getting worse. The trucks run all night long. The trucks start gearing down in front of my house and use their Jacobs brake before crossing the bridge below the house. This creates excessive noise which they wouldn't have to do if they slowed down. My wife died on Wednesday and I helped carry her out to the hearse. The funeral home had signs put up on the road and the coal trucks never slowed down for them. They did not show any respect for my wife. The funeral home director even mentioned that the trucks were not slowing down. I took pictures of the funeral home signs and my name on the mailbox so you could see it. They are still up today.
There are several things the company could do to correct this problem. They could truck the coal around the old strip bench in front of my house to the Wentz Prep Plant. They could put in a truck washer. The trucks should be slowed down to 15mph. They could put in a sprinkler system up and down the road to keep the dust down.
I sweep my porch off everyday but you can't tell it. I plan on washing my house down.

COMPANY OFFICIAL'S COMMENTS	Jerry Hamilton	7/1/05 03:00 PM

I have talked with some of the owners of trucking companies about the coal trucks traveling through the Roda Community. I can't do anything about the trucks speeding down the State Road. I keep a man full time on our permitted haulroad sweeping and watering the road as necessary to suppress the dust. I water the State Road as far down as I can but I can only do so much due to constraints concerning liability and insurance considerations.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COPY: 5281

COMPLAINT INVESTIGATION

INVESTIGATOR'S DESCRIPTION, COMMENTS, AND RECOMMENDATIONS	VARNER, CHARLES

DMLR Inspector Eddie Varner investigated the nature of this complaint today and talked with the complainant in detail. At 2:30PM on the afternoon of 7/1/05 I visited the complainants home and talked with the complainant in person. I took several pictures of coal truck traffic on State Route #685. All of the houses along State Route #685 are located very close to the road and dust from traffic is a problem for the residents. The complainant lives approximately 1.5 miles SE from the entrance to the coal haulroad permitted by A & G Coal Corp. #1101914. Trucks traveling down the straight stretch pick up speed prior to crossing the bridge located just below the complainants home. Dust is generated from the shoulders of the road in addition to blowing off the trucks themselves.

I inspected the permitted coal haulroad which has been paved at the point where it intersects State Route #685. This road was adequately surfaced and is watered down periodically everyday as needed to suppress the dust. The ditchline had been cleaned out as well. There were no maintenance problems noted with this haulroad today.

I explained to the complainant that the DMLR had jurisdiction on permitted coal haulroads, but had no jurisdiction once the trucks entered onto the State Road. I explained that speeding coal trucks fell under the jurisdiction of the State Police. The complainant understood this and stated he had to start somewhere. There were no violations noted as a result of this investigation. This complaint investigation is hereby closed out today.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

COPY: 5281

COMPLAINT INVESTIGATION

In accordance with 4 VAC 25-130-842.15 of the Virginia Coal Surface Mining Reclamation Regulations (Review of Decision not to Inspect or Enforce):

(a) Any person who is or may be adversely affected by a coal exploration or surface coal mining and reclamation operation may ask the Director to review informally an authorized representative's decision not to inspect or take appropriate enforcement action with respect to any violation alleged by that person in a request for an inspection under ' 4 VAC 25-130-842.12. The request for review shall be in writing and include a statement of how the person is or may be adversely affected and why the decision merits review.

(b) The Division shall conduct the review and inform the person, in writing, of the results of the review within 30 days of his receipt of the request. The person alleged to be in violation shall also be given a copy of the results of the review.

(c) Informal review under this Section shall not affect any rights which a citizen may have to formal review under Section 45.1-249 of the Act[1], or a citizen's right to file suit pursuant to Section 45.1-246.1 of the Act.

(d) Any person who requested a review of a decision not to inspect or enforce under this Section and who is or may be adversely affected by any determination made under Subsection (b) of this Section may request review of that determination by filing an application for formal review and request for hearing under the **Virginia Administrative Process Act** Section **2.2-4000A** et seq of the Code of Virginia.

A request for a review of the complaint investigation and/or for a formal hearing should be addressed to the attention of the:

Hearings Coordinator
Division of Mined Land Reclamation
P. O. Drawer 900
Big Stone Gap, Virginia 24219

[1] Virginia Coal Surface Mining Control and Reclamation Act of 1979, as amended.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

RECEIVED
MAR - 4 2004
ENF

COMPLAINT INVESTIGATION

OFFICE USE ONLY
3-4-04
COPIED TO:
- ✓ Complainant
- ✓ Company
- ✓ P.R. Coordinator
- ___ Technical Section
- ✓ Other (specify) Delegate Bud Phillips

COMPLAINT NO.	INVESTIGATION NO.	PERMIT NO.	DATE/TIME RECEIVED	DATE OF REPORT
0400061	CEV0003562	1701819	3/2/04 04:30 PM	3/4/04

COMPLAINANT NAME, ADDRESS, PHONE	COMPANY/PERMITTEE NAME, ADDRESS, PHONE
Campbell, Nell 1482 Roda Road Appalachia, VA 24216 (H) (276)565-1062	NALLY & HAMILTON ENTERPRISES, INC. P. O. BOX 157 109 SOUTH FOURTH STREET BARDSTOWN, KY 40004 (502)348-0084

LOCATION	COUNTY(S)	WISE
Roda		

COMPLAINT STATUS/DATE	COMPLAINT TYPE	INVESTIGATION TYPE
RESOLVED 3/4/04	HAULROAD	INITIAL CLOSE OUT

ENFORCEMENT			
TYPE OF ACTION	ACTION NUMBER	COMPLAINANT NOTIFIED	REQUEST TO ACCOMPANY
		03/04/04 08:55 AM	NO

ATTACHMENT(S): 2
Photos

COMMENTS FROM:		
COMPLAINANT	Campbell, Nell	03/03/04 08:45 AM
COMPANY OFFICIAL	Tracy Creech	3/3/04 10:45 AM
INVESTIGATOR/SIGNATURE	VARNER, CHARLES Charles Varner	

COMPLAINANT'S COMMENTS	Campbell, Nell	03/03/04 08:45 AM

I don't want to cause anyone any problems, but mud along the road is so bad I can't get to my mailbox. Coal truck traffic is very heavy and they get over on the shoulders of the road to pass each other and drag it out onto the road.

COMPANY OFFICIAL'S COMMENTS	Tracy Creech	3/3/04 10:45 AM

No comment.

INVESTIGATOR'S DESCRIPTION, COMMENTS, AND RECOMMENDATIONS	VARNER, CHARLES

DMLR Inspector Eddie Varner investigated the nature of this complaint today and discussed the matter with the complainant by phone. The complainant is located 1450' from the entrance of Nally & Hamilton Ent., Inc. #1701819. I inspected Haulroad A this morning for compliance with haulroad requirements. Nally & Hamilton are not hauling coal over this section of road but three other companies haul coal over this road. The coal haulroad was surfaced with stone so as to prevent mud from being tracked onto the State Road. Company representatives from A & G Coal Corp. applied additional gravel and graded the haulroad while I was on site. This haulroad had been watered this morning when I arrived on site.

I met at the Roda Church with Mr. Joe Buchanan of A&G Coal Corporation to discuss the nature of this complaint and the status of the coal haulroad. It is my understanding the coal haulroad will be relinquished to another permit in the near future and plans are being finalized to get this done as soon as possible. Once the road has been relinquished to another company, additional measures will be implemented on the permitted coal haulroad to reduce the possibility of

offsite impacts. Mr. Buchanan informed me that the company had 300 tons of gravel stockpiled on the site to be used on the shoulders of the State Road. VDOT was to have started work on Monday (3/1/04) but were delayed due to the recent rain.

A&G Coal Corp. is currently sweeping and watering State Route #685 on an as needed basis. Coal truck traffic on this road has significantly increased over the last two or three years. There are currently two deep mines and a surface mine in the Mudlick Creek watershed which haul coal out of Roda Hollow on State Route #685. There are plans to open up at least two more deep mines which will haul out on State Route #685. The heavy volume of truck traffic has deteriorated the road to the point where major maintenance is needed on the State Road. There are numerous pot holes in the pavement, broken pavement, shoulders need reworking, and ditchlines cleaned/pulled. There are several tractor trailers which haul over the road. These trucks have to get over on the shoulder of the road to pass. When they get off the hardtop, mud is tracked onto the road which adds to the problem. In several locations along this road near Roda Church there is no way for the water on the roadbed surface to drain off the hardtop. There is an old railroad track running parallel to the State Road on the right side (traveling North) which prevents the water from draining off the road. This track needs to be removed so an adequate shoulder can be constructed.

On 2/23/04, I talked with Jackie Christian of the Wise VDOT Office about the deteriorated condition of this road and explained the situation to him. Mr. Christian stated VDOT had been meeting with some of the coal companies which use this road about doing some maintenance on St. Rt. #685. Mr. Christian was aware of this problem and stated this work was high on their priority list and they had plans for paving and shoulder work this season. Mr. Christian stated the bid would have to be let and it would be sometime in April or May at the earliest before any work could be done.

On the morning of 3/4/04 I made a site inspection of State Route #685 at the complainants home to check the status of the road. Mr. Joe Buchanan of A & G Coal Corp. had washed off the edge of the State Road in front of the complainants home, washed off the mailboxes, and put gravel down in front of the driveway and along the edge of the road. Gravel had also been put down at other residences along the road and the Roda Church parking lot had been graveled. I talked with the complainant on the morning of 3/4/04 and she was well pleased with what had been done.

There were no violations noted concerning the coal haulroad on CSMO #1701819 and no enforcement action taken. This complaint investigation is hereby closed out today.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P.O. DRAWER 900, BIG STONE GAP, VA 24219
TELEPHONE: (276) 523-8198

CEV0003562

COMPLAINT INVESTIGATION

In accordance with 4 VAC 25-130-842.15 of the Virginia Coal Surface Mining Reclamation Regulations (Review of Decision not to Inspect or Enforce):

(a) Any person who is or may be adversely affected by a coal exploration or surface coal mining and reclamation operation may ask the Director to review informally an authorized representative's decision not to inspect or take appropriate enforcement action with respect to any violation alleged by that person in a request for an inspection under ' 4 VAC 25-130-842.12. The request for review shall be in writing and include a statement of how the person is or may be adversely affected and why the decision merits review.

(b) The Division shall conduct the review and inform the person, in writing, of the results of the review within 30 days of his receipt of the request. The person alleged to be in violation shall also be given a copy of the results of the review.

(c) Informal review under this Section shall not affect any rights which a citizen may have to formal review under Section 45.1-249 of the Act[1], or a citizen's right to file suit pursuant to Section 45.1-246.1 of the Act.

(d) Any person who requested a review of a decision not to inspect or enforce under this Section and who is or may be adversely affected by any determination made under Subsection (b) of this Section may request review of that determination by filing an application for formal review and request for hearing under the **Virginia Administrative Process Act** Section **2.2-4000A** et seq of the Code of Virginia.

A request for a review of the complaint investigation and/or for a formal hearing should be addressed to the attention of the:

Hearings Coordinator
Division of Mined Land Reclamation
P. O. Drawer 900
Big Stone Gap, Virginia 24219

[1] Virginia Coal Surface Mining Control and Reclamation Act of 1979, as amended.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINED LAND RECLAMATION
P. O. DRAWER 900; BIG STONE GAP, VA 24219
TELEPHONE: (540) 523-8198

Photographic Documentation

Permittee	Nally & Hamilton Ent., Inc.			**Permit No.**	1701819
File ID	107-0720	**Date**	3/3/04	**Taken by**	Eddie Varner

Photo of – 1 of 2

Comments/Observations

Picture shows complainants mailbox and edge of State Route #685 before cleanup was done.

File ID	107-0739	**Date**	3/4/04	**Taken by**	Eddie Varner

Photo of – 2 of 2

Comments/Observations

Picture shows complainants mailbox after cleanup was done on the evening of 3/3/04.

Signature	Eddie Varner

Appendix D:

Appalachia Town Ordinance No. 2009-1

ORDINANCE NO. 2009-1, 2009

AN ORDINANCE OF THE TOWN COUNCIL OF THE TOWN OF APPALACHIA, VIRGINIA REGULATING THE MINING OF COAL AND OTHER MINERALS WITHIN THE TOWN OF APPALACHIA BOUNDERIES AND OTHER OWNED PROPERTIES

WHEREAS, The Town Council of the Town of Appalachia, Virginia recognizes that it is responsible for the health, safety, welfare and properties of it's citizens, and

WHEREAS, The Town Council of the Town of Appalachia, Virginia recognizes the need to control, regulate, and limit the mining of coal and other minerals within it's boundaries and other owned properties in order to protect the health, safety, welfare and properties of it's citizens, and

WHEREAS, The Town Council of the Town of Appalachia, Virginia recognizes that the mining of subsurface or surface coal and other minerals and related blasting should be permitted in the Town of Appalachia and other owned properties only after a thorough procedural review by Town Officials to include applications for a Town mining permit, public hearings and final review of the mining plans by the Town Council of the Town of Appalachia, Virginia.

NOW THEREFORE BE IT ORDAINED AND ENACTED, as follows.

1. It shall be unlawful for any person, corporation or any other entity to strip-mine, open-pit mine, auger-mine or deep-mine *coal* or *any other minerals* within the boundaries of the Town of Appalachia or the properties owned by or controlled by the Town of Appalachia until a thorough review of the mining plan, including blasting plans, is conducted by Town Officials.

2. Any violations of this Ordinance shall be punishable as a Class 1 Misdemeanor and The Town shall reserve the right to seek injunctive relief against the defendant in order to force compliance of this ordinance.

3. PROCEDURAL REVIEW:

   (a) Any person, corporation or other entity seeking to mine minerals outlined in 1. above shall first notify Town Officials of such intentions and submit documentation pursuant to that notification. To include (a) copies of such mining documentation to be submitted to the Division of Mines, Minerals and Energy pursuant to obtaining a mining permit from that organization, (b) copies of documentation to be submitted to other state and federal organization required by them in order to commence operations, (c) detailed copies of blasting plans related to the mining operations (d) copies of plans concerning any tree removal or deforestation concerning

the mining operation and (e) complete and submit a Town of Appalachia mining permit application to Town Officials.

(b) The permit application as well as related documentation and a fee of _____ shall be submitted by Town Officials to the Town of Appalachia Planning Commission for a review and comments to the Town Council of the Town of Appalachia concerning the application. During the course of the Planning Commission review at least one public hearing shall be conducted following advertisement as required by the Town of Appalachia Zoning Ordinance.

(c) Upon completion of the review, comments concerning the application shall be forwarded to the Town Council of the Town of Appalachia for further review. If the Town of Appalachia Planning Commission for whatever reason is unable to conduct the review, then the Town Council shall conduct the review. A duly advertised public hearing shall be conducted by the Town Council before rendering a final opinion on the matter.

4. The requirements of this ordinance are considered reasonable regulatory measures to protect and inform the citizens of the Town of Appalachia and nothing contained herein shall be construed as to violate, replace or usurp the rules of federal or state laws concerning mining.

Appendix E:

Report of Dr. Dudley F. Rochester

OUTDOOR AIR POLLUTION, HEALTH AND HEALTH COSTS IN VIRGINIA

Report for State Advisory Board - Air Pollution
Dudley F. Rochester, M.D. (November 2006)

Introduction, Mission Statement & Scope

The 2006 State Advisory Board – Air Pollution asked SAB member Dudley F. Rochester, M.D., to prepare a report on a) the impacts of outdoor air pollution on human health and health costs, and b) the effects of interventions to lower air pollution.

The mission is to review the relevant medical, epidemiological and economic data in literature related to health effects of outdoor air pollution, to organize and interpret the findings of these articles, and to present the results in a format that emphasizes the impacts of outdoor air pollution on health and health costs in Virginia.

Most of the available articles reviewed for this report focused on ozone and particulate matter. The report summarizes data about direct effects of ozone and/or particulate matter on human health, health and other related costs, and impacts of interventions that lower air pollution levels on health and health costs.

This report does not cover a) economic impacts of ambient air pollution such as damage to farm animals, crops and forests, or loss of tourism business; b) indoor air pollution; and c) mercury, which is the subject of a separate 2006 report by the State Advisory Board – Air Pollution.

Executive Summary

- Outdoor air pollution from ozone and fine particulate matter causes significant morbidity (asthma and other respiratory diseases, heart disease and stroke) and premature mortality (adult and infant). The death rate attributable to air pollution is approximately 45% of that attributable to tobacco, and 8% of overall mortality.

- Direct medical costs in the United States come to approximately $400 per year per Medicare recipient, and overall health costs are approximately $800 a year per adult. In Virginia that comes to $4.8 billion per year, or 1.6 % of Virginia's gross domestic product.

- Interventions that lower the air concentrations of ozone and particulate matter are associated with reductions in respiratory illness and overall death rate. In Virginia, a 33% reduction in current levels of ambient particulate matter and ozone would reduce respiratory illnesses in children by approximately one-third. Premature deaths would fall by 21 per 100,000 of the population per year (approximately 2.5% of the total death rate). Reducing medical costs would save $1.6 billion per year.

Ozone & Particulate Matter (PM)

Ozone precursors. Volatile organic compounds (VOC) are substances such as paint thinners, gasoline, solvents and many other organic chemicals, from nature as well as from human endeavor, that evaporate into the air. Oxides of nitrogen (NOx) are produced by burning fossil fuels in electric power plants, other types of factories and in internal combustion engines located on- and off-road. Approximately 45% of VOC and 63% of NOx come from mobile sources. Ozone is formed in the troposphere, the part of the earth's atmosphere that is close to the ground, through chemical reactions powered by sunlight and involving VOC and NOx. Ozone can be transported by wind currents to hundreds of miles away from its source. Sulfur dioxide (SO_2) and NOx are important precursors of $PM_{2.5}$ formed in the atmosphere.

Sources of Particulate Matter. Some fine particles come from disruption of the earth's crust by sandstorms, excavation, volcanic activity and other phenomena. Although the mass of particles of crustal origin is approximately four times that of particles resulting from the combustion of fossil fuel, we inhale many more of the latter because they are finer particles. Fine particles originating from fossil fuel combustion are formed in stationary sources such as power plants and factories, as well as in mobile sources such as internal combustion engines on- and off-road, locomotives, construction equipment, farm and yard equipment, boats, airplanes etc. In addition, fine particles are formed by chemical processes in the atmosphere involving gases emitted by burning fossil fuels.

Classes of Particulates. Particulate matter (PM) exists in multiple classes. The term black smoke (BS) refers to a mixture of sizes, measured optically. Another group is total suspended particulates (TSP). Smaller particulates are referred to by their size, specifically, by their diameter in micrometers (μ). The two principal groups of particulates monitored by US EPA and Virginia DEQ are those with a mean diameter under 10 μ (PM_{10}) and particles with a mean diameter less than 2.5 μ ($PM_{2.5}$). PM_{10} and $PM_{2.5}$ are referred to as fine particles. On average, $PM_{2.5}$ particles comprise about 70% of PM_{10} by mass. However, PM2.5 particles are 10 to 100 times more numerous, and owing to their smaller size, they have a higher ratio of surface to volume.

The concentrations of the different types of particulate matter in air tend to vary up and down together. BS concentration is easily determined by absorption of light by particulate matter, and the BS level can be used as an indicator of diesel exhaust emissions (Gotschi 2002).

Particulates Relevant to Health. Most of the reports that deal with health effects of particulate air pollution concern PM_{10} and $PM_{2.5}$. These are the particulates that are most harmful to human health, especially those produced in motor vehicles (Laden 2000, Lanki 2006). The technology for measuring $PM_{2.5}$ levels in air was not widely available until the mid-1990s, so some studies report only on TSP, BS and other particulates.

Air Concentration Trends in Virginia

Emissions of PM_{10}, NOx, sulfate (SO_2) and VOC fell by 10 to 46% from 1990 to 2002. In like fashion, air concentrations of ozone, PM_{10}, NOx and SO_2 fell by 12 to 39 % from 1993 to 2003. However, between 2004 and 2005 the air concentrations of ozone, PM_{10} and $PM_{2.5}$ increased by approximately 5 to 12% in Virginia (Table 1). The utilization of electric power is projected to grow until 2050, the population of Virginia increased approximately 33% between 1980 and 2000, and vehicle miles traveled increased 99% during the same period. Recently adopted EPA diesel, gasoline and emissions standards may ameliorate the rise in emissions of $PM_{2.5}$ over coming decades. However, if trends in population, power consumption and vehicle miles traveled continue upward, one can expect that particulate emissions and air concentrations will either continue to grow or at least remain high.

Table 1, based on data supplied by the EPA website for cities and counties in Virginia, shows air concentration data for ozone, PM_{10} and $PM_{2.5}$ for years 2004 and 2005. The values for PM_{10} and $PM_{2.5}$ are annual means; and the values for ozone are 8-hour maxima. The EPA standard is 50 micrograms per cubic meter of air ($\mu g/m^3$) for PM_{10}, 15 $\mu g/m^3$ for PM2.5, and 80 parts per billion (ppb) for ozone.

Table 1: Average values for ozone, PM_{10} and $PM_{2.5}$ in Virginia

		Year		Percent
Pollutant	Units	2004	2005	Difference
Ozone	ppb	75	79	+5.3
PM_{10}	$\mu g/m^3$	18.8	21.0	+11.7
$PM_{2.5}$	$\mu g/m^3$	13.2	14.1	+6.8

The average values from all monitoring sites in the state for ozone and $PM_{2.5}$ are close to the EPA standards. In the large metropolitan areas of Virginia, the 8-hour ozone standard is often exceeded, and the $PM_{2.5}$ standard is sometimes exceeded.

Assessment of Health Effects

The impact of air pollution on health can be assessed in multiple ways. Questionnaires distributed to patients and/or their families provide information about respiratory symptoms such as wheezing, shortness of breath, tightness in the chest, cough and production of sputum. The function of the lungs can be assessed by various breathing tests. Such data can be recorded over many years to determine if there are long-term decrements in lung function. Events such as the number of asthma attacks, visits for emergency care and hospitalizations can be tabulated. Death rates from asthma, chronic obstructive pulmonary diseases (COPD) and lung cancer can be related to short-and long-term exposure to ozone and fine particulates.

Mechanism of Air Pollution-Induced Illness

Particle deposition in the lungs: Respiratory and other illnesses may be related to the presence of fine particulate material in the lungs. In a study that compared findings in Mexican and Canadian cities, the lungs of women who died of non-respiratory diseases were studied for their particle content. The prevailing level of PM_{10} in the air was 4.7 times higher in Mexico City than in Vancouver, and the lungs examined in Mexico City contained 7.4 times more particles than lungs from Vancouver. The particles in the lungs had characteristics of diesel exhaust (Brauer 2001).

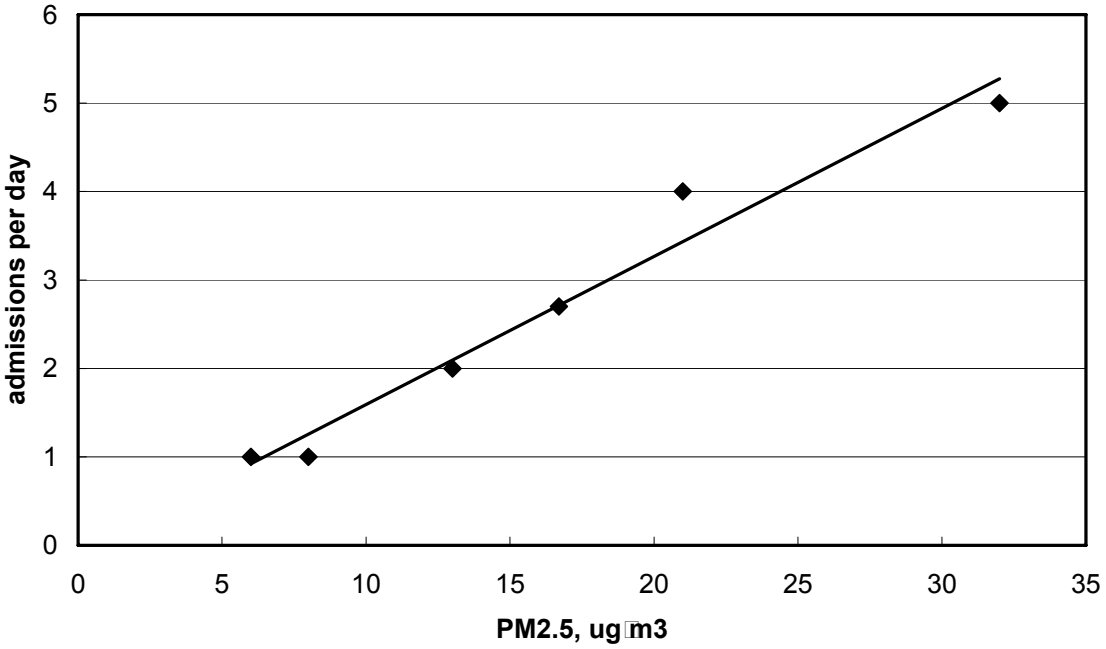
Inflammation. Ozone is a highly reactive substance that reacts with biological compounds to form oxygen free radicals. These radicals are also highly reactive, promoting inflammation and damaging living tissues. Fine particulate matter contains heavy metals and endotoxin which can also initiate inflammation (Ghio 2001, Long 2001, Tolbert 2002, Schaumann 2004). Instillation of fine particles into the lungs of human volunteers evokes an inflammatory response characterized by the appearance of inflammatory cells and substances called cytokines in the lungs (Ghio 2001, Schaumann 2004). Humans who inhaled fine particulate matter developed biochemical markers of inflammation in their blood and urine (Fujii 2001, Ruckeri 2006, Rabinovitch 2006).

The thickness of the inner and middle lining of the human carotid artery, which is related to inflammation in the lining, is proportional to the concentration of $PM_{2.5}$ (Kunzli 2005). Cardiovascular mortality related to air pollution is thought to be mediated by inflammation (Pope 2004).

Respiratory Illness

Morbidity. The prevalence of respiratory illness in children is related to levels of ozone and fine particulate pollution (Romieu 1996, Sheppard 1999, Gent 2003, Rabinovitch 2006). In addition to $PM_{2.5}$ and PM_{10}, TSP, SO_2 and NOx are also involved (Zhang 2002). Deaths from asthma are related to NOx and ozone (Sunyer 2002). Figure 1, based on data from Sheppard (1999) illustrates the number of hospitalizations per day in Seattle for asthma as related to the concentration of $PM_{2.5}$. Hospitalization rates for adults with respiratory diseases are also related to ozone and PM_{10} (Atkinson 2001, McGowan 2002).

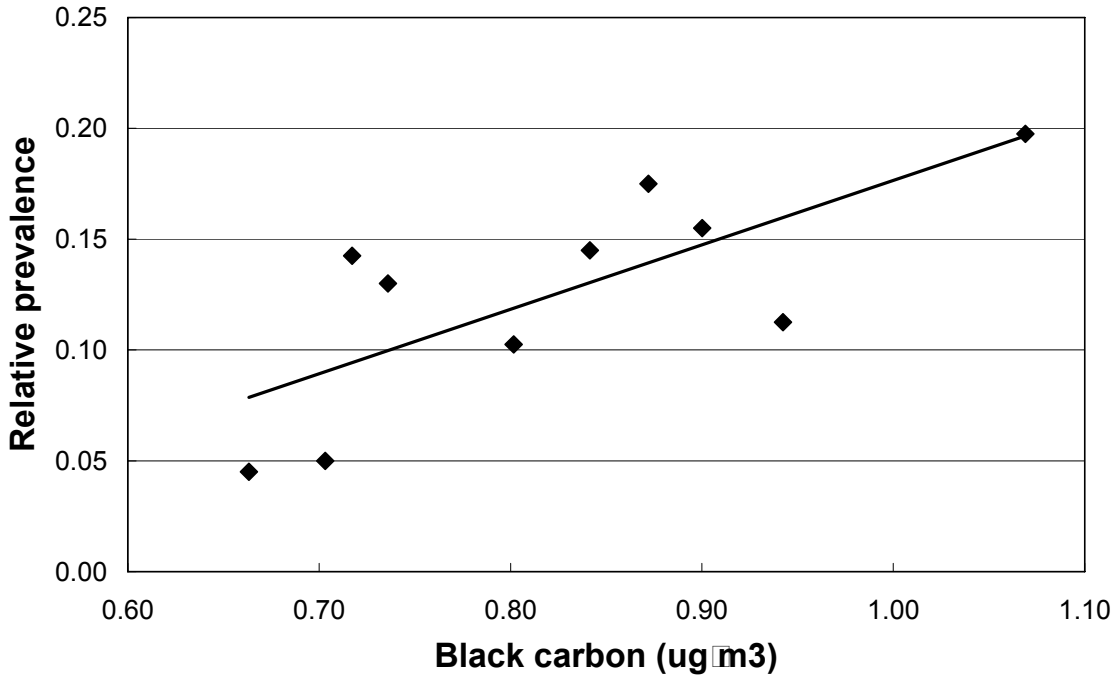
Figure 1. PM2.5 and Hospitalizations for Asthma



Lung function. As children grow, their lungs become larger and the numerical values for tests of lung function also increase. Several studies involving three to eight years of follow-up have shown that deficits in the growth of lung function, as assessed by lung function tests, are related to exposure to ozone, fine particulates, NOx and acid vapor (Gauderman 2002, 2004, Horak 2002).

Influence of traffic. Respiratory illness in children and adults is higher in areas adjacent to high motor vehicle traffic (Hoek 2002, Garshick 2003, Kim 2004, McConnell 2006). Figure 2 (Kim 2004) shows the effect of the concentration of black carbon in the air on the prevalence of bronchitis in school children. Each point on the graph is one school in Southern California. It is clear that the higher the black carbon concentration in the air, the higher is the prevalence of bronchitis (a 40% increase in black carbon doubles the relative prevalence).

Figure 2. Black Carbon □ Bronchitis in Schools



Infant Morbidity & Mortality

Low birth weight, a predictor of infant mortality, is associated with maternal exposure to SO_2 and TSP during the third trimester of pregnancy (Wang 1997). Exposure to CO, PM10 and NOx is associated with increased mortality in infants aged 1-12 months (Ritz 2006). Maternal exposure to ambient air pollution is associated with a variety of fetal abnormalities (Bocksay 2005, Perera 2002). Cardiac defects in fetuses are associated with exposure of mothers to carbon monoxide and ozone in the first trimester of pregnancy (Ritz 2002).

Infant mortality increases with increasing levels of PM_{10} (Ha 2003). In US metropolitan areas, mortality from all causes, sudden infant death syndrome and childhood respiratory diseases increase in proportion to PM_{10} concentrations in the air (Kaiser 2004).

Cardiovascular Disease & Stroke

Fine particulate pollution is associated with an increase in the incidence of heart attacks and precipitation of congestive heart failure (Wellenius 2005a, Wellenius 2006, Dominici 2006), and in the incidence of ischemic strokes (Hong 2002a, 2002b, Wellenius 2005b, Low 2006). The number of emergency admissions for heart attack and the risk of death from heart attacks both increase when $PM_{2.5}$ increases (Zanobetti 2005, Dominici 2006). High levels of exposure to $PM_{2.5}$ lead to atherosclerosis, which underlies both ischemic stroke and heart attacks (Kunzli 2005). The probability of having a heart attack is increased by exposure to traffic (Peters 2004).

Adult Mortality

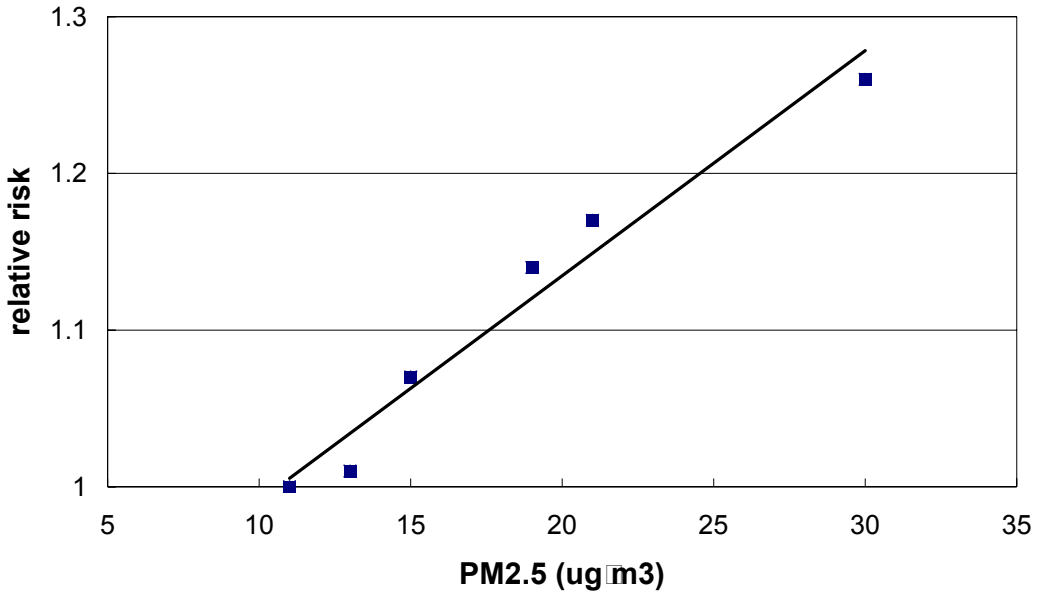
The association between fine particulate air pollution and increased risk of dying from all causes other than trauma has been demonstrated repeatedly (Schwartz and Dockery 1992, Dockery 1993, Pope 1995, Samet 2000, Goldberg 2001a, Goldberg et al. 2001b, Valois 2001, Pope 2002, Ballester 2002, Medina 2004, Jerrett 2005). The relative risk from of an exposure to equal mass concentrations is much higher for $PM_{2.5}$ than from PM_{10} (Samet 2000, Pope 2002). Exposure to ozone carries a finite risk of mortality unrelated to exposure to particulates (Gryparis 2004, Bell 2005). The risks of dying from COPD, lung cancer and heart disease after exposure to air pollution are substantially higher than the risk for all-cause mortality.

Worldwide, $PM_{2.5}$ causes about 3% of mortality from cardiopulmonary disease, 5% of mortality from cancer of trachea, bronchus and lung, and about 1% of mortality from acute respiratory infections in children under age 5 years. It amounts to 0.8 million premature deaths (1.2 %) and 6.4 million years of life lost (Cohen 2005). Even short-term exposure to particulates increases the mortality rates beyond the effect of hastening the death of the most vulnerable people (Zanobetti 2002, Hoyos 2003).

The data in Figure 3 (see below) are taken from the original six cities study (Dockery 1993). Each point in the graph represents a single city. The six cities are located in the eastern and Midwestern parts of the United States. The mean air concentrations of $PM_{2.5}$ ranged from 11 $\mu g/m^3$ of air in the least polluted city to 30 $\mu g/m^3$ in the most polluted.

In the six cities study, the relative risk of dying is highest in the most polluted city. These findings have not been altered by extensive reanalysis and follow-up (Dockery 1993, Laden 2000, Laden 2006). By way of comparison, the relative risk of dying prematurely is 2.3 for a current smoker, 1.5 for a former smoker and 1.3 from PM2.5 in a heavily polluted city.

Figure 3: Relative Risk of Dying



The relationship between daily death rate and the concentration of either ozone or $PM_{2.5}$ is linear, i.e. relative risk of dying varies directly with the level of pollutant. Statisticians find no evidence for a threshold, i.e. a little air pollution is bad and more is worse (Goldberg et al., 2001a, Schwartz 2002, Gryparis 2004, Bell 2006). The magnitude of the relationship depends on duration of exposure (Dominici 2003, Goodman 2004).

Table 2 shows the death rates in the United States. The overall death rate in the United States is approximately 830 per 100,000 of the population per year. The death rate from tobacco use is approximately 17% of the US total (US Census Bureau). Air pollution accounts for approximately 8%, with a range of 12 to 146 and a median value of 64 deaths per year per 100,000 of the population (Pope 1995, Samet 2000, Kunzli 2000, Pope 2002, Clancy 2002, Ballester 2002, Medina 2004, Jerrett 2005). Note that the rate for air pollution exceeds the rate for alcohol, firearms and motor vehicle accidents combined.

Table 2: Comparison of Mortality Rates in the United States		
Cause of death	Rate/100,000	Percent
US total	830	100
Tobacco	150	18
Air pollution	64	8
Alcohol, firearms, & motor vehicle accidents combined	57	7

Health Costs of Air Pollution

There is a strong correlation between the concentration of PM_{10} in the air and utilization of outpatient and inpatient medical services by Medicare recipients in the United States (Fuchs and Franks 2002). These investigators estimated that reducing the concentration of PM_{10} by 10 $\mu g/m^3$ would lead to a savings of $177 per year per senior citizen. Given the currently prevailing level of PM_{10}, the total direct medical cost would be approximately $370 per Medicare recipient per year.

In southern California, the total cost of school absences related to air pollution was approximately $245 million (Hall 2003). It was estimated that the reductions in air pollution estimated to occur by 2010 will result in fewer children visiting emergency rooms, fewer hospitalizations, a reduction in number of low birth rate infants, with an annual medical savings of approximately $267 million for children (Wong 2004).

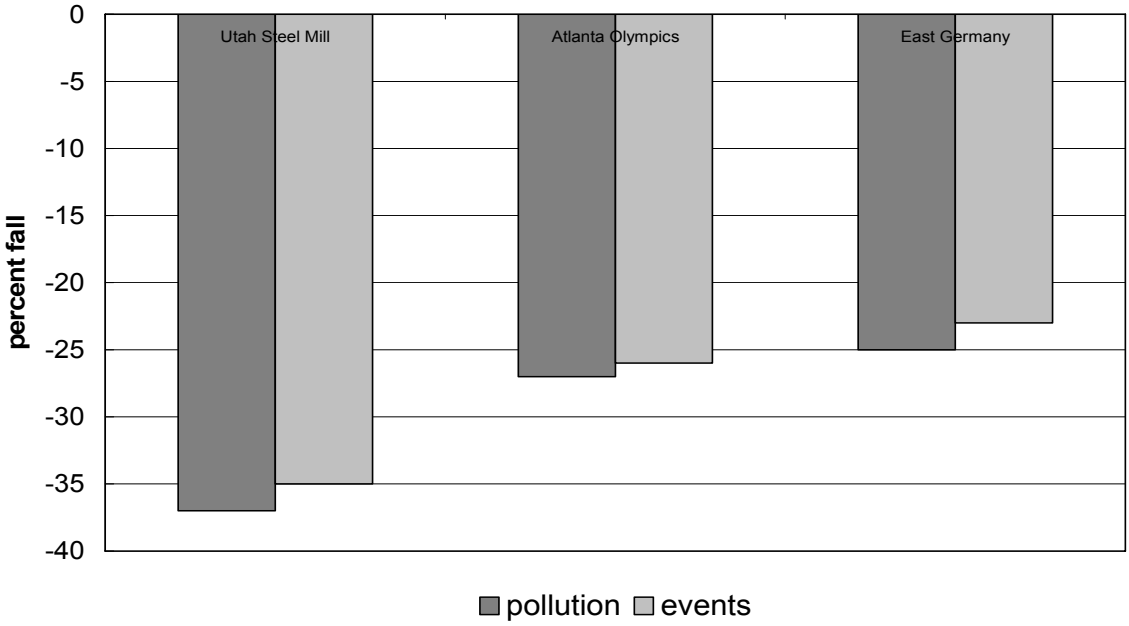
Studies based on large populations indicate that total health costs of air pollution, which include the impact of premature deaths, range from $600 to $1,000 per adult per year (Hall 1992, Levy 2001, Kunzli 2002, Hall 2006). The average is approximately $800 per adult per year. In Virginia that would come to approximately $4.8 billion per year, or 1.6 % of Virginia's gross domestic product.

Effect of Interventions

Rate of fall. When emissions of air pollutants cease, air pollution levels drop rapidly. In a 2003 power outage that affected mid-Atlantic states there were 50-90% reductions in SO_2, ozone and light scattering particles within 24 hours (Marufu 2004).

Morbidity. In several places local or regional levels of particulate air pollution fell for several weeks or longer. Studies of these events have yielded valuable information on the impact of interventions on pollution-related illnesses. In the Salt Lake City area a steel plant was closed for a year for economic reasons (Pope 1989). In East Germany, particulate pollution fell substantially after reunification (Heinrich 2000). The downtown area of Atlanta was closed to traffic for several weeks during the 1996 summer Olympic Games (Friedman 2001). The results of these studies are depicted in Figure 4 on page 10. Note that for each percent decrement in air pollution (dark grey bars), there is a nearly identical decrement in respiratory illness (light grey bars).

Figure 4. Effect of Interventions



Mortality. In Dublin, Ireland the sale of bituminous coal for home space and water heating was banned in 1990. Mortality ascribable to air pollution was studied for 6 years before and 6 years after the ban. The concentration of black smoke (BS) in the air fell by 70%. Death rates from all causes except trauma fell by 5.7%, respiratory deaths fell by 15.5 % and cardiovascular deaths fell by 10.3%. Approximately 75 deaths per year per 100,000 population could be attributed to air pollution (Clancy 2002).

Consequences of Lowering Air Pollution in Virginia

A one-third reduction in current levels of ambient particulate matter and ozone would be expected to reduce asthma and bronchitis in children by approximately one-third. Premature deaths would fall by 21 per 100,000 of the population per year, or approximately 2.5% of the total death rate. The savings from reduced medical costs would come to approximately $1.6 billion per year.

Progress to Date

The data presented in the references cited do not take into account measures taken in recent years to ameliorate outdoor air pollution. In the United States, measures have already been in effect for several years to reduce emissions from on-road vehicles and power plants. Internal combustion engines are more efficient. As of October 2006, diesel fuel has 90% less sulfur. In 2007, emissions from selected off-road vehicles will be curtailed.

Summary

Fine particulate matter and ozone have the greatest impact on human health. At levels prevailing in Virginia, they are responsible for increased morbidity and mortality. The death rate from air pollution is approximately 40% of that for tobacco use. The health costs are approximately $4.8 billion (1.6% of Virginia's gross domestic product).

Interventions that reduce air pollution are accompanied by a comparable percentage fall in respiratory illness in children, and a substantial decrease in death rate. A one-third reduction of air pollution in Virginia could lower children's respiratory illnesses by approximately one-third, reduce death rate by 3% and save Virginia 1.6 billion dollars per year.

Recommendations

Use Energy Efficiently

Home: Insulate. Adjust thermostats for less cooling in summer and less heating in winter. Conserve water and use hot water judiciously.

Architecture: Build environmentally compatible residential and commercial buildings.

Energy supply: Utilize renewable sources (solar, wind, geothermal, etc.).

On-road vehicles: Maintain proper tire inflation. Keep engine tuned. Minimize unnecessary idling (idling engines pollute excessively). Drive within the speed limits (fuel consumption increases drastically above 65 mph). Avoid excessive acceleration and braking.

Enact Legislation

Off-road vehicles: Develop and enact emissions standards for off-road vehicles that parallel standards for on-road vehicles.

Control idling and speed limits: Excessive idling and speeding waste fuel. Banning idling and putting in place lower speed limits would signal the public that energy efficiency is an important component of environmental health.

Bibliography

Atkinson RW, Anderson HR, Sunyer J, Ayres J, et al. Acute effects of particulate air pollution on respiratory admissions: results from APHEA 2 project. Air Pollution and Health: a European Approach. Am J Respir Crit Care Med 2001; 164:1860-66.

Ballester F, Saez M, Perez-Hoyos S, et al. The EMECAM project: a multicentre study on air pollution and mortality in Spain: Combined results for particulates and sulfur dioxide. Occup Environ Med 2002; 59:300-08.

Bell ML, Dominici F, Samet JM. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology. 2005; 16:436-45.

Bell ML, Peng RD, Dominici F. The exposure-response curve for ozone and risk of mortality and the adequacy of current ozone regulations. Environ Health Perspect 2006; 114:532-536.

Brajer V, Hall JV. Change in the distribution of air pollution exposure in the Los Angeles Basin from 1990 to 1999. Contemporary Economic Policy 2005; 23:50-58.

Brauer, M., Avila-Casado, C., Fortoul, T.I., Vedal, S., Stevens, B., and Chung, A. Air Pollution and Retained Particles in the Lung, Environ Health Perspect 2001; 109:1039-1043.

Clancy L, Goodman P, Sinclair H, Dockery DD. Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study. Lancet 2002; 360:1210-14.

Cohen AJ, Ross Anderson H, , Ostro B, Pandey KD, Krzyzanowski M, Kunzli N, Gutschmidt K, Pope A, Romieu I, Samet JM, Smith K. The global burden of disease due to outdoor air pollution. J Toxicol Environ Health 2005; 68:1301-1307.

Dockery DW, Pope CA III, Xu X et al. An association between air pollution and mortality in six U.S. cities. N Engl J Med 1993; 329:1753-1759.

Dominici F, McDermott A, Zeger S, Samet JM. Airborne particulate matter and mortality: timescale effects in four US cities. Am J Epidemiol 2003; 157:1055-1065.

Dominici F, Peng RD, Bell ML, Pham L, McDermott A, Zeger SL, Samet JM. Fine particulate air pollution and hospital admissions for cardiovascular and respiratory diseases. JAMA 2006; 295:1127-1134.

Friedman MS, Powell KE, Hutwagner L, Graham LM, Teague GW. Impact of changes in transportation and commuting behaviors during the 1996 summer Olympics games in Atlanta on air quality and childhood asthma. JAMA 2001; 285:897-905.

Fuchs VR, Frank SR. Air pollution and medical care use by older Americans: A cross-area analysis. Health Affairs 2002; 21:207-214.

Fujii, T., Hayashi, S., Hogg, J.C., Vincent, R., and Van Eeden, S.F. Particulate Matter Induces Cytokine Expression In Human Bronchial Epithelial Cells. Am. J. Respir. Cell Mol. Biol. 2001; 25:265-271.

Garshick E, Laden F, Hart JE, Caron A. Residence near a major road and respiratory symptoms in U.S. Veterans. Epidemiology 2003; 14:728-36.

Gauderman WJ, Gilliland GF, Vora H, Avol E, Stram D, McConnell R, Thomas D, Lurmann F, Margolis HG, Rappaport EB, Berhane K, Peters JM. Association between air pollution and lung function growth in southern California children. Am J Respir Crit Care Med 2002; 166:76-84.

Gauderman WA, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Kuenzli N, Lurmann F, Rappaport E, Margolis H, Bates D, Peters J. The effect of air pollution on lung development from 10 to 18 years of age. N Engl J Med 2004; 351:1132-1134.

Gent JF, Triche EW, Holford TR, Belanger K, Bracken MB, Beckett WB, Leaderer BP. Associations of low-level ozone and fine particles with respiratory symptoms in children with asthma. JAMA 2003; 290:1859-1867.

Ghio, A.J. and Devlin, R.B. Inflammatory Lung Injury after Bronchial Instillation of Air Pollution Particles. Am. J. Crit. Care Med. 2001; 164:704-708.

Goldberg MS, Burnett RT, Bailar JC III et al. The association between daily mortality and ambient particle pollution in Montreal, Quebec. 1. Non-accidental mortality. Environmental Research 2001; 86:12-15

Goldberg MS, Burnett RT, Bailar JC 3rd, Brook J, Bonvalot Y, Tamblyn R, Singh R, Valois MF, Vincent R. The association between daily mortality and ambient air particle pollution in Montreal, Quebec. 2. Cause-specific mortality. Environ Res 2001; 86:26-36.

Goodman PG, Dockery DW, Clancy L. Cause-specific mortality and the extended effects of particulate pollution and temperature exposure. Environ Health Perspect 2004; 112:179-185.

Gotschi T, Oglesby L, Mathys P, Monn C, Manalis N, Koistinen K, Jantunen M, Hanninen O, Polanska L, Kunzli N. Comparison of black smoke and PM2.5 levels in indoor and outdoor environments of four European cities. Environ Sci Technol 2002; 36:1191-1197.

Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, Samoli E, Medina S, Anderson HR, Niciu EM, Wichmann H-E, Kriz B, Kosnik M, Skorkovsky JM, Dortbudak Z. Acute effects of ozone on mortality from the "Air Pollution and Health: A European Approach" Project. Am J Respir Crit Care Med 2004; 170:1080-1087.

Ha EH, Lee JT, Kim H, Lee BE, Park HS, Christiani DC. Infant susceptibility of mortality to air pollution in Seoul, South Korea. Pediatrics 2003; 111:284-290

Hall JV, Brajer V, Lurmann F. The Health and Related Economic Benefits of Attaining Healthful Air in the San Joaquin Valley. Institute for Economic and Environmental Studies 2006; pp1-85.

Hall JV, Brajer V, Lurmann FL. Economic valuation of ozone-related school absences in the south coast air basin of California. Contemporary Economic Policy 2003; 21:407-417.

Hall JV, Winer AM, Kleinman MT, Lurmann FW, Brajer V, Colome SD. Valuing the health benefits of clean air. Science 1992; 255:812-817.

Heinrich J, Hoelscher B, Wichmann HE. Decline of ambient air pollution and respiratory symptoms in children. Am J Respir Crit Care Med 2000; 161:1930-1936.

Heinrich J, Hoelscher B, Frye C, Meyer I, Pitz M, Cyrys J, Wjst M, Neas L, Wichmann HE. Improved air quality in reunified Germany and decreases in respiratory symptoms. Epidemiology. 2002; 13:394-401.

Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. Association between mortality and indicators of traffic-related pollution in the Netherlands: a cohort study. Lancet 2002; 360:11203-1209.

Hong YC, Lee J-T, Kim H, Kwan HJ. Air pollution: a new risk factor in ischemic stroke mortality. Stroke 2002; 33:2165-2169.

Hong YC, Lee TJ, Kim H, Ha EH, Schwartz J, Christiani DC. Effects of air pollution on acute stroke mortality. Environ Health Perspect 2002; 110:187-191.

Horak F Jr, Studnicka M, Gartner C, Spengler JD, Tauber E, Urbanek R, Veiter A, Frischer T. Particulate matter and lung function growth in children: a 3-yr follow-up in Austrian schoolchildren. Eur Respir J 2002; 19:838-845.

Hoyos SP, Wichmann HE, Katsouyanni K. The temporal pattern of respiratory and heart disease mortality in response to air pollution. Enviro Health Perspect 2003;111:1188-93.

Jerrett M, Burnett RT, Ma R, Pope CA, Krewskki D, Newbold KB, Thurston G, Shi Y, Finkelstein N, Calle EE, Thun MJ. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology 2005; 16:727-736.

Kaiser R, Romieu I, Medina S, Schwartz J, Krzyzanowski M, Kunzli N. Air pollution attributable postneonatal infant mortality in U.S. metropolitan areas: a risk assessment study. Environ Health. 2004; 3:1-4.

Kim JJ, Smorodinsky S, Lipsett M, Singer BC, Hodgson AT, Ostro B. Traffic-related air pollution near busy roads. The East Bay children's respiratory health study. Am J Respir Crit Care Med 2004; 170:520-526

Kunzli N., Kaiser, R., Medina, S., Studnicka, M., Chanel, O., Filliger, P., Herry, M., Horak, F. Jr., Puybonnieux-Texier, V., Quenel, P., Schneider, J., Seethader, J., Vergnaud, J-C., and Sommer, H. Public-Health Impact of Outdoor and Traffic-Related Air Pollution: A European Assessment. The Lancet 2000; 356:795-801.

Kunzli N. The public health relevance of air pollution abatement. Eur Respir J 2002; 20:198-209.

Kunzli N, Jerrett M, Mark WJ, Beckerman B, LaBree L, Gilliland F, Thomas D, Peters J, Hodis HN. Ambient air pollution and atherosclerosis in Los Angeles. Environ Health Perspect 2005; 113:201-206.

Laden F, Neas LM, Dockery DW, Schwartz J Association of fine particulate matter from different sources on daily mortality in six U.S. cities. Environ Health Perspect 2000; 108:941-947.

Laden F, Schwartz J, Speizer FE, Dockery DW. Reduction in fine particulate air pollution and mortality. Extended follow-up of the Harvard six cities study. Am J Respir Crit Care Med 2006; 173:667-672.

Lanki T, de Hartog JJ, Heinrich J, Hoek G, Janssen NA, Peters A, Stolzel M, Timonen KL, Vallius M, Vanninen E, Pekkanen J. Can we identify sources of fine particles responsible for exercise-induced ischemia on days with elevated air pollution? The ULTRA study. Environ Health Perspect 2006; 114:655-660.

Levy JI, Carrothers TJ, Tuomisto JT, Hammitt JK, Evans JS. Assessing the public health benefits of reduced ozone concentrations. Environ Health Perspect 2001; 109:1215-1226.

Long CM, Suh HH, Kobzik L, Catalano PJ, Ning YY, Koutrakis P. A pilot investigation of the relative toxicity of indoor and outdoor fine particles: in vitro effects of endotoxin and other particulate properties. Environ Health Perspect 2001; 109:1019-1026.

Low RB, Bielory L, Qureshi AI, Dunn V, Stuhlmiller DF, Dickey DA. The relation of stroke admissions to recent weather, airborne allergens, air pollution, seasons, upper respiratory infections, and asthma incidence, September 11, 2001, and day of the week. Stroke 2006; 37:951-957.

Marufu LT, Taubman BF, Piety CA, Doddridge BG, Stehr JW, Dickerson RR. The 2003 North American electrical blackout: An accidental experiment in atmospheric chemistry. Geophys Res Lett 2004; 31: L13106.

McConnell R, Berhane K, Yao L, Jerrett M, Lurmann F, Gilliland F, Kunzli N, Gauderman J, Avol E, Thomas D, Peters J. Traffic, susceptibility, and childhood asthma. Environ Health Perspect 2006; 114:766-772.

McGowan JA, Hider RN, Chacko E, Town GI. Particulate air pollution and hospital admissions in Christchurch, New Zealand. Aust N Z J Public Health 2002; 26:23-9.

Medina S, Plasencia A, Ballester F, Mucke HG, Schwartz J, on behalf of the Apheis group. Apheis: Public health impact of PM_{10} in 19 European cities. J Epidemiol Community Health 2004; 58:831-836.

Peters A, von Klot S, Heier M, Trentinaglia I, Hormann A, Wichmann HE, Lowel H. Exposure to traffic and the onset of myocardial infarction. New Engl J Med 2004; 351:1721-1730.

Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 2002; 287:1132-1141.

Pope CA III, Burnett RT, Thurston GD, Thun MJ, Calle RE, Krewski D, Godleski JJ. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiologic evidence of general pathophysiological pathways of disease. Circulation 2004; 109:71-77.

Pope CA III, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW Jr. Particulate air pollution as a predictor of mortality in a prospective study of US adults. Am J Respir Crit Care Med 1995; 151:669-674.

Pope CA III. Respiratory disease associated with community air pollution and a steel mill, Utah Valley. Am J Public Health 1989; 79:623-628.

Rabinovitch N, Strand M, Gelfand EW. Particulate levels are associated with early asthmatic worsening in children with persistent disease. Am J Respir Crit Care Med 2006; 173:1098-1105.

Ritz, B., Yu, F., Fruin, S., Chapa, G., Shaw, G.M. and Harris, J.A. Ambient Air Pollution and Risk of Birth Defects in Southern California. Am J Epidemiol 2002; 155:17-25.
Ritz B, Wilhelm M, Zhao Y. Air pollution and infant death in southern California, 1989-2000. Pediatrics 2006; 118:493-502.

Romieu I , Meneses F, Ruiz S et al. Effects of air pollution on the respiratory health of asthmatic children living in Mexico City. Am Rev Respir Crit Care Med 1996; 154:300-307.

Roosli M, Kunzli N, Braun-Fahrlander C, Egger M. Years of life lost attributable to air pollution in Switzerland: dynamic exposure-response model. Int J Epidemiol. 2005; 34:1029-35.

Ruckeri R, Ibald-Mulli A, Koenig W, Schneider A, Woelke G, Cyrys J, Heinrich J, Mardr V, Frampton M, Wichmann HE, Peters A. Air pollution and markers of inflammation and coagulation in patients with coronary heart disease. Am J Respir Crit Care Med 2006; 173:432-441.

Samet JM, Domenici F, Curriero FC, Coursac I, Zeger SL. Fine particulate air pollution and mortality in 20 U.S. cities, 1987-1994. N Engl J Med 2000; 343:1742-1749.

Schaumann F, Borm PJA, Herbrich A, Knoch J, Pitz M, Schins RPF, Luettig B, Hohlfeld JM, Heinrich J, Krug N. Metal-rich ambient particles (particulate matter$_{2.5}$) cause airway inflammation in healthy subjects. Am J Respir Crit Care Med 2004; 170:898-903.

Schwartz J, Dockery DW. Increased mortality in Philadelphia associated with daily air pollution concentrations. Am Rev Respir Dis 1992; 145:600-604.

Schwartz J, Laden F, Zanobetti A. The concentration-response relation between PM2.5 and daily deaths. Environ Health Perspect. 2002; 110:1025-1029.

Sheppard L, Levy D, Norris G, Larson TV, Koenig JQ. Effects of ambient air pollution on nonelderly asthma hospital admissions in Seattle, Washington, 1987-1994. Epidemiology 1999; 10:23-30.

Sunyer J, Basagana X, Belmonte J, Anto JM. Effect of nitrogen dioxide and ozone on the risk of dying in patients with severe asthma. Thorax 2002; 57:687-93.

Tolbert PE, Klein M, Metzger KB, Peel J, Flanders WD, Todd K, Mulholland JA, Understanding the Health Effects of Components of the Particulate Matter Mix: Progress and Next Steps. HEI Perspectives. April 2002.

Valois MF, Vincent R. The association between daily mortality and ambient air particle pollution in Montreal, Quebec. 2. Cause-specific mortality. Environ Res 2001; 86:26-36. Wang, X., Ding, H., Ryan, L., and Xu, X. Association Between Air Pollution and Low Birth Weight: A Community-Based Study. Environ Health Perspect 1997; 105:514-520.

Wellenius GA, Bateson TF, Mittleman MA, Schwartz J. Particulate air pollution and the rate of hospitalization for congestive heart failure among medicare beneficiaries in Pittsburgh, Pennsylvania. Am J Epidemiol. 2005; 161:1030-6.

Wellenius GA, Schwartz J, Mittleman MA. Air pollution and hospital admissions for ischemic and hemorrhagic stroke among medicare beneficiaries. Stroke. 2005; 36:2549-53.

Wellenius GA, Schwartz J, Mittleman MA. Particulate air pollution and hospital admissions for congestive heart failure in seven United States cities. Am J Cardiol. 2006; 97:404-408.

Wong EY, Gohlke J, Griffith WC, Farrow S, Faustman EM. Assessing the health benefits of air pollution reduction for children. Environ Health Perspect 2004; 112:226-232.

Zanobetti A, Schwartz J, Samoli E, Gryparis A, Touloumi G, Atkinson R, Le Tertre A, Bobros J, Celko M, Goren A, Forsberg B, Michelozzi P, Rabczenko D, Aranguez Ruiz E, Katsouyanni K. The temporal pattern of mortality responses to air pollution: a multicity assessment of mortality displacement. Epidemiology. 2002; 13:87-93.

Zanobetti A, Schwartz J. The effect of particulate air pollution on emergency admissions for myocardial infarction: a multicity case-crossover analysis. Environ Health Perspect. 2005; 113:978-982.

Zhang JJ, Hu W, Wei F, Wu G, Korn LR, Chapman RS. Children's respiratory morbidity prevalence in relation to air pollution in four Chinese cities. Environ Health Perspect. 2002; 110:961-967.

Appendix F:

CV of Dr. Viney P. Aneja

BIOGRAPHICAL SKETCH

Viney P. Aneja

Viney Aneja is a Professor in the Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University. He obtained his B. Tech. degree in Chemical Engineering from the Indian Institute of Technology, Kanpur, India; and MS and Ph.D. degrees from the Department of Chemical Engineering, N. C. State University, Raleigh, N.C. Before joining the faculty of the Department of Marine, Earth, and Atmospheric Sciences at N. C. State in 1987, he conducted and supervised research at Corporate Research and Development, General Electric Company, New York, and Northrop Service, in Research Triangle Park in the areas of environmental engineering and separations technology. In 2001 he was also appointed Professor of Environmental Technology, Department of Forestry and Environmental Resources. In addition, he has been a visiting professor at the University of Uppsala, Sweden in 1979; at Jawahar Lal Nehru University in New Delhi, India in 1980; and at the Arrhenius Laboratory in Stockholm, Sweden in 1985.

Dr. Aneja's industrial and academic research contributions have been extensively recognized. He won the Noryl Division Proprietary Innovation Award from General Electric in 1983, the Air Pollution Control Association Award for Distinguished Service in 1984, the General Electric Managerial Award in 1986, and at North Carolina State University he received the 1991-92 Outstanding Extension Service Award. In 1998 the Air and Waste Management Association gave him its Frank A. Chambers Award, the Association's highest scientific honor; in 1999 he became a Fellow of the Association; in 2001 he received the Association's Lyman A. Ripperton Award for distinguished achievement as an educator. He is the recipient of the 2007 North Carolina Award in Science, the highest award a civilian can receive from the Governor of North Carolina.

At North Carolina State University Dr. Aneja has developed one of the nation's leading agricultural air-quality research programs (http://www.meas.ncsu.edu/airquality). He has published over 140 scientific papers, 116 book chapters and conference proceedings scientific papers, 5 US patents, and two books on his research. Dr. Aneja has directed 7 post doctoral fellows, 11 doctoral dissertations and 37 masters' theses.

Much of his work has focused on the science needed to make important decisions on environmental policies in North Carolina and the nation. He has conducted research on natural and anthropogenic emissions of nitric oxide, ammonia, and sulfur compounds and demonstrated the important roles of these substances in ozone formation and gas-to-particle conversion. His research on atmospheric photochemical oxidants in the North Carolina mountains has clarified the role of long range transport of pollutants and impact of these compounds on the formation of acid rain and on the damage to trees at high elevation. His most recent research has concentrated on the critical issue of the contribution of animal feeding operations to air quality; quantifying the emissions, transformation, transport and fate of pollutants in the environment. His contributions have been featured on CNN, ABC, CBS, NBC, National Public Radio, Public Broadcasting Service, The New York Times, Associated Press, Environmental Manager, and Fortune magazine. Dr. Aneja's research has enjoyed

support from a broad base of public and private sources. While conducting his extensive research, Dr. Aneja has maintained a heavy teaching load. He teaches a large and popular introductory course (Introduction to Weather and Climate), an upper division air quality course (Fundamentals of Air Pollution), and graduate courses, and has also given numerous short courses to public and private sector audiences.

Dr. Aneja has a long and distinguished record of public service, and he has been frequently sought as a lecturer and consultant to the Federal and State governments, professional societies, international organizations, and the private sector on issues related to environmental science and public policy. He was invited to visit the University of Munich, Germany in 1988 to discuss the problem of forest decline; to Berlin, Germany, during 1992 to discuss environmental issues in Eastern Europe; the Ministry of International Trade and Industry, Japan, in 1994 to discuss urban and rural air quality; to the University of Sydney, Australia, and Hebrew University, Jerusalem, Israel in 1996 to discuss environmental issues; and the Ministry of Agriculture, Rome, Italy, in 1999 to discuss the role of intensively managed agriculture on the environment. In 2000 he was a member of the North Carolina Delegation to the Netherlands on Agricultural Air Quality, and in 2001 he was leader of the U.S. Department of State Delegation to France on Environment Science and Technology. In 1990 Dr. Aneja served on the NASA panel for the selection of NASA Specialized Centers for Research and Training; and from 1994 to 2000 he served on the Exam Advisory Committee of the Institute of Professional Environmental Practice. From 1987-90 he served as the Site Director for the Mountain Cloud Chemistry Program. In 1990 he was appointed the Mission Scientist for the "Southern Oxidant Study"; in 1994 he was appointed Program Scientist for the U.S. EPA and NSF funded Project "NOVA"; in 1996 he was appointed the Science Team Leader for the North Carolina Department of Environment and Natural Resources Program on "Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, Deposition, and Assessment," and in 2001 he was appointed Program Scientist and Principal Investigator for the Animal and Poultry Waste Management Center/ Smithfield Foods funded Program OPEN (Odor, Pathogens, and Emissions of Nitrogen). He served as a member of the Technical Advisory Committee on North Carolina Environmental Defense Fund, a member of the North Carolina Progress Board; and serves as a Director of the Air and Waste Management Association, and Chair of the Association's Education Council. He has served on the editorial boards of the journals *Environmental Pollution, Chemosphere, Journal of the Air and Waste Management Association,* and *Environmental Manager;* and currently serves as Associate Editor for *International Journal of Air Quality, Atmosphere, and Health; International Journal of Applied Environmental Sciences; The Open Environmental & Biological Monitoring Journal* and the *Scientific Journals International*; and on the Reader Advisory Panel of *Nature*.

Appendix G:

Particulate Matter (PM_{10}) and Meteorological Sampling

Cherokee Instruments, Inc.
901 Bridge Street
Fuquay Varina, NC (USA) 27526
(919) 552-0554 Tel
(919) 552-3991 Fax
(800) 399-4236 Toll Free
sales@ampcherokee.com
www.ampcherokee.com

April 8, 2009

Dr. Viney P. Aneja
Professor Air Quality
North Carolina State University

RE: Ambient Air Sampling Equipment
Cherokee Rental Order No. ????

Dear Dr. Aneja:

North Carolina State University, acting on behalf of the Sierra Club, arranged for the procurement of some ambient air monitoring devices to support an ambient air sampling project. This document serves as a summary of the ambient air equipment procured and pertinent calibration information.

Particulate Matter Samplers

Two (2) Andersen/GMW Model GUV-16H High Volume air samplers equipped with PM10 size selective inlets were employed to collect ambient particulate matter with an effective aerodynamic size of less than 10 microns (PM10). The samplers were provided with volumetric flow controllers for constant flow control, a Dickson circular chart recorder for historical trend of volumetric flow through the sampler, and a mechanical timer and elapsed time indicator for total sampling time indication. Samples were collected onto 8-inch x 10-inch quartz fiber filters that were obtained from and pre-tared at (insert laboratory).

The functionality and calibration of the particulate samplers was verified immediately prior to the field effort at our service center in Fuquay Varina, North Carolina. Dr. Viney Aneja of NC State University witnessed the initial testing of these instruments. The instrumentation was then transported to the field location and setup, calibrated and operated onsite various locations in accordance with the manufacturer's specifications and USEPA methodology.

All calibrations were conducted used a High Volume Air Sampler Calibration Kit, Model Andersen/GMW Veriflow. The calibration kit included a calibrated orifice transfer standard that was referenced to a spirometer as well as 8-inch x 10-inch mounting plate adapter and water slack tube manometer. The Veriflow orifice is capable of providing various pressure drops across the sampler flow controller in order to simulate particulate matter loading onto the filter. Calibrations were performed on each sample at site conditions prior to collection of the first sample at each location. These calibrations included volumetric flow verification through the sampler via comparison of the calibrated orifice results to the volumetric flow controller lookup tables.

Meteorological Sampler

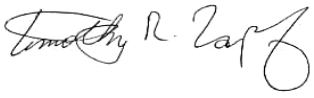
One (1) Met One Model Automet portable weather station equipped with an onboard datalogger was employed to measure and record site weather conditions during sampling events. The station was provided with wind speed, wind direction, temperature, and barometric pressure and relative

humidity sensors. All sensors were mounted on a portable tripod with telescoping mast such that meteorological data could be obtained at a height of 5 to 10-ft above grade. All data was collected in real-time and averaged/stored at 15-minute data intervals using the onboard datalogger.

The functionality and calibration of the meterological sensors were verified immediately prior to the field effort at our service center in Fuquay Varina, North Carolina. Verification of the individual sensors functionality was accomplished using constant RPM motor, compass, reference thermocouple and local airport barometric pressure. The instrumentation was then transported to the field location and setup and operated onsite at various locations in accordance with the manufacturer's specifications and USEPA methodology. No site calibrations were performed.

Please let me know if I can send you any additional information. If I can be of any further assistance, do not hesitate to give me a call at (800) 399-4236. Thank you for considering Cherokee Instruments for your equipment needs.

Regards,



Timothy Zapf
Operations Manager
Cherokee Instruments, Inc.

PM 10 High Volume Samplers
PM 10 Size Selective High Volume Sampling Systems

Andersen/GMW's High Volume PM 10 Sampling Systems meet all Federal Reference Method Performance specifications for the measurement of PM 10 and have been EPA designated as an approved Method for the determination of ambient PM 10 particulate concentrations. Each PM 10 Sampler bears an identification label with the FRM designation number RFPS-1287-063. Volumetric and Mass Flow Controlled Systems are available for 24 hour ambient PM 10 measurements.

Mass Flow Controlled High Volume Air Sampling Systems

The Mass Flow Controlled High Volume Samplers feature accurate collection of total suspended particulates and PM 10, meeting EPA specifications. Air flow through the system is maintained at a constant rate by an electronic probe which automatically adjusts the speed of the blower/motor to correct for variations in line voltage temperature, pressure, and filter loading.

Adjustable over a range from 20CFM to 60CFM, air flow is controlled at a constant standard condition of 25°C temperature and 760 mm Hg pressure within plus or minus 1 CFM. By maintaining an exact air flow rate through the sampler, the particulate concentration is extremely accurate and reliable.

The high volume air sampler incorporates a pressure recorder or a well type manometer for flow verification. The elapsed time indicator is calibrated in hours, tenths, and hundredths. A wide variety of electronic and mechanical timers are available, along with the Flow Manager (see specification sheet for Flow Manager).

FEATURES

- Accurately Samples Aerodynamic Diameter of Particles Less than 10 Micrometers (PM 10)
- All Weather, Outdoor Shelter Constructed of Anodized Aluminum
- High Speed Motor Designed for 24-Hour Continuous Sampling
- Rugged electronic circuit and mass flow probe for accurate sampling
- Optional brushless blower motor available
- Electronic Flow Manager available for data logging and sampler field data

GRASEBY

Graseby Andersen Division • 500 Technology Court • Smyrna, GA 30082 USA
TEL: 770-319-9999 • FAX 770-319-0336
1-800-241-6898

Volumetric Flow Controlled Air Sampling Systems

The Andersen/GMW Volumetric Flow Controller (VFC) is a critical flow orifice venturi device used to control gas flow. When applied to a high volume air sampler, this flow control principal incorporates a smooth-wall venturi orifice that gradually opens to a recovery section. Vacuum is provided by a blower/motor downstream of the venturi. Over 95% of the energy lost in differential pressures across the restricting orifice is recovered in this design.

Flow control is accomplished by restricting, and thus accelerating the air flow through the venturi. At a point in the flow stream, air velocity will equal the acoustic velocity, or speed of sound, and critical flow will be achieved. As long as downstream changes are small, all conditions at the venturi (including the flow rate) are determined by upstream conditions. This is referred to as "choking" and is a characteristic of all VFC's. The PM 10 utilizes this principle of choked or critical flow to maintain a constant actual flow rate of 40 ACFM (1.13 ACMM) over the sample period. Since critical flow through the venturi is not greatly affected by changes in the filter loading, ambient temperature or barometric pressure, a stable "Volumetric flow" rate is maintained.

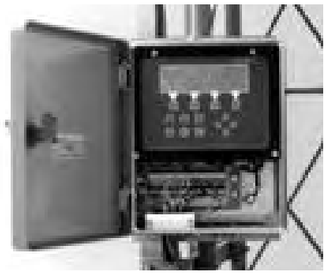
The orifice used in this system can also be described as a well documented Critical Venturi Meter (CVM). CVM is a specially machined nozzle or restriction device designed to react to a specific pressure ratio expressed in absolute terms. When air reaches the speed of sound in the throat (smallest diameter) of the CVM, a sound pressure barrier is set up that will not allow more air through under the existing temperature and pressure conditions. This is the "critical flow" point of the meter, thus the name Critical Venturi Meter. The Volumetric Flow Controller regulates flow at a constant but unadjustable rate without any moving parts or electronic components. Each PM 10 Sampler bears an identification label with the EPA designation number RFPS-1287-063.

FEATURES

- Accurately Samples Aerodynamic Diameter of Particles Less than 10 Micrometers (PM 10)
- All Weather, Outdoor Shelter Constructed of Anodized Aluminum
- High Speed Motor Designed for 24-Hour Continuous Sampling
- Optional Brushless Blower Motor Available
- Meets All Federal Reference Method Performance Specifications for the Measurement of PM 10
- No Electronic Components
- Electronic Flow Manager Available for Data Logging and Sampler Field Data

Specifications:	Mass Flow Control	Volumetric Flow Control
Motor:	HP 0.6	HP 1.0
Amperage:	6.25	7.0
Wattage:	750	840
Flow Set Point:	20 to 60 ACFM	40 ACFM
Flow Control Accuracy:	+/- 2.5%	<1% Deviation over 24-hour period
Power Source:	115v,60Hz or 220v,50/60Hz	115v,60Hz or 220v,50/60Hz
Net Weight:	112 lbs.	136 lbs
Shipping Sizes & Weights:		
Shelter:46" x 20" x 23"	70 lbs.	74 lbs.
Inlet: 32" x 32" x 26"	65 lbs.	58 lbs.
VFC, Blower & Filter Holder:		
28" x 21" x 19"	N/A	27 lbs.
Federal Reference Method		
Designation Number:	RFPS-1287-063	RFPS-1287-063

Met One Instruments



INSTALLATION
Installation is a snap with the AutoMet. Each system is pre-tested and certified. Measurements may be easily added in the future using any AutoMet™ Sensor. The supplied tool kit enables anyone to do the installation.

For portable applications, AX carrying cases provide convenient transport and the "Easi-Up" tripod takes less than 5 minutes to deploy.

CONSTRUCTION
The AutoMet sensor array is solidly constructed of aluminum alloy and finished with a protective gloss white powder coat paint.

The electronics data package is housed in a non-ferrous Nema 4 enclosure. All electronics are conservatively rated, circuit boards are environmentally coated, with built-in surge protection.

INPUTS
8 analog, and 1 pulse (Rain)

POWER REQUIREMENTS
12 VDC from internal battery pack, external expansion battery, solar panel or 115/230 VAC using the power module.

Met One Instruments

Sales & Service: 1600 Washington Blvd., Grants Pass, OR 97526
Phone 541/471-7111, Fax 541/471-7116
Regional Service: 3206 Main St., Suite 106, Rowlett, TX 75088
Phone 214/412-4747, 214/412-4715, Fax 214/412-4716
http://www.metone.com

AutoMet is a registered trademark of Met One Instruments, Inc.
Windows 3.1 and Windows 95 are trademarks of Microsoft® Corporation

AutoMet™

AutoMet™ is a complete, self-contained, Digital Meteorological Monitoring System that provides instant access to weather information. It is ideal in situations when it is necessary to monitor and collect reliable data requiring extreme ease of installation without complicated programming.

FEATURES
- Meets or exceeds PSD regulatory requirements
- User-friendly plug-n-play configuration
- Rapid deployment– installs in minutes
- Low operating cost
- Rugged–all metal sensor array
- Keyboard/Display
- Lasting accuracy, 20,000 hour MTBF
- 200-Day storage capacity
- Data retrieval through RS-232 port, modem, radio/cellular phone
- Direct printer output
- Palm size Data Transfer Module

Met One Instruments

AutoMet™

Met One Instruments

- WIND SPEED
- WIND DIRECTION
- TEMPERATURE
- RELATIVE HUMIDITY
- SOLAR RADIATION
- BAROMETRIC PRESSURE
- PRECIPITATION
- AND MORE, CONSULT FACTORY

AUTO-PROGRAMMING
Gathering reliable data has never been easier. AutoMet features a unique self-configuring interface allowing it to program itself. Simply plug in an AutoMet™ Sensor and AutoMet identifies the sensor type, determines its range, and writes the programming to record the sensor data.

AUTOMET™ SENSORS
AutoMet sensor array consists of selected sensors that incorporate the unique AutoMet interface.

STANDARD SENSORS
AutoMet will also work with a wide variety of standard sensors. Standard sensors are used with your logger, their logger or any of our other standard loggers.

Optional Automatic Direction Alignment (ADA) unit allows the system to collect valid wind data without the necessity of manual compass alignment procedures.

PASSWORD PROTECTION
Set-up files are protected by 4-character passwords to ensure data integrity. Passwords may be changed at any time.

AVERAGING PERIODS
Quick and easy setting of flexible averaging periods of 1, 5, 15 or 60 minutes ensures compliance with regulatory requirements.

AUTOMATIC ALARMS
Two automatic alarms may be set at any measurement channel to signal personnel about hazardous conditions or to turn equipment on or off in the event that measurement falls above, below, or within predetermined ranges.

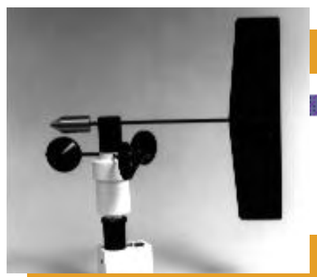
DATA STORAGE
Internal memory module is sufficient to collect data for a period in excess of 200 days, when data is recorded on an hourly basis.

FIELD DIRECT DATA
Collecting real time or historical data from a field site has never been easier. Data can be read on site using the built-in display, your portable computer, printer, or carried off site by using Data Transfer Module.

DATA TRANSFER MODULE
The palm size Data Transfer Module may be used to transfer data from the AutoMet to any computer equipped with an RS-232 communications port.

DESKTOP DATA
Data is available on command using AutoMet and any of the communications options available. Data may be transferred to desktop computer directly via cable, radio telemetry or by a dial-up modem.

TELEMETRY OPTIONS
A license free spread spectrum radio system provides a high reliability data link between the sensor array control unit and the remote display module.

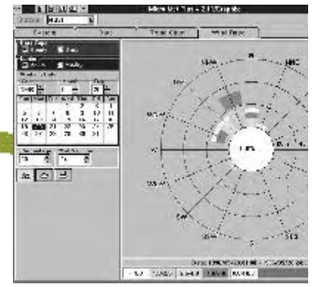


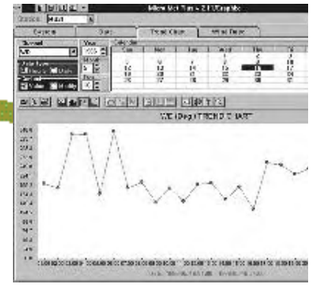
LARGE BUILT-IN DISPLAY
AutoMet includes a keyboard with 8 X40 character back-lit LCD display which allows system configuration, operation, and retrieval of data with simple menu-driven commands and context sensitive hot-keys.

Prompted display provides the easiest, quickest way to set up and scan data. Special calibration mode marks data gathered during calibration periods.

SOFTWARE
AutoMet Software is a complete package of communications, data collection, and data reporting tools with a windows-like operating environment. AutoMet Software provides complete environmental reporting in compliance with EPA and other requirements. Software support for modem, radio, direct connection, and Data Transfer Module are provided.

Summary reports are generated by AutoMet Report using monthly data files. The operator selects the period to be printed with beginning and ending prompts. Report footers provide the summary scalar averages, vector averages and percentage of data collection. AutoMet Plus Software, operates under both Windows 3.1® and greater, and Windows 95®. It provides the same reporting functions plus full graphic capabilities. Data may be reported, graphed and wind rose plots may be produced.





1600 Washington Blvd
Grants Pass Or 97526
Tel # 541-471- 7111
Fax # 541 -471 -7116

Met One Instruments

System Test Certification

Central Region Sales & Service
3206 Main St. Suite 106
Rowlett, Texas 75088
Tel # 972- 412- 4747

Job Number 72571 **Customer** CHEROKEE INSTRUMENTS

Test Date 6/30/2008 **Calibration Due** 6/30/2009 **Tested By** Laurie Thurn

Model # 466A **Ser#** H6261 **Customer Station**

Measurement	Expected	Actual	Error	Spec	Notes
Wind Speed	Tested W/	034A	Ser#	N/A	Tested on ch 1
Zero 0.00 Hz	0.3 m/s	0.3 m/s	±0.0 m/s	± 0.3 m/s	
Mid 26.82 Hz	21.7 m/s	21.9 m/s	+0.2 m/s	± 0.3 m/s	
Span 53.65 Hz	43.1 m/s	43.4 m/s	+0.3 m/s	± 0.3 m/s	
Sensor	8.3 m/s	— m/s	— m/s	± 0.4 m/s	
Wind Direction	Tested W/	034A	Ser#	N/A	Tested on ch 2
Zero 0.000 Vdc	0 °	0 °	± 0 °	± 2 °	
Mid 0.950 Vdc	137 °	136.8 °	-0.2 °	± 2 °	
Mid 2.500 Vdc	360 °	359.9 °	-0.1 °	± 2 °	
Sensor 10°	10 °	— °	— °	± 3 °	
90°	90 °	— °	— °	± 3 °	
180°	180 °	— °	— °	± 3 °	
270°	270 °	— °	— °	± 3 °	
350°	350 °	— °	— °	± 3 °	
Air Temperature	Tested W/	083C-1-35	Ser#	N/A	Tested on ch 3
Zero 73449 ohm	-30.0 °C	-29.8 °C	-0.2 °C	± 0.3 °C	
Mid 17092 ohm	30.0 °C	30.0 °C	±0.0 °C	± 0.3 °C	
Span 10545 ohm	50.0 °C	49.9 °C	-0.1 °C	± 0.3 °C	
Sensor	— °C	— °C	— °C	± 0.4 °C	
Relative Humidity	Tested W/	083C-1-35	Ser#	N/A	Tested on ch 4
Zero 0.000 Vdc	0.0%	0.0 %	±0.0 %	±0.3%	
Mid 0.500 Vdc	50.0%	49.9 %	-0.1 %	± 0.3%	
Span 0.950 Vdc	95.0%	94.9 %	-0.1 %	± 0.3%	
Sensor	— %	— %	— %	± 3.0 %	
System Pwr Req	< 50 mA				
					Page # 1 of 2

1600 Washington Blvd
Grants Pass Or 97526
Tel # 541- 471- 7111
Fax # 541 -471 -7116

Met One Instruments

System Test Certification

Central Region Sales & Service
3206 Main St. Suite 106
Rowlett, Texas 75088
Tel # 972- 412- 4747

Job Number	72571	**Customer**	CHEROKEE INSTRUMENTS
Test Date	6/30/2008	**Tested By**	Laurie Thurn

Measurement	Expected	Actual	Error	Spec	Notes
Baro Pressure	Tested W/	090D	Ser#	N/A	880.5/1083.6 mbar
Zero 0.000 Vdc	880.5 mbar	880.5 mbar	±0.0 mbar	± 0.6 mbar	Tested on ch 5
Mid 0.500 Vdc	982.1 mbar	982.0 mbar	-0.1 mbar	± 0.6 mbar	
Span 0.950 Vdc	1073.5 mbar	1073.5 mbar	±0.0 mbar	± 0.6 mbar	
Sensor	— mbar	— mbar	— mbar	± 0.8 mbar	

Model # 466A **Ser#** H6261

AutoMet System Configuration

CHEROKEE INSTRUMENTS	72571	6/30/2008

MODEL 466A SERIAL NO. H6261

MEASUREMENT	SENSOR	CABLE	UNITS	DATALOGGER OFFSET	DATALOGGER MULTIPLIER	SOFTWARE OFFSET	SOFTWARE MULTIPLIER	NOTES
Wind Speed	034A	3013	m/s	0.3	44.7	0.3	44.7	1
Wind Direction	034A	3013	Deg	0.0	360.0	0.0	360	1
Air Temperature	083C-1-35	2348	°C	-73.0	178.9	-73.0	223.62	2
Relative Humidity	083C-1-35	2348	%	0.0	100.0	0.0	250	1
Baro Pressure	090D	1169	mm	880.5	203.2	880.5	507.98	1
Battery Voltage			VDC	0.0	15	0.0	37.5	1
Sigma Theta			Deg	0.0	120.0	0.0	120.0	3

NOTES:

1) ALL CHANNELS ARE SET TO MANUAL EXCEPT WIND SPEED. SET WIND SPEED TO COUNTER #1. SET COUNTER #1 F.S.FREQ TO 56.0 Hz AND LO FREQ.

2) AIR TEMPERATURE SLOPE SET TO Y (INVERSE SLOPE)

3) SIGMA THETA IS COMPUTED IN THE DATALOGGER AS THE STANDARD DEVIATION OF WIND DIRECTION USING THE YAMARTINO ALGORITHM.

Met-One System QA/QC Check

Cherokee Instruments, Inc.

Analyzer Type	Wheather station	Analyzer Asset #	3363
Analyzer Model	Met One	Manual with Instrument?	Y
Analyzer Serial No.	H6261	Power Cord and Signal Cable?	Y
Case No.			

Barometric Pressure sensor	X1609
Radiation sheild	
Relative humidity sensor	X1399
Data transfer module	A4998

	TYPE	UNITS	PREC	MULT	OFFSET	VOLT	INV SLOPE	VECT/SCAL	MODE
CH 1	WS	MPH	1	100	0	2.5	N	V	Count 1
CH 2	WD	DEG	1	360	0	2.5	N	V	Manual
CH 3	AT	C	1	178.9	-72.9	2	Y	S	Manual
CH 4	RH	%	1	100	0	1	N	S	Manual
CH 5	BP	Hg	2	6	26	1	N	S	Manual
CH 6	BV	VDC	1	15	0	1	N	S	Manual
CH 7	no								
CH 8	no								
CH 9	Rain	IN	2	0.01	0	1	N	S	Manual

Wind sensor works

Wind direction

0°	Y
90°	Y
180°	Y
270°	Y

	Acutal	Recorded	
Air temp	30	30	Deg C
Relative humidity			
Baro Pressure	29	29	mmHg
Rain	0	0	in

Technician: MJH Date: 7/11/2008

Cherokee Instruments, Inc.
Particulate Sampler Calibration
Volumetric Flow Controller

Site		**Calibration Orifice**	
Location:	???	Make:	???
Date:	???	Model:	???
Tech.:	???	Serial:	???
Sampler:	???	Slope:	???
Serial #:	???	Int.:	???

Temp (deg F):	???	Elevation (ft):	???
Ta (deg K):	255	SL Press (in Hg):	???
Ta (deg C):	-18	Pa (mm Hg):	0

Run Number	Orifice "H2O	Qa m3/min	Sampler "H2O	Pf mm Hg	Po/Pa	Look Up m3/min	% of Diff
1	3.20	#DIV/0!	17.30	32.287	#DIV/0!	1.193	#DIV/0!
2	3.15	#DIV/0!	19.10	35.646	#DIV/0!	1.186	#DIV/0!
3	3.10	#DIV/0!	19.70	36.766	#DIV/0!	1.185	#DIV/0!
4	3.10	#DIV/0!	21.10	39.378	#DIV/0!	1.180	#DIV/0!
5	3.00	#DIV/0!	29.90	55.802	#DIV/0!	1.150	#DIV/0!

Calculations

Calibrator Flow (Qa) = 1/Slope*(SQRT(H20*(Ta/Pa))-Intercept)

Pressure Ratio (Po/Pa) = 1-Pf/Pa

% Difference = (Look Up Flow-Calibrator Flow)/Calibrator Flow*100

Appendix H:

PM_{10} sample mass and chemical analysis

10 October 2008

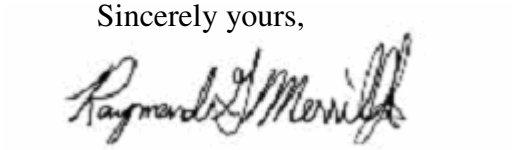
Viney P. Aneja
North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202

RE: PM-10 Filter Analysis 7-2008

Enclosed are the results of analyses for samples received by the ERG laboratory on or after 08/08/08. High Volume (Hi Vol) 8/10 inch fiberglass filters were analyzed to determine mass. Quarts Hi Vol 8/10 inch filters were analyzed for mass and a group of metals common to the EPA National Ambient Air Toxics Stations program. A list of the samples received in this project is listed in the **ANALYTICAL REPORT FOR SAMPLES**. Results and reporting/detection limits are provided in the **GRAVIMETRIC MEASUREMENT** and **INORGANICS BY COMPENDIUM METHOD IO-3.5** data tables in this report. Data has been reported using the total sample volume provided by your staff on chain of custody forms. The ERG LIMS tracking numbers for this work are 8081414 and 8090908. Samples were stored after receipt at ambient temperature in an environmentally controlled room prior to analysis. This report includes a cover page, 3 pages of narrative, 21 pages of filter mass data and inorganic analysis results. Inorganic analysis was performed according to our NELAC certification. A copy of the COCs for this sample set is also provided as an attachment.

ERG remains committed to serving you in the most effective manner. Should you have any questions or need additional information and technical support, please contact me at (919) 468-7887. Thank you for choosing ERG as a part of your analytical laboratory support team.

Sincerely yours,



Raymond G. Merrill
ERG Project Manager and
Laboratory Technical Director

Narrative

The Analytical Report of Samples table lists samples received by ERG's laboratory tracked under ERG LIMS numbers 8081414 and 8090908. Samples were received on 08/08/08. Samples were equilibrated in an environmentally controlled balance room prior to analysis. Our analysis procedure covers the determination of metals on PM10 or TSP filters used to sample ambient air and submitted to the laboratory.

Gravimetric Analysis

Gravimetric measurements are performed with a Satorius LA 120S equipped with a large area weighing chamber. Calibration is checked with NIST Class S weights. Ambient filters are equilibrated for 24 hours under balance room conditions prior to weighing. Tare weights are recorded prior to filter media shipment and use. Sample plus filter tare weights are measured after 24 hour equilibration under environmentally controlled balance room conditions. Initial and final weights are recorded and entered into the ERG LIMS for subsequent review and reporting. Samples are handled and analyzed conforming to 40 CFR 50, Appendix J, Section 9.16 - 9.17.

Inorganic Analysis

A 4"x 1" portion is cut from the exposed filter after final filter mass has been determined gravimetrically. This portion of filter is extracted initially in 4% nitric acid via sonication for a total of 90 minutes, followed by the addition 15mL of water and sonicated again for an additional 90 minutes. The extract is analyzed by ICP-MS. The analysis is completed using the manufacturer software.

Analyses were performed on the ELAN 9000 ICP/MS manufactured by Perkin Elmer Corporation. The instrument consists of an inductively coupled plasma source, ion optics, a quadrupole spectrometer, a computer that controls the instrument, data acquisition, and data handling (ELAN Software SCIEX, Version 3.0), a printer, an autosampler (AS-93plus) and a recirculator. The quadrupole mass spectrometer has a mass range of 2 to 270 atomic mass units (amu). Inorganic analysis follows the requirements in EPA Compendium Method IO-3.5.

Inorganic Quality Control

A summary of the quality control requirements that were met except as flagged for inorganic analysis are provided in Table 1. Standard method quality control includes:

- Method Spikes and Method Spike Duplicates, one per sample batch.

The method spikes and method spike duplicates are controlled within ∀25% RPD of the target values. If the spikes are outside of these limits, calibration and extraction volumes are checked. If no calibration or calculation error if found the samples are re-extracted and reanalyzed.

- Performance Evaluation (PE) Samples from a secondary source. PE samples are prepared and analyzed in the same way as field samples.
- Blanks including:
  - 1) a method blank (MB) that contains all the reagents in the sample preparation procedure. Blanks are prepared and analyzed as a sample to determine the background levels from the instrument.
  - 2) A rinse blank consists of 2% nitric acid in DI water. The rinse blank is used to flush the system between standards and samples. The results must be below the MDL
  - Initial calibration blanks (ICB) are analyzed immediately following the high standard verification. The absolute value of the instrument response must be less than the method detection limit. Samples results for analyses less than 5 times the amount of the blank are flagged or analysis is repeated.
  - Continuing calibration blanks (CCB) are analyzed following each continuing calibration verification sample. The acceptance criteria for the CCB are the same as the ICB.

- Laboratory Control Spike (LCS) prepared from a secondary source of calibration standards and analyze with each sample batch. The results must be within 80-120% RPD of actual values.

Narrative Table 1. Summary of Quality Control Procedures for Metals Analysis

Parameter	Frequency	Acceptance Criteria	Corrective Action
Initial calibration standards (IC)	Daily, at least 4 calibration points	Correlation coefficient ∃ 0.995	1) Repeat analysis of calibration standards. 2) Reprepare calibration standards and reanalyze.
Initial calibration standards (ICAL)	Daily, at least 4 calibration points	Correlation coefficient 0.995	1) Repeat analysis of calibration standards. 2) Reprepare calibration standards and reanalyze.
Initial calibration blank (ICB)	Immediately after HSV	Must be ≤ MDL	1)Locate and resolve contamination problems before continuing. 2) Reanalyze
High standard verification (HSV)	Before ICB	Recovery from 95 to 105%	1) Repeat analysis of HSV. 2) Reprepare HSV.
Initial calibration verification (ICV)	Immediately after calibration	Recovery 90-110%	1) Repeat analysis of calibration check standard. 2) Repeat analysis of calibration standards. 3) Reprepare calibration standards and reanalyze.
Interference Check Standard (ICS)	Following the ICV/QCS, every 8 hours and at the end of each run	Recovery from 80 to 120%	1) Repeat analysis of ICS. 2) Reprepare ICS.
Continuing calibration verification (CCV)	Analyze before the 1st sample, after every 10 samples, and at the end of the run	Recovery 90-110%	1) Repeat analysis of continuing calibration verification sample. 2) Reprepare continuing calibration. 3) Reanalyze samples since last acceptable continuing calibration verification.
MB	1 per 20 samples, a minimum of 1 per batch	Analytes below MDL	1) Reanalyze. 2) Reprepare blank and reanalyze. 3) Repeat analyses of all samples since last clean blank.
LCS	1 per 20 samples, a minimum of 1 per batch	Recovery 80-120%, with the exception of Ag and Sb	1) Reprepare sample batch. 2) Reanalyze.
MS/MSD	1 per 20 samples per sample batch	Recovery 75-125%, with the exception of Ag and Sb	1) Reprepare sample batch. 2) Reanalyze.
Serial Dilution	1 per batch	Recovery 90-110% of undiluted sample	1) Reprepare dilution 2) Flag data.

North Carolina State University	Project: PM-10 Filter Analysis 7-2008	
5136 Jordan Hall Room 5136	Project Number: 3290.00.133.001	**Reported:**
Raleigh NC, 27695-8202	Project Manager: Viney P. Aneja	10/10/08 14:26

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
6735808	8090908-01	Air	08/03/08 23:59	09/01/08 16:14
6735899	8090908-02	Air	08/03/08 23:59	09/01/08 16:14
6735830	8090908-03	Air	08/04/08 23:59	09/01/08 16:14
6735833	8090908-04	Air	08/04/08 23:59	09/01/08 16:14
6735832	8090908-05	Air	08/05/08 23:59	09/01/08 16:14
6735859	8090908-06	Air	08/05/08 23:59	09/01/08 16:14
6735833	8090908-07	Air	08/06/08 23:59	09/01/08 16:14
6735834	8090908-08	Air	08/06/08 23:59	09/01/08 16:14
Q0164739	8090908-09	Air	08/07/08 23:59	09/01/08 16:14
Q0164738	8090908-10	Air	08/07/08 23:59	09/01/08 16:14
6735839	8090908-11	Air	08/08/08 23:59	09/01/08 16:14
6735840	8090908-12	Air	08/08/08 23:59	09/01/08 16:14
6735835	8090908-13	Air	08/09/08 23:59	09/01/08 16:14
6735836	8090908-14	Air	08/09/08 23:59	09/01/08 16:14
6735837	8090908-15	Air	08/10/08 23:59	09/01/08 16:14
6735838	8090908-16	Air	08/10/08 23:59	09/01/08 16:14
6735841	8090908-17	Air	08/11/08 23:59	09/01/08 16:14
6735842	8090908-18	Air	08/11/08 23:59	09/01/08 16:14
6735843	8090908-19	Air	08/12/08 23:59	09/01/08 16:14
6735844	8090908-20	Air	08/12/08 23:59	09/01/08 16:14
6735845	8090908-21	Air	08/13/08 23:59	09/01/08 16:14
6735846	8090908-22	Air	08/13/08 23:59	09/01/08 16:14
6735847	8090908-23	Air	08/14/08 23:59	09/01/08 16:14
6735848	8090908-24	Air	08/14/08 23:59	09/01/08 16:14

North Carolina State University	Project: PM-10 Filter Analysis 7-2008	
5136 Jordan Hall Room 5136	Project Number: 3290.00.133.001	**Reported:**
Raleigh NC, 27695-8202	Project Manager: Viney P. Aneja	10/10/08 14:26

Gravimetric Measurement

Eastern Research Group

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
6735808 (8090908-01) Air	**Sampled: 08/03/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.19800	0.0000	g	1	B8J1006	08/03/08	10/10/08	NA	
6735899 (8090908-02) Air	**Sampled: 08/03/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.45520	0.0000	g	1	B8J1006	08/03/08	10/10/08	NA	
6735830 (8090908-03) Air	**Sampled: 08/04/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.24990	0.0000	g	1	B8J1006	08/04/08	10/10/08	NA	
6735833 (8090908-04) Air	**Sampled: 08/04/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.66130	0.0000	g	1	B8J1006	08/04/08	10/10/08	NA	
6735832 (8090908-05) Air	**Sampled: 08/05/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.29530	0.0000	g	1	B8J1006	08/05/08	10/10/08	NA	
6735859 (8090908-06) Air	**Sampled: 08/05/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.28520	0.0000	g	1	B8J1006	08/05/08	10/10/08	NA	
6735833 (8090908-07) Air	**Sampled: 08/06/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.15950	0.0000	g	1	B8J1006	08/06/08	10/10/08	NA	
6735834 (8090908-08) Air	**Sampled: 08/06/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.18990	0.0000	g	1	B8J1006	08/06/08	10/10/08	NA	
Q0164739 (8090908-09) Air	**Sampled: 08/07/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.15480	0.0000	g	1	B8J1006	08/07/08	10/10/08	NA	

The results in this report apply only to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Ray Merrill, Technical Director

North Carolina State University	Project: PM-10 Filter Analysis 7-2008	
5136 Jordan Hall Room 5136	Project Number: 3290.00.133.001	**Reported:**
Raleigh NC, 27695-8202	Project Manager: Viney P. Aneja	10/10/08 14:26

Gravimetric Measurement

Eastern Research Group

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Q0164738 (8090908-10) Air	**Sampled: 08/07/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.29530	0.0000	g	1	B8J1006	08/07/08	10/10/08	NA	
6735839 (8090908-11) Air	**Sampled: 08/08/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.15200	0.0000	g	1	B8J1006	08/08/08	10/10/08	NA	
6735840 (8090908-12) Air	**Sampled: 08/08/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.57520	0.0000	g	1	B8J1006	08/08/08	10/10/08	NA	
6735835 (8090908-13) Air	**Sampled: 08/09/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.0301	0.0000	g	1	B8J1006	08/09/08	10/10/08	NA	
6735836 (8090908-14) Air	**Sampled: 08/09/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.0499	0.0000	g	1	B8J1006	08/09/08	10/10/08	NA	
6735837 (8090908-15) Air	**Sampled: 08/10/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.14680	0.0000	g	1	B8J1006	08/10/08	10/10/08	NA	
6735838 (8090908-16) Air	**Sampled: 08/10/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.23610	0.0000	g	1	B8J1006	08/10/08	10/10/08	NA	
6735841 (8090908-17) Air	**Sampled: 08/11/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.34920	0.0000	g	1	B8J1006	08/11/08	10/10/08	NA	
6735842 (8090908-18) Air	**Sampled: 08/11/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.40730	0.0000	g	1	B8J1006	08/11/08	10/10/08	NA	

Eastern Research Group

The results in this report apply only to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Ray Merrill, Technical Director

North Carolina State University	Project: PM-10 Filter Analysis 7-2008	
5136 Jordan Hall Room 5136	Project Number: 3290.00.133.001	**Reported:**
Raleigh NC, 27695-8202	Project Manager: Viney P. Aneja	10/10/08 14:26

Gravimetric Measurement

Eastern Research Group

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
6735843 (8090908-19) Air	**Sampled: 08/12/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.28410	0.0000	g	1	B8J1006	08/12/08	10/10/08	NA	
6735844 (8090908-20) Air	**Sampled: 08/12/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.45930	0.0000	g	1	B8J1006	08/12/08	10/10/08	NA	
6735845 (8090908-21) Air	**Sampled: 08/13/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.32690	0.0000	g	1	B8J1006	08/13/08	10/10/08	NA	
6735846 (8090908-22) Air	**Sampled: 08/13/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.73510	0.0000	g	1	B8J1006	08/13/08	10/10/08	NA	
6735847 (8090908-23) Air	**Sampled: 08/14/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.28510	0.0000	g	1	B8J1006	08/14/08	10/10/08	NA	
6735848 (8090908-24) Air	**Sampled: 08/14/08 23:59**	**Received: 09/01/08 16:14**							
Weight (gm)	0.56150	0.0000	g	1	B8J1006	08/14/08	10/10/08	NA	

The results in this report apply only to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Ray Merrill, Technical Director

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

Eastern Research Group

The results in this report apply only to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Ray Merrill, Technical Director

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/08/08 16:18
SUBMITTED: 08/08/08 to 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Description: Q0164739 **Lab ID:** 8090908-09 **Sampled:** 08/07/08 23:59
Matrix: Air **Sample Volume:** 1631.05 m^3 **Received:** 09/01/08 16:14
Comments: **Analysis Date:** 09/23/08 15:23

Inorganics by Compendium Method IO-3.5

Analyte	CAS Number	Results ng/m³ Air	Flag	MDL ng/m³ Air
Antimony	7440-36-0	1.81	D	0.006
Arsenic	7440-38-2	0.720	D	0.010
Beryllium	7440-41-7	0.041	D	0.012
Cadmium	7440-43-9	0.090	D	0.008
Chromium	7440-47-3	3.16	D	0.178
Cobalt	7440-48-4	0.697	D	0.009
Lead	7439-92-1	3.32	D, B	0.107
Manganese	7439-96-5	19.4	D	0.021
Mercury	7439-97-6	0.972	A-01, D, B	0.024
Nickel	7440-02-0	14.3	D	0.110
Selenium	7782-49-2	0.568	D	0.024

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/08/08 16:18
SUBMITTED: 08/08/08 to 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Description: Q0164738 **Lab ID:** 8090908-10 **Sampled:** 08/07/08 23:59
Matrix: Air **Sample Volume:** 1631.05 m³ **Received:** 09/01/08 16:14
Comments: **Analysis Date:** 09/23/08 15:31

Inorganics by Compendium Method IO-3.5

Analyte	CAS Number	Results ng/m³ Air	Flag	MDL ng/m³ Air
Antimony	7440-36-0	1.83	D	0.006
Arsenic	7440-38-2	0.958	D	0.010
Beryllium	7440-41-7	0.067	D	0.012
Cadmium	7440-43-9	0.263	D	0.008
Chromium	7440-47-3	2.74	D	0.178
Cobalt	7440-48-4	0.915	D	0.009
Lead	7439-92-1	3.90	D, B	0.107
Manganese	7439-96-5	34.1	D	0.021
Mercury	7439-97-6	0.140	A-01, D, B	0.024
Nickel	7440-02-0	3.04	D	0.110
Selenium	7782-49-2	0.613	D	0.024

Raymond L. Merrill

Authorized Signature(s)

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/08/08 16:18
SUBMITTED: 08/08/08 to 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Inorganics by Compendium Method IO-3.5 - Quality Control

Batch B8H2805 - ICP-MS Extraction

Analyte	Result	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (B8H2805-BLK1)				Prepared: 08/28/08 Analyzed: 09/10/08						
Antimony	ND	0.006	ng/m³ Air							U
Arsenic	ND	0.010	ng/m³ Air							U
Beryllium	ND	0.012	ng/m³ Air							U
Cadmium	ND	0.008	ng/m³ Air							U
Chromium	ND	0.178	ng/m³ Air							U
Cobalt	ND	0.009	ng/m³ Air							U
Lead	ND	0.107	ng/m³ Air							U
Manganese	ND	0.021	ng/m³ Air							U
Mercury	ND	0.024	ng/m³ Air							U
Nickel	ND	0.110	ng/m³ Air							U
Selenium	ND	0.024	ng/m³ Air							U
LCS (B8H2805-BS1)				Prepared: 08/28/08 Analyzed: 09/10/08						
Antimony	4.23	0.006	ng/m³ Air	4.50		94.0	75-125			
Arsenic	2.14	0.010	ng/m³ Air	2.25		95.1	75-125			
Beryllium	2.26	0.012	ng/m³ Air	2.25		100	75-125			
Cadmium	2.16	0.008	ng/m³ Air	2.25		96.0	75-125			
Chromium	10.8	0.178	ng/m³ Air	11.2		96.4	75-125			
Cobalt	2.22	0.009	ng/m³ Air	2.25		98.7	75-125			
Lead	10.5	0.107	ng/m³ Air	11.2		93.8	75-125			
Manganese	10.7	0.021	ng/m³ Air	11.2		95.5	75-125			
Mercury	1.01	0.024	ng/m³ Air	1.12		90.2	75-125			
Nickel	11.2	0.110	ng/m³ Air	11.2		100	75-125			
Selenium	2.20	0.024	ng/m³ Air	2.25		97.8	75-125			
LCS Dup (B8H2805-BSD1)				Prepared: 08/28/08 Analyzed: 09/10/08						
Antimony	4.24	0.006	ng/m³ Air	4.50		94.2	75-125	0.236	20	
Arsenic	2.14	0.010	ng/m³ Air	2.25		95.1	75-125	0.00	20	
Beryllium	2.27	0.012	ng/m³ Air	2.25		101	75-125	0.442	20	
Cadmium	2.17	0.008	ng/m³ Air	2.25		96.4	75-125	0.462	20	
Chromium	10.8	0.178	ng/m³ Air	11.2		96.4	75-125	0.00	20	
Cobalt	2.20	0.009	ng/m³ Air	2.25		97.8	75-125	0.905	20	
Lead	10.5	0.107	ng/m³ Air	11.2		93.8	75-125	0.00	20	
Manganese	10.7	0.021	ng/m³ Air	11.2		95.5	75-125	0.00	20	
Mercury	1.02	0.024	ng/m³ Air	1.12		91.1	75-125	0.985	20	
Nickel	11.2	0.110	ng/m³ Air	11.2		100	75-125	0.00	20	
Selenium	2.20	0.024	ng/m³ Air	2.25		97.8	75-125	0.00	20	

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/08/08 16:18
SUBMITTED: 08/08/08 to 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Analyte	Result	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Inorganics by Compendium Method IO-3.5 - Quality Control										
Batch B8I1102 - ICP-MS Extraction										
Blank (B8I1102-BLK1)				Prepared: 09/11/08 Analyzed: 09/29/08						
Antimony	ND	0.006	ng/m³ Air							U
Arsenic	ND	0.010	ng/m³ Air							U
Beryllium	ND	0.012	ng/m³ Air							U
Cadmium	ND	0.008	ng/m³ Air							U
Chromium	ND	0.178	ng/m³ Air							U
Cobalt	ND	0.009	ng/m³ Air							U
Lead	0.518	0.107	ng/m³ Air							
Manganese	ND	0.021	ng/m³ Air							U
Mercury	0.161	0.024	ng/m³ Air							
Nickel	ND	0.110	ng/m³ Air							U
Selenium	ND	0.024	ng/m³ Air							U
LCS (B8I1102-BS1)				Prepared: 09/11/08 Analyzed: 09/29/08						
Antimony	4.29	0.006	ng/m³ Air	4.50		95.3	75-125			
Arsenic	2.11	0.010	ng/m³ Air	2.25		93.8	75-125			
Beryllium	2.25	0.012	ng/m³ Air	2.25		100	75-125			
Cadmium	2.17	0.008	ng/m³ Air	2.25		96.4	75-125			
Chromium	10.7	0.178	ng/m³ Air	11.2		95.5	75-125			
Cobalt	2.18	0.009	ng/m³ Air	2.25		96.9	75-125			
Lead	11.2	0.107	ng/m³ Air	11.2		100	75-125			B
Manganese	10.6	0.021	ng/m³ Air	11.2		94.6	75-125			
Mercury	1.01	0.024	ng/m³ Air	1.12		90.2	75-125			A-01, B
Nickel	11.0	0.110	ng/m³ Air	11.2		98.2	75-125			
Selenium	2.22	0.024	ng/m³ Air	2.25		98.7	75-125			
LCS Dup (B8I1102-BSD1)				Prepared: 09/11/08 Analyzed: 09/29/08						
Antimony	4.27	0.006	ng/m³ Air	4.50		94.9	75-125	0.467	20	
Arsenic	2.12	0.010	ng/m³ Air	2.25		94.2	75-125	0.473	20	
Beryllium	2.23	0.012	ng/m³ Air	2.25		99.1	75-125	0.893	20	
Cadmium	2.16	0.008	ng/m³ Air	2.25		96.0	75-125	0.462	20	
Chromium	10.7	0.178	ng/m³ Air	11.2		95.5	75-125	0.00	20	
Cobalt	2.19	0.009	ng/m³ Air	2.25		97.3	75-125	0.458	20	
Lead	11.3	0.107	ng/m³ Air	11.2		101	75-125	0.889	20	B
Manganese	10.6	0.021	ng/m³ Air	11.2		94.6	75-125	0.00	20	
Mercury	1.00	0.024	ng/m³ Air	1.12		89.3	75-125	0.995	20	A-01, B
Nickel	11.0	0.110	ng/m³ Air	11.2		98.2	75-125	0.00	20	
Selenium	2.23	0.024	ng/m³ Air	2.25		99.1	75-125	0.449	20	

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/10/08 16:23
SUBMITTED: 08/08/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Analyte	Result	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Inorganics by Compendium Method IO-3.5 - Quality Control										
Batch B8H2805 - ICP-MS Extraction										
Matrix Spike (B8H2805-MS1)	**Source: 8081323-01**			Prepared: 08/28/08		Analyzed: 09/10/08				
Antimony	6.95	0.006	ng/m³ Air	4.29	4.11	66.2	75-125			
Arsenic	2.98	0.010	ng/m³ Air	2.15	1.01	91.6	75-125			
Beryllium	1.97	0.012	ng/m³ Air	2.15	0.013	91.0	75-125			
Cadmium	2.08	0.008	ng/m³ Air	2.15	0.173	88.7	75-125			
Chromium	12.9	0.178	ng/m³ Air	10.7	3.19	90.7	75-125			
Cobalt	2.31	0.009	ng/m³ Air	2.15	0.336	91.8	75-125			
Lead	19.4	0.107	ng/m³ Air	10.7	10.9	79.4	75-125			
Manganese	22.5	0.021	ng/m³ Air	10.7	12.4	94.4	75-125			
Mercury	0.685	0.024	ng/m³ Air	1.07	0.066	57.9	75-125			
Nickel	10.9	0.110	ng/m³ Air	10.7	0.803	94.4	75-125			
Selenium	8.77	0.024	ng/m³ Air	2.15	6.52	105	75-125			
Matrix Spike Dup (B8H2805-MSD1)	**Source: 8081323-01**			Prepared: 08/28/08		Analyzed: 09/10/08				
Antimony	6.81	0.006	ng/m³ Air	4.29	4.11	62.9	75-125	2.03	20	
Arsenic	2.91	0.010	ng/m³ Air	2.15	1.01	88.4	75-125	2.38	20	
Beryllium	1.94	0.012	ng/m³ Air	2.15	0.013	89.6	75-125	1.53	20	
Cadmium	2.05	0.008	ng/m³ Air	2.15	0.173	87.3	75-125	1.45	20	
Chromium	12.7	0.178	ng/m³ Air	10.7	3.19	88.9	75-125	1.56	20	
Cobalt	2.29	0.009	ng/m³ Air	2.15	0.336	90.9	75-125	0.870	20	
Lead	18.9	0.107	ng/m³ Air	10.7	10.9	74.8	75-125	2.61	20	
Manganese	21.6	0.021	ng/m³ Air	10.7	12.4	86.0	75-125	4.08	20	
Mercury	0.727	0.024	ng/m³ Air	1.07	0.066	61.8	75-125	5.95	20	
Nickel	10.8	0.110	ng/m³ Air	10.7	0.803	93.4	75-125	0.922	20	
Selenium	8.49	0.024	ng/m³ Air	2.15	6.52	91.6	75-125	3.24	20	

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/10/08 10:56
SUBMITTED: 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Inorganics by Compendium Method IO-3.5 - Quality Control

Batch B8I1102 - ICP-MS Extraction

Analyte	Result	PQL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Matrix Spike (B8I1102-MS1)	**Source: 8082911-01**			Prepared: 09/11/08	Analyzed: 09/29/08					
Antimony	4.74	0.006	ng/m³ Air	5.36	1.43	61.8	75-125			D
Arsenic	2.88	0.010	ng/m³ Air	2.68	0.543	87.2	75-125			D
Beryllium	2.38	0.012	ng/m³ Air	2.68	ND	88.8	75-125			D
Cadmium	2.63	0.008	ng/m³ Air	2.68	0.342	85.4	75-125			D
Chromium	14.1	0.178	ng/m³ Air	13.4	2.33	87.8	75-125			D
Cobalt	2.56	0.009	ng/m³ Air	2.68	0.141	90.3	75-125			D
Lead	19.3	0.107	ng/m³ Air	13.4	7.79	85.9	75-125			D, B
Manganese	17.3	0.021	ng/m³ Air	13.4	5.41	88.7	75-125			D
Mercury	1.03	0.024	ng/m³ Air	1.34	0.378	48.7	75-125			A-01, D, B
Nickel	14.0	0.110	ng/m³ Air	13.4	1.91	90.2	75-125			D
Selenium	2.51	0.024	ng/m³ Air	2.68	0.176	87.1	75-125			D
Matrix Spike Dup (B8I1102-MSD1)	**Source: 8082911-01**			Prepared: 09/11/08	Analyzed: 09/29/08					
Antimony	4.74	0.006	ng/m³ Air	5.36	1.43	61.8	75-125	0.00	20	D
Arsenic	2.90	0.010	ng/m³ Air	2.68	0.543	87.9	75-125	0.692	20	D
Beryllium	2.41	0.012	ng/m³ Air	2.68	ND	89.9	75-125	1.25	20	D
Cadmium	2.63	0.008	ng/m³ Air	2.68	0.342	85.4	75-125	0.00	20	D
Chromium	14.0	0.178	ng/m³ Air	13.4	2.33	87.1	75-125	0.712	20	D
Cobalt	2.57	0.009	ng/m³ Air	2.68	0.141	90.6	75-125	0.390	20	D
Lead	19.3	0.107	ng/m³ Air	13.4	7.79	85.9	75-125	0.00	20	D, B
Manganese	17.2	0.021	ng/m³ Air	13.4	5.41	88.0	75-125	0.580	20	D
Mercury	1.02	0.024	ng/m³ Air	1.34	0.378	47.9	75-125	0.976	20	A-01, D, B
Nickel	14.0	0.110	ng/m³ Air	13.4	1.91	90.2	75-125	0.00	20	D
Selenium	2.53	0.024	ng/m³ Air	2.68	0.176	87.8	75-125	0.794	20	D

CERTIFICATE OF ANALYSIS

North Carolina State University
5136 Jordan Hall Room 5136
Raleigh, NC 27695-8202
ATTN: Viney P. Aneja
PHONE: (919) 515-7808 **FAX:** (919) 515-7802

FILE #: 3290.00.133.001
REPORTED: 10/10/08 10:56
SUBMITTED: 09/01/08
AQS SITE CODE:
SITE CODE: PM-10 Filter Analysis 7-2008

Notes and Definitions

U	Under Detection Limit
D	Data reported from a dilution
B	Analyte is found in the associated blank as well as in the sample (CLP B-flag).
A-01	Method Blank Subtracted
ND	Analyte NOT DETECTED at or above the Method Detection Limit (MDL)
NR	Not Reported
RPD	Relative Percent Difference
MDL	Method Detection Limit

467
CSX
467

United States Senate

WASHINGTON, DC 20510

October 23, 2013

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, DC 20310-0108

Dear Assistant Secretary Darcy:

We are concerned by the Army Corps of Engineers' continued refusal to conduct an environmental impact statement for Ambre Energy's proposed coal terminal at Port of Morrow, and its recent decision to deny information requested by a cooperating agency in lieu of a more detailed environmental study pursuant to the Endangered Species Act.[1]

The Corps' current scope of environmental review appears to fall short of its own regulations governing National Environmental Policy Act (NEPA) implementation. Those regulations state that "in some situations, a specific activity … is merely one component of a larger project," and that an environmental review under NEPA should "address the impacts of the specific activity requiring a [Department of Army] permit and those portions of the entire project over which the district engineer has sufficient control and responsibility to warrant Federal review."[2] By refusing to evaluate the potential impacts of the project on the full length of the Columbia River, the Corps is limiting its ability to consider direct, indirect, and cumulative impacts of 8.8 million tons of coal that would be shipped by railroad to Boardman, Oregon; loaded onto barges; shipped some 200 miles on the Columbia, and then transferred mid-stream near Clatskanie, Oregon, to ocean-going ships that would travel further down the Columbia to the Pacific Ocean.

The Corps' decision to pursue such a narrow scope casts aside the advice of the National Marine Fisheries Service (NMFS), which must be consulted pursuant to section 7 of the Endangered Species Act (ESA) and section 305 of the Magnuson-Stevens Fishery Conservation and Management Act. The NMFS recommended in a December 27, 2012 letter that the Corps prepare a draft environmental impact statement in order to perform a comparative analysis of "coal transshipping projects … at various sites in the Pacific Northwest." The letter cited both "public controversy" and the "potential for substantial impacts" to trust species under its purview, including ESA-listed species such as salmon, sturgeon, sea turtles and marine mammals such as whales and sea lions.

---

[1] Casandra Profita, *Army Corps Shrinks Endangered Species Review for Columbia River Coal Export Project*, Oregon Public Broadcasting, September 5, 2013, http://earthfix.opb.org/communities/article/corps-shrinks-endangered-species-review-for-morrow/. Accessed October 22, 2013.

[2] *33 C.F.R. § 325 App. B § 7(b)*

By restricting its review to a mere mile of the river, the Corps is moving in the opposite direction of expert recommendations made by NMFS. Moreover, the Corps has further exacerbated the issue by refusing to provide nine of the 15 pieces of information that NMFS said were "necessary" to comply with ESA regulations in the absence of an EIS. This information would have answered questions about the expected increases in barge and ocean-going traffic, increases and impacts of train traffic, the threat of invasive species, and the impact to marine life.

The need for an in-depth endangered species review and information-sharing requested by NMFS was underscored by the applicant itself in a biological assessment prepared for Ambre's subsidiary Coyote Island Terminals, LLC, in April, 2012. That report said the project would have "unavoidable impacts" on protected fish and habitat – a conclusion that was reported by regional media outlets.[3] Coyote Island Terminals' April, 2012 assessment determined that the probability of increased traffic required review of a 276-mile "action area"[4] from Port of Morrow (river mile 253) to the Columbia Bar, five miles into the Pacific Ocean. The document determined that "the action area includes all areas that could be potentially affected by the proposed action and is not limited to the actual construction and operation areas" being proposed at Port of Morrow.[5]

In addition to the issues raised above, this project has generated substantial interest from the public,[6] and deserves a fuller accounting of its impacts by your agency in the NEPA process. The Council on Environmental Quality requires consideration of the "degree to which the effects on the quality of the human environment are likely to be highly controversial" to determine whether a proposed federal action "significantly" affects the environment.[7] Courts have found that "the effects of an action are 'highly controversial' when there is 'a substantial dispute [about] the size, nature, or effect of the major federal action rather than the existence of opposition to a use."[8] The fact that there is a substantial dispute about the effect of the shipping terminal upon the Columbia River ecosystem itself justifies preparation of an EIS.[9]

Your agency has received correspondence from us both expressing concerns about the Corps' approach to assessing the impacts of coal projects in Oregon, and along the Columbia River.[10] These concerns have been heightened by the agency's recent actions in relation to the proposed coal export terminal at Port of Morrow. We both believe that

---

[3] Barbara LaBoe, *Report: Columbia River coal transport likely to threaten fish habitat*, Longview Daily News, June 11, 2012, http://tdn.com/news/local/report-columbia-river-coal-transport-likely-to-threaten-fish-habitat/article_b1cfca26-b42d-11e1-85e9-0019bb2963f4.html. Accessed October 22, 2013.

[4] 50 C.F.R. Part 402.02 defines action area as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action."

[5] Anderson, Perry & Associates, Inc., *Biological Assessment for the Morrow Pacific Project*, La Grange, OR: April, 2012, at section 1.3, available at http://www.scribd.com/doc/96830239/Boardman-Coal-Terminal-BA-RFS. Accessed October 22, 2013.

[6] Courtney Flatt, *Columbia River Coal Comments Most in DEQ History*, Northwest Public Radio, August 26, 2013, http://earthfix.opb.org/energy/article/columbia-river-coal-comments-most-in-deq-history/. Accessed October 22, 2013.

[7] *40 C.F.R. 1508.27(b)(4)*

[8] *Friends of the Earth v. USACE, 109 F. Supp. 2d at 43.*

[9] *Id.*

[10] Letter from Sen. Merkley to Secretary McHugh and Secretary Salazar, copied to Major General Temple, June 18, 2012; letter from Chairman Wyden to Assistant Secretary Darcy, March 13, 2013 (see attached).

the Corps must conduct an EIS for any coal export facilities proposed along the Columbia River.

This approach would allow for a full accounting of the impacts of these projects on all parts of the Columbia River, in particular the Columbia River Gorge National Scenic Area, and the adjacent Mark O. Hatfield Wilderness, both of which are protected by federal law. The agency also must have a full accounting of how the project might affect important fishing grounds for Columbia River Treaty Tribes. The Corps is depriving the public of valuable information by continuing to ignore the recommendations and information requests of the NMFS, the applicant's original assessment of a proper scope of endangered species review, as well as the wishes of Oregon citizens and their elected leaders.

Please provide answers to the following questions no later than November 15, 2013:

1.) Please explain why the Army Corps has chosen to pursue individual environmental impact statements for coal export terminals proposed in Cherry Point, WA, and Longview, WA, but thus far has refused to begin an EIS for the Port of Morrow.

2.) An April, 2012, biological assessment prepared for Ambre Energy's subsidiary concluded that federal endangered species regulations require that the "action area" for the permit should be "Port of Morrow … Columbia River between Port of Morrow and Port Westward …Port Westward and Columbia River/Pacific Ocean … plus approximately 41 upland acres of upland area at the new Port of Morrow facility at Boardman."[11] Please detail:

    a. The action area your agency currently plans to pursue;

    b. A comparison of how the action area referenced in question 2(a) differs from Ambre Energy's April, 2012, assessment of the "action area" referenced above; and

    c. The reasons for any differences between the two.

3.) Please provide the expected marine traffic increases in conjunction with the Gateway Pacific Terminals project, and the Port of Morrow project. How does the marine traffic today compare to what these projects would add to their respective marine transport systems?

    a. Please explain the rationale behind the scope of review for each project, and any differences between the two.

[11] *Supra* note 5, at section 1.3.

Thank you for your prompt attention to this matter. If any questions arise, please contact Peter Gartrell on Sen. Wyden's staff at 202-224-4971 or Adrian Deveny on Sen. Merkley's staff at 202-224-3753.

Sincerely,

Ron Wyden
Chairman
Senate Committee on Energy and
Natural Resources

Jeff Merkley
United States Senator

Cc: The Honorable Nancy Sutley, Chair, Council on Environmental Quality
The Honorable Samuel Rauch III, Acting Assistant Administrator for Fisheries, National Oceanic and Atmospheric Administration
Col. John Eisenhauer, Portland District Commander and District Engineer, U.S. Army Corps of Engineers
Mr. William Stelle, Regional Administrator, West Coast Region, National Marine Fisheries Service

Attachments: Letter from Senator Jeff Merkley to Secretary McHugh and Secretary Salazar, June 18, 2012
Letter from Chairman Ron Wyden to Assistant Secretary Darcy, March 13, 2013

LEYDA CONSULTING, INC.
PROFESSIONAL WETLAND SCIENCE
2405 East Ninth Street • Vancouver, Washington, 98661 • 360.510.2737 • www.leydaconsulting.com

March 23, 2011

Jan Hasselman
Earthjustice
705 Second Avenue, Suite 203
Seattle, WA 98104-1711

RE: DRAFT Wetland Reconnaissance and Rating Review for Proposed Coal Terminal 4029 Industrial Way, Cowlitz County, Washington

Mr. Hasselman:

Leyda Consulting, Inc., (LCI) presents this draft technical memorandum and four attached figures, photographs, and wetland data forms as the preliminary results of our investigation at the Millennium Bulk Logistics property in Cowlitz County, Washington. The investigation includes an evaluation of the Anchor QEA and Coldwater Resources wetland delineation reports, additional wetland determinations to verify areas not sampled in the previous reports, and revisions to the wetland rating forms and changes in categories.

Precipitation Data & Analysis

LCI performed the wetland reconnaissance and data collection in March, which is a time of year when wetlands are typically saturated or inundated. Some wetlands begin collecting water as the rains begin in October. They may reach full hydrology (saturation or inundation) by March or April, and then slowly dry out until July or August. Typically, September is the driest month for seasonally flooded wetlands; often, wetlands are just beginning to become saturated in October and may not yet exhibit full saturation or inundation.

The wetland reconnaissance was performed on March 8, 2011. The monthly averages, normal ranges, and recorded precipitation totals for the water year-to-date preceding fieldwork are shown in Table 1 below. Precipitation levels are considered "normal" when they fall between the "30% chance of more" than that amount and the "30% chance of less" than that amount. Table 1 also shows the summary of the most recent Water Year (October 1st through March 8) precipitation compared to the average Water Year. Daily precipitation totals for two weeks before the fieldwork are listed in Table 2 below.

Table 1: Monthly Precipitation Data near Longview, WA

Month	Precipitation (inches)				% Average
	NRCS WETS Table 1971-2000[1]			National Weather Service (NWS)[2]	
	30% Chance will have:		WETS Average	Recorded Total	% of WETS Average
	Less	More			
July 2010	*0.31*	*0.99*	*0.80*	*0.36*	*45*
August 2010	*0.39*	*1.29*	*1.06*	*0.00*	*0*
September 2010	*0.71*	*2.20*	*1.76*	*3.20*	*181*
October 2010	1.93	3.99	3.28	4.43	135
November 2010	4.23	7.52	6.29	7.05	112
December 2010	4.44	7.50	6.32	9.42	149
January 2011	3.83	6.97	5.81	5.01	86
February 2011	3.45	5.72	4.84	4.24	88
March 2011	*3.32*	*4.84*	*4.21*	*2.30*	
Water Year-to-Date Totals[3]:	**17.88**	**31.70**	**26.54**	**30.15**	**114**

Months in *italics* are not included in the Water Year-to-Date or are incomplete months up to the time of the field visit.
[1]Historic Normal Range and Average from WETS data for Vancouver, WA (Station #458773 - Vancouver 4 NNE), NRCS 2002 (ftp://ftp.wcc.nrcs.usda.gov/support/climate/wetlands/wa/).
[2]Average and Recorded Totals for Vancouver, WA (Station #458773 - Vancouver 4 NNE) from NOAA, March 15, 2011 (http://nowdata.rcc-acis.org/pQR/).
[3]Water Year-to-Date includes the totals for each column starting October 1st – February 28th.

Table 2: Daily Precipitation Two Weeks Prior to Field Visit near Longview, WA

Date:	Feb 21	Feb 22	Feb 23	Feb 24	Feb 25	Feb 26	Feb 27	Feb 28
Precip. (in.)[1]:	0.04	0.08	0.06	0.38	0.02	0.00	0.04	0.80

Date:	Mar 1	Mar 2	Mar 3	Mar 4	Mar 5	Mar 6	Mar 7	Mar 8
Precip. (in.)[1]:	1.25	0.27	0.15	0.05	0.41	0.01	0.00	0.16

[1]Precipitation for Vancouver, WA (Station #458773 - Vancouver 4 NNE) from NOAA, March 15, 2011 (http://nowdata.rcc-acis.org/pQR/).

The recorded precipitation for the water year preceding the field visit is within normal limits. The recorded total of 30.15 inches (October 2010 – February 2011) is less than the upper limit of 31.70 inches, so "normal circumstances" are present with regards to precipitation-driven wetland hydrology. Wetlands that are not artificially drained are expected to be fully saturated by this time of year, since precipitation has been within average limits for the water year and since this is the wettest time of year in this ecosystem.

Wetland Reconnaissance Findings

LCI identified wetlands in several locations shown as uplands in the other wetland delineation reports. Those areas include the designated coal pile area, the cleared area south of Wetland AQ-B, one place along the levee, the land surrounding an excavated pit, and several areas around wetland CR-D. The additional wetlands were sampled, and the sampling point locations mapped on the attached figures.

Wetland Rating Findings

LCI found many differences in the wetland rating criteria selected in the rating forms. The observations and changes to the wetland ratings are listed in Table 3 below.

Table 3. Wetland AQ-B Rating Corrections; Anchor Rating: Cat. III / LCI Rating: Cat. II

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	1	Est. Size	2 acres	-	10.92 acres	-	Anchor Figure 5; report says 10.8 A, p.11)
2	5	D 1.2 ("S 1.2")	NO. Soil 2" below surface clay or organic.	0	YES. Clay is present. Report says top 2" of soil is organic	4	Anchor Data Form AQ-B-2Wet lists clay at 2", and organic soil above that. LCI observed clay soil at 2"
3	5	D 1.3	Wetland has persistent, ungrazed, vegetation >= ½ of area.	3	Wetland has persistent, ungrazed, vegetation >= 95% of area	5	LCI Observed ~95.4% of the total wetland area to be dominated by persistent, ungrazed vegetation.
4	5	D 1.4	Seasonal ponding is between ¼ and ½ of total wetland area	2	Same		LCI Observed ~20% to be seasonally inundated
5	6	D 3.3	Area of basin is 10 to 100 times the size of the wetland	3	Area of basin is less than 10 times size of wetland	5	Office analysis needed
6	13	H 1.1	The forested class does NOT have 3 out of 5 strata (canopy, subcanopy, shrubs, herbs, moss) that each cover 20% w/in the forested polygon	1	Same		The understory in the forested class is primarily reed canarygrass. Wetland lacks 20% cover of shrubs in forested areas
7	13	H 1.1	NO Scrub-shrub Cowardin class present	1	Same		Scrub-shrub class is present but does not meet the size threshold
8	13	H 1.2	Permanently and Occasionally flooded hydroperiods	1	Seasonal flooding, and seasonal saturation present – points unchanged	1	LCI observed seasonal flooding in depressional areas (~2.2 acres) and seasonal saturation elsewhere (~8.6 acres)

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
9	14	H 1.5	NO ¼ acre of thin stemmed veg or woody branches in areas of permanent or seasonal inundation	2	¼ acre of thin stemmed veg or woody branches in Areas of permanent or seasonal inundation	3	LCI observed ~80% of seasonally inundated areas were vegetated by reed canarygrass (1.8 acres)
10	15	H 2.2.3	Wetland is NOT within 3 miles of a large field or pasture	0	Wetland is within 3 miles of a large field or pasture	1	Figure 1 shows large field (>40 A) to north
11	16	H 2.3	No priority habitats	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: report says that "site hydrology is…primarily driven by Columbia R. water levels." Meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain.

Wetland AQ-B at site visit:

1. Item 2: Sample for clay, as noted above. Sample for organic soil at same depth.

   Soil sampled, clay observed (3" ribbon), documented, and photographed.

2. Item 3: Estimate if persistent, ungrazed vegetation is =>95% of the wetland. If not, estimate area of grazed veg and/or veg <6" tall when wetland has water.

   LCI sketch-mapped areas of persistent, ungrazed vegetation and calculated size with AutoCAD. LCI estimated that 95.4% of the wetland contains persistent vegetation.

3. Item 4: Check for seasonal (not permanent) ponding: is seasonal ponding >5.46A?

   LCI sketch-mapped areas of seasonal ponding and calculated size with AutoCAD. The ponding constitutes 0.07 acres and does not meet the ¼ acre threshold.

4. Item 6: Map the extent of the strata under the canopy; does each cover 20% of forested part (around 2 A)?

   LCI determined that the forested component did not have three strata.

5. Item 8: Hydroperiods: check for permanent, occasional, and seasonal inundation; estimate areas (need 10% of wetland [1 acre] or a ¼ acre).

   LCI sketch-mapped hydrologic regimes in the field and calculated sizes with AutoCAD. Likely permanent ponding in main ditch (0.07 acres – does not meet threshold), seasonal flooding in depressional areas (2.24 acres) and seasonal saturation elsewhere (8.61 acres).

6. Item 9: Check for thin-stemmed/woody vegetation acreage in permanent and seasonally inundated areas; is it at least a ¼ acre?

   LCI sketch-mapped areas of thin-stemmed vegetation in the field and calculated

sizes with AutoCAD. Area totaled 1.8 acres.

In office *(optional)*:

7. Item 5: Obtain topography or stormwater plan that shows drainage basin that drains to Wetland AQ-B. If it is less than 106.2 acres, then question D 3.3 will change.

Additional Field Observations: *Inundation in ditch at the outlet was 26" deep (4" from ditch bottom to outlet bottom and 22" of inundation above the bottom of the outlet). We also observed duckweed trapped at 12" above the current water level, indicating higher water levels occur during storm events or periods of higher rainfall. This changes question D3.2 to 5 points, further increasing the rating score by 4 points.*

Conclusions: 18 points added to the original 42 for a total of 60 points (Category II). Additional 5 points possible from Item #5 and #11.

Table 4. Wetland AQ-C Rating Corrections; Anchor Rating: CAT III / LCI Rating: CAT II

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	1	Est. Size	2 acres	-	6.18 acres	-	Anchor Figure 5; report says 6.2 A, p.13)
2	5	D 1.2	No clay or organic soil 2" below surface	0	Clay is present	4	SP AQ-C-6Wet lists clay loam at 2" deep; SP AQ-C-8Wet lists organic soil at 2"; LCI Observed clay at 2" below surface
3	5	D 1.3	Wetland has persistent, ungrazed, vegetation >= ½ of area	3	Same		LCI observed ~ 8% unvegetated inundated areas; does not meet 95% threshold
4	5	D 1.4	Seasonal ponding is between ¼ and ½ of total wetland area	2	Same		LCI observed ~1.7 Acres Seasonal Inundation (27.5% total area)
5	6	D 3.3	Area of basin is 10 to 100 times the size of the wetland	3	Area of basin is less than 10 times size of wetland	5	Office analysis needed
6	13	H 1.1	The forested class does NOT have 3 out of 5 strata (canopy, subcanopy, shrubs, herbs, moss) that each cover 20% w/in the forested polygon	1	Same		Forested class does not have 3 layers; primarily reed canarygrass understory
7	13	H 1.2	Permanently and Occasionally flooded hydroperiods	1	Seasonally flooded and seasonally saturated	1	Rating Form Question D 1.4 says Seasonal Ponding is present; LCI observed saturation as well. The area rated by Anchor as occasionally flooded is more

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
							likely to be seasonally flooded
8	14	H 1.5	NO ¼ acre of thin stemmed veg or woody branches in areas of permanent or seasonal inundation	1	¼ acre of thin stemmed veg or woody branches in areas of permanent or seasonal inundation	2	LCI observed approx. 1.2 acres of wetland to be inundated and vegetated with reed canarygrass
9	14	H 1.5	NO standing snags >4"	1	Standing snags >4"	2	LCI observed 10 snags >4" diameter
10	15	H 2.1	Buffer does not meet any of the above criteria	1	No paved areas or bldgs. w/in 50m of wetland for >50% of circumference	2	LCI observed adjacent roads to be gravel rather than paved
11	15	H 2.2.3	Wetland is NOT within 3 miles of a large field or pasture	0	Wetland is within 3 miles of a large field or pasture	1	Figure 1 shows large field (>40 A) to north
12	16	H 2.3	No priority habitats	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: report says that "site hydrology is…primarily driven by Columbia R. water levels"; meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain

Wetland AQ-C at site visit:

1. Item 2: Sample for clay, as noted above. Sample for organic soil at same depth.

   Soil sampled, clay observed, documented, and photographed.

2. Item 3: Estimate if persistent, ungrazed vegetation is =>95% of the wetland. If not, estimate area of grazed veg and/or veg <6" tall when wetland has water.

   LCI observed approx. 0.5-acre (8%) of the wetland to be unvegetated and seasonally ponded.

3. Item 4: Check for seasonal (not permanent) ponding: is seasonal ponding >3.09A?

   LCI observed approximately 1.7 Acres of seasonal ponding.

4. Item 5: Map the extent of the strata under the canopy; does each cover 20% of the forested part?

   LCI observed that canopy does not contain three strata.

5. Item 7: Hydroperiods: check for permanent, occasional, and seasonal inundation; estimate areas (need 10% of wetland [0.6 acre] or a ¼ acre).

   LCI observed seasonal ponding and seasonal saturation.

6. Item 8: Check for thin-stemmed/woody vegetation acreage in permanent and seasonally inundated areas; is it at least a ¼ acre?

   LCI observed that ~1.2 acres of wetland to meet this criteria.

7. Item 9: Check for standing snags >4" dbh in wetland.

   LCI observed at least 10 snags >4" dbh within the wetland. All were 6-10' tall.

8. Item 10: Check for paved vs. gravel roads w/in 50m and 25m.

   Roads are not paved.

In office *(optional)*:

9. Item 5: Obtain topography or stormwater plan that shows drainage basin that drains to Wetland AQ-C. If it is less than 60 acres, then question D 3.3 will change.

Additional Field Notes: *LCI Observed coyote scat; 2' water depth in ditched areas, water 2" above the bottom of the culvert. Culvert was flowing north, from AQ-C to AQ-B.*

Conclusions: 13 points added to the original 40 for a total of 53 (Category II). Additional 5 points possible depending on Items 5 and 12.

Table 5. Combined Wetland CR-A & CR-D Rating Corrections / LCI Rating: Category II

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	5	D 1.2 ("S 1.2")	NO. Soil 2" below surface clay or organic	0	Same		LCI observed silt loam and sandy loam at 2"
2	6	D 3.3	Area of basin is 10 to 100 times the size of the wetland	3	Area of basin is less than 10 times size of wetland	5	Office analysis needed
3	7	H 1.2	Seasonally and Occasionally flooded hydroperiods	1	Seasonal and saturated hydroperiods; Same points	1	LCI observed seasonal saturation and seasonally flooded regimes
4	8	H 1.5	NO ¼ acre of thin stemmed persistent veg or woody branches in areas of permanent or seasonal inundation; NO Snags	1	¼ acre of thin stemmed persistent veg or woody branches in areas of permanent or seasonal inundation; Snags are recorded by Coldwater for Wetland CR-D	3	LCI observed; ~0.95-acre thin stemmed persistent veg in inundated areas; Snags are recorded for Wetland CR-D
5	10	H 2.3	No priority habitats	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: Anchor report says that "site hydrology is…primarily driven by Columbia R. water levels"; Meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain
6	9	H 2.1	Buffer does not meet any of the above criteria	1	No paved areas or bldgs. w/in 25m of wetland for >95% of circumference	2	Road to the SE is paved

Wetland D connects to Wetland A. The connection between A and D is not constricted and hydrologic regime does not change, thus they should be rated as one wetland rating unit.

Wetland CR-A at site visit:

1. Item 1: Sample for clay, as noted above. Sample for organic soil at same depth.

   LCI observed silt loam and sandy loam at 2" depth.

2. Item 3: Hydroperiods: check for permanent, occasional, and seasonal inundation; estimate areas (need 10% of wetland [0.05 acre] or a ¼ acre).

   LCI observed approx. 1 acre of seasonal inundation and approx. 0.48 acre of seasonal saturation.

3. Item 4: Check for persistent thin-stemmed/woody vegetation acreage in permanent and seasonally inundated areas; is it at least a ¼ acre?

   LCI observed ~0.95-acre thin stemmed persistent veg (rcg) in inundated areas; Snags are recorded for Wetland CR-D in the Coldwater Resources report.

4. Item 6: Check for paved vs. gravel roads within 50m and 25m.

   LCI observed a paved road to the south of Wetland A/D

In office *(optional)*:

5. Item 3: Obtain topography or stormwater plan that shows drainage basin that drains to Wetland CR-A. If it is less than 4.6 acres, then question D 3.3 will change.

Calculations: Wetland A: 0.46 acre + Wetland D: 1.02 acre = 1.48 acre
Seasonally inundated: ~1 acre (68%)
Seasonally saturated: ~ 0.48 acre (32%)
Unvegetated area (in areas of deepest ponding): 5% of inundated areas (just in ditch) = 0.05 acre
Thin-stemmed persistent vegetation in seasonally inundated areas: remainder of inundated areas, approx. 0.95 acre

Conclusions: Wetland A/D: original 48 points (49 with snags) + 2 = 51 points (Category II) + a possible additional 5 points for Items 3 and 6.

Table 6. Wetland CR-B Rating Corrections; Coldwater Category III / LCI Rating: Category II

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	5	D 1.2 ("S 1.2")	NO. Soil 2" below surface clay or organic	0	Same		LCI Observed Silt Loam at 2" depth
2	6	D 3.2	Depth of storage 0.5'- < 2' from surface or bottom of outlet	3	Same		LCI Observed 6-12" of storage depth
3	7	H 1.2	Seasonally and Occasionally flooded hydroperiods	1	Seasonally inundated and seasonally saturated hydroperiods	1	LCI Observed seasonally saturated (20%) and seasonally flooded (80%) regimes.
4	9	H 2.1	Buffer does not meet any of the above criteria	1	No paved areas or bldgs. W/in 50m of wetland for >50% of circumference	2	Paved road 20' from southeast wetland edge, 51% of the buffer circumference is not adjacent to the paved road
5	10	H 2.3	No priority habitats	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: Anchor report says that "site hydrology is…primarily driven by Columbia R. water levels"; meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain

Wetland CR-B at site visit:

1. Item 1: Sample for clay, as noted above. Sample for organic soil at same depth.

   LCI Sampled soils and observed silt loam at 2" depth.

2. Item 2: Check depth of storage, look for water marks on culvert or OHWM; > 2'?

   LCI observed water depths ranging up to 12".

3. Item 3: Hydroperiods: check for permanent, occasional, and seasonal inundation; estimate areas (need 10% of wetland [0.05 acre] or a ¼ acre).

   LCI observed seasonally saturated areas (~20%) and seasonally inundated areas (80%).

4. Item 4: Check for paved vs. gravel roads w/ in 50m, and 25m.

   Paved road is 20' from Southeast wetland edge. Wetland B perimeter is 666' in length. 325' (48.7%) of the wetland circumference is adjacent to the paved road. 341' (51.3%) of the circumference is not.

Calculations: Wetland B is 8,248 SF; Estimated 20% saturated and 80% seasonally inundated.

Conclusion: Original 50 points plus 1 point = 51 (Category II). Additional 1 point possible from Item 5.

Table 7. Wetland CR-C Rating Corrections; Coldwater Category III / LCI Rating: Category III

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	5	D 1.2 ("S 1.2")	NO. Soil 2" below surface clay or organic	0	Same		LCI observed sandy loam 2" below soil surface
2	5	D 1.3	Wetland has persistent, ungrazed, vegetation >= ½ of area	3	Same		LCI Observed >5% unvegetated inundated area
3	5	D 1.4	Seasonal ponding is < ¼ of total wetland area	0	Seasonal ponding is > ¼ the wetland area	2	LCI Observed 27% seasonal ponding
4	6	D 3.2	Depth of storage 0.5'- < 2' from surface or bottom of outlet	3	Same		LCI Observed 6-12" depths of ponding
5	7	H 1.2	Seasonally ponded and saturated hydroperiods	1	Same		LCI Observed seasonal saturation and seasonal inundation
6	8	H 1.5	NO ¼ acre of thin stemmed persistent veg or woody branches in areas of permanent or seasonal inundation	2	Same		LCI Observed that inundated areas are not vegetated
7	9	H 2.1	Buffer does not meet any of the above criteria	1	No paved areas or bldgs. W/in 50m of wetland for >50% of circumference	2	LCI calculated 15% of the wetland circumference is within 50m of a paved road
8	10	H 2.3	No priority habitats	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: Anchor report says that "site hydrology is…primarily driven by Columbia R. water levels"; meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain

19 possible extra points; 43 points + 14 to 16 possible extra points = 57-59 points, which is a CAT II.

Wetland CR-C at site visit:

1. Item 1: Sample for clay, as noted above. Sample for organic soil at same depth.
   LCI Sampled soils and observed silt loam at 2" depth.
2. Item 2: Check depth of storage, look for water marks on culvert or OHWM; > 2'?
   LCI observed water depths ranging up to 12".

3. Item 4: Hydroperiods: check for permanent, occasional, and seasonal inundation and saturation only; estimate areas (need 10% of wetland [0.05 acre] or a ¼ acre).

   LCI observed seasonally saturated areas (~73%) and seasonally inundated areas (27%).

4. Item 5: Check for persistent thin-stemmed/woody vegetation acreage in permanent and seasonally inundated areas; is it at least a ¼ acre?

   Same.

5. Item 6: Check for paved vs. gravel roads w/ in 50m, and 25m.

   Wetland C perimeter is 1,044' in length. 165'(16%) of the wetland circumference is within 50m of a paved road.

Calculations:
Total area: 19,283 SF; seasonal inundation approx. 5,122 SF (27%), seasonal saturation approx. 14,161 SF (73%). Inundated areas are unvegetated.

Conclusion: Original 43 points + 5 = 48 points (remains Category III). An additional 1 point may be possible from Item 8.

Table 8. Wetland CR-F Rating Corrections; Coldwater Category III / LCI Rating: Category II

Item No.	Pg. No.	Question No.	Anchor Answer	Pts.	LCI Answer	LCI Pts.	LCI Conclusion Supported by:
1	5	D 1.2 ("S 1.2")	NO. Soil 2" below surface clay or organic	0	Clay soil at 2" below the surface	4	LCI observed clay soil at 2" depth
2	6	D 3.2	Depth of storage < 0.5' from surface or bottom of outlet	0	Depth of storage is 0.5'-< 2' from surface or bottom of outlet	3	LCI Observed 6-12" ponding throughout most of the wetland
3	7	H 1.2	Seasonally flooded hydroperiod	0	Seasonally flooded and seasonally saturated hydroperiods	1	LCI Observed additional undelineated wetland area adjacent that is seasonally saturated (15% of total area)
4	8	H 1.5	NO ¼ acre of thin stemmed persistent veg or woody branches in areas of permanent or seasonal inundation	1	¼ acre of thin stemmed persistent veg or woody branches in areas of permanent or seasonal inundation	2	Seasonally inundated area is dominated by willow with branches throughout the water (.33 acres)
5	9	H 2.1	Buffer does not meet any of the above criteria	1	No paved areas or bldgs. w/in 50m of wetland for >50% of circumference	2	LCI used AutoCAD to determine that 46% of the circumference is adjacent to paved road
6	10	H 2.3	None	0	Riparian: wetland is adjacent to riparian area	1	Columbia River adjacent to wetland: Anchor report says that "site hydrology is…primarily driven by Columbia R. water levels"; meets WDFW definition of influence of GW and b/c it is in 100-yr floodplain

Wetland CR-F at site visit:

1. Item 1: Sample for clay, as noted above. Sample for organic soil at same depth.

   LCI observed clay soils at 2" depth; 3" soil ribbon, see photo.

2. Item 2: Check depth of storage, look for water marks on culvert or OHWM; > 0.5'?

   LCI observed inundation 6-12" depth throughout the majority of the wetland.

3. Item 4: Hydroperiods: check for permanent, occasional, seasonal inundation, and saturated only; estimate areas (need 10% of wetland [0.04 acre] or a ¼ acre)

   LCI observed 15% of area to be seasonally saturated and 85% seasonally inundated.

4. Item 5: Check for persistent thin-stemmed/woody vegetation acreage in permanent and seasonally inundated areas; is it at least a ¼ acre?

   LCI observed woody stems throughout 0.33 acres of seasonally inundated area.

5. Item 6: Check for paved vs. gravel roads w/in 50m and 25m. Total circumference of the wetland is 796'. Length adjacent to paved road is 370' (46%).

Calculations: Additional wetland area is approximately 2,429 SF (15%) saturated, emergent wetland. Original wetland is 14,278 SF (85%) of seasonally inundated, scrub-shrub wetland with many small branches in the water. New total area is: 16,707 SF (0.38 acre)

Conclusions: Original 47 points + 17 points = 64 points (Category II). Additional 1 point possible from Item 6.

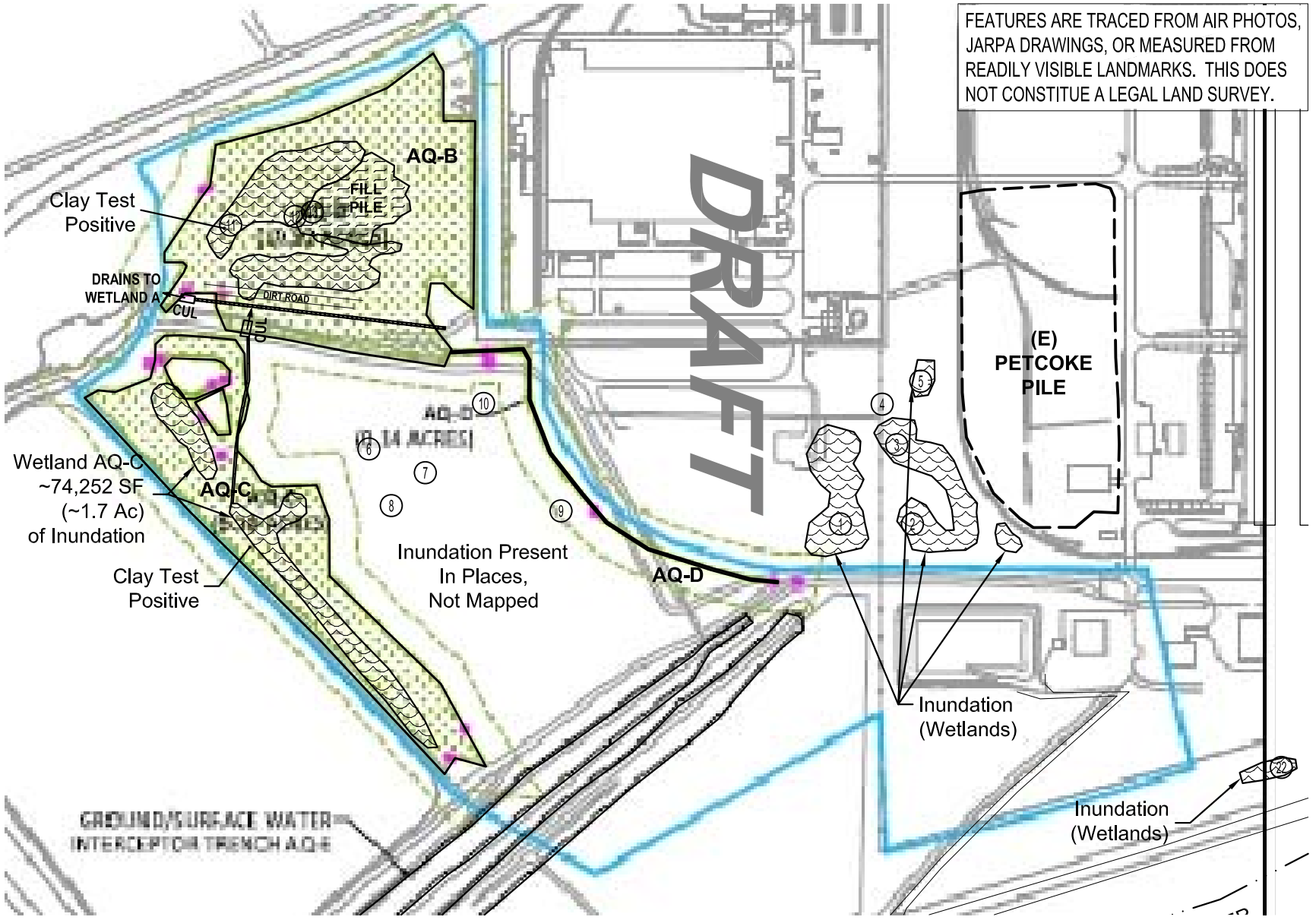
Conclusion

LCI found additional wetlands not described previously in the Anchor QEA or Coldwater Resources delineation reports. LCI also found that wetlands AQ-B, AQ-C, CR-A/D, CR-B, CR-C, and CR-F all qualify for Category II status. LCI recommends a wet-season delineation to determine the actual presence and extent of on-site wetlands.

Sincerely,

Joseph D. Leyda, MA
Professional Wetland Scientist
Certified Ecologist

Attachments: Figures 1-4, Photos, Data



LCI
LEYDA CONSULTING INCORPORATED
2405 EAST NINTH ST
VANCOUVER, WA
(360) 510-2737
www.leydaconsulting.com

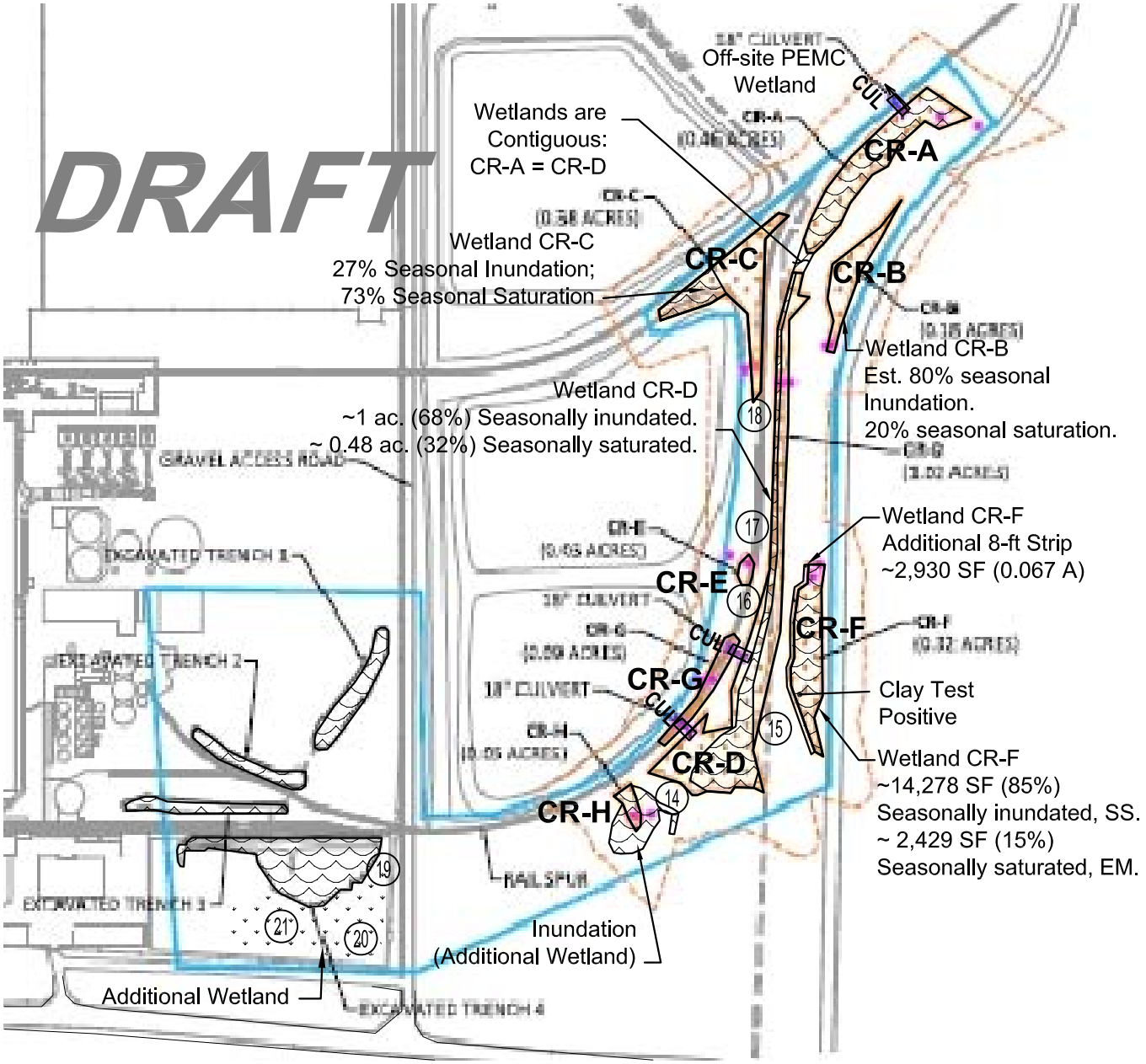
DRAFT WETLAND RECONNAISSANCE MAP

MILLENNIUM BULK LOGISTICS - 4029 INDUSTRIAL WAY
COWLITZ COUNTY, WASHINGTON

MARCH 23 2011

FOR: EARTHJUSTICE

FIGURE 1



LEGEND

REPORTED WETLAND

NEW WETLAND

20 SAMPLE PLOT

INUNDATION

FILL

FEATURES ARE TRACED FROM AIR PHOTOS, JARPA DRAWINGS, OR MEASURED FROM READILY VISIBLE LANDMARKS. THIS DOES NOT CONSTITUE A LEGAL LAND SURVEY.

N TRUE

N PROJECT

0 300

LEYDA CONSULTING INCORPORATED
LCI
2405 EAST NINTH ST
VANCOUVER, WA
(360) 510-2737
www.leydaconsulting.com

DRAFT WETLAND RECONNAISSANCE MAP

MILLENNIUM BULK LOGISTICS - 4029 INDUSTRIAL WAY
COWLITZ COUNTY, WASHINGTON

MARCH 23 2011

FOR: EARTHJUSTICE

FIGURE 2

LEYDA CONSULTING INCORPORATED
LCI
2405 EAST NINTH ST
VANCOUVER, WA
(360) 510-2737
www.leydaconsulting.com

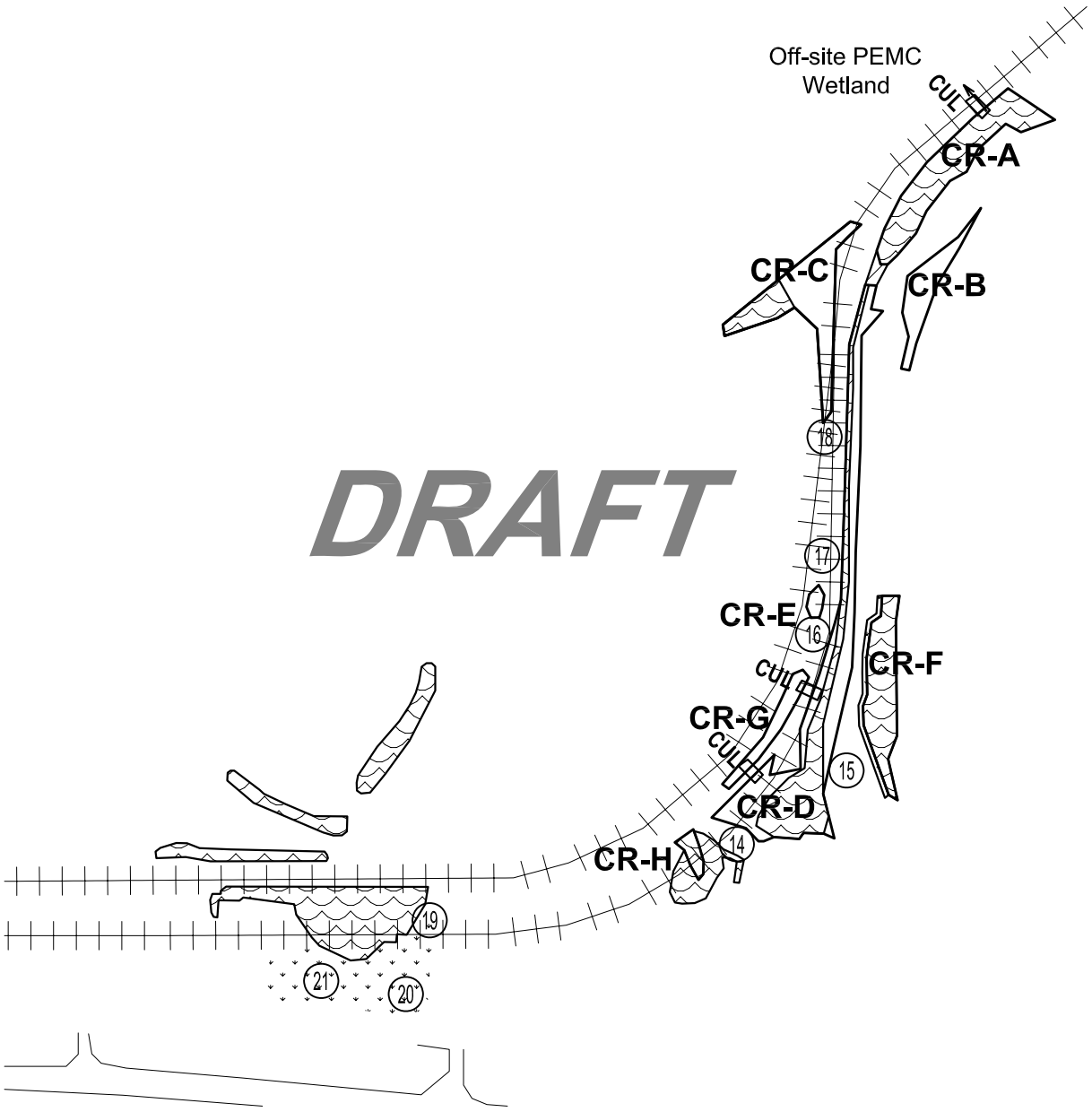
DRAFT ADDITIONAL IMPACTS - WEST

MILLENNIUM BULK LOGISTICS - 4029 INDUSTRIAL WAY
COWLITZ COUNTY, WASHINGTON

MARCH 23 2011

FOR: EARTHJUSTICE

FIGURE 3



LEGEND

REPORTED WETLAND

NEW WETLAND

20 SAMPLE PLOT

INUNDATION

FILL

FEATURES ARE TRACED FROM AIR PHOTOS, JARPA DRAWINGS, OR MEASURED FROM READILY VISIBLE LANDMARKS. THIS DOES NOT CONSTITUE A LEGAL LAND SURVEY.

N TRUE

N PROJECT

0 300

LEYDA CONSULTING INCORPORATED
LCI
2405 EAST NINTH ST
VANCOUVER, WA
(360) 510-2737
www.leydaconsulting.com

DRAFT ADDITIONAL IMPACTS - EAST

MILLENNIUM BULK LOGISTICS - 4029 INDUSTRIAL WAY
COWLITZ COUNTY, WASHINGTON

MARCH 23 2011

FOR: EARTHJUSTICE

FIGURE 4

Photo 1. Wetland near existing petcoke pile and in area of proposed coal pile.

Photo 2. Iron-rich water in ditch along road south of Sampling Points 1-4.

Photo 3. Sampling Point 1, in wetland near petcoke pile and in area of proposed coal pile.

Photo 4. Sampling Point 2, near petcoke pile and in area of proposed coal pile. View to north.

Photo 5. Sampling Point 2, near petcoke pile and in area of proposed coal pile. View to east.

Photo 6. Sampling Point 3, near petcoke pile and in area of proposed coal pile.

Photo 7. Puddle in petcoke pile, at base, inside containment barrier.

Photo 8. Puddle next to petcoke pile, outside containment barrier. Black dust is visible.

Photo 9. Close-up of puddle with black petcoke dust visible outside containment barrier.

Photo 10. Sampling Point 4, near petcoke pile and north of proposed coal pile.

Photo 11. Goose dropping and matted vegetation Black Mud Pit field, west of Wetland AQ-C.

Photo 12. Wetland and waterfowl in depression in Black Mud Pit field, west of Wetland AQ-C.

Photo 13. Clay ribbon from Wetland AQ-C.

Photo 14. Clay ribbon from Wetland AQ-C.

Photo 15. Sampling Point 6 view south, at proposed new rail track, in Anchor upland.

Photo 16. View north of Sampling Point 6, at proposed new rail track, in Anchor upland.

Photo 17. Sampling Point 7, near proposed track and conveyor in Anchor upland.

Photo 18. Sampling Point 8 view south, under proposed track and conveyor in Anchor upland.

Photo 19. Sampling Point 8 view north, under proposed track and conveyor in Anchor upland.

Photo 20. Sampling Point 10, near proposed conveyor in Anchor upland.

Photo 21. Wetland AQ-B outlet, drains to Wetland A. Wetland AQ-B is on the right.

Photo 22. Wetland AQ-B outlet. Duckweed found on beams around outlet.

Photo 23. Beaver-gnawed log along channel in Wetland AQ-B.

Photo 24. Clay ribbon from Wetland AQ-B at Sampling Point 11.

Photo 25. Sampling Point 11 in Wetland AQ-B, view north.

Photo 26. Beaver-gnawed log and stump in Wetland AQ-B.

Photo 27. Upturned black cottonwood tree showing shallow root system in Wetland AQ-B.

Photo 28. Sampling Point 12, at base of fill pile in Wetland AQ-B.

Photo 29. Sampling Point 13, on top of fill pile in Wetland AQ-B.

Photo 30. Barrel in Wetland AQ-B.

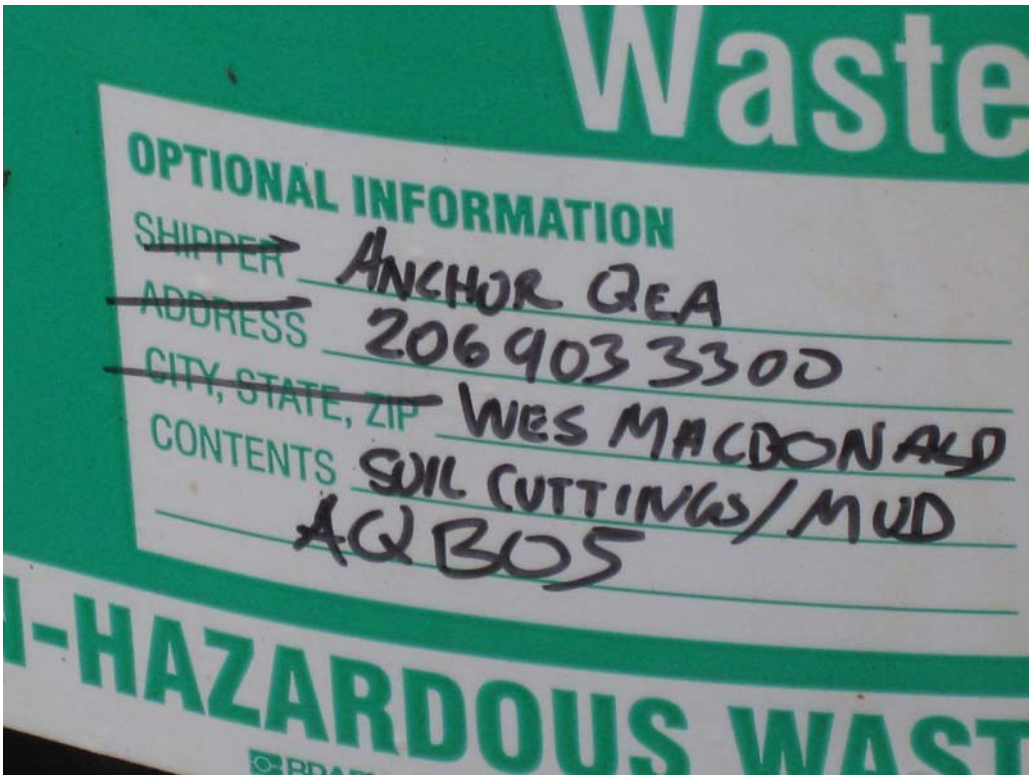


Photo 31. Barrel label.

Photo 32. Barrel labels.

Photo 33. Wetland A, view northwest from near Wetland AQ-B outlet.

Photo 34. Wetland A, view west from near Wetland AQ-B outlet.

Photo 35. Sampling Point 14, between Wetland CR-D and CR-H.

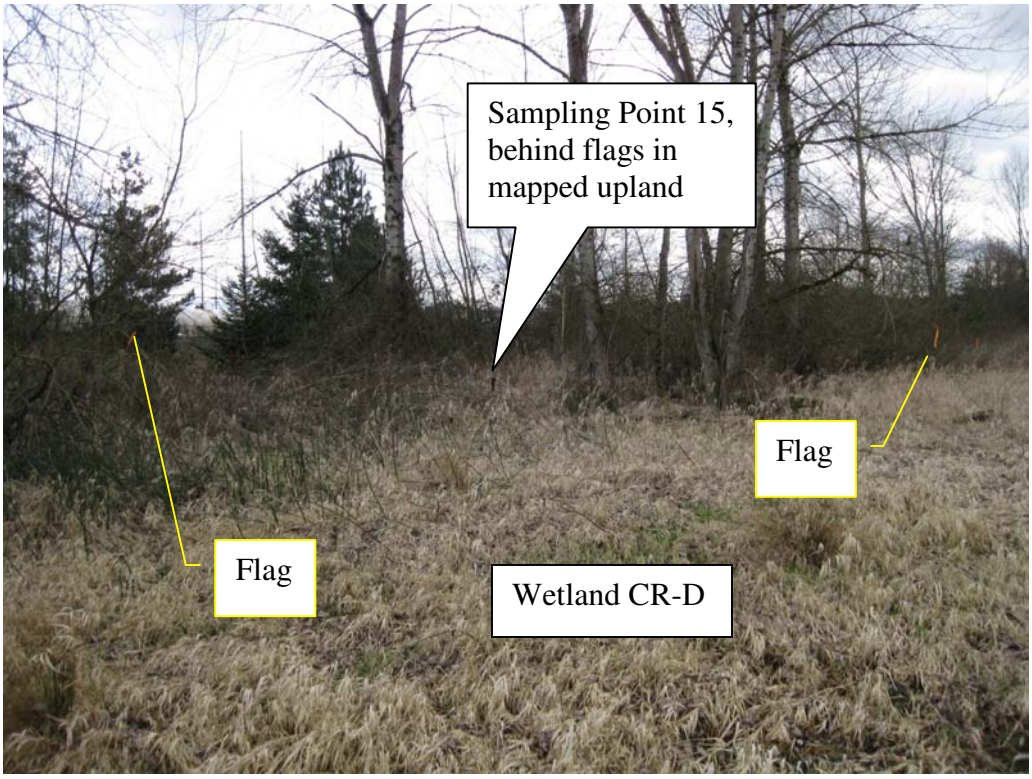


Photo 36. Sampling Point 15, in trees between Wetland CR-D and CR-F.

Photo 37. Sampling Point 16, facing the edge of Wetland CR-E, near proposed new track.

Photo 38. Sampling Point 17, facing Wetland CR-E, near proposed new track.

Photo 39. Sampling Point 18, south of Wetland CR-C, near proposed rail track.

Photo 40. Sampling Point 20, south of excavated pit and proposed rail track.

Photo 41. Sampling Point 21, view west.

Photo 42. Clay ribbon from Wetland CR-F.

Photo 43. Sampling Point 22, at base of levee facing facility fence.

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 1**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PUB2C

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In large cleared area, historically graded industrial area. In proposed coal pile area.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	1	N	FAC
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	1% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 99

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 0 (A)

Total Number of Dominant Species Across All Strata: 0 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 0 (A/B)

Prevalence Index worksheet:

Total % Cover of:			**Multiply by:**	
OBL species		x 1 =		
FACW species		x 2 =		
FAC species	1	x 3 =	3	
FACU species		x 4 =		
UPL species		x 5 =		
Column Totals:	1	(A)	3	(B)

Prevalence Index = B/A = 3.0

Hydrophytic Vegetation Indicators:

- _____ Dominance Test is >50%
- _____ Prevalence Index is ≤3.0[1]
- _____ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- _____ Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance or industrial uses. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-20	10YR 3/1	100					Sand	Fill sand, graded in past

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? Yes X No ___

Remarks: The soil has been historically disturbed by grading and is likely fill material, since it differs from the soil map unit texture and lacks horizons. However, the soil has a low chroma and is inundated during the growing season, and so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes X No ___ Depth (inches): 3 in

Water Table Present? Yes X No ___ Depth (inches): Surface

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): surface

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 2**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In proposed coal stockpile area, NW of existing petcoke pile. Soil and vegetation are disturbed.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Juncus effusus*	5	N	FACW
2. *Juncus bufonius*	20	Y	FACW
3. *Agrostis sp.*	10	N	FAC-W
4. *Hypochaeris radicata*	5	N	FACU
5. *Holcus lanatus*	20	Y	FAC
6. *Agropyron repens*	5	N	FAC
7.			
8.			
9.			
10.			
11.			
	60% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 45

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ Dominance Test is >50%
- ___ Prevalence Index is ≤3.0[1]
- ___ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Wetland Non-Vascular Plants[1]
- **X** Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance or industrial uses. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-16	2.5Y 3/1	80	7.5YR 3/4	5-20	C	M	Sand	Fill sand, graded in past
								Bands of clay also observed

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- X Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: The soil has been historically disturbed by grading and is likely fill material, since it differs from the soil map unit texture and lacks horizons. However, the soil has a low chroma and is inundated during the growing season, and so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes X No ___ Depth (inches): 0.5

Water Table Present? Yes X No ___ Depth (inches): Surface

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 3**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PUB2C

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In proposed coal stockpile area, NW of existing petcoke pile. Soil and vegetation are disturbed.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Agrostis sp.*	5	N	FAC-W
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	5% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 95

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: _____ (A)

Total Number of Dominant Species Across All Strata: _____ (B)

Percent of Dominant Species that are OBL, FACW, or FAC: _____ (A/B)

Prevalence Index worksheet:

Total % Cover of:			**Multiply by:**
OBL species		x 1 =	
FACW species		x 2 =	
FAC species	5	x 3 =	15
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	5	(A)	15 (B)

Prevalence Index = B/A = 3.0

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance or industrial uses. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-18	10 YR 3/1	100					Sand	Fill sand, graded in past

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: The soil has been historically disturbed by grading and is likely fill material, since it differs from the soil map unit texture and lacks horizons. However, the soil has a low chroma and is inundated during the growing season, and so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 4
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 4**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 17- Caples silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Near proposed coal stockpile area, NW of existing petcoke pile. Soil and vegetation are disturbed.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Holcus lanatus*	2	N	FAC
2. *Medicago lupulina*	0.5	N	FAC
3. *Agrostis sp.*	3	N	FAC-W
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	5.5% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: _____ (A)

Total Number of Dominant Species Across All Strata: _____ (B)

Percent of Dominant Species that are OBL, FACW, or FAC: _____ (A/B)

Prevalence Index worksheet:

Total % Cover of:			**Multiply by:**
OBL species		x 1 =	
FACW species		x 2 =	
FAC species	5.5	x 3 =	16.5
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	5.5 (A)		16.5 (B)

Prevalence Index = B/A = 3.0

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance or industrial uses. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-18	10 YR 3/1.5	100					Sand	Fill sand, graded in past

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? Yes X No ___

Remarks: The soil has been historically disturbed by grading and is likely fill material, since it differs from the soil map unit texture and lacks horizons. However, the soil has a low chroma and is inundated during the growing season, and so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 17 & filling

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 10

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks: The water table (free water in the soil pit) is expected to rise to near the level of saturation, and is reported here as "filling" because it continued to rise while the soil and vegetation data were collected.

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 5**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 17- Caples silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PUB2C

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Near proposed coal stockpile area, NW of existing petcoke pile. Soil and vegetation are disturbed.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	20	Y	FACW
2. *Juncus effusus*	5	Y	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	25% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 80

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ Dominance Test is >50%
- ___ Prevalence Index is ≤3.0[1]
- ___ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance or industrial uses. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 5

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-18	10YR 3/1	100					Sand	Fill sand, graded in past

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks: The soil has been historically disturbed by grading and is likely fill material, since it differs from the soil map unit texture and lacks horizons. However, the soil has a low chroma and is inundated during the growing season, and so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 7
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 6**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In field east of Wetland AQ-C, in area where conveyor and railroad track are proposed. This area was forested in a 2005 GoogleEarth air photo, and is now cleared of woody vegetation. Numerous woody debris piles are present. The vegetation is therefore disturbed within the last five years, and is treated as atypical.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	100	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Using Procedure 4.g on p. 105 and/or Procedure 5.b, a nearby undisturbed reference site is located in the forested wetland to the north, which is hydrophytic vegetation (black cottonwood, *Populus balsamifera*). Also, Procedure 5.a on p. 109 says that plants observed growing in saturated soils are hydrophytic. Since saturated soils are present, wetland hydrology is positive, hydrophytic vegetation prior to disturbance can be assumed present.

SOIL

Sampling Point: 6

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10	10 YR 3/2	70	10 YR 3/4	30	C	M	Silt loam	
10-18	10 YR 4/2	85	10 YR 3/4	10	C	M	Silt loam	Wood chunk in profile
			10YR 4/1	5	C	M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: Subsurface wood chunks indicate soil disturbance during logging operations. Although the soil has been disturbed, the layers are distinct and can be read. Wetland hydrology is present, so the soil is hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes ___	No ___	Depth (inches): ___	
Water Table Present?	Yes X	No ___	Depth (inches): 16 & rising	**Wetland Hydrology Present?** Yes X No ___
Saturation Present? (includes capillary fringe)	Yes X	No ___	Depth (inches): 4	

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks: The water table (free water in the soil pit) is expected to rise to near the level of saturation, and is reported here as "filling" because it continued to rise while the soil and vegetation data were collected.

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 7**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: East of AQ-C and 146 ft north of proposed conveyor. This area was forested in a 2005 GoogleEarth air photo, and is now cleared of woody vegetation. Numerous woody debris piles are present. The vegetation is therefore disturbed within the last five years, and is treated as atypical.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Juncus sp. (very small)*	2		FACW
2. *Phalaris arundinacea*	25	Y	FACW
3. *Poa sp.*	20	Y	
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	47% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: _____ (A)

Total Number of Dominant Species Across All Strata: _____ (B)

Percent of Dominant Species that are OBL, FACW, or FAC: _____ (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Using Procedure 4.g on p. 105 and/or Procedure 5.b, a nearby undisturbed reference site is located in the forested wetland to the north, which is hydrophytic vegetation (black cottonwood, *Populus balsamifera*). Also, Procedure 5.a on p. 109 says that plants observed growing in saturated soils are hydrophytic. Since saturated soils are present, wetland hydrology is positive, hydrophytic vegetation prior to disturbance can be assumed present.

SOIL

Sampling Point: 7

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-18	10 YR 4/2	85	10 YR 3/4	10	C	M	Silt loam	
			10 YR 4/1	5	C	M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): _____

Water Table Present? Yes X No ___ Depth (inches): 4 & rising

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 8**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification:

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: This area was forested in a 2005 GoogleEarth air photo, and is now cleared of woody vegetation. Numerous woody debris piles are present. The vegetation is therefore disturbed within the last five years, and is treated as atypical.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	95	Y	FACW
2. *Juncus effusus*	10		FACW
3. *Algae present*			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	105% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Using Procedure 4.g on p. 105 and/or Procedure 5.b, a nearby undisturbed reference site is located in the forested wetland to the north, which is hydrophytic vegetation (black cottonwood, *Populus balsamifera*). Also, Procedure 5.a on p. 109 says that plants observed growing in saturated soils are hydrophytic. Since saturated soils are present, wetland hydrology is positive, hydrophytic vegetation prior to disturbance can be assumed present.

SOIL

Sampling Point: 8

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-4	10 YR 3/1	100					Silt loam	
4-18	10 YR 3/2	60	10 YR 3/6	40	C	M	Silt loam	Prominent

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 4
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 9**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: About 30' from the proposed coal pile, and about 40' from the proposed conveyor. This area was forested in a 2005 GoogleEarth air photo, and is now cleared of woody vegetation. Numerous woody debris piles are present. The vegetation is therefore disturbed within the last five years, and is treated as atypical.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Agrostis sp.*	60	Y	FAC-W
2. *Phalaris arundinacea*	40	Y	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Using Procedure 4.g on p. 105 and/or Procedure 5.b, a nearby undisturbed reference site is located in the forested wetland to the north, which is hydrophytic vegetation (black cottonwood, *Populus balsamifera*). Also, Procedure 5.a on p. 109 says that plants observed growing in saturated soils are hydrophytic. Since saturated soils are present, wetland hydrology is positive, hydrophytic vegetation prior to disturbance can be assumed present.

SOIL

Sampling Point: 9

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 4/1	100					Loam	
2-16	10 YR 3/2	50	10 YR 4/1	40	C	M	Loam	
			10 YR 3/4	10	C	M	Loam	Distinct

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes X No ___ Depth (inches): 1

Water Table Present? Yes X No ___ Depth (inches): Surface

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 10**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: This area was forested in a 2005 GoogleEarth air photo, and is now cleared of woody vegetation. Numerous woody debris piles are present. The vegetation is therefore disturbed within the last five years, and is treated as atypical.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	100	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		
% Bare Ground in Herb Stratum:			

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Using Procedure 4.g on p. 105 and/or Procedure 5.b, a nearby undisturbed reference site is located in the forested wetland to the north, which is hydrophytic vegetation (black cottonwood, *Populus balsamifera*). Also, Procedure 5.a on p. 109 says that plants observed growing in saturated soils are hydrophytic. Since saturated soils are present, wetland hydrology is positive, hydrophytic vegetation prior to disturbance can be assumed present.

SOIL

Sampling Point: 10

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-16	10 YR 4/1	80	7.5 YR 4/6	10	C	M	Silt loam	Prominent
			10 YR 3/4	10	C	M	Silt loam	Distinct

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 6
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 11**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification:

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In Wetland AQ-B, west side.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Populus balsamifera*	35	Y	FAC
2.			
3.			
4.			
	35% = Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1. *Sambucus racemosa*	20	Y	FACU
2.			
3.			
4.			
5.			
	20% = Total Cover		

Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	100	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 66 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

_____ Prevalence Index is ≤3.0[1]

_____ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

_____ Wetland Non-Vascular Plants[1]

_____ Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 11

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-3	10 YR 3/1	90	7.5 YR 3/4	10	C	M	Clay loam	Prominent
3-12	10 YR 3/1	90	10 YR 3/4	10	C	M	Clay loam	Distinct
12-16	10 YR 4/1	75	10 YR 3/4	25	C	M	Clay loam	Distinct

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes X	No ___	Depth (inches):	8
Water Table Present?	Yes X	No ___	Depth (inches):	Surface
Saturation Present? (includes capillary fringe)	Yes X	No ___	Depth (inches):	Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 12**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: In Wetland AQ-B, at base of fill pile on west side. Paired with SP 13.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	100	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

_____ Prevalence Index is ≤3.0[1]

_____ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

_____ Wetland Non-Vascular Plants[1]

_____ Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 12

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-3	10YR 4/1	80	7.5 YR 3/4	20	C	M	Clay loam	Prominent
3-16	10 YR 3/1	60	7.5 YR 3/4	40	C	M	Clay loam	Prominent

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes X	No ___	Depth (inches):	9
Water Table Present?	Yes X	No ___	Depth (inches):	Surface
Saturation Present? (includes capillary fringe)	Yes X	No ___	Depth (inches):	Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 13**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.145305 | Long: -123.010000 | Datum:

Soil Map Unit Name: 127-Maytown silt loam, 0-3% slopes (contains 5% Godfrey, listed hydric) | NWI classification:

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**		**No**	**X**	
Hydric Soil Present?	**Yes**	.	**No**	**X**	**Is the Sampled Area within a Wetland?** **Yes** _____ **No** **X**
Wetland Hydrology Present?	**Yes**		**No**	**X**	

Remarks: On top of fill pile in Wetland AQ-B, several feet above the native soil elevation. Pair with SP 12.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1. *Unknown shrub*	80	Y	?
2.			
3.			
4.			
5.			
	80% = Total Cover		
Herb Stratum (Plot size:)			
1. *Festuca rubra*	10	Y	FAC
2. *Oxalis sp.*	5		FAC
3. *Cirsium vulgare*	20	Y	FACU
4. *Verbascum thapsus*	5		NL (UPL)
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	40% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: _____ (A)

Total Number of Dominant Species Across All Strata: _____ (B)

Percent of Dominant Species that are OBL, FACW, or FAC: _____ (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- _____ Dominance Test is >50%
- _____ Prevalence Index is ≤3.0[1]
- _____ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- _____ Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes** **No** **X**

Remarks: The Unknown Shrub is a dominant species, but it's indicator status is unknown, so the determination cannot be completed. The determination must be made on soils and hydrology.

SOIL

Sampling Point: 13

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-6	10 YR 3/2	100					Loam	
6-16	10 YR 3/2	100					Sandy loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** **X**

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B)**
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B)**
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): _____

Water Table Present? Yes ___ No X Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes ___ No X Depth (inches): _____

Wetland Hydrology Present? **Yes** ___ **No** **X**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 14**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 199-Snohomish silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: East side, between Wetland CR-H and CR-D.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Equisetum telmateia*	70	Y	FACW
2. *Festuca rubra*	60	Y	FAC
3. *Cirsium vulgare*	10		FACU
4. *Holcus lanatus*	5		FAC
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	145% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 14

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 2/1	100					Loamy sand	
2-16	10 YR 3/1	100					Loamy sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: the soil has a low chroma and is saturated during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 8

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 7

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 15**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 199-Snohomish silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PFOE

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Populus balsamifera*	70	Y	FAC
2.			
3.			
4.			
	70% = Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	90	Y	FACW
2. *Equisetum hyemale*	5		FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	95% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 5

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

_____ Prevalence Index is ≤3.0[1]

_____ Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

_____ Wetland Non-Vascular Plants[1]

_____ Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL **Sampling Point: 15**

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 2/1	100					Loamy sand	
2-9	10 YR 3/1	90	10 YR 3/4	10	C	M	Loamy sand	Distinct
9-16	10YR 3/1	80	10 YR 3/4	20	C	M	Loamy sand	Distinct

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- **X** Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** **X** **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- **X** High Water Table (A2)
- **X** Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 10

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 8

Wetland Hydrology Present? **Yes** **X** **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 16**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 199-Snohomish silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	80	Y	FAC
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	80% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 20

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 16

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 3/1	100					Sandy loam	
2-16	2.5 Y 3/1	100					Sandy loam	Quarry spall at 16”

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: the soil has a low chroma and is saturated during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 8

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 6

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 17**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 199-Snohomish silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	80	Y	FAC
2. *Unknown forb*	1		?
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	81% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 20

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 17

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 2/1	100					Sandy loam	
2-16	2.5 Y 3/1	80	2.5 Y 4/1	15	C	M	Sandy loam	
			10 YR 4/4	5	C	M	Sandy loam	Prominent

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 10

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 7

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 18**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 199-Snohomish silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: South of CR-C. The soil profile contains mixed textures, which indicates past disturbance.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Phalaris arundinacea*	40	Y	FACW
2. *Schedonorus phoenix*	20	Y	FAC
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	60% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 20 (flooded)

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**
OBL species	x 1 =	
FACW species	x 2 =	
FAC species	x 3 =	
FACU species	x 4 =	
UPL species	x 5 =	
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 18

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-9	2.5 Y 3/1	100					Sandy loam	
9-16	2.5 Y 3/1	80	10 YR 3/2	15	C	M	Sandy loam	Chunks of 10 YR 3/2 w/ 20% 7.5 YR 3/4, silt loam texture
			7.5 YR 3/4	5	C	M	Silt loam	Distinct

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: The different textures in the soil profile indicate past disturbance and mixing of soils below 9 inches deep. Therefore, the soils are atypical. The soil has a low chroma and is saturated during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- X Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 3
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 19**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 17- Caples silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Near excavated pit, about 55' south of the existing tracks. The vegetation is likely mowed and regularly disturbed.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	90	Y	FAC
2. *Agrostis exarata*	10		FAC
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		
% Bare Ground in Herb Stratum:			

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: Vegetation is disturbed by maintenance mowing. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 19

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-2	10 YR 2/2	100					Silty clay loam	
2-16	10 YR 3/1	90	7.5 YR 3/4	10	C	M	Silty clay loam	Prominent

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): 11 & rising

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 5

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 20**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 17- Caples silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Near excavated pit. Soil profile shows angular rock at 10 inches below the surface, indicating past grading and disturbance.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		
Herb Stratum (Plot size:)			
1. *Agrostis exarata*	80	Y	FACW
2. *Schedonorus phoenix*	20	Y	FAC
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 5

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 20

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-6	10 YR 3/1	80	10 YR 3/6	20	C	M	Loam	Prominent
6-16	10 YR 3/1	70	10 YR 3/6	30	C	M	Loam	Prominent. Angular rock at 10 inches.

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- X Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks: The presence of angular rock indicates past grading and soil disturbance. Therefore, the soils are atypical. The soil has a low chroma and is saturated during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes X No ___ Depth (inches): Surface

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No** ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 21**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-3

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.134710 | Long: -122.992757 | Datum:

Soil Map Unit Name: 17- Caples silty clay loam, 0-3% slopes (listed hydric) | NWI classification: PEME

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation _____ Soil X or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Near excavated pit. The soil profile has angular rock, indicating past grading and disturbance.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	90	Y	FAC
2. *Agrostis exarata*	10		FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	100% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum:

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

X Dominance Test is >50%

Prevalence Index is ≤3.0[1]

Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

Wetland Non-Vascular Plants[1]

Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks:

SOIL

Sampling Point: 21

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-16	10 YR 3/1	80	7.5 YR 3/4	20	C	M	Sandy loam	Prominent
								Angular gravel at 8 inches

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? **Yes** X **No** ___

Remarks: The presence of angular rock indicates past grading and soil disturbance. Therefore, the soils are atypical. The soil has a low chroma and is saturated during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes ___	No X	Depth (inches): ___		
Water Table Present?	Yes X	No ___	Depth (inches): 4	**Wetland Hydrology Present?**	**Yes** X **No** ___
Saturation Present? (includes capillary fringe)	Yes X	No ___	Depth (inches): 4		

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: 4029 Industrial Way | City/County: Cowlitz County | Sampling Date: 03/08/2011

Applicant/Owner: Owner: Millennium Bulk Logistics | State: Washington | **Sampling Point: 22**

Investigator(s): Joseph Leyda | Section, Township, Range: T8N R3W S38

Landform (hillslope, terrace, etc.): Floodplain, Columbia R. | Local relief (concave, convex, none): Concave | Slope (%): 0-1

Subregion (LRR): LRR A Northwest Forests and Coast | Lat: 46.142468 | Long: -123.005713 | Datum:

Soil Map Unit Name: 5- Arents,, 0-5% slopes | NWI classification: PEMC

Are climatic / hydrologic conditions on the site typical for this time of year? Yes **X** No _____ (If no, explain in Remarks.)

Are Vegetation X Soil _____ or Hydrology _____ significantly disturbed? Are "Normal Circumstances" present? Yes ___ No X

Are Vegetation _____ Soil _____ or Hydrology _____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	**Yes**	**X**	**No**		
Hydric Soil Present?	**Yes**	**X**	**No**	**Is the Sampled Area within a Wetland?**	**Yes X No**
Wetland Hydrology Present?	**Yes**	**X**	**No**		

Remarks: Inundated area along levee. The vegetation is disturbed by mowing.

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	% =Total Cover		

Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
	% = Total Cover		

Herb Stratum (Plot size:)			
1. *Schedonorus phoenix*	10	Y	FAC
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	10% = Total Cover		

Woody Vine Stratum (Plot size:)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum: 90

Dominance Test worksheet:

Number of Dominant Species that are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species that are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		**Multiply by:**	
OBL species		x 1 =	
FACW species		x 2 =	
FAC species		x 3 =	
FACU species		x 4 =	
UPL species		x 5 =	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- Dominance Test is >50%
- Prevalence Index is ≤3.0[1]
- Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- Wetland Non-Vascular Plants[1]
- X Problematic Hydrophytic Vegetation[1] (Explain)*

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? **Yes X No**

Remarks: The wetland is regularly mowed during levee maintenance, so the vegetation is disturbed and atypical. The area is nearly flat, and wetland hydrology is present, and soils are present or disturbed. The wetland determination is based on the other two parameters according to Procedure 4.e(4) on p. 105. Since the wetland determination is positive based on the other parameters, this one is marked present.

SOIL

Sampling Point: 22

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-6	10 YR 3/1	100					Gravelly loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) (**except MLRA 1**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- X Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? Yes X No ___

Remarks: Gravel hard pan at 6 inches deep. The soil has a low chroma and is flooded during the growing season, so it is considered hydric by definition (NRCS, http://soils.usda.gov/use/hydric/criteria.html).

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) (**except MLRA 1, 2, 4A, and 4B**)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) (**LRR A**)
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) (**MLRA 1, 2, 4A, and 4B**)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) (**LRR A**)
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present?	Yes	X	No	___	Depth (inches): 2
Water Table Present?	Yes	X	No	___	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes	X	No	___	Depth (inches): Surface

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Biological Assessment

MORROW PACIFIC PROJECT

anderson perry & associates, inc.
engineering · surveying · natural resources

1901 N. Fir Street
La Grande, Oregon 97850
(541) 963-8309
www.andersonperry.com

April 2012

BIOLOGICAL ASSESSMENT

FOR

THE MORROW PACIFIC PROJECT

MORROW AND COLUMBIA COUNTIES, OREGON,
AND THE COLUMBIA RIVER NAVIGATION CHANNEL,
PORT OF MORROW TO THE COLUMBIA BAR

APRIL 2012

Prepared for:

Coyote Island Terminal, LLC
Ambre Energy North America

Prepared by:

ANDERSON PERRY & ASSOCIATES, INC.

Civil Engineers

La Grande, Oregon
Walla Walla, Washington

Copyright 2012 by Anderson Perry & Associates, Inc. Job No. 1199-462

TABLE OF CONTENTS

List of Acronyms A-1

Executive Summary ES-1

Table ES-1 Listed Species Affected by the Morrow Pacific Project ES-2

1.0 Introduction 1-1
1.1 Background 1-1
1.2 Project Information 1-2
1.3 Action Area 1-2
1.4 Project Purpose and Need 1-3

2.0 Evaluation Methods 2-1

3.0 Project Description 3-1
3.1 Port of Morrow 3-1
3.1.1 Coal Storage Building and Staging 3-1
3.1.2 Coal Conveyer System 3-1
3.1.3 Loading Dock 3-2
3.1.4 Dock Walkway 3-2
3.1.5 Dolphins 3-3
3.1.6 Construction 3-3
3.1.6.1 Upland Facilities 3-3
3.1.6.2 In-water Facilities 3-4
3.1.7 Pile Driving 3-5
3.1.7.1 Piling Installation 3-5
3.1.7.2 Distance to Underwater Sound Thresholds 3-7
3.1.8 Equipment 3-10
3.1.9 Restoration 3-11
3.1.10 Site Operation 3-11
3.2 Columbia River Between the Port of Morrow and Port Westward 3-11
3.3 Port Westward and Columbia River/Pacific Ocean 3-12

Table 3-1 Summary of Pilings Needed for the Port of Morrow Construction 3-6
Table 3-2 Impact Hammer Use at the Port of Morrow 3-6
Table 3-3 Fish Injury and Disturbance Thresholds for Underwater Construction Activity 3-7
Table 3-4 Underwater Distance to Noise Thresholds for Pilings Installed at the Port of Morrow 3-9
Table 3-5 Summary of Barge and Tow Traffic per Year at Bonneville Dam for Project Full Capacity 3-12
Table 3-6 Summary of OGV Traffic per Year in the Lower Columbia River for Project Full Capacity 3-13

4.0 Natural History and Species Occurrence 4-1
4.1 Steelhead 4-5
4.1.1 General Background Pertinent to the Columbia River 4-5
4.1.2 Affected Distinct Population Segments 4-6
4.1.2.1 Upper Columbia River DPS 4-6
4.1.2.2 Middle Columbia River DPS 4-6
4.1.2.3 Lower Columbia River DPS 4-7
4.1.2.4 Upper Willamette River DPS 4-7
4.1.2.5 Snake River Basin DPS 4-8
4.1.3 Critical Habitat 4-9
4.2 Chinook Salmon 4-9
4.2.1 General Background Pertinent to the Columbia River 4-11
4.2.2 Affected Evolutionarily Significant Units 4-11
4.2.2.1 Upper Columbia River Spring-run ESU 4-11
4.2.2.2 Lower Columbia River ESU 4-12
4.2.2.3 Snake River Fall-run ESU 4-12
4.2.2.4 Snake River Spring/summer-run ESU 4-13
4.2.2.5 Upper Willamette River ESU 4-14
4.2.3 Critical Habitat 4-14
4.2.3.1 Upper Columbia River Spring-run ESU, Lower Columbia River ESU, Upper Willamette River ESU 4-14
4.2.3.2 Snake River Spring/summer-run ESU, Snake River Fall-run ESU 4-14
4.3 Chum Salmon – Columbia River ESU 4-15
4.3.1 Current Status 4-15
4.3.2 General Background Pertinent to the Columbia River 4-15
4.3.3 Presence in Action Area 4-16
4.3.4 Critical Habitat 4-16
4.4 Coho Salmon – Lower Columbia River ESU 4-16
4.4.1 Current Status 4-16
4.4.2 General Background Pertinent to the Columbia River 4-16
4.4.3 Presence in Action Area 4-17
4.4.4 Critical Habitat 4-17
4.5 Sockeye Salmon – Snake River ESU 4-17
4.5.1 Current Status 4-17
4.5.2 General Background Pertinent to the Columbia River 4-17
4.5.3 Presence in Action Area 4-18
4.5.4 Critical Habitat 4-18
4.6 Bull Trout – Columbia River DPS 4-18
4.6.1 Current Status 4-18
4.6.2 General Background Pertinent to the Columbia River 4-18
4.6.3 Presence in Action Area 4-19
4.6.4 Critical Habitat 4-19

4.7 Green Sturgeon – Southern DPS 4-20
4.7.1 Current Status 4-20
4.7.2 General Background Pertinent to the Columbia River 4-21
4.7.3 Presence in Action Area 4-21
4.7.4 Critical Habitat 4-21
4.8 Eulachon – Southern DPS 4-22
4.8.1 Current Status 4-22
4.8.2 General Background Pertinent to the Columbia River 4-22
4.8.3 Presence in Action Area 4-23
4.8.4 Critical Habitat 4-23
4.9 Steller Sea Lion – Eastern DPS 4-24
4.9.1 Current Status 4-24
4.9.2 General Background Pertinent to the Columbia River 4-24
4.9.3 Presence in Action Area 4-25
4.9.4 Critical Habitat 4-25
4.10 Killer Whale – Southern Resident DPS 4-25
4.10.1 Current Status 4-25
4.10.2 General Background Pertinent to the Columbia River 4-25
4.10.3 Presence in Action Area 4-26
4.10.4 Critical Habitat 4-26
4.11 Other Whales – Humpback, Fin, Sei, Sperm, and Blue 4-26
4.11.1 Current Status 4-26
4.11.2 General Background Pertinent to the Columbia River 4-26
4.11.3 Presence in Action Area 4-27
4.11.4 Critical Habitat 4-27
4.12 Leatherback Turtle 4-27
4.12.1 Current Status 4-27
4.12.2 General Background Pertinent to the Columbia River 4-27
4.12.3 Presence in Action Area 4-28
4.12.4 Critical Habitat 4-28
4.13 Other Sea Turtles – Green, Loggerhead, and Olive Ridley 4-28
4.13.1 Current Status 4-28
4.13.2 General Background Pertinent to the Columbia River 4-28
4.13.3 Presence in Action Area 4-29
4.13.4 Critical Habitat 4-29

Table 4-1 ESA Listed and Proposed Species in the Action Area 4-1
Table 4-2 Timing of Fish Presence in the Columbia River at Port of Morrow (RM 271) 4-3
Table 4-3 Timing of Fish Presence in the Columbia River at Port Westward (RM 53) 4-4

5.0 Baseline Conditions 5-1
5.1 Port of Morrow 5-1

5.1.1 Upland Facilities 5-1
5.1.2 In-water Facilities 5-1
5.2 Columbia River Between the Port of Morrow and Port Westward 5-1
5.3 Port Westward and Western Columbia River/Pacific Ocean 5-7

Table 5-1 Matrix of Pathways and Indicators for Pacific Salmon and Steelhead 5-3
Table 5-2 Matrix of Pathways and Indicators for Columbia River Bull Trout 5-4
Table 5-3 Pollutants Present in the Columbia River in the Action Area 5-5

6.0 Analysis of Effect 6-1
6.1 Effects on NMFS and USFWS Matrix Indicators 6-1
6.1.1 Port of Morrow 6-1
6.1.2 Columbia River Between the Port of Morrow and Port Westward 6-3
6.1.3 Port Westward and Columbia River/Pacific Ocean 6-4
6.2 Noise Effects 6-5
6.3 Ship Strike Effects 6-5
6.4 Habitat Effects 6-6
6.5 Effects to Specific Species 6-7
6.5.1 Direct Harm 6-7
6.5.1.1 Salmonids 6-7
6.5.1.2 Green Sturgeon 6-9
6.5.1.3 Eulachon 6-9
6.5.1.4 Steller Sea Lion 6-10
6.5.1.5 Killer Whale, Leatherback Turtle, Other Whales – Humpback, Fin, Sei, Sperm, Blue; Other Turtles – Green, Loggerhead, Olive Ridley 6-10
6.5.2 Critical Habitat Impacts 6-11
6.5.2.1 Steelhead: UCR DPS, MCR DPS, LCR DPS, UWR DPS, SR Basin DPS; Chinook Salmon: UCR Spring-run ESU, LCR ESU, UWR ESU; Chum Salmon: CR ESU 6-11
6.5.2.2 Chinook Salmon: SR Fall-run ESU, SR Spring/summer-run ESU, Sockeye Salmon: SR ESU 6-13
6.5.2.3 Coho Salmon: LCR ESU 6-14
6.5.2.4 Bull Trout: CR DPS 6-14
6.5.2.5 Green Sturgeon: Southern DPS 6-15
6.5.2.6 Eulachon: Southern DPS 6-16
6.5.2.7 Steller Sea Lion: Eastern DPS 6-17
6.5.2.8 Killer Whale: Southern Resident DPS 6-17
6.5.2.9 Other Whales: Humpback, Fin, Sei, Sperm, Blue 6-17
6.2.3.10 Leatherback Turtle 6-17
6.2.3.11 Other Turtles: Green, Loggerhead, Olive Ridley 6-17
6.5.3 Indirect Impacts 6-18

7.0 Conservation Measures 7-1

8.0 Essential Fish Habitat Consultation 8-1
8.1 Pacific Coast Salmon 8-1
8.2 Coastal Pelagic Species 8-2
8.3 Pacific Coast Groundfish 8-3

Table 8-1 Species in the Action Area Potentially Affected by EFH Regulations 8-4

9.0 Interrelated and Interdependent Effects 9-1

10.0 Cumulative Effects 10-1

11.0 Finding of Effect 11-1
11.1 Statement of Take for Fish 11-1
11.2 Steelhead and Critical Habitat 11-1
11.2.1 UCR DPS, MCR DPS, SR DPS 11-1
11.2.2 LCR DPS, UWR DPS 11-2
11.3 Chinook Salmon and Critical Habitat 11-2
11.3.1 UCR Spring-run ESU, SR Fall-run ESU, SR Spring/summer-run ESU 11-2
11.3.2 LCR ESU, UWR ESU 11-3
11.4 Columbia River ESU Chum Salmon and Critical Habitat 11-4
11.5 Lower Columbia River ESU Coho Salmon 11-4
11.6 Snake River ESU Sockeye Salmon and Critical Habitat 11-5
11.7 Columbia River DPS Bull Trout and Critical Habitat 11-5
11.8 Southern DPS Green Sturgeon and Critical Habitat 11-6
11.9 Southern DPS Eulachon and Critical Habitat 11-7
11.10 Eastern DPS Steller Sea Lion and Critical Habitat 11-7
11.11 Southern Resident DPS Killer Whale and Critical Habitat 11-8
11.12 Other Whales – Humpback, Fin, Sei, Sperm, Blue 11-8
11.13 Leatherback Turtle and Critical Habitat 11-8
11.14 Other Turtles – Green, Loggerhead, and Olive Ridley 11-9

12.0 References 12-1

Appendix A – Figures
Figure 1A – Port of Morrow to Columbia Bar Project Corridor Map
Figure 1B – Port of Morrow Site Location and Vicinity Maps
Figure 1C – Port Westward Site Location and Vicinity Maps
Figure 2A – Port of Morrow Site Aerial Photograph – 2011
Figure 2B – Port Westward Site Aerial Photograph – 2011
Figure 3A – Port of Morrow Site Tax Lot Map
Figure 3B – Port Westward Site Tax Lot Map
Figure 4 – Conceptual Port of Morrow Facility
Figure 5 – Covered Barge
Figure 6 – Port of Morrow Site – Proposed Mooring and Storage Facilities
Figure 7 – Distance to Underwater Thresholds for Fish

Figure 8 – Port of Morrow Site On-Site Mitigation Detail
Figure 9 – Port Westward – Aerial View Transloading Operation
Figure 10 – Port Westward Transloading Operation

Appendix B – Project Site Photographs

Appendix C – Project Plan Sheets

Appendix D – Agency Correspondence

LIST OF ACRONYMS

BA	Biological Assessment
BMP	Best Management Practice
dB	Decibel
CALTRANS	California Department of Transportation
CFR	Code of Federal Regulations
CR	Columbia River
DEQ	Oregon Department of Environmental Quality
DPS	Distinct Population Segment
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ESCP	Erosion and Sediment Control Plan
ESU	Evolutionarily Significant Unit
FHWA	Federal Highway Administration
FHWG	Fisheries Hydroacoustic Working Group
FPC	Fish Passage Center
FR	Federal Register
HAPC	Habitat Areas of Particular Concern
HDPE	High-Density Polyethylene
LCFRB	Lower Columbia Fish Recovery Board
LCR	Lower Columbia River
m	Meter
MCR	Middle Columbia River
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
NPCC	Northwest Power and Conservation Council
ODFW	Oregon Department of Fish and Wildlife
OGV	Ocean-Going Vessel
OHWE	Ordinary High Water Elevation
ORBIC	Oregon Biodiversity Information Center
OWRD	Oregon Water Resources Department
PCE	Primary Constituent Element
PFMC	Pacific Fisheries Management Council
RM	River Mile
RMS	Root Mean Square Pressure
SAR	Stock Assessment Report
SEL	Sound Exposure Level
SF	Square Feet
SR	Snake River
SRB	Snake River Basin
SWPP	Stormwater Pollution Prevention Plan
UCR	Upper Columbia River
USACE	U.S. Army Corps of Engineers

USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWR	Upper Willamette River
W.M.	Willamette Meridian
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

Coyote Island Terminal, LLC, a division of Ambre Energy North America, has contracted with Anderson Perry & Associates, Inc., to prepare a Biological Assessment (BA) and Section 10 Permit application for the Morrow Pacific project. The project is funded by Ambre Energy North America. A permit from the U.S. Army Corps of Engineers (USACE) will be required for in-water work, which constitutes the federal nexus. Endangered Species Act (ESA) consultation will be initiated by the USACE.

The purpose of this project is to develop an environmentally responsible coal transfer facility in the Pacific Northwest for export of low-sulfur Montana coal to United States trade allies in Asia. The project was designed to minimize train traffic through urban areas, reduce the exposure of coal to the environment, and use existing infrastructure while minimizing impacts to the environment. The project involves transporting coal on existing rail lines to a new coal handling facility near Boardman, Oregon (Morrow County), transloading the coal by a telescoping chute to enclosed barges and transporting it down the Columbia River to an existing dock near Clatskanie, Oregon (Columbia County), and then transferring the coal through enclosed conveyors from barges to ocean-going vessels (OGV) for export.

Construction will only occur at the Port of Morrow site near Boardman, and will take approximately 10 to 12 months. Construction at this site includes installation of mooring and breasting dolphins, installation of a walkway and enclosed conveyor, construction of the upland coal storage facility, and planting/site restoration. The recommended in-water work window for the portion of this project in Morrow County is December 1 to March 31, when salmonid abundance in the area is at seasonal minimums, and all work below the ordinary high water elevation (OHWE) will take place during this period. Work outside of the OHWE may occur year-round as weather permits. Site restoration will include seeding disturbed upland areas and planting woody species on the disturbed riverbank areas.

Other activities that will take place as part of the proposed project include barge traffic downstream in the existing Columbia River navigation channel to Port Westward, near Clatskanie, and transloading the coal from the barges to OGV. The coal will then be shipped out the Columbia River via established shipping lanes. No in-water or terrestrial construction activities are planned for the Port Westward site, as there is an existing dock at the site.

The proposed project will result in unavoidable impacts to protected species and critical habitat as project activities take place. Impacts are expected to be primarily behavioral and not likely to result in mortality. Based on this conclusion and the implementation of conservation measures during project construction, and assuming compliance with all other permit conditions, it is anticipated that the proposed project will have effects on listed species, designated critical habitat, and Essential Fish Habitat (EFH), as shown in Table ES-1.

Table ES-1. Listed Species Affected by the Morrow Pacific Project

Species	ESU[1]/DPS[2]	ESA Determination	Critical Habitat Determination	EFH Determination
Steelhead *(Oncorhynchus mykiss)*	Upper Columbia River DPS	LTAA[3]	LTAM[4]	--[5]
	Middle Columbia River DPS	LTAA	LTAM	
	Lower Columbia River DPS	LTAA	LTAM	
	Upper Willamette River DPS	LTAA	LTAM	
	Snake River Basin DPS	LTAA	LTAM	
Chinook salmon *(Oncorhynchus tshawytscha)*	Upper Columbia River spring-run ESU	LTAA	LTAM	LTAA
	Lower Columbia River ESU	LTAA	LTAM	
	Snake River fall-run ESU	LTAA	LTAM	
	Snake River spring/summer-run ESU	LTAA	LTAM	
	Upper Willamette River ESU	LTAA	LTAM	
Chum salmon (*Oncorhynchus keta)*	Columbia River ESU	LTAA	LTAM	--
Coho salmon (*Oncorhynchus kisutch)*	Lower Columbia River ESU	LTAA	--	LTAA
Sockeye salmon (*Oncorhynchus nerka)*	Snake River ESU	LTAA	LTAM	--
Bull trout (*Salvelinus confluentus)*	Columbia River DPS	LTAA	LTAM	--
Green sturgeon (*Acipenser medirostris)*	Southern DPS	LTAA	LTAM	--
Eulachon (*Thaleichthys pacificus)*	Southern DPS	LTAA	LTAM	--
Steller sea lion (*Eumetopias jubatus)*	Eastern DPS	NLTAA[6]	NAM[7]	--
Killer whale (*Orcinus orca)*	Southern Resident DPS	NLTAA	NAM	--
Humpback whale (*Megaptera novaeangliae*)	--	NLTAA	--	--
Fin whale (*Balaenoptera physalus*)	--	NLTAA	--	--
Sei whale (*Balaenoptera borealis*)	--	NLTAA	--	--
Sperm whale (*Physeter catodon*)	--	NLTAA	--	--
Blue whale (*Balaenoptera musculus*)	--	NLTAA	--	--
Leatherback turtle (*Dermochelys coriacea)*	--	NLTAA	NAM	--
Green turtle (*Chelonia mydas*)	--	NLTAA	NAM	--
Loggerhead turtle (*Caretta caretta*)	North Pacific Ocean DPS	NLTAA	--	--
Olive ridley turtle (*Lepidochelys olivacea*)	--	NLTAA	--	--
Coastal Pelagic species	--	--	--	No Effect
Pacific Coast Groundfish	--	--	--	NLTAA

[1]Evolutionarily Significant Unit, [2]Distinct Population Segment, [3]May Affect, Likely to Adversely Affect, [4]May Affect, Likely to Adversely Modify, [5]Not Applicable, [6]May Affect, Not Likely to Adversely Affect, [7]No Adverse Modification

1.0 INTRODUCTION

1.1 Background

Coyote Island Terminal, a division of Ambre Energy North America, proposes to transport low-sulfur coal from Montana to U.S. trade allies in Asia. Three modes of transport are involved: rail, barges, and OGVs. First, coal treated with surfactants will be transported from coal mines along an existing rail line from Montana to the Port of Morrow where the coal will be offloaded in an indoor stilling shed, temporarily stored in enclosed storage barns, and then loaded through telescoping chutes onto enclosed barges to be transported down the Columbia River to Port Westward, where it will be transferred by enclosed conveyors to OGVs that will carry the coal across the Pacific Ocean to Asian markets. New facilities associated with the project consist of a coal transfer facility at the Port of Morrow and covered barges. All other components of the project involve use of existing facilities, including rail lines, rail cars, the Port Westward dock, and OGVs.

On May 16, 2011, the Port of Morrow Commission approved the development of the Port of Morrow coal transfer facility, and in a public meeting on January 26, 2012, the Port of St. Helens Commission approved the lease option for the transloading facility at Port Westward, near Clatskanie, Columbia County, Oregon.

The coal transfer facility at the Port of Morrow near Boardman, Morrow County, Oregon, will consist of five new components: enclosed storage buildings, enclosed coal conveyor system, loading dock with enclosed telescoping loader, dock walkway, and dolphins for moorage. Outside of the storage buildings, the remaining components are associated with in-water construction. The loading dock facility at the Port of Morrow was designed to allow the moorage of a four-barge tow.

Once the coal is loaded onto enclosed barges at the Port of Morrow, the barges will transport the coal down the Columbia River in the existing navigation channel, through the John Day, The Dalles, and Bonneville Dams, to a transloading facility at Port Westward. Panamax-sized OGVs will moor at the existing dock, and the river barges will moor alongside, such that a floating transloader can transfer the coal from the barges to the OGVs. No terrestrial or in-water construction is anticipated at the Port Westward site. The OGVs will transfer the coal through the remainder of the Columbia River to the Pacific Ocean and, subsequently, Asian markets.

This BA has been prepared in association with the USACE Joint Permit Application filed for the project to obtain a Section 10 Permit under the Rivers and Harbors Act of 1899. The USACE has jurisdiction over the proposed construction at the Port of Morrow and associated transportation within the Columbia River.

1.2 Project Information

Project Name:	Morrow Pacific Project
Location:	Columbia River at Port of Morrow River Mile (RM) 271 HUC-6: 170701 T4N, R25E, Section 2, Willamette Meridian (W.M.), Morrow County, Oregon Columbia River at Port Westward RM 53 HUC-6: 170800 T8N, R4W, Section 37, W.M., Columbia County, Oregon Columbia River between the Port of Morrow (RM 271) and the Columbia Bar (RM -5)
Project Applicant:	Coyote Island Terminal, LLC Ambre Energy North America 170 S. Main Street, Suite 700 Salt Lake City, Utah 84101 Contact – John Thomas, Secretary (801) 539-3788
Preparer:	Anderson Perry & Associates, Inc. 1901 N. Fir Street La Grande, Oregon 97850 Contact – Sue Brady, Biologist (541) 963-8309

1.3 Action Area

The ESA requires that potential effects to listed and proposed endangered and threatened species be evaluated in relation to the complex extent of area influenced by the proposed action, referred to as the action area (50 CFR Part 402.02). The action area encompasses the location(s) where measurable direct and indirect effects resulting from the proposed action are foreseeable and are reasonably certain to occur (USFWS, 1998; NMFS, 1996).

The action area includes all areas that could be potentially affected by the proposed action and is not limited to the actual construction and operation areas as defined in Section 3 of this BA.

For this BA, the action area is defined as three primary components:

1. **Port of Morrow**. This action area component consists of the enclosed storage buildings, enclosed coal conveyor system, loading dock with enclosed loader, dock walkway, dolphins for moorage, and all associated adjacent areas that could be impacted by Coyote Island's activities at the Port of Morrow. The Port of Morrow facility is at RM 271.

2. **Columbia River between the Port of Morrow and Port Westward**. This action area component consists of the Columbia River (below the OHWE) from the Port of Morrow to Port Westward. This project component involves use of established shipping lanes in the Columbia River by barges.

3. **Port Westward and Columbia River/Pacific Ocean**. This action area component consists of the Columbia River from Port Westward (RM 53) to its terminus with the Pacific Ocean, out to and including the Columbia Bar located approximately five miles offshore. This project component consists of transferring coal from barges to OGVs at Port Westward and use of established shipping lanes in the Columbia River to the Columbia Bar by OGVs.

Overall, the action area includes a total of 276 miles of Columbia River channel below the OHWE, plus approximately 35 acres of upland area at the new Port of Morrow facility at Boardman.

1.4 Project Purpose and Need

The purpose of the proposed project is to develop and successfully operate an environmentally responsible coal transfer facility in the Pacific Northwest for export of low-sulfur Montana coal to U.S. trade allies in Asia. The project has been designed to minimize train traffic through major urban areas, reduce the exposure of coal to the atmosphere, and use existing infrastructure while minimizing impacts to the environment.

A coal transfer/transloading facility at the Port of Morrow, with an in-stream transloading facility at an existing dock at Port Westward, will begin to provide a secure route for high-value coal to supply the substantial and growing need of trade allies in Asia, establish an environmentally responsible coal export facility, and operate a socially responsible industry in Oregon. The upstream location of the facility at the Port of Morrow reduces the distance traveled and number of urban areas crossed by trains from Montana carrying coal treated with dust suppressant. At the two transfer and transloading facilities (Port of Morrow and Port Westward), coal is nearly fully enclosed as it moves from train to storage facility to covered barge to OGV, minimizing exposure of coal or coal dust to humans or the environment. At the Port of Morrow through to Port Westward, the Morrow Pacific project creates local, family-wage jobs in Oregon, supports mining-related jobs nationally, and provides low-sulfur coal to Asian countries to generate electricity.

2.0 EVALUATION METHODS

Factors considered in evaluating project impacts include federally listed species' dependence on specific habitat components that would be removed or modified, the abundance and distribution of habitat, habitat components in the project vicinity, distribution and population levels of the species, the possibility of direct impact to the species, the degree of impact to habitat, and the potential to mitigate adverse effects.

The National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators described in *Making Endangered Species Act Determination of Effect for Individual or Grouped Actions at the Watershed Scale* (NMFS, 1996) was used to assess the current condition of various steelhead and salmon habitat parameters. The U.S. Fish and Wildlife Service (USFWS) matrix described in *A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale* (USFWS, 1998) was used to assess the current condition of bull trout habitat parameters.

Further information on resources in the action area was obtained through the use of online databases, site visits, watershed planning documents, and ongoing personal communication with agency personnel. Port of Morrow and Port Westward site data were collected during site surveys conducted in January 2012. Other data were collected from previous studies conducted in the Port of Morrow site vicinity, as well as aquatic surveys conducted within the Columbia River. The Washington State Department of Transportation (WSDOT) Construction Noise Impact Analysis methods (WSDOT, 2011) were used to evaluate the hydroacoustic impacts of construction at the Port of Morrow.

Anderson Perry staff met with Gary Miller (USFWS) and Spencer Hovekamp (NMFS) on November 29, 2011, to discuss preliminary project consultation needs, and on February 24, 2012, with Ben Meyer (NMFS) to discuss more detailed requirements for preparation of this BA. In addition, Oregon Department of Fish and Wildlife (ODFW) personnel were consulted on January 23, 2012 (Bill Duke, ODFW Pendleton office) and January 31, 2012 (John North, ODFW Clackamas office) to discuss listed fish species potentially present in the action area and the timing of their presence at the Port of Morrow and Port Westward sites.

3.0 PROJECT DESCRIPTION

Descriptions of all elements involved in the proposed action are included in this section. Please see Figures 1 through 10 in Appendix A for location and vicinity maps, aerial photographs, tax lot maps, conceptual design renderings, estimated hydroacoustic impact, and planting plan. Photographs of existing site conditions are presented in Appendix B. Construction details for the Port of Morrow site are shown on the plan sheets in Appendix C.

3.1 Port of Morrow

Development at the Port of Morrow will include construction of coal storage buildings, enclosed coal conveyor system, loading dock with telescoping loader, dock walkway, and dolphins. These facilities will be located on approximately 35 acres of uplands as well as the adjacent Columbia River shoreline and substrate below the OHWE (see Figure 1B, Appendix A).

3.1.1 Coal Storage Building and Staging

For the coal storage buildings, approximately 24 acres of existing vegetation will be removed, the site will be graded, and three new storage buildings will be placed at the site, along with a train unloading barn (stilling shed) and enclosed conveyor structure (see Figure 6, Appendix A). The storage buildings will be directly adjacent to the rail line. The new conveyer system will be adjacent to the southwest corners of the three buildings and will cross the rail line to the dock.

One temporary staging area (approximately 0.5 acre) is planned between the railroad tracks and the shoreline (see Figure 2A, Appendix A). Disturbed areas will be reseeded with native grassland species.

3.1.2 Coal Conveyer System

The elevated conveyor will be approximately 30 feet wide and 270 feet long, located above water, and supported by up to three reinforced concrete capped support bents (see Figure 4, Appendix A). The conveyor will be elevated from 50 to 90 feet above the water surface. The landward support bent portion will be entirely above the OHWE and will consist of 32 16-inch diameter round steel piles that will be installed with vibratory and impact hammers to a depth of 35 feet. The support bents may be installed using a land-based crane located 150 feet upland from the OHWE. The support bents will be constructed near the top of the existing bank above the OHWE to provide a transition between the shore and the fixed dock.

Two concrete capped support bents will be installed in the water. These support bents consist of ten 24-inch diameter round steel piles installed to a minimum depth of 35 feet. The total area of physical impact at the water surface is 62.8 SF. Prior to installation of each bent, four 16-inch diameter temporary template piles will be

installed with a vibratory hammer to support the installation of the permanent piles. Once the permanent piles have been installed, the template piles will be removed. Refer to Section 3.1.7, Pile Driving, for a description of the pile driving, associated noise levels, and mitigation planned for the project to minimize underwater noise impacts.

The completed conveyor will be enclosed and have a telescoping chute to eliminate potential fugitive dust. The enclosed conveyor will create a non-grated, solid metal surface above the water of 8,100 square feet (SF). In addition, the two concrete pile caps will create an above-water surface area of 960 SF. The elevation of the top of the conveyor will be set to allow a clearance of at least 50 feet between the conveyor and the water surface at the OHWE. This elevation was chosen for operability, as well as to limit shadow casting under the conveyor. The total above-water surface area of the elevated conveyor and pile caps is 9,060 SF, and the total area of impact at the water surface is 71 SF.

3.1.3 Loading Dock

The elevated fixed dock will be approximately 6 feet wide and 275.5 feet long, supported by up to four bents (see Figures 4 and 5, Appendix A). Each support bent will consist of two 16-inch diameter round steel piles that will be installed with a vibratory hammer mounted on a barge and supported by two supply barges. Piles will be installed to a depth of approximately 35 feet. Prior to installation of each bent, two 16-inch diameter temporary template piles will be installed with a vibratory hammer to support the installation of the permanent piles. Once the permanent piles have been installed, the template piles will be removed. Six permanent piles will be installed below the OHWE and two will be installed above the OHWE for the elevated fixed dock.

The elevation of the top of the fixed dock will be set to allow a clearance of at least 9 feet between the dock and the water surface at the OHWE to allow more light penetration under the dock. In addition, the surface of the dock will be grated. The total above-water surface area of the elevated fixed dock is 990 SF, and the total area of physical impact at the water surface is 8.4 SF.

3.1.4 Dock Walkway

The elevated fixed walkway will be approximately 4 feet wide and 1,160 feet long, supported by 30 support bents (see Figure 4, Appendix A). Each support bent will consist of two 14-inch diameter round steel piles that will be installed with a vibratory hammer mounted on a barge supported by two supply barges. Piles will be installed to a depth of approximately 25 feet. Prior to installation of each bent, two 16-inch diameter temporary template piles will be installed with a vibratory hammer to support the installation of the permanent piles. Once the permanent piles have been installed, the template piles will be removed. All piles will be installed below the OHWE.

The surface of the walkway will consist of grated expanded metal decking. The elevation of the top of the walkway will be set to allow a clearance of at least 9 feet between the walkway and the water surface at the OHWE to allow more light penetration under the walkway. The total above-water surface area of the walkway is 4,232 SF, and the total area of impact at the water surface is 66 SF.

3.1.5 Dolphins

In addition to the dock, conveyor, and walkway structures, two mooring dolphins and seven breasting dolphins will be constructed (see Figure 6, Appendix A).

Mooring Dolphins. One mooring dolphin will be installed at the upstream and downstream ends of the structure, for a total of two dolphins. Each dolphin will consist of six 16-inch diameter battered steel piles. Prior to installation of the permanent piles, four temporary template piles will be installed with a vibratory hammer to support the installation of the permanent piles. Once the permanent piles have been installed, the template piles will be removed. A metal bracing will be installed two feet above the pool height at the time of construction. Avian anti-perching devices will be installed atop the piles.

Breasting Dolphins. Seven breasting dolphins will be installed between the two mooring dolphins, adjacent to the walkway. The breasting dolphins will be 160 feet apart at the OHWE. Six dolphins will consist of six battered steel piles (16-inch diameter) and one dolphin will consist of five battered steel piles (16-inch diameter). In addition, three high-density polyethylene (HDPE) fender piles (18-inch diameter) will be installed on the dolphin face using only a vibratory hammer. Prior to installation of the permanent piles, four temporary template piles will be installed with a vibratory hammer to support the installation of the permanent piles. Once the permanent piles have been installed, the template piles will be removed. A metal bracing will be installed 2 feet above the pool height at the time of construction. Avian anti-perching devices will be installed atop the piles.

3.1.6 Construction

3.1.6.1 Upland Facilities

Construction of upland facilities will occur from 2012 through 2014. These facilities will consist of the negative pressure enclosed storage buildings, a train unloading barn, and the conveyor structure components that are on land. Existing vegetation will be removed, the property graded, and structures erected at the site beginning in fall 2012. Hay bales and a silt fence will be placed along the construction site perimeter. One storage building, the train unloading barn, and the conveyer structure will be constructed within 10 to 12 months. The remaining two storage buildings will be constructed within three years of initial site construction. Prior to commencing construction, an Erosion and Sediment

Control Plan (ESCP) will be prepared and approved by the Oregon Department of Environmental Quality (DEQ). A sediment fence, bioswales, and other erosion control methods for on-site stormwater containment will be installed along the shoreline side of the property to avoid runoff and soil loss onto the shoreline and into the Columbia River. No materials disposal will be needed. The contractor will limit disturbance of riverbank and upland sites to that area required for buildings and staging. Thus, removal of vegetation will be kept to the minimum required for construction activities. No woody vegetation will be removed. Once construction is complete, the remaining disturbed areas will be restored to original slopes and planted and seeded with native grass and woody species.

Upland construction of the coal unloading, storage, and transfer facility will be conducted prior to, during, and after the mooring facility construction and will occur outside the in-water work window. The Port of Morrow facility will use the best available technologies, such as wet scrubbers and enclosed conveyors, to reduce dust and spillage and improve environmental and occupational safety.

3.1.6.2 In-water Facilities

Construction of in-water facilities is planned for the ODFW recommended in-water work window for the project area, which is December 1 through March 31. The loading dock facility will incorporate the following major components of work and new in-water structures:

1. Construction staging.
2. Construction of an elevated, fixed dock and conveyor system supported by four two-pile dock support bents, as well as three concrete capped conveyor support bents. The dock deck will be expanded metal.
3. Construction of an elevated, fixed operation personnel access (walkway) supported by 12 bents, each consisting of two 14-inch diameter round steel piles with expanded metal deck. This structure will provide a safe walkway for workers mooring and loading barges.
4. Construction of nine dolphins installed adjacent to the walkway to assist in vessel mooring activities.
5. Restoration.

The riverward edge of the loading dock facility will extend approximately 190 feet from the OHWE of 268 feet, at a water depth of approximately 28 feet.

Staging and primary construction of the Port of Morrow dock facility will occur from three barges: one barge for the crane and pile driving equipment and two barges for materials delivery and staging. The crane barge will have two spuds that will be used throughout the project; the materials barges will be tied to the crane barge and will not require the use of spuds. Spuds are heavy steel piles used to moor the barge. The piles will be located in a well at the bottom of the

crane barge and will function as anchors for the three barges. Crews will access the barges daily on a 16-foot aluminum crew boat launched from the Port of Morrow recreational dock approximately two miles downstream.

No in-water work area isolation or fish salvage is planned, as NMFS has determined that it is not necessary for this project (NMFS, 2012f).

3.1.7 Pile Driving

3.1.7.1 Piling Installation

Oregon Water Resources Department (OWRD) well logs indicated that the substrate in the Port of Morrow area of the Columbia River is composed of coarse-grained alluvium, mainly sand with some gravel (OWRD, 2012). According to the pile driving logs obtained from the 2006 construction of the Tidewater Ethanol Dock, located immediately upstream of the proposed project, bedrock is located at approximately 35 feet below the mud line. Due to the dense substrate in the work area, it is anticipated that an impact hammer and a vibratory hammer will be needed for installation of elevated conveyor support bents and all the main dolphin piles. A vibratory hammer will be used to the extent feasible. All pile driving activities will take place from barges, and equipment will not be required to enter the water. Barge-mounted pile driving equipment includes:

Vibratory Hammer. The vibratory hammer is a common tool used to install steel piles in appropriate sediment. Methods for its use begin by placing a choker around the pile and lifting it into a vertical position with a crane. Then the pile is lowered into position and set in place at the mud line. The pile is held steady while the vibratory hammer installs the pile to the required tip elevation. A total of 194 permanent and 118 temporary piles will be driven by the vibratory hammer.

Impact Hammer. For load-bearing structures to meet design criteria and ensure proper functioning, piles must often be proofed by striking them with an impact hammer. An impact hammer is a large steel device that works with a hydraulic or diesel piston with a guide that holds the hammer in alignment with the pile while the piston moves up and down, striking the top of the pile and driving it into the substrate from the downward force of the hammer on the top of the pile. While the impact hammer is used, an observer will record the distance the pile is embedded with each impact hammer blow. A bubble curtain will be employed during impact hammer installation or proofing of steel piles to reduce the peak (instantaneous) decibel (dB) levels, cumulative sound exposure levels (SEL), and root mean square (RMS) pressure. In addition, acoustic monitoring will be conducted according to the NMFS monitoring protocol. A total of 105 piles will require the use of an impact hammer.

A summary of the number of pilings, size, and driving method is presented in Table 3-1.

Table 3-1. Summary of Pilings Needed for the Port of Morrow Construction

Structure		Number, Size, and Installation Method for Piles									Total Number of Piles
		Permanent Below OHWE			Permanent Above OHWE			Temporary Below OHWE			
Elevated Fixed Dock (3 bents)		6	16"	V[1]	2	16"	V	6	16"	V	**14**
Elevated Conveyor (3 bents total)	1 Above OHWE	N/A			32	16"	V/I	N/A			**32**
	2 Below OHWE	20	24"	V/I[2]	N/A			16	16"	V	**36**
Elevated Fixed Walkway (30 bents)		60	14"	V	N/A			60	16"	V	**120**
Mooring Dolphins (2)		12	16"	V/I	N/A			8	16"	V	**20**
Breasting Dolphins (7)		41	16"	V/I	N/A			28	16"	V	**69**
		21	18"	V				N/A			**21**
Total Number of Piles		**160**			**34**			**118**			**312**
No. of Piles Requiring Impact Hammer		**73**			**32**			**0**			**105**

[1]V – Only vibratory hammer used
[2]V/I – Vibratory and impact hammers used

For vibratory driving, typically three to four permanent piles per day are driven. Thus, approximately 55 days of pile driving using the vibratory hammer will be required to install 194 permanent piles.

Prior to using the impact hammer, either a confined or unconfined bubble curtain (as specified by NMFS) will be installed around the piles to reduce peak dB levels. Based on pile driving logs from adjacent facilities, it is estimated that each pile would require up to 150 strikes. The elevated conveyor support bents will require a total of up to 1,500 strikes per day, representing less than five hours of impact driving. The mooring and breasting dolphins will require a total of up to 900 strikes per day, representing less than five hours of impact driving. A summary of the number of strikes and estimated time is shown in Table 3-2.

Table 3-2. Impact Hammer Use at the Port of Morrow

Structure		No. Piles	Strikes Per Pile	Total Strikes	Total Time (assuming 2 sec/strike)	Number of Days
Elevated Conveyor Bents	1 Above OHWE	32	150	4,800 (maximum 1,500 per day)	2.7 hours	3.2
	2 Below OHWE	20	150	3,000 (maximum 1,500 per day)	1.7 hours	2
Mooring Dolphins (2)		12	150	1,800 (maximum 900 per day)	1 hour	2
Breasting Dolphins (7)		41	150	6,150 (maximum 900 per day)	3.4 hours	6.8
Total		**105 Piles**		**15,750 Strikes**	**8.8 Hours**	**14 Days**

In summary, a total of 312 piles will be used for the proposed project, 194 of which will be permanent. Use of the vibratory hammer for 312 temporary and permanent piles will occur over 55 days. Of the permanent piles, 105 will require impact driving (73 below the OHWE). Assuming the maximum number of strikes per day, approximately 9 hours over 14 days (not necessarily consecutive) will be required for all impact hammer driving activities during the course of project construction.

3.1.7.2 Distance to Underwater Sound Thresholds

Noise and sound analyses are generally conducted using metric units. Thus, this section of the BA also includes metric distances for noise, consistent with industry practices. NMFS has used sound threshold levels for fish since 2005, and these criteria were revised in 2008 (FHWG, 2008). Table 3-3 provides the current thresholds for underwater noise levels by functional group for fish. These thresholds represent levels of sound that produce either a behavioral disturbance (e.g., disruption of migration or foraging) or injury (e.g., internal tissue damage, hearing loss, or death) to fish within the threshold radius (Hastings and Popper, 2005).

Table 3-3. Fish Injury and Disturbance Thresholds for Underwater Construction Activity

Functional Group	Underwater Noise Thresholds		
	Vibratory Pile Driving Disturbance Threshold	Impact Pile Driving Disturbance Threshold	Injury Threshold
Fish ≥ 2 grams	Behavior Effects Threshold 150 dB RMS		187 dB cumulative SEL
Fish < 2 grams			183 dB cumulative SEL
Fish All Sizes			206 dB peak

The proposed construction at the Port of Morrow will involve piling installation using vibratory and impact hammers, which produce sound levels above the thresholds for fish disturbance and injury. The WSDOT guidance and calculator for estimating the distances to the noise thresholds for various piling sizes were used to evaluate the distance to each threshold for each of the piling sizes that will be used in the project (WSDOT, 2011). These findings are presented in Table 3-4. Installation techniques that were considered include un-attenuated impact driving, attenuated impact driving (includes use of a bubble curtain), and vibratory driving. Attenuation for pile driving is defined as decreasing the sound level, and for this project consists of use of a bubble curtain to confine the noise within the bubble curtain. Attenuation would only be used for impact driving. A graphical representation of the noise level distances at the Port of Morrow site is shown in Figure 7, Appendix A, using the threshold distances for the 24-inch pilings, as they represent the greatest hydroacoustic impact.

The elevated conveyor piles installed above the OHWE using an impact driver may have some hydroacoustic effects; however, this will be less than the in-water impact driving effects. Therefore, the pilings installed above the OHWE were not addressed in the hydroacoustic effects analysis below, as the in-water driving provides a more conservative estimate of hydroacoustic effects.

Table 3-4. Underwater Distance to Noise Thresholds for Pilings Installed at the Port of Morrow

Pile Size and Action		Distance (m) to Threshold			
		Fish Injury			Fish Disturbance
		Peak (206 dB)	SEL (187 dB)	SEL (183 dB)	RMS (150 dB)
14-inch Pilings	Vibratory Driving Received Level[1]				162 dB RMS @ 22m
	No Attenuation	N/A	N/A	N/A	139
16-inch Pilings	Impact Driving Received Level[2]	200 dB peak @ 9m	170 dB SEL @ 22m	170 SEL @ 22m	187 dB RMS @ 9m
	Impact Pile Driving No Attenuation	4	5	10	2,636
	Impact Pile Driving with -10 dB for Attenuation	1	1	2	568
	Vibratory Driving Received Level[1]				167 dB RMS @ 9m
	No Attenuation	N/A	N/A	N/A	122
18-inch Pilings	Vibratory Driving Received Level[1]				167 dB RMS @ 10m
	No Attenuation	N/A	N/A	N/A	122
24-inch Pilings	Impact Driving Received Level[2]	212 dB peak @ 10m	181 dB SEL @ 10m	181 dB SEL @ 10m	189 dB RMS @10m
	Impact Pile Driving No Attenuation	25	522	964	3,981
	Impact Pile Driving with -10 dB for Attenuation	5	112	208	858
	Vibratory Driving Received Level[1]				169 dB RMS @ 10m
	No Attenuation	N/A	N/A	N/A	185

[1]Vibratory driving assumes 20 dB lower than RMS levels for impact driving.
[2]All received level values taken or estimated from WSDOT BA guidance, Table 7-9 (WSDOT, 2011).

In summary, a vibratory hammer will be used to install 312 temporary and permanent piles (see Table 3-1), which will result in fish disturbance out to a maximum of 185 meters (607 feet) from the area of vibratory pile driving (see Table 3-4) and will occur up to a maximum of 55 days. Vibratory pile driving will result in fish disturbance but not result in fish injury (see Table 3-4). No bubble curtain would be used for vibratory pile driving.

An impact hammer will also be used on 105 of the 312 piles, of which 73 will be below the OHWE (20 24-inch piles and 53 16-inch piles) (see Table 3-1). Use of the impact hammer would occur over 14 days and include use of a bubble curtain to lessen sound effects to aquatic organisms, including fish. Use of a bubble curtain would reduce noise impacts by up to four to five times relative to the noise impacts that would have occurred if a bubble curtain were not used (see Table 3-4).

Use of the impact hammer with a bubble curtain for the 20 24-inch piles would result in maximum noise impacts of:

- fish injury to all sizes at peak (instantaneous) sound levels up to 5 meters (16 feet) from the driving activity,
- cumulative injury to fish ≥ 2 grams in size up to 112 meters (367 feet) from pile driving activity,
- cumulative injury to fish < 2 grams in size up to 208 meters (682 feet) from pile driving activity, and
- disturbance to all fish regardless of size up to 858 meters (2,815 feet) from pile driving activity (see Tables 3-3 and 3-4).

Use of an impact hammer with a bubble curtain for the 53 16-inch piles would result in fish injury at a distance of up to 2 meters (7 feet) from the pile driving activity regardless of fish size and fish disturbance at a distance of up to 568 meters (1,863 feet) from the pile driving activity (see Tables 3-3 and 3-4).

3.1.8 Equipment

Limited land-based equipment will be used for construction of the dock facility. A land-based crane may be needed for placement of the conveyor system. If used, the crane would be located 150 feet beyond the OHWE in an upland location. In addition, a loader and backhoe may be used in the upland staging area.

As discussed in Section 3.1.7.1, Piling Installation, in-water work will take place from three floating barges. One barge will be mounted with a crane and pile driving equipment, while the others will be used for supplies and will be tied to the first barge. A tug will be on site and used to move barges around the work area. The tug and barges will be equipped with hazardous materials cleanup kits and floating booms and will follow a spill-prevention plan.

3.1.9 Restoration

The contractor will limit disturbance of the riverbank and upland sites. Removal of vegetation will be kept to the minimum required for construction activities. No woody vegetation will be removed. Once construction is complete, the disturbed shoreline areas will be restored to original slopes and planted and seeded with native grass and woody species. Additional mitigation for near-shore habitat loss will be accomplished through the removal of existing derelict piles from the Columbia River at a future location to be developed in cooperation with NMFS. The number of derelict piles and their location are yet to be determined.

3.1.10 Site Operation

Coal will be offloaded from the rail cars and stored in enclosed, negative-pressure storage buildings and transferred into enclosed barges via enclosed conveyors (see Figures 4, 5, and 6, Appendix A). The barges will be maneuvered at the mooring facility using a tug, which will then transport the four-barge tow down river. No permanent tug will be assigned to the Port of Morrow facility. Fueling for the tugs will take place at an existing dock at Vancouver, Washington, and the tugs will be docked there when not in use.

3.2 Columbia River Between the Port of Morrow and Port Westward

When the project is operating at full capacity, approximately one to two four-barge tows per day will be required to transport coal from the Port of Morrow to Port Westward. Each barge will have a capacity of 2,727 metric tons (3,500 short tons). The draft of each barge when fully loaded or ballasted will be 13.6 feet, and the draft when empty will be 2.5 feet. The average speed of the four-barge tow will be approximately 6 to 9 knots upstream and 7 to 10 knots downstream. The barges will be required to pass through three lock systems (John Day Dam, The Dalles Dam, Bonneville Dam), and will take approximately 38 hours to travel from the Port of Morrow to Port Westward using established shipping lanes.

The barges will be enclosed, as will the loading conveyer system at the Port of Morrow and the floating transloader at Port Westward, to avoid environmental contamination and loss of coal and coal dust during transport and loading.

The barges will receive coal at the Port of Morrow facility and travel down the Columbia River to Port Westward. One of the barges in the four-barge tow will be ballast-capable. After the coal is unloaded at Port Westward, the empty barges will travel upstream to the Tidewater dock at Vancouver, Washington, where the empty ballast-capable barge will be ballasted, to protect the empty barges from drift when traveling upstream. The four-barge tow with three empty barges and one ballasted barge will travel upstream to the Port of Morrow, where the ballast water will be released into the Columbia River. Coal will then be loaded in all four barges.

A summary of the anticipated increase in barge and vessel (four-barge tow) traffic, considering the project at full capacity (8.0 million metric tons per year), is presented in Table 3-5, below. Current and historic high traffic levels were obtained from the USACE Navigation Center traffic counts at the Bonneville Dam from 1993 through 2010 (USACE, 2011a). Note that the additional traffic levels presented below represent barge and tow round-trips (i.e., each barge is counted twice, for the upriver and downriver trips).

Table 3-5. Summary of Barge and Tow Traffic per Year at Bonneville Dam for Project Full Capacity

Additional Traffic from the Project (Per Year)		Total Traffic	Bonneville Dam		Effect Relative to:	
			Current Level (2010)	Historic High (1995)	Current Levels (2010)	Historic High Levels (1995)
Total Barges	**5,029**	**10,382**	5,353	8,037	94% increase	29% increase
Total Tows	**1,258**	**3,972**	2,714	4,040	46% increase	98% of historic high

The total number of barges and the number of vessels (barge tows) on the Columbia River will increase above current levels as a result of the proposed project. When compared to historic high levels, there is a 29 percent increase in the total number of individual barges, although the total number of vessels (barge tows) will remain lower than the historic high level.

3.3 Port Westward and Columbia River/Pacific Ocean

The proposed action at Port Westward involves the use of an existing commercial loading dock facility (see Figure 1C, Appendix A) near Clatskanie to facilitate operations of the Morrow Pacific project. Coal will be transloaded from the enclosed barges onto OGVs, and then shipped out of the Columbia River using established shipping lanes.

The existing dock at Port Westward was built in the early 1940s as part of a military facility, and has most recently been used as a commercial loading dock for ethanol and diesel. The OGV will moor to the dock, and the barge tow will pull up alongside (see Figure 9, Appendix A). Transloading will be accomplished through the use of a floating transloader (see Figure 10, Appendix A) with an enclosed transfer system. No terrestrial or aquatic construction is proposed at this time, as the dock and access roads that serve it are adequate for the proposed use.

When the project is operating at full capacity, approximately two to three OGVs per week will leave Port Westward, for a total of approximately 133 ships per year. Each vessel will have a capacity of 60,000 metric tons. These vessels will be approximately 700 to 900 feet long and 105 feet wide, with a draft when fully loaded of approximately 41 feet (draft of 18 feet before loading). The average speed of the OGV will be approximately 10 to 12 knots when traveling both upstream and downstream. Fueling for the OGVs will likely be accomplished using a bunker barge based out of Portland, Oregon. The vessels may be fueled at the Port

Westward dock, but this will more likely take place while the OGVs are at anchor farther downstream.

One tug will be assigned permanently to Port Westward to maneuver the barges. This tug will return to a dock at Vancouver, Washington, for fueling and when not in use at Port Westward. Barges will be staged along the upstream 600 feet of dock when they are not being unloaded. Some off-site barge staging may occur at existing tie-offs located in the Vancouver harbor area, on the north side of Hayden Island and at Mathews Point. These tie-offs consist of barges that are spudded to the river bottom in 15 to 20 feet of water.

A summary of the anticipated increase in OGV traffic, considering the project at full capacity (8.0 million metric tons), is presented in Table 3-6, below. Current and historic high traffic levels were obtained from the Merchants Exchange of Portland traffic counts for vessel arrivals to the lower Columbia River from 1992 through 2011 (Merchants Exchange, 2011).

Table 3-6. Summary of OGV Traffic per Year in the Lower Columbia River for Project Full Capacity

Additional Traffic from the Project (Per Year)		Total Traffic	Arrivals to the Columbia River		Effect Relative to:	
			Current Level (2010)	Historic High (1995)	Current Levels (2010)	Historic High Levels (1995)
OGV	**133**	**1,690**	1,557	2,413	9% increase	70% of historic high

The total number of OGVs in the lower Columbia River will show a slight increase above current levels as a result of the proposed project; however, OGV traffic will remain lower than the historic high level.

4.0 NATURAL HISTORY AND SPECIES OCCURRENCE

Species lists for this project were obtained from the USFWS and NMFS on January 7, 2012, for species present in Morrow and Columbia Counties. These species could be affected from development at the Port of Morrow, operation of barges between the Port of Morrow and Port Westward, and operation of OGVs downstream of Port Westward. A database search of the Oregon Biodiversity Information Center (ORBIC) identified 20 records of rare species within a two-mile radius of the Columbia and Morrow County project areas (ORBIC, 2012). For the presence of threatened and endangered species at the mouth of the Columbia River and the nearshore marine portion of the action area, the list of species developed for the project titled "Major Rehabilitation of the Jetty System at the Mouth of the Columbia River" was used, as presented in the 2011 NMFS Biological Opinion for that project (NMFS, 2011b). In addition, NMFS requested evaluation of several sea turtle species for this BA (NMFS, 2012c). Appendix D contains the information used to identify the federally listed species to be evaluated for this BA.

The federally listed species that may occur in the action area are provided in Table 4-1 along with their federal and state status and presence of critical habitat. The presence and use of the area by the listed species are described in the following sections.

Table 4-1. ESA Listed and Proposed Species in the Action Area

Species	ESU/DPS	Federal Status	State Status (OR)[1]	Critical Habitat in Action Area
Steelhead *(Oncorhynchus mykiss)*	Upper Columbia River DPS	T	--	Y
	Middle Columbia River DPS	T	SC	Y
	Lower Columbia River DPS	T	SC	Y
	Upper Willamette River DPS	T	SV	Y
	Snake River Basin DPS	T	SV	Y
Chinook salmon *(Oncorhynchus tshawytscha)*	Upper Columbia River spring-run ESU	E	--	Y
	Lower Columbia River ESU	T	SC	Y
	Snake River fall-run ESU	T	LT	Y
	Snake River spring/summer-run ESU	T	LT	Y
	Upper Willamette River ESU	T	SC	Y
Chum salmon *(Oncorhynchus keta)*	Columbia River ESU	T	SC	Y
Coho salmon *(Oncorhynchus kisutch)*	Lower Columbia River ESU	T	LE	--
Sockeye salmon *(Oncorhynchus nerka)*	Snake River ESU	E	--	Y
Bull trout *(Salvelinus confluentus)*	Columbia River DPS	T	SC	Y
Green sturgeon *(Acipenser medirostris)*	Southern DPS	T	--	Y
Eulachon *(Thaleichthys pacificus)*	Southern DPS	T	--	Y

Species	ESU/DPS	Federal Status	State Status (OR)[1]	Critical Habitat in Action Area
Steller sea lion *(Eumetopias jubatus)*	Eastern DPS	T	--	N
Killer whale *(Orcinus orca)*	Southern Resident DPS	E	--	N
Humpback whale *(Megaptera novaeangliae)*	--	E	LE	--
Blue whale *(Balaenoptera musculus)*	--	E	LE	--
Fin whale *(Balaenoptera physalus)*	--	E	LE	--
Sei whale *(Balaenoptera borealis)*	--	E	LE	--
Sperm whale *(Physeter catodon)*	--	E	LE	--
Leatherback turtle *(Dermochelys coriacea)*	--	E	LE	Y
Green turtle *(Chelonia mydas)*	--	T	LE	N
Loggerhead turtle *(Caretta caretta)*	North Pacific Ocean DPS	E	LT	--
Olive ridley turtle *(Lepidochelys olivacea)*	--	T	LT	--

[1] SC = Sensitive Critical, SV = Sensitive Vulnerable, LT = Listed Threatened, LE = Listed Endangered,
-- = Not Applicable

Summaries of when listed fish species may be present at the Port of Morrow and Port Westward sites are presented in Tables 4-2 and 4-3. These tables were prepared based on conversations with ODFW biologists (ODFW 2012a, 2012b) and review of adult and smolt passage data from McNary Dam (representative of timing at Port of Morrow) and Bonneville Dam (representative of timing at Port Westward) from the Fish Passage Center web site (FPC, 2012b and 2012c). Outside of these two sites, fish use of the Columbia River represents a continuum based on run timing, as upstream or downstream movement occurs during migration. Adult fish would be found at upstream reaches later than downstream reaches, as they migrate upstream, and the opposite would be true for juvenile fish migrating downstream. In addition, juveniles may be found in the lower reaches of the river (downstream of Port Westward) for a significant portion of the year, as estuarine areas represent important rearing habitat while juveniles make the physiological transition from fresh water to salt water.

Table 4-2. Timing of Fish Presence in the Columbia River at Port of Morrow (RM 271)

Species	ESU/DPS		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ODFW In-water Work Window														
Steelhead	Upper Columbia River	Adult	migration											
		Juvenile	migration and limited rearing											
	Middle Columbia River	Adult	migration											
		Juvenile	migration and limited rearing											
	Snake River Basin	Adult	migration											
		Juvenile	migration and limited rearing											
Chinook	Upper Columbia River spring-run	Adult				migration								
		Juvenile	migration and limited rearing											
	Snake River fall-run	Adult								migration				
		Juvenile	migration and limited rearing											
	Snake River spring/summer-run	Adult				migration								
		Juvenile	migration and limited rearing											
Sockeye	Snake River	Adult						migration						
		Juvenile	migration and limited rearing											
Bull Trout	Columbia River	Adult	overwintering and foraging			upstream movement						overwintering and foraging		
		Juvenile	migration and limited rearing											

Table 4-3. Timing of Fish Presence in the Columbia River at Port Westward (RM 53)

Species	ESU/DPS		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Steelhead	Upper Columbia River	Adult						migration						
		Juvenile	rearing/migration											
	Middle Columbia River	Adult						migration						
		Juvenile	rearing/migration											
	Lower Columbia River	Adult	migration					migration						migration
		Juvenile	rearing/migration											
	Upper Willamette River	Adult	migration											migration
		Juvenile	rearing/migration											
	Snake River Basin	Adult						migration						
		Juvenile	rearing/migration											
Chinook	Upper Columbia River spring-run	Adult			migration									
		Juvenile	rearing/migration											
	Lower Columbia River	Adult			migration					migration				
		Juvenile	rearing/migration											
	Snake River fall-run	Adult								migration				
		Juvenile	rearing/migration											
	Snake River spring/summer-run	Adult			migration									
		Juvenile	rearing/migration											
	Upper Willamette River	Adult			migration									
		Juvenile	rearing/migration											
Chum	Columbia River	Adult										migration		
		Juvenile		rearing/migration										
Coho	Lower Columbia River	Adult								migration				
		Juvenile	rearing/migration											
Sockeye	Snake River	Adult						migration						
		Juvenile	rearing/migration											
Bull Trout	Columbia River	Adult/subadult	unlikely to be present											
		Juvenile	not present											
Green Sturgeon	Southern	Adult/subadult							foraging					
		Juvenile	not present											
Eulachon	Southern	Adult	migration/spawning											m/s
		Juvenile	rearing/migration											

4.1 Steelhead

Five steelhead DPSs will be affected by the proposed project. A DPS is a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. The ESA provides for listing species, subspecies, or distinct population segments of vertebrate species.

According to StreamNet (2012), the action area is used as a migration corridor for adults, and juveniles may use it for migration and rearing. Please see Tables 4-2 and 4-3 for a summary of when the five steelhead DPSs may be present at the Port of Morrow and Port Westward. The entire length of the action area is located within critical habitat for Upper Columbia River, Middle Columbia River, and Snake River Basin ESUs, whereas critical habitat for Lower Columbia River and Upper Willamette River ESUs is located well downstream of the construction area at the Port of Morrow.

For the Port of Morrow site, steelhead adults and juveniles from three DPSs (Upper Columbia River, Middle Columbia River, and Snake River Basin) may occur at the site during the construction in-water work window (see Table 4-2). For the remainder of the Columbia River, adults and juveniles from all five DPSs occur during different seasons of the year (see Table 4-3).

Adult steelhead pass McNary Dam in the greatest numbers from mid-June through mid-November although small numbers are recorded passing the site through the remainder of the year. Adult steelhead passage at Bonneville Dam occurs primarily from early June through October (FPC, 2012b). Juvenile steelhead pass McNary and Bonneville Dams primarily during April through June but small numbers are recorded throughout the year as some fish rear over the winter in Columbia River reservoirs prior to completing their smolt migrations (FPC, 2012c).

Information describing steelhead status and use of the Columbia River was obtained from listings in the Federal Register, 5-year reviews, and critical habitat descriptions, and is summarized below.

4.1.1. General Background Pertinent to the Columbia River

Anadromous steelhead populations in the Columbia River can be broadly divided into two life history forms: summer-run (which migrate upstream as adults from mid-May through mid-October) and winter-run (which migrate upstream as adults from mid-November to early April). Summer-run (stream-maturing) steelhead enter fresh water sooner than winter-run steelhead and require several months to mature prior to spawning. Juvenile summer and winter steelhead migrate downstream as smolts primarily from mid-March through July and subadults typically spend one to three years in the ocean before maturing and migrating back to their natal streams to spawn (63 FR 11798).

4.1.2. Affected Distinct Population Segments

A discussion of the ESA listing status and designated critical habitat status follows for each DPS, as well as its use of the action area.

4.1.2.1. Upper Columbia River DPS

Current Status. Upper Columbia River (UCR) steelhead were listed as endangered on August 18, 1997 (62 FR 43937). This status was upgraded to threatened on January 5, 2006 (71 FR 834), reinstated to endangered status per U.S. District Court decision in June 2007, and re-upgraded to threatened per U.S. District Court order in June 2009 (74 FR 42605). The five-year review on August 15, 2011 (76 FR 50448) concluded that this species should remain listed as threatened. Critical habitat was designated on September 2, 2005 (70 FR 52630). This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the United States-Canada border, as well as six artificial propagation programs. This DPS exhibits a summer-run life history strategy.

Presence in Action Area. According to StreamNet (2012), the action area is used for steelhead migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that UCR steelhead are present in the Columbia River through the entire action area. Adults use the action area as a migration corridor, and juveniles use it for migration and rearing. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, UCR adult and juvenile steelhead may be present all year (see Table 4-2). For the Port Westward site, UCR adult steelhead are present from mid-May through mid-October (see Table 4-3) and juveniles may be present all year. The entire length of the action area is located within designated critical habitat for UCR steelhead (70 FR 52630).

4.1.2.2. Middle Columbia River DPS

Current Status. Middle Columbia River (MCR) steelhead were listed as threatened on March 25, 1999 (64 FR 14517). This status was reaffirmed on January 5, 2006 (71 FR 834) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams from above the Wind River, Washington, and the Hood River, Oregon (exclusive), upstream to, and including, the Yakima River, Washington, as well as seven artificial propagation programs. Steelhead from the Snake River Basin are excluded from this DPS. This DPS exhibits a summer-run life history strategy.

Presence in Action Area. According to StreamNet (2012), the action area is used for steelhead migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that MCR steelhead are present in the Columbia River through the entire action area. Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, MCR adult and juvenile steelhead may be present all year (see Table 4-2). For the Port Westward site, MCR steelhead adults are present from mid-May through mid-October and juveniles may be present all year (see Table 4-3). The entire length of the action area is located within designated critical habitat for MCR steelhead (70 FR 52630).

4.1.2.3. Lower Columbia River DPS

Current Status. Lower Columbia River (LCR) steelhead were listed as threatened on March 19, 1998 (63 FR 13347). This status was reaffirmed on January 5, 2006 (71 FR 834) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between the Cowlitz and Wind Rivers, Washington (inclusive), and the Willamette and Hood Rivers, Oregon (inclusive), as well as ten artificial propagation programs. Steelhead populations in the Upper Willamette River Basin above Willamette Falls, Oregon, and from the Little and Big White Salmon Rivers, Washington, are excluded from this DPS. This DPS exhibits both summer-run and winter-run life history strategies.

Presence in Action Area. According to StreamNet (2012), the action area is used for steelhead migration. A conversation with John North, ODFW biologist, confirmed that LCR steelhead are only present in the portion of the action area downstream of the confluence with the Hood River (RM 169). Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. The action area is not likely to be used for spawning (ODFW, 2012b). LCR steelhead are not present at the Port of Morrow site. For the Port Westward site, LCR adult steelhead may be present all year except from April through mid-May and mid-October through mid-November and juveniles may be present all year (see Table 4-3). The portion of the action area downstream of the Hood River (RM 169) is located within designated critical habitat for LCR steelhead (70 FR 52630).

4.1.2.4. Upper Willamette River DPS

Current Status. Upper Willamette River (UWR) steelhead were listed as threatened on March 25, 1999 (64 FR 14517). This status was reaffirmed on January 5, 2006 (71 FR 834) and upheld in the five-year review on August 15,

2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River (inclusive). This DPS exhibits a winter-run life history strategy.

Presence in Action Area. According to StreamNet (2012), the action area is used for steelhead migration. A conversation with John North, ODFW biologist, confirmed that UWR steelhead are only present in the portion of the action area downstream of the confluence with the Willamette River (RM 101). Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. The action area is not likely to be used for spawning (ODFW, 2012b). UWR steelhead are not present at the Port of Morrow site. For the Port Westward site, UWR adult steelhead may be present from mid-November through July and juveniles may be present all year (see Table 4-3). The portion of the action area downstream of the confluence with the Willamette River (RM 101) is located within designated critical habitat for UWR steelhead (70 FR 52630).

4.1.2.5. Snake River Basin DPS

Current Status. Snake River Basin (SRB) steelhead were listed as threatened on August 18, 1997 (62 FR 43937). This status was reaffirmed on January 5, 2006 (71 FR 834) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams in the Snake River Basin of southeast Washington, northeast Oregon, and Idaho, as well as six artificial propagation programs. This DPS exhibits a summer-run life history strategy.

Presence in Action Area. According to StreamNet (2012), the action area is used for steelhead migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that SRB steelhead are present in the Columbia River through the entire action area. Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, SRB adult and juvenile steelhead may be present all year (see Table 4-2). For the Port Westward site, SRB adult steelhead may be present from mid-May through mid-October and juveniles may be present all year (see Table 4-3). The entire length of the action area is located within designated critical habitat for SRB steelhead (70 FR 52630).

4.1.3. Critical Habitat

Critical habitat for all five of the affected steelhead DPSs is described in terms of the following six primary constituent elements (PCEs) (70 FR 52630). Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

1. *Freshwater spawning sites with water quality and quantity conditions and substrate supporting spawning, incubation, and larval development*.

2. *Freshwater rearing sites with (i) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) water quality and forage supporting juvenile development; and (iii) natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.*

3. *Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.*

4. *Estuarine areas free of obstruction with (i) water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between freshwater and saltwater; (ii) natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and (iii) juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.*

5. *Nearshore marine areas free of obstruction and excessive predation with (i) water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.*

6. *Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.*

4.2. Chinook Salmon

Five Chinook salmon ESUs will be affected by the proposed project. An evolutionarily significant unit is a Pacific salmon population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species. The ESA provides for listing species, subspecies, or distinct population segments of vertebrate species.

According to StreamNet (2012), the action area is used as a migration corridor for adults, and juveniles may use it for migration and rearing. In addition, LCR Chinook salmon spawn in the action area near the Bonneville Dam (ODFW, 2012b). Please see Tables 4-2 and 4-3 for a summary of when the five Chinook salmon ESUs may be present at the Port of Morrow and Port Westward. The entire length of the action area is located within critical habitat for UCR spring-run, Snake River (SR) fall-run, and SR spring/summer-run ESUs, whereas critical habitat for LCR and UWR ESUs is located well downstream of the construction site at the Port of Morrow.

For the Port of Morrow site, Chinook salmon juveniles from three ESUs (UCR spring-run, SR fall-run, and SR spring/summer-run) and adults from two ESUs (UCR spring-run and SR spring/summer-run) may occur at the site during the in-water work window (see Table 4-2). Adult Chinook salmon, migrating upstream, begin passing McNary Dam in March with the largest numbers passing from mid-April through October (FPC, 2012b). USACE (2011b) uses the following dates as a general guide for separating Chinook runs as they pass McNary Dam: spring-run, April 1 through June 8 (although some begin arriving in March in some years); summer-run, June 9 through August 8; and fall-run, August 9 through October 31. Most juvenile Chinook, migrating downstream as smolts, pass McNary Dam from early April through early October although some are present throughout the year. The majority of yearling smolts, mostly spring- and summer-run, pass McNary Dam from April through June while sub-yearlings, mostly fall-run, pass from early May through early October (FPC, 2012c).

For Port Westward and the remainder of the Columbia River, adults and/or juveniles from all five ESUs may be present at some time during the year (see Table 4-3). Adult Chinook begin migrating past Bonneville Dam in March with the largest numbers passing from April through October (FPC, 2012b). USACE (2011b) uses the following general guide for separating runs of Chinook passing Bonneville Dam: spring-run, March 15 through May 31; summer-run, June 1 through July 31; and, fall-run, August 1 through November 15. Most Chinook juveniles migrate downstream as smolts past Bonneville Dam from March through August although some juveniles are present throughout the year. Yearling smolts generally pass Bonneville Dam from mid-March through June while sub-yearlings generally pass from April through August (FPC, 2012c).

Chinook salmon are regulated under a federal fishery management plan, and the provisions of the Magnuson-Stevens Act protecting EFH apply to all ESUs of this species (see Section 8.0 of this BA).

Information describing Chinook salmon status and use of the Columbia River was obtained from status listings in the Federal Register, 5-year reviews, and critical habitat descriptions, and is summarized below. The life history and habitat requirements of Chinook salmon are described in detail in *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California* (Myers et al., 1998), which was used to describe habitat requirements and use of the action area.

4.2.1. General Background Pertinent to the Columbia River

Chinook salmon populations in the Columbia River can be broadly divided into three life history forms: spring-run (which migrate from late February through mid-June), spring/summer-run (which migrate from late February through late October), and fall-run (which migrate from mid-August through late November). Juveniles and subadults typically spend one to three years in the ocean before migrating back to their natal streams to spawn (Myers et al., 1998). Chinook salmon spawning (Lower Columbia River ESU) in the action area takes place only near Ives Island, downstream of the Bonneville Dam (ODFW, 2012b; StreamNet, 2012).

Chinook salmon migrate upstream from the ocean to spawn in freshwater streams and rivers. Eggs spawned in the fall remain in the redds and hatch the following spring. Fry, fingerlings, and smolts may have different emergence, movement, and migration patterns depending on seasonal temperatures and prey resource availability. Fingerlings may migrate downstream and distribute into other rearing areas upon emergence, or they may remain in their natal reach to rear and forage until the following spring. Outmigration of yearling spring/summer-run smolts typically occurs in the spring of the year following emergence, while most fall-run Chinook migrate during their first year. Chinook salmon require clean spawning gravel, cool water in summer and fall, and holding pools for pre-spawning adults. Rearing and foraging juveniles require slower moving, off-channel areas for resting and in-stream woody debris and streambank vegetation for cover (Myers et al., 1998).

4.2.2. Affected Evolutionarily Significant Units

A discussion of the ESA listing status and designated critical habitat status follows for each ESU, as well as its use of the action area.

4.2.2.1. Upper Columbia River Spring-run ESU

Current Status. UCR spring-run Chinook salmon were listed as endangered on March 24, 1999 (64 FR 14308). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This ESU includes all naturally spawned populations of spring Chinook salmon in all river reaches accessible to spring Chinook salmon in Columbia River tributaries upstream of Rock Island Dam and downstream of Chief Joseph Dam in Washington, as well as six artificial propagation programs.

Presence in Action Area. According to StreamNet (2012), the action area is used for Chinook salmon migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that UCR spring-run Chinook salmon are present in the Columbia River through the entire action area. Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. The

action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, UCR adult Chinook salmon may be present from March through June while juveniles may be present all year (see Table 4-2). For the Port Westward site, UCR adult Chinook salmon may be present from mid-February through mid-June while juveniles may be present all year (see Table 4-3). The entire length of the action area is located within designated critical habitat for UCR spring-run Chinook salmon (70 FR 52630).

4.2.2.2. Lower Columbia River ESU

Current Status. LCR Chinook salmon were listed as threatened on March 24, 1999 (64 14308). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This ESU includes all naturally spawned populations of Chinook salmon from the Columbia River and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point between Washington and Oregon east of the Hood River and the White Salmon River, and includes the Willamette River to Willamette Falls, Oregon, exclusive of spring-run Chinook salmon in the Clackamas River, as well as seventeen artificial propagation programs. This ESU exhibits spring-run, fall tule, and late-fall bright life history strategies.

Presence in Action Area. According to StreamNet (2012), the action area is used for Chinook salmon migration, with an area immediately downstream of Bonneville Dam used for fall Chinook spawning. A conversation with John North, ODFW biologist, confirmed that LCR Chinook salmon are present in the portion of the action area downstream of the confluence with the Hood River (RM 169). Adults use the action area as a migration corridor, and juveniles may use it for migration and rearing. Spawning is present in the action area only near Bonneville Dam (ODFW, 2012b; FPC, 2012a). LCR Chinook salmon are not present at the Port of Morrow site. For the Port Westward site, LCR adult Chinook salmon may be present from mid-February through mid-November while juveniles may be present all year (see Table 4-3). The portion of the action area downstream of the confluence with the Hood River (RM 169) is located within the final designated critical habitat for LCR Chinook salmon (70 FR 52630).

4.2.2.3. Snake River Fall-run ESU

Current Status. SR fall-run Chinook salmon were listed as threatened on April 22, 1992 (57 FR 14653), with a correction on June 3, 1992 (57 FR 23458). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on December 28, 1993 (58 FR 68543). This ESU includes all naturally spawned populations of fall-run Chinook salmon in the mainstem Snake River below Hells Canyon Dam, and in the Tucannon River, Grande Ronde River, Imnaha River,

Salmon River, and Clearwater River, as well as four artificial propagation programs.

Status in Action Area. According to StreamNet (2012), the action area is used for Chinook salmon migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that SR fall-run Chinook salmon are present in the entire action area. Adults and juveniles use the action area as a migration corridor, and juveniles may use it for rearing, especially the estuary. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, SR fall-run adult Chinook salmon may be present from August through October and juveniles may be present all year (see Table 4-2). For the Port Westward site, SR fall-run adult Chinook salmon may be present from mid-July through mid-October and juveniles may be present all year (see Table 4-3). The entire length of the action area is located within designated critical habitat for SR fall-run Chinook salmon (58 FR 68543).

4.2.2.4. Snake River Spring/summer-run ESU

Current Status. SR spring/summer-run Chinook salmon were listed as threatened on April 22, 1992 (57 FR 14653) and corrected on June 3, 1992 (57 FR 23458). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year review on August 15, 2011 (76 FR 50448). A final designation of critical habitat was published on December 28, 1993 (58 FR 68543) and revised on October 25, 1999 (64 FR 57399). This ESU includes all natural populations of spring/summer-run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins, as well as fifteen artificial propagation programs.

Presence in Action Area. According to StreamNet (2012), the action area is used for Chinook salmon migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that SR spring/summer-run Chinook salmon are present in the entire action area. Adults and juveniles use the action area as a migration corridor, and some juveniles may use it for rearing, especially the estuary. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). For the Port of Morrow site, SR spring/summer-run adult Chinook salmon may be present from March through early August and juveniles may be present all year (see Table 4-2). For the Port Westward site, SR spring/summer-run adult Chinook salmon may be present from mid-February through July and juveniles may be present all year (see Table 4-3). The entire length of the action area is located within designated critical habitat for SR spring/summer-run Chinook salmon (58 FR 68543).

4.2.2.5. Upper Willamette River ESU

Current Status. UWR Chinook salmon were listed as threatened on March 24, 1999 (64 FR 14308). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This ESU includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River and in the Willamette River, and its tributaries, above Willamette Falls, Oregon, as well as seven artificial propagation programs.

Presence in Action Area. According to StreamNet (2012), the action area is used for Chinook salmon migration. A conversation with John North, ODFW biologist, confirmed that UWR Chinook salmon are present in the portion of the action area downstream of the confluence with the Willamette River (RM 101). Adults use the action area as a migration corridor, and juveniles use it for migration and estuary rearing. The action area is not likely to be used for spawning (ODFW, 2012b). UWR Chinook salmon are not present at the Port of Morrow site. For the Port Westward site, UWR adult Chinook salmon may be present from mid-February through May and juveniles may be present all year (see Table 4-3). The portion of the action area downstream of the confluence with the Willamette River (RM 101) is located within the final designated critical habitat for UWR Chinook salmon (70 FR 52630).

4.2.3. Critical Habitat

Two separate Federal Register critical habitat designations apply to the various affected ESUs of Chinook salmon. Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

4.2.3.1. Upper Columbia River Spring-run ESU
Lower Columbia River ESU
Upper Willamette River ESU

The September 2005 Federal Register (70 FR 52630) identifies six PCEs of critical habitat for these three ESUs. These are the same as for steelhead, listed in Section 4.1.3, Critical Habitat, above.

4.2.3.2. Snake River Spring/summer-run ESU
Snake River Fall-run ESU

The December 1993 Federal Register (58 FR 68543) identifies four components of critical habitat for these two ESUs:

1. *Spawning and Juvenile Rearing Areas. This component is further broken out into specific habitat components, and includes (a) spawning gravel, (b) water quality, (c) water quantity, (d) water temperature, (e) cover/shelter, (f) food, (g) riparian vegetation, and (h) space.*

2. *Juvenile Migration Corridors. This component is further broken out into specific habitat components and include (a) substrate, (b) water quality, (c) water quantity, (d) water temperature, (e) water velocity, (f) cover/shelter, (g) food, (h) riparian vegetation, (i) space, and (j) safe passage conditions.*

3. *Areas for Growth and Development to Adulthood.*

4. *Adult Migration Corridors.*

4.3. Chum Salmon – Columbia River ESU

4.3.1. Current Status

Columbia River (CR) chum salmon were listed as threatened on March 25, 1999 (64 FR 14508). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year status review on August 15, 2011 (76 FR 50448). Critical habitat was designated on September 2, 2005 (70 FR 52630). This ESU includes all naturally spawned populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, as well as three artificial propagation programs.

4.3.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of chum salmon are described in detail in the proposed rule to designate chum salmon as a threatened species (63 FR 11774), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Like most other salmonids this species is semelparous and requires stable gravel beds in cold freshwater rivers for spawning, but chum salmon spend more of their life history in marine waters than other Pacific salmonids. Chum salmon usually spawn in the lower reaches of coastal river systems, typically within 60 to 100 miles of the ocean, and juveniles migrate to the ocean almost immediately after emerging from the redds. Unlike other salmonids in the same genus, which spend months or years rearing in fresh water, this ocean-type migratory pattern means that juvenile chum salmon depend less on freshwater conditions than on favorable estuarine and marine conditions for growth and development (63 FR 11774).

4.3.3. Presence in Action Area

According to StreamNet (2012), the action area downstream of Bonneville Dam is used for chum salmon migration, with an area immediately downstream of the dam used for spawning. A conversation with John North, ODFW biologist, confirmed that chum salmon are not present at the Port of Morrow site and are present only downstream of Bonneville Dam. Adults use this portion of the action area as a migration corridor, and juveniles use it for rearing and migration (ODFW, 2012b). Spawning occurs within the action area downstream of the Bonneville Dam, primarily at the Ives Island complex (RM 143), the region around the mouth of Multnomah Creek (RM 136), and at the I-205 bridge (RM 113) (StreamNet, 2012; FPC, 2012a). For the Port Westward site, adult chum salmon may be present from mid-October through December and juveniles may be present from February through May (see Table 4-3). The portion of the action area downstream of the confluence with the Hood River (RM 169) is located within the designated critical habitat for CR chum salmon (70 FR 52630).

4.3.4. Critical Habitat

The September 2005 Federal Register (70 FR 52630) identifies six PCEs of critical habitat for CR chum salmon. These are the same as for steelhead, listed in Section 4.1.3, Critical Habitat, above. Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

4.4. Coho Salmon – Lower Columbia River ESU

4.4.1. Current Status

LCR coho salmon were identified as a separate ESU and listed as threatened on June 28, 2005 (70 FR 37160). The LCR ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries from the mouth of the Columbia River up to and including the Big White Salmon and Hood Rivers, the Willamette River to Willamette Falls, Oregon, as well as 25 artificial propagation programs.

Critical habitat for LCR coho salmon has not been designated. However, coho salmon are regulated under a federal fishery management plan and the provisions of the Magnuson-Stevens Act protecting EFH apply to all ESUs of this species (see Section 8.0 of this BA).

4.4.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of coho salmon are described in detail in the proposed rule to designate coho salmon as a threatened species (63 FR 11774), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Coho salmon migrate upstream to freshwater spawning habitats with stable gravel substrates. Like other salmon species, coho salmon require clean, cool waters for egg, larval, and juvenile growth and development. Smolts typically spend one to two years in fresh water, migrating downstream in the spring. Preferred summer and winter freshwater habitats consist of quiet areas with low velocity, such as backwater pools, beaver ponds, dam pools, and side channels, with winter habitats generally having greater water depth and more large woody debris (63 FR 11774).

4.4.3. Presence in Action Area

According to StreamNet (2012), the action area is used for LCR coho salmon migration, with an area immediately downstream of the Bonneville Dam used for limited spawning. A conversation with John North, ODFW biologist, confirmed that LCR coho salmon are present downstream of the confluence with the Hood River (RM 169). Adults use this portion of the action area as a migration corridor, with some spawning activity near Ives Island, downstream of the Bonneville Dam, and juveniles use this portion of the action area for rearing and migration (ODFW, 2012b; FPC, 2012a). For the Port Westward site, adult coho salmon may be present from mid-July through December, while juveniles may be present all year (see Table 4-3).

4.4.4. Critical Habitat

Critical habitat for LCR coho salmon has not been designated.

4.5. Sockeye Salmon – Snake River ESU

4.5.1. Current Status

Snake River sockeye salmon were listed as endangered on November 20, 1991 (56 FR 58619). This status was reaffirmed on June 28, 2005 (70 FR 37160) and upheld in the five-year status review on August 15, 2011 (76 FR 50448). Critical habitat was designated on December 28, 1993 (58 FR 68543). The Snake River ESU includes all anadromous and residual sockeye salmon from the Snake River Basin, Idaho, as well as artificially propagated sockeye salmon from the Redfish Lake captive propagation program.

4.5.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of the various life history strategies of sockeye salmon are described in detail in *Status Review of Sockeye Salmon from Washington and Oregon* (Gustafson et al., 1997), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Sockeye salmon are more frequently associated with lakes than other species of salmon and may be divided into three life-history forms: anadromous, residual, and kokanee.

Residual sockeye salmon and kokanee remain in fresh water for their entire life cycle; the term residual sockeye is used to identify resident, non-migratory offspring of anadromous sockeye salmon parents, and the term kokanee is used to identify entire populations that no longer migrate to the ocean. Residual and kokanee forms of sockeye salmon do not occur in the action area. Anadromous sockeye salmon rear for one to three years in their natal freshwater lake, migrate downstream and spend an additional one to four years at sea while growing to maturity, then migrate back to their natal freshwater habitat to spawn (Gustafson et al., 1997).

4.5.3. Presence in Action Area

According to StreamNet (2012), the action area is used for sockeye salmon migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that SR sockeye salmon may be present in the entire action area. Adults and juveniles use the action area as a migration corridor, and juveniles may be present at the Port of Morrow site during the in-water work window. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). Sockeye salmon adults use the Port of Morrow area from mid-May through Mid-November, and juveniles may be present throughout the year (see Table 4-2). Sockeye salmon adults may occur at the Port Westward site from mid-May through August, and juveniles may be present throughout the year (see Table 4-3). The entire length of the action area is located within designated critical habitat for SR sockeye salmon (58 FR 68543).

4.5.4. Critical Habitat

The December 1993 Federal Register (58 FR 68543) identifies four PCEs of critical habitat for this species. These are the same as listed in Section 4.2.3.2, Critical Habitat, for SR spring/summer-run and SR fall-run Chinook salmon.

4.6. Bull Trout – Columbia River DPS

4.6.1. Current Status

Columbia River Basin bull trout were listed as threatened on June 10, 1998 (63 FR 31647). Critical habitat for Columbia River Basin bull trout was designated on September 26, 2005 (70 FR 56211) and revised on October 18, 2010, with an effective date of November 17, 2010 (75 FR 63898). This DPS encompasses the mainstem Columbia River and its tributaries, excluding the Jarbidge River in Nevada and east of the Continental Divide in Montana.

4.6.2. General Background Pertinent to the Columbia River

The life history of bull trout is described in detail in the final rule to list the Columbia River DPS as a threatened species (63 FR 31647). A summary follows to assist in the discussion of effects related to the proposed action.

Bull trout have more specific habitat requirements than most other salmonids and are found primarily in cold streams, although individual fish are found in larger, warmer river systems throughout the Columbia River Basin. Water temperature above 15°C (59°F) is believed to limit bull trout distribution. Resident and juvenile migratory bull trout prey on zooplankton, terrestrial and aquatic insects, and small fish, while adult migratory bull trout prey on various fish species. All life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders, and pools. Juvenile and adult bull trout frequently inhabit side channels, stream margins, and pools with suitable cover.

Migratory corridors link seasonal habitats for all bull trout life histories. Migrations facilitate gene flow among local populations when individuals from different local populations interbreed, or stray to non-natal streams. Local populations that are extirpated by catastrophic events may also become reestablished by bull trout migrants (63 FR 31647).

4.6.3. Presence in Action Area

According to StreamNet (2012), the portion of the action area upstream of Bonneville Dam is used for bull trout migration. Conversations with Bill Duke and John North, ODFW biologists, confirmed that a few bull trout may be present in the upstream portions of the action area (ODFW, 2012a), but are very rare in the area below Bonneville Dam (ODFW, 2012b). Adults use the upstream portions of the action area as overwintering and foraging habitat, and juveniles may use it for rearing when water temperatures are low enough. The action area is not likely to be used for spawning (ODFW 2012a, 2012b). Bull trout may be present at the Port of Morrow when water temperatures are low enough, primarily from October through June (see Table 4-2), but are unlikely to be present at Port Westward (see Table 4-3). The entire length of the action area is located within designated critical habitat for bull trout (75 FR 63898).

4.6.4. Critical Habitat

Bull trout critical habitat is described in terms of the following nine PCEs (75 FR 63898). Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

1. *Water quality – springs, seeps, groundwater sources, and subsurface connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.*

2. *Migration corridors – migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.*

3. *Food availability – an abundant food base including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.*

4. *In-stream habitat – complex river, stream, lake, reservoir, and marine shoreline aquatic environments; and processes with features such as large wood, side channels, pools, undercut banks and diverse substrates, to provide a variety of depths, gradients, velocities, and structure.*

5. *Water temperature – ranging from 2 to 15°C (36° to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range. Specific temperatures within this range will vary depending on bull trout life history stage and form; geography; elevation; diurnal and seasonal variation; shade, such as that provided by riparian habitat; and local groundwater influence.*

6. *Substrate characteristics – substrates of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount (e.g., less than 12 percent) of fine substrate less than 0.85 mm (0.03 in.) in diameter and minimal embeddedness of these fines in larger substrates are characteristic of these conditions.*

7. *Stream flow – a natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph.*

8. *Water quantity – sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.*

9. *Non-native species – few or no non-native fish; predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); inbreeding (e.g., brook trout); or competitive (e.g., brown trout) species present.*

4.7. Green Sturgeon – Southern DPS

4.7.1. Current Status

The southern DPS of green sturgeon was listed as threatened on April 7, 2006 (71 FR 17757). Critical habitat was designated on October 9, 2009 (74 FR 52300). This DPS includes all spawning populations of green sturgeon south of the Eel River (exclusive), principally including the Sacramento River green sturgeon spawning population.

4.7.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of green sturgeon are described in detail in the proposed critical habitat rule (73 FR 52084), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Green sturgeon are large, slow-growing anadromous fish that spend most of their life cycle in the nearshore oceanic and estuarine environments of the Pacific coast of North America. This species is iteroparous, making repeated migrations into freshwater rivers to spawn. Spawning has been confirmed in only three rivers: the Rogue River in Oregon, the Klamath River in California (northern DPS), and the Sacramento River in California (southern DPS). Adult and subadult green sturgeon are found in certain estuaries in California, Oregon, and Washington during the summer and coastal marine waters in central California, Vancouver Island, and southeast Alaska during the winter. This species spends most of its time near the bottom of the water column in waters as deep as 350 feet and are benthic feeders, consuming shrimp, mollusks, crustaceans, and small fish.

The Columbia River estuary supports large summer aggregations of green sturgeon, with individuals from all known spawning populations, including the southern DPS (73 FR 52084).

4.7.3. Presence in Action Area

A conversation with John North, ODFW biologist, confirmed that adult and subadult southern DPS green sturgeon may be present in the lower portion of the Columbia River and are seen infrequently as far upstream as the Bonneville Dam (ODFW, 2012b). Green sturgeon use this portion of the action area as a migration corridor and summer foraging area from mid-June through mid-September. The Columbia River is not used for spawning, and juvenile green sturgeon are not present in the action area (ODFW, 2012b). The portions of the action area in the Columbia River estuary downstream of Wallace Island (RM 46), as well as the coastal marine area between the mouth of the Columbia River and the Columbia Bar are located within designated critical habitat for southern DPS green sturgeon (74 FR 52300).

4.7.4. Critical Habitat

Southern DPS green sturgeon critical habitat is described in terms of PCEs for the following three areas used by different life stages of the species (74 FR 52300). Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

1. *Freshwater riverine systems. Components of this system include: (i) food resources providing abundant prey for larval, juvenile, subadult, and adult life stages; (ii) substrate type or size suitable for egg deposition and development,*

larval development, and subadults and adults; (iii) water flow regime necessary for normal behavior, growth, and survival of all life stages; (iv) water quality necessary for normal behavior, growth, and viability of all life stages; (v) migratory corridor necessary for the safe and timely passage of southern DPS fish within riverine and estuarine habitats; (vi) depth of holding pools (>5m) with adequate flow and water quality to maintain the physiological needs of holding adult and subadult fish; and (vii) sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.

2. *Estuarine areas. Components of this system include: (i) food resources providing abundant prey for juvenile, subadult, and adult life stages; (ii) water flow regime within the Sacramento River bays and estuaries that is adequate to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds; (iii) water quality necessary for normal behavior, growth, and viability of all life stages; (iv) migratory corridor necessary for the safe and timely passage of southern DPS fish within riverine and between estuarine and riverine or marine habitats; (v) depth diversity necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages; and (vi) sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.*

3. *Nearshore marine waters. Components of this system include: (i) migratory corridors necessary for the safe and timely passage of southern DPS fish within marine and between estuarine and marine habitats; (ii) water quality in nearshore areas with adequate dissolved oxygen and acceptably low levels of contaminants that may disrupt the normal behavior, growth, and viability of adult and subadult green sturgeon; and (iii) food resources providing abundant prey items for subadults and adults, which may include benthic invertebrates and fishes.*

4.8. Eulachon – Southern DPS

4.8.1. Current Status

Southern DPS eulachon were listed as threatened on March 18, 2010 (75 FR 13012). Critical habitat was designated on October 20, 2011 (76 FR 65324). This DPS includes all populations spawning from the Skeena River in British Columbia (inclusive) south to the Mad River in northern California (inclusive).

4.8.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of eulachon are described in detail in the critical habitat listing (76 FR 65324), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Eulachon are small anadromous fish, spending most of their life cycle in the ocean and migrating into the lower reaches of large rivers to spawn. This species is semelparous. Eggs are typically deposited onto sand or gravel and incubate for 20 to 40 days before hatching. The larvae are carried downstream into estuarine areas, where they may remain for several weeks. Larval and young juvenile eulachon are dispersed into nearshore marine environments by estuarine, tidal, and ocean currents. Once entering the ocean, eulachon tend to disperse to deeper areas over the continental shelf, and are mainly found near the bottom of the water column in waters between 60 and 300 feet deep, though occasionally to 600 feet deep. Larvae and juveniles eat phytoplankton, small crustaceans, and worm larvae, while oceanic adults eat zooplankton, mainly crustaceans. Spawning adults do not feed. Eulachon remain in the ocean for two to five years before returning to their natal streams to spawn.

The Columbia River Basin contains the highest production of eulachon south of Canada, primarily in the mainstem Columbia River and the Cowlitz River. Eulachon in the Columbia River system typically spawn in January, February, and March, when water temperatures are between 4°C and 10°C (39°F and 50°F). Spawning has been reported in the Columbia River between RM 35 and RM 73 (76 FR 65324).

4.8.3. Presence in Action Area

A conversation with John North, ODFW biologist, confirmed that southern DPS eulachon may be present in the lower portion of the Columbia River as far upstream as the Bonneville Dam. Adult eulachon use this portion of the action area as a migration corridor and spawning area from December through March, and juveniles use this area for rearing and migration from February through April (ODFW, 2012b). The portion of the action area from the Bonneville Dam (RM 146) to the mouth of the Columbia River is located within designated critical habitat for southern DPS eulachon (76 FR 65324).

4.8.4. Critical Habitat

Southern DPS eulachon critical habitat is described in terms of the following three essential features (76 FR 65324). Section 5.0, Baseline Conditions, provides more detailed information on existing habitat conditions and elements that support these PCEs within the action area.

1. *Freshwater spawning and incubation sites. Components of this feature include: (a) flow regimes (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of freshwater discharge over time) that support spawning and survival of all life stages; (b) water quality suitable for spawning and viability of all eulachon life stages; (c) water temperatures suitable, within natural ranges, in eulachon spawning reaches; and (d) substrate suitable for eulachon egg deposition and development.*

2. *Freshwater and estuarine migration corridors. Components of this feature include: (a) migratory corridors to provide safe and unobstructed pathways for adults to access freshwater spawning habitats, for larval stages to access estuarine rearing habitats, and for juveniles and adults to access oceanic habitats; (b) flow regimes (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of freshwater discharge over time) that support spawning migration of adults and outmigration of larval eulachon from spawning sites; (c) water quality suitable for survival and migration of spawning adults and larval eulachon; (d) water temperature suitable for survival and migration; and (e) food resources to support larval eulachon survival.*

3. *Nearshore and offshore marine foraging habitat. Components of this feature include: (a) food resources that support foraging leading to adequate growth and reproductive development for adults and juveniles in the marine environment; and (b) water quality suitable for adequate growth and reproductive development.*

4.9. Steller Sea Lion – Eastern DPS

4.9.1. Current Status

Steller sea lions were originally listed as threatened on November 26, 1990 (55 FR 49204). When the eastern and western DPSs were designated on June 5, 1997 (62 FR 30772), the western Steller sea lion DPS was reclassified as endangered, while the eastern Steller sea lion DPS remained listed as threatened. Critical habitat for eastern DPS Steller sea lions was designated on August 27, 1993 (58 FR 45269). This DPS includes all Steller sea lion populations east of 144 degrees West longitude (a line near Cape Suckling, Alaska).

4.9.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of Steller sea lions are described in detail in the *Recovery Plan for the Steller Sea Lion* (NMFS, 2008b), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

This species is relatively long-lived, with males living up to 20 years and females up to 30 years. Haulout sites are used for resting and refuge during the non-breeding season by all ages and sexes, and by non-breeding adults and subadults year-round. Steller sea lions are generalist predators and eat mainly fish and cephalopods. Some prey species, such as salmon, herring, cod, eulachon, and capelin, are preferentially targeted by sea lions when they become seasonally abundant. Steller sea lions may travel long distances during the year, between feeding areas and breeding rookeries (NMFS, 2008b).

4.9.3. Presence in Action Area

Eastern DPS Steller sea lions are known to use the action area. Four known haulout areas are located in the Columbia River: 1) the tip of the South Jetty of the Columbia River, RM 0; 2) the East Mooring Basin in Astoria, RM 15; 3) Phoca Rock, downstream of Bonneville Dam, RM 132; and 4) Bonneville Dam tailrace, RM 146. Of the four sites, the highest numbers are seen at the South Jetty (NMFS, 2012a). Areas near Bonneville Dam have been increasingly used in recent years by eastern DPS Steller sea lions in the spring, attracted by the high numbers of fish entering the upstream fish ladders during migration (Stansell et al., 2010).

4.9.4. Critical Habitat

Critical habitat for eastern DPS Steller sea lions consists of (a) Alaska rookeries, haulouts, and associated areas; (b) California and Oregon rookeries and associated areas; and (c) three special aquatic foraging areas in Alaska (58 FR 45269). None of these areas occur in the action area. The closest areas of designated critical habitat are the Oregon rookery areas, located at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock). These areas are approximately 240 miles south of the Columbia River and will not be affected by the proposed project.

4.10. Killer Whale – Southern Resident DPS

4.10.1. Current Status

Southern resident DPS killer whales were listed as endangered on November 18, 2005 (70 FR 69903), and this status was upheld in the five-year review in January 2011 (NMFS, 2011a). This DPS includes whales from J, K, and L pods, wherever they occur in the wild. Critical habitat for southern resident DPS killer whales was designated on November 29, 2006 (71 FR 69054).

4.10.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of killer whales are described in detail in the *Recovery Plan for Southern Resident Killer Whales* (NMFS, 2008a), which is included herein by reference. A summary follows to assist in the discussion of effects related to the proposed action.

Killer whales are the largest members of the dolphin family of toothed whales and are found in all oceans, although most commonly in coastal waters and higher latitudes. The killer whales in the northeastern Pacific region can be classified in three ecotypes based on ecological, behavioral, morphological, and genetic characteristics: offshore form, transient form, and resident form (which includes the southern resident DPS). Only the southern resident DPS is federally listed and described in this BA. Resident killer whales are fish eaters and live in stable, close-knit matrilineal pods of 10 to 60

individuals. The three pods that compose the southern resident DPS reside for most of the year (late spring, summer, and fall) in the inland waterways of Washington state and British Columbia, including the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, and to a lesser extent in coastal waters off California, Oregon, Washington, and British Columbia. Little is known about the winter range of southern resident killer whales (NMFS, 2008a).

Killer whales have the most varied diet of all cetaceans and often use a coordinated hunting strategy, working as a team to capture and share prey. Salmon comprises a large percentage of the diet of southern resident DPS killer whales, especially Chinook salmon (NMFS, 2008a; Hanson et al., 2005).

4.10.3. Presence in Action Area

The only portion of the action area that southern resident DPS killer whales are likely to use is the nearshore marine habitat between the mouth of the Columbia River and the Columbia Bar, although they may occasionally enter the lower reaches of the Columbia River in pursuit of salmon. Killer whale distribution is correlated with salmon runs, particularly Chinook salmon, and killer whales have been recorded in the vicinity of the Columbia River in March and October (NMFS, 2008a).

4.10.4. Critical Habitat

All designated areas of critical habitat for southern resident DPS killer whales are located in the Puget Sound and Strait of Juan de Fuca regions of Washington State (71 FR 69054), approximately 150 miles north of the Columbia River, and will not be affected by the proposed project.

4.11. Other Whales – Humpback, Fin, Sei, Sperm, and Blue

4.11.1. Current Status

These five whale species were listed as endangered on June 2, 1970 (35 FR 8491), and no critical habitat has been designated.

4.11.2. General Background Pertinent to the Columbia River

The life histories and habitat requirements of these whale species are described in detail in the NMFS Office of Protected Resources species Internet web pages (NMFS, 2012d). A brief summary follows to assist in the discussion of effects related to the proposed action.

Humpback, fin, sei, and blue whales are baleen whales that feed by filtering small organisms such as krill, small fish, and squid out of the water column. The sperm whale is a toothed whale and feeds primarily on large squid. These species are all large, long-

lived whales that typically inhabit open ocean areas. These species may use nearshore marine areas for foraging and as migration corridors between summer feeding areas in northern latitudes and winter breeding areas farther south. None of the five species uses the action area for breeding. Threats to the species include ship strikes, entanglement in drift nets or other fishing gear, and increasing levels of anthropogenic sound in the ocean (NMFS, 2012d).

4.11.3. Presence in Action Area

The only portion of the action area that these species may occupy is the area between the mouth of the Columbia River and the Columbia Bar. In general, these whales typically use open ocean habitat and are widely distributed; it is therefore unlikely that these species may be found in the action area. Based on the most recent stock assessment reports (NMFS, 2012b), humpback whales are the most likely to be found close to shore, followed by fin whales and blue whales, although near-shore sightings are generally more likely to occur farther south than the action area, in California. A humpback whale was seen inside the Columbia Bar on May 12, 2011, when it collided with a sailboat approximately 2.3 miles southwest of the tip of the South Jetty (Schroeder, 2011). Sei and sperm whales are usually found farther offshore, and it is unlikely that they would be seen inside the Columbia Bar (NMFS, 2012b).

4.11.4. Critical Habitat

Critical habitat for these five whale species has not been designated.

4.12. Leatherback Turtle

4.12.1. Current Status

Leatherback turtles were listed as threatened on June 2, 1970 (35 FR 8491). Critical habitat was designated on January 26, 2012 (77 FR 4170).

4.12.2. General Background Pertinent to the Columbia River

The life history and habitat requirements of this species are described in detail in the NMFS Office of Protected Resources species Internet web page (NMFS, 2012e). A brief summary follows to assist in the discussion of effects related to the proposed action.

Leatherback turtles are the largest living reptile and can reach a length of 6.5 feet and a weight of up to 2,000 pounds. Leatherback turtles prey on jellyfish and salps, migrating to temperate waters to take advantage of higher prey densities during the summer. This species is highly migratory and usually pelagic, although it does use coastal habitats for foraging. Leatherback turtles nest in the tropics and use the action area only for migrating and feeding. Threats to this species include entanglement in nets and other

fishing gear, loss of nesting habitat, marine trash (especially plastic debris that can be mistaken for jellyfish prey), and environmental contamination (NMFS, 2012e).

4.12.3. Presence in Action Area

Suitable migrating and foraging habitat for leatherback turtles occurs in the action area only in the nearshore marine waters between the mouth of the Columbia River and the Columbia Bar. This area is located in Area 2 of the final critical habitat designation, which extends from Cape Flattery, Washington, to Cape Blanco, Oregon. High seasonal densities of a primary prey species (brown sea nettle) occur in this area, and it is known to be the principal leatherback foraging area in Washington and Oregon, particularly the important habitat associated with the Columbia River plume (77 FR 4170). Distribution of leatherback turtles is correlated with jellyfish density, and while it is possible that leatherback turtles may be found within the action area, satellite tracking data indicates that they are most likely to forage in continental shelf and slope waters between the 200 meter (656 feet) and 2,000 meter (6,562 feet) depth contours (Benson et al., 2011), which is beyond the seaward extent of the action area.

4.12.4. Critical Habitat

Leatherback critical habitat is described in terms of one PCE. This consists of the occurrence of prey species, primarily jellyfish of the order *Semaeostomeae*, of sufficient condition, distribution, diversity, abundance, and density necessary to support individual as well as population growth, reproduction, and development of leatherbacks (77 FR 4170). The portion of the action area between the mouth of the Columbia River and the Columbia Bar is within the designated critical habitat.

4.13. Other Sea Turtles – Green, Loggerhead, and Olive Ridley

4.13.1. Current Status

Green, loggerhead, and olive ridley turtles were listed as threatened on July 28, 1978 (43 FR 32800). Loggerhead turtles were later split into nine DPSs, and the North Pacific Ocean DPS was listed as endangered on September 22, 2011 (76 FR 58868). Of these three species, critical habitat has been designated only for green turtles, on September 2, 1998 (63 FR 46693).

4.13.2. General Background Pertinent to the Columbia River

The life histories and habitat requirements of these turtle species are described in detail in the NMFS Office of Protected Resources species Internet web pages (NMFS, 2012e). A brief summary follows to assist in the discussion of effects related to the proposed action.

These three species range in size from large to relatively small. The green turtle can weigh up to 350 pounds, while the olive ridley turtle weighs up to 100 pounds. Green turtles are exclusively herbivorous, grazing on seagrasses and algae. Loggerhead turtles prey on whelks and conch, and olive ridley turtles have a more varied diet, consuming algae, tunicates, crustaceans, fish, and mollusks. These species are all highly migratory and are usually pelagic, although they do use coastal habitats for foraging and nesting. Threats to these turtle species include entanglement in nets and other fishing gear, loss of nesting habitat, disease, marine trash, environmental contamination, and human harvest of eggs and adults (NMFS, 2012e).

4.13.3. Presence in Action Area

Suitable habitat for green, loggerhead, and olive ridley turtles occurs in the action area only in the nearshore marine waters between the mouth of the Columbia River and the Columbia Bar. The action area is used only for migrating and feeding. Green and loggerhead turtles are known to use coastal waters for foraging, while olive ridley turtles mainly use coastal waters as migration corridors between pelagic foraging areas and tropical nesting beaches farther south. None of these turtles nest in the action area (NMFS, 2012e).

4.13.4. Critical Habitat

Of these three species, critical habitat has been designated only for the green turtle. This critical habitat is entirely located in the waters around Culebra Island, Puerto Rico (63 FR 46693), and will not be affected by the proposed project.

5.0 BASELINE CONDITIONS

5.1 Port of Morrow

5.1.1 Upland Facilities

The upland vegetation at the Port of Morrow project site where the upland facilities and staging will be located consists of a mix of native and introduced species dominated by rabbitbrush (*Chrysothamnus nauseosus*), Russian thistle (*Salsola iberica*), and annual grasses, primarily cheatgrass (*Bromus tectorum*) (see Photographs 6 and 8, Appendix B). Russian thistle and cheatgrass are non-indigenous invasive species. There are no wetlands or unique plant communities in the vicinity of the upland facilities.

5.1.2 In-water Facilities

For the Port of Morrow, little riparian vegetation exists along the shoreline where in-water facilities are planned. Some individual willow (*Salix* sp.) plants as well as false indigo (*Amorpha fruticosa*), an invasive woody species, were noted near the OHWE during a site visit in December 2011 (see Photographs 1 and 2, Appendix B). Other species present along the shoreline include bitterbrush (*Purshia* sp.), sagebrush (*Artemesia* sp.), and yarrow (*Achillea millefolium*). There are no trees within the impact area, although scattered introduced trees are near the site of in-water facilities. Much of the river shoreline is a mixture of sand, large gravels, and small cobbles, which extend into the water to the extent visible from the shoreline. Small pieces of driftwood were observed on the shore above the water level, but no large or small wood was evident in the water where in-water facilities will be located. There are no wetlands or other important aquatic plant communities along the water line, and the substrate below the proposed dock consists of sand, gravels, cobbles, and other depositional materials not suitable for spawning and marginally suitable for benthic prey production.

5.2 Columbia River Between the Port of Morrow and Port Westward

The Columbia River is the largest river in the Pacific Northwest, draining an area of approximately 258,000 square miles and located in portions of seven states and British Columbia. Beginning at Columbia Lake, British Columbia, the river travels 1,200 miles through 14 dams before reaching the Pacific Ocean on the border between Washington and Oregon (USGS, 1990). The action area for the proposed project is located in the mid to lower reaches of the river, from RM 271 at Boardman, Oregon, to the Columbia Bar, which is approximately five miles beyond the mouth of the river.

The proposed project extends from the Columbia Basin Province (Port of Morrow site) downstream through the Columbia Gorge, the Coast Range Province (Port Westward site), and the Columbia River Estuary to the Pacific Ocean. Climate in these areas ranges from hot and arid in the interior Columbia Basin region to a milder maritime climate in the Coast Range and

coastal areas (Franklin and Dyrness, 1988). The Columbia River is highly regulated for hydropower, transportation, and flood control, and much of the action area is a series of reservoirs created by the John Day Dam (RM 215), The Dalles Dam (RM 192), and the Bonneville Dam (RM 146). The lower, estuarine reaches of the river are tidally influenced up to the Bonneville Dam, with the upper limit of salt intrusion at approximately RM 30, depending on river discharge levels (Chawla et al., 2008).

Table 5-1 documents the environmental baseline and effects of the proposed action on relevant indicators for salmon and steelhead for the portion of the Columbia River that would be affected by the Morrow Pacific project. The completion of this checklist was based on use of the Matrix of Pathways and Indicators developed for Pacific salmon by NMFS (NMFS, 1996). Table 5-2 documents the environmental baseline and effects of the proposed action on relevant indicators for bull trout. Table 5-2 was based on use of the USFWS matrix described in *A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale* (USFWS, 1998).

The functionality of each indicator was evaluated in terms of the criteria established by NMFS and USFWS and was rated as follows: properly functioning, at risk, or not properly functioning. The potential effect of the proposed project construction and transfer of coal within the Columbia River on the functionality of each indicator was then determined. This determination consisted of evaluating whether the project has the potential to restore, maintain, or degrade the functionality of each indicator. Information used to create the tables was obtained from consultation with NMFS, USFWS, ODFW, and various online resources. Further explanation of the effects of the action on the baseline conditions is found in Section 6, Analysis of Effect.

Table 5-1. Matrix of Pathways and Indicators for Pacific Salmon and Steelhead. A checklist for documenting the environmental baseline and effects of the proposed action(s) on relevant environmental indicators.

Pathways: Indicators	**ENVIRONMENTAL BASELINE**			**EFFECTS OF THE ACTION**		
	Properly Functioning	**At Risk**	**Not Properly Functioning**	**Improve**	**Maintain**	**Degrade**
Water Quality:						
Temperature			X		X	
Sediment			X		X(-)	
Chemical Contamination/ Nutrients			X		X(-)	
Habitat Access:						
Physical Barriers		X			X	
Habitat Elements:						
Large Woody Debris		X			X	
Pool Frequency		X			X	
Pool Quality		X			X	
Off-channel Habitat		X			X	
Refugia		X			X	
Channel Conditions and Dynamics:						
Width/Depth Ratio		X			X	
Streambank Condition		X			X	
Floodplain Connectivity			X		X	
Flow/Hydrology:						
Peak/Base Flows			X		X	
Drainage Network Increase		X			X	
Watershed Conditions:						
Road Density and Location		X			X	
Disturbance History		X			X	
Riparian Reserves		X			X	

X (+,-) demonstrates temporary, localized impacts, but no significant impacts at the watershed scale.

Table 5-2. Matrix of Pathways and Indicators for Columbia River Bull Trout. A checklist for documenting the environmental baseline and effects of the proposed action(s) on relevant environmental indicators.

Pathways: Indicators	**ENVIRONMENTAL BASELINE**			**EFFECTS OF THE ACTION**		
	Functioning Appropriately	**Functioning At Risk**	**Functioning at Unacceptable Risk**	**Improve**	**Maintain**	**Degrade**
Subpopulation Character:						
Subpopulation Size			X		X	
Growth and Survival			X		X	
Life History Diversity/Isolation			X		X	
Persistence and Genetic Integrity Subpopulation			X		X	
Water Quality:						
Temperature			X		X	
Sediment			X		X (-)	
Chemical Contamination/ Nutrients			X		X(-)	
Habitat Access:						
Physical Barriers		X			X	
Habitat Elements:						
Fine Sediment		X			X (-)	
Pool Frequency		X			X	
Large Woody Material		X			X	
Riparian Habitat		X			X	
Channel Conditions and Dynamics:						
Streambank Condition		X			X	
Floodplain Connectivity			X		X	
Flow/Hydrology:						
Change in Peak/Base Flows			X		X	
Drainage Network Increase		X			X	
Integration of Species and Habitat Conditions		X			X	

X (+,-) demonstrates temporary, localized impacts, but no significant impacts at the watershed scale.

Water Quality. The Columbia River is listed as a water quality limited stream for the following parameters by the DEQ Integrated Report (DEQ, 2012).

Table 5-3. Pollutants Present in the Columbia River in the Action Area

Parameter	River Mile	Parameter	River Mile
Category 5, 303(d) list, TMDL needed:		*Category 3B, Potential Concern:*	
arsenic	0-142	aldrin	0-142
arsenic(tri)	35.2-98	alkalinity	0 to 34.5
DDT metabolite (DDE)	0-142	alpha-BNC	0-142
fecal coliform	0-35.2	benzo(a)anthracene	0-142
PCB	0-188.6	benzo(g,h,i)perylene	0-142
pH	121.8-319.3	BHC	0-142
PAH	98-142	cadmium	0-142
temperature	0-306.1	chromium(hex)	0-142
		chrysene	0-142
Category 4A, TMDL approved:		copper	0-142
		cyanide	35.2-142
dioxin (2,3,7,8-TCDD)	0-303.9	DDD	0-142
total dissolved gas	0-287.1	DDT	0-142
		dieldrin	0-142
		dioxins/furans	0-142
		endrin	0-142
		iron	0-142
		lead	0-142
		manganese	75.5-137.1
		mercury	0-142
		nickel	0-142
		pH	35.2-98
		phenol	0-142
		phosphate phosphorus	0-319.3
		PAH	0-98
		pyrene	0-142
		radionuclides	0-142
		silver	0-142
		tributylin	0-142
		zinc	0-142

Much of the Columbia River is water quality limited, particularly in areas where historic industrial and agricultural practices have contaminated the river through direct discharge or indirectly through surface runoff or via tributaries. Many of these pollutants are contained within river sediments (TechLaw, 2011) and could be released to the water column if these sediments are disturbed (Asplund, 2000; Eggleton and Thomas, 2004). As a result, the water quality pathway and associated indicators are considered **not properly functioning.**

Habitat Access. There are 14 hydroelectric dams on the mainstem Columbia River; however, most have fish passage facilities. There are three dams within the action area: John Day, The Dalles, and Bonneville. All provide upstream and downstream passage, through

upstream ladders for adults, downstream juvenile passage facilities, or spill. Migrating salmon may be injured or killed while passing these dams, although upstream and downstream fish passage facilities at all three locations and turbine upgrades at the Bonneville Dam have been installed to minimize the risk to fish. Recent juvenile salmonid downstream survival rates through the Bonneville Dam, The Dalles Dam, and the John Day Dam were approximately 96 percent, 96 percent, and 91 percent, respectively (Johnson et al., 2011; Ploskey et al., 2011; Weiland et al., 2011). Predation by piscivorous birds and fish on juvenile salmonids is elevated in the areas around the dams, as migrating fish are concentrated in passage facilities before they are able to disperse to the safer deep water areas of the river channel (USACE, 2005). Predation on adults by sea lions can also be a factor in the area downstream of Bonneville Dam (Stansell et al., 2010). Exclusionary devices and other deterrents are used to help reduce the impact of predation on salmon. While passage is possible, the dams do interrupt salmonid migration, so this habitat indicator is considered **at risk**.

Habitat Elements. Habitat elements include substrate, large woody material, pool frequency and quality, off-channel habitat, and refugia. These habitat elements can be limiting in the lower Columbia River, especially in the areas within and upstream of the Columbia Gorge where forests are naturally lacking and where the dams have created large reservoirs (NPCC, 2004a). In the lower reaches, where the surrounding land is more forested, these habitat elements are more available but still do not fully meet the desired standard and may be degraded by industrial activities, urbanization, agricultural and forestry activities, and shipping channel maintenance (NPCC, 2004a; NPCC, 2004b; LCFRB, 2004).

Aquatic vegetation, side channels, and slower water refuges are present among the islands, sloughs, and marshes located in the estuary, and this complex habitat generally supports adequate prey species for adult and juvenile fish. Diking and filling riparian wetlands and floodplains to improve agricultural land and provide flood control has further reduced access to rearing areas adjacent to the river in the lower mainstem and estuary, input of large woody debris to the river system, and food base available to migrating and rearing salmonids (LCFRB, 2004). These habitat elements are identified as **at risk**.

Channel Conditions and Dynamics. Due to the creation of large reservoirs by hydroelectric dams along much of the length of the river, the width/depth ratio is considered **at risk**. Streambank condition and floodplain connectivity is considered **at risk** due to agricultural and forestry practices, urban development, and roads. These activities can lead to reduced and altered riparian vegetation communities, increased erosion, increased bank armoring (riprap), and reduced linkage of channel and off-channel areas (NPCC, 2004a; NPCC, 2004b; LCFRB, 2004).

Flow/Hydrology. The Columbia River drains a very large area and is fed by rains and snowmelt from the surrounding mountains. Historically, peak flows would occur in the spring and low base flows would occur in the late summer and early fall. Currently, Columbia River flows are impacted dramatically by the operation of the hydroelectric dams, which are managed for hydropower production, recreation, navigation, irrigation, anadromous fish passage, and flood control (NPCC, 2004a; NPCC, 2004b; LCFRB, 2004). Water quantity below

the Bonneville Dam is affected by dam operation, which affects river levels and may dewater LCR Chinook, chum, and coho salmon redds that are high in the floodplain (FPC, 2012; NPCC, 2004a; NPCC, 2004b). Hydrology in the basin as a whole has been altered because of dam operations, roads, urban development, agricultural practices, and forest management practices along the Columbia River and on its tributaries (NPCC, 2004a; NPCC, 2004b; LCFRB, 2004). Peak/base flow in the Columbia River is considered **not properly functioning** due to hydroelectric dam operations. No new roads will be constructed as a result of this project, and drainage network increases are considered **functioning properly.**

Watershed Conditions. Much of the Columbia River Basin has roads in close proximity to waterways. Disturbance history in the Columbia watershed is high and riparian reserves along much of the mainstem Columbia River are degraded (NPCC, 2004a; NPCC, 2004b; LCFRB, 2004). As a result, indicators of watershed conditions are considered **at risk.**

Subpopulation Character (Bull Trout). There are numerous physical barriers to fish movement in the Columbia River watershed, including 14 major hydroelectric dams on the mainstem Columbia. In addition, the formation of large reservoirs by the dams and lack of streamside shade in much of the central portion of the river can create thermal barriers that may limit bull trout movement. Highly modified in-channel and riparian habitat in the Columbia River Basin further limits bull trout use of these areas and may lead to population isolation (USFWS, 2008; NPCC, 2004a; NPCC 2004b). As a result, indicators of subpopulation character are considered **functioning at unacceptable risk** for bull trout.

Integration of Species and Habitat Conditions (Bull Trout). Moderate to severe habitat alteration and reduced subpopulation connectivity are present in the Columbia River watershed (USFWS, 2008). As a result, the integration of species and habitat condition indicators are considered **at risk** for bull trout.

5.3 Port Westward and Western Columbia River/Pacific Ocean

Refer to Section 5.2, Columbia River Between the Port of Morrow and Port Westward, for a description of baseline conditions within the Columbia River. The Port Westward site is a developed commercial dock historically used for transfer of ethanol and diesel to OGVs. The dock is adjacent to an ethanol plant that is no longer in service, as well as the Bradbury Slough (see Figure 1C, Appendix A). Wetlands and hardwood trees are scattered throughout upland areas adjacent to the dock (see Figure 9, Appendix A). The site is relatively flat along the shoreline. Minimal on-site data were collected for this area because there will be no changes to existing conditions as a result of this project. The Port Westward dock is located at a water depth of approximately 60 feet and is composed of timber with an asphalt roadway surface.

The only marine habitat in the action area is the nearshore area between the mouth of the Columbia River and the Columbia Bar. There are no major obstructions to migration in this area, and minimal cover, such as large wood and aquatic vegetation, is present. Nearshore water quality is heavily influenced by the water quality of the Columbia River, which has elevated levels of several contaminants (see Section 5.2, Columbia River Between Port of

Morrow and Port Westward). The Columbia River jetties, which extend out approximately 0.5 mile (North Jetty) and 2.5 miles (South Jetty) from the mouth of the river, provide underwater structure for aquatic organisms, haulout areas for seals and sea lions, and perching/roosting areas for birds.

6.0 ANALYSIS OF EFFECT

This section addresses possible impacts to listed species from the proposed action, which includes Port of Morrow site construction (installation of the dolphins, construction of the walkway, dock, conveyor, and coal unloading/storage facility, and planting and restoration activities), downstream transportation of coal by barges, transloading of coal from the barges to OGVs at Port Westward, and travel of the OGVs out of the Columbia River.

This section is organized into five primary areas:

1. Changes to baseline conditions following the salmon and bull trout matrices of pathways and indicators and focusing on physical changes.
2. Noise impacts that are expected to occur to all listed fish species that would occur at the Port of Morrow during pile driving.
3. Ship strike impacts to marine mammals and turtles.
4. Habitat impacts expected to occur as a result of project construction and operations.
5. Species-specific and critical habitat impacts based on each species' use of the Port of Morrow and Columbia River.

In addition, each area is also subdivided into the three components of the action area and includes direct and indirect construction and operational impacts.

6.1 Effects on NMFS and USFWS Matrix Indicators

Analyses within this section follow the matrix of pathways and indicators for Columbia River salmon, steelhead, and bull trout. Refer to Tables 5-1 and 5-2.

6.1.1 Port of Morrow

Water Quality. Earth-disturbing activities, including piling installation below the OHWE and upland construction activities, may cause an increased delivery of sediment to the Columbia River and increased turbidity in the water column. Sediment introduced into waterways can degrade fish habitat and reduce primary productivity, leading to a decreased food base for listed species that use the area (NPCC, 2004a, 2004b). Physical effects of increased turbidity on fish can include damage to gill tissue and physiological stress (Bash et al., 2001). Behavioral effects of increased turbidity on salmonids include disruption of migration and feeding behavior, reduced ability of fish to locate prey, and avoidance of areas of increased turbidity (Bash et al., 2001; Salo et al., 1980).

Because erosion control measures, such as silt fences, will be used during construction, very little sediment is expected to be released from the upland portion of the project site. As temporary and permanent pilings are installed and the temporary pilings are removed, sediment disturbance will occur at the site and downstream of the site. These

impacts will be localized in the vicinity of the dock site and temporary over the four-month in-water construction period. In addition, operation of tugboats and barges at the site may result in localized sediment disturbances, although placement of the mooring facility in a water depth of approximately 28 feet will minimize this potential. As the proposed construction area represents a relatively small area on the bank of the river, fish are likely to avoid areas with higher turbidity (Salo et al., 1980), and will therefore be minimally impacted.

Construction in and near water bodies increases the risk that toxic or harmful substances such as fuel, lubricants, hydraulic fluids, or coolants may enter the water. These chemicals can be acutely toxic to fish at high levels of exposure and can cause acute and chronic effects to fish species, aquatic invertebrates, and aquatic and riparian vegetation (Neff, 1985). In-channel work will include pile driving; however, the work will be conducted from barges to avoid placement of pile driving equipment directly into the river channel. The operation of equipment adjacent to the Columbia River also has the potential to release toxic or harmful substances and kill or injure listed fish or disrupt normal behavior. In addition to avoiding placement of equipment directly into the water, conservation measures include use of non-toxic lubricants for pile driving equipment, which should minimize the opportunity for contaminants to come into contact with the water and affect ESA-listed fish.

Loading the barges at the Port of Morrow will increase the risk of coal entering the river. However, the coal handling devices will be enclosed and, therefore, minimize the risk of coal spills. Additionally, studies have shown that Powder River Basin coal, a low-sulfur sub-bituminous coal, is less likely to release toxic contaminants than other coals, and poses minimal risk to the environment in the event that an accidental release should occur (Golder Associates, Inc., 2012).

Although impacts to water quality, including turbidity and chemical contaminants, may occur as a result of the proposed construction and project operation, these will not have a significant impact on the river as a whole. Currently, the water quality pathways and indicators are considered "not properly functioning" for the project area (see Tables 5-1, 5-2, and 5-3 in Section 5.0, Baseline Conditions).

Habitat Access. Upstream and downstream adult and juvenile fish passage within the Columbia River will be maintained during the in-water construction period, although fish will likely avoid the immediate construction site. The area of avoidance for turbidity and noise effects from in-water work will occur in a relatively small area on the bank and nearshore area of the Columbia River. Following construction, approximately 249 square feet of riverbed will be occupied by the pilings and unavailable to aquatic organisms. This impact will be mitigated by the removal of existing derelict piles from the Columbia River at a future location to be developed in cooperation with NMFS. These derelict piles contain creosote, which is toxic to aquatic organisms (Stratus, 2006). The number of derelict piles and their location are yet to be determined. The piles used

for the Port of Morrow will be steel piles that pose no potential for toxic contaminant releases.

Habitat Elements. The Port of Morrow site does not contain any large woody debris, pools, off-channel habitat, or refugia. These habitat elements will not be affected by the proposed construction. Installation of the pilings will increase in-water structures at the site.

Channel Conditions and Dynamics. Channel conditions at the Port of Morrow, including its width/depth ratio, streambed condition, and floodplain connectivity will remain unchanged by the proposed construction and project operation.

***Flow Hydrology*.** Flow hydrology will remain unchanged at the Port of Morrow site during construction and project operation.

Watershed Conditions. There are no new roads planned for the Port of Morrow site. The site is currently disturbed from previous commercial and agricultural uses. The upland site will result in an approximately 23-acre increase in impervious surfaces for the storage buildings and loss of an equal amount of existing disturbed vegetation. Use of silt fences during site construction will minimize disturbance to adjacent vegetated areas. No wetlands will be impacted. Following construction, graded areas with open soil will be re-vegetated with native vegetation.

Subpopulation Character (Bull Trout). The proposed construction and project operation will not impact the size of bull trout subpopulations or permanently affect their ability to migrate through the Port of Morrow portion of the action area. Temporary, localized disturbance from noise and turbidity may cause bull trout to avoid the work area during construction.

Integration of Species and Habitat Conditions (Bull Trout). Temporary increases in waterborne sediment will occur during construction. The sediment impact is expected to occur on a daily basis when piles are being installed, and sediment is expected to dissipate after pile driving is complete. Sediment disturbance from construction will occur only within the in-water work window. During construction activities, no fill material, including concrete, will be allowed to enter the water column, and channel disturbance will be kept to a minimum. Bull trout are present in low numbers in the action area (ODFW, 2012a, 2012b) and are unlikely to be significantly impacted.

6.1.2 Columbia River Between the Port of Morrow and Port Westward

Water Quality. Increased barge traffic between the Port of Morrow and Port Westward presents an increased risk to water quality, as the potential for fuel spills and other environmental contamination, such as accidental coal release, will increase. The barges will be enclosed to minimize the potential for coal or coal dust to spill into the river during transit between the Port of Morrow and Port Westward. To minimize the

potential for water quality impacts from contaminant leaks, barge operators will be required to follow established safe operation protocols and maintain onboard spill containment kits. Tidewater has an Integrated Contingency Plan in place that addresses Best Management Practices (BMPs) for their tugs and barge tows while in transit on the Columbia River.

6.1.3 Port Westward and Columbia River/Pacific Ocean

Water Quality. Increased OGV traffic downstream of Port Westward may present an increased risk to water quality through the potential for fuel spills and other environmental contamination, such as accidental coal release. However, OGV operators will be required to follow established safe operation protocols, including spill prevention and containment.

Propeller wash from tugboats and OGVs will disturb the sediments at the Port Westward dock and may cause trapped contaminants to be released into the water column. Monitoring performed in May 2010 for the U.S. Environmental Protection Agency (USEPA) at the Port Westward site revealed elevated levels of semi-volatile organic compounds and inorganic compounds in the sediments near the dock and in Bradbury Slough (TechLaw, 2011), which accumulated over many years from the area's previous uses as a military facility and then commercial transfer facility.

Transloading from the barges to the OGVs at Port Westward will increase the risk of coal entering the river. However, the coal handling devices will be enclosed, therefore minimizing the risk of coal spills. Additionally, studies have shown that Powder River Basin coal, a low-sulfur sub-bituminous coal, is less likely to release toxic contaminants than other coals and poses minimal risk to the environment in the event that an accidental release should occur (Golder Associates, Inc., 2012).

***Channel Conditions and Dynamics*.** Channel conditions at Port Westward, including width/depth ratio, streambed condition, and floodplain connectivity, will remain unchanged by the project operation. Existing channel maintenance and dredging operations in the Columbia River will continue at current levels.

Flow/Hydrology. Basin hydrology (peak/base flow) and the drainage network will not be affected by operations at Port Westward or downstream. Flow in the Columbia River will not be altered by the proposed project.

Watershed Condition. Road density and location and disturbance history will not be affected by operations at Port Westward.

Subpopulation Character (Bull Trout). The proposed project will not impact the size of bull trout subpopulations or affect their ability to migrate through the action area.

Integration of Species and Habitat Conditions (Bull Trout). Temporary periodic increases in waterborne sediment may occur during project operations at Port Westward; however, these impacts will be of short duration and conditions will quickly return to previous conditions. Bull trout are unlikely to be present in the vicinity of Port Westward (ODFW, 2012b) and are unlikely to be significantly impacted.

6.2 Noise Effects

Underwater sound can produce a range of effects on fish. These thresholds represent levels of sound that produce either a behavioral disturbance or injury to fish within the threshold radius. Behavioral effects caused by vibratory and impact pile driving can include disruption of migration or foraging activities as fish disperse into surrounding areas to avoid the disturbance area. Fish injuries caused by intense sound pressures near the source of impact pile driving can include swim bladder and other internal tissue damage, hearing loss, or death (Hastings and Popper, 2005).

During in-water construction activities at the Port of Morrow, fish will be subject to disturbance and/or injury as a result of vibratory and impact pile driving, as described in Section 3.1.7.2, Distance to Underwater Sound Thresholds. Depending on the size of the pile, vibratory driving will produce a disturbance effect at a distance of up to 185 meters (607 feet) from the pile, while attenuated impact driving may produce a disturbance effect at a distance of up to 858 meters (2,815 feet) from the pile. Fish injury effects may occur from attenuated impact driving, at a distance of up to 208 meters (682 feet) from the pile. Fish will be subject to noise impacts from vibratory driving activities for a total of approximately 55 days, and from impact driving activities for a total of approximately 8.8 hours, spread over 14 days (not necessarily consecutive). These impacts will be minimized by using vibratory pile driving whenever possible and using a bubble curtain to attenuate underwater sounds when using an impact hammer. Use of a vibratory hammer prior to use of an impact hammer should elicit an avoidance response in fish using the area and reduce the potential of physical injury when impact driving is used.

6.3 Ship Strike Effects

Marine mammals and sea turtles could be impacted by OGV traffic in the nearshore marine portion of the action area between the mouth of the Columbia River and the Columbia Bar through disturbance or direct mortality in the event of a collision.

Collisions between ships and whales have occurred historically, and have been summarized for areas on the east coast of the United States and elsewhere in the world (Laist et al., 2001; Jensen and Silber, 2003), as well as within Washington State (Douglas et al., 2008). Laist et al. (2001) reported a higher incidence of increased injury and mortality when the ship speed increased, and the whale species most likely to collide with ships included fin whales, right whales, humpback whales, sperm whales, and gray whales. This study reported that most vessel strikes between whales and large vessels (80 m [262 feet] or larger) occurred when vessels were travelling at 14 knots or more, and noted that larger cetaceans and those that

spend more time at the surface are at increased risk of collision. Douglas et al. (2008) reported that of 19 stranding records of presumed ship and whale collisions in Washington State, most were of fin whales and grey whales. The six records that occurred within 50 miles of the mouth of the Columbia River included four grey whales, one fin whale, and one sperm whale (Douglas et al., 2008).

Similar studies have been conducted on the incidence of ship strikes on marine turtles near ports and in shipping lanes (Hazel and Gyuris, 2006; Hazel et al., 2007). These studies showed that the risk of a ship strike increased as ship speed increased, and that vessel strikes can be a significant cause of mortality for sea turtles.

The proposed project will increase OGV and barge traffic, which could lead to increased risk of injury or mortality of marine mammals or sea turtles at the mouth of the Columbia River, and increased risk of injury and mortality of Steller sea lions downstream of Bonneville Dam. However, both barge and OGV traffic will travel at speeds of 10 to 12 knots, which is less than the 14 knots or more reported when most vessel strikes occur. In addition, OGV traffic will increase by 9 percent over current levels as a result of this project, but will remain below historic high levels (see Table 3-6). Therefore, increased OGV traffic should not present a significantly increased risk to whales, sea turtles, and Steller sea lions.

6.4 Habitat Effects

Port of Morrow Site. Permanent piling installation as well as temporary piling installation and removal at the Port of Morrow construction site will result in a temporary increase in turbidity, which may cause fish to avoid the area of the sediment plume, interrupting normal migration, rearing, or foraging behavior. The temporary loss of this amount of habitat will have a minimal effect on this species in the context of the entire amount of habitat available in the Columbia River.

The proposed project will have a permanent effect on conditions in the Columbia River channel at the locations of the dolphins, which will occupy approximately 249 square feet of riverbed. This impact will be mitigated by the removal of existing derelict piles from the Columbia River at a future location to be developed in cooperation with NMFS. The number of derelict piles and their location are yet to be determined.

Predation by piscivorous birds could increase as the new pilings may provide perches. This effect will be minimized by installing anti-perching devices on top of the new pilings.

In addition, there will be shading effects from the dolphins, walkway, conveyor, and barge staging at the Port of Morrow site. Nearshore shading can lead to increased predation by fish species that use light/shadow transitions to lie in wait for potential prey and avoid detection (USACE, 2010). This effect will be minimized by constructing the walkway and conveyor structures at a sufficient height (+9 feet) above the mean pool elevation to reduce shading, using expanded metal grating for the walkway deck, and managing the staging of

vessels to minimize the length of time that the vessels are stationary and shading the nearshore area.

Dolphins and support structures for the dock and conveyor may also create microhabitats with cover and reduced velocity. These microhabitats may also result in increased predation as some predator species use these microhabitats to enhance their ability to capture prey (Beamesderfer and Rieman, 1988).

Tug operation at the Port of Morrow may disturb sediments through propeller wash, leading to temporary increases in turbidity at the dock and a short distance downstream.

Barge Traffic Between the Port of Morrow and Port Westward. An impact to habitat from the increased barge traffic on the Columbia River will be the increased potential for toxic materials to enter the river. However, barge operators will follow established safety and operational protocols to minimize the risk of accidental spills or other release of contaminants.

Port Westward Site and Downstream. Tug and OGV operation at Port Westward may disturb sediments through propeller wash, leading to temporary increases in turbidity at the dock and a short distance downstream.

In addition, there will be shading effects from barge and ship staging at Port Westward. Nearshore shading can lead to increased predation by fish species that use light/shadow transitions to lie in wait for potential prey and avoid detection (USACE, 2010). This effect will be minimized by managing the staging of vessels to minimize the length of time that the vessels are stationary and shading the nearshore area.

6.5 Effects to Specific Species

6.5.1 Direct Harm

6.5.1.1 Salmonids

Port of Morrow Site. Based on Table 4-2 and conversations with Bill Duke, ODFW biologist, it is possible that multiple species of salmonids could be present at the Port of Morrow site during the recommended in-water work window of December 1 through March 31 (ODFW, 2012a). Species and life stages that may be present during the in-water work window include adult and juvenile steelhead (UCR, MCR, SR); adult Chinook salmon (UCR spring-run, SR spring/ summer-run); juvenile Chinook salmon (UCR spring-run, SR spring/summer-run, SR fall-run); juvenile SR sockeye salmon; and adult and juvenile CR bull trout (see Table 4-2). All in-water work will be completed during the ODFW preferred in-water work window of December 1 through March 31. These dates represent times of minimal abundance of salmonids in the area. In addition, direct effects to listed species are expected to be primarily behavioral disturbance and the potential for mortality will be low.

Activities below the OHWE associated with in-water work primarily consist of temporary and permanent piling installation. To avoid direct harm to fish from construction equipment, all work will take place from barges and construction equipment will not enter the water. Direct harm could result from increased turbidity and contact (or near-contact) with materials during piling installation and from the hydroacoustic effects of pile driving (see Section 6.2, Noise Effects).

Direct impacts may also occur to salmonids during operation of the facilities at the Port of Morrow. Studies have found that entrainment through towboat propellers has the potential to injure or kill fish and other aquatic organisms, through pressure changes, shear stress, and turbulence (Killgore et al., 2005; Killgore et al., 2001; Cada 1990). In addition, disturbance of migrating and foraging behavior may occur from tug and barge traffic and the sediment disturbance resulting from propeller wash at the dock.

Barge Traffic Between Port of Morrow and Port Westward. All 14 listed salmonid species addressed in this BA could be impacted through direct contact with tug propellers during tug transit between the Port of Morrow and Port Westward, as mentioned above. As a result of this project, barge vessel traffic will increase by approximately 46 percent above current traffic levels, which represents 98 percent of historic high levels, leading to a corresponding increase in the potential for impact to ESA-listed species (see Table 3-5).

Port Westward Site and Downstream. All 14 listed salmonids addressed in this BA may be impacted by OGV traffic downstream of Port Westward. As mentioned above, there is the potential for harm to occur to these species through direct contact with propellers of the vessels and disturbance of migrating and foraging behavior from tug and barge traffic and sediment disturbance from propeller wash at the dock.

In addition, large vessels with drafts of approximately 30 feet or greater have been shown to cause wake stranding of fish that tend to congregate in shallow nearshore riverine waters (Ackerman, 2002; Pearson and Skalski, 2011). Wake stranding occurs when the large waves caused by vessel wakes carry fish up a beach and strand them. Beaches with flatter slopes are particularly susceptible to this, as the wave travels a greater distance up the beach, reducing the ability of the fish to return to the river before the water is no longer sufficiently deep for them to maneuver. Multiple factors interact at low slope beaches and contribute to the likelihood of stranding occurring at any given beach, including ship kinetic energy (which takes into account ship size, draft, and speed), tidal height, fish presence, and unique beach characteristics (Pearson and Skalski, 2011). Studies have shown that juvenile Chinook salmon are the most common species affected by wake stranding, including at County Line Park, approximately one mile downstream of Port Westward on the north side of the Columbia River (Ackerman, 2002; Pearson and Skalski, 2011). Pearson and Skalski (2011) found

that for County Line Park, 15.4 percent of deep-draft vessel passages past the site resulted in wake stranding, with an average of 7.3 fish stranded per stranding event, of which 82 percent were Chinook salmon.

The OGVs leaving Port Westward could impact listed species by causing wake stranding and through direct contact with fish. It is expected that when the project is operating at full capacity, three OGVs will make the round trip from the Columbia Bar to Port Westward each week.

6.5.1.2 Green Sturgeon

Port of Morrow Site. This species is not present at the Port of Morrow and will not be affected by the construction there.

Barge Traffic Between the Port of Morrow and Port Westward. This species may be present downstream of the Bonneville Dam, but as this species is a benthic dweller, preferring deeper areas of the river, it is unlikely that green sturgeon will be found close enough to the surface to be directly impacted by tug propellers.

Port Westward Site and Downstream. It is unlikely that green sturgeon will be directly impacted by barge and tug traffic. Green sturgeon may be directly affected by deep-draft vessels in the shipping channels, and the level of OGV traffic in the lower Columbia River will increase by 9 percent over current levels but will not exceed historic high levels (see Table 3-6). The impact to green sturgeon will be minimal from these vessel operations.

Channel maintenance activities in the lower Columbia River that may affect green sturgeon, including channel dredging, will continue at current levels.

6.5.1.3 Eulachon

Port of Morrow Site. This species is not present at the Port of Morrow and will not be affected by the construction there.

Barge Traffic Between the Port of Morrow and Port Westward and ***Port Westward Site and Downstream.*** Eulachon may be directly impacted by barge and tug traffic downstream of the Bonneville Dam, and OGV traffic downstream of Port Westward. As mentioned above, increased vessel traffic may increase the potential for harm to occur through direct contact with tug or OGV propellers. Barge vessel traffic will increase by approximately 46 percent above current traffic levels, which represents 98 percent of historic high levels (see Table 3-5), and the level of OGV traffic in the lower Columbia River will increase by 9 percent, which represents 70 percent of the historic high levels (see Table

3-6), leading to a corresponding increase in the potential for impact to this species.

In addition, tug and OGV operation at Port Westward may disturb the sediments at the dock, periodically increasing turbidity in the immediate area. This may have a negative effect on adult eulachon movement through the area, spawning behavior, egg incubation, and juvenile foraging.

Channel maintenance activities in the lower Columbia River that may affect eulachon, including channel dredging, will continue at current levels.

6.5.1.4 Steller Sea Lion

Port of Morrow Site. This species is not present at the Port of Morrow and will not be affected by the construction there.

Barge Traffic Between the Port of Morrow and Port Westward and ***Port Westward Site and Downstream.*** Direct impacts to this species will be limited to the potential for ship strikes by the barges and tugs moving through the area between the Bonneville Dam and Port Westward and OGVs moving between Port Westward and the Columbia Bar. It is expected that when the project is operating at full capacity, three OGVs will make the round trip from the Columbia Bar to Port Westward each week. This represents an increase of 9 percent above current traffic levels but does not represent an increase above historic high levels of large-vessel traffic in this section of the Columbia River (see Table 3-6). Barge vessel traffic will increase by approximately 46 percent above current levels, and will represent approximately 98 percent of historic high levels (see Table 3-5), leading to a corresponding increase in the potential for an effect on Steller sea lions; however, this species is an agile swimmer and is expected to avoid contact with barges, tugs, and OGVs.

6.5.1.5 Killer Whale
Leatherback Turtle
Other Whales – Humpback, Fin, Sei, Sperm, Blue
Other Turtles – Green, Loggerhead, Olive Ridley

Port of Morrow Site. These species are not present at the Port of Morrow and will not be affected by the construction there.

Barge Traffic Between the Port of Morrow and Port Westward. These species are not present between the Port of Morrow and Port Westward and will not be affected by barge traffic.

Port Westward Site and Downstream. Direct impacts to these species may occur through the potential for ship strikes by OGVs moving through the area

between the mouth of the Columbia River and the Columbia Bar, as discussed in Section 6.3, Ship Strike Effects, above. It is expected that when the project is operating at full capacity, three OGVs will make the round trip from the Columbia Bar to Port Westward each week.

6.5.2 Critical Habitat Impacts

The proposed action could affect critical habitat for listed species. In the short term, a temporary increase in turbidity and disturbance of in-stream habitat at the Port of Morrow construction site will occur during piling installation and removal. Implementation of the conservation measures in Section 7.0 is expected to minimize the project's potential temporary adverse effects on aquatic habitat. Approximately 249 square feet of riverbed at the Port of Morrow will be permanently impacted by the installation of the pilings. Tug and barge operation at the Port of Morrow has the potential to disturb sediments, leading to increased turbidity and possibly releasing pollutants contained in the sediment.

Barge traffic between the Port of Morrow and Port Westward is not expected to significantly affect critical habitat, as it is an activity that is currently taking place. Tug and barge operations at the Port of Morrow, tug, barge, and OGV operation at Port Westward, and OGV operations downstream of Port Westward have the potential to disturb sediments, leading to increased turbidity and possibly releasing pollutants contained in the sediment.

The critical habitat PCEs include sites essential to support one or more life stages of these ESUs/DPSs (sites for spawning, rearing, migration, and foraging). In turn, these sites contain physical or biological features essential to the conservation of these ESUs/DPSs (e.g., spawning gravels, water quality and quantity, side channels, prey species). Effects to specific types of sites and the features associated with them for the various critical habitat listings of the species addressed in this BA are as follows:

6.5.2.1 Steelhead:	**Upper Columbia River DPS** **Middle Columbia River DPS** **Lower Columbia River DPS** **Upper Willamette River DPS** **Snake River Basin DPS**
Chinook Salmon:	**Upper Columbia River Spring-run ESU** **Lower Columbia River ESU** **Upper Willamette River ESU**
Chum Salmon:	**Columbia River ESU**

The September 2005 Federal Register (70 FR 52630) identifies six PCEs of critical habitat for these nine DPSs/ESUs, including:

1. ***Freshwater spawning sites*.** The action area is not used by steelhead (UCR, MCR, LCR, UWR, or SR), UCR spring-run Chinook salmon, or UWR Chinook salmon for spawning.

   The area immediately downstream of Bonneville Dam is used for spawning by LCR Chinook salmon and CR chum salmon. The only effects to this area will be from the increased barge traffic in established shipping lanes on the river. This traffic will not affect existing water quantity, salinity, or natural cover conditions in this area. There may be a slightly increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased barge traffic. Similarly, juvenile forage could be affected if reduced water quality affects prey species distribution and abundance.

2. ***Freshwater rearing sites.*** Existing water quantity, floodplain connectivity, side channels, large wood, aquatic vegetation, and other natural cover will not be affected by the proposed project. There may be a slightly increased risk to water quality, as construction at the Port of Morrow may temporarily increase turbidity in the immediate area, and the potential for fuel spills and other environmental contamination will increase with increased barge traffic. Similarly, juvenile and adult forage could be affected if reduced water quality affects prey species distribution and abundance.

3. ***Freshwater migration corridors.*** Freshwater migration corridors will not be significantly impacted by the proposed project. Existing large wood, side channels, aquatic vegetation, and other natural cover will not be affected by the proposed project. Existing impediments to migration will not be affected. There may be an increased risk of predation on juveniles at the Port of Morrow site as a result of shading by the dolphins, above-water structures, and barges, and creation of microhabitats with reduced velocity. There may be a slightly increased risk to water quality, as construction at the Port of Morrow may temporarily increase turbidity in the immediate area, and the potential for fuel spills and other environmental contamination will increase with increased shipping traffic. Similarly, juvenile and adult forage could be affected if reduced water quality affects prey species distribution and abundance.

4. ***Estuarine areas.*** The only effect to the estuarine environment will be the increased vessel traffic in established shipping lanes in the lower Columbia River. This traffic will not affect existing water quantity, salinity, or natural cover conditions in this area. There may be a slightly increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased shipping

traffic. Similarly, juvenile and adult forage could be affected if reduced water quality affects prey species distribution and abundance.

5. ***Nearshore marine areas.*** The only effect to the nearshore marine environment will be the increased vessel traffic in established shipping lanes beyond the mouth of the Columbia River. This traffic will not affect existing water quantity or natural cover conditions in this area. There may be a slightly increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased shipping traffic. OGV traffic will increase by 9 percent above current levels, but will not exceed historic levels (see Table 3-5).

6. ***Offshore marine areas.*** No offshore marine areas occur in the action area, so this PCE will not be affected by the proposed project.

6.5.2.2 Chinook Salmon: Snake River Fall-run ESU
Snake River Spring/summer-run ESU

Sockeye Salmon: Snake River ESU

The December 1993 Federal Register (58 FR 68543) identifies four components of critical habitat for these three ESUs:

1. ***Spawning and Juvenile Rearing Areas.*** The action area is not used by these species for spawning, but does provide rearing habitat. The proposed project will not affect water quantity, water temperature, riparian vegetation, or available space. There may be an effect on water quality through increased turbidity from construction, sediment disruption by vessel operation at the docks, and by the increased risk of toxic chemical release from the vessels. Similarly, juvenile forage could be affected if reduced water quality affects prey species distribution and abundance.

2. ***Juvenile Migration Corridors.*** Freshwater migration corridors will not be significantly impacted by the proposed project. Existing large wood, side channels, aquatic vegetation, and other natural cover will not be affected by the proposed project. Existing impediments to migration will not be affected. There may be an increased risk of predation on juveniles at the Port of Morrow site, as a result of shading by the dolphins, above-water structures, and barges, and creation of low velocity microhabitats. There may be a slightly increased risk to water quality, as construction at the Port of Morrow may temporarily increase turbidity in the immediate area, and the potential for fuel spills and other environmental contamination will increase with increased barge and OGV traffic. Ship traffic through the nearshore marine portion of the action area will

represent an increase of 9 percent above current levels but will remain lower than historic OGV traffic levels (see Table 3-6). Similarly, juvenile and adult forage could be affected if reduced water quality affects prey species distribution and abundance.

3. ***Areas for Growth and Development to Adulthood.*** Areas for growth and development to adulthood refer to ocean habitat, which will not be affected by the proposed project.

4. ***Adult Migration Corridors.*** Adult migration corridors have the same habitat components as identified in the juvenile corridors. See paragraph 2 above.

6.5.2.3 Coho Salmon: Lower Columbia River ESU

Critical habitat has not been designated for coho salmon.

6.5.2.4 Bull Trout: Columbia River DPS

Bull trout critical habitat is described in terms of the following nine PCEs (75 FR 63898):

1. ***Water quality and thermal refugia.*** This project will not affect existing springs, seeps, or other groundwater inputs to the Columbia River that may affect water temperature and thermal refugia.

2. ***Migration corridors.*** This project will not affect existing bull trout migration corridors.

3. ***Food availability.*** This project will have a minimal effect on food availability in the action area. Some in-stream habitat disruption will take place at the Port of Morrow site as a result of the construction of the dolphins and related facilities requiring piles; however, this impact will be mitigated by the removal of existing derelict piles from the Columbia River at a future location to be developed in cooperation with NMFS. The number of derelict piles and their location are yet to be determined. Turbidity may be temporarily impacted during construction as a result of installing the permanent pilings and installing and removing the temporary pilings. Vessel operation may also create periodic localized turbidity plumes at the Port of Morrow and Port Westward sites. Increased turbidity may elicit an avoidance response from bull trout and reduce prey availability in the area.

4. ***In-stream habitat.*** The proposed project will not have a significant impact on in-stream habitat complexity. The installation of dolphins at the Port of Morrow site represents a localized increase in cover.

5. ***Water temperature.*** The Columbia River is listed on the DEQ 303(d) list for temperature. The proposed project will not affect the current temperature regime in the river.

6. ***Substrate characteristics.*** The action area is not used by bull trout for spawning, so this PCE will not be affected.

7. ***Stream flow.*** The Columbia River does not currently exhibit a natural hydrograph or flow timing, due to the operations of the hydroelectric dams. This PCE will not be affected by the proposed project.

8. ***Water quantity and quality.*** The proposed project will not affect the water quantity available in the Columbia River. Water quality may be affected through increased turbidity from construction, sediment disruption by vessel operation at the docks, and by the increased risk of toxic chemical release from the vessels.

9. ***Non-native species.*** Non-native species, such as smallmouth bass, are present in the Columbia River and may use the dolphins at the Port of Morrow site as cover, increasing their predation on juvenile salmonids. This effect will be minimized by decreasing shading through elevating the walkway and conveyor and using metal grating for the walkway. Removal of derelict piles will also mitigate for this effect.

6.5.2.5 Green Sturgeon: Southern DPS

Green sturgeon critical habitat is described in terms of PCEs for the following three areas used by different life stages of the species (74 FR 52300):

1. ***Freshwater riverine systems (including food, substrate, water flow, water quality, migratory corridors, depth, and sediment quality).*** No designated freshwater critical habitat is located in the action area, so this PCE will not be affected by the proposed project. However, adult and subadult green sturgeon do use freshwater portions of the Columbia River as summer foraging habitat. There may be an increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased shipping traffic. Similarly, adult and subadult forage could be affected if reduced water quality affects prey species distribution and abundance. Sediment quality could be locally impacted at the Port Westward dock as propeller wash from

the tugs and OGV disturbs the riverbed sediments and potentially exposes toxic contaminants.

2. ***Estuarine areas (including food resources, water flow regime, water quality, migratory corridors, depth, and sediment quality).*** The habitat components of water flow regime, migratory corridors, depth, and sediment quality will not be affected by the proposed project. Impacts to water quality and food resources are the same as for freshwater areas, above.

3. ***Nearshore marine waters (including migratory corridors, water quality, and food resources).*** The only nearshore marine waters within the action area are between the mouth of the Columbia River and the Columbia Bar, approximately five miles offshore. This project will not impact nearshore migratory corridors, but water quality and food resources may be impacted by the increased risk of environmental contamination from increased ship traffic. Ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent above current levels but will remain lower than historic OGV traffic levels (see Table 3-6).

6.5.2.6 Eulachon: Southern DPS

Southern DPS eulachon critical habitat is described in terms of the following three essential features (76 FR 65324):

1. ***Freshwater spawning and incubation sites (including flow regime, water quality, water temperature, and spawning substrate).*** The habitat components of flow regime and water temperature will not be affected by the proposed project. There may be an increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased shipping traffic. Spawning substrate could be locally impacted at the Port Westward dock, as propeller wash from the tugs and OGV may disturb riverbed sediments, increase turbidity, and potentially expose toxic contaminants.

2. ***Freshwater and estuarine migration corridors (including migratory corridors, flow, water quality, and food).*** The habitat components of migratory corridors and flow will not be affected by the proposed project. Larval forage could be affected if reduced water quality affects prey species distribution and abundance. Impacts to water quality are the same as for freshwater spawning areas, above.

3. ***Nearshore and offshore marine foraging habitat (including food and water quality).*** The only nearshore marine waters within the action area

are between the mouth of the Columbia River and the Columbia Bar, approximately five miles offshore. There may be an increased risk to water quality, as the potential for fuel spills and other environmental contamination will increase with increased shipping traffic. Ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent above current levels but will remain lower than historic OGV traffic levels (see Table 3-6). Adult and juvenile food resources could be affected if reduced water quality affects prey species distribution and abundance.

6.5.2.7 Steller Sea Lion: Eastern DPS

The closest areas of designated critical habitat for eastern DPS Steller sea lion are the Oregon rookery areas, located at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock) (58 FR 45269). These areas are approximately 240 miles south of the Columbia River and will not be affected by the proposed project.

6.5.2.8 Killer Whale: Southern Resident DPS

All designated areas of critical habitat for southern resident DPS killer whales are located in the Puget Sound and Strait of Juan de Fuca regions of Washington State (71 FR 69054). These areas are approximately 150 miles north of the Columbia River and will not be affected by the proposed project.

6.5.2.9 Other Whales: Humpback, Fin, Sei, Sperm, Blue

Critical habitat has not been designated for these species.

6.5.2.10 Leatherback Turtle

Leatherback turtle critical habitat is described in terms of one PCE, the occurrence of jellyfish prey species (77 FR 4170). This PCE will be not be affected by the proposed project, as the only impact to the nearshore marine environment will be ship traffic through established shipping lanes at the mouth of the Columbia River. Ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent above current levels but will remain lower than historic OGV traffic levels (see Table 3-6), and will not affect jellyfish occurrence or distribution.

6.5.2.11 Other Turtles: Green, Loggerhead, Olive Ridley

Of these three species, critical habitat has been designated only for the green turtle. This critical habitat is located entirely in the waters around Culebra

Island, Puerto Rico (63 FR 46693) and will not be affected by the proposed project.

6.5.3 Indirect Impacts

The construction of the coal handling facility at the Port of Morrow will alter the existing land use of this area, as this area has historically been used as an agricultural area and is currently vegetated with a disturbed sagebrush community. The project will not change the existing land uses at Port Westward since no terrestrial development is anticipated as part of the proposed project and the dock has historically been used for commercial and industrial purposes.

Streambed and bank modifications associated with the construction and operation of the facility at the Port of Morrow may temporarily impact salmonid food sources and predator/prey relationships by increasing turbidity and disturbing the balance of microorganism populations found within this reach of the Columbia River. The operation of the transloading facility at Port Westward may have a similar effect on the salmonid, green sturgeon, and eulachon food sources at that site.

Indirect impacts to Steller sea lions and killer whales may occur as a result of impacts to prey species, particularly Chinook salmon. Direct effects to adult fish are expected to be minimal, mainly resulting from increased risk of injury or mortality from contact with vessel hulls and propellers. In addition to direct contact with vessel propellers, juvenile salmon are at risk from increased wake stranding as a result of increased OGV traffic downstream of Port Westward. Barge tow traffic will increase by 46 percent above current levels, which represents approximately 98 percent of historic high levels (see Table 3-5), and OGV traffic will increase by 9 percent above current levels, which represents 70 percent of historic levels (see Table 3-6); the risk of impacts to fish will increase accordingly. However, this traffic is expected to have a minimal effect on overall salmon populations and the marine mammals that prey on salmon.

7.0 CONSERVATION MEASURES

Conservation measures are intended to minimize or avoid environmental impacts to listed species or critical habitat. To be in compliance with federal ESA regulations, additional conservation measures may be agreed upon by state and federal government representatives as terms and conditions of the resulting Biological Opinion from agency review of this BA. The following BMPs will be used during the project activities:

Construction at the Port of Morrow:

1. Any spoils material will be disposed of at an upland site.

2. The pile driving barge will remain in waters that have a minimum depth of 6 feet to avoid grounding on and potentially impacting the near shore.

3. A vibratory hammer will be used for installation of piles (to the extent possible) to limit adverse effects.

4. A bubble curtain will be required when an impact hammer is used for pile installation. Acoustic monitoring will take place when pile driving is conducted with an impact hammer. Work will cease and additional noise mitigation will be applied if underwater noise reaches an unacceptable threshold level, as determined by NMFS.

5. Because use of a bubble curtain for impact pile driving is difficult and has not often been implemented successfully, selection of a contractor for pile driving will be based on demonstrated past successful experience using bubble curtains for impact pile driving projects.

6. All in-water work will be performed within the ODFW in-water work window.

7. A Stormwater Pollution Prevention Plan (SWPP) will be prepared for the Port of Morrow site to protect the riparian area from erosion and runoff.

8. All upland staging, refueling, and storage of heavy equipment will be kept at least 150 feet away from water. For track-mounted equipment, large cranes, and other equipment whose limited mobility makes it impractical to move it for refueling, precautions to minimize the risk of fuel reaching the Regulated Work Area will be taken. Spill prevention measures will be implemented and fuel containment systems will be designed to completely contain a potential spill. Other pollution control devices and measures (such as diapering, parking on absorbent material, etc.) adequate to provide containment of hazardous material will also be used as necessary. Refueling operations will be completed

in a way that will minimize the amount of fuel remaining in vehicles stored during non-work times.

9. The contractor will limit alteration or disturbance of riverbank or riparian vegetation to only those areas necessary for construction.

10. A temporary erosion control plan will be used to prevent sediment from entering the water. Sediment control BMPs will include the use of sediment fencing and sediment barriers (i.e., bio-filter, sandbags, straw bales, and wattles), minimizing vegetation removal, and covering bare soil and stockpiles. BMPs shall conform to DEQ requirements for stormwater discharges associated with industrial activities.

11. Erosion control devices will be inspected daily during the rainy season and weekly during the dry season. If inspection reveals that erosion controls are ineffective, the contractor will immediately mobilize work crews during work or non-work hours to make repairs, install replacements, or install additional controls as necessary.

12. Heavy equipment will be checked for leaks prior to the start of the work day. The contractor will complete all necessary repairs prior to commencing work activities.

13. Over-water concrete work will be completely contained and no concrete will be allowed to enter the water.

14. All construction debris and waste will be disposed of at designated sites. Garbage will be disposed of in dumpsters in upland locations. Excess waste materials will not be disposed of in waters. Any debris or garbage that enters water will be retrieved by the contractor.

15. Work on the bank, including excavation or fill, is not anticipated.

16. Barges and equipment will carry hazardous materials cleanup kits at all times.

17. Additional mitigation for near-shore habitat loss will be accomplished through the removal of existing derelict piles from the Columbia River at a future location to be developed in cooperation with NMFS. The number of derelict piles and their location are yet to be determined.

18. Dock shading will be reduced through constructing the walkway and conveyor structures at a sufficient height (+9 feet) above the mean pool elevation, use of expanded metal grating for the walkway deck, and managing the staging of vessels to minimize the length of time that the vessels are stationary and shading the nearshore area.

Project Operation.

19. The coal storage facility at the Port of Morrow was designed with an enclosed rail unloading barn. The storage facility will be fully enclosed and under negative pressure, with a wet scrubber system to control and prevent dust from escaping into the environment. Process water will be fully contained on site and will be reused during operations.

20. The barge loading system at the Port of Morrow will be fully enclosed to contain coal dust. The system features fully enclosed conveyors from the storage barns to the barges. A telescoping chute loader will ensure that coal is placed near the bottom of the barge. The coal barges will be equipped with sliding doors to fully enclose the barge once loaded.

21. The transloader at Port Westward will have an enclosed and telescoping chute to transfer the coal from the barges to the OGV to prevent coal from spilling and to minimize the amount of dust generated.

22. Spill prevention and containment plans will be in place for the barges and ships, as well as at the two port facilities, to reduce the risk of toxic materials from entering the environment.

8.0 ESSENTIAL FISH HABITAT CONSULTATION

Public Law 94-265, the Sustainable Fisheries Act of 1996, amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to establish new requirements for EFH descriptions in federal fishery management plans and to require federal agencies to consult with NMFS on activities that may adversely affect EFH. The MSA states, *"Essential Fish Habitat means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."* The Pacific Fisheries Management Council (PFMC) described and identified EFH for three species of Pacific Coast salmon (PFMC, 2012), coastal pelagic species (PFMC, 2009), and Pacific Coast groundfish (PFMC, 2011). These Fishery Management Plans have recommended an EFH designation for these fisheries that would include those waters and substrate necessary to ensure the production needed to support a long-term sustainable fishery (i.e., properly functioning habitat conditions necessary for the long-term survival of the species through the full range of environmental variation).

The MSA requires consultation for all actions that may adversely affect EFH and does not distinguish between actions in EFH and actions outside EFH. Any reasonable attempt to encourage the conservation of EFH must take into account actions that occur outside EFH, such as upstream and upslope activities that may have an adverse effect on EFH. Therefore, EFH consultation with NMFS is required by federal agencies undertaking, permitting, or funding activities that may adversely affect EFH, regardless of its location. The Morrow Pacific project may affect Pacific salmon species (Chinook salmon and coho salmon), groundfish, and coastal pelagic species.

8.1 Pacific Coast Salmon

Identification of Essential Fish Habitat. Salmon fishery EFH includes all those freshwater streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to Pacific salmon species in Washington, Oregon, Idaho, and California, except above the impassable barriers identified by the PFMC (2012). Chief Joseph Dam, Dworshak Dam, and the Hells Canyon Complex (Hells Canyon, Oxbow, and Brownlee Dams) are among the listed manmade barriers that represent the upstream extent of the Pacific salmon fishery EFH. Salmon EFH also excludes areas upstream of longstanding naturally impassable barriers (i.e., natural waterfalls in existence for several hundred years). The riparian zone adjacent to the designated waterways is also considered EFH. This zone provides shade, sediment, nutrient/ chemical regulation, streambank stability, and large woody debris/organic matter. In the estuarine and marine areas, designated salmon EFH extends from the near shore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone offshore of Washington, Oregon, and California north of Point Conception (PFMC, 2012).

All currently viable waters and most habitats historically accessible to Chinook and coho salmon, including the Columbia River, have been designated as Pacific salmon EFH. Short-term impacts to freshwater EFH include localized riverbank and riverbed modifications at the Port of

Morrow that may yield temporary sediment pulses in the river. Erosion control measures and streambank stabilization with seeding will help to minimize impacts to freshwater EFH.

Impacts to estuarine and nearshore marine EFH are limited to the operation of tugs, barges, and OGVs, which may cause localized sediment disturbance in the vicinity of the dock at Port Westward. Barge and vessel traffic will be above current levels (46 percent increase for barge tows and 9 percent increase for OGVs, as shown in Tables 3-5 and 3-6), but will not exceed historic levels and will have minimal effects on Pacific salmon EFH.

Conclusion. The effects of project construction at the Port of Morrow may result in unavoidable temporary increases in noise and turbidity, minimal loss of herbaceous riparian vegetation, and modification of in-stream habitat where pilings are installed. These impacts are adverse to EFH. However, seeding and planting the disturbed areas after construction, and the conservation measures described in Section 7.0, Conservation Measures, will help minimize the adverse effects on EFH associated with project construction. Impacts to EFH from operation of the project include sediment disturbance from tug propeller wash at the Port of Morrow and Port Westward docks. Following analysis of the possible impacts that may result from the Morrow Pacific project, a determination of **may affect, likely to adversely affect** is indicated for designated Pacific Coast salmon EFH.

8.2 Coastal Pelagic Species

Identification of Essential Fish Habitat. Coastal pelagic species EFH is designated for four species of finfish (northern anchovy, Pacific sardine, Pacific [chub] mackerel, and jack mackerel) and one invertebrate (market squid). In 2009, the Fishery Management Plan was amended to include all krill species and to prohibit their harvest (PFMC, 2009). Designated EFH includes all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone and above the thermocline where sea surface temperatures range between 10°C and 26°C (50°F to 79°F). The northern boundary of EFH is dynamic, varying as the sea surface temperature is seasonally and annually cooled (PFMC, 2009).

The portions of the action area in the Columbia River estuary and out to the Columbia Bar are included in designated coastal pelagic species EFH. The potential impact to this habitat is limited to OGV traffic in established shipping lanes, which will increase by 9 percent above current levels but is not expected to exceed historic levels (see Table 3-6), and will have minimal effects on coastal pelagic species EFH.

Conclusion. The only aspect of the proposed project that may affect coastal pelagic species EFH is the operation of OGVs through the lower Columbia River estuary to the Columbia Bar, which is not expected to significantly affect the estuarine and coastal nearshore region of the action area. Following analysis of the possible impacts that may result from the Morrow Pacific project, a determination of **no effect** is indicated for designated coastal pelagic species EFH.

8.3 Pacific Coast Groundfish

Identification of Essential Fish Habitat. Pacific Coast groundfish EFH is designated for 82 species of groundfish. Based on habitat suitability probability maps provided in Appendix B, Section B-4 of the Fishery Management Plan (PFMC, 2011), and surveys cited in the Lewis and Clark National Wildlife Refuge and Julia Butler Hansen Refuge for the Columbian White-tailed Deer: Comprehensive Conservation Plan and Environmental Impact Statement (USFWS, 2010), 33 of these species may occur in the action area, as shown in Table 8-1. Groundfish EFH is described as all waters from the high tide line (and parts of estuaries) to 3,500 meters in depth. Habitat Areas of Particular Concern (HAPC) are a subset of EFH used to focus management and restoration efforts. The current HAPC types are estuaries, canopy kelp, seagrass, rocky reefs, and areas of interest, which are defined as a variety of submarine features such as banks, seamounts, and canyons, along with Washington State waters (PFMC, 2011).

The portions of the action area in the Columbia River estuary and out to the Columbia Bar are included in designated Pacific Coast groundfish EFH. The potential impact to the majority of this area is limited to OGV traffic in established shipping lanes, which represents a 9 percent increase above current levels, but is not expected to exceed historic levels (see Table 3-6), and will have minimal effects on Pacific Coast groundfish EFH. Increased turbidity from tug and OGV propeller wash may adversely impact groundfish foraging and movement in the area around the Port Westward site, which is within the range of some species of groundfish that can enter fresh water (e.g., starry flounder) (PFMC, 2011).

Conclusion. The only aspects of the proposed project that may affect Pacific Coast groundfish EFH are the operation of OGV through the Columbia River estuary to the Columbia Bar and periodic increased turbidity and shading at the Port Westward dock. OGV traffic will not significantly affect the estuarine and coastal nearshore region. Increased turbidity levels and increased shading at the Port Westward dock will be periodic, while vessels are operating at the dock, and fish will be able to disperse to other areas to avoid the turbidity plume and shaded areas. Following analysis of the possible impacts that may result from the Morrow Pacific project, a determination of **may affect, not likely to adversely affect** is indicated for designated Pacific Coast groundfish EFH.

Table 8-1. Species in the Action Area Potentially Affected by EFH Regulations

Species		Life Stage present in AA				EFH Determination
		Adult	Juvenile	Larva	Egg	
Pacific salmon	Chinook salmon	X	X	X	X	LTAA
	Coho salmon	X	X	X	X	
Coastal pelagic fish	Northern anchovy	X	X	X	X	No Effect
	Pacific sardine	X*	X*	X*	X*	
	Pacific (chub) mackerel	X*	X*	X*	X*	
	Jack mackerel	X				
	Market squid	X	?	?	?	
Pacific coast groundfish	Arrowtooth flounder	X	X	X	X	NLTAA
	Big skate	X	X		X	
	Black rockfish		X			
	Blue rockfish			X		
	Bocaccio		X	X		
	Butter sole	X				
	Cabezon	X				
	California skate	X	X		X	
	Chilipepper		X			
	Curlfin sole	X				
	Dover sole	X	X			
	English sole	X	X	X		
	Flathead sole	X	X			
	Kelp greenling			X		
	Lingcod		X	X	X	
	Longnose skate	X	X		X	
	Pacific cod			X	X	
	Pacific Ocean perch			X		
	Pacific rattail			X	X	
	Pacific sanddab	X				
	Pacific whiting	X				
	Petrale sole		X			
	Ratfish	X	X		X	
	Rex sole		X			
	Rock sole	X				
	Sablefish	X	X		X	
	Sand sole	X	X	X		
	Soupfin shark	X	X			
	Spiny dogfish	X	X			
	Splitnose rockfish		X	X		
	Starry flounder	X	X		X	
	Stripetail rockfish		X			
	Widow rockfish		X			

*Denotes presence during periods of warm water and high abundance.

9.0 INTERRELATED AND INTERDEPENDENT EFFECTS

Interrelated actions include actions that are part of a larger action and depend on the larger action for justification. Interdependent actions are defined as actions with no independent utility apart from the proposed action. The coal that is being exported by the proposed project is mined in Montana and will be transported by rail to the Port of Morrow. This rail transportation could be considered an interrelated and interdependent action, and the effects of the rail portion of the project are addressed in the Morrow Pacific Project Environmental Assessment.

10.0 CUMULATIVE EFFECTS

Cumulative effects are defined as the effects of future state, local, or private activities (non-federal) that are reasonably certain to occur in the project's watershed.

No specific non-federal actions are known for the Port Westward area at this time (Columbia County, 2012). Known non-federal actions in or near the Port of Morrow include:

- The Umatilla Basin Aquifer Restoration Project in Morrow and Umatilla Counties. Effects include diversion of water from the Columbia River during the month of October and the months of December through March. Construction of some new pipeline will be necessary to reach the aquifer recharge area (Langford, 2010). The project is currently in Stage I, with some water diversion and monitoring underway (Langford, 2012; Morrow County, 2012).

- Continued industrial development at the Port of Morrow, including Port infrastructure (road improvements, etc.), agricultural product processing facilities, data centers, and others (Morrow County, 2012).

Additional projects within the watershed will occur as population growth and urban development continue. Current agricultural, logging, commercial, and industrial practices will continue in the region.

Projects with a federal nexus that are reasonably certain to occur are discussed in Section 6.1, Effects on NMFS and USFWS Matrix Indicators, under Watershed Conditions.

11.0 FINDING OF EFFECT

11.1. Statement of Take for Fish

Although listed fish species are present in the action area and may be exposed to harm from the construction activities at the Port of Morrow and from the operational activities at the Port of Morrow, along the Columbia River, and at Port Westward, it is not possible to quantify the number of fish that will be exposed to underwater noise, construction activities, and operational activities. Construction activities will occur during the approved in-water work window, when salmonid abundance is at seasonal minimums for the area and direct effects will primarily be behavioral avoidance of noise and turbidity. Potential impacts are summarized in the individual species accounts below.

11.2. Steelhead and Critical Habitat

11.2.1. Upper Columbia River DPS
Middle Columbia River DPS
Snake River DPS

Project construction activities at the Port of Morrow site will affect these DPSs through noise impacts, turbidity, and other habitat impacts (such as shading and the potential for accidental spills) during project construction. Shading from the conveyor, walkway, and pilings at the Port of Morrow, as well as staged barges and tugs, may increase predation in the area around the new mooring facility. Habitat disturbance and shading will also occur from vessel operation at the Port of Morrow dock.

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port of Morrow and Port Westward docks. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from the conveyor, walkway, and pilings at the Port of Morrow, as well as staged barges and tugs, may increase predation in the area around the new barge loading facility.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these three DPSs. Although conservation measures, such as use of vibratory pile driving when feasible, use of a bubble curtain during impact pile driving, erosion control measures, and an in-water work period, as well as enclosed coal barges, storage, and loading facilities, will be implemented to substantially reduce the chance for adverse impacts, direct harm cannot be ruled out. In addition, vessel traffic (tug and OGV) may have direct impacts on these DPSs. The proposed project **may affect,** and is **likely to adversely affect,** UCR steelhead, MCR steelhead, and SR steelhead.

Critical habitat components for steelhead will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Temporary negative impacts to water quality and food resources may occur as a result of the proposed improvements at the Port of Morrow site, and are expected to occur during the four-month in-water construction period. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for UCR steelhead, MCR steelhead, and SR steelhead.

11.2.2. Lower Columbia River DPS
Upper Willamette River DPS

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port Westward dock. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from staged barges and tugs may increase predation in the dock area at Port Westward.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these two DPSs. Although established safe vessel operating procedures and conservation measures, such as enclosed coal barges and loading facilities and minimal staging of barges, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** LCR steelhead and UWR steelhead.

Critical habitat components for steelhead will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for LCR steelhead and UWR steelhead.

11.3. Chinook Salmon and Critical Habitat

11.3.1. Upper Columbia River Spring-run ESU
Snake River Fall-run ESU
Snake River Spring/summer-run ESU

Project construction activities at the Port of Morrow site will affect these ESUs through noise impacts, turbidity, and other habitat impacts (such as shading and the potential for accidental spills) during project construction. Shading from the conveyor, walkway, and pilings at the Port of Morrow, as well as staged barges and tugs, may increase

predation in the area around the new mooring facility. Habitat disturbance and shading will also occur from vessel operation at the Port of Morrow dock.

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port of Morrow and Port Westward docks. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from the conveyor, walkway, and pilings at the Port of Morrow site, as well as staged barges and tugs, may increase predation in the area around the new mooring facility.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these three ESUs. Although conservation measures such as use of vibratory pile driving when feasible, use of a bubble curtain during impact pile driving, erosion control measures, and an in-water work period, as well as enclosed coal barges, storage, and loading facilities, will be implemented to substantially reduce the chance for adverse impacts, direct harm cannot be ruled out. In addition, vessel traffic (tug and OGV) may have direct impacts on this species. The proposed project **may affect,** and is **likely to adversely affect,** UCR spring-run Chinook salmon, SR fall-run Chinook salmon, and SR spring/summer-run Chinook salmon.

Critical habitat components for Chinook salmon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Temporary negative impacts to water quality and food resources may occur as a result of the proposed improvements at the Port of Morrow site, and are expected to occur during the four-month in-water construction period. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for UCR spring-run Chinook salmon, SR fall-run Chinook salmon, and SR spring/summer-run Chinook salmon.

11.3.2. Lower Columbia River ESU
Upper Willamette River ESU

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port Westward dock. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from staged barges and tugs may increase predation in the dock area at Port Westward.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these two ESUs. Although established safe vessel operating procedures and conservation

measures, such as enclosed coal barges and loading facilities and minimal staging of barges, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** LCR Chinook salmon and UWR Chinook salmon.

Critical habitat components for Chinook salmon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for LCR Chinook salmon and UWR Chinook salmon.

11.4. Columbia River ESU Chum Salmon and Critical Habitat

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port Westward dock. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from staged barges and tugs may increase predation in the dock area at Port Westward.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although established safe vessel operating procedures and conservation measures, such as enclosed coal barges and loading facilities and minimal staging of barges, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** Columbia River chum salmon.

Critical habitat components for chum salmon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Ongoing negative impacts to water quality, substrate at the dock, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for Columbia River chum salmon.

11.5. Lower Columbia River ESU Coho Salmon

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port Westward dock. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from staged barges and tugs may increase predation in the dock area at Port Westward.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although established safe vessel operating procedures and conservation measures, such as enclosed coal barges and loading facilities and minimal staging of barges, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** Lower Columbia River coho salmon.

Critical habitat has not been designated for Lower Columbia River coho salmon.

11.6. Snake River ESU Sockeye Salmon and Critical Habitat

Project construction activities at the Port of Morrow site will affect this species through noise impacts, turbidity, and other habitat impacts (such as shading and the potential for accidental spills) during project construction.

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance from vessel operation at the Port of Morrow and Port Westward docks. Juvenile fish are susceptible to wake stranding from OGV traffic downstream of Port Westward. Shading from the conveyor, walkway, and pilings at the Port of Morrow site, as well as staged barges and tugs, may increase predation in the area around the new mooring facility.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although conservation measures (such as use of vibratory pile driving when feasible, use of a bubble curtain during impact pile driving, erosion control measures, and an in-water work period, as well as enclosed coal barges, storage, and loading facilities) will be implemented to substantially reduce the chance for adverse impacts, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** SR sockeye salmon.

Critical habitat components for sockeye salmon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Temporary negative impacts to water quality and food resources may occur as a result of the proposed improvements at the Port of Morrow site, but are expected to be of short duration. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for SR sockeye salmon.

11.7. Columbia River DPS Bull Trout and Critical Habitat

Project construction activities at the Port of Morrow site will affect this species through noise impacts, turbidity, and other habitat impacts (such as shading and the potential for accidental spills) during project construction. Shading from the conveyor, walkway, and pilings,

as well as staged barges and tugs, may increase predation in the area around the new mooring facility. Habitat disturbance and shading will also occur from vessel operation at the Port of Morrow dock.

During project operation, the increased barge traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug or barge hulls and propellers, and habitat disturbance from vessel operation at the Port of Morrow dock. Bull trout are unlikely to be present in the lower Columbia River, but if they were present, they could potentially be impacted by barge, tug, and OGV traffic.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although conservation measures (such as use of vibratory pile driving when feasible, use of a bubble curtain during impact pile driving, erosion control measures, and an in-water work period, as well as enclosed coal barges, storage, and loading facilities) will be implemented to substantially reduce the chance for adverse impacts, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** Columbia River bull trout.

Critical habitat components for bull trout will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Temporary negative impacts to water quality and food resources may occur as a result of project construction at the Port of Morrow site, but are expected to be of short duration. Ongoing negative impacts to water quality, substrate at the docks, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for Columbia River bull trout.

11.8. Southern DPS Green Sturgeon and Critical Habitat

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with OGV hulls and propellers and habitat disturbance from vessel operation at the Port Westward dock.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although established safe vessel operating procedures and conservation measures, such as enclosed coal barges and loading facilities, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** southern DPS green sturgeon.

Critical habitat components for green sturgeon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Ongoing negative impacts to water quality, substrate at the dock, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for southern green sturgeon.

11.9. Southern DPS Eulachon and Critical Habitat

During project operation, the increased barge and OGV traffic on the Columbia River may lead to increased risk of injury or mortality from direct contact with tug, barge, or OGV hulls and propellers, and habitat disturbance and shading from vessel operation at the Port Westward dock. Shading from staged barges and tugs may increase predation on this species in the dock area at Port Westward.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for this species. Although established safe vessel operating procedures and conservation measures, such as enclosed coal barges and loading facilities and minimal staging of barges, will be implemented to reduce the chance for adverse impacts to the fish and their environment, direct harm cannot be ruled out. The proposed project **may affect,** and is **likely to adversely affect,** southern DPS eulachon.

Critical habitat components for eulachon will be affected by the proposed project. Conservation measures have been incorporated to minimize the long-term impacts to critical habitat. Ongoing negative impacts to water quality, substrate at the dock, and food resources may occur as a result of project operations. As a result, the proposed project **may affect,** and is **likely to adversely modify,** critical habitat for southern DPS eulachon.

11.10. Eastern DPS Steller Sea Lion and Critical Habitat

The project could directly affect this species through the increased risk of ship strikes as barge and OGV traffic in the lower Columbia River increases, and indirectly as project components impact Chinook salmon and eulachon populations that represent important prey species for Steller sea lions.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for Steller sea lions. Steller sea lions are the most abundant listed marine mammal in the action area, with a total of 75 individuals observed at the Bonneville Dam in 2010 (Stansell, 2010). These individuals could potentially be impacted by barge and OGV traffic as they travel from the Pacific Ocean to the dam. Although this species is an agile swimmer and it is unlikely that ship strikes present a significant threat, direct harm cannot be ruled out and indirect effects may result from impacts to Chinook salmon and eulachon populations. These impacts are expected to be minor; therefore, the proposed project **may affect,** but is **not likely to adversely affect,** eastern DPS Steller sea lion.

Critical habitat for eastern DPS Steller sea lions consists of (a) Alaska rookeries, haulouts, and associated areas; (b) California and Oregon rookeries and associated areas; and (c) three special aquatic foraging areas in Alaska. None of these areas occur in the action area, and, as a result, the proposed project will cause **no adverse modification to** eastern DPS Steller sea lion critical habitat.

11.11. Southern Resident DPS Killer Whale and Critical Habitat

The project could directly affect this species through the increased risk of ship strikes as OGV traffic in the nearshore marine environment increases, and indirectly as project components impact Chinook salmon populations that represent an important prey species for southern resident killer whales.

After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for southern resident DPS killer whales. Although it is unlikely that killer whales are found inside the Columbia Bar, direct harm from ship strikes cannot be ruled out, and indirect effects may result from impacts to Chinook salmon populations. These effects are expected to be minor; therefore, the proposed project **may affect,** but is **not likely to adversely affect,** southern resident DPS killer whales.

All designated areas of critical habitat for southern resident killer whales are located in the Puget Sound and Strait of Juan de Fuca regions of Washington State, and, as a result, the proposed project will cause **no adverse modification** to southern resident DPS killer whale critical habitat.

11.12. Other Whales – Humpback, Fin, Sei, Sperm, and Blue

The project could affect these five species through the increased risk of ship strikes as OGV traffic in the nearshore marine environment increases. After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these five species, although it is unlikely since these whales are more commonly found in the Pacific Ocean where they could more easily forage outside of traditional shipping lanes. In addition, ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent for recent ship traffic but will be less than historic ship traffic levels (see Table 3-6). However, direct harm from ship strikes cannot be ruled out and, therefore, the proposed project **may affect,** but is **not likely to adversely affect,** humpback, fin, sei, sperm, and blue whales.

Critical habitat has not been designated for these species.

11.13. Leatherback Turtle and Critical Habitat

The project could affect this species through the increased risk of ship strikes as OGV traffic in the nearshore marine environment increases. After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for leatherback turtles, although it is unlikely since this species is more commonly found beyond the seaward end of the action area. However, direct harm from ship strikes cannot be ruled out and, therefore, the proposed project **may affect,** but is **not likely to adversely affect,** leatherback turtles.

Critical habitat components for leatherback turtles will be not affected by the proposed project, as the only component identified is the presence of adequate populations of jellyfish prey. Ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent above current ship traffic but will remain lower than historic ship traffic levels (see Table 3-6) and will not affect jellyfish occurrence or distribution. As a result, the proposed project will cause **no adverse modification** to critical habitat for leatherback turtles.

11.14. Other Turtles – Green, Loggerhead, and Olive Ridley

The project could affect these species through the increased risk of ship strikes as OGV traffic in the nearshore marine environment increases. After evaluating the potential effects, it has been determined that the proposed action described for the Morrow Pacific project could result in a probability of take for these three turtles, although it is unlikely since these turtles are more commonly found beyond the seaward end of the action area. In addition, ship traffic through the nearshore marine portion of the action area will represent an increase of 9 percent above current ship traffic but will remain lower than historic ship traffic levels (see Table 3-6). However, direct harm from ship strikes cannot be ruled out and, therefore, the proposed project **may affect,** but is **not likely to adversely affect,** green, loggerhead, and olive ridley turtles.

Critical habitat has not been designated for loggerhead and olive ridley turtles. Green turtle critical habitat is entirely located in the waters around Culebra Island, Puerto Rico, and, as a result, the proposed project will cause **no adverse modification** to critical habitat for green turtles.

12.0 REFERENCES

Ackerman, Nicklaus K. "Effects of Vessel Wake Stranding of Juvenile Salmonids in the Lower Columbia River, 2002 - A Pilot Study." S.P. Cramer & Associates, Inc. September 26, 2002.

Asplund, T.R. (2000). The Effects of Motorized Watercraft on Aquatic Ecosystems. Wisconsin Department of Natural Resources, Madison, Wisconsin. March 17, 2000.

Bash, J., C. Berman, and S. Bolton (2001). Effects of Turbidity and Suspended Solids on Salmonids. Final Research Report for the Washington Department of Transportation. November 2001.

Beamesderfer, R.C. and B.E. Rieman (1988). Predation by Resident Fish on Juvenile Salmonids in a Mainstem Columbia Reservoir: Part III. Abundance and Distribution of Northern Squawfish, Walleye, and Smallmouth Bass. Pages 211-248, in: T.P. Poe and B.E. Rieman, editors. Predation by Resident Fish on Juvenile Salmonids in John Day Reservoir, 1983-1986. Final Report of Research (Contracts DE-AI73-B2BP34796 and DE-AI79-82BP35097), Bonneville Power Administration, Portland, Oregon.

Benson, S. R., T. Eguchi, D. G. Foley, K. A. Forney, H. Bailey, C. Hitipeuw, B. P. Samber, R. F. Tapilatu, V. Rei, P. Ramohia, J. Pita, and P. H. Dutton (2011). Large-scale movements and high-use areas of Western Pacific leatherback turtles, *Dermochelys coriacea*. *Ecosphere* 2(7):art84. doi:10.1890/ES11-00053.1

Cada, G. F. (1990). "A review of studies relating to the effects of propeller-type turbine passage on fish early life stages," *North American Journal of Fisheries Management* 10, 418-426.

Chawla, A., D. Jay, A.M. Baptista, M. Wilkin, and C. Seaton (2008). Seasonal variability and estuary-shelf interactions in circulation dynamics of a river-dominated estuary. *Estuaries and Coasts*, 31(2): 269-288.

Columbia County (2012). 2 April 2012 telephone conversation between Bill Potter, Columbia County Land Development Services, and Sue Brady, AP Biologist.

Code of Federal Regulations (50 CFR 402.02). TITLE 50 – Wildlife and Fisheries Chapter IV – Joint Regulations (United States Fish and Wildlife Service, Department of the Interior and National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Department of Commerce); Endangered Species Committee Regulations, Subchapter A; Part 402 – Interagency Cooperation – Endangered Species Act of 1973, as amended.

Douglas, A.B., J. Calambokidis, S. Raverty, S.J. Jeffries, D.M. Lambourn, and S.A. Norman (2008). Incidence of ship strikes of large whales in Washington State. *Journal of the Marine Biological Association of the United Kingdom* 88:1121-1132.

Eggleton, J. and K.V. Thomas (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International* 30(7):973–980**.**

Federal Register for June 2, 1970 (35 FR 8491). *Part 17 - Conservation of Endangered Species and Other Fish or Wildlife.*

Federal Register for July 28, 1978 (43 FR 32800). *Listing and Protecting Loggerhead Sea Turtles as "Threatened Species" and Populations of Green and Olive Ridley Sea Turtles as Threatened Species or "Endangered Species." Final Rule.*

Federal Register for November 26, 1990 (55 FR 49204). *Listing of Steller Seal Lions as Threatened under the Endangered Species Act. Final Rule.*

Federal Register for November 20, 1991 (56 FR 58619). *Endangered and Threatened Species: Endangered Status for Snake River Sockeye Salmon. Final Rule.*

Federal Register for April 22, 1992 (57 FR 14653). *Endangered and Threatened Species: Threatened Status for Snake River Spring/Summer Chinook Salmon, Threatened Status for Snake River Fall Chinook Salmon. Final Rule.*

Federal Register for June 3, 1992 (57 FR 23458). *Endangered and Threatened Species: Threatened Status for Snake River Spring/Summer Chinook Salmon, Threatened Status for Snake River Fall Chinook Salmon. Correction.*

Federal Register for August 27, 1993 (58 FR 45269). *Designated Critical Habitat; Steller Sea Lion. Final Rule.*

Federal Register for December 28, 1993 (58 FR 68543). *Designated Critical Habitat: Snake River Sockeye Salmon, Snake River Spring/Summer Chinook Salmon, and Snake River Fall Chinook Salmon. Final Rule.*

Federal Register for June 5, 1997 (62 FR 30772). *Endangered and Threatened Wildlife and Plants; Change in Listing Status of Steller Sea Lion. Final Rule.*

Federal Register for August 18, 1997 (62 FR 43937). *Endangered and Threatened Species: Listing of Several Evolutionarily Significant Units (ESUs) of West Coast Steelhead. Final Rule.*

Federal Register for March 10, 1998 (63 FR 11798). *Endangered Species: Proposed Threatened Status for Two ESUs of Steelhead in Washington and Oregon. Proposed rule; request for comments.*

Federal Register for September 2, 1998 (63 FR 46693). *Designated Critical Habitat; Green and Hawksbill Sea Turtles. Final Rule.*

Federal Register for March 10, 1998 (63 FR 11774). *Endangered and Threatened Species; Proposed Threatened Status and Designated Critical Habitat for Hood Canal Summer-Run Chum Salmon and Columbia River Chum Salmon. Proposed Rule; Request for Comments.*

Federal Register for March 19, 1998 (63 FR 13347). *Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Final Rule, Notice of Determination.*

Federal Register for June 10, 1998 (63 FR 31647). *Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout. Final Rule.*

Federal Register for March 24, 1999 (64 FR 14308). *Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington. Final Rule.*

Federal Register for March 25, 1999 (64 FR 14508). *Endangered and Threatened Species: Threatened Status for Two ESUs of Chum Salmon in Washington and Oregon. Final Rule; Notice of Determination.*

Federal Register for March 25, 1999 (64 FR 14517). *Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington and Oregon. Final Rule.*

Federal Register for October 25, 1999 (64 FR 57399). *Designated Critical Habitat: Revision of Critical Habitat for Snake River Spring/Summer Chinook Salmon. Final Rule.*

Federal Register for June 28, 2005 (70 FR 37160). *Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. Final Rule.*

Federal Register for September 2, 2005 (70 FR 52630). *Endangered and Threatened Species; Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho. Final Rule.*

Federal Register for September 26, 2005 (70 FR 56211). *Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Bull Trout. Final Rule.*

Federal Register for November 18, 2005 (70 FR 69903). *Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. Final Rule.*

Federal Register for January 5, 2006 (71 FR 834). *Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. Final Rule.*

Federal Register for April 7, 2006 (71 FR 17757). *Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. Final Rule.*

Federal Register for November 29, 2006 (71 FR 69054). *Endangered and Threatened Species; Designation of Critical Habitat for Southern Resident Killer Whale. Final Rule.*

Federal Register for September 8, 2008 (73 FR 52084). *Endangered and Threatened Wildlife and Plants: Proposed Rulemaking To Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. Final Rule.*

Federal Register for August 24, 2009 (74 FR 42605). *Listing Endangered and Threatened Species: Change in Status for the Upper Columbia River Steelhead Distinct Population Segment. Final Rule, correcting amendment.*

Federal Register for October 9, 2009 (74 FR 52300). *Endangered and Threatened Wildlife and Plants; Final Rulemaking to Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. Final Rule.*

Federal Register for March 18, 2010 (75 FR 13012). *Endangered and Threatened Wildlife and Plants; Threatened Status for Southern Distinct Population Segment of Eulachon. Final Rule.*

Federal Register for October 18, 2010 (75 FR 63898). *Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States. Final Rule.*

Federal Register for August 15, 2011 (76 FR 50448). *Endangered and Threatened Species; 5-Year Reviews for 17 Evolutionarily Significant Units and Distinct Population Segments of Pacific Salmon and Steelhead. Notice of availability of 5-year reviews.*

Federal Register for September 22, 2011 (76 FR 58868). *Endangered and Threatened Species; Determination of Nine Distinct Population Segments of Loggerhead Sea Turtles as Endangered or Threatened. Final Rule.*

Federal Register for October 20, 2011 (76 FR 65324). *Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Southern Distinct Population Segment of Eulachon. Final Rule.*

Federal Register for January 26, 2012 (77 FR 4170). *Endangered and Threatened Species: Final Rule to Revise the Critical Habitat Designation for the Endangered Leatherback Sea Turtle. Final Rule.*

Fisheries Hydroacoustic Working Group (FHWG) (2008). Memorandum of Agreement in Principle for Interim Criteria for Injury to Fish from Pile Driving. California Department of Transportation (CALTRANS) in coordination with the Federal Highway Administration (FHWA). Available at: <http://www.wsdot.wa.gov/NR/rdonlyres/4019ED62-B403-489C-AF05-5F4713D663C9/0/InterimCriteriaAgreement.pdf>

Fish Passage Center (FPC) (2012a). Spawning Redd Maps. Retrieved on March 1, 2012, from: <http://www.fpc.org/spawning/spawning_reddmaps.html>

FPC (2012b). Adult Passage Data. Retrieved on April 10, 2012, from: <http://www.fpc.org/adultsalmon_home.html>

FPC (2012c). Smolt Data. Retrieved on April 10, 2012, from: <http://www.fpc.org/smolt_home.html>

Franklin, J.F. and C.T. Dyrness (1988). Natural Vegetation of Oregon and Washington. Oregon State University Press.

Gustafson, R.G., T.C. Wainwright, G.A. Winans, F.W. Waknitz, L.T. Parker, and R.S. Waples (1997). Status review of sockeye salmon from Washington and Oregon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-33, 282 p.

Golder Associates, Inc. (2012). *Literature Review of Potential Impacts from Coal in Surface Waters.* Report submitted to Schwabe, Williamson, and Wyatt, February 9, 2012.

Hastings, M.C. and A.N. Popper (2005). Effects of sound on fish. Prepared by Jones & Stokes for the California Department of Transportation, Sacramento, CA. 23 August 2005. <http://www.dot.ca.gov/hq/env/bio/files/Effects_of_Sound_on_Fish23Aug05.pdf>

Hanson, B., R. W. Baird, and G. Schorr (2005). Focal behavioral observations and fish-eating killer whales: Improving our understanding of foraging behavior and prey selection. Abstract at the 16th Biennial Conference on the Biology of Marine Mammals, San Diego, CA.

Hazel, J., I.R. Lawler, H. Marsh, and S. Robson (2007). *Vessel speed increases collision risk for the green turtle Chelonia mydas.* Endangered Species Research 3(2):105-113.

Hazel J. and E. Gyuris (2006). *Vessel-related mortality of sea turtles in Queensland, Australia.* Wildlife Research 33:149–154.

Jensen, A.S. and G.K. Silber (2003). *Large Whale Ship Strike Database*. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR-25, 37 pp.

Johnson, G., et al. "Survival and Passage Yearling and Subyearling Chinook Salmon and Steelhead at The Dalles Dam, 2010." Pacific Northwest National Laboratory. December 2011.

Killgore, K. J., Maynord, S. T., Chan, M. D., and Morgan, R. P., II (2001). "Evaluation of propeller induced mortality on early life stages of selected fish species," *North American Journal of Fisheries Management* 21, 521-529.

Killgore, J., C. Murphy, D. Wolff, T. Keevin (2005). *Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study: Evaluation of Towboat Propeller-Induced Mortality of Juvenile and Adult Fishes*. Prepared for U.S. Army Engineers, Rock Island District. June 2005.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta (2001). *Collisions between ships and whales*. Marine Mammal Science, 17(1):35-75.

Langford, S.D. (2010). *Full Steam Ahead for the Umatilla Basin Aquifer Restoration Project.* Western Water Law and Policy Reporter. January, 2010.

Langford, S.D. (2012). 2 April 2012 telephone conversation between Shonee Langford, Senior Counsel with Schwabe, Williamson & Wyatt, and Sue Brady, AP Biologist.

Lower Columbia Fish Recovery Board (LCFRB) (2004). *Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. 15 December 2004.*

Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended by the Sustainable Fisheries Act of 1996, Public Law 94-265. 16 United States Code 1801 et. seq.

Merchants Exchange of Portland Custom Report (2011). "Count of Vessel Arrivals by Year 1992-2011 (Including & Excluding Barges)." n.d.

Morrow County (2012). 10 April 2012 telephone conversation between Carla McLane, Morrow County Planning Department, and Sue Brady, AP Biologist.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grand, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples (1998). *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.* U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

National Marine Fisheries Service (NMFS) (1996). *Making Endangered Species Act Determination of Effect for Individual or Grouped Actions at the Watershed Scale*. Habitat Conservation Program. Portland, Oregon.

NMFS (2008a). Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington. January 2008.

NMFS (2008b). Recovery Plan for the Steller Sea Lion (*Eumetopias jubatus*): Revision. National Marine Fisheries Service, Northwest Region, Seattle, Washington. March 2008.

NMFS (2011a). Southern Resident Killer Whales *(Orcinus orca)* 5-Year Review: Summary and Evaluation. Northwest Regional Office, Seattle, WA. January 2011.

NMFS (2011b). Endangered Species Act Biological Opinion and Conference Report and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River. NMFS No. 2010/06104. 18 March 2011.

NMFS (2012a). Steller Sea Lion Haulout and Rookery Locations in Oregon Waters. Retrieved from: <http://www.nwr.noaa.gov/Marine-Mammals/upload/MM-Steller-locations-OR.pdf>

NMFS (2012b). Marine Mammal Stock Assessment Reports (SARs) by Species/Stock. NOAA Fisheries, Office of Protected Resources. Retrieved from: <http://www.nmfs.noaa.gov/pr/sars/species.htm>

NMFS (2012c). 1 February 2012 telephone conversation between Lynne Barre, NMFS Biologist, and Sue Brady, AP Biologist.

NMFS (2012d). Species Information for Cetaceans. NOAA Fisheries, Office of Protected Resources. Retrieved from: <http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/>

NMFS (2012e). Species Information for Sea Turtles. NOAA Fisheries, Office of Protected Resources. Retrieved from: <http://www.nmfs.noaa.gov/pr/species/turtles/>

NMFS (2012f). 9 March 2012 e-mail from Ben Meyer, NMFS Biologist, to Catie Kerns, AP Natural Resources Specialist.

Neff, J.M. (1985). Polycyclic aromatic hydrocarbons. p. 416-454 *In:* G.M. Rand, Petrocelli, S.R., eds. Fundamentals of aquatic toxicology. Washington, D.C.: Hemisphere Publishing.

Northwest Power and Conservation Council (NPCC) (2004a). *Columbia Gorge Mainstem Subbasin Plan*. 28 May 2004.

NPCC (2004b). *Draft Lower Mid-Columbia Mainstem Subbasin Plan*. 8 December 2004.

Oregon Department of Environmental Quality: Water Quality (DEQ) (2012). Water Quality Assessment Database. 2004/2006 Report. Retrieved from: <http://oregondeq.com/WQ/assessment/ rpt0406/results.asp>

Oregon Department of Fish and Wildlife (ODFW) (2012a). 23 January 2012 telephone conversation between Bill Duke, ODFW Fish Biologist, and Sue Brady, AP Biologist.

ODFW (2012b). 31 January 2012 telephone conversation between John North, ODFW Fish Biologist, and Sue Brady, AP Biologist.

Oregon Biodiversity Information Center (ORBIC) (2012). Rare, Threatened, and Endangered Species of Oregon, database search on January 19, 2012. Portland State University, Portland, Oregon.

Oregon Water Resources Department (OWRD) (2012). Well Log Query. Accessed on 3/19/12. <http://apps.wrd.state.or.us/apps/gw/well_log/Default.aspx>

Pacific Fisheries Management Council (PFMC) (2009). *Coastal Pelagic Species Fishery Management Plan*, as amended through July 2009. Portland, Oregon.

PFMC (2011). *Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery*, as amended through December 2011. Portland, Oregon.

PFMC (2012). *Pacific Coast Salmon Plan: Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California, as revised through Amendment 16*. Adopted January 2012. Portland, Oregon.

Pearson, W.H. and J.R. Skalski. "Factors Affecting Stranding of Juvenile Salmonids by Wakes from Ship Passage in the Lower Columbia River." River Research and Applications. 27(2011): 923-936.

Ploskey, G.R., et al. "Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2010." Pacific Northwest National Laboratory. February 2011.

Salo, E.O., N.J. Bax, T.E. Prinslow, C.J. Whitmus, B.P. Snyder, C.A. Simenstad (1980). *The effects of construction of naval facilities on the outmigration of juvenile salmonids from Hood Canal, WA*. Final Report. Fisheries Research Institute, College of Fisheries, University of Washington, Seattle, WA. Prepared for the U.S. Navy, OICC Trident, April 1980.

Schroeder, D. (2011). "He's got one whale of a tale." The Daily Astorian, May 13, 2011, Astoria, Oregon.

Stansell, R. J., K. M. Gibbons, and W. T. Nagy (2010). *Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2008-2010*. U.S. Army Corps of Engineers Portland District, Fisheries Field Unit.

Stratus Consulting Inc. (2006). *Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*. Prepared for NOAA Fisheries, Southwest Division, Habitat Conservation Division. 31 December 2006.

StreamNet (2012). *StreamNet Mapper*. Fish Distribution Maps. Accessed on 2/14/12. <http://map.streamnet.org/website/bluesnetmapper/viewer.htm>

TechLaw, Inc. (2011). *Beaver Army Terminal Site Inspection Report*, Clatskanie, Columbia County, Oregon, prepared for USEPA, February 2011.

U.S. Army Corps of Engineers (USACE) (2005). *Finding of No Significant Impact: Avian Predation Deterrent Program, Lower Columbia and Lower Snake Rivers* (with appendices). U.S. Army Corps of Engineers: Walla Walla District. September 2005.

USACE (2010). *Minimizing Effects of Over-Water Docks on Federally Listed Fish Stocks in McNary Reservoir: A Literature Review for Criteria*. U.S. Army Corps of Engineers: Walla Walla District. January 2010.

USACE (2011a). *Navigation Data Center*. 11 July 2011. Data retrieved on 15 November 2011 from: <http://www.ndc.iwr.usace.army.mil/pms/lock2010web.htm>

USACE (2011b). Annual Fish Passage Report 2011, Columbia and Snake River Projects. U.S. Army Corps of Engineers, Portland and Walla Walla Districts. Portland, Oregon, and Walla Walla, Washington.

U.S. Fish and Wildlife Service (USFWS) (1998). *A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale.* Portland, Oregon.

USFWS (2008). *Bull Trout (Salvelinus confluentus) 5-Year Review: Summary and Evaluation*. Portland, Oregon. 25 April 2008.

USFWS (2010). *Lewis and Clark National Wildlife Refuge and Julia Butler Hansen Refuge for the Columbian White-tailed Deer: Comprehensive Conservation Plan and Environmental Impact Statement*. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge Complex, Ilwaco, Washington.

U.S. Geological Survey (USGS) (1990). *Water Fact Sheet: Largest Rivers in the United States.* Open-file Report 87-242. Revised May 1990. Retrieved from: <http://pubs.usgs.gov/of/1987/ofr87-242/pdf/ofr87242.pdf>

Washington Department of Transportation (WSDOT) (2011). Biological Assessment Preparation for Transportation Projects: Advanced Training Manual; Chapter 7, Construction Noise Impact Assessment. Olympia, WA., February 2011.

Weiland, M.A., et al. "Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival Proportions at John Day Dam, 2009." Pacific Northwest National Laboratory. September 2011.

APPENDIX A

Figures

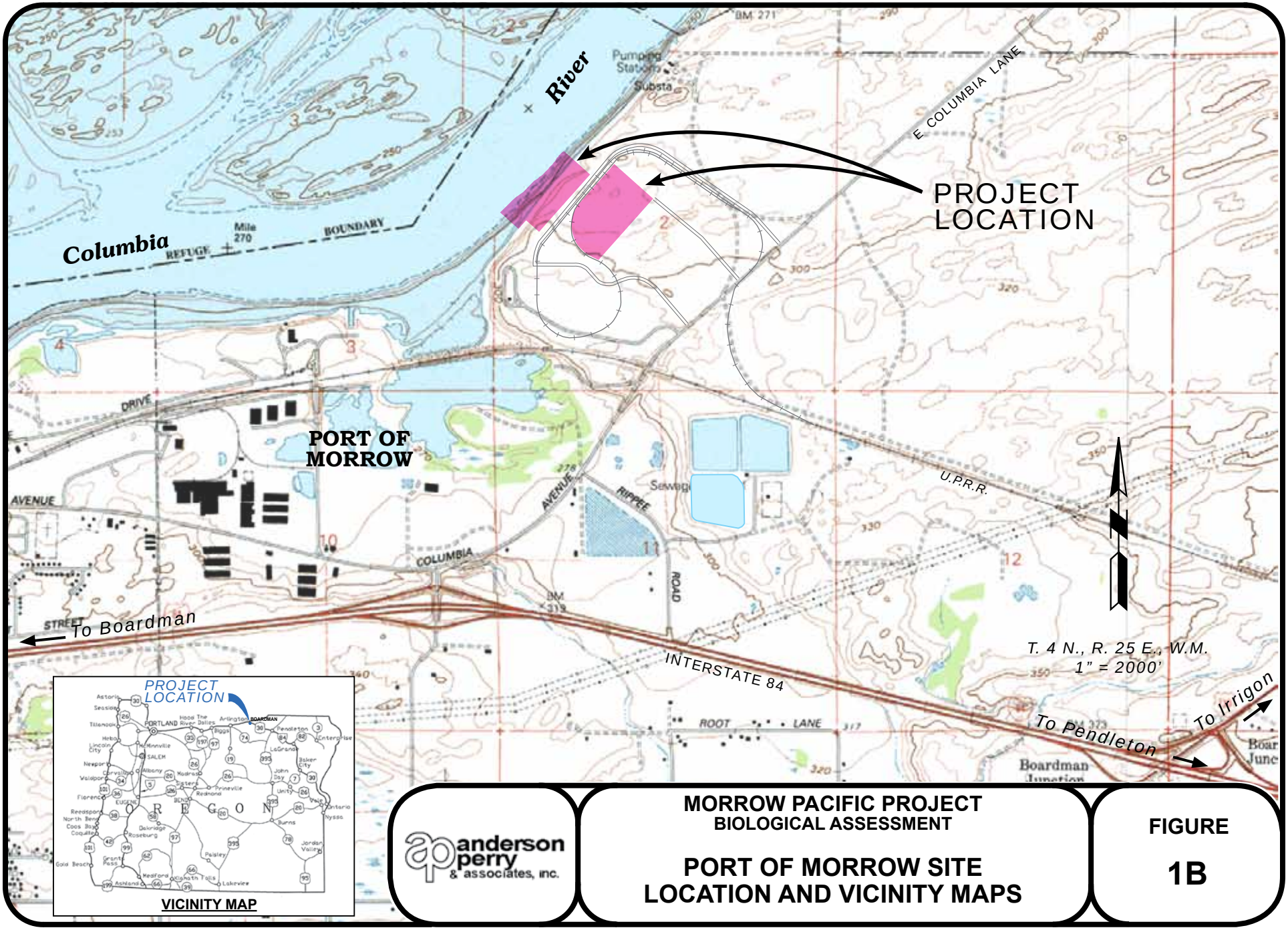
Job 1199-462-221 Mar. 21, 2012 lbauer

anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW TO COLUMBIA BAR
PROJECT CORRIDOR MAP

FIGURE
1A



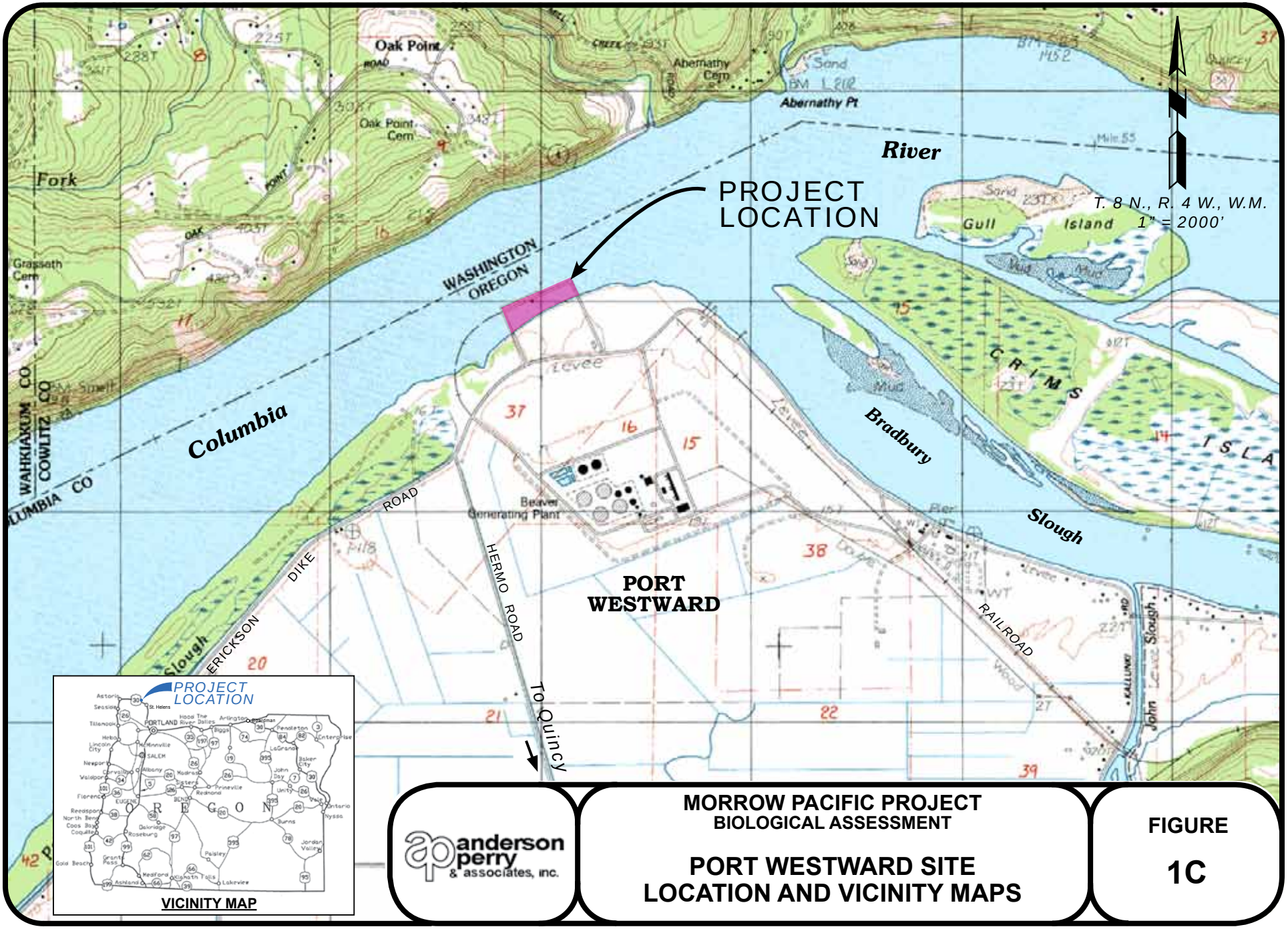
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE LOCATION AND VICINITY MAPS

FIGURE

1B



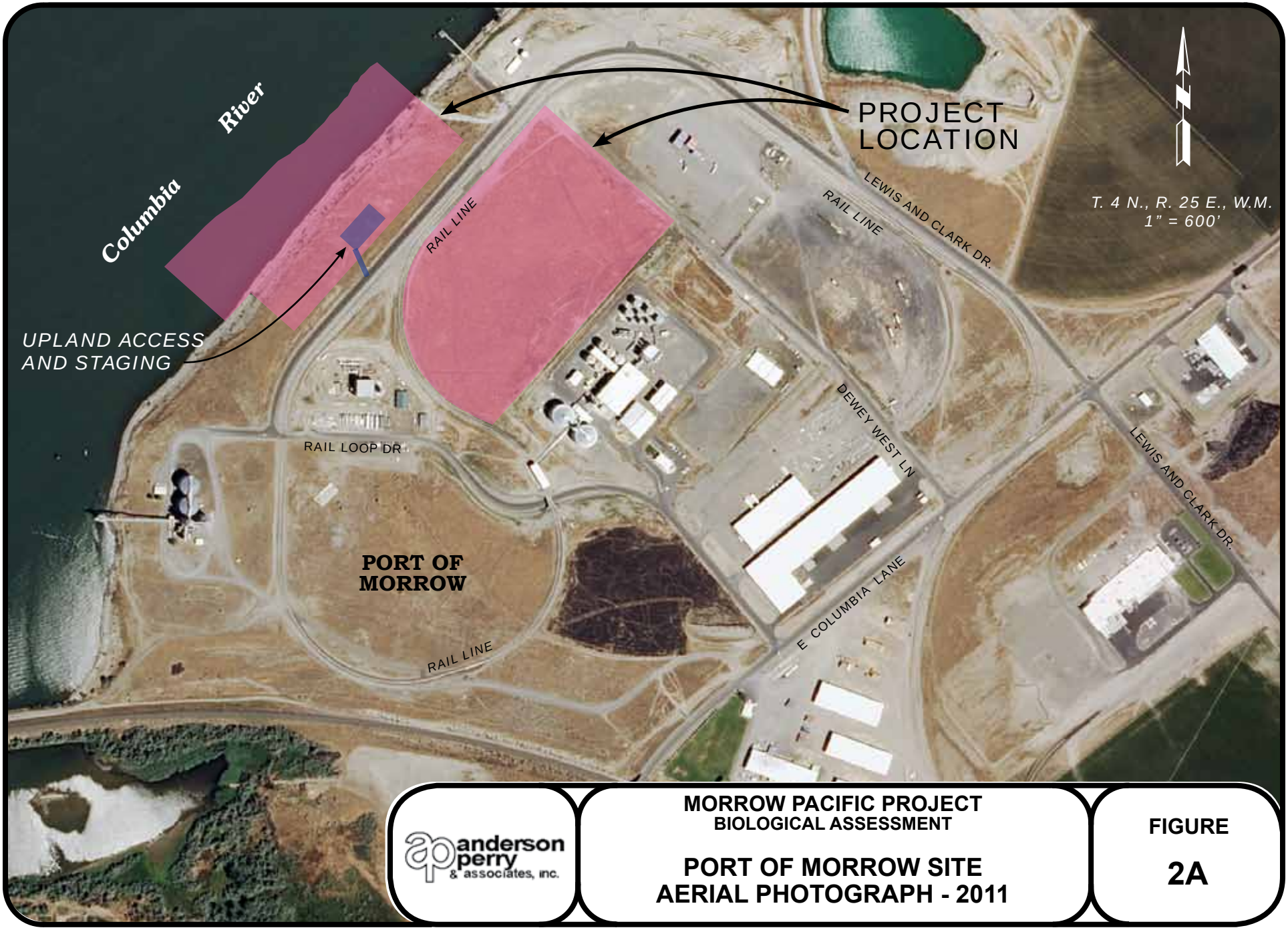
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT WESTWARD SITE LOCATION AND VICINITY MAPS

FIGURE

1C



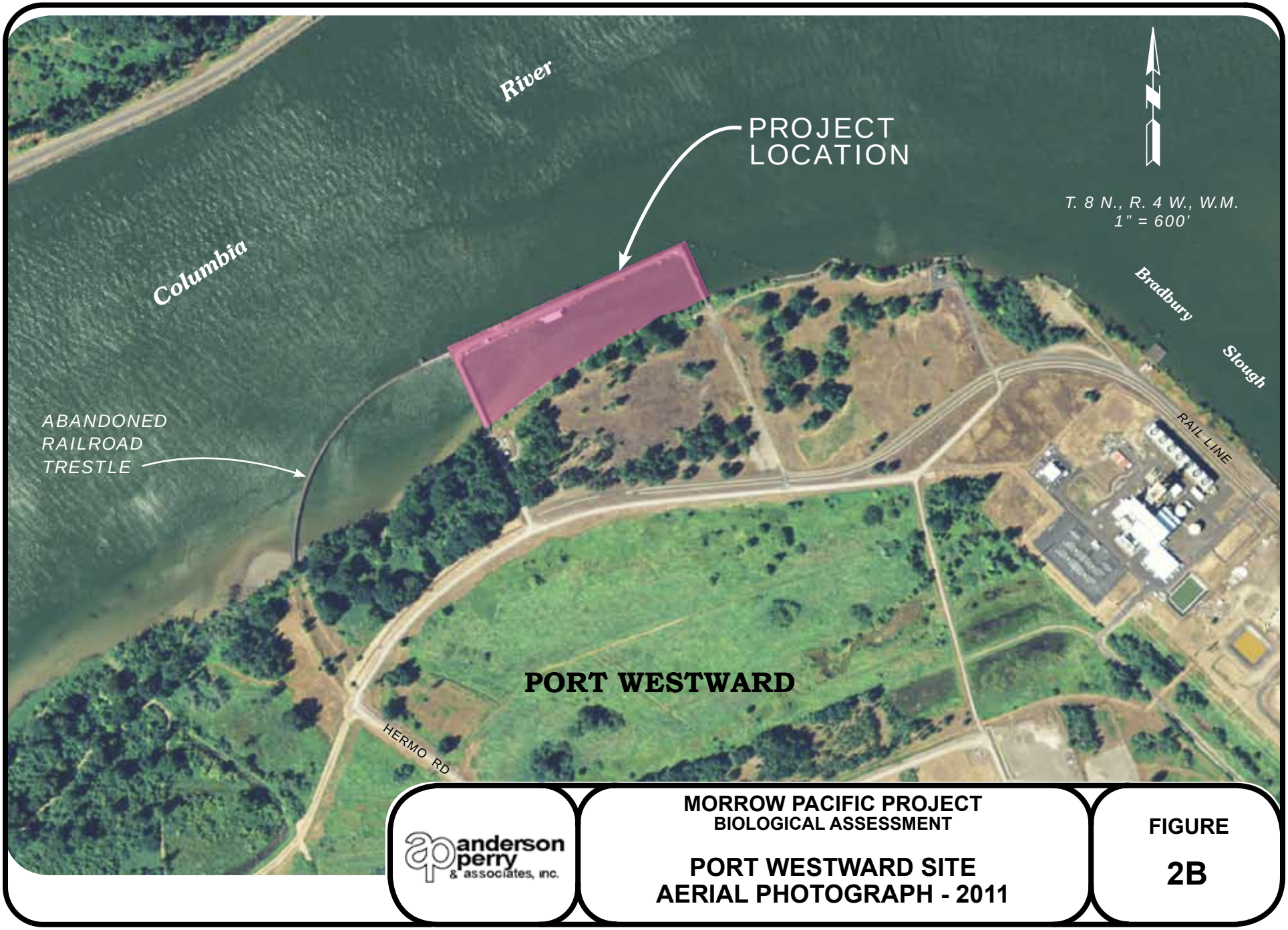
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE
AERIAL PHOTOGRAPH - 2011

FIGURE

2A



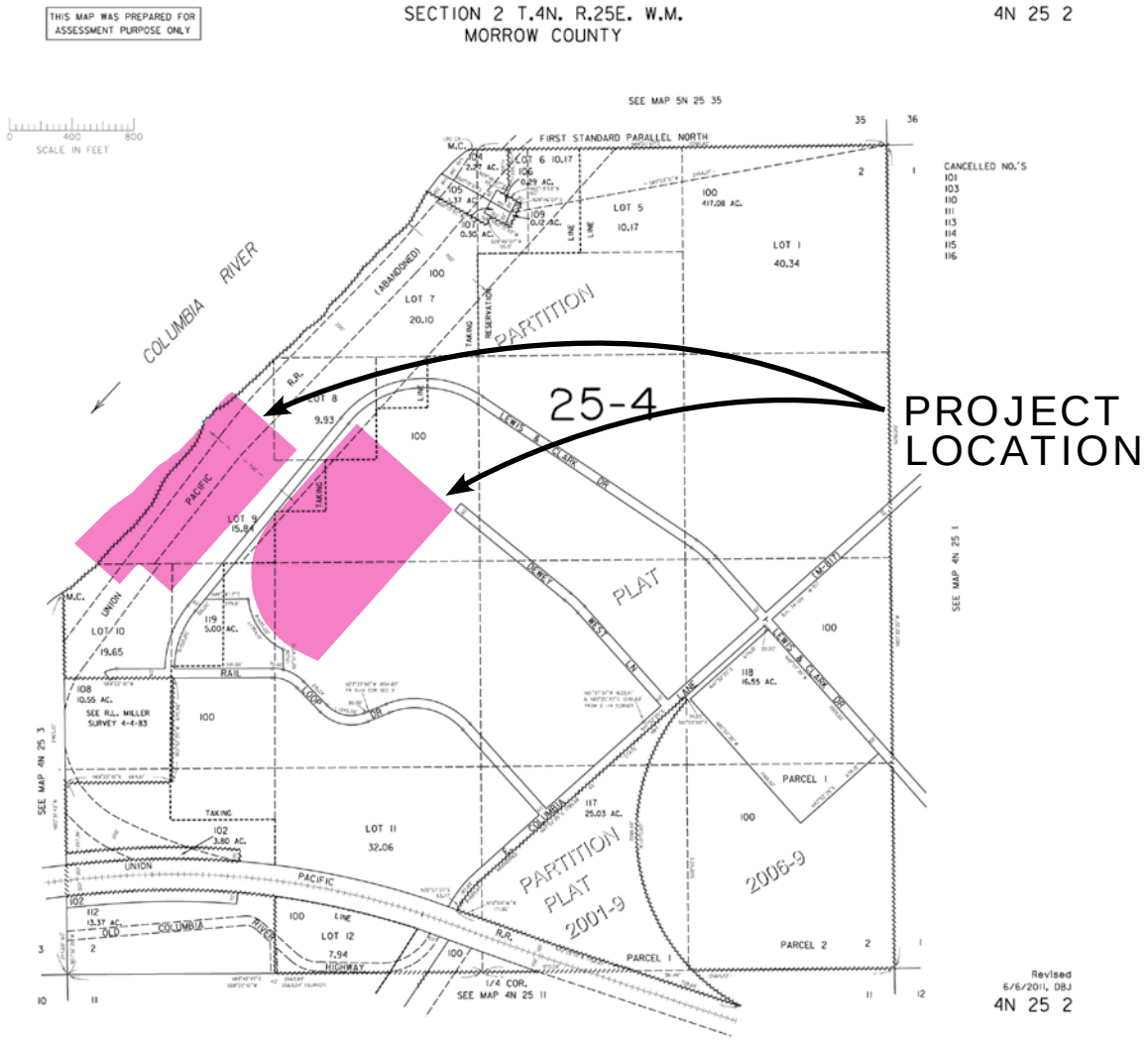
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT WESTWARD SITE
AERIAL PHOTOGRAPH - 2011

FIGURE

2B



T. 4 N., R. 25 E., W.M.
1" = 1200'

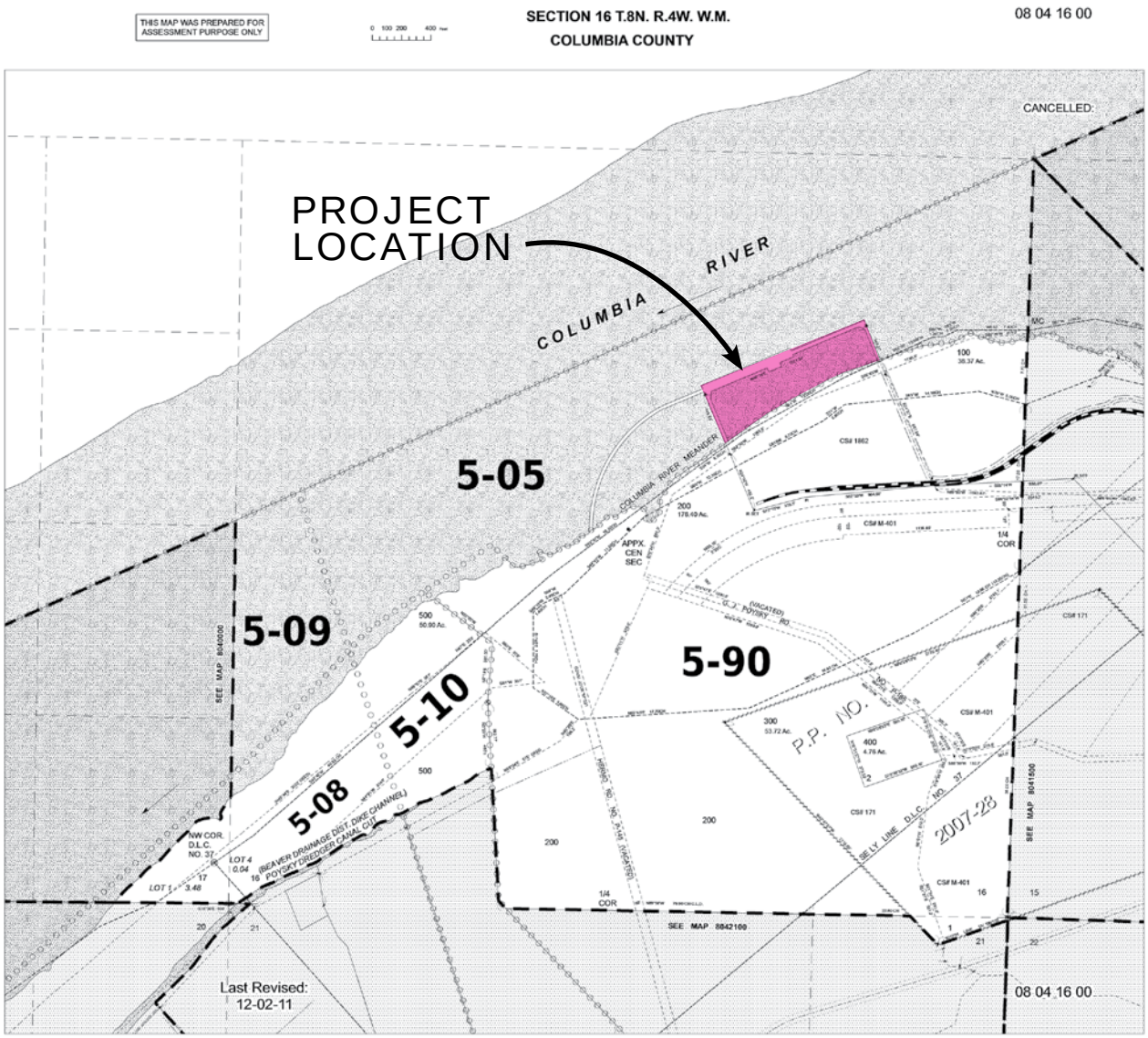
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE TAX LOT MAP

FIGURE

3A



T. 8 N., R. 4 W., W.M.
1" = 1200'

anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT WESTWARD SITE TAX LOT MAP

FIGURE

3B

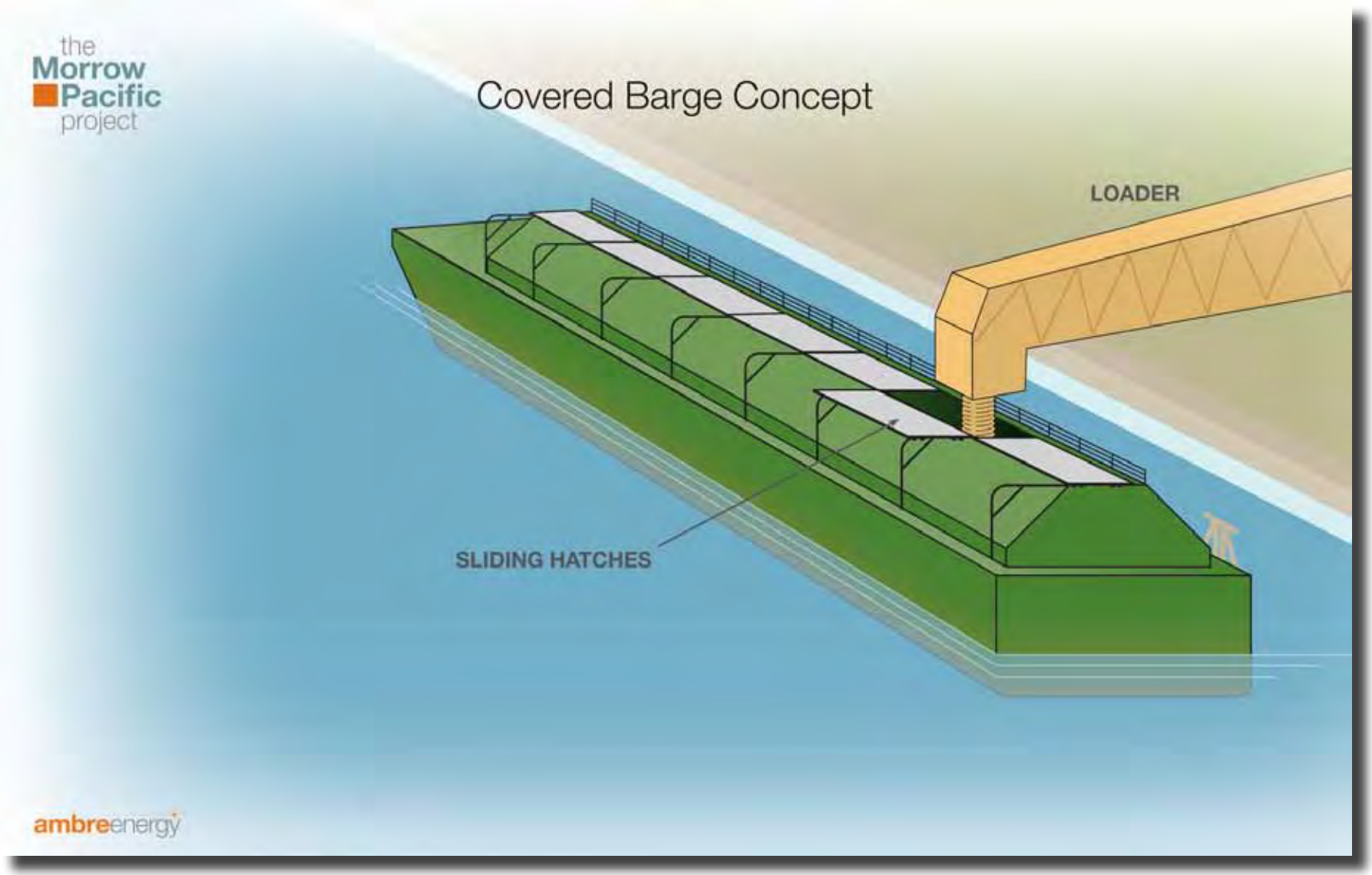
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

CONCEPTUAL PORT OF MORROW FACILITY

FIGURE

4



anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

COVERED BARGE

FIGURE

5

T. 4 N., R. 25 E., W.M.
1" = 350'±

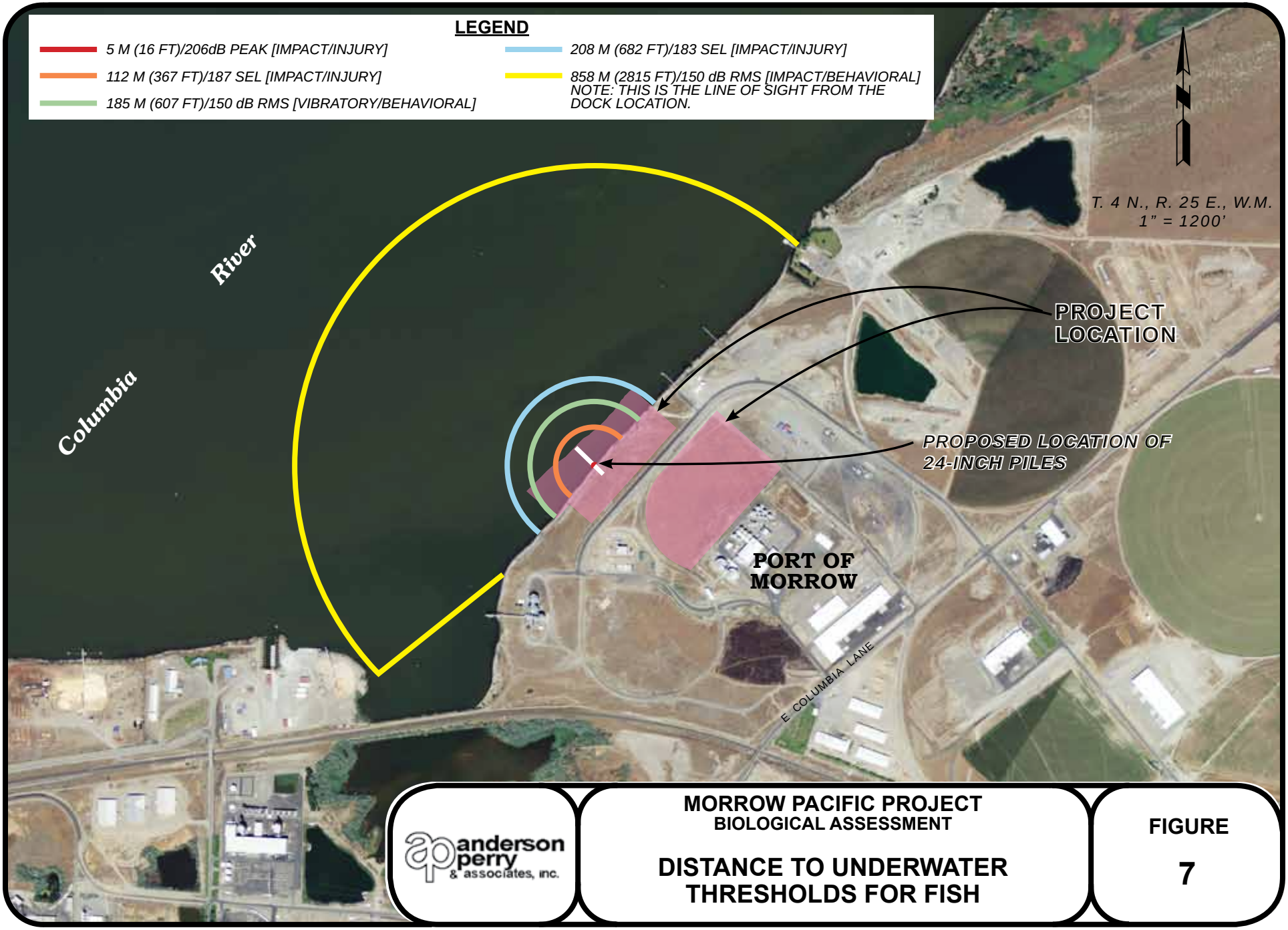
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE - PROPOSED MOORING AND STORAGE FACILITIES

FIGURE

6



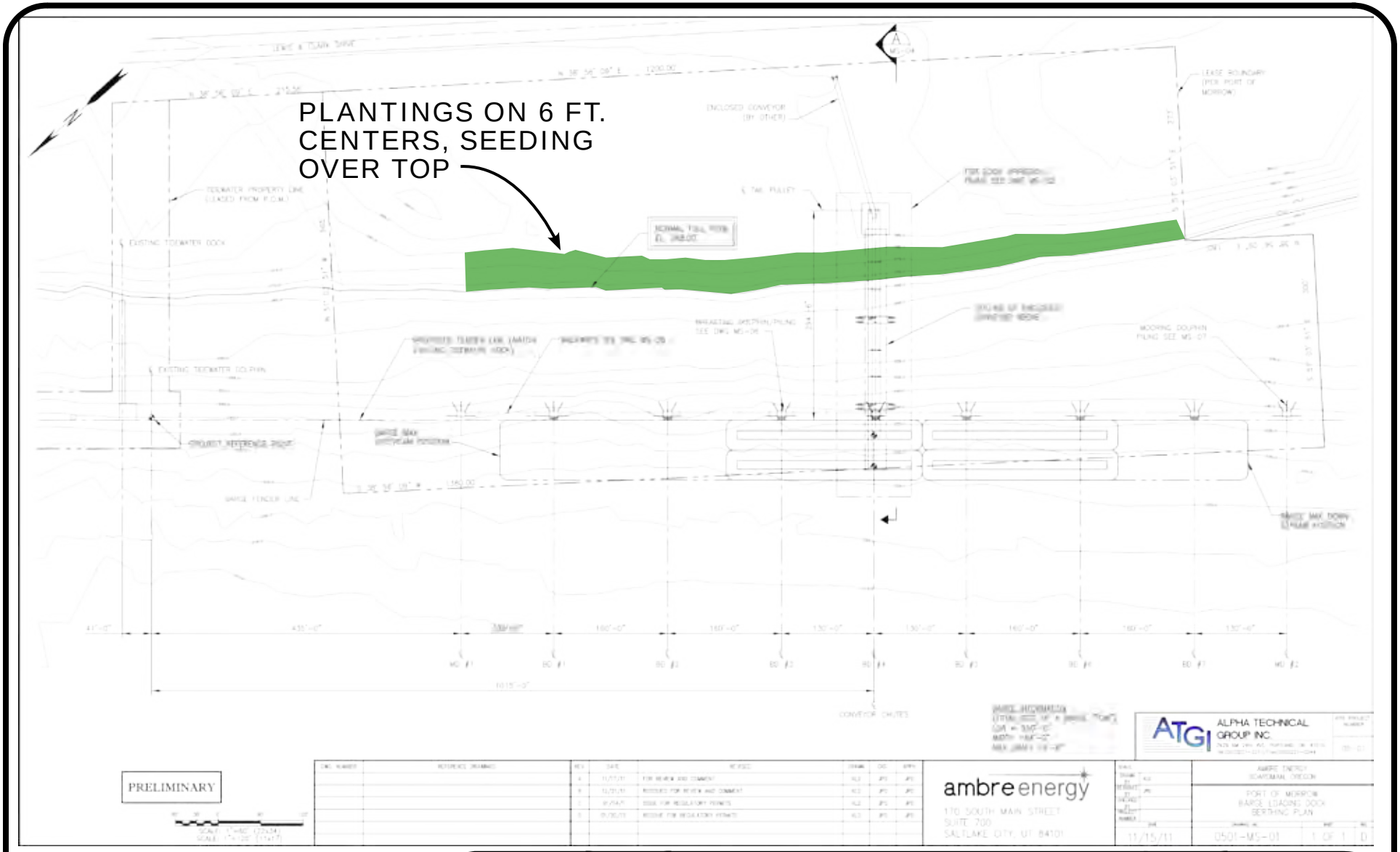
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

DISTANCE TO UNDERWATER THRESHOLDS FOR FISH

FIGURE

7



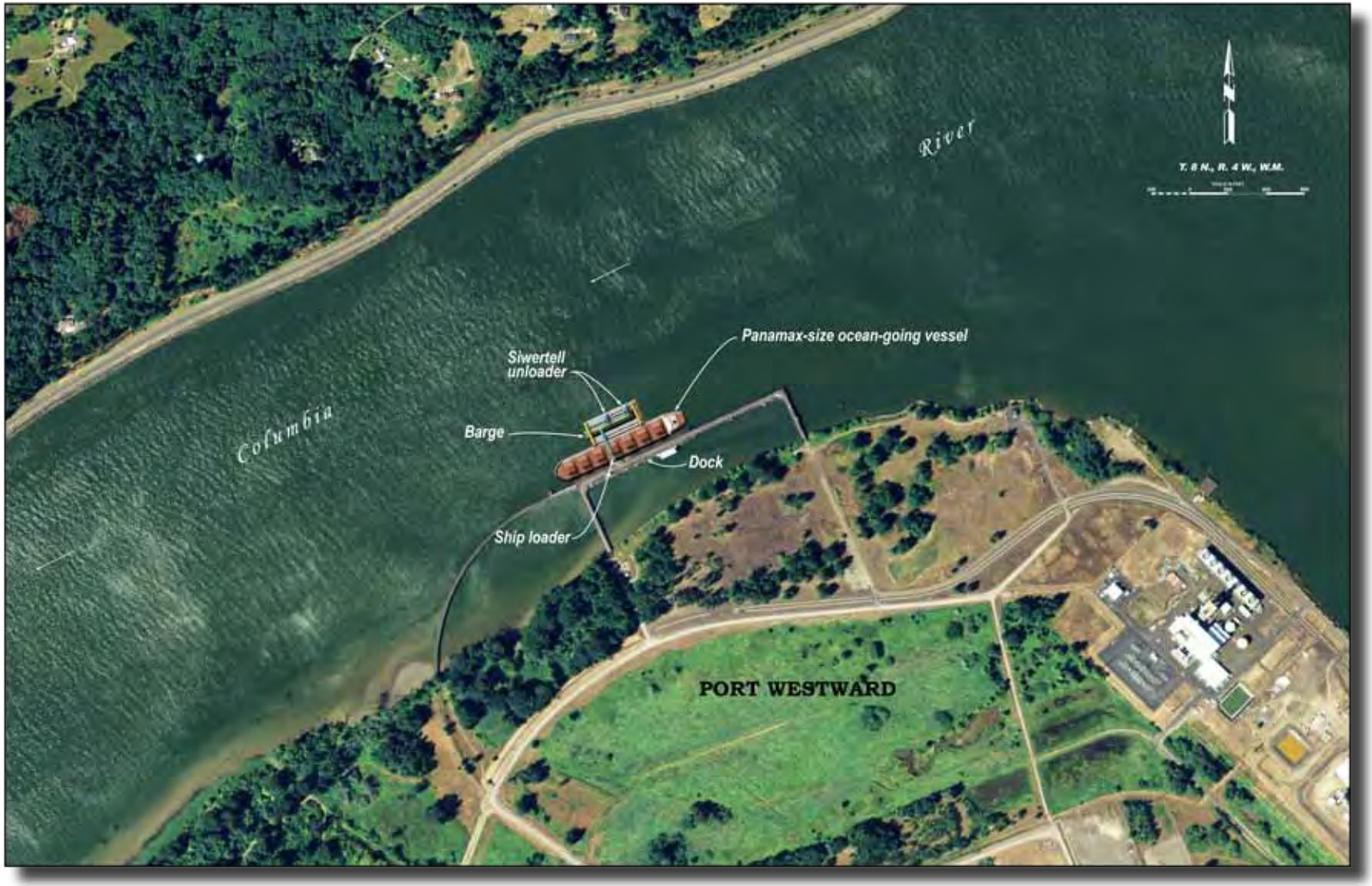
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE ON-SITE MITIGATION DETAIL

FIGURE

8



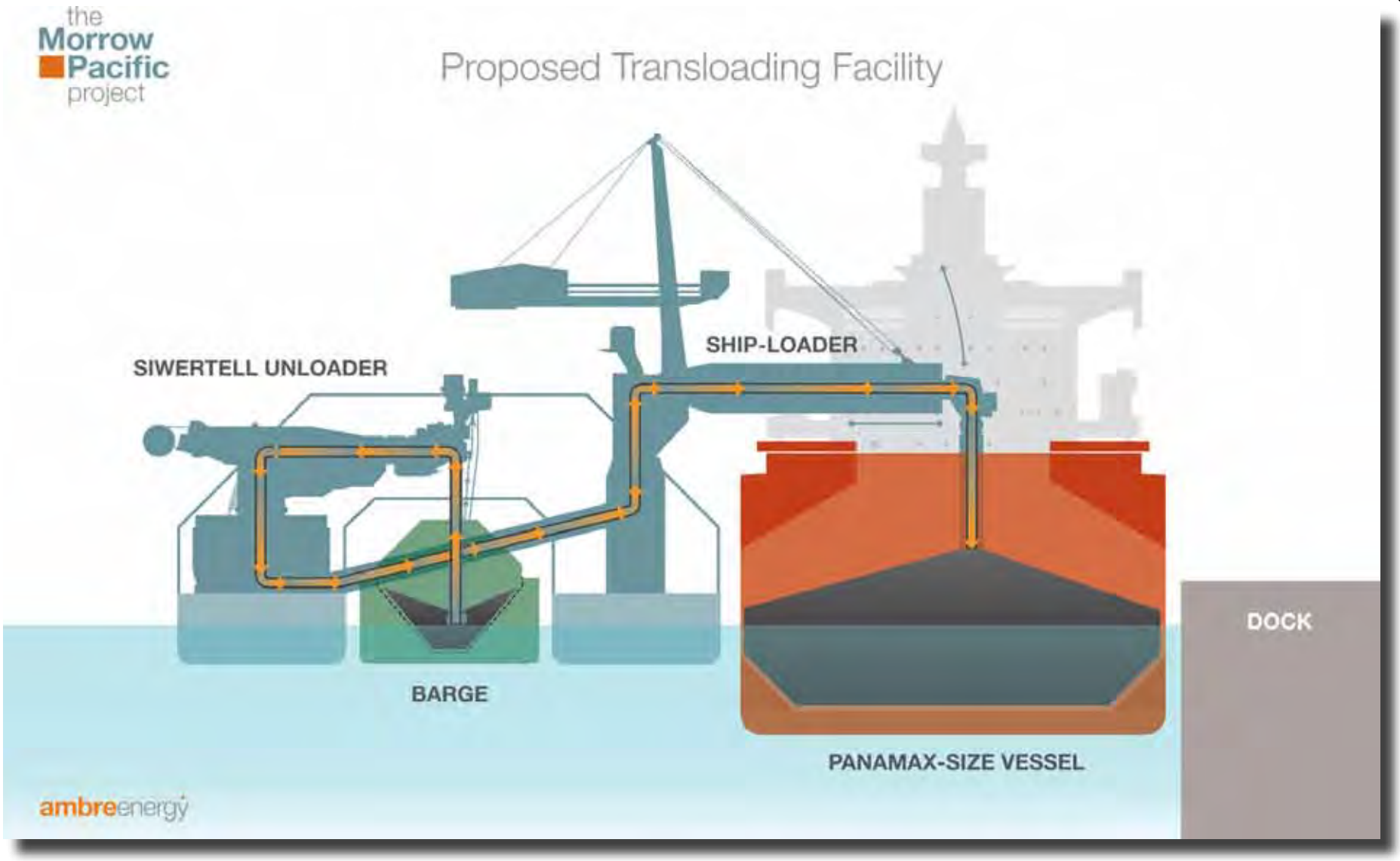
anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT WESTWARD - AERIAL VIEW TRANSLOADING OPERATION

FIGURE

9



anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT WESTWARD TRANSLOADING OPERATION

FIGURE

10

APPENDIX B

Project Site Photographs

PHOTOGRAPH 1 - Shoreline looking east toward the existing loading facility. Photograph taken by Brad Baird on November 9, 2011.

PHOTOGRAPH 2 - Shoreline looking west. Photograph taken by Brad Baird on November 9, 2011.

Job□1199-462-221 Feb. 17, 2012 lbauer

PHOTOGRAPH 3 - Looking west to upland site. Photograph taken by Brad Baird on November 9, 2011.

PHOTOGRAPH 4 - Typical bank in project area. Photograph taken by Brad Baird on November 9, 2011.

anderson perry & associates, inc.

MORROW PACIFIC PROJECT
BIOLOGICAL ASSESSMENT

PORT OF MORROW SITE
SITE PHOTOGRAPHS 2

APPENDIX

B-2

Job 1199-462-221 Feb. 17, 2012 lbauer

PHOTOGRAPH 5 - Loading facility immediately east of project site. Photograph taken by Brad Baird on November 9, 2011.

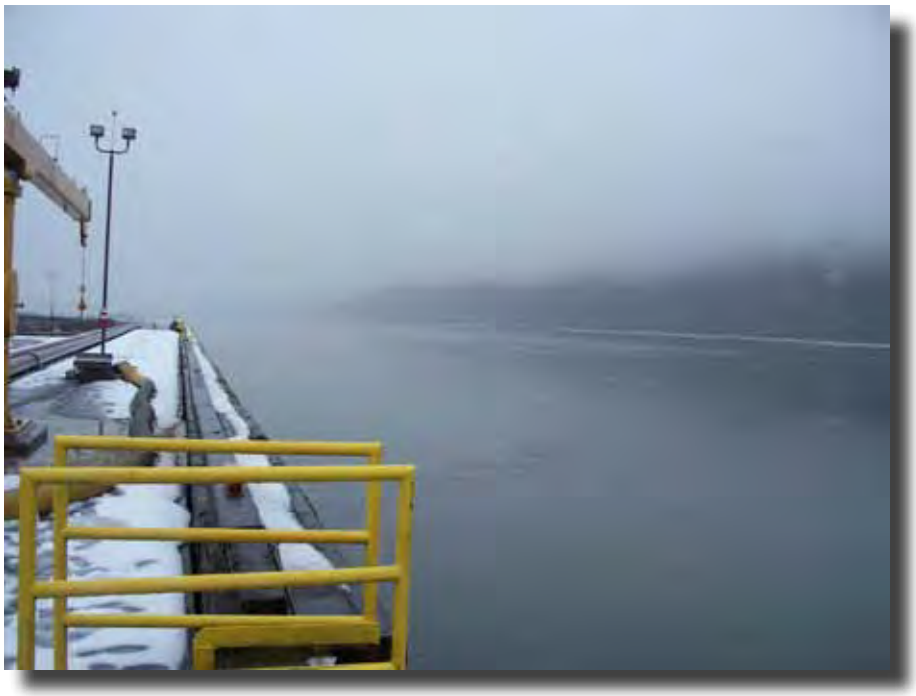
PHOTOGRAPH 6 - Upland staging area. Photograph taken by Brad Baird on December 22, 2011.

Job□1199-462-221 Feb. 17, 2012 lbauer

PHOTOGRAPH 7 - Site access. Photograph taken by Brad Baird on December 22, 2011.

PHOTOGRAPH 8 - Facility construction site - spoils area looking south. Photograph taken by Brad Baird on December 22, 2011.

Job□1199-462-221 Feb. 17, 2012 lbauer



PHOTOGRAPH 9 - West end of the existing dock looking downstream. Photograph taken by Sue Brady on January 19, 2012.

PHOTOGRAPH 10 - East end of the existing dock looking upstream. Photograph taken by Sue Brady on January 19, 2012.

Job□1199-462-221 Feb. 17, 2012 lbauer

PHOTOGRAPH 11 - Shoreline at the west end of the project area. Photograph taken by Sue Brady on January 19, 2012.

PHOTOGRAPH 12 - Shoreline at the east end of the project area. Photograph taken by Sue Brady on January 19, 2012.

Job□1199-462-221 Feb. 17, 2012 lbauer

PHOTOGRAPH 13 - Existing access road to project site. Photograph taken by Sue Brady on January 19, 2012.

Job 1199-462-221 Feb. 17, 2012 lbauer

APPENDIX C

Project Plan Sheets

BARGE LOADING DOCK

DRAWING INDEX		
DRAWING NO.	**SHEET NO.**	**TITLE**
GENERAL		
0501–MG–01	1 OF 1	DRAWING INDEX & VICINITY MAP
STRUCTURAL		
0501–MS–00	1 OF 1	GENERAL NOTES
0501–MS–01	1 OF 1	BERTHING PLAN
0501–MS–02	1 OF 1	DOCK PILING/FRAMING PLAN
0501–MS–03	1 OF 1	CONVEYOR SUPPORT DETAILS
0501–MS–04	1 OF 1	DOCK SECTIONS & DETAILS SHT 1
0501–MS–05	1 OF 1	DOCK SECTIONS & DETAILS SHT 2
0501–MS–06	1 OF 1	BREASTING DOLPHIN PLAN AND DETAILS
0501–MS–07	1 OF 1	MOORING DOLPHIN PLAN AND DETAILS
0501–MS–08	1 OF 1	WALKWAY PLANS
0501–MS–09	1 OF 1	WALKWAY SECTIONS AND DETAILS

VICINITY MAP
SCALE: NTS

PRELIMINARY

PROJECT LOCATION
BOARDMAN, OREGON

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227–3317/Fax:(503)227–3244

ATGI PROJECT NUMBER: 05–01

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	01/04/12	ISSUE FOR REGULATORY PERMITS	CWP	JPD	JPD
		B	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

SCALE: 1"=1"
DRAWN BY: CWP
DESIGNED BY: JPD
CHECKED BY:
PROJECT NUMBER:
DATE: 12/30/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
DRAWING INDEX AND VICINITY MAP

DRAWING NO.	SHEET	REV.
0501–MG–01	1 OF 1	B

GENERAL NOTES

DESIGN CRITERIA/CODES

1. BUILDING CODES
   a. IBC 2009/O.S.S.C. 2010.
   b. ASCE 7–05.

2. WIND/SEISMIC LOADS
   a. SEISMIC DESIGN PARAMETERS:
      1. Ss = 0.47/S1=0.15 (MCE VALUES)
      2. Sds = 0.45/Sd1=0.22 (MODIFIED – SITE CLASS D)
   b. WIND = 95 MPH (3 SEC GUST) EXPOSURE "C"

3. GRAVITY LOADS
   a. DEAD – CALC'D PER DWGS.
   b. CATWALK LIVE = 50 PSF
   c. CONVEYOR DEAD AND LIVE LOADS PROVIDED BY MILL CREEK ENGINEERING

4. BERTHING/MOORING LOADS/DESIGN CRITERIA
   a. MAX APPROACH VEL = 6"/S
   b. MAX APPROACH ANGLE = 5 DEG.
   c. BASIC WIND SPEED = 80MPH STANDARD OPERATING PROCEDURES REQUIRE BARGES SECURED TO DOCK AT ALL TIMES. (NOT ABLE TO TAKE ON BALLAST/ANCHOR IN MAIN CHANNEL)

PILES AND PILE DRIVING

1. DESIGN DATA
   a. PILING DESIGN LOADS, MATERIAL SPECIFICATIONS AND EMBEDMENT REQUIREMENTS ARE AS NOTED ON THE DESIGN DRAWINGS AND ARE BASED ON PAST PROJECTS AT SITE.

2. SUBSURFACE CONDITIONS
   a. PILE TIP ELEVATIONS SHOWN IN THE DRAWINGS FOR PILES ARE ESTIMATES ONLY. ACTUAL PILE TIP ELEVATIONS MAY VARY FROM THIS ESTIMATED TIP ELEVATION DUE TO VARYING SOIL CONDITIONS. IF THE LOAD BEARING CAPACITY OF THE PILE HAS NOT BEEN REACHED AT THE INDICATED TIP ELEVATION, DRIVING SHALL CONTINUE UNTIL THE LOAD BEARING CAPACITY IS REACHED, AS DIRECTED BY ENGINEER.

3. MATERIALS
   a. ALL STEEL PIPE PILING SHALL CONFORM TO ASTM A252 GR. 3 (Fy= 45 KSI MIN).
   b. ALL STEEL HP PILING SHALL CONFORM TO ASTM A690 (Fy=50 ksi MIN)

5. EXECUTION
   a. ALL DRIVING EQUIPMENT SHALL BE SUBJECT TO APPROVAL BY THE ENGINEER. ALL BEARING PILES SHALL BE DRIVEN TO REFUSAL ONTO BEDROCK. REFUSAL IS DEFINED BY MINIMUM OF 10 BLOWS/IN. WITH 30,000 FT.LB IMPACT HAMMER.

   b. PILE SPLICING, IF REQUIRED, SHALL BE A FULL PENETRATION BUTT WELD WITH MIN. 1/4" BACKING RING PER A.W.S. D1.1. ALL WELDERS SHALL BE QUALIFIED FOR THE WORK, AS PRESCRIBED IN AWS D1.1 AND COPIES OF THEIR CERTIFICATION SHALL BE SUBMITTED TO OWNER'S REPRESENTATIVE.

   c. PILE CUT–OFFS ARE THE PROPERTY OF THE CONTRACTOR.

   d. PILING SHALL BE INSTALLED TO THE FOLLOWING TOLERANCES UNLESS NOTED:
      –3" MAX HORIZONTAL DEVIATION FROM DESIGN LOCATION AT THE CUT OFF ELEVATION.
      – 1% MAX. VERTICAL/SLOPE DEVIATION FROM DESIGN LOCATION – 3/8" MAX VERT CUT OFF TOLERANCE.

   e. ALL "IN WATER" WORK SHALL BE DONE IN ACCORDANCE WITH CONDITIONS OUTLINED IN U.S. ARMY CORPS OF ENGINEERS' PERMIT. CONTRACTOR SHALL MAINTAIN A COPY OF PERMIT ON SITE.

6. SUBMITTALS
   a. SUBMIT DESCRIPTIONS OF PILE DRIVING EQUIPMENT FOR APPROVAL PRIOR TO COMMENCEMENT OF PILE INSTALLATIONS. INCLUDE DETAILS OF THE PILE HAMMER, POWER PLANT, LEADS, CUSHION MATERIAL AND HELMET.

   b. SUBMIT MATERIAL CERTIFICATIONS TO SHOW CONFORMANCE TO SPECIFICATIONS.

CONCRETE

1. CONCRETE SHALL DEVELOP 4000 PSI COMPRESSIVE STRENGTH IN 28 DAYS UNLESS NOTED & CONFORM TO THE FOLLOWING:
   a. SLUMP SHALL BE 4" (±1" TOL.) PER ASTM
   b. C143 TESTING STANDARD.
   c. CONCRETE SHALL BE AIR ENTRAINED TO CONTAIN 5% AIR (±1% TOL.)
   d. COARSE AGGREGATE SIZE 3/4" MAX.CEMENT SHALL BE TYPE II.

2. REINFORCING STEEL SHALL BE DEFORMED BARS CONFORMING TO ASTM A615 GRADE 60. ALL REINFORCING STEEL THAT IS TO BE WELDED SHALL BE DEFORMED BARS CONFORMING TO ASTM A706.

3. SPLICES SHALL BE LAPPED 42 BAR DIAMETERS OR 2'–0" MIN U.N.O

4. GROUT SHALL BE A NON–SHRINK, NON METALLIC FLOWABLE HIGH–STRENGTH GROUT (5 STAR OR EQUAL).

STRUCTURAL STEEL

1. DESIGN FABRICATION AND ERECTION OF STRUCTURAL STEEL SHALL BE IN ACCORDANCE WITH THE "MANUAL OF STEEL CONSTRUCTION" OF AMERICAN INSTITUTE OF STEEL CONSTRUCTION, 13th EDITION, UNLESS OTHERWISE MODIFIED ON THE DRAWING OR IN THE SPECIFICATIONS.

2. ERECTOR SHALL PROVIDE ALL TEMPORARY SHORING AND BRACING NEEDED FOR STABILITY UNTIL THE STRUCTURE IS COMPLETED.

3. MATERIAL SHALL MEET THE REQUIREMENTS OF THE FOLLOWING SPECIFICATIONS, UNLESS NOTED OTHERWISE:
   STRUCTURAL STEEL – ASTM A36
   WELDED STEEL – AWS D1.1
   ELECTRODES – E70XX
   HIGH STRENGTH BOLTS – ASTM A325 – 3/4"Ø GALV. BOLTS, NUTS & WASHERS UNLESS OTHERWISE NOTED.

4. ALL STEEL FRAMING IS UNPAINTED U.N.

STRUCTURAL OBSERVATIONS

THE FOLLOWING "STRUCTURAL OBSERVATIONS" ARE REQUIRED BY THE ENGINEER OF RECORD (EOR), IN ACCORDANCE WITH CHAPTER 17 OF THE I.B.C;

1. THE EOR SHALL OBSERVE CONSTRUCTION AT FOLLOWING STAGES:
   a. AT COMPLETION OF BEARING PILE INSTALLATION.

   b. AT COMPLETION OF ALL STRUCTURAL FRAMING AND BRACING.

SPECIAL INSPECTIONS

THE FOLLOWING SPECIAL INSPECTIONS ARE REQUIRED FOR THIS PROJECT IN ACCORDANCE WITH CHAPTER 17 OF THE INTERNATIONAL BUILDING CODE:

1. PILE DRIVING (CONTINUOUS)
   VERIFY ALL PILING IS INSTALLED PER DESIGN DRAWINGS/SPECS INCLUDING:
   a. VERIFY THAT ADEQUATE LOAD BEARING IS REACHED IN BEARING PILES AS DIRECTED BY THE ENGINEER,
   b. VERIFY THAT THE PROPER EMBEDMENT IS OBTAINED.

2. STRUCTURAL WELDING (PERIOIC)
   VERIFY ALL STRUCTURAL WELDING IS PERFORMED PER DESIGN DRAWINGS/SPECS.
   a. ALL WELDERS SHALL BE QUALIFIED FOR THE WORK, AS PRESCRIBED IN A.W.S. D1.1 AND COPIES OF THEIR CERTIFICATION SHALL BE PROVIDED TO THE SPECIAL INSPECTOR.

   b. THE OWNER SHALL RETAIN A CERTIFIED SPECIAL INSPECTOR TO PERFORM THE INSPECTIONS OUTLINED ABOVE. THE CONTRACTOR SHALL BE RESPONSIBLE FOR NOTIFYING THE INSPECTOR TWO DAYS PRIOR TO ALL REQUIRED INSPECTIONS.

   c. SEE O.S.S.C 2010 TABLE 1704.3 FOR ADDITIONAL REQUIREMENTS.

   d. FULL PENETRATION GROVE WELD (I.E. PILES) REQUIRE "CONTINUOUS INSPECTION.

   e. SINGLE PASS FILLET WELDS ≤ 5/16" REQUIRE "PERIODIC" INSPECTION ONLY.

NOTE:
OHWE = ORDINARY HIGH WATER ELEVATION

PRELIMINARY

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	01/04/12	ISSUE FOR REGULATORY PERMITS	CWP	JPD	JPD
		B	01/20/12	REISSUE FOR REGULATORY PERMITS	CWP	JPD	JPD
		C	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ATGI ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227–3317/Fax:(503)227–3244

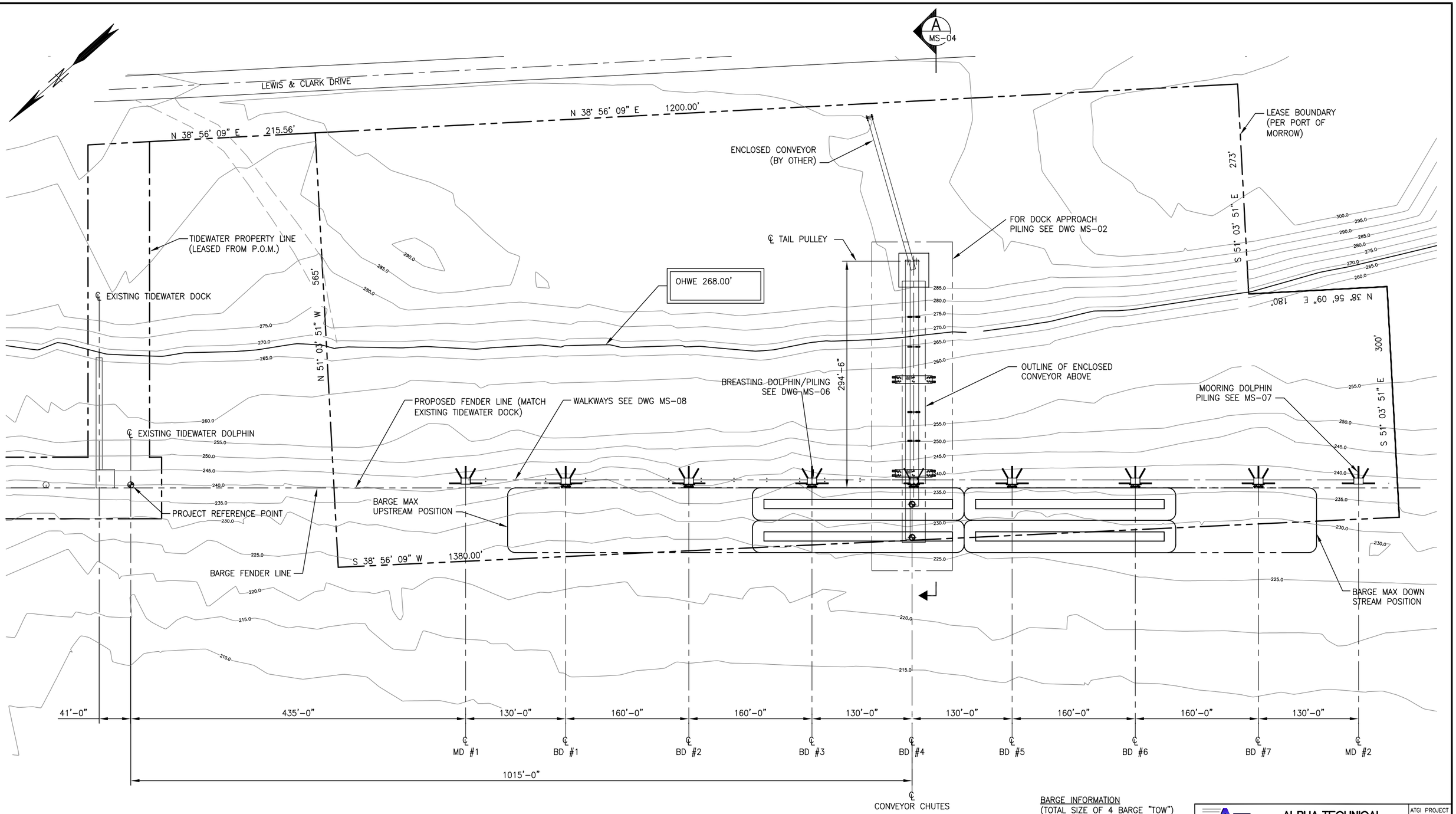
ATGI PROJECT NUMBER: 05–01

SCALE: 1"=1"	
DRAWN BY	CWP
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	12/30/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
GENERAL NOTES

DRAWING NO.	SHEET	REV.
0501–MS–00	1 OF 1	C



BARGE INFORMATION
(TOTAL SIZE OF 4 BARGE "TOW")
LOA = 550'-0"
WIDTH =84'-0"
MAX DRAFT 13'-6"

PRELIMINARY

60' 30' 0' 60' 120'
SCALE: 1"=60' (22x34)
SCALE: 1"=120' (11x17)

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/1	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

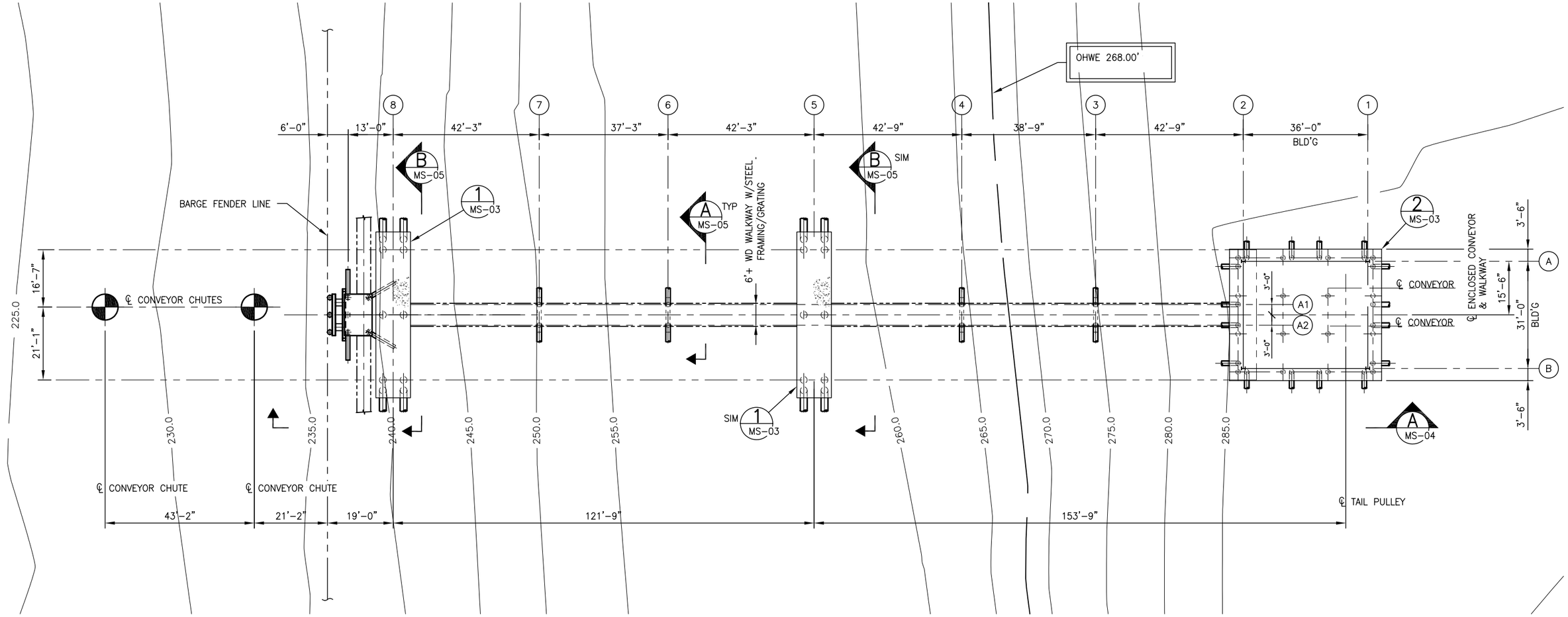
ATGI PROJECT NUMBER 05-01

SCALE:	
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
BERTHING PLAN

DRAWING NO.	SHEET	REV.
0501-MS-01	1 OF 1	E



NOTE:
1. BENTS ①, ②, ⑤, ⑧ HAVE CONCRETE SURFACE PADS. ALL ELSE IS METAL GRATED WALKWAY.

DOCK PILING PLAN

1"=15'-0"

PRELIMINARY

30' 20' 10' 0' 15' 30'

SCALE: 1"=15' (22x34)
SCALE: 1"=30' (11x17)

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

ATGI PROJECT NUMBER: 05-01

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

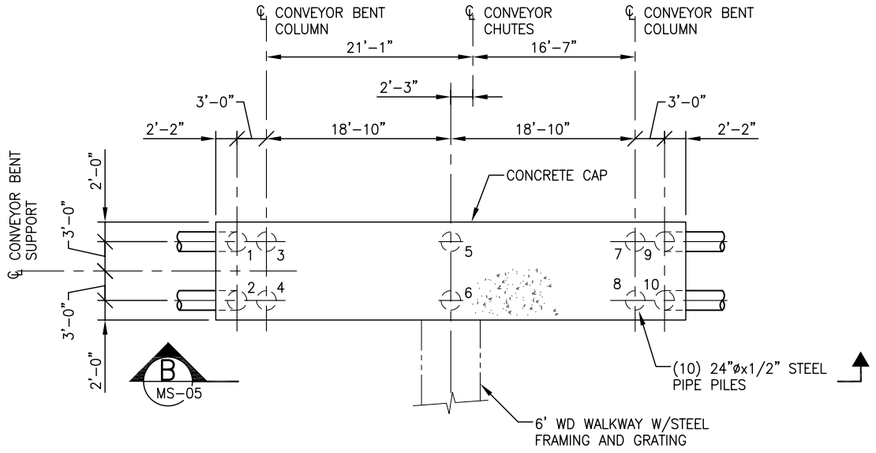
ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

SCALE: AS SHOWN
DRAWN BY: KLD
DESIGNED BY: JPD
CHECKED BY:
PROJECT NUMBER:
DATE: 11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

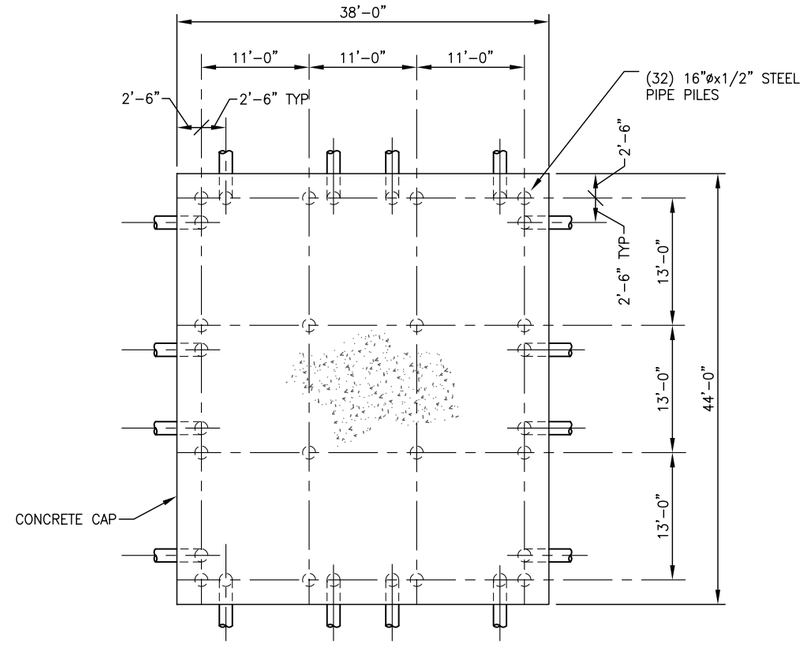
PORT OF MORROW
BARGE LOADING DOCK
DOCK PILING/FRAMING PLAN

DRAWING NO.: 0501-MS-02
SHEET: 1 OF 1
REV.: E



DETAIL 1 (CONVEYOR SUPPORT "OVER WATER")

MS–02, MS–04



DETAIL 2 (CONVEYOR SUPPORT "UPLAND")

MS–02, MS–04

PRELIMINARY

SCALE: 1/8"=1'–0"

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227–3317/Fax:(503)227–3244

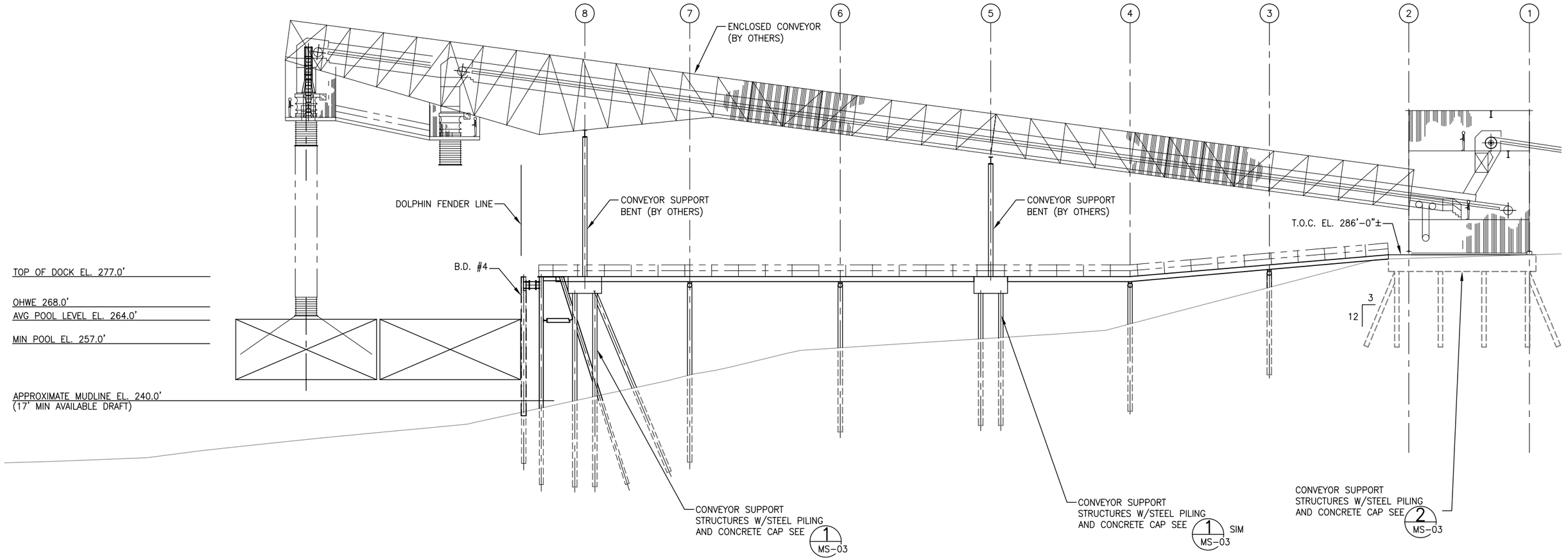
ATGI PROJECT NUMBER: 05–01

SCALE: AS SHOWN	
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
CONVEYOR SUPPORT DETAILS

DRAWING NO.	SHEET	REV.
0501–MS–03	1 OF 1	E



SECTION A
1"=15'-0" MS-01

30' 20' 10' 0' 15' 30'

SCALE 1"=15' (22"x34")
SCALE 1"=30' (11"x17")

PRELIMINARY

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMIT	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

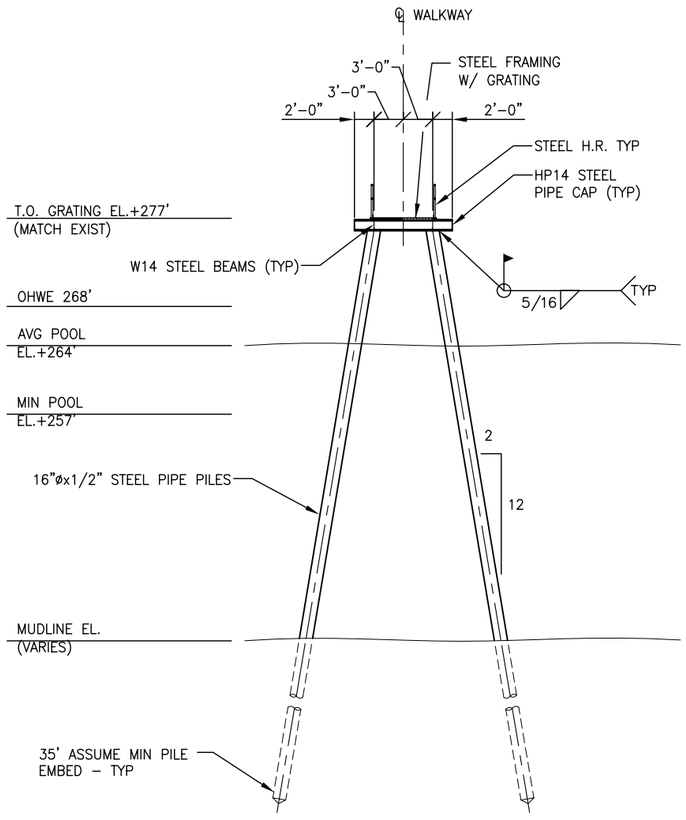
ATGI PROJECT NUMBER: 05-01

SCALE: AS SHOWN	
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

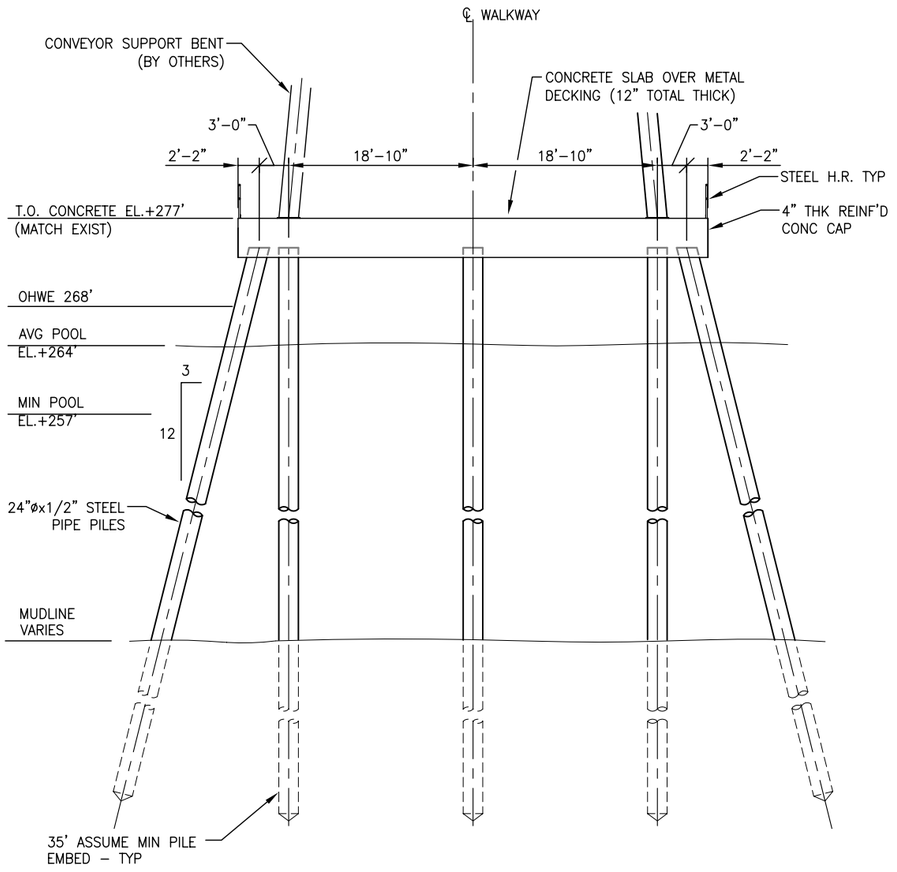
PORT OF MORROW
BARGE LOADING DOCK
SECTION "A"

DRAWING NO.	SHEET	REV.
0501-MS-04	1 OF 1	E



SECTION A-A (DOCK APPROACH WALKWAY)

MS-01, MS-02, MS-03



SECTION B-B (CONVEYOR SUPPORT STRUCT'S)

MS-01, MS-02, MS-03

PRELIMINARY

2' 0' 2' 4' 6' 8' 10' 12'
SCALE: 1/8"=1'-0"

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

ATGI PROJECT NUMBER: 05-01

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

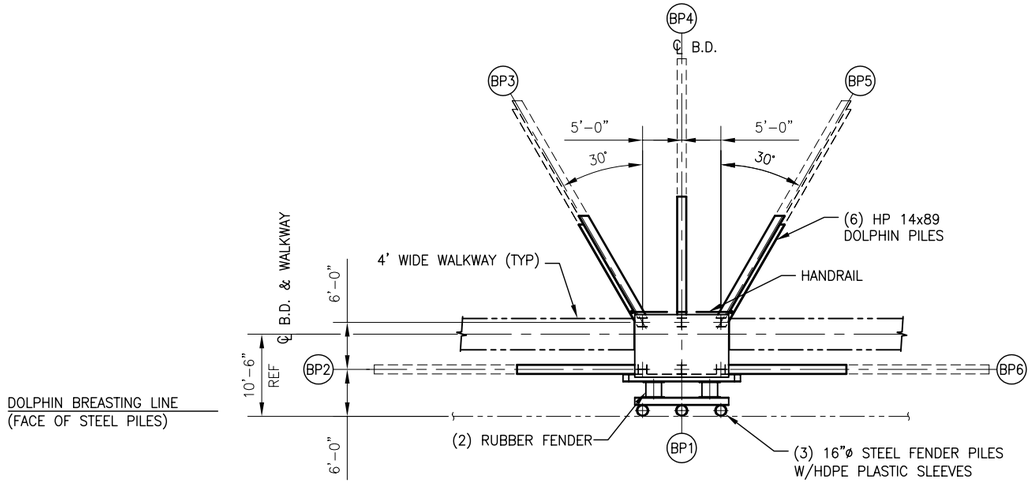
ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

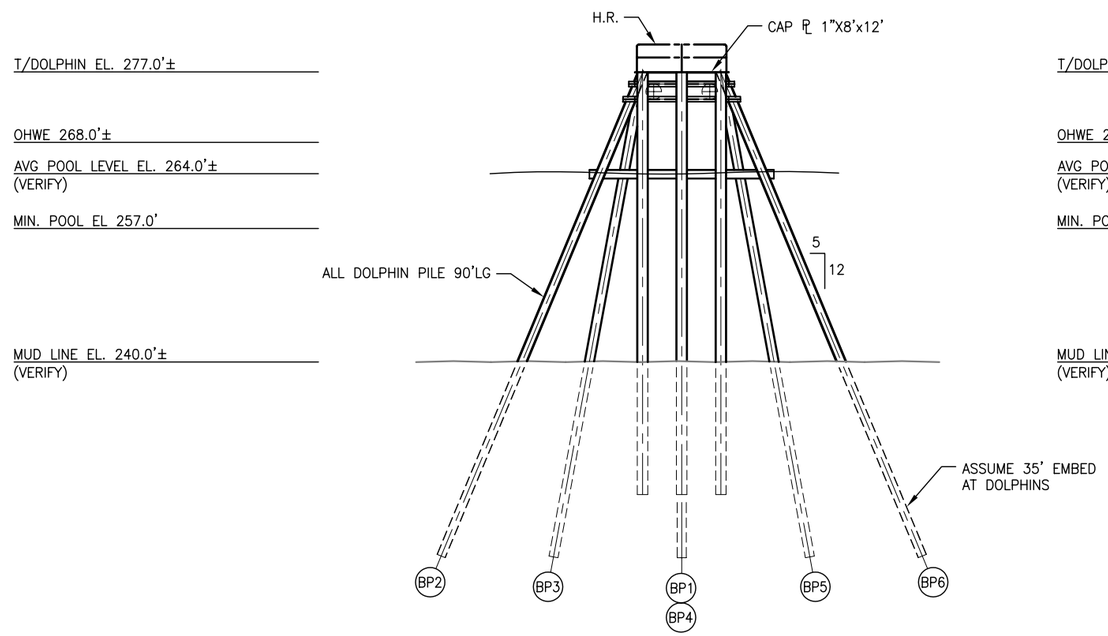
SCALE: AS SHOWN
DRAWN BY: KLD
DESIGNED BY: JPD
CHECKED BY:
PROJECT NUMBER:
DATE: 11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

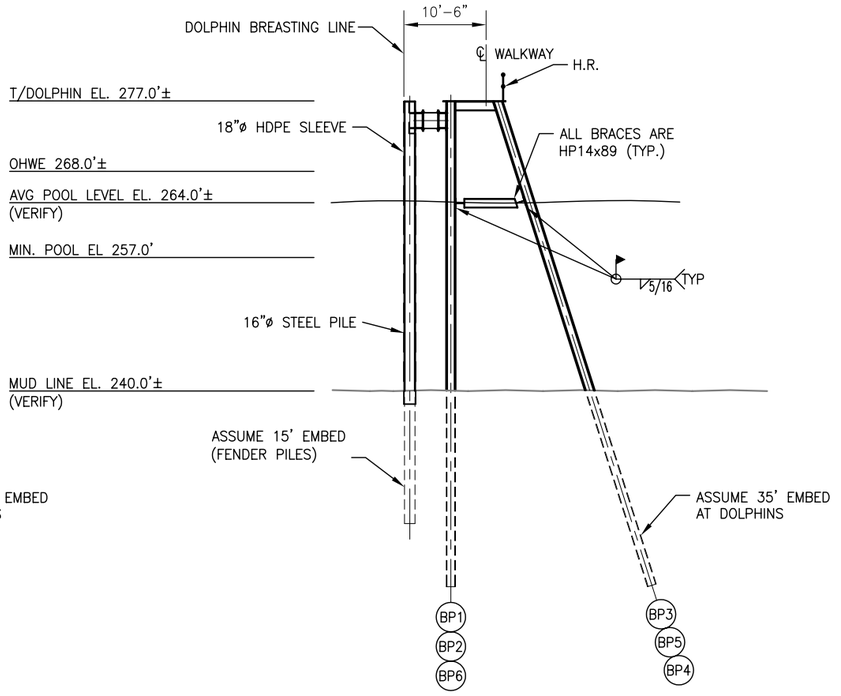
PORT OF MORROW
BARGE LOADING DOCK
SECTION "A" & "B"

DRAWING NO.: 0501-MS-05
SHEET: 1 OF 1
REV.: E





RIVER SIDE ELEV.



DOWN RIVER SIDE ELEV.

BREASTING DOLPHIN DETAIL A

1"=10'–0"

NOTE:
ELEVATION OF STEEL BRACING SHOWN IS APPROX. LOCATE BRACING 2"0" ABOVE WATER LEVEL AT TIME OF CONSTRUCTION

PRELIMINARY

10' 0' 10' 20'
SCALE: 1"=10' (22x34)
SCALE: 1"=20' (11x17)

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ATGI ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227–3317/Fax:(503)227–3244

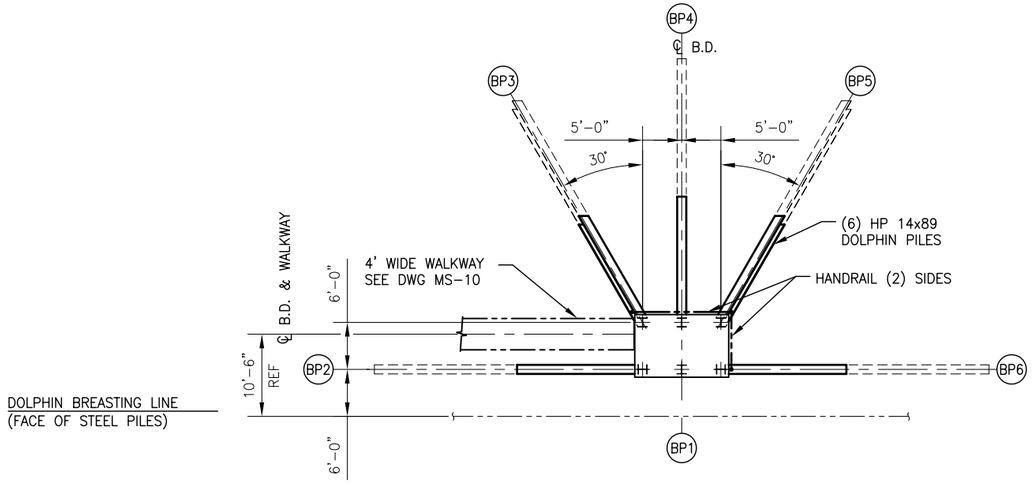
ATGI PROJECT NUMBER: 05–01

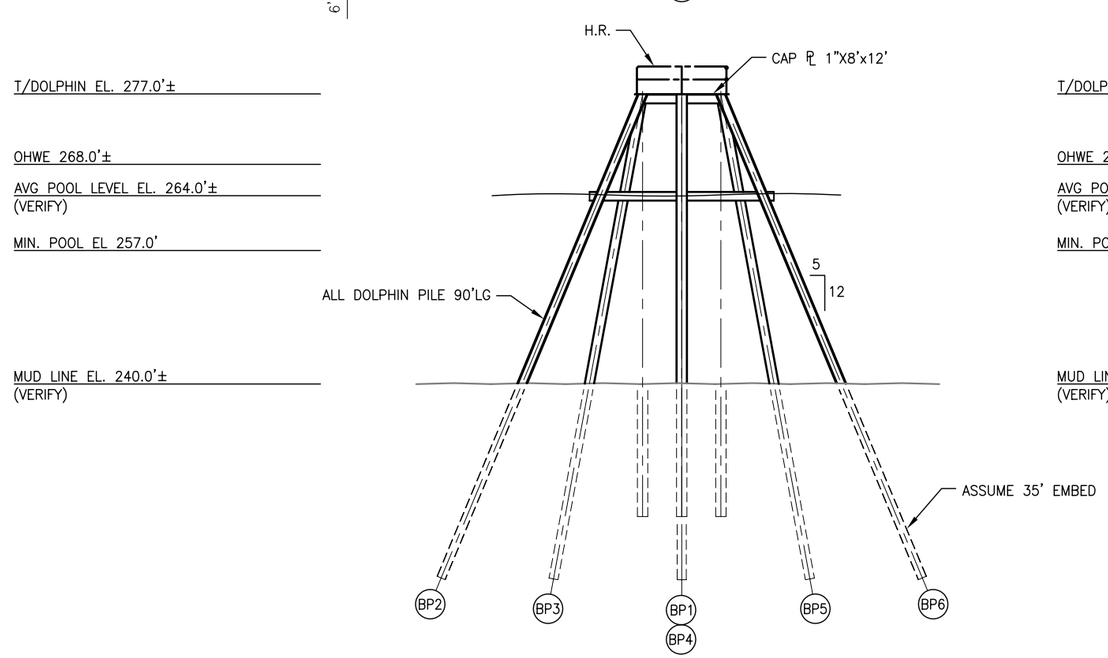
SCALE:	1"=10'–0"
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

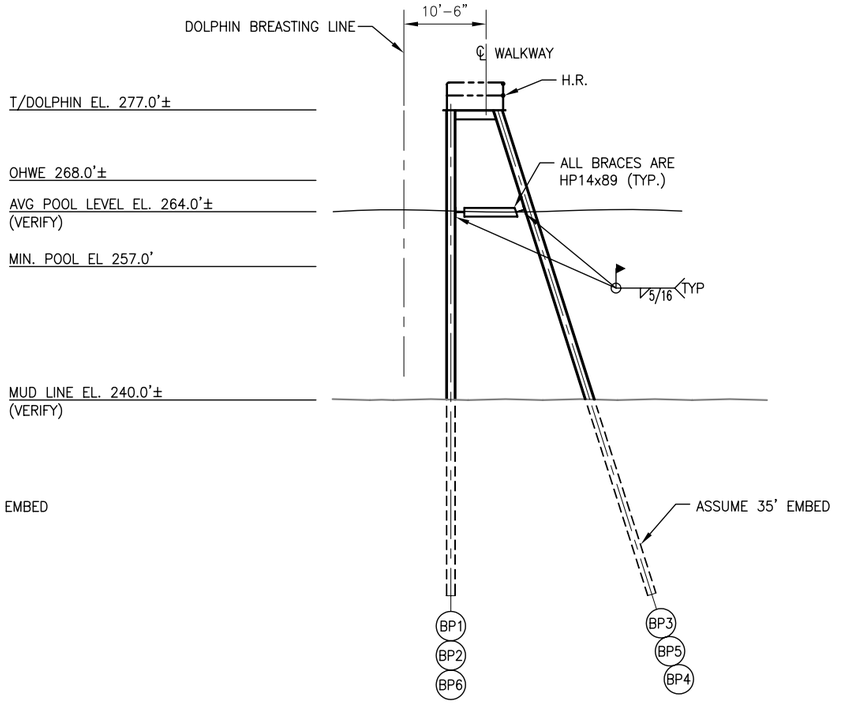
PORT OF MORROW
BARGE LOADING DOCK
BREASTING DOLPHIN PLAN AND DETAILS

DRAWING NO.	SHEET	REV.
0501–MS–06	1 OF 1	E





RIVER SIDE ELEV.



DOWN RIVER SIDE ELEV.

NOTE:
ELEVATION OF STEEL BRACING SHOWN IS APPROX. LOCATE BRACING 2"0" ABOVE WATER LEVEL AT TIME OF CONSTRUCTION

MOORING DOLPHIN
DETAIL A
1"=10'-0"

10' 0' 10' 20'
SCALE: 1"=10' (22x34)
SCALE: 1"=20' (11x17)

PRELIMINARY

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

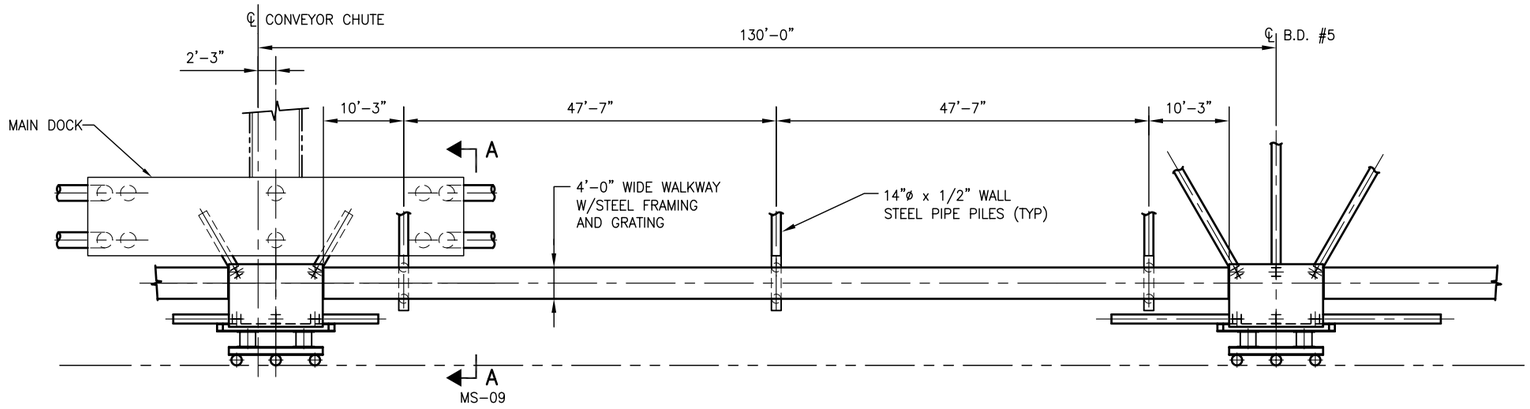
ATGI PROJECT NUMBER: 05-01

SCALE:	1"=10'-0"
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

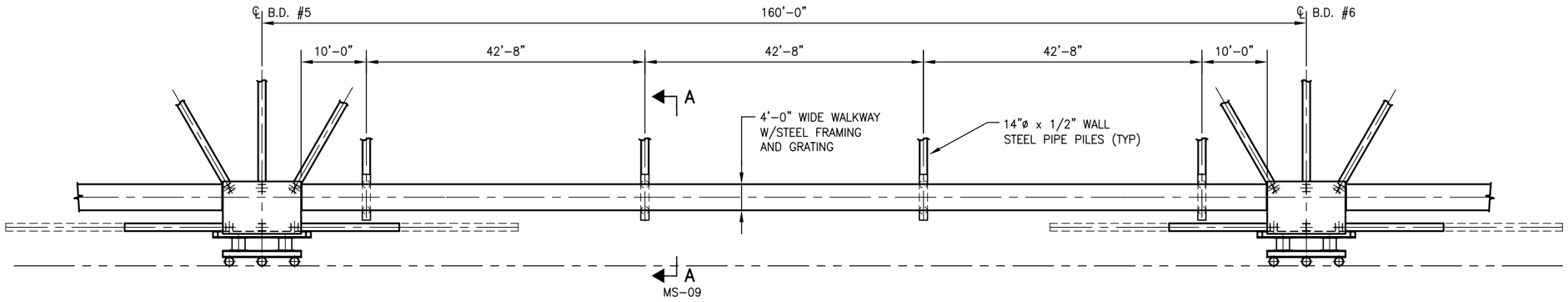
AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
MOORING DOLPHIN PLAN AND DETAILS

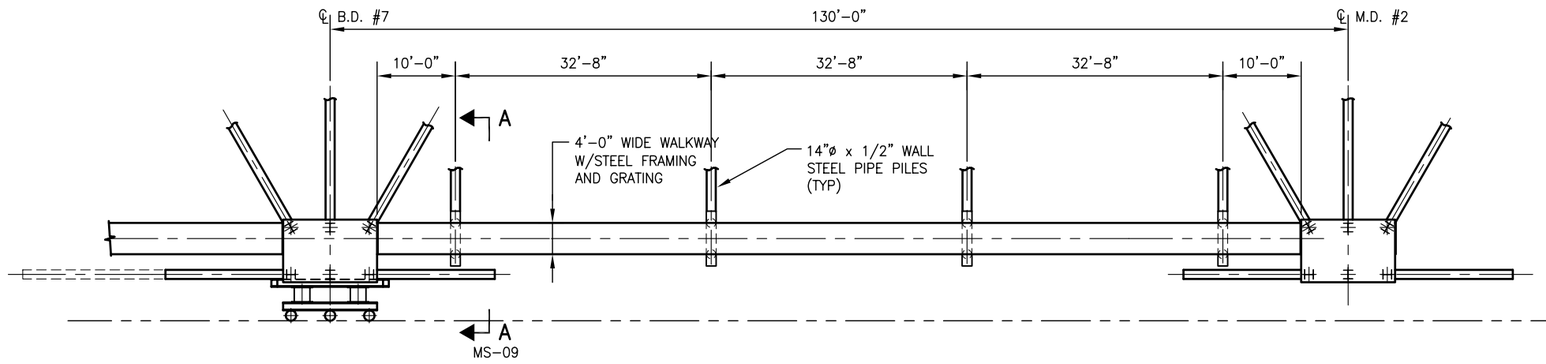
DRAWING NO.	SHEET	REV.
0501-MS-07	1 OF 1	E



WALKWAY PLAN – DOCK/B.D. #5 (SIM @ DOCK/B.D. #3)
(TYP 2)



WALKWAY PLAN – B.D. #5/6 (SIM @ B.D. #6/7, 2/3, 1/2)
(TYP 4)



WALKWAY PLAN – B.D. #7/M.D. #2 (SIM @ B.D. #1/M.D. #1)
(TYP 2)

PRELIMINARY

10' 0' 10' 20'
SCALE: 1"=10' (22x34)
SCALE: 1"=20' (11x17)

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISUUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227-3317/Fax:(503)227-3244

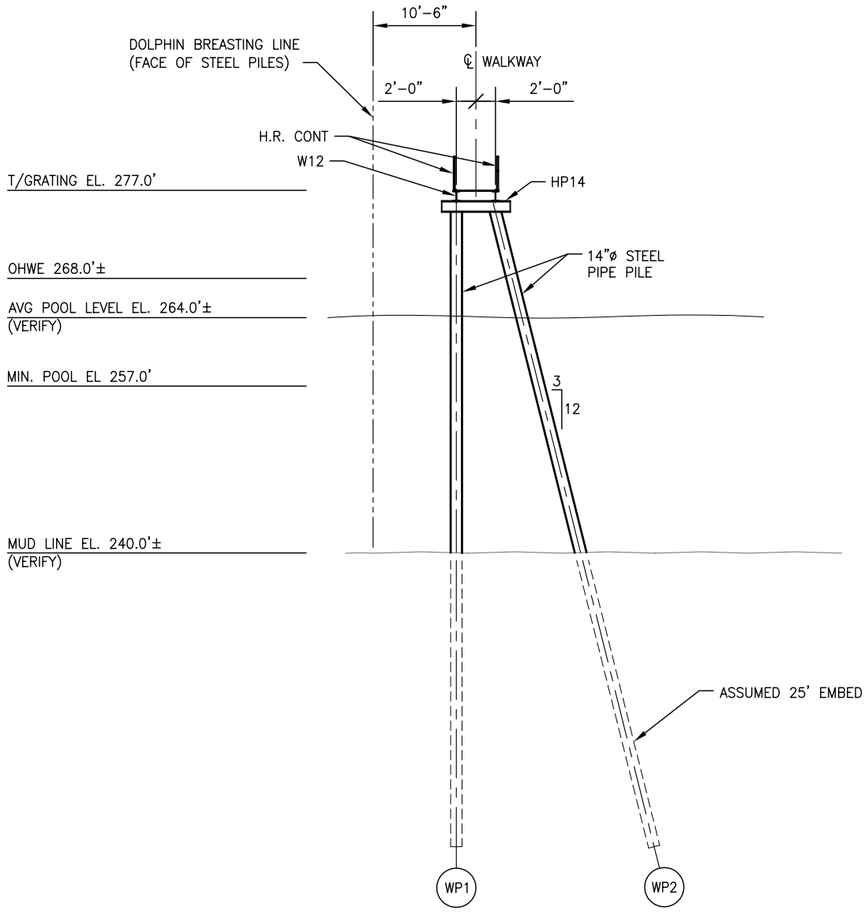
ATGI PROJECT NUMBER: 05-01

SCALE: 1"=10'-0"	
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
WALKWAY PLANS

DRAWING NO.	SHEET	REV.
0501-MS-08	1 OF 1	E



SECTION A–A (TYP WALKWAY BETWEEN DOLPHINS)

MS–08

PRELIMINARY

SCALE: 1/8"=1'–0"

ALPHA TECHNICAL GROUP INC.
2929 NW 29th AVE, PORTLAND, OR. 97210
Tel:(503)227–3317/Fax:(503)227–3244

ATGI PROJECT NUMBER: 05–01

DWG. NUMBER	REFERENCE DRAWINGS	REV.	DATE	REVISED	DRAWN	CKD.	APPV.
		A	11/17/11	FOR REVIEW AND COMMENT	KLD	JPD	JPD
		B	12/21/11	REISSUED FOR REVIEW AND COMMENT	KLD	JPD	JPD
		C	01/04/12	ISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		D	01/20/12	REISSUE FOR REGULATORY PERMITS	KLD	JPD	JPD
		E	01/25/12	REISSUE FOR REGULATORY PERMITS	HVT	JPD	JPD

ambre energy
170 SOUTH MAIN STREET
SUITE 700
SALTLAKE CITY, UT 84101

SCALE: AS SHOWN	
DRAWN BY	KLD
DESIGNED BY	JPD
CHECKED BY	
PROJECT NUMBER	
DATE	11/15/11

AMBRE ENERGY
BOARDMAN, OREGON

PORT OF MORROW
BARGE LOADING DOCK
WALKWAY SECTION

DRAWING NO.	SHEET	REV.
0501–MS–09	1 OF 1	E

APPENDIX D

Agency Correspondence

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oregon Fish and Wildlife Office
2600 SE 98th Avenue, Suite 100
Portland, Oregon 97266
Phone: (503) 231-6179 FAX: (503) 231-6195

January 7, 2012

Subject: Lists of threatened and endangered species that may occur in selected Oregon counties

To Whom It May Concern:

This letter accompanies a species list(s) downloaded from our website (http://www.fws.gov/oregonfwo/Species/Lists/RequestList.asp), which shows threatened and endangered species that may occur within the area of your proposed project. The species list(s) fulfills the requirement of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems on which they depend may be conserved. Under section 7(a)(1) and 7(a)(2) of the Act and pursuant to 50 CFR 402 *et seq.*, Federal agencies are required to utilize their authorities to carry out programs which further species conservation and to determine whether projects may affect threatened and endangered species, and/or designated critical habitat. A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (NEPA) (42 U.S.C. 4332 (2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to the Biological Assessment be prepared to determine whether they may affect listed and proposed species or critical habitats. Recommended contents of a Biological Assessment are described in Enclosure A, as well as 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that threatened and endangered species and/or designated critical habitat may be affected by the project, the agency is required to consult with the Service following the requirements of the regulations that implement the Act (50 CFR 402).

The county species list(s) includes a list of candidate species under review for listing and those species that the Service considers "species of concern." Candidate species have no protection under the Act but are included for consideration as it is possible candidates could be listed prior to the completion of your project. Species of concern are those taxa whose conservation status is of concern to the Service (many previously known as Category 2 candidates), but for which further information is still needed.

TAKE PRIDE IN AMERICA

If a proposed project may affect only candidate species or species of concern, you are not required to perform a Biological Assessment or evaluation or consult with the Service. However, the Service recommends minimizing impacts to these species to the extent possible in order to prevent potential future conflicts. Therefore, if early evaluation of the project indicates that it is likely to adversely impact a candidate species or species of concern, your agency may wish to request technical assistance from this office.

If your project includes communications or cell towers, you should be aware that migratory birds, another of our Trust Resources, can suffer significant mortality from collisions with towers. Further information on this issue can be obtained from the following web sites: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm and http://www.towerkill.com. Please refer to the recently approved Service Guidance on the Siting, Construction, Operation and Decommissioning of Communications Towers (http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html). We recommend its application to relevant projects. We also recommend the tower site evaluation form (found on the guidance webpage), which you may find useful in helping to determine the effects of your proposed project to endangered species and migratory birds.

The bald eagle (*Haliaeetus leucocephalus*) has recovered and was removed from the Federal List of Endangered and Threatened Wildlife and Plants in 2007. The bald eagle occurs in all Oregon counties, and the species continues to be protected under the Bald and Golden Eagle Protection Act. For more information on bald eagles, and for the Service's "National Bald Eagle Management Guidelines," please visit the Service's regional webpage devoted to the bald eagle (http://www.fws.gov/pacific/eagle/).

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to investigate opportunities for incorporating conservation of threatened and endangered species into project planning processes as a means of complying with the Act. Please include a copy of this letter and any species lists downloaded from our website with any request for consultation or correspondence about your project that you submit to our office. If you have questions regarding your responsibilities under the Act, please contact Cat Brown at (503) 231-6179. For questions regarding listed salmon and steelhead trout, please contact NOAA Fisheries Service, 525 NE Oregon Street, Suite 500, Portland, Oregon 97232, (503) 230-5400.

Enclosure A

ENCLOSURE A

RESPONSIBILITIES OF FEDERAL AGENCIES UNDER SECTION 7(a) and (c) OF THE ENDANGERED SPECIES ACT

SECTION 7(a) Consultation/Conference

Section 7(a) of the Act requires:

1. Federal agencies to utilize their authorities to carry out programs to conserve endangered and threatened species;
2. Consultation with the U.S. Fish and Wildlife Service (Service) when a Federal action may affect a listed endangered or threatened species or designated critical habitat to insure that any action authorized, funded or carried out by a Federal agency is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat. The process is initiated by the Federal agency after it has determined if its action may affect a listed species; and
3. Conference with the Service when a Federal action is likely to jeopardize the continued existence of a proposed species or result in destruction or adverse modification of proposed critical habitat.

SECTION 7(c) Preparation of a Biological Assessment

Section 7(c) of the Act requires Federal agencies or their designees to prepare a Biological Assessment (BA) for construction projects.[1] For actions that are not construction projects, we recommend that a biological evaluation similar to a BA be prepared to evaluate the effects of the proposed project on listed and proposed species and critical habitats. The purpose of the BA or biological evaluation is to identify listed and proposed species which are likely to be affected by a proposed project. The process is initiated by a Federal agency by requesting a list of threatened and endangered species and critical habitats. The BA or biological evaluation should be completed within 180 days after its initiation (or within such a time period as is mutually agreeable). If the BA is not initiated within 90 days of receipt of the species list, the accuracy of the species list should be informally verified with the Service. No irreversible commitment of resources is to be made during the preparation of the BA which would foreclose reasonable and prudent alternatives to jeopardy to listed species. Planning, design, and administrative actions may be taken; however, no construction may begin.

A biological assessment or biological evaluation should include the following information:

1. Description of proposed action (project).
Describe the following and attach any relevant maps, diagrams, or designs;

- **Who** is proposing the action?
- **Where** is the action? Be as specific as possible. Include maps, county, township, range, stream, and any other pertinent information.
- **What** is the proposed action? Describe what is planned, the objectives of the action, include designs, diagrams, and best management practices applied, etc.
- **How** is the action going to be implemented? Give specific details, such as what type

[1] A construction project (or other undertaking having similar physical impacts) is a major Federal action significantly affecting the quality of the human environment as referred to in NEPA (42 U.S.C. 4332. (2)c.

of equipment is used, how the action area will be accessed, etc.
- **When** will the action be implemented?

2. Description of listed and proposed species and critical habitat, status, distribution and habitat use by the species in the project area.

Identify which listed, proposed and candidate species and critical habitats may potentially be affected (beneficially or adversely) by the action. Describe how the species use the project area. Assistance with this information can be obtained from local offices of the Service.

3. Description of the action area.

Describe all areas affected by the proposed project. The action area refers to the area directly or indirectly affected by the proposed action; this area will usually be larger than the project footprint. Include on-site inspection or survey data, views of recognized experts (e.g., ODFW), and literature reviews.

4. Effects of the proposed action on listed and proposed species and designated or proposed critical habitat.

Describe in detail the effects of the action on the species and their habitats including direct and indirect effects, as well as effects that are interrelated and interdependent effects. Summarize your analysis of all project effects.

5. Description of measures to minimize effects to listed species, and proposed project monitoring.

Describe methods to be used to avoid, minimize and correct adverse short and long-term effects. Describe what will be monitored, who will monitor and the frequency of monitoring.

6. Determination of effect.

Clearly state your final effects determination for each listed and proposed species and designated and proposed critical habitat. Effects determinations may be:
- no effect
- may affect, not likely to adversely affect (appropriate for actions that have only beneficial, insignificant, or discountable effects)
- may affect, likely to adversely affect (appropriate for actions with effects to listed species or designated critical habitat that are not entirely insignificant, discountable or wholly beneficial)

7. Attachments.

Attachments should include all relevant information supporting the above categories such as maps, project design, drawings, specifications, pollution control plan, photos of project site and adjacent area, site survey data, and literature cited.

For more information on consultation under section 7 of the Endangered Species Act, visit the Service's national consultation website at http://www.fws.gov/endangered/what-we-do/consultations-overview.html.

FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES
AND SPECIES OF CONCERN
UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE
WHICH MAY OCCUR WITHIN COLUMBIA COUNTY, OREGON

LISTED SPECIES

Mammals

Terrestrial:

Columbian white-tailed deer (Columbia River distinct population segment)	*Odocoileus virginianus leucurus*	E

Birds

Northern spotted owl	*Strix occidentalis caurina*	CH T

Plants

Water howellia	*Howellia aquatilis*	T
Nelson's checker-mallow	*Sidalcea nelsoniana*	T

PROPOSED SPECIES

None

No Proposed Endangered Species	PE
No Proposed Threatened Species	PT

CANDIDATE SPECIES

Mammals

Red tree vole (North Oregon Coast distinct population segment)	*Arborimus longicaudus*

Birds

Streaked horned lark	*Eremophila alpestris strigata*

SPECIES OF CONCERN

Mammals

White-footed vole	*Arborimus albipes*
Silver-haired bat	*Lasionycteris noctivagans*
Long-eared myotis bat	*Myotis evotis*
Fringed myotis bat	*Myotis thysanodes*
Long-legged myotis bat	*Myotis volans*
Yuma myotis bat	*Myotis yumanensis*
Camas pocket gopher	*Thomomys bulbivorus*

Birds

Olive-sided flycatcher	*Contopus cooperi*
Yellow-breasted chat	*Icteria virens*
Lewis' woodpecker	*Melanerpes lewis*
Mountain quail	*Oreortyx pictus*

Band-tailed pigeon	*Patagioenas fasciata*
Oregon vesper sparrow	*Pooecetes gramineus affinis*
Purple martin	*Progne subis*

Reptiles and Amphibians

Northern Pacific pond turtle	*Actinemys marmorata marmorata*
Coastal tailed frog	*Ascaphus truei*
Northern red-legged frog	*Rana aurora aurora*

Fish

Malheur mottled sculpin	*Cottus bairdi ssp.*
River lamprey	*Lampetra ayresi*
Pacific lamprey	*Lampetra tridentata*
Coastal cutthroat trout	*Oncorhynchus clarki ssp*

Invertebrates

Clams:

California floater mussel	*Anodonta californiensis*

Plants

Oregon sullivantia	*Sullivantia oregana*

DELISTED SPECIES

Birds

Aleutian Canada goose	*Branta canadensis leucopareia*
American Peregrine falcon	*Falco peregrinus anatum*
Bald eagle	*Haliaeetus leucocephalus*

Definitions:

Listed Species: An endangered species is one that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered in the foreseeable future.

Proposed Species: Taxa for which the Fish and Wildlife Service or National Marine Fisheries Service has published a proposal to list as endangered or threatened in the Federal Register.

Candidate Species: Taxa for which the Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.

Species of Concern: Taxa whose conservation status is of concern to the U.S. Fish and Wildlife Service (many previously known as Category 2 candidates), but for which further information is still needed. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.

Delisted Species: A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

Key:

FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES AND SPECIES OF CONCERN UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE WHICH MAY OCCUR WITHIN COLUMBIA COUNTY, OREGON

E	Endangered
T	Threatened
CH	Critical Habitat has been designated for this species
PE	Proposed Endangered
PT	Proposed Threatened
PCH	Critical Habitat has been proposed for this species

Notes:

Marine & Anadromous Species: Please consult the National Marine Fisheries Service (NMFS) (http://www.nmfs.noaa.gov/pr/species/) for marine and anadromous species. The National Marine Fisheries Service (NMFS) manages mostly marine and anadromous species, while the U.S. Fish and Wildlife Service manages the remainder of the listed species, mostly terrestrial and freshwater species.

Marine Turtle Conservation and Management: All six species of sea turtles occurring in the U.S. are protected under the Endangered Species Act of 1973. In 1977, NOAA Fisheries and the U.S. Fish and Wildlife Service signed a Memorandum of Understanding to jointly administer the Endangered Species Act with respect to marine turtles. NOAA Fisheries has the lead responsibility for the conservation and recovery of sea turtles in the marine environment and the U.S. Fish and Wildlife Service has the lead for the conservation and recovery of sea turtles on nesting beaches. For more information, see the NOAA Fisheries webpage on sea turtles http://www.nmfs.noaa.gov/pr/species/turtles/.

Gray Wolf: In 2008, the Service published a final rule that established a distinct population segment of the gray wolf (*Canis lupis*) in the northern Rocky Mountains (which includes a portion of Eastern Oregon, east of the centerline of Highway 395 and Highway 78 north of Burns Junction and that portion of Oregon east of the centerline of Highway 95 south of Burns Junction). Any wolves found west of this line in Oregon belong to the conterminous USA population [see 73 FR 10514]. On May 5, 2011, the Fish and Wildlife Service published a final rule – as directed by legislative language in the Fiscal Year 2011 appropriations bill – reinstating the Service's 2009 decision to delist biologically recovered gray wolf populations in the Northern Rocky Mountains. Gray wolves in Oregon are State-listed as endangered, regardless of location.

FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES
AND SPECIES OF CONCERN
UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE
WHICH MAY OCCUR WITHIN MORROW COUNTY, OREGON

PROPOSED SPECIES

None

No Proposed Endangered Species	PE
No Proposed Threatened Species	PT

CANDIDATE SPECIES

Mammals

Terrestrial:

Washington ground squirrel	*Urocitellus washingtoni*

SPECIES OF CONCERN

Mammals

Silver-haired bat	*Lasionycteris noctivagans*
Small-footed myotis bat	*Myotis ciliolabrum*
Long-eared myotis bat	*Myotis evotis*
Yuma myotis bat	*Myotis yumanensis*

Birds

Northern goshawk	*Accipiter gentilis*
Western burrowing owl	*Athene cunicularia hypugaea*
Ferruginous hawk	*Buteo regalis*
Olive-sided flycatcher	*Contopus cooperi*
Willow flycatcher	*Empidonax traillii adastus*
Yellow-breasted chat	*Icteria virens*
Lewis' woodpecker	*Melanerpes lewis*
Mountain quail	*Oreortyx pictus*
White-headed woodpecker	*Picoides albolarvatus*

Reptiles and Amphibians

Northern sagebrush lizard	*Sceloporus graciosus graciosus*

Fish

Margined sculpin	*Cottus marginatus*
Pacific lamprey	*Lampetra tridentata*

Plants

Robinson's onion	*Allium robinsonii*
Laurence's milk-vetch	*Astragalus collinus var. laurentii*

DELISTED SPECIES

Birds

FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES AND SPECIES OF CONCERN UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE WHICH MAY OCCUR WITHIN MORROW COUNTY, OREGON

American Peregrine falcon	*Falco peregrinus anatum*
Bald eagle	*Haliaeetus leucocephalus*

Definitions:

Listed Species: An endangered species is one that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered in the foreseeable future.

Proposed Species: Taxa for which the Fish and Wildlife Service or National Marine Fisheries Service has published a proposal to list as endangered or threatened in the Federal Register.

Candidate Species: Taxa for which the Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.

Species of Concern: Taxa whose conservation status is of concern to the U.S. Fish and Wildlife Service (many previously known as Category 2 candidates), but for which further information is still needed. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.

Delisted Species: A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

Key:

E	Endangered
T	Threatened
CH	Critical Habitat has been designated for this species
PE	Proposed Endangered
PT	Proposed Threatened
PCH	Critical Habitat has been proposed for this species

Notes:

Marine & Anadromous Species: Please consult the National Marine Fisheries Service (NMFS) (http://www.nmfs.noaa.gov/pr/species/) for marine and anadromous species. The National Marine Fisheries Service (NMFS) manages mostly marine and anadromous species, while the U.S. Fish and Wildlife Service manages the remainder of the listed species, mostly terrestrial and freshwater species.

Marine Turtle Conservation and Management: All six species of sea turtles occurring in the U.S. are protected under the Endangered Species Act of 1973. In 1977, NOAA Fisheries and the U.S. Fish and Wildlife Service signed a Memorandum of Understanding to jointly administer the Endangered Species Act with respect to marine turtles. NOAA Fisheries has the lead responsibility for the conservation and recovery of sea turtles in the marine environment and the U.S. Fish and Wildlife Service has the lead for the conservation and recovery of sea turtles on nesting beaches. For more information, see the NOAA Fisheries webpage on sea turtles http://www.nmfs.noaa.gov/pr/species/turtles/.

Gray Wolf: In 2008, the Service published a final rule that established a distinct population segment of the gray wolf (*Canis lupis*) in the northern Rocky Mountains (which includes a portion of Eastern Oregon, east of the centerline of Highway 395 and Highway 78 north of Burns Junction and that portion of Oregon east of the centerline of Highway 95 south of Burns Junction). Any wolves found west of this line in Oregon belong to the

conterminous USA population [see 73 FR 10514]. On May 5, 2011, the Fish and Wildlife Service published a final rule – as directed by legislative language in the Fiscal Year 2011 appropriations bill – reinstating the Service's 2009 decision to delist biologically recovered gray wolf populations in the Northern Rocky Mountains. Gray wolves in Oregon are State-listed as endangered, regardless of location.

Endangered Species Act Status of West Coast Salmon & Steelhead

(Updated Aug. 11, 2011)

Species[1]			Current Endangered Species Act Listing Status[2]	ESA Listing Actions Under Review
Sockeye Salmon (*Oncorhynchus nerka*)	1	Snake River	Endangered	
	2	Ozette Lake	Threatened	
	3	Baker River	Not Warranted	
	4	Okanogan River	Not Warranted	
	5	Lake Wenatchee	Not Warranted	
	6	Quinalt Lake	Not Warranted	
	7	Lake Pleasant	Not Warranted	
Chinook Salmon (*O. tshawytscha*)	8	Sacramento River Winter-run	Endangered	
	9	Upper Columbia River Spring-run	Endangered	
	10	Snake River Spring/Summer-run	Threatened	
	11	Snake River Fall-run	Threatened	
	12	Puget Sound	Threatened	
	13	Lower Columbia River	Threatened	
	14	Upper Willamette River	Threatened	
	15	Central Valley Spring-run	Threatened	
	16	California Coastal	Threatened	
	17	Central Valley Fall and Late Fall-run	Species of Concern	
	18	Upper Klamath-Trinity Rivers	Not Warranted	
	19	Oregon Coast	Not Warranted	
	20	Washington Coast	Not Warranted	
	21	Middle Columbia River spring-run	Not Warranted	
	22	Upper Columbia River summer/fall-run	Not Warranted	
	23	Southern Oregon and Northern California Coast	Not Warranted	
	24	Deschutes River summer/fall-run	Not Warranted	
Coho Salmon (*O. kisutch*)	25	Central California Coast	Endangered	
	26	Southern Oregon/Northern California	Threatened	
	27	Lower Columbia River	Threatened	• Critical habitat
	28	Oregon Coast	Threatened	
	29	Southwest Washington	Undetermined	
	30	Puget Sound/Strait of Georgia	Species of Concern	
	31	Olympic Peninsula	Not Warranted	
Chum Salmon (*O. keta*)	32	Hood Canal Summer-run	Threatened	
	33	Columbia River	Threatened	
	34	Puget Sound/Strait of Georgia	Not Warranted	
	35	Pacific Coast	Not Warranted	
Steelhead (*O. mykiss*)	36	Southern California	Endangered	
	37	Upper Columbia River	Threatened	
	38	Central California Coast	Threatened	
	39	South Central California Coast	Threatened	
	40	Snake River Basin	Threatened	
	41	Lower Columbia River	Threatened	
	42	California Central Valley	Threatened	
	43	Upper Willamette River	Threatened	
	44	Middle Columbia River	Threatened	
	45	Northern California	Threatened	
	46	Oregon Coast	Species of Concern	
	47	Southwest Washington	Not Warranted	
	48	Olympic Peninsula	Not Warranted	
	49	Puget Sound	Threatened	• Critical habitat
	50	Klamath Mountains Province	Not Warranted	
Pink Salmon (*O. gorbuscha*)	51	Even-year	Not Warranted	
	52	Odd-year	Not Warranted	

1 The ESA defines a "species" to include any distinct population segment of any species of vertebrate fish or wildlife. For Pacific salmon, NOAA Fisheries Service considers an evolutionarily significant unit, or "ESU," a "species" under the ESA. For Pacific steelhead, NOAA Fisheries Service has delineated distinct population segments (DPSs) for consideration as "species" under the ESA.

ESA-Listed Marine Mammals

Under the jurisdiction of NOAA Fisheries that may occur:

off Washington & Oregon

- Southern Resident killer whale (*Orcinus orca*) (E); critical habitat
- humpback whale *(Megaptera novaeangliae)* (E)
- blue whale *(Balaenoptera musculus)* (E)
- fin whale (*Balaenoptera physalus)* (E)
- sei whale (*Balaenoptera borealis)* (E)
- sperm whale (*Physeter macrocephalus)* (E)
- Steller sea lion *(Eumetopias jubatus)* (T); critical habitat

in Puget Sound

- Southern Resident killer whale (*Orcinus orca*) (E); critical habitat
- humpback whale *(Megaptera novaeangliae)* (E)
- Steller sea lion *(Eumetopias jubatus)* (T); critical habitat

(E) = Endangered
(T) = Threatened

Search NOAA Fisheries
Print Version
What's New
About the NWR
About this Website
A-Z Index
Species Lists
Publications
Biological Opinions
Public Consultation Tracking System (PCTS)
Site Map

7600 Sand Point Way NE, Seattle, WA 98115-0070
Regional Receptionist: 503-230-5400
Email: Content Manager

Page last updated: December 15, 2011

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to NMFS No:
2010/06104

March 18, 2011

Joyce E. Casey
Chief, Environmental Resources Branch
U.S. Army Corps of Engineers, Portland District
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Endangered Species Act Biological Opinion and Conference Report and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River.

Dear Ms. Casey:

The enclosed document contains a biological opinion (Opinion) and conference report prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of the U.S. Army Corps of Engineers' proposed major rehabilitation of the jetty system at the mouth of the Columbia River. The Corps' authority for this action comes from the original authority for construction of the project granted by Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884), and subsequently renewed with authorizations related to construction, operation and maintenance of the Columbia River navigation channel. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of eulachon (*Thaleichthys pacificus*), Steller sea lions (*Eumetopias jubatus*), and humpback whales (*Megaptera novaeangliae*).

Furthermore, NMFS concluded that the proposed action may affect, but is not likely to adversely affect the following species:

- Fin whale (*Balaenoptera physalus*)
- Southern Resident killer whale (*Orcinus orca*)
- Sperm whale (*Physeter macrocephalus*)
- Sei whale (*B. borealis*)
- Blue whale (*B. musculus*)
- Leatherback sea turtle (*Dermochelys coriacea*)#
- Lower Columbia River (LCR) Chinook salmon (*O. tshawytscha*)*
- Upper Willamette River (UWR) Chinook salmon (*O. tshawytscha*)*
- Upper Columbia River (UCR) spring-run Chinook salmon (*O. tshawytscha*)*
- Snake River (SR) spring/summer-run Chinook salmon (*O. tshawytscha*)*
- SR fall-run Chinook salmon (*O. tshawytscha*)*
- Columbia River (CR) chum salmon (*O. keta*)*

- LCR coho salmon (*O. kisutch*)#
- Oregon Coast coho salmon (*O. kisutch*)
- Southern Oregon/Northern California Coasts coho salmon (*O. kisutch*)
- SR sockeye salmon (*O. nerka*)*
- LCR steelhead (*O. mykiss*)*
- UWR steelhead (*O. mykiss*)*
- Middle Columbia River steelhead (*O. mykiss*)*
- UCR steelhead (*O. mykiss*)*
- SR basin steelhead (*O. mykiss*)*
- Southern distinct population segment (DPS) green sturgeon (*Acipenser medirostris*)*

Additionally, NMFS concluded that the proposed action is not likely to adversely affect designated critical habitat for the above species or proposed critical habitat for eulachon, leatherback turtles, and LCR coho salmon.

The Corps also requested a conference report for critical habitat that NMFS proposed for leatherback turtles, LCR coho salmon, and eulachon. An action agency is not required to consult on proposed critical habitat unless its action is likely to destroy or adversely modify the proposed critical habitat. Nonetheless, NMFS encourages action agencies to complete a conference process to identify and resolve any conflicts that may arise between a proposed action and proposed critical habitat. Here, the effects of the proposed action on proposed critical habitat are likely to be similar to the effects on critical habitats that are already designated in the action area. Please note, however, that the Corps has a duty to reinitiate this consultation if NMFS designates these critical habitats before the action is completed and may comply with that duty by requesting that NMFS adopt the conference report as a final report or biological opinion.

The NMFS is not including an incidental take statement for eulachon as NMFS has not issued protective regulations for eulachon under section 4(d) of the ESA. Additionally, NMFS is not including an incidental take authorization for marine mammals at this time because the incidental take of marine mammals has not been authorized under section 101(a)(5) of the Marine Mammal Protection Act and/or its 1994 Amendments. Following issuance of such regulations or authorizations for marine mammals, NMFS may amend this biological opinion to include an incidental take statement for marine mammals, as appropriate.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes no conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH, as NMFS determined that there are no conservation recommendations, in addition to those proposed by the Corps, that can be implemented that would avoid, minimize, or offset potential adverse effects. Therefore, no response is required.

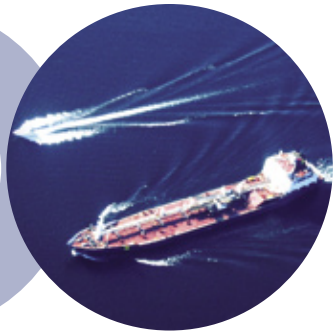
In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the

EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted, if applicable.

If you have questions regarding this consultation, please contact Robert Anderson, Fishery Biologist with the Oregon State Habitat Office, at 503.231.2226, or Zachary Radmer, Fishery Biologist with the Oregon State Habitat Office, at 503.872.2738. For questions about the marine mammal determinations contact Alison Agness of the Northwest Region, Protected Resources Division at 206.526.6152.

Sincerely,

William W. Stelle, Jr.
Regional Administrator



Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships:

Impacts, Mitigation Options and Opportunities for Managing Growth

EXECUTIVE SUMMARY

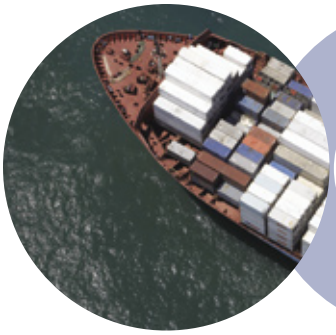
icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

The goal of the International Council on Clean Transportation (ICCT) is to dramatically reduce conventional pollutant and greenhouse gas emissions from personal, public, and goods transportation in order to improve air quality and human health, and mitigate climate change. The Council is made up of leading regulators and experts from around the world that participate as individuals based on their experience with air quality and transportation issues. The ICCT promotes best practices and comprehensive solutions to improve vehicle emissions and efficiency, increase fuel quality and sustainability of alternative fuels, reduce pollution from the in-use fleet, and curtail emissions from international goods movement.

www.theicct.org
Published by The International Council on Clean Transportation
© March 2007 The International Council on Clean Transportation

Designed by Big Think Studios
Printed on 100% recycled paper with soy-based ink

Photos: middle photo on cover, Chris Van Patten; page 6, Farol Thomson



Authors:

Axel Friedrich
Head of Department, Environment, Transport, and Noise Division
Umweltbundesamt (Federal Environmental Agency), Germany

Falk Heinen
Head of Section, Environment, Transport, and Noise Division
Umweltbundesamt (Federal Environmental Agency), Germany

Fatumata Kamakaté
Senior Scientist
The International Council on Clean Transportation, USA

Drew Kodjak
Executive Director
The International Council on Clean Transportation, USA

The authors would like to thank our many colleagues around the world that have generously contributed their time and insight in reviewing and commenting on the draft version of this report. We would also like to thank the William and Flora Hewlett Foundation for their support. We are particularly grateful to the following International Council on Clean Transportation participants who have closely reviewed this report and support its findings and recommendations.

ICCT Review Team:

Mr. Kong Ha
Chairman
Clean Air Initiative for Asian Cities, Hong Kong

Dr. Youngil Jeong
Director
Korean Institute for Machinery and Materials, Korea

Dr. Alan C. Lloyd
President
The International Council on Clean Transportation, USA

Mr. Michael P. Walsh
Chairman, Board of Directors
The International Council on Clean Transportation, USA

This document does not necessarily represent the views of organizations or government agencies represented by ICCT reviewers or participants.

In a world of global supply chains and rapidly expanding trade, ocean shipping—currently the dominant mode of transport for international cargo—is becoming an increasingly important source of air pollution and greenhouse gas emissions.

Today, ocean-going vessels transport 90 percent of all trade by volume to and from the 25 members of the European Community (EC), and nearly 80 percent by weight of all goods shipped in and out of the United States (EC 2006, US DOT 2003). Over the last three decades, activity in the marine shipping sector, as measured in metric ton-kilometers, has grown on average by 5 percent every year, as shown in Figure ES-1. Since emissions from ocean-going vessels have only been moderately controlled, this growth has been accompanied by a commensurate increase in the sector's contribution to local and global air pollution.

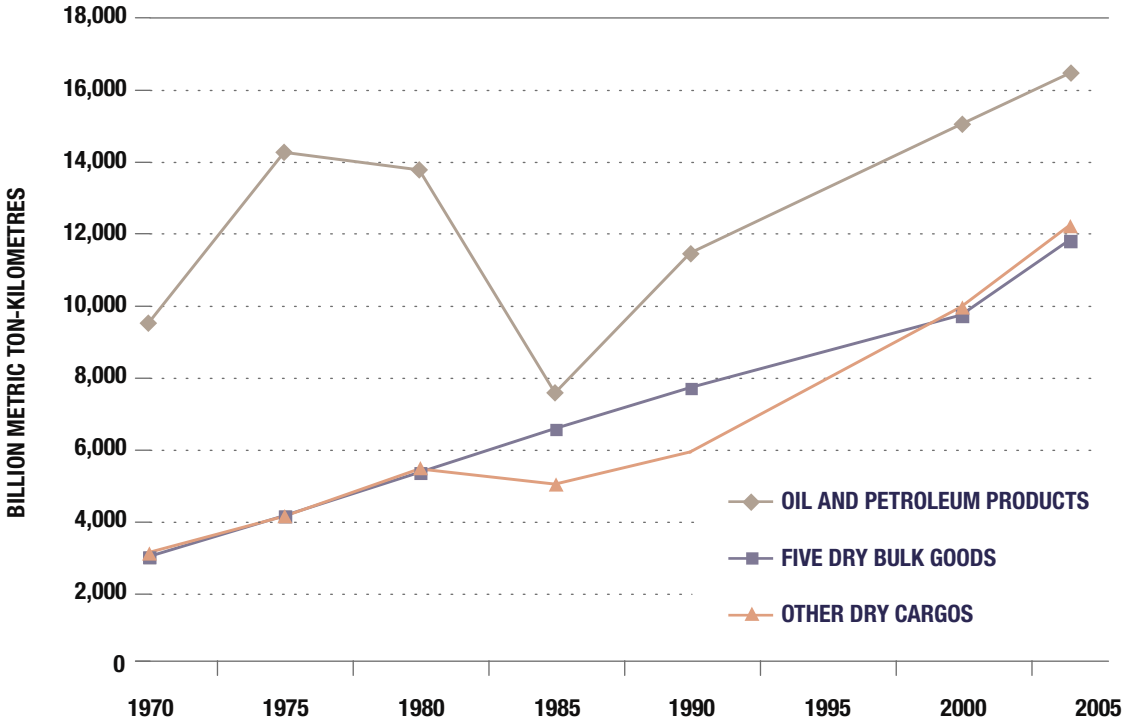


FIGURE ES-1. World Seaborne Freight Transport in Metric Ton-Kilometers by Type of Freight (UNCTAD 2005)

Ocean-going vessels contribute significantly to global emissions of nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM). Indeed it is estimated that by 2020, ship emissions contributions to the European Union (EU) NO_x and SO_x inventories will surpass total emissions generated by all land-based mobile, stationary and other sources in the twenty-five nations (EC 2005). Figure ES-2 and Figure ES-3 show projected NO_x and SO_x emissions from marine and land-based sources in Europe. Air quality impacts from ocean-going vessels are especially significant in port cities and nations with extensive coastlines adjacent to shipping corridors. Studies making use of geographic marine activity data have estimated that about 70–80 percent of all ship emissions occur within 400 km (248 miles) of land (IMO 2000, Corbett et al. 1999). Pollutants such as NO_x, SO_x, and PM have been linked to a variety of adverse public health outcomes, including increased risk of premature death from heart and pulmonary diseases and worsened respiratory disease. Marine emission sources are therefore responsible for a growing share of the public health impacts of exposure to air pollution in many regions. Although ocean-going vessels are among the most efficient modes of freight transport, they also generate substantial quantities of greenhouse gas emissions. Currently, carbon dioxide (CO_2) emissions from the international shipping sector as a whole exceed annual total greenhouse gas emissions from most of the nations listed in the Kyoto protocol as Annex I countries (Kyoto Protocol 1997).

Relative to other sectors, the regulation of commercial marine vessels represents a significant political and legal challenge as ships

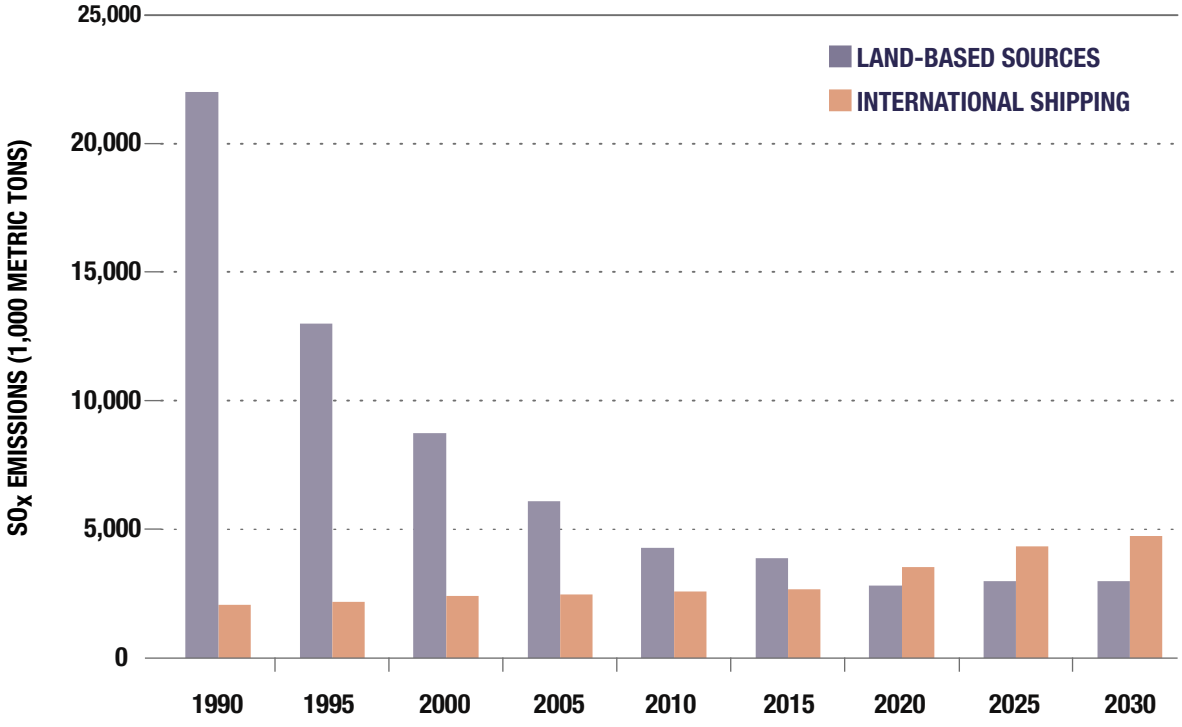


FIGURE ES-2. Inventories and Projections of SO_x Emissions in Europe from Land-based and International Shipping Sources (EC 2005)

operate largely outside of national boundaries. Ocean-going vessels are mainly subject to oversight by the International Maritime Organization (IMO), under the purview of the United Nations. Unfortunately, IMO efforts to mitigate environmental impacts of emissions from global shipping have not kept pace with the industry's growth and the evolution of control technologies for controlling emissions. The international process for establishing new regulatory requirements is further complicated by the complex relationships that exist between those nations to which most ships are registered under so-called "flags of convenience" and the large shipping interests (typically headquartered in other nations) that own most of the ships. As a result, the IMO adopted standards in 1997 that represented only a modest improvement in emissions from unregulated engines. When these standards entered into force they reflected levels already achieved by the average in-use engine. The IMO's current fuel sulfur limit of 4.5 percent is almost twice the average sulfur content of fuels in use in ships today and several thousand times the sulfur level of fuels used on-road in Europe and North America. These standards at best codify the industry's existing practices.

Under these circumstances, accelerated adoption of cleaner marine fuels and wider deployment of existing pollution control technologies and emission reduction strategies could dramatically improve the environmental performance of the shipping sector. To explore these opportunities, the ICCT undertook a review of the status of pollution control measures and programs

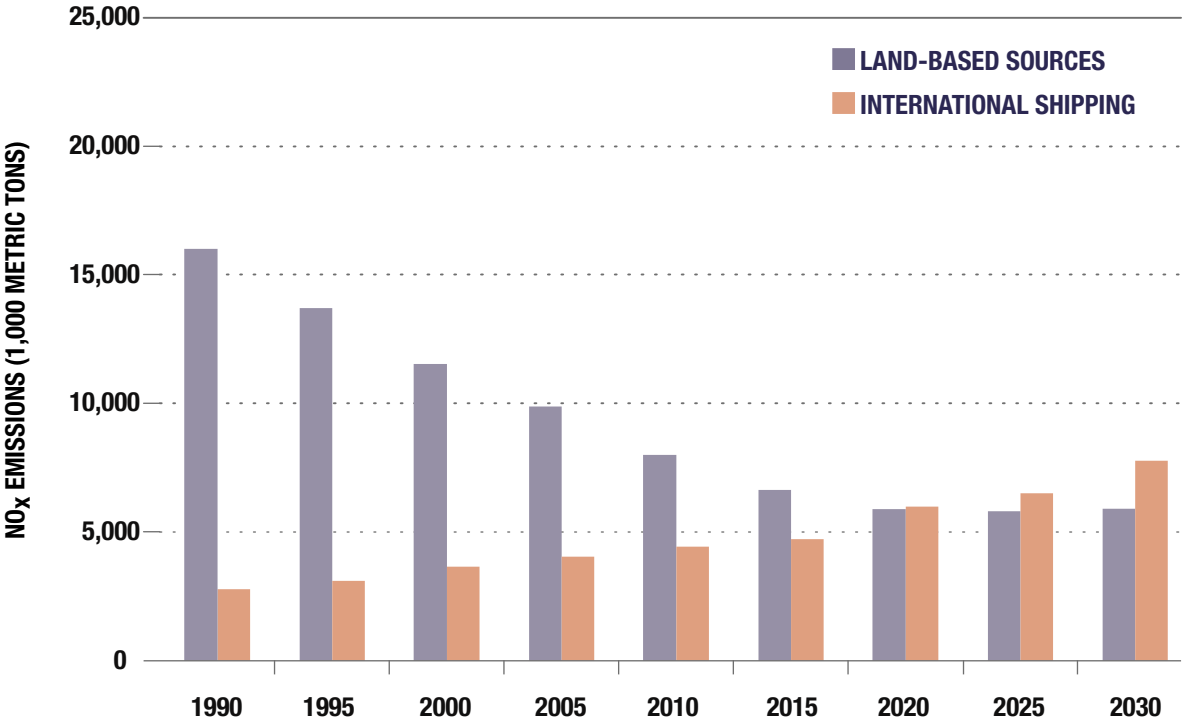


FIGURE ES-3. Inventories of NO_x Emissions in Europe from Land-based and International Shipping Sources (EC 2005)

implemented to date throughout the world. This report describes the results of the ICCT review, focusing on the emission-reduction potential, feasibility, costs, and cost- effectiveness of available environmental mitigation measures for the shipping sector. It also analyzes the legal context within which local, regional, and international programs can be developed. The report concludes with a series of policy recommendations aimed at achieving steady, incremental progress towards reducing emissions from marine vessels that will result in significant environment and public health benefits.

Lower sulfur fuels, optimized engines, and exhaust after-treatment, such as selective catalytic reduction (SCR), have been shown to significantly improve the environmental performance of marine vessels. Other measures such as shore-side electricity and improved auxiliary engines can reduce so-called "hotelling" emissions—that is emissions generated while ships are docked at port. The feasibility and cost-effectiveness of these measures has been demonstrated at several ports. As shown in Figure ES-4, available options for reducing marine NO_x emissions are very cost-effective compared to remaining pollution control options for other mobile and stationary sources, especially in countries that have adopted a range of regulations to limit land-based emissions.

Nations in Europe and North America—along with port cities throughout the world—have deployed a suite of strategies to address air pollution from ships. These strategies have included

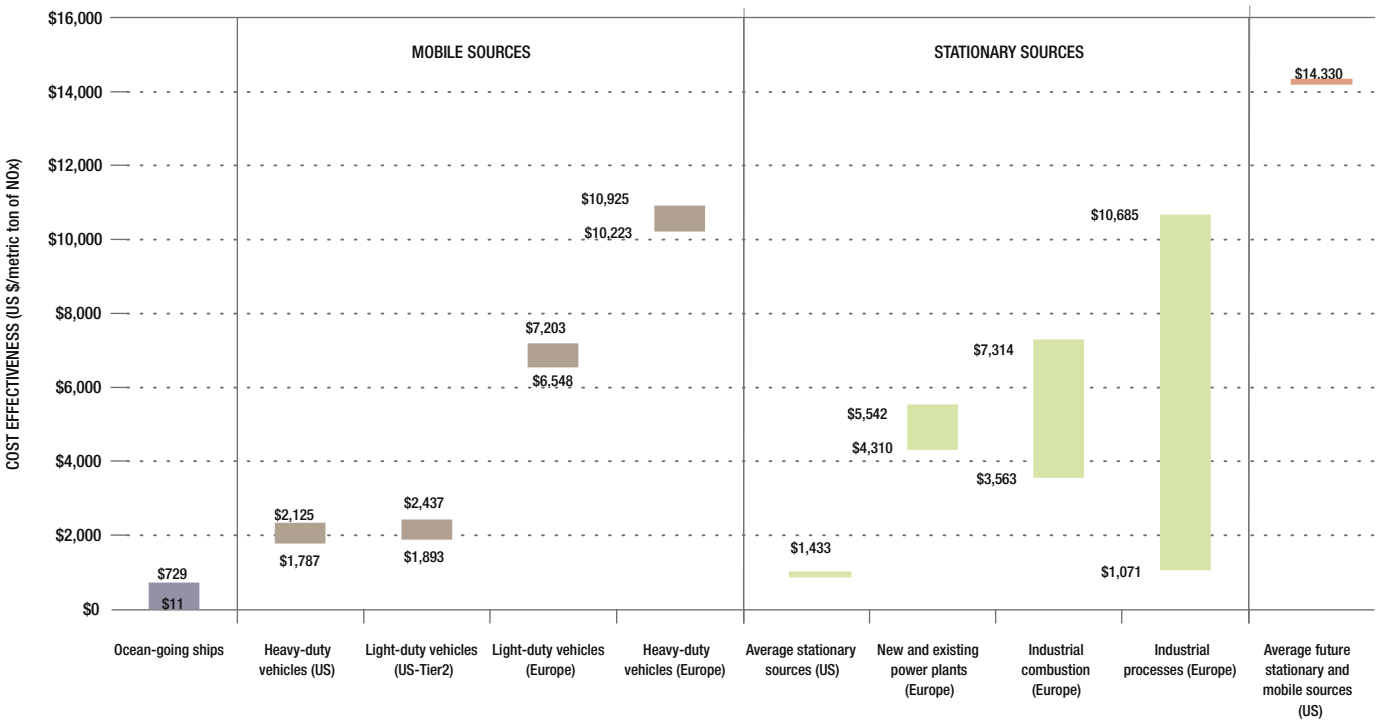


FIGURE ES-4. Comparing the Cost-Effectiveness of NO_x Control Options for Various Source Categories (Entec 2005b, US EPA 1999, 2000, 2005)

regulations, voluntary programs, and market-based programs. Examples of regulatory approaches have included national engine standards for the domestic vessel fleet and fuel sulfur standards for vessels operating in coastal waters and harbors. The voluntary harbor speed limits implemented in the San Pedro Bay by the ports of Los Angeles and Long Beach provide an example of a voluntary approach. Meanwhile, Sweden has experimented with a market-based approach by imposing a system of environmentally differentiated fairway and port dues that vary with ship emissions. This successful program has led to increased use of lower-sulfur fuels and to the installation of SCR systems on a number of ships calling on Swedish ports.

The recommendations advanced in this report identify implementation milestones in each of several distinct categories: (1) marine fuels, (2) new engines, (3) new vessels, (4) existing engines and vessels, (5) greenhouse gas emissions, (6) and in-port emissions. In the near-term, these recommendations generally call for widespread adoption of proven best available technologies in the 2010 timeframe. The ICCT's medium-term recommendations propose intermediary steps to be taken between 2012 and 2017. Finally, technology-forcing, long-term recommendations are proposed for the post-2020 period. Implementing these recommendations will require the active engagement of numerous stakeholders, including ship owners and operators, ports, and regulators. Leadership from the businesses that demand shipping services is also crucial. Shipping customers are uniquely positioned to create incentives for improved performance in the shipping sector because they can require that their goods be transported with the least possible impact on the environment.

MARINE FUELS

Reducing fuel sulfur content is an essential component of any strategy aimed at reducing SO_x and PM emissions from marine vessels. Lower sulfur fuel also enables the use of advanced after-treatment for NO_x reductions. Existing plans to implement SO_x Emission Control Areas (SECAs), starting in 2006 in the Baltic Sea and expected in 2007 for the North Sea and English Channel, mean that a portion of the world's ships are now or will soon be using 1.5 percent sulfur fuels or equivalent after-treatment. In the short term, the ICCT recommends including other major shipping areas, such as the Mediterranean and parts of the North Atlantic and Pacific Rim, in the SECA program. Moreover, decisions concerning future SECAs should take into account sulfur- and particle-related public health impacts as well as impacts on land and sea ecosystems. Finally, ICCT recommends that the fuel sulfur limit in SECAs be lowered from 1.5 percent to 0.5 percent to achieve further emissions reduction in the 2010 timeframe and to facilitate the shift to lower sulfur fuels on a global scale.

As a next step, the ICCT recommends that a uniform global fuel sulfur standard of 0.5 per-

cent be introduced in the medium term. Relative to the 2.7 percent average sulfur content of current marine fuel, this step alone will reduce SO_x emissions by approximately 80 percent and PM emissions by a minimum of 20 percent. At this level of fuel quality, selective catalytic reduction (SCR) will be fully enabled. Although SCR can function at higher fuel-sulfur levels, durability is significantly improved at lower levels.

Some uncertainty remains regarding the widespread availability of lower sulfur fuels in the recommended timeframe. However, there has been significant momentum among various stakeholders to reduce the global fuel sulfur limit. For example, some industry groups have recently expressed support for a global fuel standard requiring the use of 1 percent sulfur distillate fuel in the near term (INTERTANKO 2006). In addition, current regulations in California and Europe require low-sulfur fuels in coastal waters, inland waterways, and at ports ahead of the ICCT-recommended dates. For example, the California auxiliary engine program requires the use of 0.5 percent sulfur fuel in the state's coastal waters and at port by 2007. The allowed sulfur level is lowered to 0.1 percent by 2010. Fuel with 0.1 percent sulfur content will also be required in ports and inland waterways in Europe by 2010

Adoption of a lower global fuel sulfur limit would provide the refining industry the clear signal it needs to invest in upgrading production facilities and ensure increased fuel availability. The ICCT also encourages further efforts to implement lower sulfur fuel ahead of the recommended schedule in coastal waters, inland waterways, and at ports. These programs can facilitate a transition to fleet-wide use of lower sulfur fuels while ensuring emissions reductions in proximity to the potentially impacted populations. In the long-term, fuel standards for marine fuels should be harmonized with standards for on-road fuels (500 ppm to 10–15 ppm).

NEW ENGINES

The IMO's recent decision to review NO_x standards for ocean-going vessels represents an opportunity to make significant progress in improving the performance of marine engines. The ICCT recommends requiring new engines to achieve NO_x limits that are 40 percent lower than the current standard in the near term. This level can be reached primarily through engine upgrades. New engine standards should also be set to ensure significant reductions in PM emissions. A medium-term standard set at a level 95 percent below current standards for NO_x would require the use of additional emission control technologies, including after-treatment controls. Further PM reduction should also be required. These near- and medium-term standards should be adopted at the same time to give manufacturers sufficient lead time to prepare for compliance and to direct their research and development activities accordingly. In addition to more stringent standards, the ICCT recommends that manufacturers be (1) required to

certify engines using fuels that reflect actual in-use fuel quality; (2) be liable for in-use compliance and subject to in-use testing; and (3) be required to demonstrate the durability of emission control systems used to achieve compliance.

The production and use of engines that are significantly cleaner than the proposed standards should be encouraged both in the short and medium term through incentives to engine and technology manufacturers as well as vessel operators. Support for early technology demonstrations is necessary to ensure viable technology options are available to meet increasingly stringent standards. In the long term, the ICCT recommends deploying incentives and other strategies to further promote the use of advanced technologies, especially technologies that achieve near-zero emissions, in promising applications.

NEW VESSELS

Many opportunities exist during a vessel's design and construction phases to make changes that would facilitate the use of low-emission control technologies. In the near term, the ICCT recommends that engine rooms be designed with enough space to allow for retrofit technologies including SCR as well as tank capacity for fuel switching in SECA and coastal areas. New vessels, especially ferries and cruise ships with regular routes and ports of call, should be built with the needed on-board equipment to utilize shore power when port-side facilities exist. Standardization of international shore power requirements is also needed to ensure compatibility between shore-side facilities and ships. The ICCT supports the ongoing efforts within IMO to develop guidelines for shore-side electricity. In the long term, the ICCT encourages the use of advanced vessel design concepts that optimize energy efficiency as well as emissions performance and that incorporate propulsion from renewable energy sources including solar and wind power, where feasible.

EXISTING VESSELS AND ENGINES

Control measures targeted at existing vessels and engines are necessary to significantly impact fleet-wide emissions. A low fleet turnover rate means that the largely uncontrolled vessels that make up the majority of the international marine shipping fleet today will continue to pollute for several decades before they are retired. Most existing control technology options have been developed and demonstrated on in-use vessels, suggesting that a large-scale retrofit program should be technically feasible. In the near term, the ICCT recommends that in-use standards reflecting best available control technologies be developed within the IMO. These standards would allow, for example, future market-based programs (including the range of possible differentiated fee programs) to harmonize their emission requirements. The ICCT further recommends that any in-use standards used in market-based programs be designed to become more stringent over time so as to provide ongoing incentives for adopting the newest control technologies as they become

available, proven, and cost-effective. The program should provide additional incentives to demonstrations of advanced technologies that provide emission reductions beyond the adopted in-use standards. Also in the short term, the ICCT recommends exploring the feasibility of early ship retirement as an extension of the ship recycling programs being developed by the IMO. If determined feasible, this type of program could be implemented in the medium to long term.

GREENHOUSE GASES

The shipping sector's contribution to gases and particles that impact the Earth's climate is only beginning to be fully understood. Here, the ICCT recommends that near-term efforts focus on developing a baseline for the climate impacts of the world's vessel fleet. Once a baseline is established, market-based measures to reduce greenhouse gas emissions can be introduced, also in the near term. If cap and trade programs are developed for GHGs, they should only cover shipping sources and not include land-based sources. If the shipping sector becomes a source of credits for greenhouse gas emissions reductions, steps must be taken—as with any source of credits—to ensure that reductions are recognized only to the extent that they are quantifiable, enforceable, surplus to otherwise mandated reductions, and permanent. The ICCT also recommends that the IMO develop fuel economy standards for ships applicable to new vessels in the near term and existing vessels in the medium term.

AT PORT

The ICCT recommends that emission mitigation measures should be adopted at all major port facilities and be fully integrated with local and/or regional air quality plans. Each port type has access to a range of implementation mechanisms to reduce emissions from ships at berth. For example, landlord ports can include emission reduction requirements in their lease agreements with tenant operators. Operating ports can directly implement some infrastructure measures.

Providing shore power is often the most effective emission-reduction option for vessels while at port. In some locations, however, pollution impacts from electricity generation may make this option less attractive. The ICCT recommends that port authorities and regulators select the strategy or combination of strategies that cost-effectively provides the most environmental benefits. If shore power does not meet these criteria, other options should be implemented including requiring hotelling ships to use the lowest sulfur on-road fuels available and/or engine emission controls. The implementation of shore power and alternative mitigation technologies should prioritize new terminals as well as those that are near residential areas.

In the medium-term, the ICCT recommends that incentives be provided for utilizing low-carbon sources for shore-side power (including renewable solar and wind generators). In

the long-term, the development of cost-effective energy storage technologies and advanced low- or non-carbon generating options should make it possible to achieve near-zero hotelling emissions.

Table ES-1 summarizes the ICCT recommendations towards mitigating the impact of ocean-going vessels on air quality and climate change.

In conclusion, supplemental international action within the IMO is necessary to produce reasonable progress in addressing ship impacts on local air quality and global climate change. National and regional policy-makers are increasingly seeking to accelerate the introduction of emission control technologies and cleaner fuels into the international marine sector. Within the IMO process, several countries including Sweden, Norway, and Germany have emerged as proponents of further measures to reduce emissions from ships. The few environmental organizations that have obtained consultative status with the IMO have also been leading efforts to accelerate progress on these issues. Other environmental NGOs with related activities and expertise should consider applying for consultative status to bolster these efforts. Finally, these efforts within the IMO must be brought to the attention of the larger public. Greater public awareness of the environmental impacts of routine ship activity will undoubtedly result in added pressure to reduce emissions in much the same way that highly publicized oil spills led to an increased focus on accident prevention, impact mitigation, and accelerated phase-out of single-hull tanker ships by the IMO. Best practices and local or national successes should be shared with a global audience to demonstrate that dramatic reductions in emissions from marine vessels, both at sea and in port, are not only feasible but also cost-effective. In the end, collaboration between the public and private sectors and across a wide set of stakeholders will be essential to forge support for sustainable long-term measures to mitigate the public health and environmental impacts of shipping around the world.

TABLE ES-1. ICCT Recommendations for Ocean-Going Vessels

ICCT RECOMMENDATIONS		IMPLEMENTATION MECHANISM
Fuels	— Short term: ○ Lower fuel sulfur level in SO_x Emission Control Areas (SECAs) from 1.5% to 0.5%. ○ Include SO_x/PM related health effects in addition to impacts on air, sea, and land as justification for SECA. ○ Expand SECA program to high ship-traffic areas in Mediterranean, Pacific Rim and North Atlantic. ○ Regional limits in coastal areas, inland waterways, and at ports — Medium term: 0.5% sulfur fuel globally — Long term: Harmonization with on-road diesel fuels (500 ppm to 10-15 ppm over time)	— International standards (IMO)
New engines	— Short term: ○ NO_x standards 40% percent below current IMO standards (2000 level). ○ PM standards ○ Encourage new technology demonstration — Medium term: ○ NO_x standards 95% percent below current IMO standards (2000 level) ○ PM standards further reduced ○ Encourage new technology demonstration — Long term: Encourage the use of advanced technologies, especially near-zero emission technologies in promising applications	— International standards (IMO)
New vessels	— Short term: ○ Adopt international requirements for shore power standardization. ○ All new ships built with shore-side electricity capability, especially cruise ship and ferries — Long term: Promote the use of advanced vessel design concepts in promising applications	— Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges — International regulation (IMO)

Table continues on next page

TABLE ES-1., continued

ICCT RECOMMENDATIONS		IMPLEMENTATION MECHANISM
Existing vessels and engines	— Short term: ○ Adopt emissions performance standards by vessel class and engine characteristics based on demonstrated retrofit potential. ○ Study feasibility and potential impact of programs to promote early ship retirement and environmentally sound disposal	— International standards (IMO) — Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges
GHG	— Short term: ○ Develop GHG emission inventory and fleet baseline ○ Market-based measures for vessels ○ Implement fuel economy standards by vessel class and engine characteristics for new vessels — Medium term: Implement fuel economy standards by vessel class and engine for existing vessels	— Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges — Cap and trade program for shipping sector only — International standards (IMO)
At port	— Short term: Select strategy that provides maximum emissions reduction benefits depending on local fuel availability and environmental performance of electricity generation ○ Shore-side electricity ○ Lowest sulfur on-road fuel and NO_x and PM after-treatment — Medium term: Market-based measures to promote low- or non-carbon energy sources to supply shore-side electricity for docked ships	— Port authority requirement — Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges

Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships: Impacts, Mitigation Options and Opportunities for Managing Growth, both the executive summary and the full report, is available on our website: www.theicct.org.

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

www.theicct.org

Washington DC
1250 I St., Suite 350
Washington, DC 20005
United States of America
phone: +1 (202) 347-8932

San Francisco
1 Hallidie Plaza, Suite 503
San Francisco, California 94107
United States of America
phone: +1 (415) 399-9019

Climate Solutions ● Earthjustice ● Sierra Club

Nine Months Later and Yet No Closer:
An Update to
Permitting Coal Export Terminals in the Pacific Northwest – An Overview of Regulations and the Political Context

March 15, 2013

INTRODUCTION

As of spring 2013, three coal-export terminal projects have pending permit applications in the states of Washington and Oregon.[1] The sudden interest in opening up the West Coast to coal exports from the Powder River Basin (an area in eastern Montana and Wyoming) continues to be a hot-button controversy regionally and nationally.

Our July 2012 paper focused on the steps necessary to secure approval of these projects, and it identified some of challenges terminal proponents face in securing construction permits in a region known for its protective environmental standards and its informed and engaged citizens.[2] The basic outline of the federal, state, and local permit processes remains the same as last year, but the permitting processes and attendant environmental reviews—with extensive public participation—have begun, and this update highlights some of the major developments over the last nine months. Events of the past months show that opposition to these coal-export projects is even greater than expected and growing across the region, with a wide range of constituencies, such as businesses, community leaders, tribes, health professionals, elected officials, and activists speaking out against these projects. Opponents have stopped these proposed projects from taking regulatory shortcuts, and the predicted timelines for these projects simply to obtain the necessary federal, state, and local approvals has increased by not months, but years.

In Washington, the environmental impact statement process began for the **Cherry Point Gateway Pacific Terminal** in Bellingham. Seven scoping hearings across the State brought 10,000 people to meetings to learn about the public involvement process, including a bus of citizens from Montana who attended the scoping meeting in Spokane and addressed the harm

[1] The three projects with pending applications include the Gateway Pacific Terminal site at Cherry Point, Washington; the Millennium Bulk Logistics site in Longview, Washington; and the Morrow Pacific project (which includes the Coyote Island barging terminal at the Port of Morrow, Oregon as well as a barge/cargo vessel loading facility at the Port of St. Helens, Oregon). The Project Mainstay proposal at the Port of Coos Bay, Oregon recently lost its major project backers, and the RailAmerica coal-export proposal at the Port of Gray's Harbor, Washington has been cancelled. Three existing terminals in Canada are also contemplating significant expansions.

[2] Earthjustice, Power Past Coal, and Sierra Club, *Permitting Coal Export Terminals in the Pacific Northwest: An Overview of the Regulations and the Political Context* (July 2012), http://www.sierraclub.org/designarchive/printed/Reports/121%20Coal%20Export%20WP/high121_CoalExport_PNW_Whitepaper.pdf.

increased coal mining and transportation would do to them and their communities. Tribal nations also participated in the Cherry Point scoping process. When the scoping comment period closed, **over 124,000 public comments** had been submitted to the co-lead federal and state agencies. These comments included letters from federal and state agencies calling for an in-depth and broad environmental review. Also in Washington, the **Millenium Bulk Terminals** proposal in Longview has yet to begin its environmental impact statement scoping process, a full year after submission of its revised permit application. Ambre Energy (62% owner of Millenium Bulk Logistics) is the focus of a report cataloguing a number of financial challenges and major liabilities for Ambre. After his inauguration, Washington's newly elected **Governor Jay Inslee** quickly stressed the importance of a thorough review of all impacts from coal-export projects.

In Oregon, the U.S. Army Corps of Engineers continued to hear from the federal, state, and local level that it should demand a full environmental impact statement for the proposed project at the **Port of Morrow.** Recently, the Oregon Department of State Lands wrote project proponent Ambre Energy asking for more scientific information on project impacts and reminding Ambre that the agency has the authority and duty to deny permits that are not in the public good. **Project Mainstay** at the Port of Coos Bay has not yet submitted a permit application, likely because it has lost two of its three major financial backers.

At the national level, the U.S. Environmental Protection Agency has tightened its Clean Air Act standards for particulate matter, and federal attention has begun to focus on coal industry evasion of royalty payments due for exported coal, as well as improper leasing practices.

WASHINGTON STATE UPDATE

A. Cherry Point Environmental Scoping Process Exceeds All Expectations.

The National Environmental Policy Act (NEPA) requires a comprehensive environmental review of all direct, indirect, and cumulative impacts before any major project, such as a coal-export terminal, requiring federal approval can begin construction.[3] Washington State has its own version of NEPA, known as the State Environmental Policy Act (SEPA), which applies to any state or local issued permit.[4] Like NEPA, SEPA requires a full environmental impact statement for any permit with significant environmental effects, including local building permits.

For the Gateway Pacific Terminal project at Cherry Point, the U.S. Army Corps of Engineers, the Washington State Department of Ecology, and Whatcom County are "co-leads" on a single environmental impact statement that meets both NEPA and SEPA requirements. The public scoping process for the Cherry Point NEPA/SEPA environmental review began in September 2012. Seven scoping hearings were held throughout the state, and attendance vastly exceeded all expectations. Thousands of people testified about their concerns about the harmful impacts from the project—concerns stemming from global climate change to regional aquatic impacts to harmful business impacts to local traffic congestion. Many focused on human health concerns, and many who attended these meetings came from outside Washington, as this project

[3] 42 U.S.C. § 4332.

[4] RCW Ch. 43.21C.

will impact people living in the entire region. Heightened concern also came from tribal governments, who have ties to the lands and water at issue since time immemorial, and whose sovereign status gives them a powerful voice opposing this project.

Indeed, the Army Corps rescheduled the final hearing in Seattle in order to accommodate the larger-than-expected crowds. Best estimates are that 10,000 people from across the region attending these scoping hearings. When it opened the public comment period, the Army Corps predicted that a draft environmental impact statement would be released for public review in January 2014.[5] That was before it received approximately 124,000 written scoping comments on the Cherry Point project.[6] Overly optimistic date predictions are common with this project: when Gateway Pacific submitted its permit application in 2011, it predicted a construction start date of early 2013, a date that has already come and gone and was clearly off by at least three to five years.[7]

Comments from peer federal agencies carry particular weight with respect to the extent of the environmental review that will be necessary. The Environmental Protection Agency, National Marine Fisheries Service, National Park Service, U.S. Department of Housing and Urban Development, U.S. Fish and Wildlife Service, and U.S. Forest Service all submitted comments on the need to fully review all impacts from the project.[8] We extensively excerpt from those comments below, as the federal agencies themselves best refute any notion that this environmental review process will be quick, limited, or simple.

Environmental Protection Agency:

- "Because pollutants, including mercury, particulate matter and ozone precursors can travel long distances in the air, we would recommend using existing models to review the reasonably foreseeable potential for air and water quality impacts in the United States."

- "This evaluation would appropriately include the potential increases in fugitive coal dust and diesel emissions that would accompany the additional rail traffic to the proposed new terminal, and the potential related human health impacts to communities along the proposed routes."

- "Other reasonably foreseeable impacts that we recommend be evaluated in the EIS include the potential for effects in the United States from combustion of the exported coal."

---

[5] 77 Fed. Reg. 58531, 58532 (Sept. 21, 2012).

[6] Gateway Pacific Terminal proponents predict that construction of the terminal will take at least two years after all permits are issued. *See* http://gatewaypacificterminal.com/the-project/timetable/.

[7] Washington State Joint Aquatic Resources Permit Application (JARPA), http://gatewaypacificterminal.com/wp-content/uploads/2011/09/GPTProjectJarpa28Feb11.pdf.

[8] *Available at* http://www.eisgatewaypacificwa.gov/resources/project-library.

National Marine Fisheries Service:

- **"**These vessel crossings are expected to add to the existing vessel traffic in the Salish Sea vessel lanes and off-shore within the EEZ. The off-shore crossings may overlap with migratory corridors of ESA-listed and non-ESA-listed whales. Please include information on transportation corridors including routes and number of crossings from the pier to the edge of EEZ, [...] and any proposed conservation measures to minimize the risk of vessel collision with whales (e.g., routes that minimize overlap with migratory corridors, and slower speeds and watchstander protocols within migratory corridors)."

- "The construction and operation of the new facilities will increase rail traffic throughout the western United States as bulk commodities are transported to and from the facility and their sources. The NMFS is aware of major railroad routes along the Columbia River where numerous ESA-listed salmonids live and along the Puget Sound shoreline which provides important near shore habitat for salmonids and forage. Please include information in the train routes and the anticipated number of crossing per day."

- "Studies have demonstrated tons of coal dust is often blown out of transport carts and onto environments adjacent to railways. Please also include proposed conservation measures to reduce wind drift and studies that support estimates."

- **"**The transportation of this coal facilitates the consumption of the products, which increases carbon emissions which may contribute to changes weather patterns, warmer waters, or ocean acidification; all of which can have measurable effects on protected species or their habitat. The NMFS recognizes climate change as a threat to the health of our oceans and our marine living resources. For a complete analysis of the effects of the project to our protected species and habitats, please provide an estimate the carbon output of burning the maximum capacity of coal shipped overseas."

National Park Service:

- "Residents of Oregon and Washington are concerned about climate change and both states recently passed regulations to reduce instate emissions of greenhouse gases. Conversely, the proposed coal export projects will increase greenhouse gas emissions. … Given the magnitude of proposed coal export through the Pacific Northwest and the significant policy implications associated with the U.S. supplying coal to Asian markets, it is essential the EIS thoroughly evaluate project impacts on climate change."

- **"**The EIS should fully evaluate all direct and indirect effects of the coal export process, including railroad shipment from the Powder River Basin, terminal operations, marine vessel shipment and resulting pollutants emitted from Asian power plants."

US Department of Housing and Urban Development:

- "HUD Region 10 covers the four states of Alaska, Idaho, Oregon and Washington. Our region would like the three Co-Lead Agencies […] to consider noise from the increased train traffic to the proposed port along the entire transportation route."

US Fish and Wildlife Service:

- "How far from the proposed coal transfer facility will the direct and indirect effects of coal transport (rail and shipping) and transfer be measurable above current background levels? This analysis should include loss of coal dust, project-related increase in train and vessel traffic (including infrastructure upgrades, operation and maintenance etc), and impacts to air and water quality."

U.S. Forest Service:

- "The Forest Service is concerned with impacts associated with the trains as they travel through public lands managed by the Forest Service. … [T]he BNSF trains would pass through one or more of the following lands managed by the Forest Service: the Okanogan-Wenatchee National Forest, the Mr. Baker-Snoqualmie National Forest, the Columbia River Gorge National scenic Area."

B. Longview Environmental Review Process Still Not Begun.

Meanwhile, Millennium Bulk Terminals' second proposal for a coal-export terminal in Longview, Washington has not made any significant strides forward in the past year. In 2011, Millennium withdrew its first permit application after litigation over the project exposed the company's lying about the intended size of the project.[9] The company submitted its second application on February 22, 2012 for a terminal would ultimately export up to 44 million metric tons of coal annually. As for the Gateway Pacific Terminal, federal and state co-leads have been designated for the environmental impact statement process. The agencies concluded interviews for environmental consultants in early March 2013; the earliest we expect the NEPA/SEPA scoping process to begin is Fall 2013.

Ambre Energy, an Australian company that owns 62% of Millenium Bulk Logistics and is the sole backer of the Morrow Pacific Project, faces mounting financial challenges that could make it difficult to continue pursuing plans for U.S. coal-export developments.[10] The newspaper, *The Australian,* which has been following Ambre's financial challenges closely, called the allegations that have been reported in the media "well researched" and "damning."[11]

C. Former Governor Gregoire's Executive Order on Ocean Acidification

In February 2012, Former Washington Governor Christine Gregoire convened the Washington State Blue Ribbon Panel on Ocean Acidification to chart a course for addressing the causes and consequences of acidification. The Panel released its report and recommendations in

---

[9] *In Northwest, a Clash Over a Coal Operation,* New York Times (Feb. 14, 2011), http://www.nytimes.com/2011/02/15/us/15coal.html?-r=1.

[10] *Ambre Energy's plans for Northwest coal export terminals rest on shaky finances,* Oregonian (Feb. 13, 2013), http://www.oregonlive.com/environment/index.ssf/2013/02/ambre_energys_plans_for_northw.html.

[11] *Available at* http://www.theaustralian.com.au/business/mining-energy/ambre-takes-issue-with-us-slating/story-e6frg9df-1226578260857.

the document Washington State Blue Ribbon Panel on Ocean Acidification (2012): Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response, H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington.[12]

In November 2012, Governor Gregoire issued an Executive Order acknowledging the particular harm that ocean acidification, caused by increased emissions of greenhouse gases into the atmosphere, inflicts on Washington.[13] "[I]t is critical to our economic and environmental future that effective and immediate actions be implemented in a well-coordinated way and that we work collaboratively with federal, tribal, state, and local governments, universities, the shellfish industry, businesses, the agricultural sector, and the conservation/environmental community to address this emerging threat." The Executive Order specifically directs "[t]he Office of the Governor and the cabinet agencies that report to the Governor to advocate for reductions in emissions of carbon dioxide at a global, national, and regional level."

D. Washington Governor Jay Inslee Engaged on Coal Exports.

Newly elected Washington state Governor Jay Inslee discussed coal exports in his first press conference, stating that:

> "It is clear that **there are ramifications ultimately if we burn the enormous amounts of Powder River Basin coal that are exported through our ports**…. It is an enormous number of tons of carbon dioxide that will be released into the atmosphere, **it doesn't matter where it's burned, it ends up in Puget Sound**. That is a physical fact.…I will say that from what I know**, this is the largest decision we will be making as a state from a carbon pollution standpoint certainly during my lifetime**, and nothing comes even close to it."[14]

Governor Inslee has a long record from his time in Congress as a strong proponent of action on climate change and clean energy, and he campaigned actively on these issues.

OREGON

A. Port of Morrow Project Risks State Permit Denial.

The Army Corps has to date received over 30,000 public comments asking for a comprehensive EIS at the Morrow Pacific Project in Oregon, including comments from multiple agencies, cities and towns, Indian tribes, and public officials. Based on "the public controversy surrounding this project" and "the potential for substantial impacts" to threatened and endangered species, the National Marine Fisheries Service recommended the Army Corps prepare an environmental impact statement. In case the Army Corps refused to complete a

[12] *Available at* https://fortress.wa.gov/ecy/publications/SummaryPages/1201015.html.

[13] *Available at* http://www.governor.wa.gov/execorders/eo_12-07.pdf.

[14] *Available at* http://tvw.org/index.php?option=com_tvwplayer&eventID=2013010071 (Jan. 17, 2013 press availability, approximately minute 35:00).

thorough environmental impact statement, the Fisheries Service set forth a list of 15 separate categories of information necessary to begin its review of the potential adverse impacts of the proposed project, including an analysis of the effects of burning the coal in Asia on acid deposition and global climate change.[15]

The Oregon Department of State Lands (DSL) is slated to make a decision about granting one of the state permits necessary for the proposed Morrow Pacific project on April 1, 2013. In February 2013, however, DSL sent a letter to developer Ambre Energy setting out the additional information Ambre must provide about project impacts, including adverse effects on water resources, Tribal Fishing Treaty Rights, and cultural resources.[16] The letter outlines DSL's legal standards for issuing its permits, highlighting the agency's authority to condition or reject this risky project.[17] This letter illustrates how much more information is needed to make an accurate assessment of the full impacts posed by coal exports and increases the chances that DSL will delay the permit decision yet again. As noted above, Ambre Energy faces daunting financial challenges that call into question its ability to execute this project as well as the Millenium Project in Longview.

B. Coos Bay Project Loses Court Case and Financial Backing.

While Project Mainstay at the Port of Coos Bay has not yet submitted permit applications, it has suffered two major setbacks. First, in January 2013, an Oregon state court ordered the Port of Coos Bay to release public records concerning its potential coal terminal plans. The court ordered the Port to turn over the records without a fee, found the port's conduct to be in violation of the constitution, and issued an injunction to prohibit the Port from posing invasive questions involving constitutionally privileged information to the Sierra Club and other public interest groups in the future. In a transcript of the ruling, Judge Paula Bechtold said that the Port had "acted in bad faith and constructively denied access."[18] Second, investigative reporters learned in March 2013 that the Coos Bay project lost two of its major backers, Mitsui, a large international trading firm, and the Korean Electric Power Corporation. That leaves a

[15] Letter from NMFS to Army Corps, Re: Request for Additional Information (Dec. 27, 2012), http://www.powerpastcoal.org/wp-content/uploads/2013/03/2012_12-27_coyote_coal_NWR-2012-9480.pdf.

[16] *Available at* http://www.powerpastcoal.org/wp-content/uploads/2013/02/49123-RF_3rd-Round-PRP-Comments-Letter_02042013-tif.pdf.

[17] Or. Const. art. VIII, § 5(2) ("The [State Land] board shall manage lands under its jurisdiction with the object of obtaining the greatest benefit for the people of this state, consistent with the conservation of this resource under sound techniques of land management."); ORS 274.005 *et seq*. (describing DSL's authority to manage and lease state-owned aquatic lands).

[18] *Judge slams Coos Bay port for "bad faith" handling of records request on planned coal terminal*, Oregonian (Jan. 31, 2013), http://www.oregonlive.com/mapes/index.ssf/2013/01/judge_slams_coos_bay_port_for.html#incart_river.

California port logistics company, Metro Ports, alone in backing the terminal and looking for new business partners by the end of March 2013.[19]

NORTHWEST INDIAN TRIBES

Most proposed coal terminals will be sited within the "usual and accustomed" fishing areas of Pacific Northwest Indian tribes, which have a sovereign government-to-government relationship with the U.S. federal government. Gateway Pacific Terminal would be built within historic shell-fishing areas of the Lummi and Nooksack tribes—and on top of the spawning grounds of a critically important population of Puget Sound herring, which in turn sustains the local salmon population on which the tribes rely. Under federal court precedent, the tribes are "co-managers" of these resources along with the state and wield considerable influence over decisions that affect fishing resources.[20] Lummi Indian Nation leaders have publically announced their opposition to the Gateway Pacific Terminal.[21]

The voices of tribal opposition to coal-export projects have grown over the last year. The Affiliated Tribes of Northwest Indians called for full environmental review and government-to-government consultation with Indian tribes throughout the region.[22] The Northern Cheyenne Indian Tribe has expressed concern over the years about the impacts the proposed railroad and related coal-mining activities would have on the health, wellbeing, culture, and sacred sites of the tribe. Nine members of the Northern Cheyenne Tribe traveled 1,300-miles roundtrip to a public comment session in Spokane, Washington to voice their opposition to the mine, railroad, and Gateway Pacific Terminal. Seven different tribal organizations—the Lummi Indian Business Council, the Swinomish Indian Tribal Community, the Confederated Tribes and Bands of the Yakama Nation, the Makah Tribal Council, the Tulalip Tribes, the Nisqually Indian Tribe, and the Samish Indian Nation—submitted comments on the Cherry Point Gateway Pacific Terminal calling for full environmental review, government-to-government coordination, and protection for fish, wildlife, air and water quality, human health, and tribal sacred areas.

NATIONAL

A. Clean Air Regulatory Agencies Enact Stringent New Rules.

Coal-export facilities are potential sources of significant amounts of particulate matter. A particularly important requirement for new projects is that they must demonstrate that the proposed facility will comply with applicable standards that limit the concentration of air pollution in the outside air to levels set by the EPA, and EPA's standards for particulates just

[19] *Available at* http://earthfix.opb.org/energy/article/coal-export-terminal-faces-setback-on-south-oregon/.

[20] *U.S. v. Washington*, 384 F. Supp. 312 (W.D. Wash. 1974).

[21] *Lummi Nation leaders come out against Gateway Pacific coal terminal project*, The Bellingham Herald (Sept. 21, 2012), http://www.bellinghamherald.com/2012/09/21/2700524/lummi-nation-leaders-come-out.html.

[22] *Available at* http://www.atnitribes.org/sites/default/files/res_12_53_with%20attachment.pdf.

became more stringent. *See* Final Rule, National Ambient Air Quality Standards for Particulate Matter, 78 Fed. Reg. 3086 (Jan. 15, 2013). Any of the proposed coal-export terminals will have to meet these new rigorous standards.

B. Unfair Coal Lease Payments and Royalties Practices Investigated.

Given the substantial market uncertainty related to coal finances and coal export, it appears very likely that project economics may depend on direct subsidies and avoidance of taxes owed to federal and state governments. In 2012, the report *The Great Giveaway* concluded that anti-competitive leasing practices had allowed coal mining companies to avoid $29 billion in lease payments to the federal government over the past several decades.[23] Coal companies were able to avoid competitive bids for leases due to a loophole excluding the Powder River Basin (the largest coal reserves in the United States) from provisions applying to areas designated as "coal producing regions." In statements, federal officials admitted that these practices reduced payments from coal companies, but justified it based on the desire to maintain low electricity rates in the United States. Obviously, these concerns do not apply to coal export.

Additionally, new concerns have been raised that federal, state, and tribal governments may be losing millions of dollars in royalties as coal companies improperly base their calculations on non-arms-length sales to subsidiaries at low domestic prices, as opposed to fairly valuing the coal at the much higher prices coal commands overseas. As the rules that govern Powder River Basin sales to Asia and these types of transactions are investigated, projected profits from coal export may significantly decline. *See* Letter from Senators Wyden and Murkowski to Interior Secretary Salazar re: Federal coal royalty management (Jan. 3, 2013).[24] If the taxpayers are compensated fairly, U.S. exported coal prices may not be competitive with other thermal coal exports to the same customers from Australia, Indonesia, and other countries.

CALL FOR AREA-WIDE ENVIRONMENTAL REVIEW

The calls for a single comprehensive process that looks at the cumulative impact from all of the coal terminals have only gotten louder since release of our July 2012 paper. Such a process, known under NEPA as a programmatic, area-wide, or overview environmental impact statement, would focus on the shared impacts of all pending coal terminals in the Northwest. It would run independently of (and in addition to) the terminal-specific EIS processes and would involve the public from the Powder River Basin mining region to the coast. Governor John Kitzhaber of Oregon called on the Corps to perform a comprehensive environmental impact statement for all coal terminals, joining the U.S. Senator Patty Murray, the Environmental

[23] Sanzillo, Tom, Institute for Energy Economics and Financial Analysis, *The Great Giveaway: An analysis of the United States' long-term trend of selling federally-owned coal for less than fair market value* (June 2012), www.washingtonpost.com/wp-srv/health/documents/PRB-report.doc.

[24] *Available at* http://www.wyden.senate.gov/news/press-releases/wyden-murkowski-seek-answers-on-coal-royalty-payments.

Protection Agency, the Washington Department of Natural Resources, other sitting members of Congress, and thousands of citizens.[25]

Other federal agencies used the Cherry Point Gateway Pacific Terminal scoping process to join this call for a comprehensive, area-wide environmental review:

US Department of Housing and Urban Development:

- "HUD suggests the Co-Lead Agencies either include the cumulative impacts from all three proposed ports in this EIS, or conduct an Areawide EIS that covers all three ports. The train traffic from all three ports could have a significant noise impact on communities on our region and in order to accurately and comprehensively address this impact, it needs to be considered as a whole."

National Park Service:

- **"**Given the potential for regional export of over 100 million tons of coal per year, NPS is concerned these projects - both individually and cumulatively- could have significant long-term consequences for the residents, visitors, environmental and cultural resources of the north Rocky Mountains and Pacific Northwest. Therefore, we believe the U.S. Army Corps of Engineers, as lead federal agency, is obligated to coordinate with all involved state and local agencies in preparing a programmatic EIS that rigorously addresses the cumulative effects of all five export terminal projects in the region. The EIS should fully evaluate all direct and indirect effects of the coal export process, including railroad shipment from the Powder River Basin, terminal operations, marine vessel shipment and resulting pollutants emitted from Asian power plants."

US Fish and Wildlife Service:

- "The proposed action is only one of several facilities proposed in Washington and Oregon for transporting coal and other commodities. Please address the cumulative effect of these facilities operating concurrently in the future, if built."

Environmental Protection Agency:

- **"**EPA also recommends that environmental impacts from increases in regional rail traffic and combustion of coal in receiving markets be examined in the context of other proposed export facilities in the Pacific Northwest region, so that reasonably foreseeable cumulative environmental impacts from additional facilities can be understood before a decision is made, as NEPA contemplates. … The cumulative effects analysis would appropriately include increases in regional train traffic and related air quality effects on human health, and the potential for effects to human health and the environment from increases in the long-range transportation of air pollution, including greenhouse gas emissions."

---

[25]*Oregon Governor John Kitzhaber calls for sweeping review of planned coal exports from Northwest ports*, Oregonian (April 25, 2012),http://www.oregonlive.com/environment/index.ssf/2012/04/oregon_gov_john_kitzhaber_call.html; *Oregon Town Weighs a Future With an Old Energy Source: Coal*, New York Times (April 18, 2012), http://www.nytimes.com/2012/04/19/us/boardman-ore-considers-a-future-in-coal.html.

National Marine Fisheries Service:

- "We recognize the proposed project as part of a larger action. The larger action (i.e., transport of products) will have effects far beyond the facilities being built and improvements at Custer. The applicants should propose alternatives to reduce effects [...] throughout the entire action including transportation from the source to the edge of the EEZ."

CLOSING WORDS

Former Montana Governor Brian Schweitzer, a previously outspoken proponent of coal exports,[26] was recently quoted in the *Flathead Beacon* regarding his skepticism around the viability of coal export proposals, saying that plans for west coast coal exports were "dead."[27]

> Ambre Energy Ltd. has an active interest … But plans? You call those plans? I don't see the plan that's getting built. A plan is when you put it on a piece of paper and pay somebody to start pouring concrete. I've been out there looking at these things. **I think Cherry Point is dead.**
>
> The Millennium project in Cowlitz County there that Ambre has proposed, that is **far out into the distance.** Ambre has also got a plan that they hope to get built along the Columbia River on the Oregon side. But I think that **Oregon has poked a big hole in that balloon.** So the only export terminal that we really have is in Vancouver, and now they've got their locals up in arms when Westshore has proposed to increase from about 27 [million] to about 30 million tons.

[26] Only two years ago, Governor Schweitzer was touting the prospects for Montana coal shipments to China. "There's potential for more Montana coal to be shipped to energy-hungry China in the coming years," Schweitzer said. *Montana Gov. to Travel to China on Promotion Tour*, Associated Press (June 3, 2011), http://www.businessweek.com/ap/financialnews/D9NKJVV00.htm.

[27] *Schweitzer: Washington Coal Export Plans 'Dead,'* Flathead Beacon (Jan. 17, 2013), http://www.flatheadbeacon.com/articles/article/schweitzer_washington_coal_export_plans_dead.

Photograph Exhibits 1 to 38.

Exhibit 1: Coal debris from conveyor belt in the tidal zone. Photo taken 8-08-09.

Exhibit 2: Coal debris from conveyor belt on vegetation in the tidal zone. Photo taken 8-08-09.

Exhibit 3: Coal debris from conveyor belt on vegetation in tidal zone. Photo taken 8-08-09

Exhibit 4: Coal debris from conveyor belt on vegetation in tidal zone. Photo taken 8-08-09.

Exhibit 5: Coal debris from conveyor belt on vegetation in tidal zone. Photo taken 8-08-09.

Exhibit 6: Coal sludge falling from conveyor directly above tidal zone. Photo taken 8-08-09.

Exhibit 7: Coal debris falling from conveyor directly above tidal zone. Photo taken 8-08-09.

Exhibit 8: Coal debris falling from conveyor directly above tidal zone. Photo taken 8-08-09.

Exhibit 9: Coal debris falling from conveyor into Resurrection Bay. Photo taken 8-8-09.

Exhibit 10: Coal debris falling from conveyor into Resurrection Bay. Photo taken 8-08-09.

Exhibit 11: Coal debris falling from conveyor into Resurrection Bay. Photo taken 8-08-09.

Exhibit 12: Coal falling from conveyor onto tarp in tidal zone. Photo taken 8-08-09.

Exhibit 13: Coal falling from conveyor onto tarp in tidal zone. Photo taken 8-08-09.

Exhibit 14: Coal falling from conveyor into Resurrection Bay. Photo taken 10-11-09.

Exhibit 15: Coal falling from conveyor into Resurrection Bay. Photo taken 10-18-09.

Exhibit 16: Stripe of coal debris from conveyor belt in tidal zone. Photo taken 10-11-09.

Exhibit 17: Coal debris from conveyor belt in tidal zone. Photo taken 10-11-09.

Exhibit 18: Coal debris from conveyor belt on tidal vegetation. Photo taken 10-12-09.

Exhibit 19: Coal debris from conveyor belt in tidal zone. Photo taken 10-12-09.

Exhibit 20: Coal slab debris from conveyor belt in tidal zone. Photo taken 10-12-09.

Exhibit 21: Stripe of coal debris from conveyor belt in tidal zone. Photo taken 10-12-09.

Exhibit 22: Stripe of coal debris from conveyor belt in tidal zone. Photo taken 8-08-09.

Exhibit 23: Stripe of coal debris from conveyor belt in tidal zone. Photo taken 8-08-09.

Exhibit 24: Coal dust in Resurrection Bay. Photo taken 1-18-05.

Exhibit 25: Coal dust in Resurrection Bay. Photo taken 1-18-05.

Exhibit 26: Coal dust generated from stockpiles. Photo taken 3-20-07.

Exhibit 27: Coal dust escaping from conveyor. Photo taken 4-02-07.

Exhibit 28: Coal dust escaping from conveyor. Photo taken 4-02-07.

Exhibit 29: Coal dust escaping from stockpile. Photo taken 2-08-07.

Exhibit 30: Coal dust generated at conveyor loading area. Photo taken April 2, 2007.

Exhibit 31: Coal dust generated at conveyor loading area. Photo taken April 2, 2007.

Exhibit 32: Coal dust generated at conveyor loading area. Photo taken March 6, 2007.

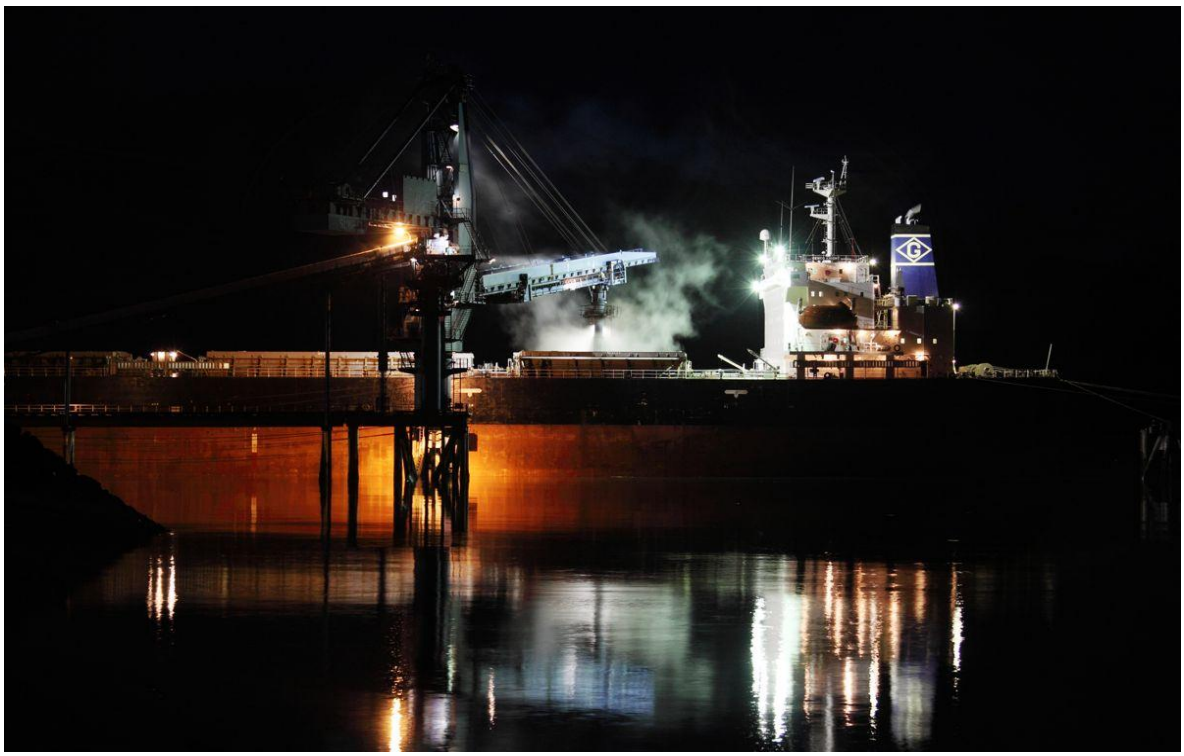


Exhibit 33: Coal dust generated while loading coal onto vessel. Photo taken Oct. 20, 2009.

Exhibit 34: Coal dust generated while loading coal onto conveyor. Photo taken Oct. 20, 2009.

Exhibit 35: Coal dust generated while loading coal onto conveyor. Photo taken Oct. 20, 2009.

Exhibit 36: Coal dust generated while loading coal onto conveyor. Photo taken Oct. 20, 2009.

Exhibit 37: Coal dust generated while loading coal onto conveyor. Photo taken Oct. 20, 2009.

Exhibit 38: Coal covered snow deposits. Snow deposits in portions of the SCLF are eventually directly discharged into Resurrection Bay. Photo taken Feb. 8, 2008.

Project Platinum

US West Coast Port Redevelopment

Table of Contents

1. **Introduction** 3
2. **Background** 3
3. **Key Transaction Terms** 3
4. **Platinum Port Site Description** 3
5. **Transportation** 4
6. **Ground Lease Terms** 4
7. **Environmental Remediation** 4
8. **Platinum Port Development Plan** 4
9. **Revenue Generation and Profitability** 5
   - Coal Exports 5
   - Petcoke Exports 6
   - Imports 6
10. **Financing Requirements** 6

Annexure A 7

- Proposed Development Concept 7

1. Introduction

- Ambre is proposing to redevelop the private "Platinum" port site on the US West coast into a multi product port with an emphasis on coal terminal facilities
- In the short to medium term Ambre will develop a 20Mtpa coal terminal. This will be the largest coal terminal on the US West coast and second only to the 21Mtpa capacity at Westshore in Vancouver, Canada on the North American west coast
- In the longer term Ambre plans to develop a 60Mtpa coal terminal which will be the largest coal terminal on the North American west coast.

2. Background

- Ambre is nearing completion on the acquisition of a number of coal mines in the Powder River Basin.
- The value uplift in this strategy is exporting the coal to Asia via the US West Coast.
- While rail capacity is available and there is identifiable demand for the coal in Asia the critical constraining factor is coal loading capacity at suitable North American West coast ports.
- In order to secure export capacity Ambre investigated a number of potential sites in NW USA and Canada for the development of a coal export terminal.
- Ambre reviewed and evaluated 29 current and potential port sites for their ability to provide up to 10Mtpa coal loading capacity in the medium term – either through excess capacity or the ability to build a coal loading terminal.
- Only Ridley at Prince Rupert, northern British Columbia has potential future spare capacity from a planned expansion from 12Mtpa to 24Mtpa over the next 3 years. However, Ridley is geographically stranded from the US Midwest.
- Two sites were identified as being capable of delivering capacity through infrastructure construction:
  1. Port of Kalama, Washington – potential to handle 10Mtpa but site is constrained as only 50 acres are available so further capacity expansion difficult. Recently the Commissioner of Port Kalama opted for the development of a multi product dry terminal at the expense of a coal terminal.
  2. Platinum port site – has the potential to be redeveloped into a multi product port with significant coal loading capacity i.e. 20Mtpa in the short to medium term with a longer term target of 60Mtpa

3. Key Transaction Terms

- Ambre will purchase the interest and operations from the existing Platinum port operator for $20mln including, but not limited to, the following key leases:
  - The Ground Lease for the Platinum site on a 60+10+10yr basis (See Ground Lease Terms)
  - The rights under the Aquatic Lease for the adjoining aquatic lands between the Ground Lease Lessor and the state Department of Natural Resources that are subleased to the Platinum port operator
- In addition Ambre is obligated to assist in the longer term environmental remediation arising out of a probable forthcoming Consent Decree issued by the state Department of Ecology to the Ground Lease lessor. Importantly Ambre's financial liability to the lessor under this Consent Decree is limited to $20mln to be paid within four years of the issue of the Consent Decree (See Environmental Remediation).
- Note: It is precisely these environmental issues which have not been adequately addressed by the current port operator which has presented Ambre with the opportunity to purchase this valuable opportunity to develop a multi product port with a focus on the coal loading terminal.

4. Platinum Port Site description

- Platinum is:
  - a private port facility
  - a 416 acre site on a river based deep draft shipping channel.
  - located 65 river miles inland from the Pacific Ocean
- Dredging is not a major issue and is only required about once every ten years.

- The workforce at the Platinum site is currently non-unionised. Some form of union involvement may be invited in the future by Ambre depending on commercial considerations.

5. Transportation

- The BNSF Railway and the Union Pacific railroad main lines run parallel to Interstate 5 approximately five miles from Platinum. An existing rail spur and rail loops delivers rail wagons direct to the port
- Platinum is located approximately three miles from north-south Interstate 5, the main roadway stretching from Mexico to Canada

6. Ground Lease terms

- The freehold to the Platinum site is held by a major US blue chip corporate.
- The Ground lease terms for Ambre are 60yrs + 2 x 10 years extensions by mutual agreement.
- Rent is zero until end 2013 and from 2014 onwards Ground lease rent is set off against the fees from the alumina and pitch handling services that Ambre is obligated to provide to the lessor.
- Ambre has the right to purchase the freehold from the lessor within the first 5 years at a fixed price and then at fair market value from year 6 onwards.

7. Environmental Remediation

- The Platinum site was an aluminum smelter for 60 years prior to 2001
- Remediation actions promised by the previous port operator have not been undertaken
- In addition, the previous port operator has contravened a number of permitting issues and has been involved in new pollution incidents
- It is likely the state Department of Ecology will issue a Consent Decree to the Ground Lease lessor requiring remediation action
- Ambre's financial liability to the lessor under the Consent Decree is limited to $20mln, payable within 4 years of the Consent Decree being issued.

8. Platinum Development Plan

1. Short to Medium term - develop a bulk materials handling port that that provides for:
    a. Exporting coal
    b. Exporting petroleum coke
    c. Importing alumina
    d. Importing cement
    e. Importing caustic soda

2. Longer term - transition to a port that:
    a. Focuses on and maximises the capacity for exporting coal with a target capacity of 60Mtpa of coal
    b. Allows the importation of alumina
    c. Allows the importation of cement (providing large capacity storage is an issue)
    d. Allows the importation of caustic soda

Please see Annexure A – Proposed Development Concept

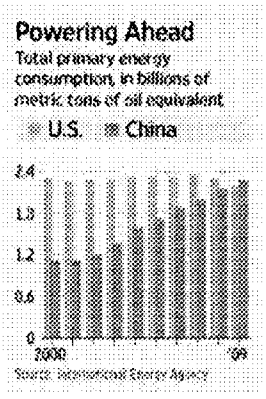
Summary of Capex and Timelines for Port Development

Stage	Stockpile capacity	Annual Capacity	Timeline	Capex
Short to Medium term				
Stage 1	100,000t - 300,000t	10 Mtpa	18mths	$120m+-$10m
Stage 2	600,000t	20 Mtpa (*)	30mths	$60m+-$10m
Longer term				
Stages 3,4,5	2.45 Mt	60 Mtpa		

(*) – Includes 2 Mtpa of Petcoke capacity.

9. Revenue Generation and Profitability

- While Platinum will be a multi product port, the primary revenue generator for the Platinum port operator will be the export of coal via its coal terminal facilities.
- Coal handling fees are expected to be set at around $9/t which compares favourably to the $8/t-$12/t coal handling fees charged at Westshore.
- Opex handling costs are estimated in the region of $1/t which delivers an exceptionally healthy margin to those operators who have scale in their coal handling facilities
- The driver for coal export from the US is predicated on the current and future growth of the seaborne coal trade caused by increasing energy consumption requirements of Asia, in particular China.
- Seaborne thermal coal demand is predicted to increase from 697Mt in 2010 to 921Mt in 2020 (*Source: Seaborne Coal Market Forecast, June 2010, Resource Management International Pty Ltd)*
- The International Energy Agency (IEA) has recently released statistics illustrating that China has surpassed the US to become the world's biggest energy consumer. This has occurred five years earlier than anticipated and from a base in 2000 when China consumed just half the energy consumed by the US.



Coal Exports

- Ambre Energy NA intends to be the anchor client for coal export through Platinum i.e. potentially Ambre would require the full 18Mtpa of coal export capacity for the planned 20Mtpa coal loading (incl 2Mtpa Petcoke) capacity planned for Stage 2.
- 10Mtpa is planned for the export of production from Ambre's coal mines in the Powder River Basin and the balance of 8Mtpa is envisaged to be utilised for Ambre coal trading purposes.
- Nevertheless, apart from Ambre's desire to secure significant capacity at Platinum there has been strong interest expressed from several other market participants re securing port access:
    - Peabody and Arch Coal for 10 Mtpa of coal loading capacity each (total 20Mtpa)
    - Westmorland and Signal Peak Mines for a number of millions of tonnes per year
    - Smaller coal producers from Utah including Horizon Mining for about 1.0 Mtpa

Petcoke exports

- Fees and costs for Petcoke are similar for those of coal ($9/t and $1/t respectively).
- Handling of Petcoke is undertaken for a large US blue chip corporate and contracted tonnage is for up to 2Mtpa.

Imports

- As stated previously Platinum will be a multi-product port with the additional capacity to handle alumina, cement and caustic soda.

Commodity	Throughput	Handling fee	Opex	Offtake
Alumina	200-300k tpa	$3/t	-	Leaseholder. Ground lease rent exactly offset by alumina & pitch handling charges
Cement	200-550k tpa	$6/t	$3/t	Blue chip French corporate
Caustic Soda	300k tpa			Chinese party

10.Financing Requirements

To deliver a multi product port with a 20Mtpa Coal Terminal within 30 months:

	$	Comments
Capex	200	Including contingency
Working capital	20	
Environmental Liability	20	This is the maximum spend and perhaps only a portion requires initial financing with the balance to come from port operations prior to expiry of 4 yrs
Total	240	Thereafter port is self funding and profitable

To deliver a multi product port with a 60Mtpa Coal Terminal : financing requirements still TBD

MBL012755

Annexure A

Proposed Development Concept

It is envisaged that the development of the coal export facilities will occur over a number of stages. The reason for considering the long term possibilities and potentials for the site is to allow a site layout to be developed that: -

- Prevents (or discourages) near term developments that either prevent or compromise long term developments or requires relocation or rebuilding of plant to allow long term plans to proceed
- Allow near term developments and capital expenditure to be utilised for all future developments
- Allow future developments to proceed by way of expanding or extending previous facilities thus making the best possible use of past capital expenditure
- Allows operations to continue during upgrades

With this in mind, the final stage is an extension of the initial stage.

A staged design concept study has been underway since January 2010 and the Stage 1 & 2 details are presented below:

Stage 1

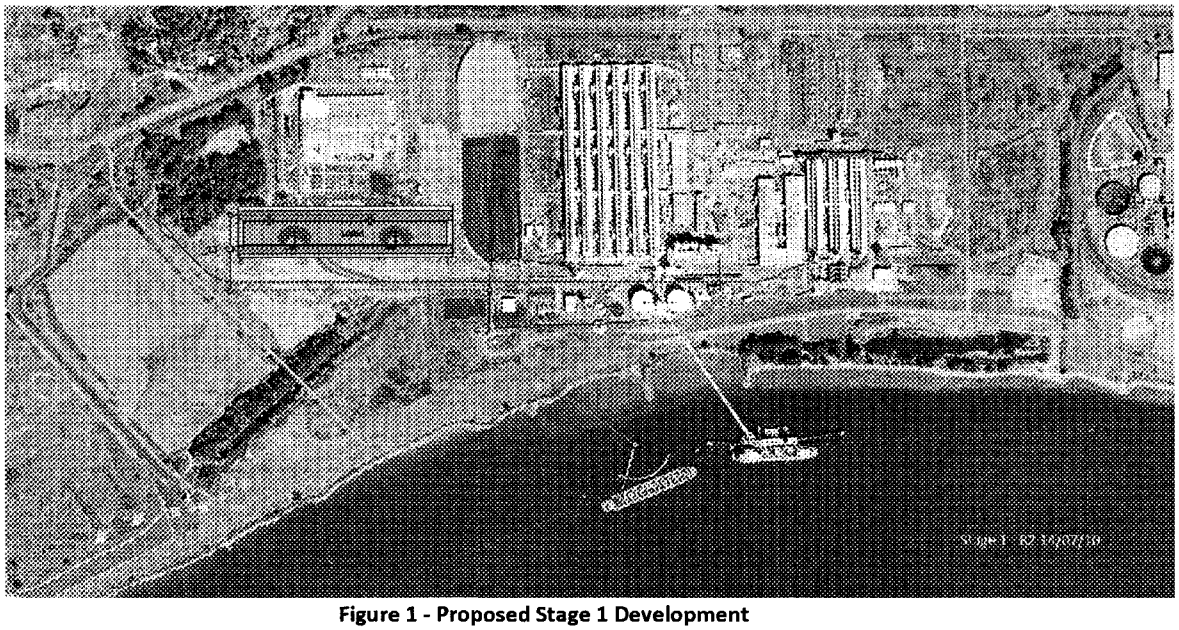


Figure 1 - Proposed Stage 1 Development

Stage 1 comprises: -

- Building of the third rail loop on site – shown in blue colour;
- Construction of coal wagon unloader with capacity of 5,000 tonnes per hour;
- Construction of coal stockpile with two radial stackers and two dozer traps (coal to be moved on stockpile by D11 dozers)
- Construction of new coal loader;
- Construction of two coal samplers;
- Construction of coal conveyors, 1.8 meter wide (location shown in orange colour on the attached graph)

Stage 2

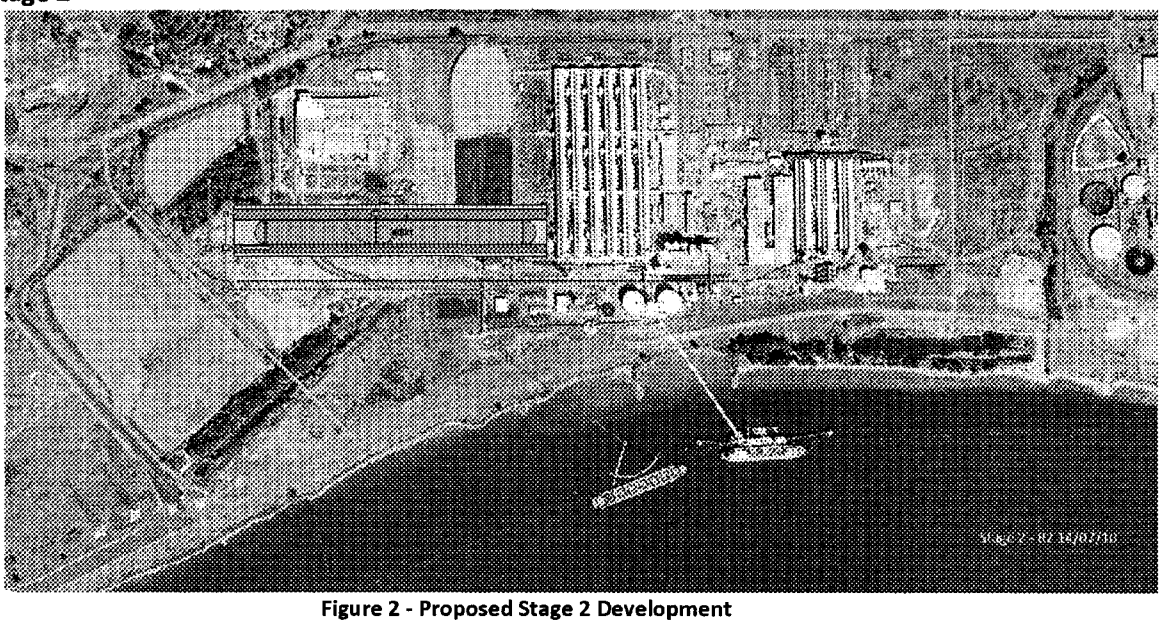


Figure 2 - Proposed Stage 2 Development

Stage 2 comprises: -

- Adding of walking stacker and coal reclaimer to fully automate coal stacking on a coal stockpile and coal reclaiming from the coal stockpile.

PERGAMON

Atmospheric Environment 37 (2003) 3817–3830

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Exhaust emissions from ships at berth

D.A. Cooper*

IVL Swedish Environmental Research Institute Limited, P.O. Box 47086, S-402 58 Göteborg, Sweden

Received 5 March 2003; received in revised form 5 May 2003; accepted 12 May 2003

Abstract

Emission measurements have been carried out on board six ships at berth during normal real-world operation (hotelling, unloading and loading activities). The study included three passenger ferries, one transoceanic container/ro-ro, one transoceanic car/truck carrier, and one chemical tanker. Emissions were measured from 22 auxiliary engines (AEs, medium and high-speed marine diesels) covering seven engine models and ranging in size from 720 to 2675 kW maximum output. The fuels varied from low sulphur gasoils (2.91 cst viscosity) through to residual oils (411 cst viscosity). Both specific emission factors (g kWh^{-1}) at a given engine load and total emissions (kg) of nitrogen oxides (NO_x), sulphur dioxide, carbon monoxide, hydrocarbons, carbon dioxide, particulate matter (PM) and polyaromatic hydrocarbons during actual harbour stops were determined. In addition, some preliminary measurements to investigate PM size distributions were undertaken.

The specific emissions showed significant variations between the different engine models and also within the same engine model on board the same ship. For example NO_x emissions varied between 9.6 and 20.2 g kWh_{corr}^{-1} between all engines and 14.2–18.6 g kWh_{corr}^{-1} between engines of the same model and fuel. Other emissions from boiler use and possible main engine warm-up prior to departure were in general expected to be considerably less than those from the AEs. The results obtained for the three passenger ferries demonstrate that empirically derived, emission formulae using dead weight tonnage can prove to be a cost-effective and accurate tool for harbour emission inventories.
© 2003 Elsevier Ltd. All rights reserved.

Keywords: Ship emissions; Diesel exhaust; Auxiliary engine; Harbour

1. Introduction

Over the past decade, several reports have outlined exhaust emissions from the growing marine transport sector as a significant air pollution source (Lloyd's Register Engineering Services, 1995; Corbett et al., 1999; Skjølsvik, 2000; European Commission, 2002a). The European shipping fleet, using fuels with an average sulphur content of 2.7% m/m, emitted approximately 2578 thousand tons of SO_2 for the year 2000 within the European monitoring and evaluation programme (EMEP) domain (European Commission, 2002a). This can be compared to 5750 thousand tons arising from European Community land-based sources and domestic sea traffic (European Environmental Agency, 2002). In light of the considerable emission reductions and tighter legislation for land-based sources that have progressed since the 1960s, further emission reduction scenarios will most certainly include the relatively untapped marine sources. Thus, an accurate assessment and control of ship emissions will play key roles in providing cost-effective solutions to achieve regional and global environmental targets in the future. Different regulatory strategies including for example, fuel sulphur capping and new engine nitrogen oxides (NO_x) emission limits (International Maritime Organisation, 1998), environmentally differentiated fairways dues (Swedish Maritime Administration, 1998; Norwegian Ministry of Fisheries, 2000) and emission trading schemes (Swedish Shipowners Association, 2002) are gaining acceptance. For more local-scale benefits, however, a focus on emissions

*Tel.: +46-31-7256200; fax: +46-31-7256290.
E-mail address: david.cooper@ivl.se (D.A. Cooper).

1352-2310/03/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/S1352-2310(03)00446-1

from ships while in port areas has been highlighted (Colvile et al., 2001). The European Commission has recently put forward a proposal to enforce a 0.2% sulphur limit on fuel used by ships at berth in European ports (European Commission, 2002b). This is despite the fact that in-port sulphur dioxide (SO_2) emissions have been estimated to account for only 6% of the total European shipping fleet emissions (European Commission, 2002a).

Although main engines (MEs) used for ship propulsion at sea, create the largest emissions, emissions from the smaller auxiliary engines (AEs), used for generating electrical power on board, cannot be entirely ignored. This is especially so when ships are stationary (with MEs shut down) and at berth in ports close to population centres. In general, AEs are used continuously except when shaft generators coupled to MEs are available at sea, or when a shore-side electricity link is provided at berth. Almost all AEs are four-stroke marine diesel engines operating at engine speeds of 500–2500 rpm (i.e. so-called medium- and high-speed diesels) with power output in the range of 30–3000 kW. The AE power requirement on board a ship can vary. A short-term maximum is often encountered when bow and stern thrusters are operated during departure from or arrival at a port. Once in port, however, the power requirement is usually less but can still vary depending on the type of ship activity, e.g. hotelling, loading operations.

Since most marine emission studies have been directed towards ME operation, there is a general lack of knowledge regarding AE operation and their emissions. Real-world emission data, i.e. actual emissions measured during normal service as oppose to those at engine manufacturers test beds, and associated uncertainty evaluations are especially valuable in this context (Corbett, 2002). Bearing this in mind, the present investigation was initiated with the primary aim of providing an improved reference material for air emissions from AEs used on ships while at berth. Besides the determination of specific emissions, case studies for actual harbour stops by the ships were investigated. In the latter case, relative contributions from boiler use (oil burners) for hot-water supply and when MEs are set at idling (short, warm-up period just prior to departure) were also estimated.

2. Experimental

2.1. Strategy and measurement ships

Initially, it was hoped that the choice of measurement ships and their AEs would reflect the shipping fleet in general, i.e. in terms of engine type (engine speed and power output), fuel used, engine age and mode of operation. Besides obtaining a representative selection of ships for the study however, consideration was given to the practicalities involved with the measurements, i.e. duration of harbour stops, locality of ports, etc. Furthermore time and economic constraints weighed heavily and not least finding shipowners willing to participate in the project. Thus, the chosen ship/engine combinations represent a compromise of these factors. An overview of the specifications of the measurement ships, AEs and fuels used are presented in Tables 1–3. Regarding AE fuels, most were classed as low-sulphur marine gasoils (MGO) although ships B and E used heavier residual oils (RO). The fuel from ship D was classed as a marine diesel oil (MDO) of type DMB (International Organisation of Standardisation, 1996a), although the subsequent analysis proved to be very similar to MGO grade except with a higher sulphur content. Since ship B uses both RO (AE1–AE4) and MGO (on AE5), this provided an opportunity to observe how emissions from the same engine model (also age and similar service history) vary for the two fuels. Regarding engine type, all the AEs were marine diesel engines where the torque load is varied at a constant speed to provide a power output range coupled to an electric generator which is typical for AEs of the

Table 1
Specifications of the six measurement ships

	Ship A	Ship B	Ship C	Ship D	Ship E	Ship F
Type	Pass. ferry	Pass. ferry	Pass. Ferry	Car/truck carrier	Container/ ro-ro	Chemical tanker
Length and width (m)	155 × 29	175 × 29	185 × 27	199 × 32	292 × 32	115 × 18
Gross register tonnage (t)	28727	39178	22528	52288	58438	5698
Dead weight tonnage (t)	2953	3938	3335	29213	51157	8245
Passenger capacity	2274	2400	1524	n. a.	n. a.	n. a.
Vehicle capacity	555	550	379	5870	[a]	[b]
No. of MEs and AEs	4 + 5	4 + 5	4 + 6	1 + 2	1 + 4	1 + 3

[a] Cargo capacity: 1000 Automobile units, 1850 TEU (20/ft Equivalent Unit) Containers and 1000 TEU ro-ro.
[b] Cargo capacity: 10 separate tanks providing a total of 8988 m^3.

Table 2
Specifications of the auxiliary engines (AEs, constant speed, four stroke marine diesel engines)

Ship	Engine model/max. output (kW)	Engine speed (rpm)	Measured AEs	Fuel type[a]
A	Sulzer 6ASL 25/30/960	750	AE1, AE2, AE3, AE4, AE5	MGO
B	Sulzer 8ASL 25/30/1270	750	AE1, AE2, AE3, AE4, AE5	RO, MGO
C	Wärtsila 824 TS/940	720	AE1, AE2, AE3, AE4, AE5, AE6	MGO
D	Wärtsilä 4R32D/1480	720	AE1, AE2	MDO
E	Wärtsilä 8R32/2675	720	AE1	RO
	Wärtsilä 6R32/2005	720	AE3	RO
F	Caterpillar 3508/720	1800	AE1, AE2	MGO

[a] MGO refers to marine gasoil, MDO as marine diesel oil, and RO as residual oil.

Table 3
Analyses of the AE fuels ("—" indicates analysis not performed)

	Ship A	Ship B	Ship B	Ship C	Ship D	Ship E	Ship F
Type	MGO[a]	RO	MGO[a]	MGO	MDO	RO	MGO
Dens. at 15°C (g cm^{-3})	0.876	0.936	0.881	0.891	0.866	0.992	0.848
Net cal. value (MJ/kg)	42.60	41.73	42.49	41.85	42.21	40.15	42.65
Viscosity at 50°C (cst)	9.4	168	10.0	3.71	3.16	411	2.91
Total PAH (% m/m)[b]	—	—	—	—	2.1	18	1.5
Carbon (% m/m)	87.0	87.5	87.5	86.7	88.6	87.5	86.3
Hydrogen (% m/m)	13.4	12.5	13.5	12.9	13.0	10.9	13.8
Nitrogen (% m/m)	<0.05	0.19	<0.05	<0.05	<0.05	0.41	<0.05
Oxygen (% m/m)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulphur (% m/m)	0.08	0.53	0.09	1.2	0.23	2.2	0.06
Ash (% m/m)	<0.005	<0.05	<0.005	—	<0.01	0.06	<0.01

[a] Fuel also classed as wide range distillate (WRD). For ship B, only AE5 operated with MGO/WRD fuel.
[b] Given as phenanthrene equivalents.

shipping fleet in general. The crankcase engine speeds of the measured AEs were largely medium speed but some could be classed as high speed (ship F).

All measurements were conducted over the period January–December 2002. Of the 22 AEs on board the six ships, the number and scope of sampling events were reduced in several cases especially regarding engines of the same model due to time and budget limitations. Since the study focused on real-world operating conditions, so-called emergency engines on board the ships, which are not normally used, were excluded from the measurements. For ships normally using only one or two AEs continuously during a harbour stop out of a larger number of available AEs, arrangements were made so that measurements could be made on all AEs. So for example, on board ships A–D, some AEs were stopped and other started to enable emission measurements on all engines. Since this procedure did not alter the total power requirement for the ships, the measured emissions still reflected real-world operation. The engine loads applied during the measurements were entirely dictated by the operational requirements and thus measurements at specific engine load settings (as in standard test cycles) were not undertaken.

2.2. Exhaust sampling location

Sampling locations along the exhaust channels were chosen with regard to obtaining a representative sample and practical considerations, i.e. available space for the gas analysers, ambient temperatures, and safety regulations. The most suitable solution was often to choose a site in the engine casing within the funnel housing although an engine room location on the lower decks was also used. In all cases, an adequate number of straight exhaust channel diameters were present upstream (> 5) and downstream (> 2) of the sampling holes, thus minimising error from uneven cross-sectional concentration profiles. On most exhaust channels two sample holes with threaded plugs were used (2″ and $2\frac{1}{2}$″ size).

2.3. Measurement parameters and methodology

All measurements were based on international standard procedures where possible (International Organisation of Standardisation, 1996b, 2000; International Maritime Organisation, 1998). Thus, some measurements (e.g. NO_x, carbon monoxide (CO), hydrocarbons

(HC), carbon dioxide (CO_2), oxygen (O_2)) relied on continual sampling with data logged on-line with a computer, while other parameters were based on grab samples (particulate matter (PM) and polyaromatic hydrocarbons (PAH)) taken over a given time period. In addition to those at the exhaust channel sampling sites, other periodic measurements of air temperature, humidity and pressure were undertaken at the air intake of the engine in the engine room. Furthermore, AE generator power was periodically (5–10 min intervals) registered from the existing instrumentation in the engine control room. An overview of the measurement parameters, methods and instrumentation together with relative uncertainty is presented in Table 4.

Concentration measurements of NO_x, CO, HC, CO_2 and O_2 were carried out using a continual emission monitoring system (CEMS) based on automatic gas analysers. Data collection, calibration and determination of NO_x and PM correction factors for ambient conditions are described elsewhere (Cooper and Andreasson, 1999; International Organisation of Standardisation, 1996b). In view of the relationship between theoretical (from fuel sulphur content) and measured exhaust SO_2 (Lloyd's Register Engineering Services, 1995), SO_2 emissions were calculated indirectly from fuel sulphur content and fuel consumption.

Total PM was sampled using a partial flow dilution system with CO_2 concentration measurement for determination of dilution ratio and fractional sampling (Cooper, 2001; International Organisation of Standardisation, 1996b). In most cases, two or three 20-min grab samples were taken during steady engine load conditions and the average value used in the subsequent evaluation. In addition to total PM sampling, other techniques were tested to investigate PM size fractions. Thus for one sample on board ship D, the glass fibre collection filter used in the dilution system was replaced by a polycarbonate filter which was then submitted for sweep electron microscopy analysis (SEM). On board ship A, an in-stack, eight-stage cascade impactor was tested where PM sizing was obtained by gravimetric analyses of the different filters. In this case, two samples were taken (one on AE5 using MGO and one on ME3 using RO of grade IF180 with 0.5% m/m sulphur content) to investigate fuel dependency on PM size. It should be borne in mind that the PM sizing exercises were carried out only as preliminary tests prior to a more thorough investigation planned.

Bearing in mind the time and equipment required for PM sampling following international standard procedure, some investigations have relied on much simpler soot number scales based on darkening of filter paper after exhaust exposure to indicate trends in emissions (Hountalas, 2001). In order to compare these types of measurements, a Bacharach soot tester (oil burner scale from 0 to 10 corresponding to filter colouration) was used directly after the PM measurements with the dilution system.

Following previous experience of PAH sampling on board ships (Cooper et al., 1996; Cooper, 2001), the

Table 4
Measurement parameters, equipment used and relative uncertainty (all gas parameters were measured in the dry exhaust gas except for HC and PM in the wet exhaust gas)

Parameter	Equipment (analysis method)	Uncertainty
NO_x (ppm)	Ecophysics CLD 700EL gas analyser (chemiluminescence)	±5%[a]
CO (ppm)	Maihak multor 610 gas analyser (infra-red absorption)	±8%[a]
CO_2 (vol%)	Maihak multor 610 gas analyser (infra-red absorption)	±6%[a]
O_2 (vol%)	Maihak multor 610 gas analyser (paramagnetic)	±5%[a]
HC (ppm C)	J. U. M. model VE7 gas analyser (flame ionisation)	±11%[a]
PM (mg nm^{-3})	Partial flow dilution system (gravimetric analysis)	±5%[b]
Soot No.	Bacharach oil burner scale (0–10) (darkening of filter paper)	n. a.
PAH (μg nm^{-3})	In-stack filter, absorption on PUF/XAD-2 (GC-MS analysis)	±10%[b]
Exhaust temp. (°C)	Fischer–Rosemount thermoelement 244P-MV1 (in situ)	±1%[b]
Ex. flow (wet nm^3 h^{-1})	Calculation using carbon balance	±5%[b]
Barom. pressure (kPa)	Vaisala analogue barometer model PTB 101B	±0.1%[b]
Air temp. (°C)	Nordtec testo 600	±2%[b]
Rel. air humidity (%)	Nordtec testo 600	±2%[b]
Engine load (kW)	From ship instrumentation for generator power[c]	±5%[b]
Fuel consumption (g kWh^{-1})	From engine test protocol and corrected for fuel calorific value	±10%[b]
SO_2 (g kWh^{-1})	From S content in fuel analysis and fuel consumption data	±10%[b]

[a] Accredited method with uncertainty at the 95% confidence interval defined by the Swedish Board for Technical Accreditation (SWEDAC).
[b] Estimated error or specified by instrument manufacturers (assumed as one standard deviation or at 68% confidence interval).
[c] Brake power calculated by assuming a 5% energy loss up to the generator or as specified by engine manufacturer.

PAH measurement technique used was based on the in-stack filter method which corresponded to sampling variant B in International Organisation of Standardisation (2000). Exhaust samples were drawn and filtered through a quartz fibre filter held inside the exhaust channel using borosilicate glassware. Thereafter, the sample was cooled and passed through a cartridge containing PUF (polyurethane foam) and XAD-2 (polyvinylbenzene resin) as PAH adsorbents. Rather than using a continual supply of cold water or portable compressor cooler equipped with a circulation pump, cooling of the sample gas was achieved by passing the sample gas through a series of glass condenser traps cooled in an ice bath. Since diesel PM are mostly submicron (Section 3.3), conditions for isokinetic sampling could be relaxed. Instead, the sample flow could be chosen with respect to analysis detection limits and maintaining the sample temperature $<20^{\circ}C$ prior to the adsorbent cartridge. This approach for sample cooling during PAH sampling significantly simplified time, location, and equipment factors without impairing measurement quality. In practice, grab samples of 1–2 h were taken with sample volumes of 0.12–0.33 nm^3 dry gas. PAH analyses were undertaken at the IVL laboratory in Gothenburg using gas chromatography and mass spectrometry (GC–MS). All PAH sample fractions, in particular, gas and liquid phase (in condense and acetone wash) PAH, were combined after extraction. An internal standard was used in the GC–MS analysis procedure and the results corrected for recovery of the standard.

Since AE operation was at a reasonably stable engine load for most of the time, exhaust gas flow, and thus specific emissions, could be calculated reliably via the carbon balance method (i.e. carbon input from the fuel balanced against carbon output in the form of measured CO_2) (International Maritime Organisation, 1998).

3. Results and discussion

For conciseness, a general overview of the concentration and emission intervals measured is shown in Table 5 and Fig. 1. Relative uncertainty (at the 95% confidence level) associated with the emission factors in g kWh^{-1} are estimated as $\pm 10\%$ (SO_2, CO_2), $\pm 17\%$ (NO_x, CO), $\pm 20\%$ (PM, HC), and $\pm 30\%$ (PAH). It can be noted that emissions expressed as g $kg\ fuel^{-1}$ can be obtained by dividing the g kWh^{-1} emission factors by the fuel consumption in g kWh^{-1} multiplied by 0.001 given in Table 5.

3.1. NO_x, SO_2, CO, HC, CO_2 and PM emissions

Fuel-dependent specific emissions of CO_2 and SO_2 are a direct reflection of the carbon and sulphur contents of

Table 5
AE measurement results at steady-state engine load operation

Ship/engine	A/AE1–AE5	B/AE1–AE4	B/AE5	C/AE1–AE6	D/AE1–AE2	E/AE1	E/AE3	F/AE1–AE2
Load (% of max.)	45–63%	47–58%	59%	36–50%	43%–48%	41%	39%	63%
Fuel type	MGO	RO	MGO	MGO	MDO	RO	RO	MGO
NO_x (ppm)	930–1393	1002–1232	1559	967–1278	901–926	1225	1005	1502–1620
CO (ppm)	69–102	121–216	—	43–67	139–144	118	97	101–102
CO_2 (vol%)	4.52–5.20	5.61–6.13	6.29	4.78–5.40	6.52–6.66	5.74	5.57	5.98–6.32
O_2 (vol%)	13.29–14.59	12.64–13.28	12.34	13.63–14.47	12.08–12.51	13.11	13.76	12.73–12.10
HC (ppm C)	30–48	17–32	107	42–61	58–68	46	47	81–87
PM (mg nm^{-3})	27–56	62	45	40–57	29–31	98	79	21–26
PM (Bach. soot scale)	4–6	6–7	7	3–5	7	6	6	6
PAH (μg nm^{-3})	—	170–220	—	23–29	370–400	1810	1400	250–290
Ex. flow (wet $nm^3\ h^{-1}$)	3290–4400	4520–4990	4970	2620–3320	3580–4150	7150	5310	2640–2790
Ex. temperature (°C)	301–405	315–335	359	273–340	372–381	361	335	342–363
Fuel cons. (g kWh^{-1})	205–219	238–251	240	216–223	213–214	216	217	214
Charge air temp. (°C)	30–43	33–43	33	30–40	46–49	48	53	—
Charge air press. (bar)	—	—	—	0.20–0.50	7.0–8.5	0.6	0.6	—
NO_x (g kWh_{corr}^{-1} [a,b])	14.9–19.2	13.3–17.5	20.2	14.2–18.6	9.6–9.9	15.2	12.9	17.5–17.9
CO (g kWh^{-1})	0.57–0.97	1.06–1.71	—	0.33–0.57	0.92–0.98	0.90	0.77	0.69–0.73
CO_2 (g kWh^{-1})	653–699	763–803	768	686–708	691–694	691	697	676
HC (g kWh^{-1})	0.12–0.21	0.07–0.14	0.41	0.19–0.25	0.19–0.23	0.17	0.19	0.29–0.30
PM (g kWh_{corr}^{-1})[a]	0.21–0.45	0.48	0.31	0.30–0.44	0.17–0.19	0.67	0.54	0.14–0.16
PAH (mg kWh^{-1})	—	0.9–1.5	—	0.15–0.19	1.9–2.0	11	9.5	1.4
SO_2 (g kWh^{-1})	0.33–0.35	2.5–2.7	0.4	5.2–5.3	1.0	9.5	9.6	0.26

[a] Corrected for ambient conditions according to International Organisation of Standardisation (1996b).
[b] NO_x emissions expressed as g NO_2 kWh_{corr}^{-1}.

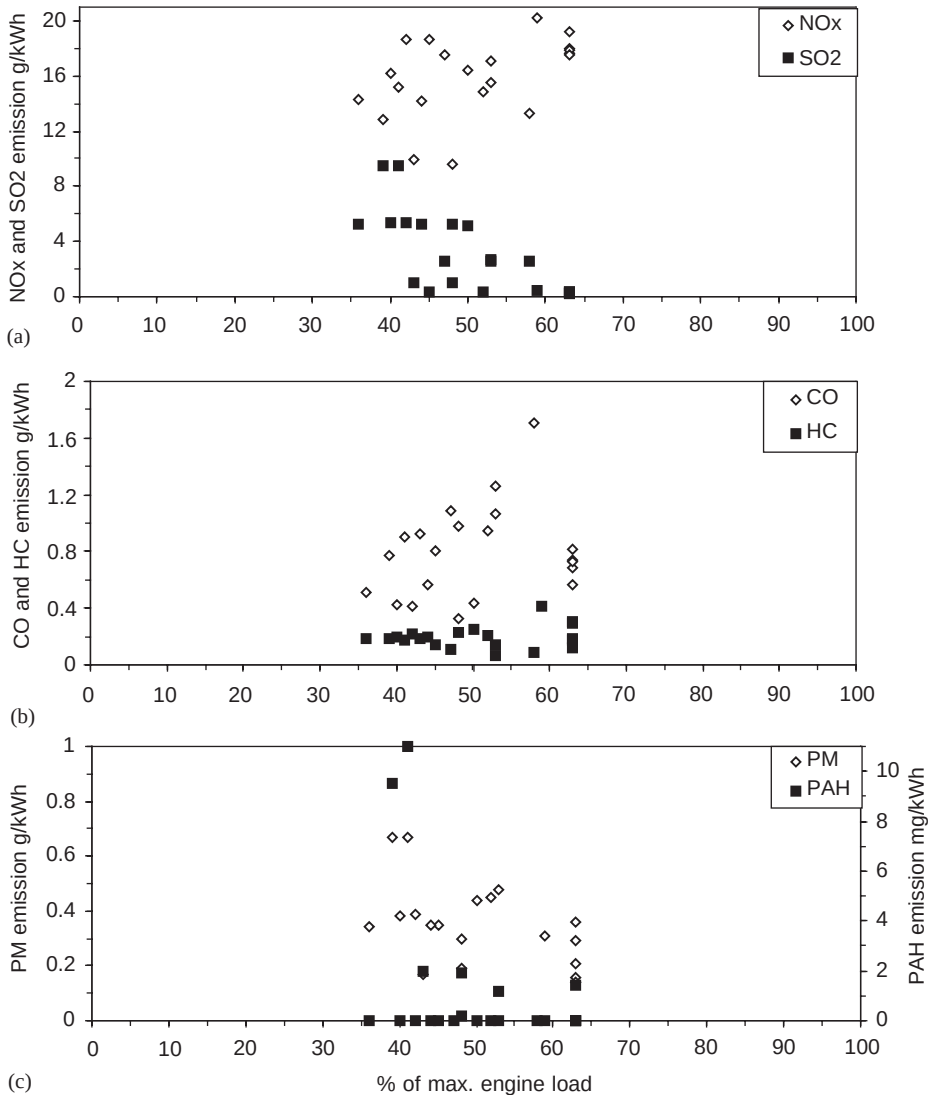


Fig. 1. Measured specific emissions against engine load.

the fuel used combined with the fuel consumption of the AEs. Since the variations in fuel carbon content (Table 3) and fuel consumption (Table 5) are small, CO_2 emissions are relatively well defined and similar for most AEs. For SO_2, significantly reduced emissions are evident when fuels with low sulphur contents are used (compare ships E and F). In view of the fuels used on the measurement ships and those of the fleet in general (European Commission, 2002a) where fuels of higher sulphur content are used, the SO_2 emissions reported in this study are probably lower than for the world fleet in general.

NO_x, CO and HC emissions varied considerably across the data, i.e. between 9.6–20.2 g kWh_{corr}^{-1}, 0.33–1.71 g kWh^{-1}, and 0.07–0.41 g kWh^{-1}, respectively. Smaller variations were also apparent between engines on the same ships (similar model, age, and fuel). For example, the six AEs on ship C had emission ranges of 14.2–18.6 g kWh_{corr}^{-1} (NO_x), 0.33–0.57 g kWh^{-1} (CO), and 0.19–0.25 g kWh^{-1} (HC). These emissions are more dependent on the local combustion conditions and, therefore, individual maintenance and service history. Higher nitrogen contents in the fuel will theoretically promote higher NO_x emissions but in the present data other factors have a greater influence (compare ships E with F and also the AEs on ship B in Tables 3 and 5). Similarly, NO_x emissions have been correlated with engine speed (International Maritime Organisation, 1998), i.e. the slower the engine speed, the longer the time period at high temperatures and, therefore, greater

thermal fixation of nitrogen in the combustion air occurs giving higher NO_x emissions. In the present data, however, the two high-speed engines on ship F had some of the highest NO_x emissions. Thus, due to the numerous differences between engines operating in the real world, the validity of accepted NO_x correlations can be questioned for a limited group of engines.

The corrected PM emission levels measured varied between 0.14 and 0.67 g kWh_{corr}^{-1}, for the entire data set and the variation between engines on the same ship appeared to be similar to that observed for CO and HC. Generally, PM emissions from marine diesels can be categorised as being both fuel dependent (sulphates and metal oxide ash constituents) and also dependent on combustion conditions (unburnt HC and carbon residue constituents). Thus higher fuel sulphur and ash contents as for AE1 and AE3 of ship E for example gave rise to higher PM emissions. Fuel dependency on PM emissions is however less pronounced than for CO_2 or SO_2 emissions, since combustion conditions can greatly affect PM emissions. The obtained soot number values (Bacharach oil burner scale) or black smoke index and the measured uncorrected PM concentrations by the dilution system for 19 measurements, varied between 3–7 and 23–103 mg nm^{-3}, respectively. No clear correlation between the entire data set and between AEs with the same fuel could be observed, i.e. a low Bacharach oil burner soot number does not necessarily imply a low PM concentration and vice versa. For individual engines, however, a correlation between soot number index and PM concentrations may exist (not investigated in this work).

Although instantaneous specific emissions were not determined in this study, the concentrations measured at start-up of AE3 on ship A (Fig. 2a), clearly indicate elevated CO and HC emissions with engine ignition. For this start-up, the engine (shut down for the previous 11 h) was operated to give a step increase up to 57% of maximum load, which was then maintained for approximately 4 h thereafter. The elevated emissions appear to be quite short lived and within a 1-min period the CO and HC concentrations stabilised to their steady-state levels. In contrast, NO_x emissions increased steadily at start-up. Similarly the rapid engine load changes associated with engaging bow thrusters prior to ship departure, gave rise to only very short-term increases in CO and HC emissions (Fig. 2b). Thus relative to the length of the harbour stops, the periods with abrupt engine load changes, e.g. start-ups, appear to be minor and thus no significantly excessive HC or CO emission cases can be identified.

Previous marine emission measurement studies have dealt mostly with those emissions arising from MEs for ship propulsion. A set of AE emission factors has, however, been reported in a recent review (European Commission, 2002a). In general, the present data are in good agreement with the review factors, although lower HC and PM emissions have been measured for ships A–F. Two other investigations have reported universal emission factors based on empirical functions from a very limited experimental data set (each on four diesel AEs) (Lloyd's Register Engineering Services, 1995; Trozzi and Vaccaro, 1998). For a sample of 10 measurements from ships A–F in this work, the Lloyd's function overpredicted NO_x emissions on average by 64%, CO emissions by 323% and HC emissions by 522% while the Trozzi and Vaccaro function is not applicable since this empirical function was restricted to engines only in the 20–500 kW size interval.

3.2. PAH emissions

The speciated and total PAH emissions determined are presented in Table 6 and Fig. 1c. Where concentrations were analysed as below the detection limit, half of the detection limit has been used in calculating the sum of total PAH. The data compare well with previous PAH measurements on marine diesel engines (Cooper et al., 1996; Cooper, 2001; Lloyd's Register Engineering Services, 1995). Between 63% and 92% of the total PAH emission in each sample is accounted for by the five napthalenes and the two phenanthrenes, which is typical of diesel exhaust (Khalili et al., 1995). Total PAH emissions were mostly in the range 0.15–2.0 mg kWh^{-1} except for two samples from ship E (9.5 and 11 mg kWh^{-1}) which used an RO fuel with a significant PAH content (Table 3). Although PAH analyses are lacking for some of the fuels in this study, the results obtained in this study indicate that fuels with higher PAH contents (typically RO) are likely to give higher PAH exhaust emissions. This type of correlation has also been established for diesel road vehicles which are driven increasingly with Environmental Class 1 diesel fuel (maximum PAH content 0.02% m/m) (Wingfors et al., 2001).

Total PAH is defined above as the sum of the 29 species listed in Table 6. It should be borne in mind, however, that the definition of "total PAH" is a rather loose term and can vary. For example, French authorities list seven components (not including naphthalene) while the American EPA list includes 16 species (including naphthalene) (European Commission, 2001). The International Standards Organisation choose not to list specific PAH species but merely define PAH as "compounds that contain two or more fused aromatic rings made up only of carbon atoms" (International Organisation of Standardisation, 2000). For national emission reporting of PAH, the United Nations Economic Commission for Europe (UNECE) require the sum of only 4 species (see UNECE species in Table 6) (United Nations, 2002).

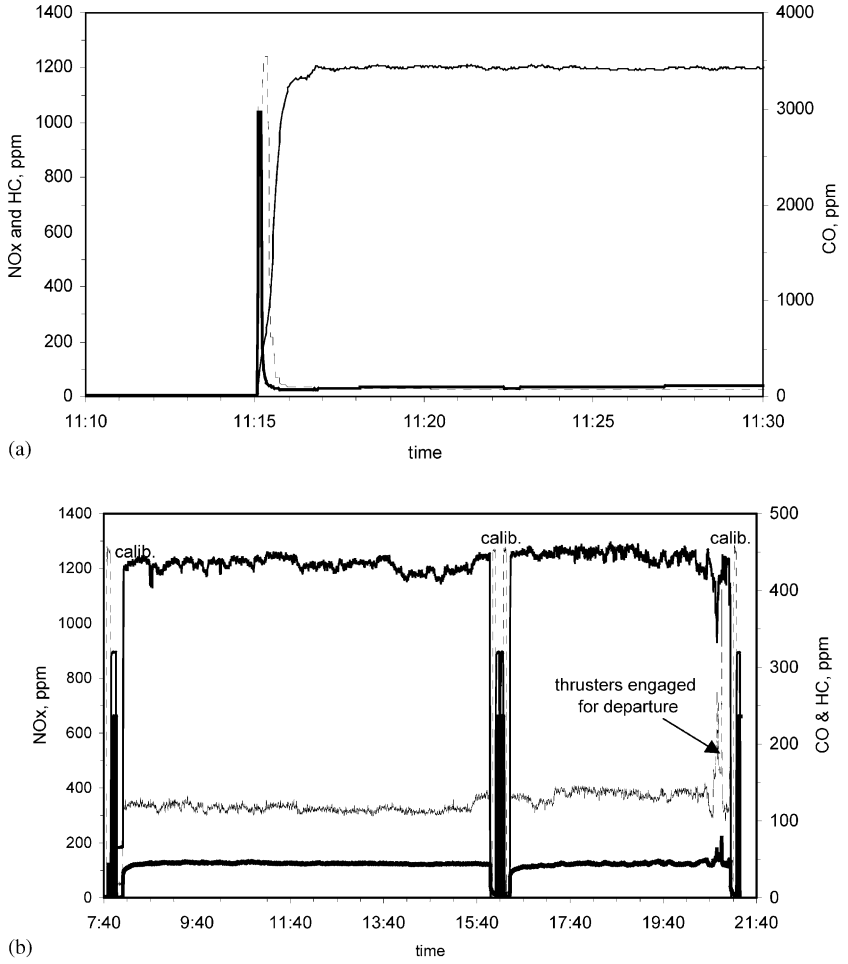


Fig. 2. NO_x (top line), HC (bold line) and CO (dashed thin line) concentration profiles during: (a) start-up of engine (AE3 on board ship A), and (b) loading/unloading activities over a 14-h period prior to departure for AE1 on board ship E (three calibration periods included).

3.3. PM sizing experiments

The results from the PM sizing experiment using the dilution tube and SEM analysis for ship D are presented in Table 7. The number of particles in % of total at different size intervals was counted and calculated at suitably chosen magnifications while PM as % m/m were calculated assuming uniform density (1 g cm^{-3}) and an average diameter for a given size interval. Although this technique for PM size distribution is relatively simple to perform, the drawback when compared to other techniques (impactors, etc.) is that all particles are collected on one filter with risk for agglomeration (i.e. biased towards larger particles).

The results from the particle sizing experiment using the cascade impactor on board ship A are presented in Table 8. The disadvantage with this technique is that a proportion of the fine particulates formed from condensing HC compounds (nuclei mode) will be missed since the impactor was mounted in the hot exhaust. This can be compared with the temperature in the dilution tube which is kept $<52^{\circ}C$ to prevent these losses (International Organisation of Standardisation, 1996b). In comparing the data in Tables 7 and 8, the larger particles account for more of the total PM mass in the ship D sample which may however be a consequence of agglomeration. Although the data are far too few to draw any firm conclusions, the smaller particles (<1 μm) appear to dominate in number but may only account for 10–50% of the total mass.

Since PM size distributions from operating marine diesel engines on board ships are lacking in the literature, the present results, although preliminary, provide a first assessment that needs to be verified. One previous study has however reported PM size data in exhaust plumes 0.6–1 km downwind of passing ships

Table 6
Speciated PAH emissions (μg kWh^{-1}) and total PAH emissions (mg kWh^{-1})

Ship/engine	B/AE1	B/AE1	B/AE1	C/AE1	C/AE1	D/AE1	D/AE2	E/AE1	E/AE3	F/AE2	F/AE2
Load (% of max.)	55%	43–58%	56%	51%	48%	43%	48%	41%	39%	32%	63%
Naphthalene	560	670	420	98	72	740	490	4740	5850	550	300
2-Methyl-naphthalene	250	310	160	38	31	540	510	1230	1080	260	190
1-Methyl-naphthalene	150	190	92	19	15	280	290	810	670	230	160
Biphenyl	16	14	8	3	4	95	73	1060	1460	78	56
2,6-Dimethyl-naphthalene	52	81	36	12	12	69	100	190	170	50	53
Acenaphthylene	2.1	3.4	0.7	0.4	0.4	<1.3	<2.1	<2.0	<4.0	4	3
Acenaphthene	5.4	7.9	2.6	0.3	0.3	<1.1	<1.8	30	25	26	22
2,3,5-Trimethyl-naphthalene	11	18	10	1.1	1.1	14	23	34	34	25	21
Fluorene	45	72	30	1.6	1.1	33	42	150	150	91	56
Dibenzothiophene	8.9	14	12	0.2	0.1	28	31	73	110	24	18
Phenanthrene	88	130	80	0.7	0.5	150	179	810	980	420	280
Anthracene	0.9	1.3	<0.5	<0.2	<0.2	<1.4	<2.3	14	<5.0	27	14
2-Methyl anthracene	3.5	<0.7	<1.3	<1.5	<0.1	<1.1	<1.9	<1.0	<3.0	<0.1	<0.1
1-Methyl-phenanthrene	<0.2	<0.2	<0.3	<0.3	<0.3	28	76	140	130	<0.2	<0.2
1-Methyl anthracene	1.8	2.2	<1.1	<0.1	<0.1	8	22	37	33	106	67
Fluoranthene	2.2	1.0	<1.2	<0.1	<0.2	8	14	10	99	150	49
Pyrene	<1.0	<0.3	<0.2	<0.1	<0.1	6	13	56	33	190	67
Retene	<0.3	<0.1	<0.1	<0.1	<0.1	<0.6	<1.0	<1.0	<2.0	32	17
Benz(a)anthracene	<0.9	<0.4	<0.5	<0.6	<0.6	<1.0	<1.6	8	6	19	7
Chrysene	<0.2	<0.2	<0.3	<0.3	<0.4	<0.8	10	27	32	42	15
Benzo(b)fluoranthene (UNECE)	<0.3	<0.3	<0.4	<0.4	<0.4	<0.9	<1.6	<2.0	<5.0	22	7
Benzo(k)fluoranthene (UNECE)	<0.5	<0.5	<0.7	<0.7	<0.7	<0.8	<1.4	<2.0	<4.0	6	2
Benzo(e)pyrene	<0.5	<0.2	<0.2	<0.2	<0.2	<0.9	<1.4	6	<4.0	12	4
Benzo(a)pyrene (UNECE)	<0.5	<0.5	<0.7	<0.7	<0.8	<1.5	<2.5	<4.0	<9.0	4	2
Perylene	<0.4	<0.4	<0.6	<0.6	<0.6	<1.2	<2.0	<3.0	<8.0	<0.2	<0.2
Indeno(1,2,3-c,d)pyrene (UNECE)	<1.2	<1.1	<1.5	<1.7	<1.7	<11	<15	<17	<44	16	3
Dibenzo(a,h)anthracene	<1.5	<1.4	<1.9	<2.1	<2.1	<10	<15	<16	<43	16	18
Benzo(g,h,i)perylene	<0.5	<0.5	<0.7	<0.7	<0.7	<11	<15	<17	<44	21	3
Coronene	<1.1	<1.0	<1.4	<1.5	<1.6	<18	<27	<29	<76	<0.3	<0.3
Sum of above 29 PAH (mg kWh^{-1})	1.2	1.5	0.9	0.18	0.14	2.0	1.9	9.5	11.0	2.4	1.4
Sum 4 PAH (UNECE) (mg kWh^{-1})	<0.001	<0.001	<0.002	<0.002	<0.002	<0.007	<0.01	<0.01	<0.03	0.047	0.013

using a differential mobility particle sizer (DMPS) (Isakson et al., 2001). This work presented only submicron PM number and mass size distributions, i.e. nuclei and accumulation modes. Previous particle size distributions from large stationary diesel engines have been reported as 77% m/m as <1 μm, 0.2% m/m in the range 1–3 μm, 2.7% m/m in the range 3–10 μm, and 20% m/m as >10 μm (US Environmental Protection Agency, 1996). Heavy-duty diesel road vehicles have exhaust PM number size distributions which have been described as being trimodal, i.e. three peaks, which may or may not overlap, are observed in the mass distribution (Brown et al., 2000). These are denoted nuclei mode (condensing HC volatiles) 0.01–0.1 μm, accumulation mode (carbon species and adsorbed material) 0.1–1 μm, and the coarse mode (re-entrained particles) 1–10 μm. For heavy-duty diesel road vehicles, the number distribution has been shown to be dominated by the nuclei mode while for the mass distribution the accumulation mode dominates.

3.4. Auxiliary engine operation and emissions from case studies

For most of the time spent at berth, power requirements of the ships were fairly constant and considerably less (9–49%) than the total installed AE power. This means that some AEs were not operated and the power output for individual AEs was usually only 25–60% of maximum. A questionnaire study targeting ME and AE operation for 81 ships (Flodeström, 1997) confirm that these AE power outputs for normal operation appear to be representative.

Procedure for standard emission test measurements ought to consider real-world operation in assigning engine load set points. Current Swedish legislation for

Table 7
PM size data from AE1 of ship D (dilution tube and SEM analysis)

Size interval (μm)	Number of particles (%)	PM (% m/m)
<0.5[a]	60.6±4.0	0.4±0.1
0.5–1	37.0±4.0	7.3±2.5
1–2[b]	1.1±0.3	1.8±0.8
2–5	1.1±0.2	22.7±1.2
5–10	0.1±0.05	25.1±3.6
10–20	0.0	30.7±5.6
>20[a,b]	0.0	12.0±6.5
Sum	100.0	100.0

[a]Average diameters in these intervals taken as 0.25 and 21 μm, respectively, for calculation purposes.
[b]Number of counted particles in this interval was <10.

Table 8
PM size data from AE5 and ME3 of ship A (in-stack cascade impactor)

Size interval (μm)	PM (% m/m) AE5 (MGO fuel)	PM (% m/m) ME3 (RO fuel)
0–0.59	39.1±4.6	32.5±3.6
0.59–0.86	7.8±0.9	6.0±0.7
0.86–1.4	10.9±1.3	6.0±0.7
1.4–2.8	12.5±1.5	9.6±1.1
2.8–4.3	6.3±0.7	14.5±1.7
4.3–6.3	9.4±1.1	7.2±0.8
6.3–9.3	4.7±0.5	10.8±1.3
9.3–14.9	6.3±0.7	8.4±1.0
>14.9	3.1±0.4	4.8±0.6
Sum	100.0	100.0

determination of the NO_x reduction certificate specifies, however, emission measurements at the 75% engine load set point for both MEs and AEs (Swedish Maritime Administration, 1998). Based on this work and others (Det Norske Veritas, 2000), a 50% AE load set point would be more appropriate. Similarly, the D2 weighting factors used for constant speed AEs in the IMO technical NO_x code (International Maritime Organisation, 1998) are biased towards higher loads, i.e. 0.05 for 100% and 0.25 for 75%.

An example of the AE load observations on board ship F for two harbour stops (one unloading and one loading cargo) is shown in Fig. 3. In this case, the power requirement was significantly greater during unloading cargo since the on board cargo pumps were in use. For loading operations, however, the pump power is normally supplied by a shore-side source. Such differences in AE operation and consequently emissions, however, are mostly limited to tankers and other self-unloaders carrying dry bulk products, e.g. cement, which have these operational alternatives at berth. In general, these type of ships will often utilise ME power (equipped with a shaft generator) while in berth if the installed AE power is insufficient.

For the other five ships studied, the AE load operation was reasonably stable, and according to the chief engineers, the power requirement very similar for all harbour stops. Thus, the measured exhaust component concentrations showed little variation (see Fig. 2b) and the resulting emission factors could be assumed valid for most harbour stops. For a short, approximately 5-min period after arrival at the quayside, however, and approximately 15 min before departure, the power requirement for all the ships studied increased to 40–56% of the total installed AE power when bow and stern thrusters used for manoeuvring the ship were engaged. Since these time periods were relatively small compared to the total time spent in berth, their emissions can be approximated using the same emission factors measured at slightly lower and more constant engine loads. Emissions were measured at partial engine loads of 39–63% of maximum, and in some cases where time allowed, specific emissions were determined at two different loads. For example, emissions were measured from AE2 on board ship F at approximately 32% and 63% engine load. The latter case was the predominant engine load used while unloading cargo (Fig. 3).

By using the emission factors determined for each AE combined with the periodic engine load observations, an estimate of the emissions from the AEs during actual harbour stops (at two Swedish and two German ports) could be calculated (Table 9). Relative uncertainty (at the 95% confidence level) associated with the calculated total emissions in kg are estimated as ±14% (SO_2, CO_2), ±20% (NO_x, CO), ±22% (PM, HC), and ±32% (PAH). Note that these emissions are only from the AEs, covering the time from when the ship is stationary at berth and up to the point of departure from the quayside. These time periods appear representative of the respective ship type in view of results from 14 European port authorities (European Commission, 2002a). Median times for hotelling and loading/unloading operations were reported from a questionnaire as 18 h (chemical tankers), 13.6 h (passenger ferries), and 38.5 h (general cargo).

Other emissions from boiler use and possible warm-up of MEs whilst in berth were not measured due to budget limitations but estimated based on operational information from the chief engineers and universal emissions factors in the literature (European Commission, 2002a; US Environmental Protection Agency, 1998). It should be noted that ships with a fixed propeller shaft (e.g. ships D and E) do not have the ability to warm up MEs whilst stationary in berth. This type of propulsion system is common for larger cargo ships but virtually absent in, for example, passenger ferries. For the six ships, average

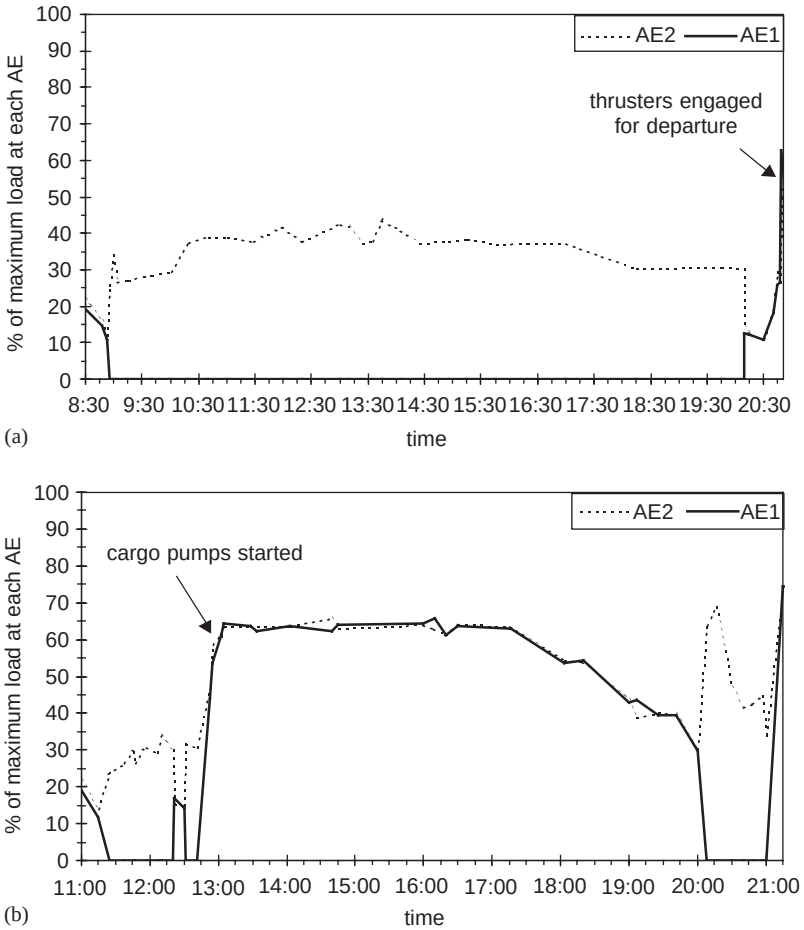


Fig. 3. AE power output for ship F: (a) harbour stop loading cargo, and (b) harbour stop unloading cargo. AE3 was not operated in either case.

Table 9
Estimates of total AE emissions (kg), fuel consumption (kg) and total power requirement (kWh) for the six measurement ships during actual harbour stops

Ship	A	B	C	D	E	F[a]	F[b]
Time in berth (h:min)	7:15	10:30	14:30	13:00	54:00	11:00	12:00
NO_x	131	260	303	178	652	133	50
CO	5.0	16	8.3	17	39	5.7	3.3
CO_2	5224	12050	13180	12650	31800	5250	2390
HC	2.6	2.3	3.9	3.8	8.2	2.3	1.1
SO_2	2.6	35	100	18	437	2.0	0.9
PM	1.2	6.2	6.8	3.3	28	1.2	0.51
PAH	0.0091	0.019	0.0032	0.036	0.48	0.012	0.007
Fuel consumption	1642	3754	4150	3890	9925	1660	756
Total power	7410	15420	18500	17960	45800	7550	3240

[a] Refers to chemical tanker unloading cargo (91% of max. capacity) using on board pumps.
[b] Refers to chemical tanker loading cargo (92% of max. capacity) not using on board pumps.

boiler emissions calculated as per cent of the AEs emissions were 1.1% (PAH), 2.8% (NO_x), 5.6% (HC), 7.1% (CO), 25% (PM), 48% (CO_2) 85% (SO_2). Generally, boilers are in continual use while in berth and the amount of fuel used was estimated to vary from 18 to 106% of the AE fuel consumed (48% as average value). Similarly, ME emissions during warm-up before departure were calculated as per cent of the AEs emissions for the four ships (A–C, and F) as 1.2% (NO_x), 1.6% (CO_2), 4.5 (PAH), 6.4% (HC), 6.8% (CO), 15% (PM), 33% (SO_2). No in-berth ME emissions could be attributed to ships D and E due to the fixed propeller power arrangement. Summarising, ME and boiler emissions can give significant emissions of SO_2 relative to those from the AEs. This is especially so in cases where AEs are run on low sulphur MGO while the boilers and MEs use RO (with higher fuel sulphur contents).

Interestingly, the emissions for ship B could be compared with emissions from an identical stop (in terms of time and operations) at a different port where a shore-side power link was used instead of AEs to supply electric power. In this case a Swedish power mix (including 48% hydroelectric power, 44% nuclear power, and 3% biomass power) and their emissions kWh^{-1} were used in the calculation (Stripple, 2002; Vattenfall, 1996). Thus for the shore-side link, emissions as per cent of the AE case were estimated as 0.2% (NO_x), 0.7% (SO_2), 1.1% (CO), 1.7% (PM), 2.4% (CO_2) and 7.6% (HC).

Since different ship types have widely different power requirements which reflect their purpose and equipment on board, no simple correlation between power requirement at berth and gross register or dead weight tonnage could be determined within the data for the six ships studied. For the three passenger ferries, however, the average power requirement correlated reasonably well with dead weight tonnage. Using this relationship and mean values for the measured emission factors from the 16 AEs on board the passenger ferries, formulae for calculating AE emissions from these passenger ferries at berth can be derived (Table 10). By comparing with the actual emissions in the case studies in Table 9, a level of uncertainty is obtained for the model. Thus, for a 10 h 30 min harbour stop for ship B, the model predicts a total NO_x emission of 254 kg (i.e. $0.00616 \times 3938 \times 10.5$) which is only a 2% underprediction of the measured emission of 260 kg (Table 9). Bearing in mind the uncertainty in the measurements, these formulae may give a useful and cost-effective emission prediction from fundamental input parameters for similar sized passenger ferries. It is possible that given an extended experimental data set, similar empirical formulae for other ship classifications may be derived thus simplifying harbour emission inventories.

Table 10
Universal functions for predicting AE emissions in kg from in berth passenger ferries based on their deadweight (Dwt in ton), time in berth (t in h) and AE fuel sulphur content (S in % m/m)

		% Difference with case studies[a]		
Emission (kg) $= k \cdot \mathrm{Dwt} \cdot t$	k	Ship A	Ship B	Ship C
NO_x	0.00616	0	2	2
CO	0.00029	−18	35	−40
CO_2	0.26345	−7	11	3
HC	6.63×10^{-5}	82	−16	23
SO_2	0.001651[b]	−7	16	4
PM	0.000131	−56	15	8
PAH	2.52×10^{-7}	69	78	−74
Fuel consumption	0.08257	−7	10	4
Total power	0.36716	−6	2	4

[a] Per cent difference between emissions measured in the three case studies for ships A, B and C in Table 9 and those predicted by the functions are shown. Negative values indicate an overprediction of the model.
[b] Emission (kg) $= k \cdot \mathrm{Dwt} \cdot t \cdot \mathrm{S}$.

4. Conclusions

To improve the limited knowledge regarding ship emissions while in berth, both specific ($g\ kWh^{-1}$) and total emissions (kg) of NO_x, SO_2, CO, HC, CO_2, PM and PAH were determined on board six ships during actual harbour stopovers, i.e. real-world emissions. The results obtained for the three passenger ferries demonstrate that empirically derived, emission formulae using dead weight tonnage can prove to be a cost-effective and relatively accurate tool for estimating total emissions from similar ferries in berth. Besides AE emissions, other emissions from boiler use and possible ME warm-up prior to departure were in general considerably less than those from the AEs, but can be significant especially for SO_2 if different fuel qualities are used. In light of eventual EU legislation to enforce low sulphur fuels in port areas, i.e. predominantly through increased MGO use, these results indicate that besides SO_2 and PM, PAH emission reductions may be expected. The measurements in this study show, however, that the variations in condition between engines in the real world and other factors affecting NO_x emissions, can hide, at least for individual engines, any expected improvements in these emissions due to the lower fuel nitrogen content of MGOs. Generally, the power consumption of the ships at berth was fairly constant and considerably less (9–49%) than the total installed AE power. Relative to the total time spent at berth, periods with abrupt engine load changes and higher loads (engagement of thrusters prior to departure) were insignificant. The observed AE operation on board the ships indicate that legislative

emission testing ought to focus on an engine load set point of 50% of maximum for AEs. A significant difference in power requirement was observed for the chemical tanker when loading and unloading (on board cargo pumps engaged) where the power requirement increased approximately by a factor of 2.5.

Acknowledgements

This project has been financed by the Port of Gothenburg, Stena Line, DFDS Seaways, the Swedish Maritime Administration, the Swedish Agency for Innovation Systems and the Swedish Environmental Department. Assistance and hospitality from the crew on board the measurement ships is gratefully acknowledged. In addition, the author thanks Magnus Ekström and Kjell Peterson (sampling), Britt Lindgren, Stefan Larsson, Bo Strandberg and Håkan Wingfors (PAH and PM analyses), Mathias Johansson (fuel analyses), Elke Hålenius (SEM analysis) and Eje Flodeström for useful discussions.

References

Brown, J.E., Clayton, M.J., Harris, D.B., King, F.J., 2000. Comparison of the particle size distribution of heavy-duty diesel exhaust using a dilution tailpipe sampler and an in-plume sampler during on-road operation. Journal of Air and Waste Management Association 50, 1407–1416.

Colvile, R.N., Hutchinson, E.J., Mindell, J.S., Warren, R.F., 2001. Millennial review—the transport sector as a source of air pollution. Atmospheric Environment 35, 1537–1565.

Cooper, D.A., 2001. Exhaust emissions from high speed passenger ferries. Atmospheric Environment 35, 4189–4200.

Cooper, D.A., Andreasson, K., 1999. Predictive NO_x emission monitoring on board a passenger ferry. Atmospheric Environment 33, 4637–4650.

Cooper, D.A., Peterson, K., Simpson, D., 1996. Hydrocarbon, PAH and PCB emissions from ferries; a case study in the Skagerak–Kattegatt–Öresund region. Atmospheric Environment 30, 2463–2473.

Corbett, J.J., 2002. Emissions from ships in the northwestern United States. Environmental Science and Technology 36, 1299–1306.

Corbett, J.J., Fischbeck, P.S., Pandis, S.N., 1999. Global nitrogen and sulfur inventories for oceangoing ships. Journal of Geophysical Research 104 (D3), 3457–3470.

Det Norske Veritas, 2000. Nordtest—simplified NO_x emission procedures based on IMO technical NO_x code. Technical Report NT TECHN Report 472, Det Norske Veritas , Oslo, Norway.

European Commission, 2001. Ambient air pollution by Polycyclic Aromatic Hydrocarbons (PAH)—Position Paper. ISBN 92-894-2057-X. www.europa.eu.int/comm/environment/air/ambient.htm.

European Commission, 2002a. Quantification of emissions from ships associated with ship movements between ports in the European Community. Entec UK Limited, July 2002. www.europa.eu.int/comm/environment/air/background.htm#transport.

European Commission, 2002b. A European strategy to reduce atmospheric emissions from seagoing ships. COM 2, 595. www.europa.eu.int/comm/environment/air/transport.htm#3.

European Environmental Agency, 2002. Annual European community CLRTAP emission inventory 1990–2000. Technical Report 91. http://reports.eea.eu.int/technical_report_2002_73/en.

Flodeström, E., 1997. Energy and emission factors for ships in operation. Swedish Transport and Communication Research Board, KFB Report 1997:24.

Hountalas, D.T., 2001. Study concerning the effect of fuel additives on performance and soot emissions of diesel engines. International Maritime Organisation MEPC 48/INF.8.

International Maritime Organisation, 1998. Annex VI to MARPOL 73/78 regulations for the prevention of air pollution from ships and NO_x technical code. Report IMO—664E.

International Organisation of Standardisation, 1996a. ISO 8217—petroleum products—fuels (class F)—specifications of marine fuels.

International Organisation of Standardisation, 1996b. ISO 8178—reciprocating internal combustion engines—exhaust emission measurement—parts 1 and 2.

International Organisation of Standardisation, 2000. ISO/DIS 11338—stationary source emissions—determination of mass concentration of polycyclic aromatic hydrocarbons—part 1: sampling.

Isakson, J., Persson, T.A., Selin Lindgren, E., 2001. Identification and assessment of ship emissions and their effects in the harbour of Göteborg, Sweden. Atmospheric Environment 35, 3659–3666.

Khalili, N.R., Scheff, P.A., Holsen, T.M., 1995. PAH source fingerprints for coke ovens, diesel and gasoline engines, highway tunnels and wood combustion emissions. Atmospheric Environment 29, 533–542.

Lloyd's Register Engineering Services, 1995. Marine exhaust emissions research programme. London, England.

Norwegian Ministry of Fisheries, 2000. Declaration for environmental differentiated shipping—Legislation 28 No. 1194, November 2000 (in Norwegian).

Skjølsvik, K.-O., 2000. Emissions from ships—The Fourth Stanley Gray lecture. Trans IMarE 1123, 95–102.

Stripple, H., 2002. IVL Swedish Environmental Research Institute Ltd., Gothenburg, Sweden. Internal IVL Report Consisting of Updated Data from Vattenfall, 1996.

Swedish Maritime Administration, 1998. Decrees concerning environmentally differentiated shipping; SJÖFS 1998:12 and SJÖS 1998:13 (English translation). Sjöfartsverket, Norrköping, Sweden.

Swedish Shipowners Association, 2002. Emissions trading scheme for NO_x and SO_2. Document prepared by Öhrlings and PriceWaterhouseCoopers. www.europa.eu.int/comm/environment/air/consultation_responses/swedishshipowners_response.pdf.

Trozzi, C., Vaccaro, R., 1998. Methodologies for estimating air pollutant emissions from ships. 22nd CIMAC International Congress on Combustion Engines, Copenhagen, 18–21 May 1998.

United Nations, 2002. United Nations Economic Commission for Europe—draft guidelines for estimating and reporting emissions data. Report EB.AIR/GE.1/2002/7.

US Environmental Protection Agency, 1996. Compilation of air pollutant emission factors—AP42, Vol. I, 5th Edition (Chapter 3.4 Large Stationary Diesel Engines) Office of the Federal Register National Archives and Records Administration. US Government Printing Office, Washington, D.C., USA.

US Environmental Protection Agency, 1998. Compilation of air pollutant emission factors—AP42, Vol. I, 5th Edition (Chapter 1.3 Fuel Oil Combustion) Office of the Federal Register National Archives and Records Administration. US Government Printing Office, Washington, D.C., USA.

Vattenfall, 1996. Electricity and the Environment—Life Cycle Analysis for Vattenfall's Electricity production—Summary Report. Vattenfall Energisystem AB, Stockholm (in Swedish).

Wingfors, H., Sjödin, Å., Haglund, P., Brorström-Lundén, E., 2001. Characterisation and determination of profiles of polycyclic aromatic hydrocarbons in a traffic tunnel in Gothenburg, Sweden. Atmospheric Environment 35, 6361–6369.

Jim Doyle
Governor

Helene Nelson
Secretary

State of Wisconsin

Department of Health and Family Services

DIVISION OF PUBLIC HEALTH

1 WEST WILSON STREET
P O BOX 2659
MADISON WI 53701-2659

608-266-1251
FAX: 608-267-2832
www.dhfs.state.wi.us

January 23, 2003

Caroline Garber
Bureau of Air Management
Wisconsin Department of Natural Resources
101 S. Webster St.
Madison, WI 53707

Dear Ms. Garber:

The Department of Health and Family Services is frequently called upon by your agency to offer guidance on the health risks associated with exposure to chemical contaminants in outdoor air. Jeff Myers recently asked me to summarize our opinion as to the toxicity of coal dust. Coal dust is a complex, heterogeneous mixture containing more than 50 different elements and their oxides. There is extensive literature on the risks associated with coal dust exposure among mine workers and others who may be occupationally exposed to coal dust. Epidemiological studies from Britain and the U.S. conducted over several decades found increased incidence of progressive massive fibrosis and chronic obstructive pulmonary disease in workers exposed at levels near the prevailing occupational exposure limit of 2 mg/m^3 (expressed as respirable dust). In response to these findings, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed reducing its time-weighted average threshold limit value (TLV-TWA) for bituminous coal dust to 0.9 mg/m^3 in 1996. This change was adopted by the ACGIH in 1998.

In issuing recommendations for environmental exposure to outdoor air contaminants, the Division of Public Health has adopted a policy whereby an ambient air concentration at which health risk is considered to be *de minimis* is calculated by dividing a TLV-TWA by an appropriate factor to account for variability within the human population and temporal differences in exposure between environmental and occupational scenarios. This factor is expressed as the product of (a) the ratio between the number of hours per week during which environmental exposure and occupational exposure are expected to be incurred (168/40), and (b) an uncertainty factor of 10 to account for the sensitivity of susceptible human subpopulations. In the case of coal dust, dividing the TLV-TWA of 0.9 mg/m^3 by the composite uncertainty factor of 42 yields a risk-based ambient air concentration of 0.02 mg/m^3 for coal dust. Based on our review, limiting exposure to this level is both necessary and sufficient to offer the public adequate protection from the potential acute and chronic health effects of coal dust exposure.

Please feel free to contact me at 608/266-7480 if you have any questions about this assessment.

Mark A. Werner, Ph.D.
Toxicologist

cc: Henry Anderson, Wisconsin Division of Public Health
Jeff Myers, Wisconsin Department of Natural Resources
Richard Wulk, Wisconsin Department of Natural Resources

Confederated Tribes and Bands
of the Yakama Nation

Established by the
Treaty of June 9, 1855

March 30, 2012

Louise Solliday
Director
Oregon Department of State Lands
775 Summer St. NE
Salem, OR 97301-1279

Lori Warner-Dickason
Northern Region Manager
Oregon Department of State Lands
775 Summer St. NE
Salem, OR 97301-1279

Bill Ryan
Assistant Director, Wetlands & Waterways
Oregon Department of State Lands
775 Summer St. NE
Salem, OR 97301-1279

Charles Redon
Resource Coordinator, Removal Fill-Permits
Oregon Department of State Lands
775 Summer St. NE
Salem, OR 97301-1279

Re: Yakama Nation's Comments on APP0049123 (Ambre Energy, Coyote Island Terminal)

Dear Director Solliday, Ms. Warner-Dickason, Messrs. Ryan and Redon:

For more than a century, outside private enterprises and governments have systematically ravaged the Yakama People's ancestral lands and waters. They've left a wake of destruction, nearly eradicated a Native culture that demands reverence for the environment, and swept away the resources upon which the Yakama People have relied for sustenance and spiritual health since time immemorial; all in the name of "progress." Today, in addressing the first ripple of a rising tide of coal transportation in the Columbia River Basin[1], the State of Oregon serves as a small but potentially effective check against perpetuating this pattern of destroying the Yakama way of life. Part of your agency's mission statement is wholly applicable here, and provides that you are to "ensure a legacy for Oregonians ... through sound stewardship of lands, wetlands, [and] waterways ... ." In this instance, you have the opportunity to honor that mission statement by preventing further degradation of the Columbia River and the lands surrounding it from additional "development" undertaken in the name of immediate economic gain and without regard for the long-term consequences.

COMMENTS ON AMBRE ENERGY'S APPLICATION No. APP0049123

These are the comments of the Confederated Tribes and Bands of the Yakama Nation ("Yakama Nation" or "Nation") on the Oregon Department of State Lands' ("DSL") review of Ambre Energy, d/b/a Coyote Island Terminal, LLC's ("Ambre") Application Number APP0049123 ("Application"). As a threshold matter, the Nation thanks DSL for accepting its comments and

[1] There are currently four known large-scale coal transport projects proposed for the Columbia River Basin that would effectively transform this fragile, already damaged landscape and waterway into a major coal export hub for United States coal en route to China. If permitted, this transformation will have far-reaching, long-term adverse impacts to the environment.

considering them as it undertakes its duties in review of Ambre's Application. The Nation is a federally recognized sovereign Indian nation. Furthermore, the Nation has reserved rights under a treaty with the United States of America ("Treaty of 1855") signed by the Nation in 1855 and ratified by the United States Congress in 1859 (12 Stat. 951). Among various reserved rights the Yakamas secured in the Treaty of 1855, is the right to take fish in all usual and accustomed places, including the Columbia River.

A constant visual reminder of the destructive pattern inflicted on the Columbia River Gorge area and its Native people is the glaring absence of Celilo Falls. Fifty-five years ago, onlookers watched as the completion of the Dalles Dam silenced the falls and destroyed an area sacred to the Yakama People. While the deliberate destruction of Celilo Falls and its surrounding villages are a symbol of the systematic destruction Yakamas have experienced in the name of progress, dams have had the immediate and ongoing effect of significantly eroding the Yakamas' right to take fish from the Columbia River and its tributaries.

Today, new fronts have been opened in the war against the Yakama way of life, including the effort to staggeringly increase the transportation of coal through the Yakamas' ancestral lands along the Columbia River that's sustained so much damage since outsiders arrived here. Like the dams, the coal now is hailed as an essential element for progress. But the definition of "progress" cannot be limited to pecuniary gain without regard to the long-term damages that financial gain will cause. In fact, anyone with an interest in ensuring a legacy for future generations "through sound stewardship" of lands must conclude that progress here means putting an end to this concerted effort to fundamentally transform and degrade the Columbia River Basin. With that in mind, through these comments the Yakama Nation highlights some of the apparent negative impacts approval of this particular application – and its corresponding cumulative impacts – will have on the region's fisheries, its air quality, global climate change, and the Yakama Nation's cultural resources.

By submission of these comments the Yakama Nation does not waive any rights to demand direct and meaningful government-to-government consultation with any governmental agency. Further, given the lack of information currently made available to the public for this project, the Yakama Nation reserves the right to supplement these comments as Ambre is compelled to release information critically important to meaningful environmental review. The Yakama Nation requests nothing more of the State of Oregon Department of State Lands than for it to live up to its mission statement. You should deny the above-referenced permit application unless comprehensive environmental analysis is accomplished and the interested indigenous peoples who've been historically ravaged by so-called "economic progress" are consulted as required by various laws, regulations, and treaties with the United States. At the very least, DSL should stay its review pending the comprehensive environmental review process that should take place at the federal level. Furthermore, before DSL makes any decision other than to reject this application as incomplete and inadequate under Oregon law, it should demand more information from Ambre Energy to fill in some of the glaring holes exposing the Application's deficiency, and it should prescribe a full state-level EIS to ensure Oregon's interests are protected should this project move forward.

We are currently working on the Nation's comments to the federal agency responsible for the environmental review under the National Environmental Policy Act ("NEPA") and expect to have those submitted in the next week or two. Those comments will set forth the Nation's request for a programmatic Environmental Impact Statement ("EIS") regarding all plans to significantly increase coal transportation through and exportation from the Northwestern United States, and its corresponding request for a comprehensive case-by-case EIS for every planned coal-related project. Frankly, until the cumulative impacts of all planned coal-transportation projects in Washington and Oregon have been identified and analyzed, including the impacts sustained from the burning of coal by its end user, and until the federal government consults with the Yakama Nation on a government-to-government level, no government should make any decisions that would allow the commencement of this project. In other words, the application is premature.

Even under DSL's own Removal and Fill Guidance ("RFG"), this application is incomplete. Before an application is complete under the RFG, it must contain "sufficient information for the Department and the public to make an informed evaluation of the project's effects, the availability of alternatives, and whether the mitigation is sufficient to offset the anticipated adverse effects."[2] The Nation notes, for example, Ambre's complete failure to even note the existence of tribal fishing sites in the area and identify the cumulative impacts Ambre's project will have on the tribal members who still rely on the river to support themselves and their loved ones. It's unconscionable that Ambre proposes to develop a coal export project that would transport 8.8 million tons of coal per year through the Columbia River Basin while refusing to acknowledge the tribal members' inextricably intertwined interests and the impacts to their fishing sites and their health implicated by this vast expansion of coal transportation in the region. And this is only one of many glaring deficiencies in this application.

At the very least, DSL should stay its decision pending the completion of programmatic and project-specific EIS's the Nation seeks under NEPA. In the alternative, DSL should demand more information from Ambre, hold public hearings on this matter, and require Ambre to complete a separate state-level EIS to address the specific issues identified here and in other comments submitted. A project of this magnitude should not be given any fast-track preference. Considering the history of damage and destruction of resources in this region, DSL should take a hard look. DSL should ensure that it serves its own stated mission and works to break the shameful pattern of destruction inflicted on the Yakama People in this area.

A. <u>Fisheries</u>

As indicated, the Treaty of 1855 reserved to the Nation the right to fish in perpetuity at all usual and accustomed places as they were known at the time of the Treaty signing. Though this right was significantly trampled upon through the destruction of Celilo Falls and other "development" in the area, in the legal arena, this powerful right has been affirmed and re-invigorated through extensive litigation beginning with the *U.S. v. Winans* case in 1911 and culminating with *United States v Oregon*, which is still active. The Yakama People continue to exercise their Treaty-

[2] *See* RFG § 6, p. 6-5.

reserved fishing rights on the Columbia River and its tributaries within the Nation's Ceded Lands and its usual and accustomed use areas. The site of the proposed action described in the Application is located completely within an area of active commercial gillnet fishing by members of the Yakama Nation.

Members of the Yakama Nation fish for their subsistence and livelihoods on the Columbia River using set gillnets that typically are anchored at one end to the river bank and to an anchored buoy up to 400 feet offshore in an orientation perpendicular to the flow of the river. Adult salmon and steelhead migrating upriver encounter the nets and become entangled in the gillnet webbing. Fishers lift the nets 2-3 times per day from small, outboard-powered boats to harvest the fish from the webbing. Because the nets generally are most effective during hours of darkness, fishers typically visit the nets at least once – and often more frequently – during the night when fish are abundant. Several hundred tribal members utilize this method of fishing. In aggregate, they may deploy over 1,000 such nets on the Columbia between Bonneville and McNary dams in the fishery administrative area known as Zone 6. Weekly fishing periods are established by tribal regulation depending on the availability of harvestable fish from mid-May to early October and February 1 to late March.

1. Impacts to Tribal Fishing Sites

The proposed coal loading dock identified as the Coyote Island Terminal would have significant direct and indirect detrimental impacts to tribal fisheries in the project area. The dredge and fill operations at the proposed site will very likely destroy four tribal gillnet sites that Yakama members currently use to exercise their tribal fishing rights.[3] These particular threatened fishing sites are high quality and critically important to the tribal members who fish there. Construction of the proposed dock will at least interfere with, and may even lead to an end of gillnet fishing at this location. From the Nation's experience with other docks and mooring dolphins, maneuvering barges into and out of the proposed dock will at least interfere with, and perhaps prohibit, fishing at sites adjacent to the proposed dock itself. It is important to note that these sites are not held or owned by individual tribal fishermen in the sense of title ownership. But rather, the Treaty-protected sites are held in trust by the Yakama Nation government for use by its enrolled members. The Nation authorizes tribal members to fish at certain sites on the Columbia through a site registration process administered by the Nation's Fisheries Program. So the fishery is regulated in a site-oriented fashion meaning fishers authorized to fish at certain locations are not at liberty to simply move their fishing operation to another location on the river. The loss of fishing sites resulting from construction of the proposed dock would have the effect of disenfranchising the fishers authorized to fish at this location, would measurably diminish the number of fishing sites available to members of the Yakama Nation to exercise their Treaty-reserved right to fish at this usual and accustomed place. Put another way, construction of this project may directly violate the Treaty of 1855.

2. Safety of Tribal Fisherman

[3] This is qualified, because there is insufficient information to determine precisely how many fishing sites Ambre's project will destroy.

Similarly, increased barge traffic through Zone 6 resulting from this project will directly and indirectly affect the safety of tribal fishers exercising their Treaty-reserved fishing rights. While the Application does not specify how much additional barge traffic this project will cause, it is reasonable to conclude that barge-and-tow activity in the project area would increase substantially; and the Corps of Engineers has confirmed as much. Each barge, particularly those in transit during hours of darkness and/or foul weather, represents an increased safety risk to fishers operating small boats, often at night and in foul weather, to harvest fish from their nets. Despite the fact that towboats are required to display lights indicating they are warped to one or more barges, the barges themselves are poorly lit and may obscure the lights of the towboat from the vantage point of a small boat. As tribal fishers may be hampered by foul weather gear, operating at night in otherwise dangerous conditions, and with barge lights obscured or confused by background lighting from Interstate 84 and fixed structures, increased barge traffic in the project area will considerably increase the safety risk to tribal fishers. The Application lacks any assessment of this increased hazard to tribal fishers and is thereby deficient in its scope. DSL should not issue a permit without analysis of the project's safety hazards to tribal fishers and without adequate mitigation for those impacts.

Coal transportation by rail also poses a potential risk to human health. Currently, there is a real risk of tribal fisherman being harmed or killed by trains traveling through the Columbia Gorge. This risk will only increase as more trains are required to transport coal to ports in the Columbia Basin. Further, the coal dust that will be accumulating along the rail lines in the Columbia Gorge poses yet another risk to human health. Coal dust has been well documented as a cause of disease in humans that sometimes results in death. Without adequate identification and analyses of these projects, DSL should not permit Ambre's project.

3. Impacts to Water Quality & Aquatic Species

Coal is associated with significant environmental problems including acidification of watersheds and metal contamination. It is likely that this project will result in the contamination of the Columbia River as chunks of coal and coal dust inadvertently fall or spill into the waters of the Columbia Basin from trains traveling to the Port of Morrow. In fact, Burlington Northern Santa Fe has stated that up to 500 lbs. of coal per car is lost during rail transportation. Coal would also likely spill into the Columbia Basin during overwater barge loading, barge accidents, or train derailment. The potential significant increase of inadvertent coal spillage in the Columbia Basin could adversely affect Yakama Nation tribal resources including our tribal fisheries. Toxic effects are both acute and chronic to the Columbia Basins' aquatic food web and culturally important aquatic foods including salmon, sturgeon, and lamprey.

4. Impacts to Habitat

Along with the toxic properties of coal there are habitat threats associated with construction of a new coal facility. Habitat for species listed under the Endangered Species Act ("ESA") will be affected by construction of the coal loading facility and create possible habitat for native and nonnative predators. Destruction of habitat and negative impacts to ESA-listed species must be evaluated and fully considered. Because of the potential impacts to our water, foods, and

ultimately our People, the DSL should require an analysis of these concerns in the review of this project and make the results available to the Yakama Nation for response before a permit may be issued.

B. Air Quality

The Yakama Nation, the federal government, and others have worked extensively over the past decade to identify, analyze, and address air quality concerns in the Columbia River Gorge ("CRG"). Through research and monitoring we have found the CRG to have some of the highest levels of air pollution and acid rain in the Northwest.[4] Local coal-fired plants and China's massive coal burning industry have been identified as major sources of this harmful pollution in the CRG.[5]

Toxic pollutants like mercury from burning coal, and other fossil fuels from the diesel-powered locomotives and marine vessels within the CRG, continue to impact the Yakama People and their cultural, historic, and Treaty-reserved resources. Not only is this harmful pollution damaging our sacred and irreplaceable pictographs and petroglyphs, it continues to impact and threaten our People and the resources that we depend on as these contaminants move through the air, water, and soil.[6]

Though not occurring soon enough, the planned closures of the last two remaining coal-fired plants in Oregon and Washington, PGE Boardman and TransAlta, are enormous victories for the region and demonstrates the region's commitment to protecting human health and the environment. Given that we as a region are saying NO to coal-fired plants, we must ask why then would we now allow and facilitate the export of 8.8 million tons of coal to be burned in China each year, only to have its harmful contaminants come back to pollute the Pacific Northwest via hemispheric transport?

The weekly increase of an additional 11 trains, 12 loaded barge tows from Port of Morrow to Port of Westward, and 3 Panamax ships moving through the Columbia River Basin to Asia from the proposed Coyote Islands Terminal, will greatly aggravate the detrimental air emissions and toxic pollutants in the CRG.

Given the significant impacts that air pollutants from burning fossil fuels has on our People, cultural heritage and Treaty-reserved resources, it is imperative that the environmental analysis

---

[4] R. S. Sletten, "The Effects of Air Pollution on Rock Images in the Columbia River Gorge: A Sacred Breath Project of the Yakama Nation" (2011).

[5] See, Jaffee, D. A. & Reidmiller, D.R., "Now you see it, now you don't: Impact of temporary closures of a coal-fired power plant on air quality in the Columbia River Gorge National Scenic Area." Atmos. Chem. Phys. 9, 7997-8005 (2009); Jaffee, D.A. & Strode S., "Fate and Transport of Atmospheric Mercury from Asia." Journal of Environmental Chemistry 5(2), 121-126 (2008).

[6] R. S. Sletten, The Effects of Air Pollution on Rock Images in the Columbia River Gorge: A Sacred Breath Project of the Yakama Nation (2011); U.S. Environmental Protection Agency, Columbia River Basin: State of the River Report for Toxics (2009).

for the Coyote Island Terminal quantifies and analyzes the effects of air emissions and associated acid deposition from the transport and burning of coal caused by this proposal. To understand project-specific and cumulative impacts, these analyses should be conducted independent of and in combination with the other coal export facilities being proposed in Oregon and Washington. Additionally, the Yakama Nation expects that transient coal dust from the transport and storage of coal at the transloading facility will be quantified and its effects on human health and the environment will be fully analyzed.

C. Climate Change

The transport and burning of 8.8 million tons of coal per year, as associated with the Coyote Island Terminal transloading facility, would have significant greenhouse gas emissions, thus contributing to and exacerbating climate change. The Yakama Nation's traditional and subsistence ways of life are in jeopardy by profound influences of climate change, especially upon water — both the quantity and quality — which affects changes in flora and fauna in the region. Warming water temperatures associated with climate change have been shown to increase the levels of toxins in water bodies, thus increasing the amount of toxins that are taken up into fish and affecting human health. Research has shown specifically that the accumulation of methylized mercury in our fish and wildlife is linked to rising water temperatures in the Columbia Basin.

The Yakama Nation expects that greenhouse gas emissions and climate change impacts associated with this proposal will be quantified and analyzed, both independent of and in combination with the other coal export facilities being proposed in Oregon and Washington. These analyses must consider all emissions from rail and barge shipments from Montana and Wyoming to Asia, operations at port terminals, as well as the burning of this coal in Asia.

D. Cultural Resources

Many known culturally sensitive sites are located along the rail routes and within close proximity to the proposed transloading facilities in both Washington and Oregon for the four proposed coal transportation/exportation projects. The Yakama Nation is concerned that rail construction, increased barge traffic, and construction of the proposed transloading facility will impact known archaeological sites, previously undocumented archaeological sites, and Traditional Cultural Properties.

The proposed Coyote Island Terminal is located within an area of extreme cultural sensitivity to the Yakama Nation. Prior to inundation by the dams, the Blalock Islands (including Coyote Island) were a river crossing and ancestral fishing area. Numerous burial sites, legendary sites, and village locations are known within close proximity to the proposed construction. The Coyote Island Terminal is within ¼ mile to the Coyote Island Burial Site, recorded as archaeological sites 45BN77. Though this site has been inundated by the backwaters of John Day Dam, potential impacts remain through construction, sedimentation changes during construction, construction-related dredging and filling, increased barge traffic over time, reservoir management changes required to accommodate increased shipping, and shipping accidents/spills. Further,

many cultural sites similar to the Coyote Island Burial Site exist within close proximity and may be impacted by the proposed project.

The information provided regarding this project is not sufficient to allow for examination of cumulative effects and impacts of this project on cultural resources over time. We request further information regarding the proposed life of the project, to what degree will there be dredge/fill operations for the construction area as well as dredge/fill of the shipping channel over time. Resources, though currently inundated, remain a high concern. Dredging/filling, will greatly impact cultural resources, fish habitat, ancestral fishing sites, Zone 6 Treaty Fishing Sites, and fishing sites throughout the upper and lower Columbia River in use today. We further request information regarding increased infrastructure requirements for overland transportation of coal to the Coyote Island Terminal; as such expansion will further impact these valued resources.

CONCLUSION

DSL should exercise its authority to meet its mission statement and reject this Application as incomplete; or at the very least, DSL should (1) stay its decision pending the EIS's the Nation and others are demanding under NEPA, (2) demand more information from Ambre so that DSL's decision on this project will be informed and comply with applicable laws and regulations, and (3) require its own state-level EIS (or similar full environmental review) to ensure that DSL honors its mission. Your agency is uniquely situated to bring the appropriate level of scrutiny a project of this magnitude requires, setting an example for other agencies to follow. Further, you have the opportunity to start righting the course when it comes to the systematic harm inflicted on the Yakama People and their culture over the past century.

This Application is woefully inadequate and incomplete under Oregon law. For example, the Application references environmental documents that will be forthcoming but are not now available. Specifically regarding the deficient information provided, before any decision is made other than to deny the Application as incomplete, we request:

- Additional information on the proposed life of the project, specifically relating to what degree Ambre intends to dredge or fill the construction area and the shipping channel over time.

- Additional information regarding increased infrastructure requirements for overland transportation of coal to the Coyote Island Terminal; given that such expansion will further impact these valued resources.

- Additional information regarding cumulative impacts specifically relating to the quantification of increased greenhouse gas emissions resulting from this project, and other coal-related projects in the area.

- Additional information regarding the cumulative impacts this project will have to all cultural resources in the area, including those resources inundated.

The purpose of this Application – shipping coal by railcar from upriver locations to barges for transport downriver – implies enormous cultural, environmental, economic, and legal consequences that cannot be adequately addressed in an Application review. Further, the purpose for the proposed Coyote Island Terminal is completely inconsistent with the vast regional investment in restoring the fish and wildlife resources devastated by human development of the Columbia Basin. The creation of a new and certain threat to the health of the Columbia River and its resources jeopardizes the integrity of regional agreements, commitments, and underlying biological analyses that are intended to improve environmental quality and natural resources status. Among these regional commitments is the Federal Columbia River Power System ("FCRPS") Biological Opinion ("BiOp") issued by National Marine Fisheries Service to the federal action agencies, which prescribes actions necessary for the FCRPS to avoid jeopardizing the existence of ESA-listed salmon and steelhead. Nowhere does the BiOp anticipate the development of a new and certain biological stressor to species already on the brink of extinction.

The time is ripe to put an end to the wake of destruction outside enterprises and governments have inflicted on the Yakama People's ancestral lands and waters. We respectfully request your agency to seize this opportunity as the moment in time when the people now occupying the lands at issue here turned the tide against destructive forces and gave meaning to your agency's mission statement, so that we may all ensure a legacy for future generations through sound stewardship of lands, wetlands, and waterways.

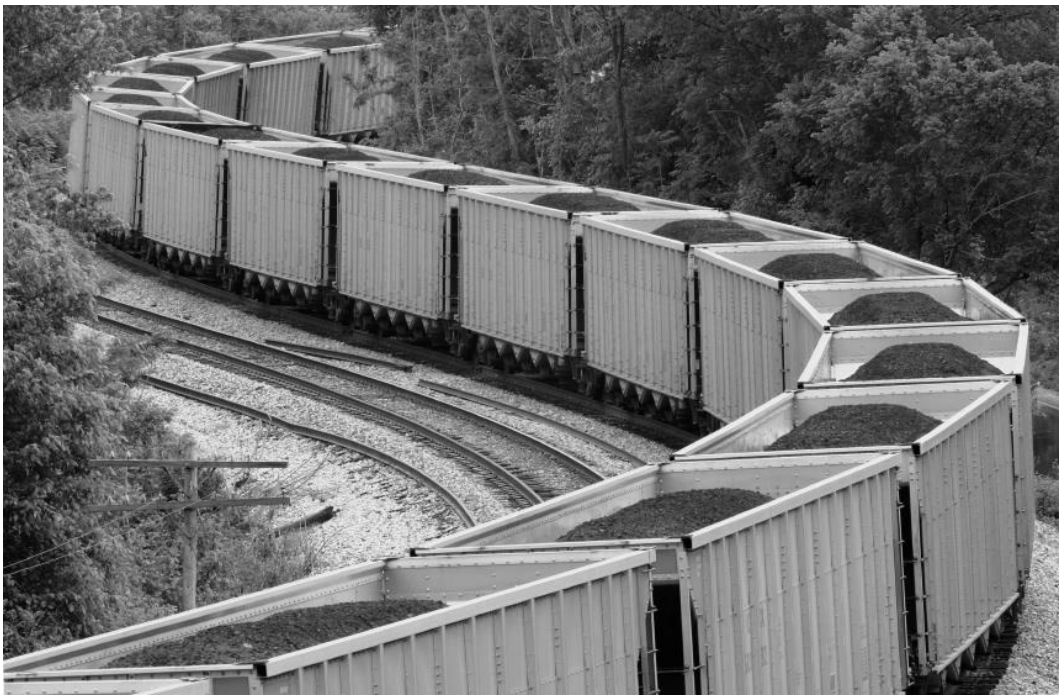
For any questions, please contact Philip Rigdon at (509) 865-5121 ext. 4655. For future notices regarding your agency's involvement in this matter, please notify our Environmental Review Coordinator, Kristina Proszek at kris@yakama.com and our legal counsel, Joe Sexton, at Joe@yakamanation-olc.org.

Sincerely,

Philip Rigdon
Deputy Director
Yakama Nation Department of Natural Resources

City of Seattle

Economic Analysis of Proposed Coal Train Operations



August 2013

Submitted to:

growseattle
office of economic development

Submitted by:

cai community attributes inc

Community Attributes tells data rich stories about communities that are important to decision-makers.

Principal: Chris Mefford

Lead Analyst: Spencer Cohen

Analysts: Diana Haring
Alex Hudson
Bryan Lobel
Tyler Schrag

Community Attributes Inc.
1411 Fourth Ave, Suite 770
Seattle, Washington 98101

www.communityattributes.com

PREFACE

Scientific evidence demonstrates that the burning of coal results in local air pollution and climate change worldwide through the effects of greenhouse gasses. Regardless of where coal burns, pollutants will be distributed globally through the atmosphere, including mercury, sulfur compounds, and smog-forming compounds. This pollution will burden public health and cost regional economies. Some regional economies will capitalize on economic opportunities to address environmental impacts, but on net the environmental and economic impacts of global warming will be dramatic if not curbed.

These important issues are not the subject or scope of this report, and therefore are not explored further. This study focuses on the potential economic impacts of coal train operations associated with the proposed Gateway Pacific Terminal in Whatcom County within Seattle. The study acknowledges regional and global considerations, including direct economic impacts and environmental and health externalities. Complete exploration of the externalities are beyond the scope of this study to quantify and express monetarily. Many direct impacts are the focus of rigorous quantitative and qualitative analysis on economic impacts for people, businesses and stakeholders within Seattle city limits.

The analysis demonstrates that the potential benefits are relatively few and low to Seattle, as would be expected given the pass-through nature of coal trains in Seattle. Some benefits are tangible and others are more speculative in nature. The direct costs of traffic impacts are tangible. The neighborhood level environmental and economic costs are also real and tangible, but more scientific work and economics studies are necessary to understand them better, and many of those may be speculative in nature, as well.

The cases to obstruct or accept coal trains passing through Seattle are not fully addressed in this report, either. Rather, this report provides an objective representation of stakeholders' perspectives, among those stakeholders scoped for interviews and research, and whose perspectives Seattle leaders requested to capture in this study. This includes local stakeholders leading efforts to build the coal terminal and facilitate transport of coal, as well as opposition leaders.

The result is much content for Seattle environmental and industrial leaders to consider, leverage or dispute, all designed to aid in an understanding of project related impacts in Seattle.

EXECUTIVE SUMMARY

Overview of Project

Once completed, the proposed Gateway Pacific Terminal in Whatcom County would be the final U.S. destination of coal mined from the Powder River Basin in northeastern Wyoming and southern Montana en route for consumption in China. **Exhibit 1** outlines the flow of coal train operations, from source to destination, with intermediary costs and benefits identified along the way.

The first phase of the project would allow for up to 25 metric tons (Mt) of coal, with capacity for an additional 23 Mt coal and 6 Mt of other dry bulk commodities as part of Phase II. Phase I was originally slated for completion in 2015, but more likely would be 2018 or later due to an extended review and permitting process.

With full build-out, up to 18 trains would travel to and from the Gateway Pacific Terminal (GPT) in Cherry Point each day (round trips of eight coal trains and one other dry bulk load). GPT-destined coal trains would be loaded in Wyoming, travel through Spokane, then head south through Pasco and along the Washington side of the Columbia River Gorge before heading north along the I-5 corridor, passing through Seattle. Empty cars heading back to the Powder River Basin or other eastern sites would either follow the same route, or head east at Everett and return by way of Stevens Pass.

Coal trains are expected to be 7,000 feet (about 1.3 miles) in length during Phase I of terminal operations. After completion of Phase II, the trains are anticipated to be 8,500 feet (1.6 miles) in length. There are eight at-grade crossings in Seattle that would be affected by more trains—Lander, Holgate, Horton, and Spokane in the SODO District, and Broad, Vine, Wall, and Clay in the North Waterfront.

Currently, approximately 30 freight trains travel each day to or through the North Waterfront district of Seattle and between 65 and 80 freight trains through the SODO district.

Some of these trains are long-haul trains 8,300 in feet length (about 150 cars), roughly equal in length to coal trains (Seattle Department of Transportation, 2012). At present, two or three coal trains per day (it varies by day) pass through Seattle heading north to the Westshore Terminal in Delta, BC.

Exhibit E-1. Coal Export Supply Chain Operations, with Intermediary Costs and Benefits

Supply Chain Activities	Geography of Impact(s)	Benefits L = Potential Large Impact M = Potential Medium Impact	Costs S = Potential Small Impact NC = Not Clear	Notes
Mining rights leased by federal government (Bureau of Land Management) to Peabody Energy	Powder River Basin	Lease revenues to federal government (M).	Use of natural resources, local environmental damages (NC).	Asset mining may occur regardless of this transaction.
Coal sold by Peabody and Cloud Peak to China	Coal company HQ and offices throughout the U.S; Wyoming mining areas.	Revenues to Peabody and Cloud Peak Energy (L); Mining and related jobs (M).		
BNSF ships coal to Cherry Point	Spread across BNSF corporation.	Revenues for rail industry (L).		EPA requesting coal transportation be included in Gateway Pacific Terminal EIS.
	Spokane		Traffic in Spokane (M-L); Coal dust (NC)	
Trains come through Seattle (some diverted)	Seattle		Congestion. Between $384,000 and $455,000 per year in travel cost burden. Fire Department mitigation strategies (M-L). Decline in property values along/near tracks due to noise, vibrations, and delays (M). Hospitality businesses near tracks see reduction in business (M-L). Coal dust (NC).	Capacity taken up on tracks. Some see this as helping to move forward capacity investments that are considered beneficial to the Port. Traffic impacts a concern and quantifiable. Insufficient information (for now) on extent of coal dust emissions and health impacts.
Gateway Pacific Terminal, owned by SSA	Seattle	Revenues to SSA. Some jobs and revenues in Seattle (S).		
	Whatcom County terminal site and regional economy.	Direct and multiplier impacts (e.g., jobs, revenues, labor income) (L).	Congestion, potential diverted investments (M).	
Coal used in Asia	China, World	Cheaper prices for Chinese energy users.	More coal burnt than otherwise, increase in GHG emissions (L).	Shippers' health important to Seattle Port

Stakeholder Concerns

The study included interviews of a broad range of stakeholders, including local businesses involved in the coal train planning, industrial businesses affected by increased train activity and local organizations opposing the coal trains. Many of these groups have funded or conducted their own studies of the anticipated impacts.

Potential benefits identified by this study include revenues and jobs created by increased train traffic and terminal operations by Seattle-based SSA Marine and local operations of BNSF Railroads. Port of Seattle and BNSF both speculate that the increased train demand could support improvements and expansion of local rail corridor infrastructure. The improvements were discussed by Port and BNSF representatives, and not drawn from funded plans or programs.

Concerns raised about the coal train's impacts to Seattle included the following perspectives:

- Coal, including concerns about the environmental impacts of mining, transporting, and burning coal
- Increased train traffic in Seattle, including impacts to roadway congestion due to traffic delays at at-grade intersections
- Capacity of railroad tracks and facilities in Seattle and throughout regional corridors
- Noise impacts on business
- The loss of parking along the North Waterfront due to seawall reconstruction and waterfront redesign, and
- The economic cost of these impacts on Seattle businesses and residents.

Additional perspectives germane to the analysis include opposite beliefs about the following two concerns:

- Whether the coal trains will travel through Seattle regardless of whether the Cherry Point facility is built
- Whether the project is of significant impact on global coal mining and demand for coal for energy.

Findings

The following sections list impacts identified due to an increase in coal trains, including benefits and costs. The anticipated benefits to Seattle consist of jobs at SSA Marine and increased revenues for BNSF. Indirect benefits include speculation that the increased train traffic and revenues could lead to

infrastructure improvements. Immediate, direct costs are primarily associated with more trains, which are longer and heavier than most trains passing through the city. These impacts include disruption to business activity, delay costs borne by drivers at surface crossing intersections, and associated mitigation.

Direct Benefits

- **Jobs and Revenues.** SSA Marine, the operator of the proposed Gateway Pacific Terminal, is an employer headquartered in Seattle, with approximately 400 FTEs in Seattle. SSA foresees growth in revenues, full time jobs, and expenditures captured within Seattle (both within SSA Marine and contracted companies) resulting from the project. SSA Marine anticipates the construction phase of the project would include up to $28 million in project expenditures on permitting, engineering, legal, and public relations-related activities, of which a large share would go to firms based in the Seattle metropolitan area. SSA Marine expects to hire 12 full-time employees (FTEs) to manage the project, with estimated total reimbursements of around $2.4 million per year. During construction, these FTEs would be in Seattle, though after construction seven positions would be relocated to Whatcom County.

- **Infrastructure improvements**. BNSF and the Port of Seattle officials suggest increased demand for the rail corridor could lead to investment in Seattle rail infrastructure. BNSF reports that they would make capital investments when the rail system nears full capacity. The Port of Seattle representatives report that such capacity investments ("triple-tracking" and additional sidings within Seattle) could make the Port more attractive and competitive. BNSF does not report displacement of transport of any other goods due to more coal cargo.

Direct Costs and Negative Impacts

- **Traffic interruptions and delays.** During Phase I of the build out, the Seattle Department of Transportation (2012) has estimated additional daily crossing gate down times of between 31 and 83 minutes. By 2026, daily crossing gate down times could increase to between 67 and 183 minutes, including a 39% to 108% increase at Broad Street (the most affected crossing).

  BNSF reports that 18 trains per day, train volumes would be only slightly above 2006 levels, and one possible scenario indicates as few as only 9 trains per day could pass through the city.

The quantifiable economic impact from anticipated congestion induced through more trains is between $384,000 and $455,000 per year (in 2013 dollars) borne by drivers and their employers. Delays in the North Waterfront aggravate tourism and recreation businesses, which rely on families and vehicle-based customers.

Congestion analyzed includes intersections affected by the proposed new sports arena; other studies underway will address the economic and transportation impacts of the arena.

- **Disruption of business**. Noise and vibrations from trains hurt many businesses, and the hospitality business in particular. Noise and vibrations are of greater magnitude with the coal trains because the coal trains are longer and heavier trains than most other trains. Hotel guests (individuals, families, and corporate clients) have reported to hotel management that they are bothered by train noise at night and the inconvenience of crossing delays, and have cited these issues as reasons for not returning.

- **Property values**. Recent estimates of property value diminutions from an increase in coal trains imply potential losses of between $270 and $475 million among commercial, residential, and industrial parcels within 600 feet of the BNSF mainline citywide. Potential losses in property value include up to $282.3 million in residential, $133 million in commercial, and $59.4 million in industrial properties. Demand would shift elsewhere within regional markets, theoretically increasing values elsewhere offsetting losses along the corridor.

Impacts to the City of Seattle

- The Seattle Fire Department may need to invest up to $150,000 in a new dispatching system to negotiate increased surface traffic. Other options include relocating the number 14 station in SODO to the west side of main line, or building an east-west bypass at Lander Street (projected to cost at least $100 million). A relocation of the number 14 station would cost approximately $9.5 million (plus the cost of land).

Environmental and Health Concerns

- **General impacts.** Environmental impacts associated with coal extraction and burning are recognized as an economic cost. Greenhouse gas emissions are known to affect the entire planet, regardless of the point of dissemination.

- **Coal dust**. No comprehensive report exists to demonstrate the extent of coal dust emissions along the proposed BNSF line. The EPA has not done a comprehensive analysis of the non-occupational health impacts of coal dust, but is calling for a review in the environmental impact study (EIS) for the proposed terminal in Cherry Point. Studies focus on coal dust emitted at and near the mines and at and near the terminal, as referenced in the body of this report. Research efforts during the course of this study found no scientific research on coal dust emissions during the middle segment of the transport phase between the mine and terminal. The EPA has requested such an analysis in the scoping comments for the Gateway Pacific Terminal environmental impact study.

  BNSF reports that they are committed to preventing coal dust emissions, and has already imposed strict rules to this end. BNSF reports a financial incentive to prevent coal dust emissions; dust can damage tracks and increase the risk of a derailment.

  BNSF charges a tariff to cover costs of treating coal dust with chemical sprays to mitigate dust. However, other industry stakeholders have challenged the tariffs, in part due to their skepticism of the efficacy of BNSF's efforts. The challenges also question the legitimacy of BNSF's stated goals for reducing coal dust. A recent lawsuit by the Sierra Club charging BNSF with dust emissions reflects growing concerns over coal dust.

- **Diesel exhaust.** The proposed coal trains, like all diesel locomotive trains, emit diesel exhaust, which has adverse health impacts for people exposed.

Impacts on operations and employment at the Port of Seattle

- The Port does not anticipate any direct increase in employment due to coal trains. Representatives of the Port expect that existing and soon-to-be-complete projects will mitigate the impacts of coal train-induced congestion on Port operations. The City of Seattle recently completed the South Street Spokane project, which includes a new connection to First Avenue South from the Spokane Street viaduct and Interstate 5, bypassing the BNSF mainline and providing direct access to Port areas from the freeway system. In addition, the Port contributed $300 million to the SR99 replacement project, which includes the construction of an overpass over the BNSF tail tracks near East Marginal Way South; this overpass is expected to be operational by the end of 2013.

- The largest segment of truck freight operates between port terminals and the two rail yards, to the west of the mainline. A smaller percentage services the Duwamish industrial region trans-loading operations, and thus could experience longer delays, but also has access to the Spokane Street Viaduct.

Additional Considerations

- Statewide, the project at Cherry Point could include 6 million metric tons per year of unspecified dry bulk commodity shipments and the use of cape-sized vessels. SSA Marine expects this capacity will reduce shipping costs for Washington-based dry bulk commodity shippers.

- Research on global demand for coal suggests the proposed increase in exporting capacity may help lower world prices for coal and thus delay China's transition away from this energy source, worsening pollution and associated impacts.

- Trains hauling empty cars from Cherry Point could potentially pass through either Stevens Pass or through Seattle, per interviews with the Washington State Department of Transportation, the Port of Seattle, BNSF, and two state reports on rail capacity.

- BNSF is ultimately the only party to have full knowledge of rail capacity along its rail lines, including through the Stevens Pass corridor.

CONTENTS

Preface i
Executive Summary ii
Introduction 1
Background and Purpose 1
Methods 1
Outline of Report 2
Global Project Context 3
Asian Demand 3
Asian Demand for Powder River Basin Coal 4
Current Conditions in Seattle 5
Current Rail and Coal Train activity 5
Duwamish MIC and North Waterfront Employment 6
Proposed Project and Activity 10
Regional Economic Impacts 11
Economic Theory 11
Major Economic Stakeholders 14
Seattle Area Impacts 17
Benefits 17
Economic Costs 20
Property Value Impacts 34
Next steps and additional considerations 36
Appendices 37
Appendix A. Estimating the costs of congestion using a value of travel time approach 38
Appendix B. Interviewed Stakeholders 40
Appendix C. Sample Interview Questions 41
Appendix D. Port of Seattle Truck Freight Flows in SODO Area 42
Bibliography 43

Blank.

INTRODUCTION

Background and Purpose

The Gateway Pacific Terminal is a proposed coal export facility to be located at Cherry Point in Whatcom County. The coal shipped through the terminal will be mined from the Powder River Basin in Wyoming and Montana and hauled to Cherry Point by train, along BNSF rail lines. The Washington line of the proposed train route extends from Spokane, down the Columbia River Gorge, and along the Pacific Coast from Longview to Ferndale. The proposal calls for 10 daily trains in 2015, with up to 18 daily trains by 2026.

In support of Port of Seattle activities, port-related businesses, manufacturing and maritime businesses, and other Seattle businesses that may be impacted by increased coal train operations the Office of Economic Development issued an RFP seeking analysis of the potential economic impacts of the proposed coal train operations in the City of Seattle, with a particular focus on Seattle's North Waterfront and Duwamish Manufacturing and Industrial Center.

The findings of this economic impact analysis will inform City of Seattle policymakers, interested stakeholders, and the general public of the potential range and magnitude of economic impacts from the proposed coal terminal and associated train operations to Seattle. This report covers the following analysis:

- Impacts on operations, employment, and sales for business along the proposed coal train route, including the Duwamish industrial and North Waterfront districts and operations at the Port of Seattle;
- Assessment of what increased demand of Seattle's rail facilities means for remaining capacity; and
- Exploration of additional infrastructure improvements or policy measures required to support coal train operations and/or mitigate coal train impacts.

Methods

The approach to this work leveraged available quantitative sources and modeled estimates of traffic congestion induced by an increase in coal trains, combined with interviews with key stakeholders.

To estimate a range of impacts in dollars associated narrowly with congestion, the report utilized estimates of congestion modeled in a previous study commissioned by the City of Seattle for three crossings and select estimates for value of travel time (VOTT, discussed further below).

To better understand and assess the diverse range of possible impacts, a pool of stakeholders representing the Port of Seattle, City of Seattle Department of Transportation, City of Seattle Fire Department, BNSF, SSA Marine, and local businesses and associations in the two primary affected areas were interviewed. See **Appendix C** for the full list of stakeholders interviewed. Questions focused on the perceived/anticipated impact additional rail traffic and resulting crossing delays would have on retail vehicle and foot traffic, supply chains and distribution, employee commuting, and the expected benefits and costs associated with more coal trains passing through Seattle. See **Appendix D** for a list of sample interview questions.

The analysis also incorporated existing related transportation and economic analyses.

Outline of Report

The report is organized as follows:

- **Global Project Context.** Background on coal trains, supply chain economics including review of proposed new terminal at Cherry Point in Whatcom County, potential new train traffic, and economic participants and stakeholders.
- **Current Conditions in Seattle.** Current conditions, including literature review of impacts of congestion on economic development, increased train traffic through urban areas, and estimations of travel time value based on previous studies.
- **Proposed Project Activity.** Detailed description of coal train operations and their interaction with Seattle.
- **Regional Economic Impacts.** Conceptual discussion of economic impacts expected along the entire rail corridor.
- **Seattle Impacts.** Focused analysis on direct economic impacts expected for local residents, businesses and stakeholders.
- **Next Steps.** Additional context for future analysis.
- **Appendices.** Collection of supporting analysis and exhibits.

GLOBAL PROJECT CONTEXT

Asian Demand

Asia is the primary source of demand for coal shipped out of the Northwest, though estimates of future demand vary. A recent report commissioned by Peabody Energy estimates that global demand for coal will grow from 7.9 billion tons in 2012 to 8.9 billion tons in 2016, with most of this increase (700 million tons, or 70% of total demand increase) coming from China (Galuszka, 2012).

China has emerged as the world's largest producer and consumer of coal, accounting for more than 45% of both global totals. In 2011, China consumed 3.8 billion tons of coal, equivalent to 47% of global coal consumption. China's annual increase of 9% in 2011 constituted 87% of the 374 million ton global increase in coal use; between 2000 and 2011, China accounted for 82% of global coal demand growth (U.S. Energy Information Administration, 2013). In 2011, China imported 190 metric tons (Mt) of coal, of which 146 Mt was used for steam (i.e. power) generation, with another 38 Mt for coking (removing impurities from coal for a more potent fuel). China's overall 2011 coal production was 2,831 Mt for steam purposes, and 504 Mt for coking (World Coal Association, 2012).

Contributing factors to Asia's external demand for coal include China's rapid industrialization, a decline in U.S. demand for coal (due to a surge in natural gas and to a lesser extent growth in renewable alternatives)—resulting in cheaper prices—and a slowdown in demand for nuclear as an alternative fuel source following the Fukushima disaster in Japan. China's demand for coal is for thermal coal used in power plants and for coking coal as a heating source in blast furnaces (Galuszka, 2012).

The International Energy Agency's (IEA) base scenario projects China's coal consumption to account for more than 50% of global demand by 2014 and increase by 638 metric tons between 2011 and 2017, followed by India. Even with a likely economic slowdown (relative to annual real GDP growth of 10%), China is expected to continue to consume high levels of energy inputs—primarily coal—well into the future. In IEA's China slowdown scenario, China's demand would grow 2% per year through 2017 (International Energy Agency, 2012).

Analysis by Deutsch Bank is more pessimistic on future demand. The report projects thermal coal could be 18% lower than forecasted levels for 2015, factoring in China's continued efforts to reduce air pollution to safer levels. According to the report, even if China takes no action to curb air pollution, coal imports will still decline by 15 million tons between 2013 and 2015 (Bockmann, 2013).

Asian Demand for Powder River Basin Coal

A recent report by the non-profit organization Sightline Institute reflects concerns on future Powder River Basin coal demand. The report highlights potential uncertainties in Asian energy markets and competition from within the Pacific Rim to satisfy demand (primarily Indonesia and Australia, and to a lesser extent Russia and smaller players). For instance, Australia's export centers are "roughly a thousand nautical miles, or 20 percent, closer to China's big eastern ports—and they have an even greater location advantage for Indian markets" (de Place & Kriese, 2012, p. 3). The report cites evidence of a Chinese slowdown and economic rebalancing away from more energy-intensive manufacturing, along with the country's existing deep reserves of coal, as factors that may undermine future demand. If China continues to depend on coal at current levels, the government has the option of building plants closer to the mines and building out a sophisticated—and needed—comprehensive grid network to help mitigate the lack of sufficient infrastructure connecting coal deposits (mostly in the north and northwest) to demand centers along the coast.

Despite these concerns, some point to the inevitably of coal, at least in the short- and medium-term. SSA Marine and Ambre Energy (owner of the proposed Longview-based Millennium Bulk Terminal) both clearly believe in the strong future demand for PRB coal from China, as evidence by their willingness to invest in these new, costly facilities.

Power (2012) argues that Chinese coal demand is largely a function of price, and the increase in coal exports with the completion of the proposed terminals will be large enough to push down global prices, "[reducing] the incentives to retire older, inefficient, coal-using production processes [and reducing] justification for additional investments in the energy efficiency of new and existing coal-using enterprises" (p. 14). The author points to previous research showing China's coal consumption is relatively elastic (i.e., an increase in coal prices is offset by an equal or greater offsetting decrease in consumption), and that the proposed terminals will only further increase burning of coal in China with a far less offsetting decline in the U.S. and other OECD economies.

CURRENT CONDITIONS IN SEATTLE

Current Rail and Coal Train activity

In keeping with general railroad practice and federal prohibitions, BNSF Railway does not normally release train volume statistics for individual line segments. But the company has argued that number of freight trains running on main lines through Seattle is approximately 20 percent lower in 2013 than in 2006. According to BNSF, after the full build-out of the Gateway Pacific Project (assuming 9 loaded and 9 empty trains, with all of these trains passing through Seattle), train volumes through Seattle would be modestly above 2006 levels. BNSF emphasized that potential Seattle rail traffic estimates would be reduced further if some of the empty trains returned via the BNSF Stevens Pass route, avoiding Seattle on their way east, or if an operating Gateway Pacific export facility diverted some of the volume currently moving north to British Columbia.

BNSF emphasizes that the largest increase in Seattle train volume traffic over the last decade has come from the growth of passenger rail service. Currently between two and three fully loaded coal trains pass through Seattle each day en route to the Westshore Terminal in Delta, BC.

An important consideration in estimating the economic costs of an increase in coal trains is whether empty trains en route back east will travel through Seattle or over Stevens Pass. The answer to this question has important implications for estimates of train traffic-induced surface congestion, property values, and other impacts within the City. The Seattle Department of Transportation estimated additional delay times in its Coal Train Traffic Impact Study (2012). The report assumed that empty cars will return east via Seattle. Seattle cost burdens associated with delays calculated in this study are based on these prior delay estimates.

The extent that the eastbound route for empty rail cars returning from Cherry Point will pass through Seattle is inconclusive, due to the high level of uncertainty and unknowns. For instance, a 2006 Washington State Transportation Commission study of rail capacity found that the Stevens Pass rail corridor had already reached 123% of practical capacity[1] and projected overcapacity to persist through 2025 (Washington State Transportation Commission, 2006). However, a more recent report by the Washington State Department of Transportation (2009) estimated Stevens Pass to be at 70% of practical capacity. Moreover, estimates of future stress on the corridor are scenario-contingent, e.g., whether or

[1] According to the 2006 report, "practical capacity" is approximately one-half of theoretical capacity, which is subject to an array of human, infrastructure, and other factors. For a more detailed discussion of the report's definition, see (Washington State Transportation Commission, 2006).

not the tunnel height at Stampede Pass is expanded to allow for double-stacking of containers. Estimates between these reports may vary because different methodologies were employed for measuring practical capacity and forecast marine cargo flow. Differences may also be attributable to improvements made by BNSF since the 2006 report. Based on interviews with the Washington State Department of Transportation and the Port of Seattle, capacity improvements have included improved exhaust ventilation in the Cascade Tunnel, allowing for a reduction in the time intervals between trains passing through, and additional sidings along the corridor (Washington State Department of Transportation, 2013; Port of Seattle, 2013).

According to the Washington Public Ports Association's (2011) most recent marine cargo forecast, BNSF has indicated plans (at least as of 2011) to divert empty bulk trains through Stampede Pass. Trains directed through Stampede Pass would be those "generated on the BNSF system from Kalama north, thereby relieving the BNSF Columbia Gorge route of eastbound empty bulk trains, except for those originating in Portland and Vancouver" (p. 37). BNSF has stated in that the empty cars will most likely go over Stevens Pass.

Duwamish MIC and North Waterfront Employment

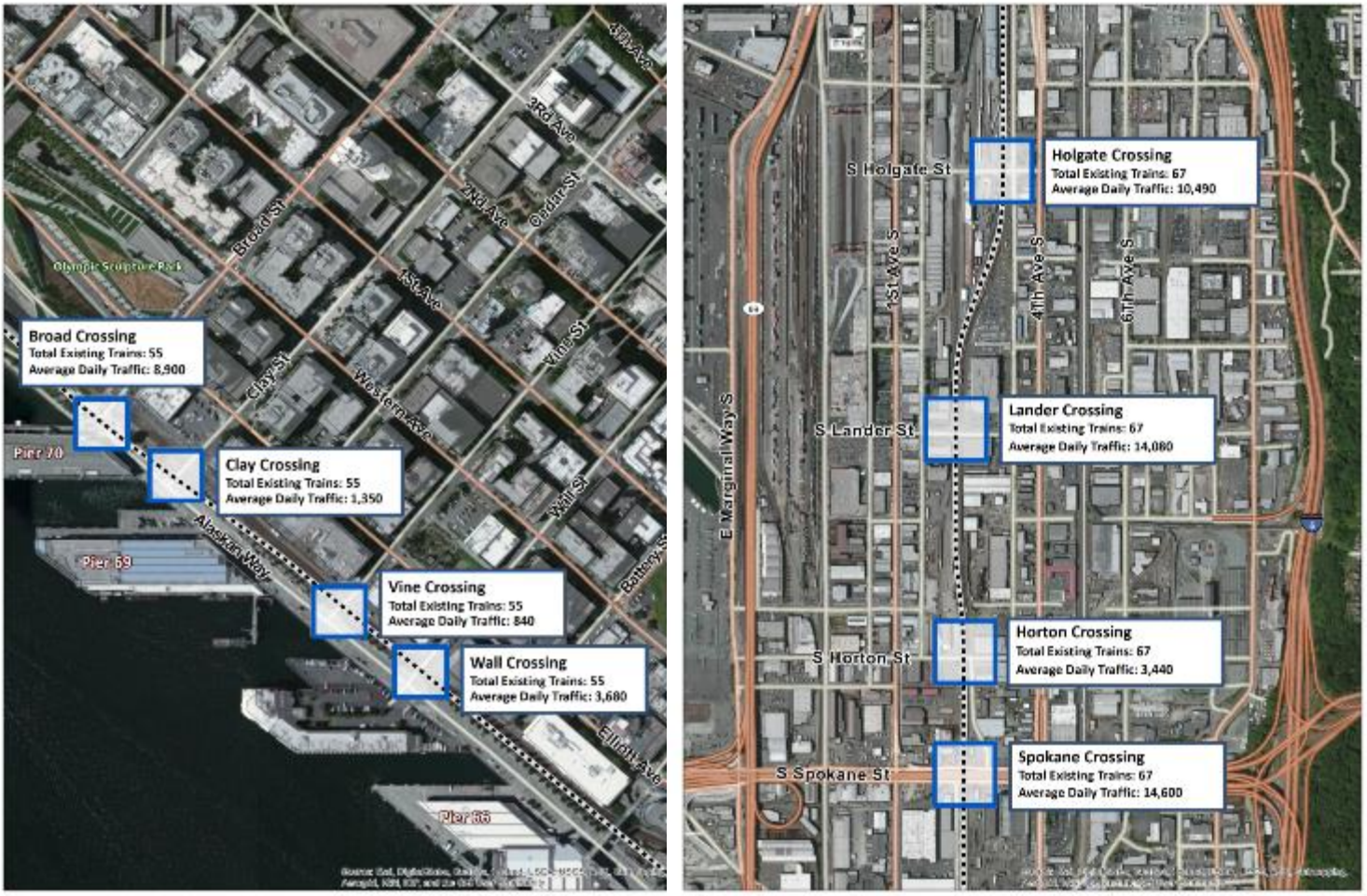
The two primary areas directly affected by increased congestion due to coal trains are the North Waterfront and Duwamish MIC, or SODO areas (SODO being a smaller area within the Duwamish MIC), each with four surface crossings. In the North Waterfront region, crossings are located at Wall Street, Broad Street, Clay Street, and Vine Street; in SODO, affected crossings are South Holgate Street, South Lander Street, South Horton Street, and South Spokane Street. **Exhibit 1** maps these intersections and current traffic flow estimates.

The SODO district, which includes census tracts 93 and 99, has a larger employment base than the North Waterfront area (census tracts 80.01 and 80.02), with nearly 44,000 covered workers in 2011 (compared to less than 17,000 in the North Waterfront). In 2011 SODO had a warehousing, transportation, and utilities employment base of almost 8,500 workers, owing to the large concentration of seaport terminals. The Port of Seattle's major intermodal container terminals are located in SODO (terminals 5, 18, 46, and to a lesser extent 30), along with BNSF's Seattle International Gateway rail yard and the Union Pacific Argo rail yard (at the far southern end). Between 2005 and 2011, the North Waterfront saw an increase in covered employment of 2,575, largely due to services, compared with a net decline of 1,977 in SODO (see **Exhibits 2 and 3**). In 2012, SODO was home to an estimated 254 street level businesses, including 86 retail businesses and 141 services establishments (Metropolitan Improvement District, 2012).

Exhibit 1. Affected Intersections in the North Waterfront and SODO

(a) North Waterfront

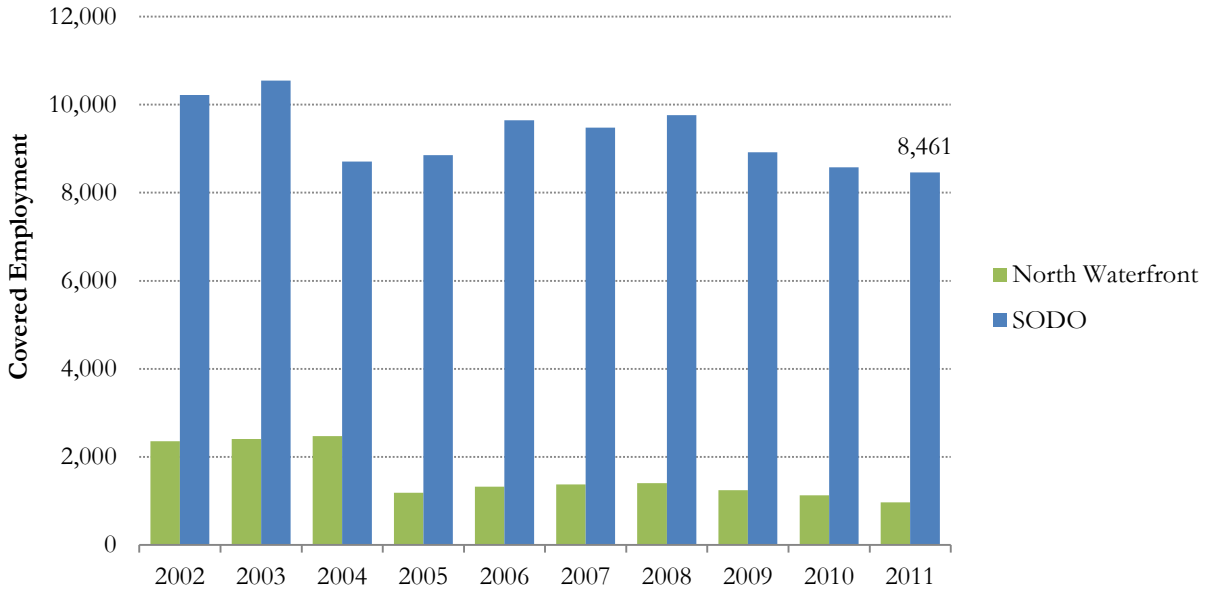
(b) SODO



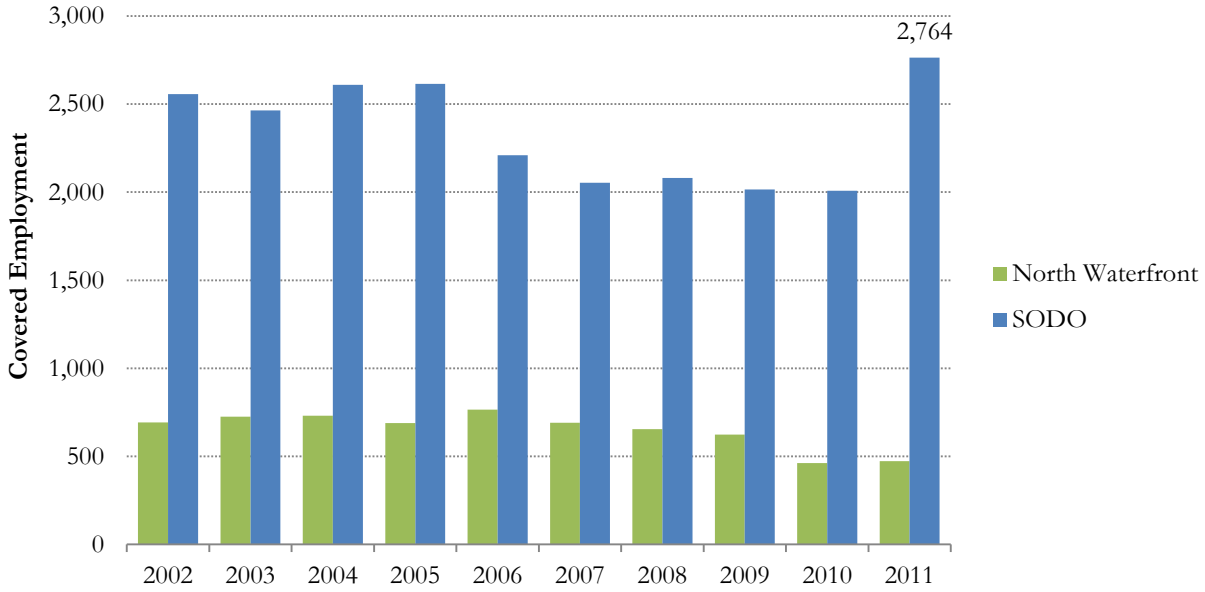
Source: Community Attributes Inc.; Seattle Department of Transportation (2012).

Exhibit 2. Employment in Affected Areas, 2002 - 2011

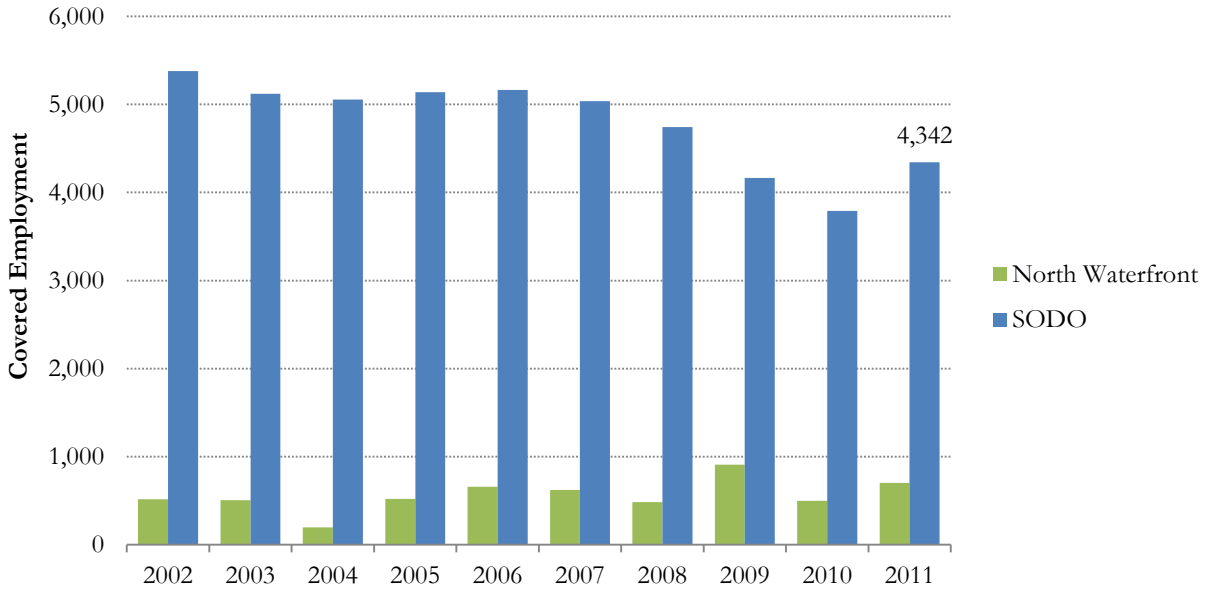
A. Warehousing, Transportation, and Utilities Profile
SODO and North Waterfront



B. Retail Profile
SODO and North Waterfront



C. Manufacturing Profile
SODO and North Waterfront



Source: Community Attributes Inc.; Puget Sound Regional Council (PSRC), based on the Quarterly Census of Employment and Wages, 2013.

Note: manufacturing data is not reported for the North Waterfront due to data suppression for various years for census tract 80.02.

Exhibit 3. Employment by Sector, North Waterfront and SODO Districts, 2011

	North Waterfront		SODO	
	Jobs, 2011	Change from 2005-2011	Jobs, 2011	Change from 2005-2011
Census Tracts	*80.01, 80.02*		*93, 99*	
Const/Res	28	(220)	2,869	154
FIRE	1,695	304	1,295	155
Manufacturing	703	181	4,342	(797)
Retail	472	(217)	2,764	149
Services	11,239	1,678	14,605	(1,145)
WTU	970	(213)	8,461	(392)
Government	1,088	285	8,874	57
Education	-	-	469	(155)
Total	**16,973**	**2,575**	**43,677**	**(1,977)**

Note: Manufacturing for North Waterfront is only for one census tract due to data suppression.

Data source: Puget Sound Regional Council, based on the Quarterly Census of Employment and Wages.

PROPOSED PROJECT AND ACTIVITY

The proposed terminal facility, the Gateway Pacific Terminal, is slated for construction at Cherry Point, just north of Bellingham in Whatcom County. The facility would include a 2,980 foot wharf with three berths. If built, the facility would be the largest of its kind in North America, capable of exporting 48 million dry metric tons of coal and an additional 6 million tons of other dry bulk commodities per year. SSA Marine identified four major reasons for its location decision: 1) the firm owns a large parcel of land on-site, of which roughly a third is slated for facility development; 2) the area was zoned as heavy industrial in the 1980s; 3) the presence of existing rail infrastructure; and 4) as a natural deep water port with no need for dredging, cape-sized vessels would be able to berth at the terminal.[2] For the latter reason, SSA expects greater economies of scale achieved through larger ships would help reduce transportation costs, often estimated to constitute up to 75% of total business costs for dry bulk shippers (Ritzman & Watters, 2013).

In February 2011, Peabody Energy—the world's largest private sector coal company—reached an agreement with SSA Marine to initially export up to 24 million metric tons of coal per year. Pacific International Terminals, a subsidiary of SSA Marine, is the developer proposing to build the facility.

Estimates vary as to the actual number of trains passing through Seattle. A report commissioned by the Seattle Department of Transportation (2012) released in the Fall of 2012 worked from the assumption that an average of 10 coal trains per day would pass through Seattle on their way to and from the Cherry Point terminal beginning in 2015, with up to eighteen trains passing through the city after full build-out of the proposed terminal.

However, it remains unclear how many trains would pass through the city, and when. In interviews, BNSF and SSA Marine report that, after full terminal build out an average of nine trains (eight coal trains and one dry bulk commodity load) would pass through Seattle heading north on a daily basis, with empty trains returning either east either through Seattle or via the faster (and steeper) Steven's Pass route (see above discussion).

[2] Cape-sized vessels are the largest class of vessels, able to carry between 180,000 and 240,000 metric tons of cargo. These vessels are too large to fit through the widened Panama Canal.

REGIONAL ECONOMIC IMPACTS

Economic Theory

Approximating the positive and negative impacts from coal shipments is not simple. The effects can manifest in a variety of ways; **Exhibit 4** helps illustrate some of these possible benefits and costs. The exhibit shows the types of impacts expected ranging from direct impacts (Tier 1, as shown), to more and more indirect impacts (Tiers 2 and 3). The increased capacity required to offload trains at the port of exit would require investments in construction and operations, the latter having a longer-term impact through greater economic activity and associated spillover effects (e.g., more jobs at a port, leading to greater spending in the regional income due to increased labor income).

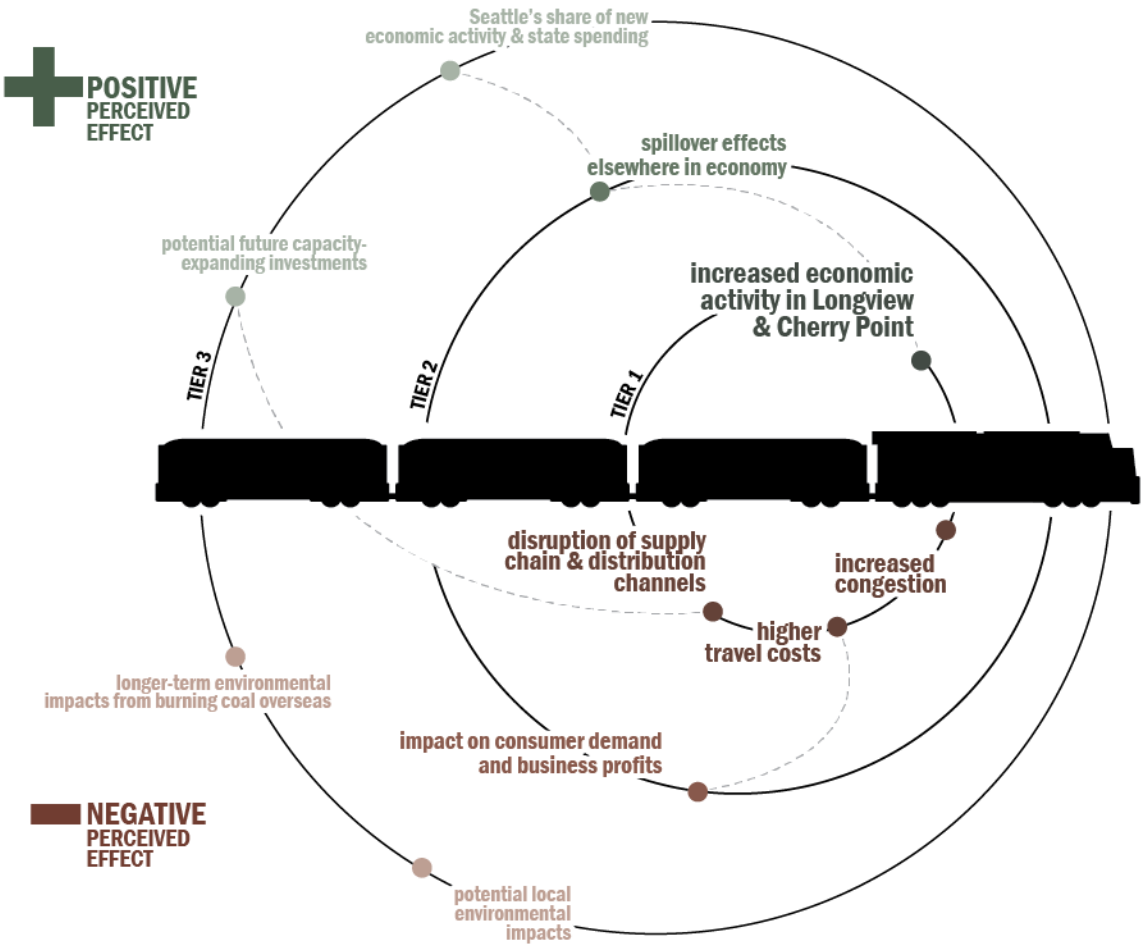
The two areas that would benefit most directly from this activity (gross benefits, not taking into account costs and impacts), under the current proposal are Cherry Point and Longview, though this increase in activity could spillover elsewhere in the state economy, including Seattle. For instance, since SSA Marine—the proposed operator at Cherry Point—is headquartered in Seattle, greater revenues earned through the Cherry Point operation could be transferred back to Seattle within the corporation, resulting in a possible increase in income spent within the city limits. Likewise, greater wealth accumulation at Cherry Point among newly hired workers could lead (through less observable channels) to some increase in spending in Seattle (either directly or indirectly). Part of the State's share of increased tax revenues (from direct, indirect, and induced impacts of the projects and operations) would likely be redistributed to Seattle, though costs due to congestion and other factors may offset these benefits.

In interviews, BNSF has indicated that if they determine that the increase in trains has the system nearing capacity, they may decide to invest in rail improvements, such as triple tracking. Such investments could in theory strengthen the competitiveness of the Port of Seattle as a whole, and would require collaboration with the City and the Port of Seattle. The public would be indirectly affected by these costs through tax revenues used to support these investments, for instance when necessary grade separations are needed to mitigate train-induced surface congestion or when capacity improvements along a privately held line are deemed necessary for regional competitiveness and in the public interest.

Trains, regardless of carrying load, can create congestion problems that erode business income and competitiveness, consumer spending through indirect "taxes" on travel, and quality of life attributes within the affected areas. For instance, a preliminary analysis commissioned by the City of Bellingham found

that an increase in trains would put pressure on an already stressed city rail crossing system; in some instances there may be insufficient time for queues to dissipate before the next train arrives (Gibson Traffic Consultants, Inc., 2012).

Exhibit 4. Hypothesized System Impacts of Additional Coal Trains



Source: Community Attributes Inc., 2013.

Congestion can disrupt supply chains and distribution systems, push up wages for commuting workers as compensation for additional commuting time, and make regions that depend on consumer traffic less attractive. Efforts to mitigate congestion can be expensive, especially if they include grade separation, though relatively sudden increases in congestion can expedite needed public investments. Increased capacity utilization can also rationalize intermodal investments, such as new rail lines and related infrastructure.

There are also clear environmental impacts, grouped into two kinds: 1) absent sufficient technology to fully contain coal dust, environmental degradation, and

other externalities resulting from spillage/emissions; and 2) the expected value of potential remediation fees associated with accidents, based on the probabilities of such an event. More broadly, coal burning in China and elsewhere contributes to GHGs and man-made global warming, and particulate matter from China can make its way back to Washington over months or years. Congestion induced by trains also leads to more idle automobiles, increasing carbon emissions.

Property values along or near affected areas may also be adversely affected due to train-related noise, vibrations, and congestion. For instance, Simons and El Jaouhari (2004) found that rail traffic affected the sale price of residential properties in Ohio in the 1990s. Using a hedonic regression model for the years 1996 and 1999, the authors found that an increase in rail traffic due to a routing reconfiguration resulted in decreases in residential property values that declined in magnitude as distance increased from the tracks.

More recently, a report commissioned by Climate Solutions estimated property values in areas north of Everett within 600 feet of the rail lines would decline 5 to 20%, depending on property type, due to the proposed train traffic increases. Similar properties in Seattle are forecast to decline by 3 to 5 percentage points less than the estimates for Everett (Climate Solutions, 2012).

However, these diminutions might be offset by an increase in values elsewhere within Seattle as property demand shifts to other areas, resulting in a transfer of wealth rather than an absolute decline.[3]

Negative impacts may primarily occur through increased congestion resulting in disruptions to supply chain and distribution channels, commuting times, and retail activities in the affected areas. Congestion can adversely impact businesses in the affected zones through a variety of channels, including the size of business markets, scheduling of business processes, deployment of personnel and vehicles, the dispersion of business locations, and use of intermodal connections. These impacts can "bear directly on either the competitive cost of doing business in a region or the ability to expand to expand business operations to meet the demands of a growing region" (Wiesbrod & Fitzroy, 2008, pp. 4-5).

Externalities associated with coal, such as remediation costs linked to spillage and coal dust in waterways over which coal trains travel also create economic impacts, sometimes indirectly. Absent additional capital expenditures to expand rail

[3] See, for instance, Zhang and Shing's (2006) analysis of London's congestion charge zone program, where the introduction of vehicle charge on congestion to enter a designated zone led to property values outside the zone increasing in value relative to the properties inside the zone.

capacity, an increase in train traffic may create costs for other shippers through the price mechanism of rail shipping rates.

Impacts also extend to community development, fiscal expenditures, and opportunity costs. A report by Public Finance Management (PFM) found that, when factoring other potential traffic mitigation costs and potential diversion of planned investments, the net economic impact to the city could actually be negligible or even negative. For instance, the report cited the risk to planned waterfront development in Bellingham from surface crossing delays as major concern. State and local agencies have committed more than $40 million for the project, which involves redevelopment of the former Georgia Pacific site in downtown Bellingham, but the project's feasibility may be compromised due to train noise and induced traffic. The Port of Bellingham projects that over a 25 to 30 year period, the project could result in $1 billion in investment and a net increase of 5,600 direct jobs (Public Financial Management, Inc., 2012).

Lastly, public sentiment about coal as a major contributor to greenhouse gases (GHGs) and congestion more generally may discourage both greater retail activities in affected areas—in this study, the SODO and North Waterfront districts—and prospective new investment or expansion by firms that rely on surface road systems. Congestion may in turn lead to a weakening of Seattle's competitiveness with other regions, particularly along the west coast, with sophisticated intermodal freight systems.

The following sections present the extent that these anticipated impacts may occur, their projected magnitude, as well as any positive benefits associated with more coal trains.

Major Economic Stakeholders

The shipment and selling of coal entails many stakeholders. These participants range from the owners of the land from which coal in mined (the U.S. Bureau of Land Management), the mining company that leases the land (Peabody Energy), the shipper (also Peabody Energy), the rail company (BNSF for coal shipments to Cherry Point), the terminal operator under the proposed plan (SSA Marine), the oceanic shipper, and market participants overseas (e.g., power plants and energy users in China and elsewhere).

Bureau of Land Management, Peabody Energy, and Cloud Peak Energy

The source of the coal, the Powder River Basin, is the single largest source of coal in the United States. In 2011, twelve active coal mines in the basin produced 423.2 million tons of coal, representing a 2.9% average annual increase since 1998. The largest producers were Peabody Energy (148.2 million tons), Arch

(115.0), and Cloud Peak Energy (76.6) (U.S. Bureau of Land Management, 2012). Peabody and Cloud Peak Energy are both entirely invested in coal. However, Cloud Peak Energy is entirely invested in Powder River Basin coal, whereas Peabody Energy has international assets.

Burlington-Northern Santa Fe (BNSF)

Burlington-Northern Santa Fe (BNSF) is the exclusive rail shipper for all coal heading north through Seattle. Currently between two and three BNSF coal trains pass daily through Seattle en route to the Westshore Terminal facility in Delta, British Columbia. BNSF has been operating in Washington for more than 100 years, and has exclusive rights to I-5 corridor rail mainline north of Tacoma (as well as other sectors of the state), though it also leases use for passenger rail.[4] BNSF currently employs roughly 3,500 workers within Washington. Since the start of the economic recovery, the company has added between 400 and 500 new workers in the state. The employment bases are not large within Seattle, but are typically industrial high-skill, high-paying jobs. Because of the training investments required, the company resorted to furloughs with retained benefits rather than layoffs during the economic downturn. The Seattle International Gateway (SIG) located in the SODO district of Seattle is a BNSF rail yard (Finn, 2013).

SSA Marine

SSA Marine is the largest U.S. terminal operator and among the top ten globally. The firm was established in 1949 by Fred Smith in Bellingham, WA, originally as a stevedoring operation, and continues to be a privately held company under management by a third generation of the founding family. It later expanded its operations into terminal operations and relocated its headquarters to Seattle in the 1960s. Today, the company directly employs approximately 400 full-time equivalent (FTE) employees in Seattle, including 130 employed in Tideworks, a software company fully owned by SSA Marine that develops software-based terminal operations solutions; both headquarter operations are located on Harbor Island in Seattle. Globally, SSA Marine employs approximately 2,000 workers, as either direct FTEs or longshoremen, many of which are based in Seattle and earn on average between $90,000 and $100,000 annually. The company currently operates fifteen terminals worldwide, with long-term leases or ownerships in the U.S. (two in Seattle, two in Oakland, three in Long Beach), Mexico (1), Vietnam (2), Chile (2), Panama (1), and Colombia (2) (Ritzman & Watters, 2013).

[4] For more detail on rail lines in Washington, see Washington State Department of Transportation (2011).

Port of Seattle and logistics firms

According to a 2009 report commissioned by the Port of Seattle, rail operations at the Port accounted for approximately 1,621 direct jobs and over $1.5 billion in direct output in 2008. However, these counts include terminal and rail operations located on Port property. Within the two directly affected districts, warehousing, transportation, and utilities (WTU) employed more than 9,400 workers in 2011.

Local businesses

Contributors to this report included businesses representing the restaurant, hospitality, tourism, and hotel industries and associations representing diverse manufacturing and logistics interests (see **Appendix D** for a list of these interviewees).

Regional economies and communities

The short-term economic impacts to communities from the Cherry Point project can be negative or positive. Potential negative impacts to communities include job losses (for reasons discussed above), congestion, lost potential investments, as well as potential health and environmental hazards from coal trains and coal terminal operations.

Recent studies for other regions of Washington commissioned by proponents of coal terminals in Washington have focused on the positive impact of an increase in economic activity associated with the construction and operation of coal terminals, of which Seattle would not be a direct recipient. For instance, a report commissioned by Millennium Bulk Terminals, which would build and operate the proposed coal terminal at the Port of Longview, used the Washington State Input-Output model to show that the proposed $600 million, 100 acre multi-year investment would lead to a short-term impact (i.e., activities related to construction) of 1,350 temporary direct jobs, $70 million in direct wages, and $232 million in direct output. Indirect and induced impacts (i.e., the increased demand on suppliers and effects of new labor income spent elsewhere in the economy) resulting from construction would add another 1,300 jobs, $65.0 million in wages, and $203 million in output. The study estimated the long-term direct impacts from terminal operations (following a complete build-out) would be 135 workers, $16.0 million in labor income, and $49.0 million in output per year, with aggregate indirect and induced impacts of an additional 165 workers, $9.0 million in labor income, and $21.0 million in output elsewhere in the economy (Millennium Bulk Terminals Longview, 2012).

A similar analysis, employing a RIMS and proprietary input-output model, was commissioned by SSA Marine to assess the economic impacts of the proposed facility in Whatcom County. The analysis estimated a net impact (direct, indirect,

and induced) from operations of 863 annual full time equivalents (FTEs) for Phase I (25 million dry metric tons), and 1,229 annual FTEs after completion of Phase II (54 million dry metric tons), with $1.4 billion in business revenues and $11.2 million in state and local taxes for Phase II. The net construction impacts for both phase I and Phase II would include nearly 22 million hours of labor, $411 million in income, $665 million in business revenues, and $92.4 million in state and local taxes (John C. Martin Associates, LLC, 2011).

An alternative study by a team of local economists, using an IMPLAN model, found a direct impact from the proposed coal terminal when fully operational of 430 workers with aggregate labor income of $40.8 million. Factoring in indirect and induced effects the authors estimated an aggregate impact of 1,229 jobs, $126.3 million in income, more than $1.4 billion in output, and $11.2 in state and local taxes per year (based on taxable output associated with economy-wide increases activities derived from expanded port activities). The construction phase of the project, based on IMPLAN estimates, would directly employ 1,648 workers with a total impact of nearly 3,000 across the economy (Brewer, Hodges, & Nelson, 2011)

SEATTLE AREA IMPACTS

Benefits

SSA Marine

In interviews, SSA Marine presented potential direct positive impacts associated with the initial terminal build out and future operations of the facility. SSA Marine anticipates hiring up to 12 full-time equivalent employees based in Seattle to handle the day-to-day project management for the proposed new terminal; with an average fully loaded annual compensation of $200,000 (40% of which is benefits), equating to $2.4 million per year.

SSA Marine anticipates pre-operation gross expenditures of roughly $13 million on regulatory and permitting expenses, e.g., environmental impact study (EIS) contractor, environmental engineers, and commissioned studies as part of the EIS. SSA Marine would spend approximately $6 million in engineering design packages to contractors once permits are awarded. Engineering support is about $3 million before the permits are finished. Legal fees and public relations will likely total $5-6 million. The firm anticipates that the majority, if not all, of this work would likely be done by firms based in the Seattle and Bellevue. Once the terminal is completed and fully operational, seven of the twelve new hires at SSA Marine would be relocated to Cherry Point (Ritzman & Watters, 2013).

Burlington-Northern Santa Fe (BNSF)

BNSF does not anticipate a direct increase in employment in Seattle; the switching yards at SIG are purposed with loading, unloading, and building trains, and these activities for coal would take place at the originating mines. However, an increase in rail traffic could spur additional capital investments such as triple-tracking in Seattle, that would further the competitiveness of the Port of Seattle for intermodal cargo traffic. BNSF has a record of making capital investments necessary to reduce congestion and bottlenecks. The company recently invested in a third track and new sidings in Auburn that allow for more capacity; siding and storage capacity reduce delays and increase the number of trains that can operate along a given section of the mainline. Ideally, BNSF has stated they prefer a siding every five miles to pull a train off and let another pass by. Without these sidings BNSF would have to hold a train and send it up 20 miles or more, reducing mainline capacity (Finn, 2013).

BNSF has refuted several of claims regarding the impact of more coal trains. In a letter to then-Governor Chris Gregoire, the company stressed that there would be adequate capacity to "handle current and future freight and passenger volumes [and that increased volume] provides the necessary private capital to refresh BNSF's physical plan and expand capacity," largely echoing the Port of Seattle's view. In 2012 (time of writing), BNSF planned $106 million in investments across the state, largely to "enhance service for existing customers." In the letter, the company did not provide a clear estimate of the net impact in train traffic, but emphasized that the increase is small relative to the total volume of rail traffic in Washington State. In response to concerns that more rail traffic would disrupt Amtrak passenger service, BNSF highlighted that the success of the current system would not have been possible "but for the fact that BNSF accommodated its own growth in freight volumes through consistent and aggressive capital investment and operations efficiencies." In terms of environmental impacts, the letter emphasized BNSF's installation of green technology (e.g., wide-span electric cranes in Seattle and advanced locomotive fleet) and its request that coal customers treat coal carloads with a surface crusting agent to prevent dust emissions (BNSF, 2012).

In BNSF's estimation, the most likely scenario would be up to nine loaded trains heading north to Bellingham upon full build-out of the Cherry Point terminal. However, it is not yet clear whether this would include, or be in addition to, the two to three coal trains that currently pass through Seattle daily en route to Vancouver, B.C., thus absorbing terminal activity in the north, nor the route of empty cars heading back to the Powder River Basin (discussed above). For loaded cars, while the route from Spokane, down to Pasco, and along the Columbia

Gorge may be longer, the load weight and grades through Stevens Pass makes the flatter southern route more economical.

Economies of coal. In BNSF's view, current economies support coal shipment—demand continues to rise in Asia, mining is cheap, and no sufficiently scalable alternatives currently exist in China and India. Transportation of coal from the Powder River Basin to Asia constitutes roughly 75% of the total cost. The proposed terminal at Longview, a 43-foot dredge channel along the Columbia, would only be able to handle medium-sized ships; the Cherry Point facility, by comparison, is a deep water port able to handle large ships.

BNSF does not view increased coal traffic as an opportunity cost question, i.e., the increase in coal-bearing trains would not displace shipments of higher value-added goods. BNSF emphasized it would not lose capacity because this business allows for investment in the network. Passenger trains were the more recent example of these same opportunity cost worries. BNSF emphasized that adjustments were made to accommodate that increase, and is confident they would do so again.

Possible congestion impacts. BNSF does not believe the added trains would increase surface traffic, similar to the position of the Port of Seattle. Over the past decade, freight traffic has actually declined, offset by an increase in passenger rail. Over the past twenty-five years, two to three coal trains have passed through Seattle each day, and BNSF does not anticipate any strain on rail capacity from the planned increase.

To accommodate additional rail traffic, lighter trains can be rerouted over the mountains at Stevens Pass (bypassing Seattle), with heavier trains taking the longer, flatter route along the Columbia Gorge. Grain and other heavy commodities were previously shipped this way, with lighter intermodal cargo using the two alternative routes; more recently, BNSF found adding extra engines to these grain trains to get them through Stevens Pass relieved congestion on the southern track. Most Port of Seattle trains go north, not south. Double tracking to the north from Sounder has reduced congestion as well.

BNSF coordinates with Amtrak and Sound Transit, and over the last decade BNSF has seen a reduction in freight trains, offset by an increase in passenger trains. Freight trains were down from 54 trains per day to 41 or 42 per day, while passenger trains went from 10 to 26 during the same time.

BNSF emphasized that rail is a critical component of Seattle's global competitiveness. Seattle is a highly rail-dependent city, anchored by the Port of Seattle; roughly 65-70% of all traffic through the Port of Seattle travels via rail,

with cargo volumes far in excess of Seattle's local demand. Critical to Port operations is the rail mainline, allowing for shipments as far east as the Midwest, and use of rail is proven to be 3 to 4 times more energy efficient than trucking per ton of cargo.

Environmental impacts—coal dust. BNSF has a policy on coal dust emissions, which includes a tariff/rule imposed on shippers and miners (the responsible parties for coal loading) requiring the application of one of three types of topical agent or spray to contain dust. Stated company policy is to reduce incidence of coal dust near the mine by 85%. Loaded coal must also be wind profiled as part of this tariff to minimize the risk of wind-induced dust emissions.[5] BNSF reports it has a strong incentive to limit dust emissions—coal dust can damage rails, and when coal dust settled within the ballast rock under the rails mixes with rainwater a concrete-like consistency can form, raising the risks of a derailment (which has occurred in recent years due directly to these coal dust-induced hazards), imposing financial and operating costs on the company.

Potential benefits associated with more coal trains. According to BNSF and the Port of Seattle, an increase in rail traffic could spur additional capital investments, such as triple-tracking in Seattle, that would further the competitiveness of the Port for intermodal cargo traffic. BNSF has a record of making capital investments necessary to reduce congestion and bottlenecks. The company recently invested in a third track and new sidings in Auburn that allow for more capacity; siding and storage capacity help reduce delays and increase the number of trains that can operate along a given section of the mainline.

Economic Costs

Congestion impacts descriptions

A recent study commissioned by the Seattle Department of Transportation modeled the impact of additional coal trains on eight crossings in the North Waterfront and SODO districts (Seattle Department of Transportation, 2012). The study assessed the impact across four categories of disruption: crossing delays/gate down times; vehicle queues at railroad crossings; safety (i.e., risks of pedestrian, bicycle, and vehicle collisions with passing trains); and emergency vehicle access.

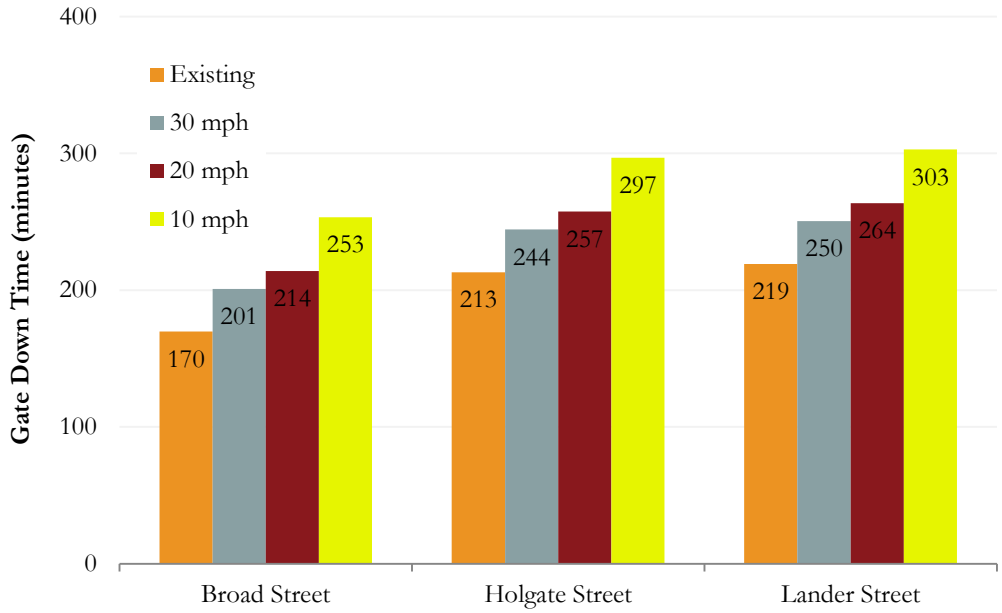
Currently, each day approximately 30 freight trains pass through the North Waterfront district, and 65-85 freight trains passing through SODO, including 1.6 mile-long long-haul trains. In addition, Sound Transit operates four Sounder trains north and nine trains south, and Amtrak operates 14 trains daily through

[5] Profiling usually takes the recognizable shape of a concave "bread loaf" in each loaded car.

Seattle. BNSF also operates rail tracks east of East Marginal Way South that serve its Seattle International Gateway intermodal terminal, with additional spur tracks off the BNSF mainline serving operations between I-5 and Fourth Avenue (Seattle Department of Transportation, 2012).

The SDOT study projects that in 2015, the estimated additional daily gate down time for coal trains could be 31 to 83 minutes, translating into an increase in daily gate down time of approximately 18% to 49% at Broad Street and 15% to 39% at both Holgate and Lander Street. By 2026, additional daily gate down time for coal trains could be approximately 67 to 183 minutes (representing an increase in daily gate down of approximately 39% to 108% at Broad Street and 31% to 86% at Holgate and Lander Streets). **Exhibit 5** summarizes these scenarios for different train speeds.

Exhibit 5. Estimated Daily Gate Down Times, by Train Speed Scenarios, 2015



Source: Seattle Department of Transportation, (2012).

Overall vehicle queue lengths at railroad crossings vary depending on when trains, including coal trains, arrive in relation to other trains and city traffic patterns. Freight trains longer than the proposed coal trains already operate today. The maximum number of vehicles queuing from a single train would not increase provided coal trains are operating at 20 mph or greater. Coal trains added to the current demand would increase the number and frequency of vehicles waiting in a queue.

The eight crossings adversely affected by the proposed increase in coal rail traffic are all within either the Northern Waterfront or Duwamish industrial zone

(SODO). If the terminal in Cherry Point is constructed and on schedule, in 2015 there would be ten 1.3 mile trains passing through Seattle; by 2026, this number may increase to 18 daily trains with an extended length of 1.6 miles. However, the current plan is for 8 coal trains plus one dry bulk commodity train, and it is possible that empty cars would be diverted over Steven's Pass rather than roundtrip through Seattle (this remains undecided).

Another limitation in estimating the congestion impacts of more trains is the lack of certainty and clarity on train schedules. While the Seattle Department of Transportation (2012) report modeled the impacts at three crossings at equally spaced time intervals throughout the day, in reality the schedule is far less certain, with the possibility of more trains passing through at specific intervals. This is due in part to the nature of mining extraction and off-loading port operations, but also uncertain weather conditions. For instance, landslides typically require 10 hours of rail segment closure for debris removal and slope stabilization, plus a 48 hour moratorium on passenger trains passing through the affected area. The advent of up to 18 additional coal trains would further aggravate these risks—potential delays not yet accounted for in the analysis.

Economic impacts associated with increased coal trains are not easy to quantify. To help illustrate these impacts, analysis was subdivided into four categories: 1) quantifiable estimates; 2) feedback from the business community and stakeholders in affected areas, primarily through interviews; 3) approximations of the costs for solutions intended to ameliorate congestion problems; and 4) impacts related to the Port of Seattle.

Congestion impacts quantified

Increased congestion can create a financial burden on vehicle travelers, as calculated by the loss in "value of travel time" (VOTT) associated with delayed travel, though these estimates do not factor in diversionary/adjustment behavior on the part of travelers along affected routes. The VOTT refers to the cost of time spent in travel—waiting as well as actual travel—including "costs to consumers of personal (unpaid) time spent on travel, and costs to businesses of paid employee time spent in travel" (Victoria Trasport Policy Institute, 2012, pp. 5.2-2).

This study employs a VOTT approach to estimate an annual dollar impact, though it should be noted that this approach is intended as an approximation and is subject to several important limitations. The VOTT estimates in this study vary based on estimation methodology and geographic scope and reflect revealed preferences of drivers based on tolls and traveling costs not directly associated with rail crossing delays. Estimates are made of the congestion impact under the

assumption that travelers, commercial drivers, and affected firms do not alter their traveling and economic behaviors to adapt to increased delays.

Importantly, calculations are based on estimated cumulative delay queues modeled by Seattle Department of Transportation (2012). These estimates were reported in physical length (as measured in feet) of queues at three of the eight affected crossings (Broad, Holgate, and Lander), but there is no available data on the traffic flows at these intersections disaggregated by vehicle type (e.g., two-axle passenger cars versus three or more axle trucks, and concomitant variation in vehicle length), nor purpose of travel (e.g., to a leisure destination, commuting, shipping, etc.). No information exists on the future costs of fuel and wages, which may impact VOTT estimates.

The traffic flow data was based on video recordings by the Seattle Department of Transportation (SDOT) for three of the eight identified affected crossings; because estimates here are based on the work previously done by SDOT (2012), direct travel cost estimates are made for these three crossings.

Travelers may assign a cost associated with the potential increase in traffic volatility, resulting in diverted trips or alternative routes that take longer on an average basis. Moreover, extended queues may, if long enough, occasionally impact the broader transportation network, adding to traffic congestions elsewhere. These impacts were not modeled, but should be mentioned as additional potential outcomes.

To calculate a dollar cost of delays due to a full schedule of 18 coal trains per day in 2026, the costs of delays with and without the additional trains were calculated to arrive at a difference. To do so, the number of uniform 25 foot long vehicles per minute at the three intersections was analyzed over a 24 hour period. Queue length estimates by the Seattle Department of Transportation (2012) are based on average traffic flows for a five-day work week. After arriving at the number of vehicles per minute at each crossing, the difference with and without the additional trains was subtracted to get an estimate of additional cars per minute in queue; this value was then multiplied by alternative estimates of VOTT divided by 60 (to get a summed total based on vehicles per minute). Calculations were varied based on the distribution of vehicles between passenger car and truck, adjusting estimated queue lengths to reflect these vehicle length differences (using a simplified approach, assigning a length of 25 feet to passenger vehicles and 60 feet to trucks, with space in between vehicles accounted for in length). **Appendix A** articulates these relationships.

The calculations suggest that an increase in the number and length of crossing queues would lead to annual dollar impact to drivers of between roughly $79,000

and $254,000 in current dollars, depending on the constitution of the fleet (with an estimate between 0% and 30% trucks), the speed of the train at Lander St. (between 10 mph and 20 mph), and the estimates of VOTT employed (**Exhibit 6a**). Though there are no estimates for the other five intersections, approximations can be made as to the total cost burden for travelers, assuming that queue length increases due to the additional trains at the other five crossings (Clay, Vine, Wall, Horton, and Spokane) are proportional to their traffic flows. For instance, Clay has weekday (Monday through Friday) traffic that is 15.1% of Broad levels, extrapolating a queue length increase (in feet-minutes) of about 727.8 feet per day; Broad can be used as the comparator crossing also for Vine and Wall, and Lander for Spokane and Horton. Assuming only up to 2% of the queue length for these intersections are trucks, analysis arrives at a total value of travel time cost burden for all intersections combined of between roughly $384,000 and $455,000 per year, based only on weekdays (**Exhibit 7b**).

Costs modeled here are isolated only for congestion in three crossings, and may actually understate the true economic impact on users of these roads. For instance, to what extent would shipping be disrupted by unpredictable, lengthy delays? Would landslides north of Seattle—already a major issue for passenger trains—and other disruptions push an already strained rail system beyond its functional capacity? How might congestion points affect the Port of Seattle's competitiveness, particularly given the already intense competition as a portal to Asia with other West Coast ports? These issues are explored below.

Exhibit 6a. Annual Value of Time Costs Due to Congestion, at Full Build-Out

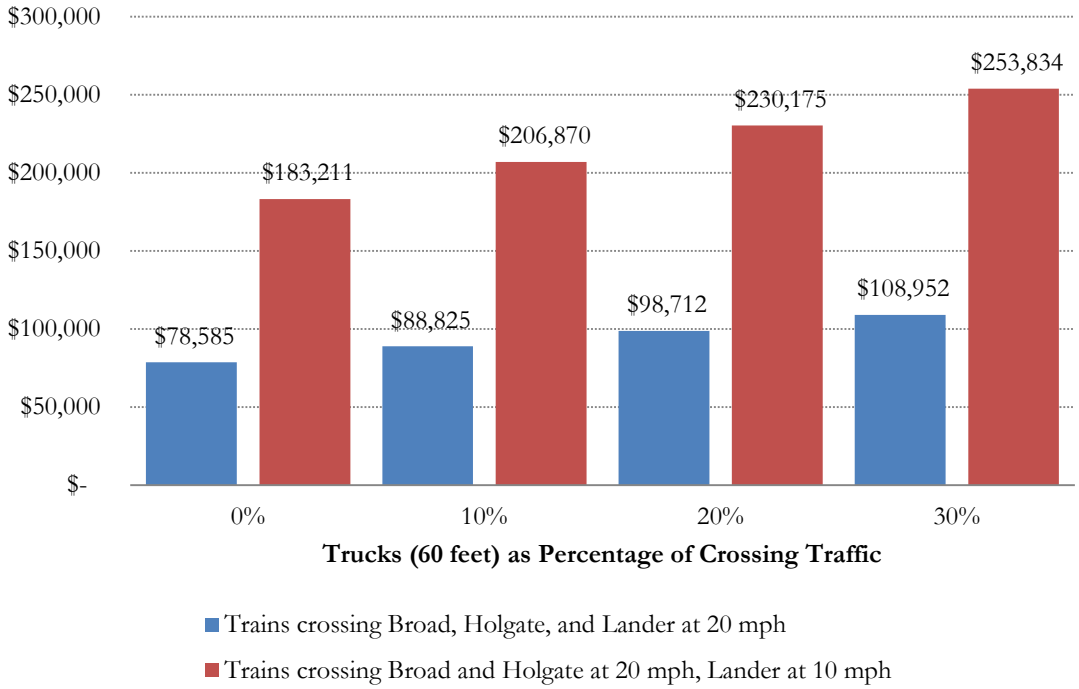
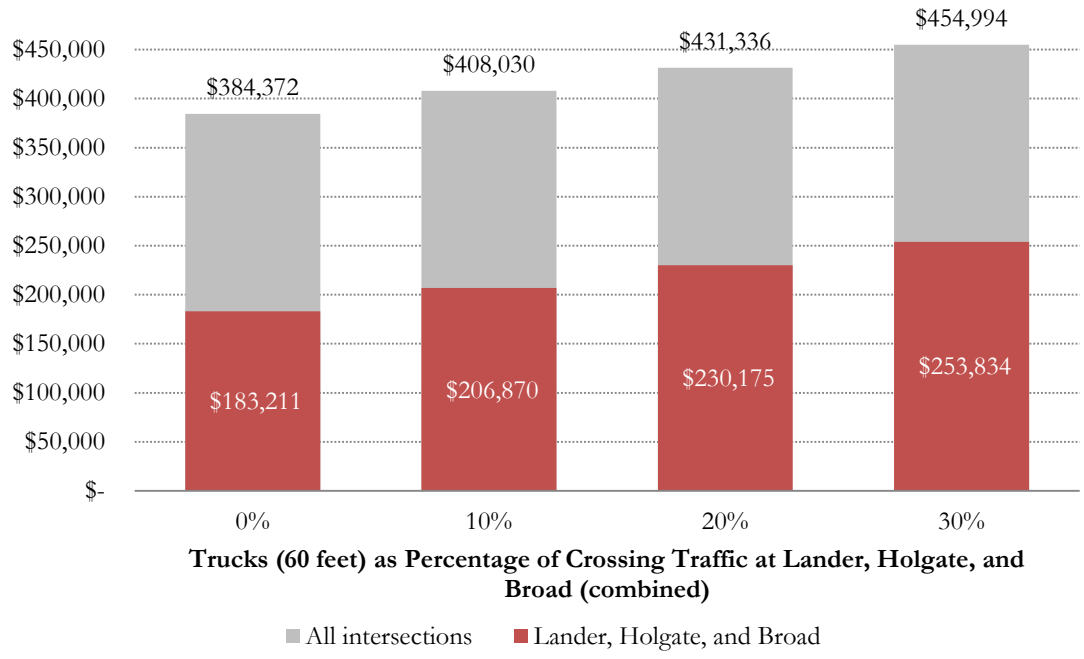


Exhibit 6b. Estimates of Annual Value of Time Costs for All Intersections, Assuming Trains Pass Lander at 10mph, at Full Build-Out



Note: based on $81.49 VOTT for trucks and $26.47 for cars, including inflation adjustments.

Anticipated public mitigation costs

The impacts of congestion can also affect health and safety, which includes associated economic costs. For instance, train-induced delays can impact aid car (e.g., ambulances, fire trucks, ladder trucks, police vehicles) access to the waterfront and the section of SODO west of the north-south tracks. Currently, the Seattle Fire Department Station 14 is to the east of the tracks, requiring crossing via Lander to provide emergency assistance to the western half of SODO. When a train delay occurs, responders must determine whether to wait out the length of delay or dispatch an aid car from another station. Because there is no certainty as to the schedule of coal trains passing through the city, no easily rendered predictive model exists for determining when congestion events might occur. A similar problem is presented at Fire Station 5. While the station is west of the tracks, and is purposed with waterfront fire and emergency response, larger incidents requiring assistance from downtown stations could be obstructed by a passing train, or delays induced by the increase in train traffic and backup either north or south.

According to the Seattle Fire Department, its Fire Alarm Center needs up-to-date and accurate information about any road closures to determine which companies to dispatch that will arrive at an emergency in the shortest amount of time. A doubling of the number of trains and blockages in the SODO/North Waterfront complicates this task. The trains would essentially double the amount of time that eight east-west crossings are blocked. In a worst case scenario it may take 10 to 12 minutes to reach areas west of a long coal train moving through those intersections. The Fire Department's response times to those areas now averages 4 minutes.

The Department is working with SDOT on getting real-time traffic condition information fed into the computer assisted dispatching (CAD) system. Traffic conditions could include the movement of coal trains and crossing closings and openings. With this real time information the CAD system can dynamically select the closest companies that will arrive at an emergency scene in the shortest amount of time. Response times would still be greater than when all of the crossings are open but the Department will be able to make the optimal dispatching decision.

Range of costs for these changes. The Fire Department has just started to work with SDOT on the traffic condition interface. Very preliminary information on the traffic condition interface suggests it will be under $150,000 to implement.

Other infrastructure improvements in SODO and/or the North Waterfront. The Fire Department agrees with the grade separations and traffic re-

configurations options in SODO and the North Waterfront areas discussed in the Seattle DOT (2012) study, but these solutions would be expensive (Nelsen, 2013). If Station 14 needed to be relocated, it would cost an estimates $9.5 million, plus the costs of land.

According to the Seattle Department of Transportation, with the advent of up to 18 coal trains a day, there are two capital-intensive infrastructure solutions, both of which would present costs to the city and taxpayers. The first option would entail construction of a new fire station to the west of the tracks, circumventing train-induced delays. The second option would be the construction of a grade separation (i.e., bridge overpass) over the tracks at Lander Street; because separation over rail lines must be at least nearly 24 feet, and the complications associated with such a project, Seattle Department of Transportation anticipates such a project would cost at least $100 million (Eaves, 2013).

Coal dust health impacts

Estimating the economic costs from adverse health outcomes is difficult within a reasonable range. There exists a large body of literature on the health impacts of coal dust at the place of extraction (i.e. at the mine), but only sparse reports on the impacts of non-occupational health hazards. For instance, a literature review by the Environment Canterbury Regional Council of New Zealand (2009) states that there are "few studies in the literature of respirable dust concentrations and/or health outcomes for non-occupational exposure to coal dust" (p. 6). While there may be risks associated with coal train dust emissions, there is insufficient updated and scientifically conducted analysis to allow for an economic impact assessment at this time. For instance, the last time the EPA published a report on the effects of transporting coal was in 1978 (U.S. Environmental Protection Agency, 1978).

Based on the above, the EPA and others have called for an examination of coal dust to be included in the environmental impact study (EIS) for the proposed terminal. The EPA's scoping comments for the EIS, the agency calls for an evaluation to include "potential increases in fugitive coal dust and diesel emissions that would accompany rail traffic to the proposed new terminal, and the potential related human health impacts to communities along the proposed routes" (U.S. Environmental Protection Agency, 2013).

Impacts on businesses in crossing areas

Several landowners, businesses, and organizations in the SODO and North Waterfront areas were interviewed, representing manufacturers, transportation and logistics firms, food and retail, and recreational activities (see **Appendix B** for list of interviewed stakeholders).

Among interviewees, most saw the coal train traffic within the larger context of disruptions brought on by seawall construction, viaduct replacement activities, and even the prospect of a new arena in SODO. Within this context, interviewees largely saw the coal trains as having only a limited impact. For instance, the North Waterfront area depends on visitor traffic. In the summer, roughly one third of total visitors are from within King County, while in the winter (largely due to less tourist traffic) about 70% come from within the county. Roughly 3.5 million people visit the waterfront each year, including 800,000 visitors to the Seattle Aquarium—more than the combined visitors to Mariner and Seahawk games. After the waterfront redevelopment is complete, this number is expected to double to 7 million visitors.

However, the Edgewater Hotel's major concerns deal directly with train noise and train-induced traffic delays. The hotel, opened during the World's Fair in Seattle 50 years ago, has 240 full-time employees and has $25 million in annual revenues. The hotel has an annual occupancy rate of about 80%, though this includes seasonal variations (winter occupancy rates are usually closer to 70%). The hotel attributes loss of business in recent years largely to disruptive train noise, which primarily affects the 50% of hotel rooms facing the city (the hotel provides complimentary earplugs for city-side rooms).

The hotel's competitiveness is also hampered by traffic, which can be an acute issue for visitors trying to get to the airport or a downtown meeting but are stuck on Alaskan Way waiting at a crossing gate. Trains crossing over Broad Street typically travel closer to 10 miles per hour, and crossing gate queue times can last as long as 25 minutes at the current train volume. The Edgewater depends heavily on car-based visitors—roughly 60% of non-corporate customers are from within the Northwest and thus come by way of automobile. Corporate clients, which used to constitute roughly 35% of total business, have since dropped to 22%, and feedback from clients indicated the noise and train traffic were major inconveniences. Reviews on TripAdvisor.com have highlighted these disruptions, further hurting business. Local businesses, including software and media firms, have since relocated to other parts of downtown and South Lake Union. The hotel recently replaced all of its windows, but due to the age of the building it cannot be retrofitted to be more soundproof. The hotel is unable to predict what the future impact of more trains would be on its business, other than to say it may need to reduce employment to offset continued declines in business (Cocks, 2013).

Other waterfront businesses, while acknowledging adverse traffic impacts due to the trains, view by many more orders of magnitude inadequate traffic and parking management during construction and limited mass transit service; an increase in

trains simply further aggravates an on-going set of problems. When traffic delays occur, these inconveniences discourage customers from visiting more frequently, hurting tourism- and recreational-based businesses in the area. Ferry traffic during construction can also be very disruptive, leading to long traffic queues on Friday nights, from Pier 52 to as far north as Pier 69.

The pending seawall construction (set to begin Fall 2013 and continuing into 2016) may further aggravate traffic delays and business operations in the area. For instance, the sidewalk in front of the Seattle Aquarium will be closed off, shortly followed by viaduct-related construction (Plunkett, 2013). These backups are also of concern because Alaskan Way is the primary route for overweight trucks carrying cargo and hazardous materials heading to Ballard.

Based on survey data collected by Ivar's Acres of Clams, Pier 57, the Seattle Aquarium, and Argosy Tours over the past sixteen years, roughly 65% of visitors to the waterfront travel by car and as family groups, typically with a local resident (from either Seattle or the surrounding suburbs) taking visitors/family members from out of town to the waterfront for dinner, a cruise, or other recreational activities. There has been a reduction in metered parking under the viaduct, which will continue following construction.

Feedback from Pier 57 helps illustrate some of these anticipated problems. Pier 57 is a family owner-operator business along the waterfront; the business owns the building and street-side land, but leases the last portion of the pier, which extends into the tidelands, from the Washington State Department of Natural Resources. Griffith family owns all businesses operating on the pier, including two large restaurants—the Fisherman and the Crab Pot, the latter one of Seattle's highest-volume restaurants—a creamery, bakery, food court, and the recent addition of the Great Wheel. Approximately 750 staff are employed at the pier during the summer months (with less during the slower off-peak season). The pier was first purchased by the family in the 1960s and converted the structure from warehouse space into recreational usage.

Business at the pier has historically been driven by outside visitors, though a large percentage of the roughly 1 million customers who have ridden the Great Wheel since it opened six months ago are from Seattle. Since the wheel opened, the pier has also seen more off-season visitor traffic (especially among locals during the Christmas season). As is with other waterfront business, most visitors come via automobile, typically as a group, with plans to visit several establishments in the area. Many such groups include the elderly and very young, thus requiring sufficient parking near the sites to reduce walking distance and steep sidewalks. As such, the pier stated they are very concerned with the loss of parking, lane

reductions, and street closures due to seawall construction. They have been working with the Seattle Department of Transportation to coordinate construction schedules to minimize disruptions, concentrating most of the heavy work during the slower off-season months.[6] However, the Pier owners expressed concern over the design of the waterfront after the viaduct is torn down (Griffith, 2013).[7]

Interviewees also expressed concerns over mass transit. The current single bus line only travels southbound on Alaskan Way, following a circuitous route that goes through the International District before heading north on First Avenue—an inconvenience for visitors whose primary purpose is recreational along the waterfront.

SODO interviewees also did not foresee any significant impacts associated with more coal trains. Again, their greater concerns were with potential impacts associated with a new arena. The SODO region has almost twice as many covered employees in warehouse, transportation, and utilities than manufacturing (8,461 versus 4,342 in 2011).

Port of Seattle

Based on interviews with the Port of Seattle, there are no plans for expansion of Port facilities to accommodate coal trains, either terminal operations or other facilities related to rail movement. The Port believes recent and on-going infrastructure projects will sufficiently mitigate traffic induced by an increase in trains.

Potential negative impacts. Two important surface separation projects currently underway are anticipated to mitigate increased rail traffic, irrespective of coal trains or other freight. The City of Seattle recently completed the South Street Spokane project, which includes a new connection to First Avenue South from the Spokane Street viaduct and Interstate 5, bypassing the BNSF mainline and providing direct access to Port areas from the freeway system. In addition, the Port contributed $300 million to the SR99 replacement project, which includes the construction of an overpass over the BNSF tail tracks near East Marginal Way South; this overpass is expected to be operational by the end of 2013. Both projects are intended to ease movement of truck freight into and out

[6] The seawall reconstruction will occur over three phases/zones, with most of the uprooting of road and sidewalk and replacement occurring during the off-season months. Each phase is assigned to a separate zone of the region, so that the entire project will be complete within three years.

[7] The plan would replace the existing space with about 40 parallel, metered parking spots along the new Alaskan Way.

of port terminals, and should sufficiently mitigate the risks of train crossing delays for freight truck.

Most trucks that leave the Port follow 599 south along the Duwamish, with the remainder heading north or east; the latter would take the Atlantic Street overpass to get on either I-5 or I-90. Overall the Port has made $1.5 billion (including the $300M for SR99) in local infrastructure improvements over the past 13 years. In the Port of Seattle's estimation, the increase in rail should not be a major concern for truck freight due to these infrastructure improvements (Styrk, 2013).

Context of freight movement at the Port. The majority of cargo entering and leaving the Port comes via rail directly to the terminal; this is especially the case at terminal 86, which primarily handles grain from the Midwest, and for intermodal (container) cargo handled at terminals 46, 18, and 5, and 30 (the latter more often used for overflow).[8] Many container shipments through the Port are loaded/offloaded between rail and ship, either directly at the terminal or drayed (i.e. trucked) between the terminals and the SIG and ARGO rail yards. Of the remainder, the majority are shipped via truck onto I-90 and I-5, unimpeded by rail crossings once the little H Atlantic Street bypass is completed in 2014, with the benefit of the SR519 and Spokane Street Viaduct. Another segment of truck freight going to trans-loading centers in the Kent Valley may possibly be affected by more rail traffic (though they would likely use the Spokane Street viaduct) to the extent it uses surface streets. This leaves containers destined to or from freight facilities in the Duwamish (estimated at about 20% of the Port's traffic) to use existing grade separations or travel east/west on surface streets. **Exhibit 7** helps illustrate these patterns for intermodal cargo (gross flows—imports and exports) While coal trains may cause some additional congestion, these delays are not expected to overflow into the primary freight truck arteries (Marginal Way, 519, and the Spokane Street Viaduct) (see **Appendix D** for primary trucking routes).

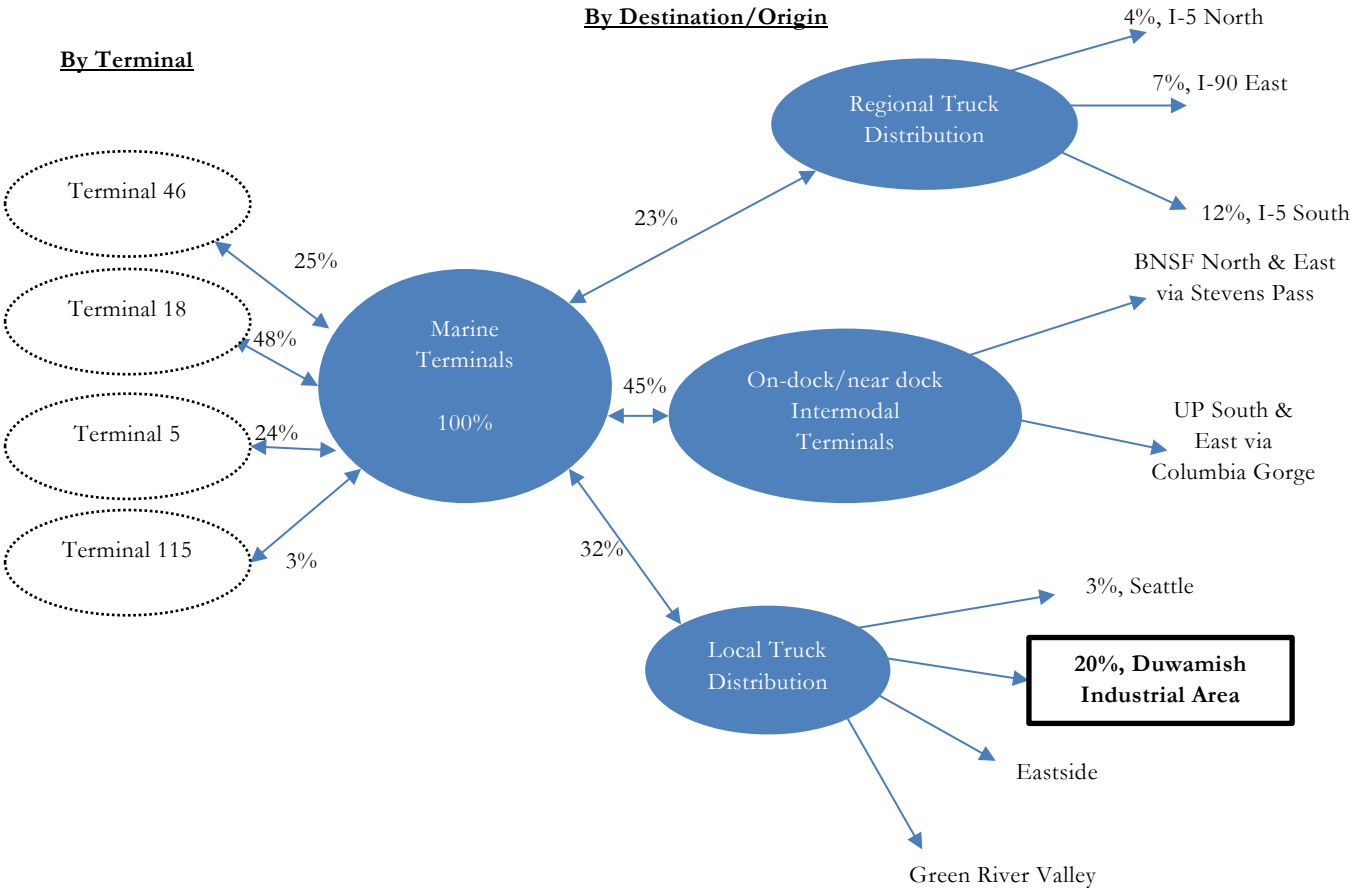
Environmental concerns. In interviews, the expressed minimal concerns about an increase in environmental risks associated with more coal trains. The majority of known dust emissions occur within 50 to 100 miles from the mining facility, and BNSF has required mining companies to use one of the three prescribed techniques for controlling coal dust (e.g., the use of a spray).

Potential benefits. The Port sees more upside to additional trains. The increase in traffic could prompt BNSF to make new rail investments, in particular "triple

[8] Terminal 91 is usually for one-time cargo shipments. The exception is for shipments of boring equipment used for the Alaskan Way tunnel, which are offloaded at T46.

tracking" to provide more capacity—more trains could mean more investment. Adding a new track would also allow for separation of freight and passenger rail—because freight trains give right of way for passenger trains, this would further mitigate rail traffic buildup. The Port also does not see more rail traffic displacing the shipment of products with greater direct benefit/return to Washington.

Exhibit 7. Projected Distribution of Intermodal Freight Volume, 2015



Source: Port of Seattle **(2003)**, based on Figure 14.

Property Value Impacts

Regional economics and property value impacts

Property value impacts are typically excluded from economic impact analyses, because of the transferrable nature of some of these impacts. In other words, while increased train traffic may make some specific parcels less desirable, and therefore be reflected in the market value of those parcels, the demand will often shift to other parcels in the market area and thereby increase their value, resulting in no net impact market-wide.

For instance, as an analogue, Zhang and Shing (2006), in their analysis of London's congestion charge zone program, found that the introduction of a vehicle charge on congestion to enter a designated zone led to property values outside the zone increasing in value relative to the properties inside the zone. This theoretical understanding may be of no consequence to property owners who are on the losing end of this impact, however. With these caveats in mind, this reports assessed the implications of coal trains for properties in close proximity to the mainline using a third party analysis.

Property value impact analysis

Analysis of property value impacts require property appraisals of those specific parcels affected, which this study is not. Climate Solutions (2012) commissioned an independent appraiser to estimate the extent to which the advent of more trains would lead to property value diminutions. The appraiser estimated diminutions of between 5-15% for Seattle properties, with the largest relative losses projected for single-family homes (ranging between 5 and 15%), but with a minimum diminution threshold of 5% across all land uses. The report considered train noise, vibrations, pollution (both real and perceived), and public stigma and perceptions as factors influencing property values.

The following findings of property along the affected corridor are intended to inform an understanding of property value impacts, rather than provide a net property values impact across the city. The analysis applied the estimated impacts from Climate Solutions report to existing King County Assessor values for total property value (land value plus improvement value) across the city within the identified rail buffer. The buffer included all parcels within 600 feet of BNSF mainline within Seattle, excluding parcels above the downtown mainline tunnel.

Across the entire city, 3,570 parcels (of all use types) reside within 600 feet of the BNSF mainline, excluding land above the downtown rail tunnel. Approximately 35% of all land area (measured in acres) within the buffer is classified as

residential, with a total assessed value (land plus improvement value) of $2.4 billion—roughly 30% of all assessed value within the 600 foot rail buffer.

Industrial land constitutes 25% of all land within the buffer, with an assessed land value of $1.2 billion, of which 53% is for warehousing. Importantly, industrial land does not include port terminal activities, which are classified as "Government and Services" and constitute 10.4% of all land (by acreage) within the buffer and with a total assessed value of $829.5 million.[9]

The analysis found that residential properties along the rail corridor would lose between $117.5 and $282.3 million (**Exhibit 8**). As explained in the previous section, it is possible that these losses might result in commensurate gains spread elsewhere across the regional housing market. Based on these estimates, Commercial land would stand to lose between $95.0 and $133.0 million in value, again expected to diffused as gains elsewhere in the office and retail markets.[10]

Exhibit 8. Implied Property Value Losses

Land Use	Number of Parcels[11]	Total Value ($mils)	Total Area (acres)	Estimated Losses ($mils)	
				Lower	Upper
Commercial	464	1900.6	452	95.0	133.0
Industrial*	443	1187.0	706	59.4	59.4
Single-family	1709	946.0	807	47.3	141.9
Multi-family	442	1404.0	188	70.2	140.4

**In both scenarios (high and low estimates), industrial lands were assigned a 5% depreciation.*

Source: Community Attributes Inc., 2013.

The Climate Solutions report found value declines among industrial lands as well, 5% depreciation. A 5% decline in industrial values would equate to $59.4 million in losses along the corridor.

[9] Data source: King County Property Assessment Data (2013).
[10] The Climate Solutions study did not separate out office space from other commercial space, though assessment data does differentiate between the two. In our application of the study we considered office space to be commercial space.
[11] Includes occupied and vacant parcels.

NEXT STEPS AND ADDITIONAL CONSIDERATIONS

The Puget Sound Regional Council plans to independently assess the economic benefits and consequences of the coal train activity for the broader central Puget Sound region in 2013. The findings in this report, while specific to the City of Seattle, may have broader regional dimensions, such as the traffic outcomes for manufacturers in the Kent Valley. A regional analysis could consider impacts on trade and economic development and the changes in property values and the distribution of these changes.

Interviewees expressed concerns that the seawall reconstruction, viaduct tear down, a possible arena in SODO, and long-term growth in Seattle's resident population will create additional stresses on the city's infrastructure and transportation system, including in the Duwamish and waterfront regions. Grade separations at South Lander and Broad Street should be considered.

While this report was focused precisely on the impacts of train volumes on the city economy, climate change is a serious issue and its impacts on Seattle should be better understood.

APPENDICES

Appendix A. Estimating the costs of congestion using a value of travel time approach

Assume a simple model in which vehicles are either 25 foot-long passenger cars or 60 foot-long commercial trucks. Take the estimates for minute-by-minute queue length for the three crossings modeled in the Seattle Department of Transportation study (2012): Broad, Holgate, and Lander (the latter two in the SODO district). To get an estimate of total queue length for all three intersections, simply sum the queue lengths for all three crossings over a 24 hour period. Then multiply this by the percentage of modeled traffic flow that are trucks and subtract the remainder (since there cannot have less than a full truck in queue). Since there are no data on the percentage of traffic flow by crossing that is truck versus car as measured in queue length, nor data on the timing of coal trains (the SDOT study modeled equally spaced intervals, while trains can pass through the city at random intervals), apply a percentage across the entire sum of queue lengths. To get the number of cars for all minutes of queue, subtract from the total queue the number of trucks multiplied by 60 feet (to remove the entire, summed length of all trucks in queue), and then divide by 25 feet, again removing the remainder (since we cannot have less than 25 feet of car).

Once the total number of cars and trucks in queue for a given percentage of trucks in the total queue length has been calculated, multiply the number of cars by the value of travel time (VOTT) for cars, divided by 60 minutes, plus the product of the number of trucks in queue and the VOTT for trucks divided by 60—the sum of these values is the estimated cost of delay in period 1. Because the data estimates for queue length are reported by the minute (for a total 1,440 minutes over a full day), the number of cars and trucks can be interpreted as car-minutes and truck-minutes in queue.

The VOTT estimates used come from two sources. The Washington State Department of Transportation publishes value of travel estimates of $76 for trucks and $16 for passenger vehicles (Washington State Department of Transportation, 2009), whereas the Puget Sound Regional Council has published estimates based on analysis in Puget Sound of $45 for medium trucks, $17.65 for home-based work single-occupant low-medium income vehicles, and $26.09 for home-based work single-occupant high-medium income vehicles (Outwater & Kitchen, 2008); the PSRC published additional estimates, but we only selected these estimates due to lack of additional information about traveler purpose (we averaged single-occupant estimates). Both sets of VOTT estimates were adjusted for inflation, using actual and forecasted for 2013 published by the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2013).

The equations below articulate these relationships.

Let $Q_{i,0}$ = total queue length for crossing i in the original period 0 and X = the percentage of traffic in crossing i that are trucks (of length 60 feet). Then,

Number of truck-minutes in queue before more coal trains = T_0

$= \sum_{i=1}^{3} Q_{i,0} * X_i$ / 60 feet - Remainder

And number of car-minutes in queue before more coal trains = C_0

$= (\sum_{i=1}^{3} Q_{i,0} - T_0 * 60)$ / 25 feet – Remainder

Costs of congestion before advent of more coal trains = $COST_{Before}$

$$= \frac{(T_0 * VOTT_{Trucks} + C_0 * VOTT_{Cars})}{60\ minutes} * (5 \text{ weekdays} * 52 \text{ weeks})$$

To get the net cost, the the above calculations were repeated using the estimated queue lengths with the advent of an additional 18 coal trains per day passing through Seattle. This would give new estimates of number of trucks in cars, T_1 and C_1, and total queue times of = $\sum_{i=1}^{3} Q_{i,1}$, allowing calculation of a net cost, which equals:

$$\frac{(T_1 - T_0) * VOTT_{Trucks} + (C_1 - C_0) * VOTT_{Cars}}{60\ minutes} * 5 \text{ weekdays} * 52 \text{ weeks}$$

To extrapolate for other intersections not modeled by the SDOT study, apply the projected percentage increase in queue length (in feet-minutes) for Broad Street to other North Waterfront crossings, and the Lander increase for Horton and Spokane. Then use the daily counts of trucks per intersection to calculate VOTT.

Appendix B. Interviewed Stakeholders

Representatives from the following organizations graciously contributed their expertise to the development of this report, directly through project interviews:

- American Life Inc.
- Argosy Cruises
- Burlington Northern Santa Fe Railroad (BNSF)
- Center for Advanced Manufacturing Puget Sound
- Climate Solutions
- Edgewater Hotel
- Great Wheel
- Ivar's Acres of Clams
- Manufacturing Industrial Council
- McMillan-Piper
- Port of Seattle
- Seattle Aquarium
- Seattle Department of Transportation
- Seattle Fire Department
- Sightline Institute
- SSA Marine
- Victoria Clipper
- Washington State Department of Transportation

Appendix C. Sample Interview Questions

Your Business & Clientele

1) What is the principal nature of your business?

2) How reliant are you on importing and exporting?

3) To what extent do you rely on rail for your business? What about on truck freight?

4) To what extent do you rely on the port for your business? Is your location in SODO (or North Waterfront) due in part to proximity to the port?

Impacts of Coal Trains

5) Are congestion and delays due to rail traffic already a concern/issue for your business? If yes, how so?

6) What factors helped drive your business to locate where it is? Will increased congestion from coal trains affect the advantages of your location? If so, please explain.

7) A recent study commissioned by the City of Seattle Department of Transportation estimated crossing gate delays at Holgate and Lander streets due to an additional 10 coal trains passing through Seattle in 2015 and up to 18 by 2026. Barring infrastructure investments to mitigate bottlenecks and further congestion, how might these further crossing delays impact your operations, employment, and sales?

8) If you (or your tenant businesses) use rail and/or truck freight, do you foresee an increase in train traffic and delays impacting shipping rates?

9) To what extent will congestion impact commute times for your employees?

10) If you are a property owner, do your anticipate any impacts on the value of your property? Please explain.

11) Are there ways you can adjust your business operations to mitigate these impacts? If so, please explain.

12) Do you foresee any positive benefits to more coal trains passing through Seattle? Please explain.

13) If these additional trains do begin to pass through Seattle, what do you think the city should do to resolve these issues?

14) Other concerns you would like to share.

Appendix D. Port of Seattle Truck Freight Flows in SODO Area

Sources: Port of Seattle (2012, p. 18); Community Attributes Inc.

BIBLIOGRAPHY

BNSF. (2012, May 14). Letter to Governor Chris Gregoire.

Bockmann, M. W. (2013, March 4). *Clean Clean-Air Policies Seen by Deutsche Cutting Coal Trade by 18%*. Retrieved March 19, 2013, from Bloomberg Businessweek: http://www.businessweek.com/news/2013-03-04/china-clean-air-policies-seen-by-deutsche-cutting-coal-trade-18-percent

Brewer, J. W., Hodges, H., & Nelson, D. M. (2011). Finance & Resource Management Consultants, Inc.

Climate Solutions. (2012, October 2012). Increased Coal Train Traffic and Real Estate Values: A study of the potential impact of increased coal train traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA. Seattle, Washington.

Cocks, D. (2013, March 28). Managing Director, Edgewater Hotel. (S. Cohen, Interviewer) Seattle, WA.

de Place, E., & Kriese, J. (2012). *US Coal Exports and Uncertainty in Asian Markets.* Seattle: Sightline Institute.

Eaves, C. (2013, March 13). Seattle Department of Transportation. (S. Cohen, Interviewer)

Environment Canterbury Regional Study. (2009, February 12). Health Effects of Coal Dust in a Non-Occupational Context: Literature Review.

Fallows, J. (2010, October 27). Dirty Coal, Clean Future. *The Atlantic.*

Finn, T. (2013, March 26). Execututive Director for Government Affairs, BNSF. (S. Cohen, & C. Mefford, Interviewers)

Futch, M. (2011). *Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles.* San Diego: UC San Diego.

Galuszka, P. (2012, November 12). With China and India Ravenous for Energy, Coal's Future Seems Assured. *New York Times.*

Gibson Traffic Consultants, Inc. (2012). *Memorandum to City of Bellingham.*

Griffith, K. (2013, March 29). Great Wheel. (S. Cohen, Interviewer)

International Energy Agency. (2012, December). Medium-Term Coal Market Review 2012.

John C. Martin Associates, LLC. (2011). *The Projected Economic Impacts for the Development of a Bulk Terminal at Cherry Point.* Lancaster, PA.

King County. (2013). Property Assessment Data.

Metropolitan Improvement District. (2012). *Metropolitan Improvement District Street Level Business Inventory.* Seattle.

Millennium Bulk Terminals Longview. (2012). *Fiscal & Economic Impacts of Millennium Bulk Terminals Longview.*

Nelsen, J. (2013, March 21). Assistant Fire Chief, Seattle Fire Department. (C. A. Inc., Interviewer)

Outwater, M., & Kitchen, M. (2008). *Value of Time for Travel Forecasting and Benefits Analysis.* Seattle: Puget Sound Regional Council.

Parametrix. (2012). *Coal Train Traffic Impact Study.*

Plunkett, M. (2013, March 25). Conservation Manager for Aquarium, Seattle Aquarium. (S. Cohen, Interviewer)

Port of Seattle. (2003). *Container Terminal Access Study.* Seattle.

Port of Seattle. (2012). *Impact of a SoDo Arena on Port of Seattle Operations.* Seattle.

Port of Seattle. (2013, June 2012). Phone interview.

Power, T. M. (2012). *The Greenhouse Gas Impact of Exporting Coal from the West Coast: An Economic Analysis.*

Public Financial Management, Inc. (2012). *The IMpact of the Development of the Gateway Pacific Terminal on the Whatcom County Economy.*

Ritzman, J., & Watters, B. (2013, April 3). Vice President, Business Development, SSA Marine; Senior Vice President and Director of Business Development, Carrix. (S. Cohen, Interviewer)

Seattle Department of Transportation. (2012). *Coal Train Traffic Impact Study.* Seattle.

Seattle, P. o. (2013, June 28).

Simons, R. A., & El Jaouhari, A. (2004, Summer). The Effect of Freight Railroad Tracks and Train Activity on Residential Property Values. *The Appraisal Journal*, pp. 223-233.

Styrk, L. (2013, March 20). Seaport Managing Director, Port of Seattle. (S. Cohen, & C. Mefford, Interviewers)

U.S. Bureau of Labor Statistics. (2013, March). Forecast of Seattle CPI-U.

U.S. Bureau of Land Management. (2012). *Powder River Basin Coal Production*. Retrieved April 5, 2013, from http://www.blm.gov/wy/st/en/programs/energy/Coal_Resources/PRB_Coal/production.html

U.S. Energy Information Administration. (2013, January 29). *China consumes nearly as much coal as the rest of the world combined*. Retrieved April 12, 2013, from Today in Energy: http://www.eia.gov/todayinenergy/detail.cfm?id=9751#

U.S. Environmental Protection Agency. (1978). *Environmental Assessment of Coal Transportation.* Cincinnati, OH: EPA.

U.S. Environmental Protection Agency. (2013, January 22). Scoping Comments for Environmental Impacts Statement for Gateway Specific Project. Seattle, Washington, USA. Retrieved April 19, 2013, from http://www.eisgatewaypacificwa.gov/sites/default/files/content/files/EPA_Reg10_McLerran.pdf#overlay-context=resources/project-library

Victoria Trasport Policy Institute. (2012). *Transportation Cost and Benefit Analysis II -- Travel Time Costs.*

Voge, A. (2013, February 7). Powder River Basin coal demand down, but foreign markets beckon. *Star-Tribune (Wyoming).*

Washington Public Ports Association. (2011). *Marine Cargo Forecast & Rail Capacity Assessment.* Olympia, WA.

Washington State Department of Transportation. (2009). *2010-2030 Freight Rail Plan.* Olympia, WA.

Washington State Department of Transportation. (2009). Mobility Project Prioritization Process Manual and Workbook. Washington.

Washington State Department of Transportation. (2011). *2011 Washington State Rail System*. Retrieved April 5, 2013, from http://www.wsdot.wa.gov/NR/rdonlyres/38F1BC1E-8757-419B-9CA4-4CF8E47D4CE5/0/2011_Ownership.pdf

Washington State Department of Transportation. (2013, June 28). Phone interview.

Washington State Transportation Commission. (2006). *State Rail Capacity and System Needs, Technical Memorandum Task 3 -- Rail Capacity Needs and Constrains.* Olympia.

Washington State Transportation Commission. (2006). *Statewide Rail Capacity and System Needs Study.* Olympia, WA.

Wiesbrod, G., & Fitzroy, S. (2008). Defining the Range of Urban Congestion Impacts on Freight and their Consequences for Business Activity. *Transportation Research Board Annual Conference, 2008*. Boston, MA: Economic Development Research Group, Inc.

World Coal Association. (2012). *Coal Statistics*. Retrieved April 9, 2013, from www.worldcoal.org: http://www.worldcoal.org/resources/coal-statistics/

Zhang, Y., & Shing, H.-F. (2006). *The London Congestion Charge and Property Prices: An Evaluation of the Impact on Property Prices Inside and Outside the Zone.* London, UK: London School of Economics.

Gateway to Extinction

Proposed Fossil Fuel Transport through Washington*

arge corporations propose the unprecedented construction
r expansion of roughly 20 coal or crude oil terminals or
efineries in Washington, Oregon, and British Columbia.
hese high-risk exports would transect Washington's wetlands,
ivers, marine resources, and prime farmlands, threatening the
ealth and viability of our communities' human health,
ultures, economies, and environments, including threatened
nd endangered species such as salmon and orcas. With so
uch at stake, permitting agencies must stop considering these
roposals in a piecemeal fashion and conduct regional
umulative studies of rail and vessel traffic.

3 B.C. COAL EXPORT PROPOSALS

KINDER MORGAN TAR SAN PIPELINE EXPORTS

Cherry Point

Vancouver Island, BC, Canada

Anacortes

Puget Sound

Bellingham/Whatcom County: Loaded Coal and Crude Trains Per Day

TODAY: 2 TRAINS/3 MILES

PROPOSED: 16 TRAINS/24 MILES

Spokane/Spokane County: Loaded Coal and Crude Trains Per Day

TODAY: 2 TRAINS/3 MILES

PROPOSED: 35 TRAINS/53 MILES

Seattle/King County: Loaded Coal and Crude Trains Per Day

TODAY: 2 TRAINS/3 MILES

PROPOSED: 18 TRAINS/27 MILES

Tacoma

BAKKEN SHALE CRUDE OIL NORTH DAKOTA

POWDER RIVER BASIN COAL MONTANA, WYOMING

ANNUAL COAL AND CRUDE OIL EXPORTS

Note that for every 2 additional ships, add 1 bunker (fuel) barge

Today: 6,272
Additional: 1,347 21% increase

Grays Harbor

Today: 82
Additional: 314 383% increase

Longview/Cowlitz County: Loaded Coal and Crude Trains Per Day

TODAY: 2 TRAINS/3 MILES

PROPOSED: 30 TRAINS/45 MILES

Columbia River

Warrenton

Clatskanie

Port Westward

Vancouver

Today: 1,422
Additional: 2,172 153% increase

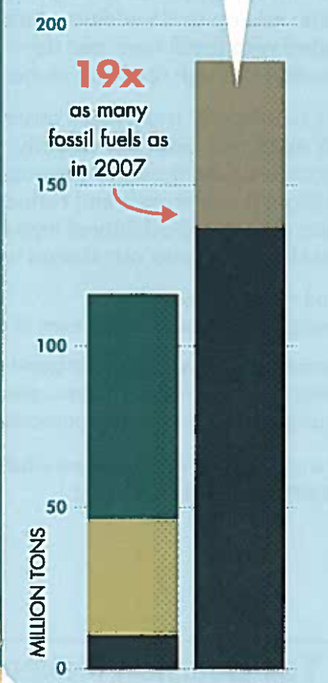
Port of Morrow

Oregon

The Big Picture

WA RAIL CARGO

189 MILLION ADDITIONAL TONS TOTAL FOSSIL FUEL CARGO



KEY:

- CHOKE POINTS
- RAIL LINE
- IMPACTED NATIVE AMERICAN RESERVATIONS
- HIGH-QUALITY FARMLAND
- IMPACTED NATIONAL PARKS AND FORESTS
- IMPACTED MARINE PROTECTED AREAS
- VESSEL PASSAGES
- MAIN IMPACTED RIVERS
- PROPOSED TERMINALS, REFINERIES, AND EXPANSIONS:† CRUDE OIL, COAL, LNG
- † See reverse for table of proposed terminals
- = 1 TRAIN/1.5 MILES***
- COAL TRAINS
- OIL TRAINS

PRODUCED BY HEALTHY PLANET/HEALTHY PEOPLE (HPHP) IN COLLABORATION WITH FRIENDS OF THE EARTH

HPHP is a coalition of individuals and organizations including Protect Whatcom, Safeguard the South Fork, and Friends of the San Juans

* Information current as of 9/25/13. For data sources and updated information, go to ProtectWhatcom.org. ** Last available data. Source: Wash. DOT. *** All trains travel west through the Columbia River Gorge. Actual rail traffic is double because of returning trains, which use one of three routes east: the Columbia River Gorge, or through Stampede or Stevens Pass.

protectwhatcom.org

Ask Elected Leaders to Add Up the Trains and Vessels

If proposed coal and crude terminals are permitted in Washington, an unprecedented number of 1.6 mile long trains would travel through our communities in the Pacific Northwest.

Considered individually, the increase in train and vessel traffic for a single proposed export terminal, or the expansion of an existing terminal, may appear relatively insignificant. However, when reviewed cumulatively, the collective impacts of train and vessel traffic add up to 35 additional trains loaded with fossil fuels per day traveling through Spokane alone.

At 1.6 miles per train, that's more than 100 miles of trains daily directly associated with these 19 proposals. In addition, the terminals and refineries place over 2,900 additional high-risk vessels a year onto our shared waters.

* bpd = barrels/day of crude
mmta = million metric tons/annum of coal

Sources: permit applications, Mitigated Determinations of Nonsignificance, general press, industry, and Sightline Institute publications.

For a complete list of sources and a full size table visit protectwhatcom.org.

Terminal or Refinery Locations (North to South)	Volume & Commodity*	Unit Trains per Day (1 way)	Vessels per Annum
Kinder Morgan pipeline/ Westridge Marine Terminal, Burnaby, BC	890,000 bpd	n.a.	358
Ridley Terminals, Prince Rupert, BC	13 mmta	2	na
Neptune Terminals, Vancouver, BC	10 mmta	1.5	176
Fraser-Surrey, Vancouver, BC	8 mmta	1.3	40
Westshore Terminal, Vancouver, BC	6 mmta	1	104
Gateway Pacific Terminal, Ferndale, WA	54 mmta	9	487
BP Cherry Point Refinery, Ferndale, WA	71,500 bpd	1	33
Phillips 66 Refinery, Ferndale, WA	35,750 bpd	0.5	17
Tesoro Refinery, Anacortes, WA	50,000 bpd	1	36
Shell Refinery, Anacortes, WA	61,286 bpd	1	45
Transcor Astra Group's U.S. Oil & Refining Co., Tacoma, WA	40,000 bpd	0.6	29
Targa Sound Terminal, Tacoma, WA	30,000 bpd	0.4	22
Imperium Bulk Liquid Terminal, Grays Harbor, WA	68,250 bpd	1	200
Westway Terminal, Grays Harbor, WA	28,692 bpd	0.4	60
Grays Harbor Rail Terminal	50,000 bpd	0.7	54
Tesoro-Savage, Vancouver Energy Dist'n Term., Vancouver, WA	360,000 bpd	5	386
Millennium Bulk Logistics, Longview, WA	44 mmta	7.4	850
Coyote Island Terminals, Boardman, OR, Port of St. Helens	8 mmta	1	156 + 624 barge tows
Global Partners' Columbia Pacific Bio-Refinery/ Port Westward Industrial Park, Clatskanie, OR	28,600 bpd	0.4	31
Totals		35.2	3,084

Tell Decision Makers to Look at the Puzzle, Not the Pieces

Federal and state Environmental Policy Acts (NEPA and SEPA) require permitting agencies to consider whether proposals pose significant risks to the environment. If, after a threshold determination, agencies conclude they must conduct and Environmental Impact Statement (EIS), they will invite comments from agencies, tribes, and the public. They will then weigh various alternatives, including the proposals with or without mitigations, and the no action alternative.

While a full EIS should include a cumulative impacts analysis of all combined rail and vessel impacts, they almost never do. By continuing to consider single proposals in a piecemeal fashion, we never fully analyze the costs and benefits of the proposals in a programmatic way consistent with state or federal energy policy. That narrow approach has to end.

Ask Washington Department of Ecology to conduct a programmatic EIS for all of the proposed crude-by-rail terminals and rail expansions at existing refineries to determine the net effect on rail and vessel traffic. Contact Annie Szvetecz, SEPA Policy Lead, 360-407-6925, aszv461@ecy.wa.gov.

Printed on recycled paper with vegetable inks, Oct 2013.

Comment on the proposed Millennium Bulk Logistics Coal Terminal in Longview, Washington through November 18, 2013

During the scoping process for Millennium, the lead agencies (Cowlitz County, WA Dept of Ecology, and the US Army Corps of Engineers) seek comments on what to analyze in the Environmental Impact Statement (EIS).

Comment online, by email, and/or in-person at a scoping hearing.

Online: www.millenniumbulkeiswa.gov Email: comments@millenniumbulkeiswa.gov

In-person: 5-8 pm; doors open at 4 pm. Your oral comment at a scoping hearing may summarize an issue you address in a more detailed written comment.

Oct 17: Tacoma Convention Center, Scoping Hearing.

For information a fact sheet on impacts associated with this coal export proposal go to:

http://www.lwvbellinghamwhatcom.org/files/2013_Millenium_Fact_Sheet_for_Comments--final.pdf

Scoping Comment Guide

The EIS addresses only **significant adverse impacts**, **alternatives**, and **mitigations**.

a. Introduce yourself. Briefly tell who you are and why you are concerned.

b. Ask to measure the impact of ___ on things such as human health, the environment, an economy, etc.

c. Tell why it is significant (because it impacts you, other people, places, environments, etc.).

d. Can this be mitigated? If not, ask that the permit be denied.

An impact is anything that would not occur **but for** activities related to the proposal. In your comment, consider what is known about the impact, what needs to be known, and if it could be mitigated.

Statements of opinion are not comments.

Ask Elected Leaders to Stop Externalizing the Costs of Transporting Fossil Fuels Through Washington State

1 Ask Gov. Jay Inslee to initiate rulemaking requiring tug escorts for all crude tankers on the Columbia River and in Grays Harbor. Contact: Ted Sturdevant, Exec. Dir. of Legislative Affairs & Policy, 360-902-4111.

2 Ask Gov. Inslee to direct the WA Dept. of Commerce State Energy Office to reinstate the Petroleum Markets Databook tracking the movement of fossil fuels by mode of transportation in WA. Contact: TedSturdevant, Exec. Dir. of Legislative Affairs & Policy, 360-902-4111.

3 Ask Senator Maria Cantwell to pass legislation classifying tar sands derived crude as "oil" to subject it to existing federal barrel taxes. Email at http://www.cantwell.senate.gov/public/index.cfm/email-maria or call one of her offices listed at http://www.cantwell.senate.gov/public/index.cfm/office-locations.

4 Ask state legislators to create the state barrel tax on crude oil moving through state lands and waters in ships, barges, pipelines, and trains. (The money should be held in a fund to pay for the public costs and risks associated with that transport.) Contact your legislators at: app.leg.wa.gov/districtfinder/.

5 Support existing efforts to impose a carbon tax on fossil fuels used, based on their CO2 contribution. Learn how at: http://Support CarbonWA.org.

EARTHRISE
law center

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

August 12, 2013

DEQ: Comment Coal Export
475 NE Bellevue Dr., Suite 110
Bend, OR 97701
Fax: 541.388.8283
Email: comment-coalexport@deq.state.or.us

Via FAX, ELECTRONIC MAIL, AND US POST

Dear Oregon Department of Environmental Quality:

Thank you for the opportunity to provide comments on the proposed Ambre Energy, dba Coyote Island Terminal, LLC (Ambre), air quality permit application. The following comments are submitted on behalf of Sierra Club, Friends of the Columbia Gorge and Columbia Riverkeeper (hereinafter, collectively "Conservation Groups"). These non-profit organizations represent tens of thousands of members across Oregon and the Pacific Northwest who are dedicated to protecting public health, the environment and natural resources of our region for future generations.

Conservation Groups submit these comments specifically regarding Ambre's Air Contaminant Discharge Permit (ACDP) application to Oregon Department of Environmental Quality (DEQ) because they are concerned about the proposed project's impacts on public health and the environment due to air and water quality diminution in Oregon and Washington. Furthermore, Conservation Groups are submitting comments regarding the need for an ACDP for the activities at Port Westward, which are a necessary part of the operation of Ambre Energy's Morrow Pacific Project.

In short, DEQ cannot issue an ACDP to Ambre because the facility will be permitted to cause violations of the National Ambient Air Quality Standard (NAAQS) for nitrogen dioxide (NO_2) and particulate matter less than 2.5 microns in diameter (PM2.5), because the facility is a federal major source of air pollution subject to the Prevention of Significant Deterioration (PSD) program, and because the permit lacks the required emission limitations and conditions to ensure compliance. Furthermore, Ambre cannot construct the Port Westward portion of the project because it is a stationary source that requires an ACDP before construction, and Ambre has neither applied for nor received an ACDP.

These comments are similar to comments already submitted to DEQ regarding the ACDP for this project on December 20, 2012, attached hereto as Exhibit 1.[1] These comments have been updated to reflect changes made in the permit application and draft permit. Moreover, DEQ's responses to Conservation Groups' concerns expressed in the December 2012 comments was woefully inadequate to demonstrate DEQ's consideration of the issues and evidence presented by Conservation Groups. In some cases, DEQ's lack of response has made it difficult for Conservation Groups to provide more information to DEQ, as it appears that DEQ has rejected, without any support, several of Conservation Groups legal and factual arguments. Conservation Groups, therefore, must urge DEQ to provide substantive responses to these specific comments in its response to comments if it issues the ACDP.

I. Oregon laws and regulations require that DEQ deny the permit application because the facility will cause violations of the NOx and PM 2.5 NAAQS.

DEQ cannot issue a permit to Ambre to build its Morrow Pacific Project because emissions from the facility will cause air pollutants to exceed the levels set by EPA to protect public health and welfare (the National Ambient Air Quality Standards, or NAAQS). These violations of the NAAQS require DEQ to deny Ambre's ACDP application and issue an order prohibiting construction of the project.

A. NOx and PM2.5 Air Quality Standards Protect Human Health and the Environment

National Ambient Air Quality Standards (NAAQS) are concentrations that EPA sets for "criteria pollutants" under the Clean Air Act. EPA must set NAAQS to protect human health and welfare.[2] Thus, the NAAQS are upper-limit concentrations of air pollutants that EPA has deemed are requisite, as a policy matter, to protect public health and welfare. The heart of the Clean Air Act is to ensure that all areas of the United States achieve and maintain these minimal levels of air quality.

Oregon regulations provide that if proposed new sources may interfere with attainment and maintenance of air quality standards, DEQ has grounds to prohibit the construction.[3] It is the declared policy of the Environmental Quality Commission (EQC) to achieve "full compliance with ambient air standards at the earliest possible date."[4]

---

[1] Conservation Groups assume that DEQ has retained these comments and the expert analysis and data underlying the comments, therefore we have not included the exhibits or underlying data as exhibits. We intend to fully and completely incorporate the comments, all exhibits, and all underlying data submitted to the agency on or about December 20, 2012, as if set out in full herein.

[2] 42 U.S.C. § 7409.

[3] OAR 340-202-0050(2).

[4] OAR 340-202-0050.

The ambient air quality standards for particulate matter (PM), PM10, and PM2.5 are found in OAR 340-202-0060. The PM2.5 standards are equivalent to the 2006 NAAQS.[5] The areas impacted by the Ambre coal export project have been designated as attainment/unclassifiable for the 2006 PM2.5 NAAQS.[6] In 2012, EPA revised the annual PM2.5 NAAQS, and area designations have not yet occurred. The ambient air quality standards for NO_2 are found in OAR 340-202-0100.[7] The entire state of Oregon has been designated as unclassifiable/attainment of the 2010 NO_2 NAAQS.[8]

In addition to its own regulations requiring that DEQ expeditiously achieve compliance with the NAAQS, Oregon has a duty under Section 110 of the Clean Air Act to implement, maintain and enforce the NAAQS.[9] This obligation includes the duty to regulate the construction of new sources to "assure that national ambient air quality standards are achieved…."[10] Moreover, Oregon has a duty to prohibit air pollution emissions in the state which will contribute to poor air quality in neighboring states, like Washington.[11]

The Clean Air Act uses the Prevention of Significant Deterioration program to protect public health and welfare, to protect special areas, to allow economic growth while preserving clean air resources, to protect one state from pollution in another state, and to ensure careful evaluation of "all the consequences" of a decision to increase air pollution.[12] Under the Clean Air Act's provisions, the state must impose all measures necessary to prevent significant air quality degradation in areas designated as "attainment or unclassifiable," as Oregon is for NO_2.[13] Ultimately, the concentration of air pollution allowed by a NAAQS – in this case 100 ppb (or 188 ug/m^3) of NO_2 and 35 ug/m^3 of PM2.5 – must not be exceeded.[14]

These ambient concentration limits are in place for good reason. Nitrogen oxides (NOx) and particulate matter are dangerous to human health and the environment. NOx are highly reactive gasses that can cause respiratory problems such as asthma attacks, respiratory tract syndrome, bronchitis, and decreased lung function. In addition to public health concerns, NOx emissions cause nitrogen deposition, which may cause soil acidification, water acidification, and

---

[5] 71 Fed. Reg. 61144 (Oct. 17, 2006).
[6] *See* http://www.epa.gov/pmdesignations/2006standards/final/region10.htm.
[7] DEQ issued a Notice of Proposed Rulemaking on July 15, 2013, indicating that it is amending OAR 340-202-0100 regulations to include the 1-hour NO_2 NAAQS in effect since April 12, 2010. This NAAQS is attained when the 3-year average of the 98th percentile of daily maximum 1-hour NO_2 concentrations does not exceed 100 ppb (or 188 ug/m^3). 75 Fed. Reg. 6474 (Feb. 9, 2013). In no event should DEQ take final action on this permit application until DEQ has finished its July 15, 2013 rulemaking.
[8] 77 Fed. Reg. 9532 (Feb. 17, 2012).
[9] 42 U.S.C. § 7410.
[10] 42 U.S.C. § 7410(a)(2)(C).
[11] 42 U.S.C. § 7410(a)(2)(D)(i)(I).
[12] 42 U.S.C. § 7470.
[13] 42 U.S.C. § 7471.
[14] 42 U.S.C. § 7473(b)(4).

eutrophication. These problems, in turn, reduce water quality and may render water unfit for aquatic life or human consumption. NOx also contributes to visibility impairment, global warming, acid rain, formation of ground-level ozone and formation of toxic chemicals. NOx is also a precursor chemical to fine particulate matter. The Columbia River Gorge National Scenic Area is particularly impaired by NOx pollution. The Columbia River Gorge National Scenic Area ranked 6th in the country for poorest visibility for Scenic Areas. Over the past 17 years, the Forest Service has documented that visibility impairment occurs on at least 95% of the days that have been monitored. The impacts of NOx on Oregon's protected parks and wilderness areas, including the Columbia River Gorge, has been well documented in DEQ's regional haze rulemaking process, and by studies by Dan Jaffe, a scientist at the University of Washington.

Particulate matter is similarly harmful. Particulate matter is a broad class of substances that exist as particles of different sizes.[15] Particles are naturally generated, but some come from human activity. Some of the smallest particles are formed in the atmosphere from NOx, sulfur oxides and volatile organic compounds reacting to form nitrates, sulfates and other small particles.[16] EPA has determined that pollution ceilings for PM2.5 are necessary because of "evidence from numerous health studies demonstrating that serious health effects are associated with exposures to elevated levels of PM2.5."[17] Those effects include premature death.[18] PM2.5 exposure also causes "increased hospital admissions, emergency room visits, absences from school or work, and restricted activity days," due to aggravated cardiovascular and respiratory problems.[19] Sadly, the populations most at risk are the sick, the old, and children.[20]

B. Emissions Modeling of Ambre's proposed coal export facility indicates that Ambre will exceed NOx and PM2.5 NAAQS by 539-701% for NOX and more than 1000% for PM2.5

As the report from AMI Environmental (2013 Report) indicates, 1-hour NO_2 concentrations resulting from the proposed activities at the Port of Morrow will exceed the 2010

---

[15] *Natural Res. Def. Council v. EPA*, 706 F.3d 428, 429 n. 2 (D.C. Cir. 2013) (citing National Ambient Air Quality Standards for Particulate Matter, 62 Fed. Reg. 38,652, 38,653 (July 18, 1997).

[16] *Id.*

[17] PM2.5 Implementation Rule, 72 Fed. Reg. 20,586 (Apr. 25, 2007).

[18] 72 Fed. Reg. at 20,586-87 ("Epidemiological studies have shown statistically significant correlations between elevated PM2.5 levels and premature mortality."); 75 Fed. Reg. 22,896, 22,900 (Apr. 30, 2010) (EPA has determined that, "Both ozone and PM2.5 are associated with serious public health problems, including premature mortality…"); *Am. Farm Bureau Fed'n v. E.P.A.*, 559 F.3d 512, 515 (D.C. Cir. 2009) ("Studies have demonstrated that both fine and coarse PM can have negative effects on public health and welfare. For example, each is associated with increased mortality (premature death) rates and morbidity (illness) effects such as cardiovascular disease and decreased lung function.").

[19] *Id.*

[20] *Id.*

NO2 NAAQS.[21] Similarly AMI Environmental's 2012 Report indicates that PM2.5 concentrations resulting from the proposed activities at the Port of Morrow will exceed the 2006 24-hour PM2.5 NAAQS.[22] Therefore, DEQ cannot issue an ACDP authorizing Ambre to build and operate the facility.

AMI conducted the modeling in 2012 in response to DEQ's request for comments on a draft permit for Ambre. The 2012 NOx modeling modeled the impact of NOx emissions from locomotives while moving coal train cars through the coal transfer process, onto barges assisted by tug boats. In the current draft ACDP, Ambre claims it will use an electric pulley system to move train cars through the coal transfer process.[23] Therefore, Conservation Groups asked AMI to repeat the NOx modeling completed in 2012 considering the NOx emissions from tugs assisting the barges as they are filled with coal, and without including the NOx emissions from locomotives while on-site.[24] Just like the 2012 modeling, AMI used an EPA approved modeling method, and used pollutant measurements from DEQ's 2011 Air Quality Annual Report as background concentrations.[25] AMI's modeling demonstrates that **NOx from the tugs alone will cause air quality to exceed the NOx NAAQS by between 539% to 701%,** depending on which Tier 3 NOx modeling methodology is used.[26] Nothing changed with the issuance of the draft ACDP to affect AMI's modeling conclusion in 2012 that **PM2.5 impacts from the fugitives from the coal cars alone will cause air quality to exceed the 2006 24-hour PM2.5 NAAQS by 1,079%.**[27]

In response to similar comments on the draft ACDP, DEQ explains in its review report that "secondary emissions" from train and tug boat engines need not be considered in either the emissions inventory to determine the applicability of permitting programs, or in any impacts

---

[21] AMI Environmental, AERMOD Modeling of 1-hour NO2 Impacts of Tug Boat Emissions at the Port of Morrow (June 2013) (attached as Exhibit 2). Conservation Groups intend to incorporate the entirety of this report, including its underlying data and conclusions, as a comment on this ACDP. The underlying modeling data files were provided to DEQ via Federal Express to arrive prior to the August 12, 2013, 5pm comment deadline. Those files, though provided separately, are fully part of these comments.

[22] AMI Environmental, AERMOD Modeling of Air Quality Impacts of Proposed Morrow Pacific Project (October 2012) (attached as Exhibit 3) at Figure 10 and Table 9 (Operation with closed barges & open trains modeling scenario results in project only concentrations of 388.6 ug/m^3. Impacts extend across the border into Washington State). Conservation Groups intend to incorporate the entirety of this report, including its underlying data and conclusions, as a comment on this ACDP.

[23] In order to avoid having the locomotive emissions included in the facilities emissions inventory for its potential to emit, the permit must require that the pulley system be used. Further, Conservation Groups note that Ambre is on the verge of bankruptcy, and is unlikely to undertake environmentally beneficial – yet expensive – operations unless required by permit.

[24] Exhibit 2 at 3.

[25] Exhibit 2 at 5. However, the NAAQS are violated even assuming no background pollution.

[26] Exhibit 2 at 8.

[27] Exhibit 3 at 20. See also Fox Report, Exhibit 4 at 2 – 9.

analysis.[28] Moreover, in response to the 2012 AMI Report demonstrating violations of several NAAQS, DEQ states that modeling is not required, but when it is required, "DEQ has requirements for developing a modeling protocol to ensure that the modeling is performed in accordance with EPA models and guidelines."[29] Both the 2012 and 2013 AMI modeling studies comply with all relevant requirements. DEQ failed to identify or articulate any specific concerns about the AMI modeling, or to request further information. DEQ's only input was to specifically recommend that AMI use both Tier 3 methods for NOx modeling, which AMI did do. The only evidence in the record is that the fugitive emissions from the coal cars on site – which are clearly primary emissions – will cause violations of the 2006 PM2.5 NAAQS.

C. Air pollution from vessels participating in the stationary industrial process must be included as emissions subject to ACDP regulations

The only evidence in the record is that the proposed facility will cause violations of the 2010 NO_2 NAAQS due to the emissions sources on tug boats. DEQ did not respond to Conservation Groups' argument that air pollution emissions from tug boats participating as a stationary source in a stationary industrial process must be included in the emissions subject to the ACDP regulations. Thus, Conservation Groups repeat their citations to authority on this point. Emissions sources, located on tugs, must be considered in the total potential emissions subject to Oregon's ACDP regulations when those sources are being used for industrial purposes rather than transportation. The tugs will be used to physically attach the barges to facility and therefore emissions are considered as part of those calculated from the on-shore facility. Vessels are considered mobile sources when they are transporting material to and from a source, but when they are performing a necessary part of the industrial process at the source, they must be considered primary emissions from the stationary source.

Oregon's regulations are different from federal regulations on this point. Oregon regulations exclude from the emissions that must be considered in permitting those emissions defined as "secondary emissions."[30] "Secondary emissions" are defined as "emissions that are a result of the construction and/or operation of a source or modification, but that do not come from the source itself."[31] "Secondary emissions may include, but are not limited to: emissions from ships and trains *coming to or from the facility*[.]"[32] Thus, in Oregon, emissions from the tugs when they are not "coming to or from the facility" are not secondary emissions, and thus are primary emissions.

---

[28] DEQ mischaracterizes Conservation Groups' comments on the proposed permit. Conservation Groups commented that emissions from locomotives and tug boats when they are being used NOT to bring material to and from the source, but rather as part of the industrial process, are not "secondary emissions," but are, in fact, primary emissions that must be considered. DEQ's response essentially ignores the comment. *See* Review Report at 15.
[29] Review Report at 15.
[30] OAR 340-200-0020(91)(c).
[31] OAR 340-200-0020(100).
[32] OAR 340-200-0020(100)(a).

As noted above, Oregon regulations are different from federal regulations. Oregon includes as secondary emissions only a subset of the total emissions from the mobile sources, or those pollutants emitted as the source is "coming to or from the facility." Federal regulations specifically require **all** mobile source emissions to be "secondary emissions." Yet even under the federal standard for secondary emissions, EPA regulates vessels as stationary sources when they are physically attached to a stationary source, or when they become stationary by attachment to the sea floor or a dock. For example, when vessels are physically attached to an Outer Continental Shelf (OCS) drilling facility, the vessel is regulated as an OCS source, which itself is a vessel that is attached to the sea floor and considered a stationary source for PSD purposes. *See* 40 C.F.R. § 55.2; *In Re: Shell Gulf of Mexico, Inc. OCS Permit No. R10OCS/PSD-AK-09-01 & Shell Offshore, Inc. Permit No. R10OCS/PSD-AK-2010-01 Noble Discovered Drillship*, 2012 WL 119962 (E.P.A.), 34, n. 16. The stationary source determination is based on whether the "vessel or barge is anchored within the project's area or tethered to a piece of equipment that is attached to the seafloor, [*sic*] and is performing any activity that supports the construction or operation of the project."[33] OCS vessels are regulated under the PSD program because EPA is permitting the activity that creates emissions and not the ship as a mobile source. *In Re: Shell Offshore* at 10. Regulation begins when the vessels become stationary by anchoring the seafloor because they are no longer operating as a vessel. After the detachment, the ships return to "vessel" (i.e. mobile source) status.

Vessels are also regulated as stationary sources when they emit in port in furtherance of the on-shore facility's purpose. EPA has required that in-port emissions of ships that service a stationary source facility be included in the PSD evaluation of the facility.[34] More specifically, EPA has stated that vessel emissions during the transfer of liquefied natural gas (LNG) from a vessel to a port should be included in the applicability determinations of preconstruction and operating permits because of the plain language in the CAA.[35] EPA found that the CAA's definition of "stationary source" gives the agency authority to consider emissions from external combustion engine vessels in New Source Review (NSR) and Title V preconstruction and operating permits.[36] EPA considers only the emissions from activities in support of the port's function – i.e. those related to the transferring and processing at the port – as stationary emissions of the port for Title V purposes.[37] Furthermore, at least one other project in Oregon

---

[33] *Environmental Protection Agency (EPA) Fact Sheet: Outer Continental Shelf Air Permit Approval – Cape Wind Energy Project,* 13, available at: http://www.epa.gov/region1/communities/pdf/CapeWind/CapeWindFactSheetFinal VersionJune10.pdf.

[34] *See e.g.*, Memorandum from the Director of the Division of Stationary Source Enforcement to Thomas Devine (April 5, 1978), *in* EPA Title V Policy and Guidance Database, 1, http://www.epa.gov/region07/air/nsr/nsrmemos/m4578.pdf (finding that emissions from ships servicing a petroleum refinery in its normal operations must be included in the facility's PSD evaluation.)

[35] *See* Letter from Michael Cathey to Diana Dutton (October 28, 2003), *in* EPA Title V Policy and Guidance Database, 7-8, http://www.epa.gov/region7/air/nsr/nsrmemos/20031028.pdf.

[36] *Id*. at 8 (citing 42 U.S.C. § 7602(z)).

[37] *Id*. at 10.

has projected regulation of vessels as stationary sources when docked or moored in port because of connection to the onshore facility. The Oregon LNG Terminal and Oregon Pipeline Project included emissions associated with vessels berthed at port in the summary of terminal emissions when determining PSD applicability analysis for the project.[38] Activities at Port of Morrow are based from a stationary dock facility. *Environmental Review* at 2-15. As a result, emissions from the loading, unloading and transloading process at Port of Morrow should be considered stationary source emissions because the activities are an integral part of the Port of Morrow coal export facility's stationary function.

Oregon regulations also indicate that emissions sources on tugs and barges should be considered stationary sources. Under state regulations, stationary sources do not have to be permanently stationary. In Oregon, "stationary source means any building, structure, facility, or installation at a source that emits or may emit any regulated air pollutant."[39] In *In Re: Shell Offshore*, the EPA's Environmental Appeals Board (EAB) found that Alaska's very similar definition of stationary source ("any building, structure, facility, or installation") includes, in certain situations, vessels.[40]

Moreover, coal transfer, which will produce emissions beyond those from the tug, barge and other vessel engines, requires regulation of the vessels through the ACDP. EPA has established that fugitive emissions from coal transfers must be taken into consideration when making a Title V major source determination for permitting requirements.[41] EPA extended this finding to all forms of "coal unloading" including dumping or unloading from trains, barges, mine cars or conveyors." *Id.* at 3.

Finally, under other CAA programs, vessels are regulated as stationary sources. For example, under the CAA's New Source Review (NSR) requirements, "emissions from the stationary source activities of vessels at dockside are considered primary emissions of the marine terminal and are regulated as such."[42]

DEQ's failure to consider air pollution emissions from the tug boats at the facility while they are engaged in assisting in the industrial process of moving coal from one form of transport to another as primary emissions from this source lacks any evidence or support in the record or elsewhere. The failure is particularly egregious where, as here, the pollution emissions will result in NO_2 and PM2.5 pollution concentrations far above levels that EPA has determined are safe.

---

[38] *See* Oregon LNG Terminal and Oregon Pipeline Project FERC Review, 4, available at https://s3-us-west2.amazonaws.com/oregonlng/oregonlng/pdfs2/RR9_Comment-ResponseMatrix.pdf.

[39] OAR 340-200-0020(141).

[40] *In Re: Shell Offshore, Inc., Kulluk Drilling Unit and Frontier Discoverer Drilling Unit*, 2007 WL 3138040, 8 (citing Alaska Admin. Code tit. 18 § 50.302(a)(1)).

[41] *See* Letter from Steven Herman to Barbara Cubin (September 11, 1997) *in* EPA Title V Policy and Guidance Database, 2-4, http://www.epa.gov/region07/air/title5/t5memos/ddapplic.pdf.

[42] Outer Continental Shelf Air Regulations, 57 Fed. Reg. 40,792,40,793 (Sept. 4, 1992).

The Environmental Quality Commission's (EQC) attempts to demonstrate that its implementation of the Clean Air Act is adequate fails if the DEQ permits a new facility to construct and operate even where extreme exceedences of the NAAQS will be caused by the source. Neighboring states similarly have a right to be concerned that their air quality will be negatively impacted by Oregon's failures to implement the regulations promulgated by the EQC to protect air quality.

II. DEQ cannot issue the ACDP because the facility is a federal major source that requires a PSD permit.

The proposed facility is a federal major source of particulate matter due to fugitive coal dust emissions and thus requires a Prevention of Significant Deterioration (PSD) permit not an air containment discharge permit (ACDP). Coal dust is dangerous, containing a number of harmful elements that cause public health concerns, including: antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, selenium, uranium, tin, boron, copper, vanadium, molybdenum, and zinc, among other components. The Applicant and DEQ wrongly calculated fugitive coal dust emissions. The correct calculations demonstrate that the facility will emit more than 250 tons of particulate matter each year, putting the facility above the major source threshold.[43]

As demonstrated in the analysis by Dr. Phyllis Fox, the fugitive emissions from coal dust erosion off of coal in train cars awaiting transfer are high enough to qualify the facility as a federal major source.[44] The Fox Report explains, in detail, why DEQ's assumptions about fugitive emissions at this facility are wrong, and, in fact, understate total emissions significantly.

For instance, Dr. Fox notes that the wind speed input in the AP-42 equation DEQ utilizes excludes peak wind gusts and that the equation used is for flat, stationary coal piles. Moving coal piles that are not flat operate differently. Studies done on coal rail cars note the constant jostling that exposes new coal dust. When revising the equation to account for the movement of the cars, about 2.4 acres or about two football fields of fresh exposed coal will be available for wind erosion 83% of the time.[45] Utilizing a wind gust speed of 64 mph, and assuming that the coal trains are disturbed twice per day on the site, the particular matter emissions are 540 tons/year.[46] Additionally, Dr. Fox finds that DEQ uses faulty estimates on the efficacy of topping agents or surfactants which DEQ implies that it "may" require. DEQ assumes an 85% control for topping agents, which even if applied, have been criticized as being based on "junk science", is actual zero upon arrival at the Port after a journey of several hundred

[43] Fugitive emissions are included in the source's potential to emit when determining whether it is a federal major source. OAR 340-200-0020(55).

[44] Fox, Phyllis, Phd. PE, Fugitive Particulate Matter Emissions from Coal Train Staging at the Proposed Coyote Island Terminal (July 19, 2013) (attached as Exhibit 4). Conservation Groups intend to incorporate the entirety of this report, including its underlying data and conclusions, as a comment on this ACDP.

[45] Exhibit 4 at 3-4.

[46] Exhibit 4 at 6-7.

miles, and may actually increase coal loss due to "saltation."[47]

Dr. Fox thus concludes that the particulate matter emissions from wind erosion of uncovered railcars to the site exceed the major source threshold of 250 tons per year.[48] The Ambre facility is a federal major source of particulate matter. As such, it requires an ACDP that complies with PSD requirements before it can be constructed or operated.

III. The permit does not include all necessary conditions and must be revised to be practically enforceable

A. Legal Background

ACDPs must be practically enforceable, and the proposed ACDP fails to meet this standard. Oregon regulations require that an ACDP include, "testing, monitoring, recordkeeping, and reporting requirements necessary **to ensure compliance** with the Plant Site Emission Limits (PSEL) and other applicable emissions limits and standards."[49] An ACDP cannot ensure compliance without practical emissions limitations and therefore without practical emissions limitations, the ACDP fails to meet its regulatory requirements.

While the ACDP proposed by DEQ is not a Title V permit, principles directly applicable to Title V permits and synthetic minor source permits are useful in evaluating the enforceability of all ACDPs. It is well established that Title V permits and synthetic minor permits must be practically enforceable.[50] For example, if a proposed facility is physically capable of emitting major levels of pollutants, it can only avoid major source constraints if there are mechanisms "in place to make certain that the emissions remain below the relevant levels."[51] In the case of this proposed ACDP, DEQ recognizes that if the facility exceeds the limits in its permit, the emissions could cause environmental harm.[52] Oregon's policy is "[t]o restore and maintain the quality of the air resources of the state in a condition as free from air pollution as is practicable, consistent with the overall public welfare." ORS 468A.010(1)(a). If, as DEQ acknowledges here, harm could result from an emissions exceedence, then the ability to enforce an ACDP is just as important as the ability to enforce the limits keeping a facility from being considered a major source. Therefore, like Title V permits and synthetic minor permits, ACDPs must be practically enforceable.

---

[47] Exhibit 4 at 7-10.
[48] Exhibit 4 at 4, 6-9.
[49] OAR 340-216-0060 (1)(b)(C).
[50] *See e.g.*, *Nat'l Min. Ass'n v. U.S. E.P.A.*, 59 F.3d 1351, 1363 (D.C. Cir. 1995); *In Re Peabody W. Coal Co.*, 12 E.A.D. 22, 7 (EAB 2005).
[51] *Weiler v. Chatham Forest Products, Inc.*, 392 F.3d 532, 535 (2d Cir. 2004).
[52] DEQ, Coyote Island Terminal LLC Information Meeting Resources: Information on the Air Contaminant Discharge Permit, Slide 7 available at http://www.oregon.gov/deq/Pages/CoyoteIslandMeetingResources.aspx (last visited June 24, 2013).

Moreover, this ACDP is "federally enforceable."[53] Courts have made clear that in order for a state-issued operating permit to be considered "federally enforceable," the restrictions within the permit must be practically enforceable.[54] Practically enforceable limits assure that emission limitations and other permit conditions will be complied with, and inform the public as well as the source itself of the facilities obligations under the permit.[55] Surely, the EQC would not have created the ACDP program if it did not intend for sources to comply with the permit limitations. Without practically enforceable limitations within the ACDP, there is no way to ensure that a facility will comply.

Very broadly speaking, practically enforceable also means that the permit will be effective.[56] EPA Guidelines describe practically enforceable permits as those that "establish[] a clear legal obligation for the source and allows compliance to be verified."[57] In a nutshell, practical enforceability requires: "(1) a technically-accurate limitation and the portions of the source subject to the limitation; (2) the time period for the limitation (hourly, daily, monthly, and annual limits such as rolling annual limits); and (3) the method to determine compliance, including appropriate monitoring, recordkeeping, and reporting."[58] The EPA has also explained that the appropriate hierarchy for specifying monitoring to determine compliance is: (1) continuous direct measurement where feasible; (2) initial and periodic direct measurement where continuous monitoring is not feasible; (3) use of indirect monitoring, e.g. surrogate monitoring, where direct monitoring is not feasible; and (4) equipment and work practice standards where direct and indirect monitoring are not feasible.[59] Permits should also specify: (1) when and what tests should be performed, (2) under what conditions tests should be performed, (3) the frequency of testing, (4) the responsibility for performing the test, (5) that the source be constructed to accommodate such testing, (6) procedures for establishing exact testing protocol, and (7) requirements for regulatory personnel to witness the testing.[60]

Other critical aspects of a practically enforceable permit are: (1) the emission limits must be clearly written, (2) the average time must be included (3) the reference dilute concentration

---

[53] Review Report at 10.
[54] *Nat'l Min. Ass'n v. U.S. E.P.A.*, 59 F.3d at 1363.
[55] *See* US EPA Region 9, Title V Permit Review Guidelines: Practical Enforceability (Permit Review Guidelines) (1999), available at http://www.epa.gov/region9/air/permit/titlev-guidelines/practical-enforceability.pdf.
[56] *See Nat'l Min. Ass'n v. U.S. E.P.A.*, 59 F.3d at 1363.
[57] *See* Permit Review Guidelines.
[58] Office of Air Quality Planning and Standards, Options for Limiting the Potential to Emit of a Stationary Source Under Section 112 and Title V of the Clean Air Act (1995), available at http://www.epa.gov/region7/air/title5/t5memos/ptememo.pdf. *See also* Conn. Agencies Regs. § 22a-174-1 (the State of Connecticut also statutorily defines practically enforceable limitations; its definition is substantially similar to the EPAs).
[59] EPA, New Source Review Workshop Manual: Prevention of Significant Deterioration and Nonattainment Area Permitting l.3 (1990), available at http://www.epa.gov/NSR/ttnnsr01/gen/wkshpman.pdf.
[60] New Source Review Workshop Manual at H-6.

must be included (e.g. as determined at 15% O_2), and (4) the source must be required to comply with the limit at all times unless exceptions are specifically allowed.[61] Finally, the following terms contain so much ambiguity and are so susceptible to subjective interpretation, they should not appear in a practically enforceable permit: (1) normally, (2) as soon as possible, (3) significant, (4) should or may, (5) use best engineering practices, and (6) take reasonable precautions.[62]

B. Ambre's permit fails to meet the minimum enforceability requirements

As currently drafted, the proposed ACDP for Ambre fails to meet these minimum requirements. The ACDP fails to meet the monitoring standards required for a practically enforceable permit because only emission factors are used to determine compliance with the PSEL; the ACDP fails to specify the necessary monitoring requirements; the ACDP fails to specify all required recordkeeping provisions; and the ACDP uses language that is so vague as to be unenforceable.

1. The ACDP fails to meet minimum monitoring standards.

As noted above, the EPA has created a hierarchy of appropriate types of monitoring which are critical to practical enforceability. When feasible, direct and continuous monitoring is preferred over all other types of monitoring. Despite the fact that direct and continuous monitoring of at least the wet scrubbers is feasible, the permit requires using only emissions factors in order to comply with the PSEL. Using emissions factors is the least effective way to ensure compliance with the permit, as the math used is based on guesses of what might happen and not what is actually going on at the facility. ACDPs should ensure compliance through the most accurate data feasible, and DEQ has not explained why monitors are not feasible for emissions sources, like the wet scrubbers, that are discrete.[63] DEQ did not consider any options other than compliance equations using non-site specific emission factors. The result is an ACDP that is not practically enforceable.

2. The ACDP fails to specify the necessary monitoring requirements.

The ACDP is not practically enforceable because many necessary requirements are missing. The missing requirements are described below:

- In section 3.1 (a) the ACDP says that the permittee must monitor the fugitive emissions conditions outlined in section 2.3. The ACDP fails to specify

[61] *See* Permit Review Guidelines.
[62] *See* Permit Review Guidelines.
[63] Several companies sell continuous emissions monitors for wet scrubbers. *See* http://www.arb.ca.gov/training/handout/401/401_cem_engineering_design.pdf (slide 47); http://www.burnsmcd.com/Resource_/PressRelease/1580/FileUpload/article-technicalpaper-PMCEMSMonitoringParticulateMatter.pdf (p. 3); http://www.altechusa.com/news.php; and http://www.epa.gov/ttn/atw/129/hmiwi/iv-b-66.pdf p. 15).

information necessary to carry out this monitoring. The ACDP does not indicate when, what or how often monitoring should occur. The ACDP must include these monitoring requirements so that it can be practically enforceable.

- In section 5.2(b) the ACDP requires that at least one of the three required observation periods be done while the chute is retracted, but does not require one of the tests to be completed while the chute is down. It is important to ensure that there are no excess emissions occurring when the chute is up and down. For this reason, the ACDP should require at least one test when the chute is retracted and one test when the chute is down.

- In section 5.3 the ACDP requires daily observations and recordings of the scrubber system flow rates and pressure readings during active operations. However, the ACDP does not state limits for flow rates and pressure. Simply observing and recording what the rates are will not ensure that the system is operating within the permitted parameters.

- Section 5.2 fails to specify what test must be used to monitor visible emissions. The EPA requires a permit to specify what type of test should be used for monitoring. Though section 5.2(a) hints that the appropriate test may be EPA Method 9, the ACDP must clearly state whether this test or some other test is required. However, Method 9 would not be effective. To begin with Method 9 does not work at night. Thus, approximately half the time, the source will be unmonitored. But worse, Method 9 does not work with it is raining or snowing. Thus, monitoring using Method 9 would result in very little monitoring and thus lack of practical enforceability.

- Section 5.1(c) requires that all tests in the section must be performed when coal is being handled within the emissions source. The ACDP fails to specify how much coal must be handled during a test. The permittee could thus choose to do its tests only during the lightest days of the week, which would lead to inaccurate information. The ACDP should include a requirement that tests conducted during times of operation with maximum capacity. Similarly, section 5.2(b) requires that a test be done while coal is being loaded into a barge without specifying how much coal should be loaded for a test. The ACDP should specify that these tests should be conducted during times of operation with maximum capacity.

- A practically enforceable permit must include a requirement that the source be constructed to accommodate the required monitoring. The ACDP does not include such a requirement for any of its monitoring requirements. The ACDP should include this requirement.

- The ACDP fails to include any requirement for regulatory personnel to witness monitoring. DEQ claims its personnel will witness monitoring.[64] The ACDP must include requirements for regulatory personnel to witness monitoring.

3. The ACDP Fails to Require all Necessary Recordkeeping.

A critical aspect of a practically enforceable permit is that the requirements may be verified. Proper recordkeeping in accordance with ACDP conditions allows DEQ and the public to verify that monitoring requirements and emission limitations are being complied with. The ACDP fails to require any recordkeeping for 5.1(b). The ACDP should require recordkeeping of the monitoring in 5.1(b) so that these requirements can be verified and therefore practically enforceable.

4. The language in the ACDP is so vague as to be unenforceable.

The ACDP contains the following impermissibly vague terms and phrases:

- Section 2.3(b) requires that fugitive dust be "adequately" controlled at all times, but fails to define adequate. "Adequateness" is completely subjective and therefore it cannot be practically enforced. The ACDP must define what adequate means in the context of controlling fugitive dust emissions.

- In section 3.1(c) and (j), the ACDP requires "routine" inspections but fails to define routine. Routine could mean every day or every month, or something in between. Without definition, the permittee cannot know how frequent their inspections must be, and the inspections – performed at some unknown interval - may not prevent the migration of coal materials offsite. The ACDP must define the frequency of "routine."

- In section 6.1(h), the ACDP requires the permittee to submit a plan as "expeditiously as possible" if certain preventative measures do not prevent fugitive emissions. This phrase is too vague to be practically enforceable. If the permittee determines that the soonest a plan can be submitted is six months from the finding of a problem because the facility fails to employ sufficient or qualified workers, the only way DEQ could enforce this requirement is through costly litigation over what as "expeditiously as possible" means. The ACDP must give the permittee a clear deadline for the submission of the plan.

- Section 8.1(b), requires the permittee to notify DEQ during non-business hours if excess emissions are of "a nature that could endanger public health." The

[64] *See* OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY, COAL EXPORT FOR WEB – DEQ PERMITTING Q & A, available at http://www.deq.state.or.us/er/docs/CoalExportProject/CoalQAAQPermits.pdf.

permittee cannot be expected to define what could endanger the public health. If the permittee wrongly determines that an emission does not endanger the public health, the public health will be endangered until DEQ business hours resume. For this reason, the ACDP must clearly define when excess emissions would be of a nature that could endanger public health so that the permittee is clearly aware of when it must report excess emissions.

As explained in detail, above, the ACDP is missing several critical elements. These problems should be addressed through additional permit conditions.

IV. Ambre must not construct the Port Westward portion of the project without an ACDP.

In addition to the proposed Port of Morrow facility that is the subject of the above comments, Ambre plans to utilize an existing dock at Port Westward where coal will be transferred from barges to ocean-going vessels (OGV) for transport to Asia. This transloading facility will be operated by Pacific Transloading, LLC, another subsidiary of Ambre Energy. This transfer will use transloading equipment and systems specifically designed for Pacific Transloading and will be conducted by a stevedoring company.

The transloading operation at Port Westward requires an ACDP because emissions will, at the least, result in an air quality concern consistent with the air quality concern presented by the Port of Morrow facility, and because the facility is likely a federal major source of air pollution. The floating transloader is a stationary source when it is docked at the port because it will be anchored in one spot and attached to land.[65]

At this time, specific complete emission information is not available for the Port Westward facility, and it is impossible to determine the facility's exact potential to emit for all pollutants from the Environmental Review (ER) prepared for the Port of Morrow project. However, the ER estimates the coal transloader's annual potential emissions from coal dust at 0.015 tons per year (30 lbs. per year) for PM_{10} and 0.0022 tons per year (4.4 lbs. per year) for $PM_{2.5}$.[66] These emissions are understated, however, because the ER likely includes the facility's passive controls, which should not be considered when determining permit applicability, since they should only be considered if required by a permit.

Even if the emissions estimates in the Environmental Review are correct, the Port Westward facility will still require an ACDP. First, as discussed above, the annual potential emissions estimates in the ER are likely significantly reduced to take passive control systems into consideration. The real amount of potential emissions from coal dust at the facility is likely

---

[65] The transloader and the tugs supporting the transfer of material from one barge to an OGV are stationary sources when used as proposed for the same reasons the tugs at the Port of Morrow's emissions should be considered part of the stationary source's primary emissions.
[66] Environmental Review for the Coyote Island Terminal Dock at the Port of Morrow (August 2012), 347, http://morrowpacific. com/wp-content/uploads/large_files/ER%20Update-DSL%20Redacted-Volume%20I-RS.pdf

much higher. Next, even if the actual amount of potential emissions does not hit the 100 ton or 10 ton per year ACDP thresholds, the facility is still likely a source of air quality concern.[67] DEQ determined that the Port of Morrow facility requires an ACDP because it is a source of air quality concern. The Port Westward facility will process the same amount of coal.

Moreover, AMI modeled NOx ambient impacts from the Port Westward Operations with two different scenarios. Both scenarios showed NOx impacts 1,923% over the 1-hour NOx NAAQS using the Tier 2 methodology.[68] While Tier 2 results do not necessarily prove a NOx NAAQS violation by themselves, they certainly show that Port Westward's operations are a "source of air quality concern." In addition, the fact that the Tier 1 analysis shows cross state impacts above the NAAQS also makes Port Westward a source of air quality concern.[69]

Thank you for the opportunity to comment on Ambre's permit application.

Sincerely,

Aubrey Baldwin
On behalf of Sierra Club, Columbia Riverkeeper, and Friends of the Columbia Gorge.

cc via email only:

Jessica Yarnall Loarie, Sierra Club Environmental Law Program
<jessica.yarnall@sierraclub.org>
Lauren Goldberg, Columbia Riverkeeper
<lauren@columbiariverkeeper.org>
Michael Lang, Friends of the Columbia Gorge
<Michael@gorgefriends.org>

Dick Pedersen, Director, Oregon DEQ
<Pedersen.dick@deq.state.or.us>
Andy Ginsburg, Air Quality Division Administrator, Oregon DEQ
<Ginsburg.andy@deq.state.or.us>
Linda Hayes-Gorman, Eastern Regional Administrator, Oregon DEQ
<hayes-gorman.linda@deq.state.or.us>
Walt West, Permit Writer, Oregon DEQ
<West.walt@deq.state.or.us>

---

[67] A Standard ACDP is required for all sources with the potential to emit more than 100 tons of any air pollutant in a year. OAR Chapter 340, Division 216, Table 1, Part C. An ACDP is also required for any source that "would have actual emissions, if the source were to operate uncontrolled, of … 10 or more tons of any single criteria pollutant." *Id.* Table 1, Part B. Moreover, an ACDP is required of any source for which DEQ has determined that "an air quality concern exists." *Id.*

[68] Ex. 3 (AMI 2012 Report) at 16.

[69] Ex. 3 at 17 – 18.

Mark Fisher, Permit Writer, Oregon DEQ
<Fisher.mark@deq.state.or.us>
Dennis McLerran, U.S. Environmental Protection Agency, Region 10 Administrator
<mclerran.dennis@epa.gov>
Kate Kelly, U.S. Environmental Protection Agency, Region 10, Air Division Chief
<Kelly.kate@epa.gov>
Oregon Governor John Kitzhaber via Richard Whitman, Natural Resources Policy Director
<Whitman.richard@state.or.us>
Washington Governor Jay Inslee via Keith Phillips,
Keith.phillips@gov.wa.gov>
Kristin Swenddal, Washington Department of Natural Resources
<Kristin.Swenddal@dnr.wa.gov>
Paul Lumley, Columbia River Intertribal Fish Commission
<plumley@critfc.org>
Julie Carter, Columbia River Intertribal Fish Commission
<carj@critfc.org>
Kristina Proszek, Yakama Nation
<kris@yakama.com>

exhibits

Exhibit 1

EARTHRISE
law center

December 20, 2012

Via email to fisher.mark@deq.state.or.us
Mr. Mark Fisher
Oregon Department of Environmental Quality
475 NE Bellevue, Suite 110
Bend, OR 97701

RE: Public Comment on DEQ Permit Applications for the Proposed Coyote Island Coal Terminal

Dear Mr. Fisher:

Thank you for the opportunity to provide comments on the proposed Ambre Energy, dba Coyote Island Terminal, LLC (Ambre), air quality permit application. The following comments are submitted on behalf of Sierra Club, Columbia Riverkeeper, Oregon Physicians for Social Responsibility, Friends of the Columbia Gorge, Earthjustice, Climate Solutions, National Wildlife Federation, Center for Biological Diversity, Greenpeace, Oregon Rural Action, Crag Law Center and Washington Environmental Council (collectively, Commenters). These non-profit organizations represent tens of thousands of members across Oregon and the Pacific Northwest who are dedicated to protecting public health, and the environment and natural resources of our region for future generations. Recent DEQ hearings on Ambre's Morrow Pacific Project drew unprecedented crowds, with the majority of people testifying against Ambre's coal export project and the harm it will cause to our air, lungs, and natural resources.

Commenters are deeply concerned about a decision that will effectively authorize the construction of a new coal export terminal on the Columbia River and allow Ambre to export **over 8.8 million tons of coal annually**. Ambre's proposal to export coal is one of three pending proposals to use the Columbia River as a major export route for U.S. coal bound for China and other countries. The decision to authorize such projects will undercut the State of Oregon's considerable efforts to improve air quality to meet federal standards throughout Oregon, combat climate instability and ocean acidification, to promote sustainable alternatives, and to invest in recovering endangered salmon runs. Commenters submit these comments specifically regarding Ambre's Air Contaminant Discharge Permit (ACDP) application to Oregon Department of Environmental Quality (DEQ) because they are concerned about the proposed project's impacts on public health and environmental impacts due to air and water quality diminution in Oregon and Washington. Furthermore, Commenters are submitting comments regarding the need for an ACDP for the activities at Port Westward, which are a necessary part of the operation of Ambre Energy's Morrow Pacific Project.

Aubrey E. Baldw
Staff Attorney and Associate Clinical Profess

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.ed
earthriselaw.o

I. Introduction

As DEQ is aware, Ambre applied for an ACDP for its proposed coal storage and transfer facility at the Port of Morrow near Boardman, Oregon. If issued, the ACDP would authorize the construction and operation of the facility and its various sources, which would emit pollutants including nitrogen oxides (NO_x), sulfur dioxide (SO_2), and fine particulates ($PM_{2.5}$ and PM_{10}). If the project goes forward as proposed, air quality modeling demonstrates that project emissions will cause National Ambient Air Quality Standards (NAAQS) violations in both Oregon and Washington. Because DEQ cannot issue a permit to a facility that will cause these violations, the Commenters urge DEQ to deny the permit application.[1] Alternatively if DEQ does not deny the permit application, the agency should require Ambre's proposed facility to comply with Prevention of Significant Deterioration (PSD) requirements in addition to meeting the requirements in a standard ACDP. To determine appropriate PSD requirements, DEQ will need to request more information from the applicant regarding projected emissions from barges, tugs, and locomotives since this information is not included in Ambre's July 2012 ACDP application. The permit application also lacks information about emergency generators and firewater pumps.

The following is a brief summary of the permitting process and Ambre's actions thus far. Though DEQ is likely familiar with much of what has occurred, this history provides context for the significant concerns Commenters have regarding Ambre's permit application.

On February 3, 2012, Ambre applied for an ACDP to construct and operate a coal transfer and storage facility and a barge loading dock at the Port of Morrow near Boardman, Oregon. If authorized, the facility would receive up to 8.8 million tons per year of Power River Basin (PRB) coal from trains coming from the intermountain region. At the facility, trains would be off-loaded, and the coal would be stored before transfer to barges for shipment down the Columbia River to Port Westward. At Port Westward, the coal would be transferred to ocean-going vessels (OGVs) for transport to Asia. The transloading facility will be operated by Pacific Transloading, LLC, another subsidiary of Ambre Energy.

On February 14, 2012, Linda Hayes-Gorman, DEQ Eastern Region Administrator, informed Ambre that the proposed facility was not among the categories of air pollution sources that are required to obtain an ACDP, citing OAR 340-216-0020(1). On February 15, 2012, DEQ Permit Writer Mark Fisher also wrote Ambre to explain that, although an ACDP is not required, the proposed

[1] OAR 340-202-0050(2). Commenters depend upon publicly available law, regulations, guidance, and application materials, and intend to incorporate all cited materials into these comments as if they were provided as exhibits. If DEQ is unable to locate any cited material, Commenters will provide the cited material in electronic format upon request.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

construction is a "type 1" change requiring notice and approval of plans in accordance with OAR 340-210-0205-0250. According to DEQ, Ambre's February 3, 2012 application satisfied the "type 1" change criteria.

DEQ later determined that Ambre's proposed facility would instead require a Standard ACDP due to the facility's potential yearly particulate matter (PM) emissions, the projection that the facility will be an air quality concern, and the need to create legally enforceable permit conditions to ensure Ambre operates its proposed emission controls and mitigation measures. On July 26, 2012, Ambre submitted a revised ACDP application to DEQ for review.

The Commenters have further investigated the air quality impacts of the proposed project, and as a result, have concerns about the permitting of the Port of Morrow facility. On October 27, 2012, Commenters shared these concerns with DEQ in a letter containing an AERMOD modeling report that demonstrates air quality impacts above the National Ambient Air Quality Standards from the Port of Morrow facility and the Port Westward transloading activities. The letter also requested that DEQ require an ACDP for the transloader at Port Westward because it should be considered a stationary source of air emissions.

On November 1, 2012, DEQ announced that it was accepting comments on Ambre's ACDP permit application and that it would hold three public hearings to answer questions and receive comments on the DEQ permit applications for the proposed facility. Ambre has applied for an ACDP, a general National Pollution Discharge Elimination System (NPDES) 1200-C permit, an industrial stormwater permit, and an individual water pollution control facilities permit for its facility at the Port of Morrow. These comments are limited to the ACDP permit and air quality issues surrounding Ambre's coal export proposal.

As explained in detail below, and in the accompanying exhibits, DEQ should allow the federal government to take the lead in permitting the Morrow Pacific Project due to the agency's limited resources, the potentially severe impacts to public health and the natural resources of the Columbia River, Ambre's checkered history in the region, and the fact that delay will not prejudice the project. Should DEQ move forward, DEQ should recognize that, as a policy matter, the Morrow Pacific Project is fundamentally at odds with Oregon's goals to address climate change and preserve air quality in the state. In particular, since Ambre's emissions will cause violations of health based air quality standards, DEQ must deny the permit application. Moreover, since the project's primary emissions will exceed major source thresholds, the project can only move forward with the project when and if it receives a new source review permit. For these reasons, DEQ should not issue an ACDP to Ambre.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

II. DEQ should allow the federal government to take the lead on permitting the Morrow Pacific Project.

As an initial matter, DEQ should take no action on the Morrow Pacific Project until the federal agencies have the opportunity to provide a detailed review pursuant to federal law. As the DEQ is well aware by now, the Morrow Pacific Project, as well as all of the other West Coast coal export proposals, have generated widespread concern from a broad cross section of federal agencies, state governments, local municipalities, and Native Tribes over the nature and extent of the environmental impacts of the proposed coal export terminals. The Environmental Protection Agency, Governor Kitzhaber, the Washington Departments of Natural Resources and Ecology, the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe and numerous other governmental entities have all called for the federal government to prepare either a programmatic or area-wide Environmental Impact Statement (EIS) to consider the cumulative environmental and human health impacts of the proposals, which would involve the export of up to 150 million tons of coal per year through the Pacific Northwest. More than 25,000 citizens have submitted comments to the U.S. Army Corps of Engineers (Corps) requesting the same careful analysis.

Commenters urge DEQ to allow the federal government to take the lead on this project for two primary reasons. First and foremost, the information provided by Ambre documents the potential for severe impacts to air quality. While Ambre did not prepare or submit information on impacts to the ambient air quality of the Morrow Pacific Project, Commenters contracted with AMI Environmental to complete an ambient air modeling analysis using the information that was provided by Ambre in its Environmental Review document, and the appropriate protocols and guidance to conduct such modeling. That analysis, discussed in detail below, demonstrates that the project will cause air quality to deteriorate well beyond the levels set by the federal government to protect public health and welfare.

Second, Ambre has a well-documented history of misleading the public and regulatory agencies. Ambre misled public officials and the general public regarding the true size and, in turn, health and environmental impacts from its proposed Millennium Bulk Terminals coal export facility in Longview, Washington, and attempted to cover up the true nature of its proposal until after the local environmental review process had been completed. Here, critical information is missing related to the environmental effects of the project, and Ambre and its consultants have reached summary conclusions in the absence of scientifically valid analysis. In particular, Ambre's claims about the risk of coal dust, stormwater discharges, process water discharges, and coal dust toxicity are all highly suspect, which further calls into question the credibility of the project proponent and also reinforces the need for a detailed and independent review conducted by government agencies that have a broad range of staff expertise and adequate resources.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

Because of potentially severe impacts to public health, the natural resources of the Columbia River, and Ambre's checkered history in the region, Commenters strongly urge DEQ to allow the federal government to take the lead on reviewing the available information and assessing the validity and transparency of the analysis and conclusions provided by Ambre and its contractors. Instead of dedicating limited state resources to further this project, DEQ would be better served by allowing the U.S. Army Corps of Engineers (Corps), National Marine Fisheries Service, and the U.S. Fish and Wildlife Service (collectively "the Services") to determine how this project will move forward, if at all, under federal law before determining whether the criteria under Oregon's air quality laws and regulations have been met. Several major federal permitting actions and assessments remain, including: the Corps' analysis under National Environmental Policy Act and the Rivers and Harbors Act, and the Services issuance of a biological opinion under Section 7 of the Endangered Species Act. The final project design, including applicable mitigation measures, could very well change as a result of federal oversight and control. The timing of these processes is uncertain, as is the outcome. What we do know, however, is that the information produced and analysis conducted as a result of the federal processes will be relevant to the findings that DEQ must make under state law. By withholding a decision under state law until the federal agencies have completed their work, DEQ will conserve severely limited state resources while allowing the public, the applicant and other stakeholders to focus on the upcoming federal review. Delay to allow federal leadership will not prejudice Ambre, because without the federal authorizations, Ambre cannot move forward with the Morrow Pacific Project.

III. The Morrow Pacific Project is fundamentally at odds with Oregon's goals to address the imminent climate crisis and protect air quality.

The Morrow Pacific Project would contribute significant greenhouse gas emissions to our already suffering planet. Not only would the proposed project cause global harm, it would also adversely impact Oregon's citizens and environment near the proposed Morrow Pacific Project by degrading air quality through coal dust and diesel fuel emissions. Moreover, Coal and coal-fired power plants contribute to climate change, and the State of Oregon and DEQ should be committed to supporting alternative sources of energy rather than promoting further consumption of fossil fuels.

The threat of climate change can no longer be ignored. The U.S. Environmental Protection Agency (EPA) has stated that the dangers presented by climate change are "not a close case" and "[i]n both magnitude and probability, climate change is an enormous problem."[2] The President of the United States,

[2] U.S. Environmental Protection Agency, Climate Change Division, Office of Atmospheric Programs, Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act, April 17, 2009, at ES-1 and 3-4,

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

Oregon's governor, and the Oregon legislature have all recognized that global warming poses a serious threat to economic well-being, public health, and the natural resources and environment of our world.

Scientific studies now conclusively show that our climate is changing due to human sources of greenhouse gases, most significantly carbon dioxide (CO_2). The World Meteorological Organization (WMO) recently announced that in 2011 the amount of greenhouse gases in the atmosphere reached a new record high.[3] WMO's recent survey also found that between 1990 and 2011, there was a 30% increase in the radiative forcing, which is the warming effect on our climate, with CO_2 accounting for about 80% of that increase.[4] To avoid catastrophic melting of ice sheets, CO_2 levels in the atmosphere must be no higher than 350 parts per million (ppm). In 2011, CO_2 levels reached 390.9 ppm.[5]

Carbon dioxide is the most important GHG, and the burning of fossil fuels is the primary source of global carbon emissions.[6] Coal plays a major role in contributing to the imminent climate catastrophe. In addition to other pollutants, coal combustion produces CO_2. Complete combustion of 1 ton of coal will generate about 2.86 tons of CO_2.[7] If approved, this project could result in the production of approximately 22,880,000 tons CO_2 *every year*.

The issuance of an ACDP would contribute significantly to global carbon emissions by endorsing the export of coal to Asia, where it will be burned under minimal regulation. Regulation of coal-fired power plants in Asia is not nearly as sophisticated as regulation in the U.S., where EPA is concerned with reducing carbon emissions from these plants. Furthermore, the proposed export project will foster greater integration of coal into Asian energy grids and will contribute to a rising demand for coal in these countries. This increased foreign consumption will negate carbon reductions efforts domestically and elsewhere.

Most importantly, the effects of climate change will be felt in Oregon, and approval of Ambre's proposed Port of Morrow facility will impact Oregon citizens in a real way. In Oregon, climate change is resulting in more extreme weather, and

---

available at http://www.epa.gov/climatechange/Downloads/endangerment/Endangerment_ TSD.pdf.

[3] World Meteorological Organization and Global Atmosphere Watch, WMO Greenhouse Gas Bulletin, November 19, 2012, at 1, available at http://www.wmo.int/pages/prog/arep/gaw/ghg/documents/GHG_Bulletin_No.8_en.pdf

[4] Id.

[5] Id.

[6] Id. at 2.

[7] B.D. Hong & E.R. Slatick, Carbon Dioxide Emission Factors for Coal U.S. Energy Information Administration: Coal, http://www.eia.gov/coal/production/quarterly /co2_ article/co2.html

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

significant increases in rainfall and flooding west of the Cascades to the coast.[8] Climate change is also affecting the viability of imperiled Pacific Northwest salmon and steelhead by causing the oceans to acidify from carbon absorption. Climate change alters water cycles and also affects the reproductive successes, range, and diet of vulnerable species.[9] Already threatened species, like salmon and steelhead, cannot be needlessly forced to bear more impact to their environment as their existence in Oregon's rivers is already diminished. Climate change also impacts forest resources, and a study indicates that the climate crisis may be responsible for the recent widespread decline in healthy Western forests.[10]

Sea level is rising, which will affect coastal communities in Western Oregon, and the Cascade snowpack is melting earlier and faster each spring.[11] Because DEQ alleges that it is "meeting the challenge of climate change head-on and participating in statewide efforts to reduce greenhouse gas emissions" it should deny the ACDP, which will facilitate a project that directly contravenes the agency's goals.[12]

In addition to the very real threats posed by climate change, the air pollutant emissions from the Morrow Pacific Project will harm residents in Oregon and Washington and our ecological resources. Modeling of the proposed project, described in more detail below and in the accompanying modeling report, indicates that concentrations of NOx and fine particulate matter will exceed the National Ambient Air Quality Standard (NAAQS) in both Oregon and Washington as a result of the proposed project.[13] Expert review of the potential fugitive emissions also demonstrate that Ambre's projections of fugitive coal dust are inaccurate by orders

---

[8] Edward Miles, PhD, Professor of Marine and Public Affairs, University of Washington, and former IPCC member and contributing author, Presentation, Global Warming/State of the Science: Northwest Regional Impacts, Portland, Oregon (Sept. 26, 2007).

[9] See Intergovernmental Panel on Climate Change (IPCC), Climate Change 2001: Impacts, Adaptation and Vulnerability (2001), available at http:www.grida.no/climate/ipcc_tar/wg2/index.htm; IPCC, Climate Change 2007: The Synthesis Report (2007), available at http:www.ipcc.ch.

[10] Phillip J. van Mantgem, et al., Widespread Increase of Tree Mortality Rates in the Western United States, Science Vol. 323, Jan. 23, 2009, available at http://www.sciencemag.org/content/323/5913/521.

[11] Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest, Consensus Statement drafted by a subcommittee of participants in the scientific meeting "Impacts of Climate Change on the Pacific Northwest" convened at OSU on June 15, 2004 at 4, available at www.ef.org/westcoastclimate/E_OSU%20Consensus%20Statement.pdf.

[12] Oregon DEQ, Climate Change, http://www.deq.state.or.us/aq/climate/index.htm (last visited December 11, 2012).

[13] AMI Environmental, AERMOD Modeling of Air Quality Impacts of the Proposed Morrow Pacific Project, attached as Exhibit 1.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

of magnitude.[14] That coal dust will itself have unaccounted for impacts on health and welfare.[15]

IV. Concentrations of air pollutants will exceed the levels set by EPA to protect public health and welfare.

National Ambient Air Quality Standards (NAAQS) are concentrations that EPA sets for "criteria pollutants" under the Clean Air Act. Criteria pollutants are pollutants that EPA has determined "cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare."[16] To date, EPA has made "endangerment findings" for six pollutants: particulate matter (PM, PM10, and PM2.5), ground-level ozone (O3), sulfur dioxide (SO2), nitrogen oxides (NOx), lead (Pb), and carbon monoxide (CO). Once EPA makes an endangerment finding, EPA must then develop "air quality criteria" for that pollutant.[17] The criteria are intended to accurately reflect the latest scientific knowledge about effects on public health and welfare that can be expected from various levels of that pollutant in the ambient air.[18] Once the criteria are established, EPA must set NAAQS to protect human health and welfare.[19] Thus, the NAAQS are upper-limit concentrations of air pollutants that EPA has deemed will protect public health and welfare. The heart of the Clean Air Act is to ensure that all areas of the United States achieve these minimal levels of air quality.

Nitrogen oxides ("NOx") are highly reactive gases emitted primarily from the combustion of fossil fuels in mobile and stationary sources. NOx can cause respiratory problems such as asthma attacks, respiratory tract symptoms, bronchitis, and decreased lung function. NOx emissions result in nitrogen deposition, which may cause "significant adverse changes" in terrestrial ecosystems such as soil acidification, increases in soil and plant susceptibility to natural stresses, and alteration of natural plant species balances. Nitrogen deposition can also adversely affect aquatic ecosystems through acidification or eutrophication, both of which cause a reduction of water quality, and can leave the waterbody unfit for many aquatic organisms and/or human consumption. In addition, NOx emissions contribute to visibility impairment, global warming, acid rain, formation of ground-level ozone and formation of toxic chemicals. NOx is also a precursor chemical to fine particulate matter.

---

[14] Phyllis Fox, Ph. D., PE, Fugitive Particulate Matter Emissions from Proposed Morrow Pacific Project, attached as Exhibit 2.
[15] See, Leyda Consulting, Ecological Impacts of Proposed Coal Shipping on the Columbia River, attached as Exhibit 3.
[16] 42 U.S.C. § 7408(a)(1)(A).
[17] 42 U.S.C. § 7408(a)(2).
[18] Id.
[19] 42 U.S.C. § 7409.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

The Columbia River Gorge National Scenic Area is particularly impaired by NOx pollution. The Columbia River Gorge National Scenic Area ranked 6th in the country for poorest visibility for Scenic Areas. Gorge air quality has been monitored for the last seventeen years. The Forest Service has documented that visibility impairment occurs on at least 95% of the days that have been monitored. The impacts of NOx on Oregon's protected parks and wilderness areas, including the Columbia River Gorge, has been well documented in DEQ's regional haze rulemaking process, and by studies by Dan Jaffe, a scientist at the University of Washington.

Deposition of pollutants also has profound negative impacts on ecosystems. Studies demonstrate that in the Western United States, some aquatic and terrestrial plant and microbial communities are significantly altered by nitrogen deposition.[20] Metals, sulfur and nitrogen concentrations in lichen tissue found in the Gorge are comparable to that found in lichen tissue sampled in urban areas. The Gorge now stands among the most polluted places in the country, including Pittsburgh and Los Angeles. Nitrogen deposition rates in the Gorge are comparable to the most polluted areas in the U.S. Oregon's "Crown Jewel" does not deserve this bombardment on its ecological resources.

Particulate Matter pollution also threatens to human health and welfare. In fact, when reviewing the NAAQS for PM2.5, EPA found that there is no level of particulate matter pollution at which there are no human health effects. According to EPA, fine particulate matter pollution causes a variety of adverse health effects, including premature death, heart attacks, strokes, birth defects, and asthma attacks.[21] Even low levels of PM can cause low birth weights, damage lung function, and increase risks of heart attack and premature death. Studies reviewed by EPA revealed a linear or almost linear relationship between diseases like cancer and the amount of fine particulate matter in the ambient air.[22] Consequently, any particulate matter contamination has adverse health effects.

The air quality impacts of the proposed operations at the Port of Morrow and Port Westward are analyzed in AMI Environmental's October 2012 Report, *AERMOD Modeling of Air Quality Impacts of the Proposed Morrow Project* (Report). The modeling includes analysis of 1-hour and annual NO_2 concentrations, 1-hour SO_2 concentrations, and 24-hour $PM_{2.5}$ concentrations resulting from the proposed activities at the Port of Morrow.

---

[20] See Mark E. Fenn, et al, Ecological Effects of Nitrogen Deposition in the Western United States, BioScience Vol. 53:4, Apr. 2003, available at http://www.bioone.org/doi/abs/10.1641/0006-3568(2003)053%5B0404:EEONDI%5D2.0.CO%3B2.

[21] 71 Fed. Reg. 2620, 2627–36 (Jan. 17, 2006).

[22] Id. at 2635–36.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

The modeled scenario involves coal unloading from trains while barges are loading, assisted by tugs, at the dock at the Port of Morrow. The modeling accounts for train and barge emissions while on-site, as well as $PM_{2.5}$ emissions from wind erosion of coal. Pollutant measurements from DEQ's 2011 Air Quality Annual Report were used as background concentrations for modeling impacts at the Port of Morrow.[23] The Report also analyzes concentrations resulting from activities at Port Westward associated with Ambre's coal export facility. These activities include the operation of the transloader, and emissions from barges and ocean going vessels while on-site being loaded and unloaded.

The pollutant emissions modeled likely severely understate actual emissions from the facility. First, this modeling assumed that Ambre's representations regarding fugitive coal dust emissions were true. As discussed below, and explained at length in Dr. Fox's report, the fugitive coal dust emissions are likely many times greater than estimated by Ambre. Similarly, Ambre's application does not include any information regarding emissions from emergency generators and firewater pumping. The proposed facility will need both.[24] Emissions from this type of equipment can be significant because the equipment is not operated only in case of an emergency, but must be operated routinely to ensure operational readiness. In addition, with their low stack heights, relatively high emissions, and proximity to the fence line, this type of equipment may cause NAAQS or PSD increment exceedances if properly modeled.[25] Thus, DEQ should require Ambre to demonstrate through a letter from its insurance company that emergency equipment is not required and include a permit condition limiting Ambre's use of such equipment. If Ambre is going to have such equipment on site, the potential emissions from the equipment must be included in the potential to emit calculation based on 8760 hours of operation per year, or the permit must include specific and enforceable conditions to limit the use of the equipment and that limited use must be factored into the potential to emit calculation for the facility.

In spite of the understated emissions used in the modeling, the modeling report concludes that the proposed project would result in exceedances of the NO_2 1-hour NAAQS of 188 µg/m^3 (by 9-10 times the NAAQS at the Port of Morrow and by 19times the NAAQS at Port Westward), the 24-hour $PM_{2.5}$ NAAQS at the Port of Morrow (by 2.4 times the NAAQS of 35 µg/m^3), and the annual NO_2 NAAQS at the Port of Morrow (by 12 times the NAAQS of 100 µg/m^3).[26] The report determines that these exceedances will occur from project emissions alone, without any

[23] Exhibit 1 at 7.
[24] Exhibit 2 at 1 (the facility will handle very flammable PRB coals, which "have been known to be delivered with the rail car or barge partially on fire").
[25] Exhibit 1 at 7.
[26] Id. at 27.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

background concentrations of the pollutants.[27] The report also demonstrates that NAAQS violations will occur in both Oregon and Washington.[28]

A. 1-hour NO_2 Impacts

The 1-hour NO_2 NAAQS is attained when the 3-year average of the 98th percentile of the daily maximum 1-hour NO_2 concentrations do not exceed 100 ppb (or 188 ug/m^3).[29] Modeling for this standard is broken into three tiers of EPA recommended techniques.[30]

Using the Tier 3 OLM modeling, NAAQS violations due to project emissions alone are expected in both Oregon and Washington. Using the Tier 3 PVMRM modeling, NAAQS violations due to project emissions alone are expected in an area stretching almost 1.9 miles to the east and south of the project site. Thus, the modeling demonstrates that, the concentration of NOx in the air will be many times over the NAAQS limit.[31]

B. Annual NO_2 Impacts

The scenario for this modeling considers NOx emissions from a train unloading, a tugboat assisting the barge loading, and a tugboat traveling on the Columbia River.[32] This modeling also uses the suggested Tier 1 and Tier 2 techniques described in the 1-hour NO_2 impact section above. No Tier 3 technique was modeled because of the lack of available data. Under the Tier 2 scenario, NAAQS exceedances were demonstrated by both the project concentration alone and the project and background concentrations combined.[33] These exceedances will occur near the project site and will affect Oregon. Under Tier 2, modeling projects that project emissions, in combination with the background concentration, will be 1,227% over the NAAQS limit.[34] In other words, the annual NAAQS will be largely exceeded by 12 times with Tier 2.[35] Although Tier 3 techniques were not used to model annual NO_2 impacts, exceedances are also expected under that scenario.[36]

---

[27] Id. at 26.
[28] Id.
[29] Id. at 11.
[30] Id. at 12.
[31] Id.
[32] Id. at 22.
[33] Id.
[34] Id.
[35] Id. at 22-23.
[36] Id. at 23.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

C. 1-hour SO_2 Impacts

The 1-hour SO_2 NAAQS is attained when the 3-year average of the 99th percentile of the daily maximum 1-hour SO_2 concentrations do not exceed 75 ppb (or 196 ug/m3).[37] Modeling predicts that the concentration of SO_2 resulting from proposed project emissions, in combination with background concentrations, will not exceed the NAAQS standard.[38] The low projected SO_2 concentrations are due to the projected use of ultra low sulfur diesel for both locomotives and boats as described in the *Environmental Review*.[39] However, locomotives and boats are legally allowed to use much higher sulfur content diesel fuel than what was assumed in the ER.[40] Therefore, the project emissions may, in fact, result in excedances of the SO_2 NAAQS. The permit must include enforceable conditions to limit the project to the use of only ultra low sulfur diesel or the application must be amended and re-submitted for public comment with an analysis of emissions using all legally available diesel fuel.

D. 24-hour $PM_{2.5}$ Impacts

The 24-hour $PM_{2.5}$ NAAQS is attained when the 3-year average of the 98th percentile 24-hour concentrations do not exceed 35 ug/m3.[41] Under the modeling scenario for enclosed barges, NAAQS exceedances were predicted when considering both the project concentration alone, and the project and background concentrations combined. That is, the modeling assumed that Ambre will be legally required to use enclosed barges, which is not included in any regulatory action as yet. At Port of Morrow, modeling predicts the 24-hour design value concentration of $PM_{2.5}$ of 96.3 ug/m3. In combination with background concentrations, the projected concentration will be 244% over the NAAQS limit. [42] In other words, the concentration of $PM_{2.5}$ in the air will be more than double the concentration considered safe by EPA, even when using Ambre's incorrect assumptions about coal dust.

E. Nitrogen Deposition Impacts

In addition to determining the concentrations in the air of pollutants emitted by the proposed facility, AMI also analyzed the dry and wet deposition of nitrogen resulting from the operations at the Port of Morrow. The analysis considered the NOx emissions from train unloading, tugboats assisting the barge loading, and a

---

[37] Id. at 18.
[38] Id. at 19.
[39] Anderson Perry and Associates, Inc., Environmental Review for the Coyote Island Terminal Dock at the Port of Morrow, August 2012, 3-126, available at http://morrowpacific._com/wp-content/uploads/large_files/ER%20Update-DSL%20Redacted-Volume%20I-RS.pdf.
[40] See 77 Fed. Reg. 61281 (Oct. 9, 2012).
[41] Exhibit 1 at 19.
[42] Id. at 20.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

tugboat traveling on the Columbia River. The predicted deposition largely exceeds the ecological screening level (ESL) of 0.5 g/m^2/yr or 5 kg/ha/yr recommended by EPA.[43] Under the Tier 2 technique, the 2011 levels of predicted nitrogen deposition are projected to be 195.9 kg/ha/yr. The predicted nitrogen deposition will adversely affect both Oregon and Washington from project emissions alone.[44]

V. Ambre incorrectly calculated emissions from fugitive coal dust, which is extremely hazardous to human health and welfare.

Coal dust is one kind of particulate matter, but the coal dust associated with the Morrow Pacific Project presents particular threats. Coal dust contains a number of harmful elements, including: antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, selenium, uranium, tin, boron, copper, vanadium, molybdenum, and zinc, among others.[45] Dr. Phyllis Fox has calculated that fugitive emissions of particulate matter coal dust from coal transfers at the Port of Morrow will be approximately 139 tons per year, which is likely an understatement. For finer particles the calculation yields 66.9 tons per year of PM10, and 10.7 tons per year of PM2.5.[46] Coal dust causes health problems in humans, including development of lung fibrosis, lung and other cancers, and genetic damage.[47] Coal dust, when deposited in water, can be harmful to aquatic organisms, including benthic organisms, which are food for juvenile salmonids.[48]

While the applicant claims coal dust emissions will be low, the applicant provides no measurements or sources beyond "engineering assumptions" to support the control efficiencies presented in the permit application. As Dr. Fox notes in her report, "this level of particulate control has not been proven at any facility anywhere in the world."[49] In fact, other terminal projects have asserted that the type of controls proposed by Ambre are not feasible, including other coal export terminals such as Millenium Bulk Terminals, Gateway Pacific Terminal, and the Kinder Morgan terminal.[50] As Dr. Fox's report demonstrates, Ambre has significantly overstated the reliable effect of its proposed controls.[51]

[43] Id. at 25.
[44] Id. at 26.
[45] Exhibit 3 at 5.
[46] Exhibit 2 at 12.
[47] Exhibit 3 at 6-9.
[48] Exhibit 3 at 9.
[49] Exhibit 2 at 10.
[50] Id.
[51] Exhibit 2.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

VI. Oregon laws and regulations require that DEQ deny the permit application.

The NAAQS violations demonstrated by modeling require DEQ to deny Ambre's ACDP application and issue an order prohibiting construction of the facility. DEQ cannot knowingly issue a permit that allows a violation of an air quality standard.[52] Because the proposed facility's emissions would violate several NAAQS limits in both Oregon and Washington, Ambre's application for an ACDP must be denied, and DEQ should issue an order prohibiting construction of the facility pursuant to its authority under Oregon Administrative Rules, Chapter 240, division 210.

Even if Ambre could overcome the NAAQS violations identified in AMI's Report, and the increment violations likely associated with the facility, the Morrow Pacific Project still cannot be legally constructed without a PSD ACDP because its emissions exceed the applicability thresholds. Ambre failed to include emissions from locomotives, barges and tugs when engaged in active loading and unloading operations in the facility's potential to emit calculation. Those emissions must be included in the potential to emit calculation, however. While locomotives and barges are "mobile sources," in that they can physically move around, mobile source emissions are not excluded from the definition of primary emissions from which DEQ must determine what type of permit is required. Under Oregon law, and consistent with federal policy, emissions from the locomotives and barges while engaged as part of the stationary source, must be considered primary stationary source emissions. When so considered, the Port of Morrow facility is a major source that requires a PSD permit. For the same reason, the Port Westward facility also requires a PSD permit.

Emissions from idling onsite locomotives or barges should not be included as secondary emissions. Instead, they should be included as primary emissions. First, these emissions are actually coming from the stationary source itself because the source's entire purpose is the unloading of trains and the loading of barges, and the facility is built around the loading and unloading processes. Thus, the trains and barges are acting as a necessary part of the stationary source when they are moving into and maintaining positions to make loading and unloading possible based upon the design of the facility. That is, the train cars are moved into the place required

---

[52] OAR 340-202-0050(2) states that:
if a source or combination of sources are singularly responsible for a violation of ambient air quality standards in a particular area, it may be appropriate to impose emission standards that are more stringent than those otherwise applied to the class of sources involved. Similarly, proposed construction of new sources or expansions of existing sources, that may prevent or interfere with the attainment and maintenance of ambient air quality standards are grounds for issuing an order prohibiting such proposed construction as authorized by ORS 468A.055 and pursuant to OAR 340-210-0200 through 340-210-0220, and OAR 340-218-0190.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

by the facility's design for unloading and maintained there by the locomotives, and barges are moved into the place required by the facility's design for loading and maintained there by the emission sources on the tugs and barges. Second, Oregon's regulatory definition of secondary emissions specifically includes only trains and vessels coming *to or from a facility*, not trains and vessels idling onsite during active loading and unloading when that loading and unloading is the only purpose of the facility. Thus, the definition of primary emissions in Oregon includes mobile sources when they are not coming to or from a facility, but are rather operating as an essential part of the facility. Third, considering the mobile source emissions as primary emissions while on-site operating as part of the stationary source is consistent with federal policy. Thus, the locomotive, tug and barge emissions must be considered as primary emissions in the potential to emit calculation of the source.

A. Emissions from idling barges and trains at the Port of Morrow are not secondary emissions because they come from the source itself.

The entire proposed facility at the Port of Morrow revolves around the unloading of trains and the loading of barges. The proposed facility will process up to 8.8 million metric tons of coal per year for transport down the Columbia River to Port Westward.[53] Trains coming into the facility will be over a mile long.[54] It will take approximately 12 hours to unload each train's coal load of approximately 13,182 metric tons. Two locomotives will be used to stage and unload each train, and each locomotive will remain idling during the entire 12 hours of unloading.[55]

These activities are the basis of the proposed Port of Morrow facility. Without trains and barges, the project would not be able to go forward, as a major part of the facility will be the train unloading barn, the unloading equipment, and the conveyors to reload the barges. Therefore, idling emissions are coming from the source itself since the locomotives and barges are integral parts of the operation and will spend a significant amount of time at the facility.

B. Oregon's regulations do not treat mobile sources while onsite as secondary emissions.

Oregon's federally approved State Implementation Plan (SIP) includes the rules applicable to sources of air pollution in Oregon.[56] The SIP contains regulations governing the state's ACDP programs and the PSD program, both of which are applicable to the Port of Morrow facility. The PSD program is designed to protect public health and welfare from actual or potential adverse effects which may

[53] Environmental Review at ES-1.
[54] Id. at 3-5.
[55] Id. at 3-129.
[56] See OAR 340-021-015 et seq.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

reasonably be anticipated to occur from air pollution.[57] The program applies when a proposed stationary source emits, or has the potential to emit, a specified amount of an air pollutant per year.[58]

A proposed stationary source's "potential to emit" must be determined when establishing whether the source is major and which permit is required to construct and operate the source. However, a source's potential to emit does not include all emissions associated with the facility. In Oregon, secondary emissions are excluded when determining a source's potential to emit.[59] They are instead included in PSD emission calculations only once the "major source" threshold has been met by primary emissions.[60] "Secondary emissions" are defined as "emissions that are a result of the construction and/or operation of a source or modification, but that do not come from the source itself."[61] "Secondary emissions may include, but are not limited to: emissions from ships and trains coming to or from the facility[.]"[62]

Thus, in Oregon, emissions from the trains and vessels at the proposed Port of Morrow and Port Westward facilities should not be considered secondary emissions, and may therefore be included in the potential to emit calculation. Had Oregon wished to include ships and trains while onsite in this definition, it could have done so by not limiting the definition to emissions from travel associated with getting to and from the facility. However, this significant omission indicates that emissions from ships and trains while onsite are not covered as secondary emissions and may be regulated as primary emissions from the stationary source.

C. In similar situations, EPA has required that permit applicants include idling emissions from vessels in their New Source Review applications, and nothing in federal law or regulations prevents DEQ from applying the plain language of its SIP.

Commenters recognize that federal decisions regarding ship and train emissions do not control in this situation because DEQ implements its own CAA program in the state, as governed by its SIP. However, EPA's guidance can be useful when Oregon is dealing with an entirely new type of source never permitted in the state before, as in this case.

Consideration of mobile source emissions when on-site and part of an industrial process as primary emission is not only consistent with Oregon law, but also federal policy when determining PSD applicability. The U.S. Environmental

[57] 42 U.S.C. § 7470.
[58] 42 U.S.C. § 7478(1), OAR 340-200-0020(67).
[59] OAR 340-200-0020(91)(c).
[60] OAR 340-224-0100.
[61] OAR 340-200-0020(100).
[62] OAR 340-200-0020(100)(a).

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School
10015 SW Terwilliger Blvd.
Portland, OR 97219-7799
phone 503-768-6929
fax 503-768-6642
abaldwin@lclark.edu
earthriselaw.org

Protection Agency has concluded that emissions from vessels when berthed at port in furtherance of the on-shore facility must be included in the potential to emit calculation for PSD applicability.[63] In *State of Texas v. EPA*, the United States Court of Appeals for the Fifth Circuit upheld EPA's authority to regulate emissions from ships and barges as they were loading and unloading.[64] In *NRDC v. EPA*, the United States Court of Appeals for the D.C. Circuit held that EPA was not automatically barred from regulating dockside emissions at marine terminals as a part of NSR.[65] In addition, the Environmental Appeals Board (EAB) has regulated off-shore drilling ships – which are marine vessels carrying drilling equipment - in the Outer Continental Shelf (OCS) as stationary sources and has subjected their emissions to PSD requirements.[66] EPA has, for more than 30 years, consistently held that it can regulate vessels as part of a stationary source when in port.[67] Finally, nothing in the Clean Air Act or federal regulatory programs preempts DEQ's authority to regulate vessel or locomotive emissions when they are acting as part of a stationary source. Because EPA considers vessel emissions as primary stationary source emissions in similar contexts to the proposed facility's loading and unloading situation, DEQ should also consider emissions from trains and barges as primary stationary source emissions.

Indeed, other permit applicants in Oregon have taken vessel emissions into consideration when determining which air quality provisions will apply to their projects. For example in their Federal Energy Regulatory Commission (FERC) review, project developers of the Oregon Liquefied Natural Gas (LNG) Terminal and Pipeline Project included emissions from vessels docked in port while transferring LNG between land and the vessel in their PSD analysis and dispersion modeling

---

[63] See e.g., Letter from Charles J. Sheehan to Michael Cathey and Diana Dutton (October 28, 2003), in EPA Title V Policy and Guidance Database, at 7, available at http://www.epa.gov/region07/air/nsr/nsrmemos/20031028.pdf (stating that vessel emission associated with LNG re-gasification and the transfer of gas to the port should be included in the applicability determinations for CAA preconstruction and operating permits).

[64] 499 F.2d 289 (5th Cir. 1974).

[65] 725 F.2d 761, 771 (D.C. Cir. 1984).

[66] See, e.g., In Re: Shell Gulf of Mexico, Inc., Shell Offshore, Inc. (Frontier Discovery Drilling Unit, 2010 WL 5478647 (E.P.A. 2010).

[67] See, e.g., Letter from Charles J. Sheehan to Michael Cathey and Diana Dutton (October 28, 2003), in EPA Title V Policy and Guidance Database, 7, available at http://www.epa.gov/region07/air/nsr/nsrmemos/20031028.pdf (stating that vessel emission associated with LNG re-gasification and the transfer of gas to the port should be included in the applicability determinations for CAA preconstruction and operating permits); Memorandum from the Director of the Division of Stationary Source Enforcement to Joe Winkler (April 12, 1979), in EPA Title V Policy and Guidance Database, 2, available at http://www.epa.gov/region07/air/nsr/nsrmemos/m041279.pdf (stating that any ship emissions which result from unloading ships are directly involved in dock operations and therefore as considered primary emissions, which should be taken into account in determining PSD applicability).

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

analysis for the proposed project.[68] Emissions from locomotives and barges at the Port of Morrow should be considered in the same manner as emissions from vessels at the Oregon LNG Terminal during loading and unloading. Coal export and LNG export are almost indistinguishable as a policy matter, and should be treated the same under the PSD regulations.

When vessel and train emissions are included, Ambre's facility will require a PSD ACDP. Ambre failed to include relevant emissions in its application, thus DEQ must require the applicant to submit more information. However, a review of the *Environmental Review* document demonstrates that the facility is a major source subject to PSD. The facility is a major source of NOx, because it will emit over 500 tons per year of NOx and over 15 tons per year of $PM_{2.5}$. DEQ must, therefore, inform the applicant that a PSD permit is necessary. Any future PSD permit can only be granted if the emissions associated with the facility, including locomotives, tugs and barges while on-site, will not cause or contribute to concentrations of pollution in the air higher than the NAAQS and specified increments.

VII. Conclusion

For the reasons stated above, and in the accompanying exhibits, Commenters request that DEQ delay its decision on Ambre's permit until the federal processes are concluded. If DEQ decides it must take action, DEQ must deny Ambre's application for an ACDP for its proposed facility at the Port of Morrow and issue an order prohibiting construction of the source until the required PSD permit is issued. DEQ must deny the permit as modeling indicates that the project will result in NAAQS violations, and DEQ cannot issue a permit that will result in excedances of the NAAQS. Moreover, the facility must not be constructed unless and until the applicant fulfils the PSD permitting requirements and DEQ issues a valid PSD permit.

In addition, for the reasons stated for the Port of Morrow facility, above, DEQ should also require Ambre to apply for and receive a PSD permit for its operations at Port Westward. The Port Westward facility has the potential to emit nearly 400 tons per year of NOx, and is thus clearly a major source subject to PSD.

[68] See Oregon LNG Terminal and Oregon Pipeline Project FERC Review Comment/Response Matrix, at 4-5, available at https://s3-us-west-2.amazonaws.com/oregonlng/oregonlng/pdfs2/RR9_Comment-ResponseMatrix.pdf.

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

Thank you for the opportunity to comment on Ambre's permit application, and happy holidays.

Sincerely,

Aubrey Baldwin
On behalf of Sierra Club, Columbia Riverkeeper, Friends of the Columbia Gorge, Oregon Physicians for Social Responsibility, Earthjustice, Greenpeace, Climate Solutions, Center for Biological Diversity, Oregon Rural Action, Crag Law Center and the National Wildlife Federation

cc:

Jessica Yarnall Loarie, Sierra Club Environmental Law Program
Brett VandenHeuvel, Columbia Riverkeeper
Michael Lang, Friends of the Columbia Gorge
Regna Merritt, Oregon Physicians for Social Responsibilty
Kristen Boyles, Earthjustice
Ross MacFarlene, Climate Solutions
James Murphy, Senior Counsel, National Wildlife Federation
Tierra Curry, Center for Biological Diversity
Bethany Cotton, Greenpeace
Bridget Callahan, Oregon Rural Action
Christopher Winter, Crag Law Center
Becky Kelley, Deputy Director, Washington Environmental Council

Andy Ginsburg, Oregon DEQ

Aubrey E. Baldwin
Staff Attorney and Associate Clinical Professor

Earthrise Law Center
at Lewis & Clark Law School

10015 SW Terwilliger Blvd.
Portland, OR 97219-7799

phone 503-768-6929
fax 503-768-6642

abaldwin@lclark.edu
earthriselaw.org

Exhibit 2

AERMOD Modeling of 1-hour NO_2 Impacts of Tug Boat Emissions at the Port of Morrow

Final Report

June 2013

Prepared for

Ms. Jessica Loarie
SIERRA CLUB
San Francisco, California

Prepared by
Mr. Khanh T. Tran
Principal

AMI Environmental
206 Black Eagle Ave
Henderson, NV 89002
Tel. (714)679-7363

Table of Contents

		Page
I.	**Introduction**	3
II.	**Modeling Methodologies**	3
	A. Model Version	3
	B. Source Emissions	3
	C. Stack Parameters	4
	D. Receptors	4
	E. Meteorological and Ozone Data	4
	F. Background Concentrations	4
III.	**Modeling Results**	7
IV.	**Conclusions**	11
V.	**References**	12

Appendix A - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Tug Boat Emissions at the Port of Morrow

Appendix B - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-OLM) of Tug Boat Emissions at the Port of Morrow

Appendix C - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-PVMRM) of Tug Boat Emissions at the Port of Morrow

I. INTRODUCTION

Air quality impacts of the proposed Morrow Pacific Project have been analyzed in a modeling study performed by AMI Environmental for the Sierra Club (AMI, 2012). In this previous October 2012 study, the AERMOD model was used to analyze the 1-hour nitrogen dioxide (NO_2) impacts from coal transfer operations at the Port of Morrow, i.e. coal offloading from trains into enclosed storage buildings and transfer into enclosed barges that are assisted by tug boats. In the present study, NO_2 impacts are analyzed with the same AERMOD model using only tug boat emissions, i.e. train emissions have been removed. Modeling methodologies and inputs are presented in Section II and modeling results in Section III.

II. MODELING METHODOLOGIES

This section documents the methodologies and assumptions used in the generation of modeling inputs such as source emissions, stack parameters, receptors, meteorological data and background concentrations.

A. Model Version

Version 12060 of the AERMOD model has been used in the modeling study. It is the same version used in the previous October 2012 study. The most recent modeling guidance by US EPA has been implemented in the AERMOD model and it is fully capable of predicting project impacts for comparison against the 1-hour NO_2 national ambient air quality standard (NAAQS) of 100 ppb (188 ug/m^3).

B. Source Emissions

In the modeled scenario, barges are loading at the dock in Port of Morrow. These barges are assisted by a tug boat. NO_x annual emissions for tug boats are taken from the Project Environmental Review (ER) as shown in Table 1. To convert these annual emissions into hourly emissions required by AERMOD, information about tug boat activities documented in the project ER are used. For tug boats, there will be 630 trips (ER August 2012 Update, page 3-18) and 9 hours for barge loading (ER August 2012 Update, page 2-12).

Table 1
Pollutant Emissions for Tug Boat at the Port of Morrow

Emission Source	NO_x (tpy)	1-hr NO_x (lb/hr)
Tug Boat	39	13.76

C. Stack Parameters

Project emissions are modeled as a point source. Stack parameters (stack height, diameter, temperature and exit velocity) for the modeled source are shown in Table 2. Emissions from the tug boat are released from a height of 20 ft (New Jersey DEP, 2009).

Table 2. Stack Parameters for Modeled Emission Sources

Source	Height (m)	Diameter (m)	Temperature (K)	Velocity (m/s)
Tug Boat	6.0	0.5	300.0	0.0

D. Receptors

The AERMOD modeling uses a Cartesian grid of discrete receptors that are located within a radius of 5 km around the Port of Morrow. The receptor grid has varying resolutions: 50 m within the first 2 km and 100 m between 2 km and 5 km. Receptors located on the leased property at Port of Morrow have been removed from consideration. A total of 16,739 receptors have been used in the AERMOD modeling for Port of Morrow. A flagpole height of 1.5 m was also assigned to the modeled receptors. The preprocessor AERMAP has been employed to obtain terrain elevations at these receptors using the National Elevation Data (NED).

E. Meteorological and Ozone Data

For Port of Morrow, the AERMOD modeling uses the 2007-2011 surface meteorological data (including 1-min ASOS wind data to minimize calm hours) from Hermiston and upper-air data from Salem. The dataset has 589 calm hours and 1,662 hours with missing data (3.79% of possible 43,824 hours). The wind rose from Hermiston in Figure 1 shows predominant winds from the southwest.

For 1-hour NO_2 modeling at Port of Morrow, the AERMOD model uses the Ozone Limiting Method (OLM) and the Plume Volume Molar Ratio Method (PVMRM). Both techniques are considered as Tier 3 by the US EPA and require hourly ozone data as input. Hourly ozone measurements at Hermiston during the same years (2007-2011) as the meteorological data are used as input to the AERMOD model.

F. Background Concentration

For comparison with the NAAQS, background concentrations at a monitoring station are added to the concentrations predicted by the AERMOD model. Monitoring data during 2007-2008 tabulated in the Oregon DEQ 2011 Air Quality Annual Report (ODEQ, 2012)

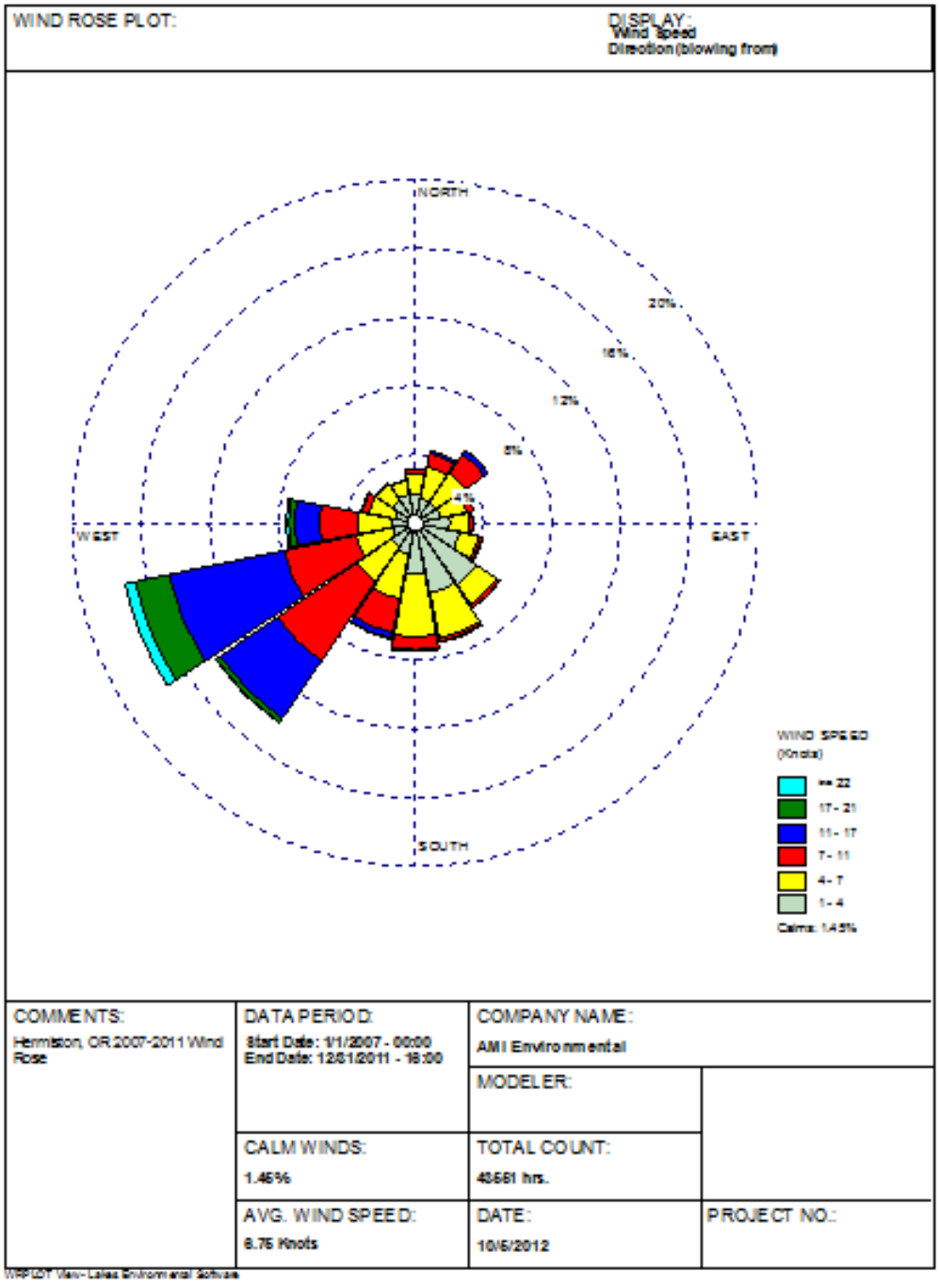
indicate that a 98th percentile of daily maximum NO_2 of 37 ppb (69.6 ug/m^3) was measured at the Hermiston municipal airport. As shown in Table 3, this NO_2 measurement is used as background concentration for modeling impacts at Port of Morrow.

While we included a background concentration to be consistent with applicable guidance, even if the background concentration was assumed to be zero, it would not affect any of the NAAQS violations discussed in this report.

Table 3. Pollutant Background Concentration (ug/m^3)

Modeled Port	1-hour NO_2
Morrow	69.6

Figure 1 – Wind Rose of Hermiston 2007-2011 Surface Winds



III. MODELING RESULTS

In January 2010, US EPA announced a new 1-hour NAAQS which is attained when the 3-year average of the 98th percentile of the daily maximum 1-hour NO_2 concentrations does not exceed 100 ppb (or 188 ug/m^3). Subsequently, US EPA issued in June 2010 a modeling guidance for using the AERMOD model with one year of onsite meteorological data or five years of offsite meteorological data (USEPA, 2010). According to the US EPA, the 8th highest maximum daily 1-hour concentration obtained with one year of onsite data or averaged over five years of offsite data should be used in the NAAQS comparison.

For 1-hour NO_2 modeling, US EPA has recommended several techniques that can be divided into three tiers:

1. Tier 1: Full conversion where the NO_x emissions are assumed to be 100% converted into NO_2,

2. Tier 2: The Tier 2 technique is known as the Ambient Ratio Method (ARM). In this technique, a default conversion rate of 0.80 recommended in the US EPA March 2011 guidance is applied to the predicted NO_x concentrations, and

3. Tier 3: Two Tier 3 techniques known as Ozone Limiting Method (OLM) and Plume Volume Molar Ratio Method (PVMRM) are currently available in the AERMOD model.

The Tier 1 and Tier 2 methods are fully approved by the US EPA. The OLM and PVMRM techniques in Tier 3 are considered to be non-regulatory defaults and their use requires the approval of US EPA and state agencies on a case by case basis (US EPA, 2011). AMI Environmental contacted ODEQ regarding the appropriate Tier 3 methodology to use in this setting. ODEQ recommended the use of both techniques (OLM and PVMRM) and, hence, they have been employed in this modeling analysis.

1-hour NO_2 impacts from NO_x emissions from a tug boat assisting barge loading at Port of Morrow have been modeled by all the above modeling techniques recommended by the US EPA: Tier 1 with full conversion; Tier 2 with 80% conversion; OLM and PVMRM in Tier 3. The Tier 3 techniques use an in-stack NO_2/NO_x ratio of 0.10 for tug boat. This ratio for tug boat is taken from source tests included in the in-stack NO_2/NO_x ratio database that has recently been setup by the US EPA OAQPS. Hourly ozone measurements at the Hermiston airport from 2007-2011 have also been used as inputs.

Three AERMOD modeling runs (Tier 1, OLM and PVMRM) have been performed with the 2007-2011 meteorological data. The tug boat is assumed to operate only during daytime hours (0600-1800). This is a conservative assumption that may understate the impacts since daytime hours typically have stronger wind and more unstable conditions

than nighttime hours. It also is conservative because it results in lower annual emissions (12 hours * 365 days * 13.76 lb/hr / 2000 lb/ton = 30.13 tpy that are lower than 39 tpy shown in Table 1).

NO_2 modeling results for the 8th highest concentrations are summarized in Appendices A-C and presented in Table 4. As shown in this table, the AERMOD model has predicted, with all modeling techniques, large exceedances of the 1-hour NAAQS of 188 ug/m^3 by project emissions alone. The highest 8th highest concentrations obtained with Tier 1 (10,753.1 ug/m^3) and Tier 2 (8,602.5 ug/m^3) are much higher than those predicted by Tier 3 techniques. The highest concentration predicted by PVMRM (1,436.4 ug/m^3) is slightly higher than that of the OLM technique (1,132.3 ug/m^3).

For Tier 1, a plot of the contour of 188 ug/m^3 is shown in Figure 2. The impacted area with concentrations exceeding 188 ug/m^3, i.e. violating the 1-hr NAAQS due to project emissions alone, has a radius of about 2 km north and west of the project site. These exceedances are also predicted within one km east and south of the project. Figure 3 shows that the area of NAAQS exceedances predicted with OLM is much smaller. As shown in Figure 4, PVMRM has predicted a much larger area of exceedances than OLM, albeit smaller than that of Tier 1.

Compared to the modeling results of the previous October 2012 study which also included train emissions, large NAAQS exceedances are primarily caused by tug boat emissions in both modeling studies. These exceedances occur near the tug boat due to its plume height which is lower than that of the train. However, the addition of train emissions increases the magnitude of the maximum impacts as well as the size of impacted areas.

Table 4. Predicted 1-Hour NO_2 Impacts of Tug Boat Operations at Port of Morrow

Modeling Method	Project Conc. (ug/m^3)	Backgr. Conc. (ug/m^3)	Total Conc. (ug/m^3)	NAAQS (ug/m^3)	Percent Over NAAQS
Tier 1 -100%	10,753.1	69.6	10,822.7	188	**5,657%**
Tier 2 - 80%	8,602.5	69.6	8,672.1	188	**4,513%**
Tier 3-OLM	1,132.3	69.6	1,201.9	188	**539%**
Tier 3-PVMRM	1,436.4	69.6	1,506.0	188	**701%**

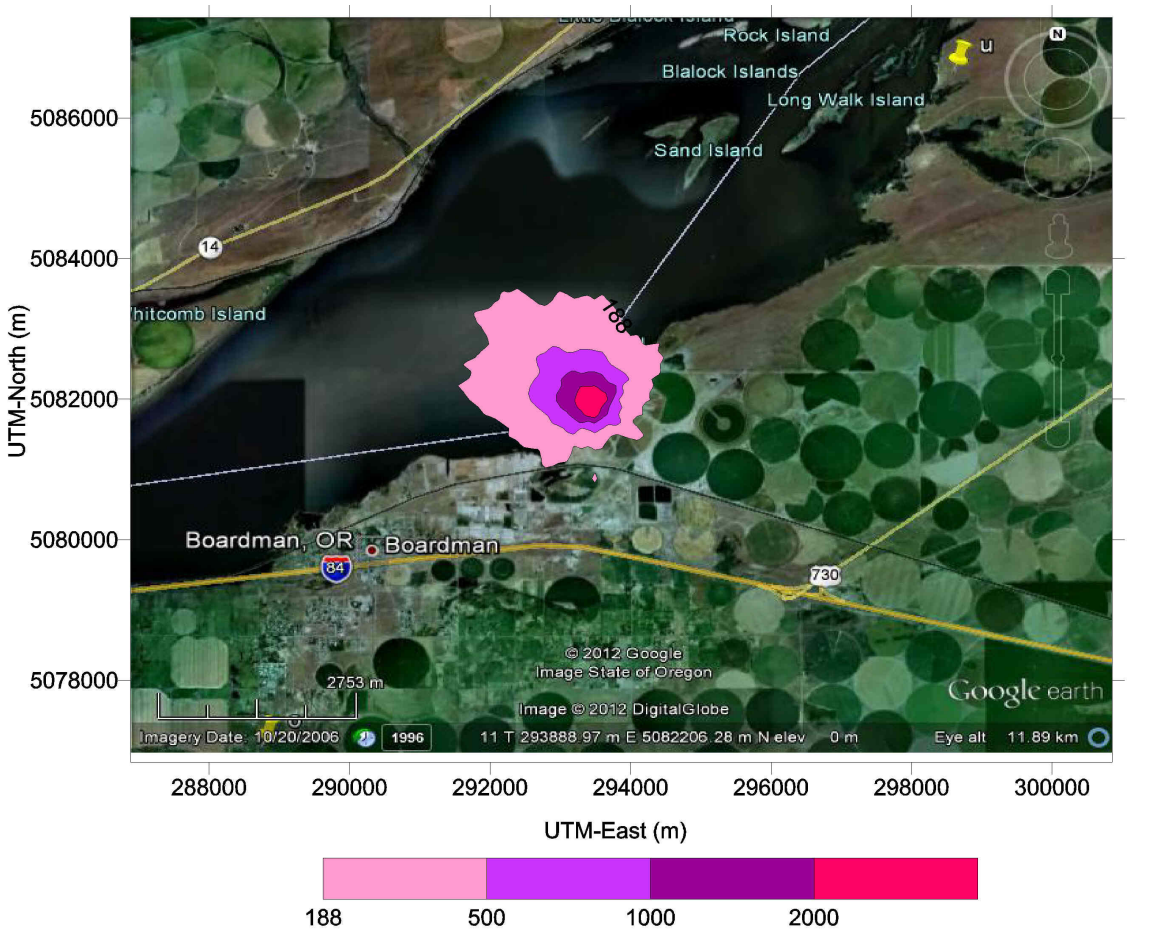


Figure 2. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 1-Full Conversion) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port of Morrow Operations Alone

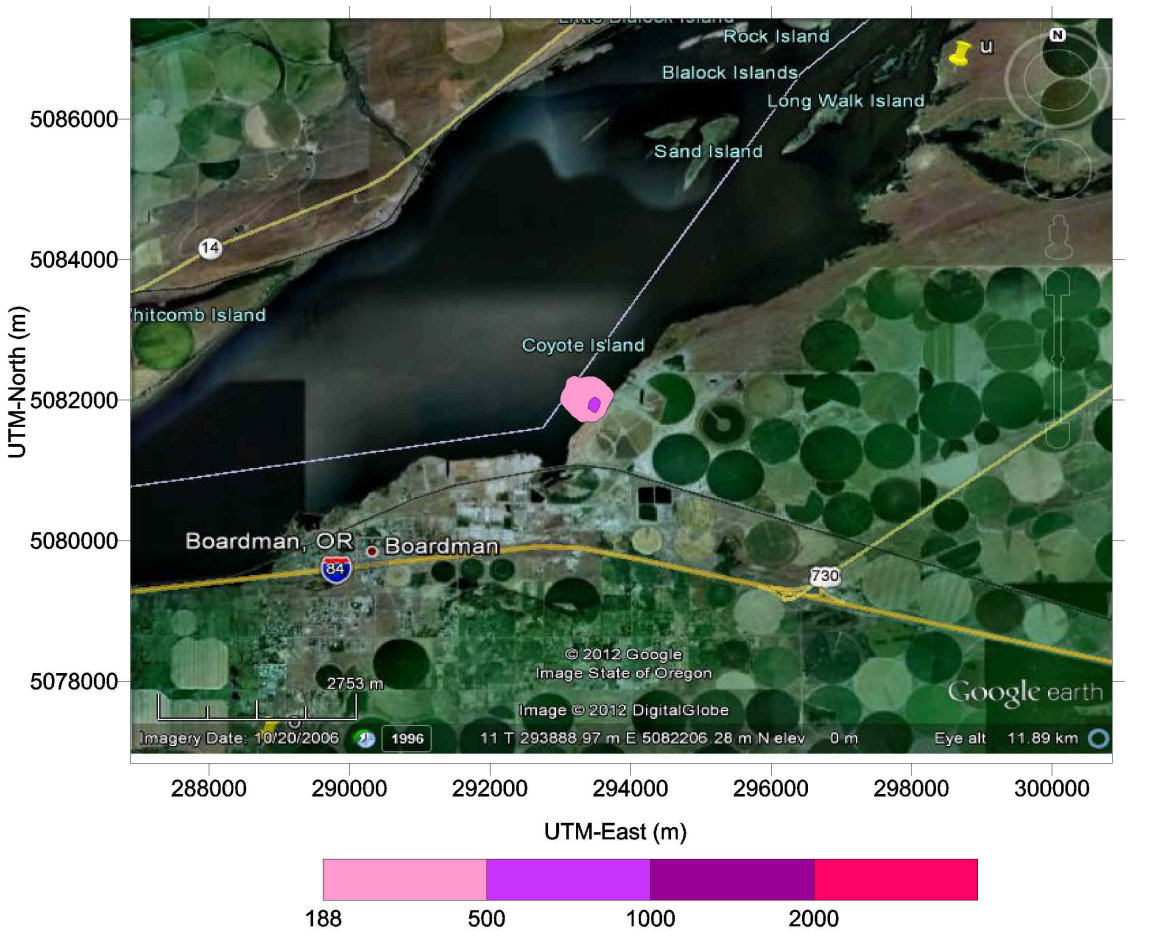


Figure 3. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 3-OLM) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port of Morrow Operations Alone

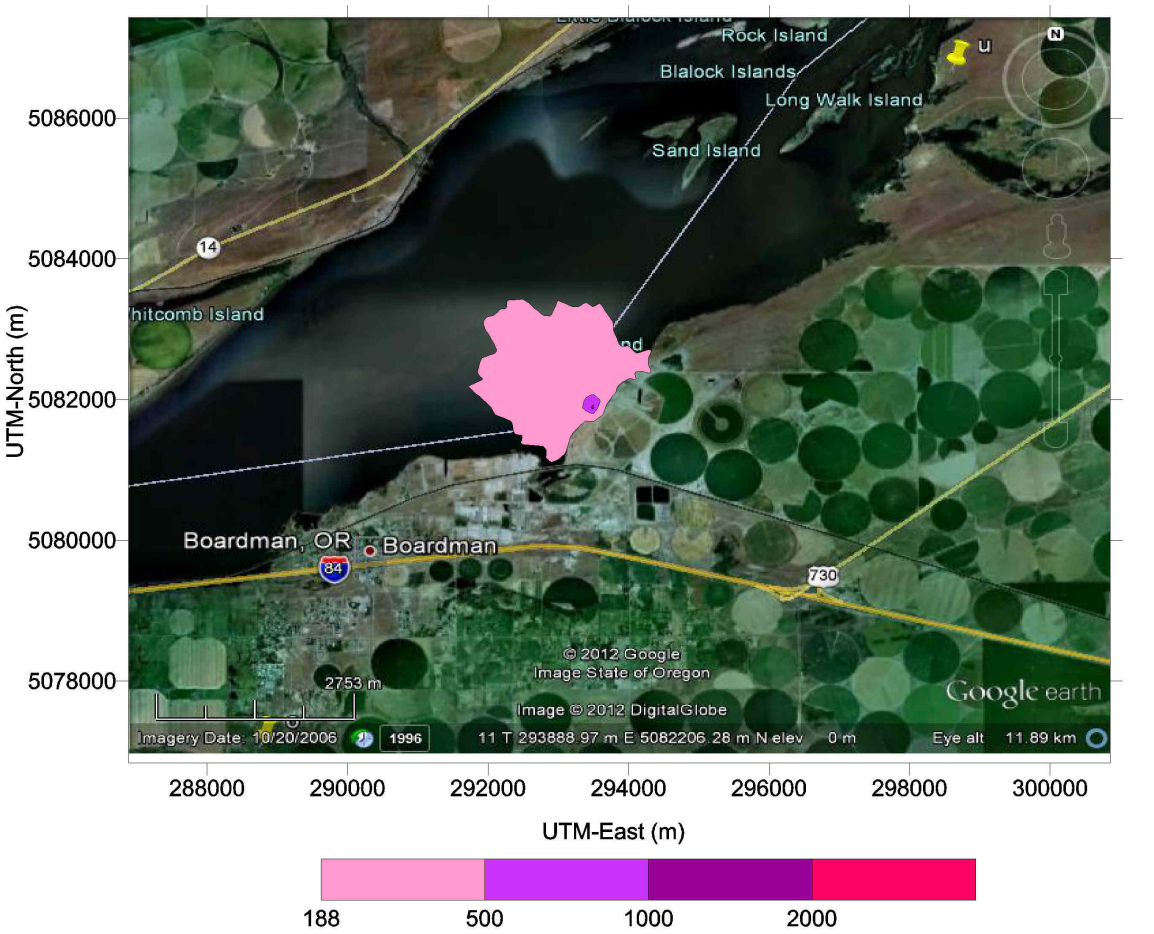


Figure 4. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 3-PVMRM) Exceeding the 1-Hour NAAQS of 188 ug/m_3 by Port of Morrow Operations Alone

IV. CONCLUSIONS

Air quality impacts of NO_x emissions from the operation of tug boats at the Port of Morrow of the Morrow Pacific Project have been analyzed with the AERMOD model. For 1-hour NO_2, modeling techniques recommended by the US EPA and known as Tier 1 (full conversion), Tier 2 (80% conversion) and Tier 3 techniques (OLM and PVMRM) have been used for modeling impacts at Port of Morrow. Using primarily project emissions documented in the project ER and the latest US EPA modeling guidance, the AERMOD model has predicted large exceedances of the NO_2 1-hour NAAQS of 188 ug/m^3 (by 5-57 times the NAAQS) at Port of Morrow. These large exceedances have been predicted to occur due to project emissions alone, i.e., without the addition of background concentrations and also in large areas around the project sites. NAAQS

exceedances will occur in both Oregon and Washington. Thus, the proposed Morrow Pacific Project will cause very adverse 1-hour NO_2 impacts in both Oregon and Washington.

The AERMOD modeling files, including input/output files, meteorological data, ozone data and model executable, have been uploaded to box.com and are available from the folder: https://www.box.com/s/wc4gyjd9zakt1lceq6v5

V. REFERENCES

AMI Environmental, 2012. *AERMOD Modeling of Air Quality Impacts of the Proposed Morrow Pacific Project*. Prepared in October 2012 for Sierra Club, San Francisco.

New Jersey DEP, 2009. *Estimated Air Quality Impacts on Surrounding Communities of $PM_{2.5}$ and SO_2 Emissions Resulting from Marine Operations at Elizabeth Port Authority Marine Terminal and Port Newark*. Available at http://www.state.nj.us/dep/stopthesoot/Port%20risk%20Summary-final%2010-9-09.pdf

Oregon DEQ, 2012. 2011 Oregon Air Quality Data Summaries. Available at: http://www.deq.state.or.us/aq/forms/2011AirQualityAnnualReport.pdf

U.S. EPA, 2012. Addendum to User's Guide of the AMS/EPA Regulatory Model AERMOD version 12060, February 2012. Available at: http://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip

U.S. EPA, 2011. *Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS*. Memorandum issued on March 1st, 2011 from Tyler Fox, Leader of Air Quality Modeling Group, OAQPS. Available at http://www.epa.gov/region7/air/nsr/nsrmemos/appwNO2_2.pdf

U.S. EPA, 2010a. *Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS*. Memorandum issued on June 28, 2010 from Tyler Fox, Leader of Air Quality Modeling Group, OAQPS. Available at http://www.epa.gov/ttn/scram/guidance/clarification/ClarificationMemo_AppendixW_Hourly-NO2-NAAQS_FINAL_06-28-2010.pdf

Appendix A

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Tug Boat Emissions at the Port of Morrow

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	10753.06256 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	2ND HIGHEST VALUE IS	8619.07615 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	3RD HIGHEST VALUE IS	8426.72946 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	4TH HIGHEST VALUE IS	6129.71738 AT (293495.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	5TH HIGHEST VALUE IS	5407.10366 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	6TH HIGHEST VALUE IS	5407.10366 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	7TH HIGHEST VALUE IS	5058.33679 AT (293445.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	8TH HIGHEST VALUE IS	5057.32734 AT (293436.00, 5081947.00, 81.42, 81.42, 1.50)	DC
	9TH HIGHEST VALUE IS	4488.52974 AT (293545.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	10TH HIGHEST VALUE IS	4455.88593 AT (293495.00, 5082033.00, 81.42, 81.42, 1.50)	DC

Appendix B

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-OLM) of Tug Boat Emissions at the Port of Morrow

**MODELOPTs: NonDFAULT CONC ELEV FLGPOL OLM

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	1132.25427	(293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	2ND HIGHEST VALUE IS	929.52762	(293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	3RD HIGHEST VALUE IS	895.20415	(293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	4TH HIGHEST VALUE IS	684.53081	(293495.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	5TH HIGHEST VALUE IS	614.34103	(293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	6TH HIGHEST VALUE IS	614.34103	(293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	7TH HIGHEST VALUE IS	582.73616	(293445.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	8TH HIGHEST VALUE IS	581.83077	(293436.00, 5081947.00, 81.42, 81.42, 1.50)	DC
	9TH HIGHEST VALUE IS	520.72193	(293495.00, 5082033.00, 81.42, 81.42, 1.50)	DC
	10TH HIGHEST VALUE IS	519.30665	(293545.00, 5081983.00, 81.42, 81.42, 1.50)	DC

Appendix C

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-PVMRM) of Tug Boat Emissions at the Port of Morrow

**MODELOPTs: NonDFAULT CONC ELEV FLGPOL PVMRM

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG) OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	1436.42076 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50) DC
	2ND HIGHEST VALUE IS	1273.84137 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50) DC
	3RD HIGHEST VALUE IS	1137.13397 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50) DC
	4TH HIGHEST VALUE IS	854.17325 AT (293495.00, 5081983.00, 81.42, 81.42, 1.50) DC
	5TH HIGHEST VALUE IS	755.39301 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50) DC
	6TH HIGHEST VALUE IS	755.39301 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50) DC
	7TH HIGHEST VALUE IS	739.41167 AT (293436.00, 5081947.00, 81.42, 81.42, 1.50) DC
	8TH HIGHEST VALUE IS	699.35336 AT (293445.00, 5081983.00, 81.42, 81.42, 1.50) DC
	9TH HIGHEST VALUE IS	644.53467 AT (293545.00, 5081983.00, 81.42, 81.42, 1.50) DC
	10TH HIGHEST VALUE IS	638.88375 AT (293545.00, 5081883.00, 86.36, 87.14, 1.50) DC

EXHIBIT 3

AERMOD Modeling of Air Quality Impacts of the Proposed Morrow Pacific Project

Final Report

October 2012

Prepared for

Ms. Jessica Loarie
SIERRA CLUB
San Francisco, California

Prepared by
Mr. Khanh T. Tran
Principal

AMI Environmental
206 Black Eagle Ave
Henderson, NV 89002
Tel. (714)679-7363

Table of Contents

		Page
I.	**Introduction**	4
II.	**Modeling Methodologies**	4
	A. Model Version	4
	B. Source Emissions	4
	C. Stack Parameters	6
	D. Receptors	6
	E. Meteorological and Ozone Data	7
	F. Background Concentrations	7
III.	**Modeling Results**	11
	A. 1-hour NO_2 Impacts	11
	B. 1-hour SO_2 Impacts	18
	C. 24-hour $PM_{2.5}$ Impacts	19
	D. Annual NO_2 Impacts	22
	E. Nitrogen Deposition Impacts	24
IV.	**Conclusions**	27
V.	**References**	28

Appendix A - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port of Morrow Operations

Appendix B - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-OLM) of Port of Morrow Operations

Appendix C - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-PVMRM) of Port of Morrow Operations

Appendix D - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port Westward Operations with Transloader using Emergency Power

Appendix E - Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port Westward Operations with Transloader using Shore Power

Appendix F - Summary of AERMOD-Predicted 1-hour SO_2 Impacts of Port of Morrow Operations with Ultra Low Sulfur Fuel

Table of Contents (continued)

Appendix G - Summary of AERMOD-Predicted 1-hour SO_2 Impacts of Port Westward Operations with Ultra Low Sulfur Fuel

Appendix H - Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Enclosed Barges and Trains

Appendix I - Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Open Barges and Closed Trains

Appendix J - Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Closed Barges and Open Trains

Appendix K - Summary of AERMOD-Predicted Annual NO_2 Impacts of Port of Morrow Operations

Appendix M - Summary of AERMOD-Predicted NO_2 Deposition Impacts of Port of Morrow Operations

I. INTRODUCTION

This document presents the methodologies and results of a modeling analysis of air quality impacts of the proposed Morrow Pacific Project (MPP) in Oregon. The MPP includes three operating stages. In the first stage, coal will be offloaded from trains at the Port of Morrow via enclosed facilities into enclosed storage buildings and transferred into enclosed barges by enclosed conveyors. In the second stage, coal will be shipped down the Columbia River by enclosed barges to Port Westward in Columbia County. The MPP third stage involves the coal transloading from barges into ocean-going vessels (OGV). An Environmental Review (ER) and an air pollution permit application have been prepared for the MPP. However, no dispersion modeling has been performed in these documents to quantify the project impacts. Hence, AMI Environmental has been asked by Sierra Club to conduct an air quality modeling analysis using the regulatory dispersion model AERMOD to predict project impacts of criteria pollutants, such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and fine particulates ($PM_{2.5}$). Project impacts are compared against applicable national ambient air quality standards (NAAQS).

II. MODELING METHODOLOGIES

This section documents the methodologies and assumptions used in the generation of modeling inputs such as source emissions, stack parameters, receptors, meteorological data and background concentrations.

A. Model Version

Version 12060 of the AERMOD model has been used in the modeling study. It is currently the latest version of the model that has been approved by the U.S. Environmental Protection Agency (USEPA, 2012). The most recent modeling guidance by US EPA has been implemented in the AERMOD model and it is fully capable of predicting project impacts for comparison against recent short-term NAAQS, e.g. the 1-hour NO_2 NAAQS of 100 ppb (188 ug/m^3), the 1-hour SO_2 NAAQS of 75 ppb (196 ug/m^3 and the 24-hour $PM_{2.5}$ NAAQS of 35 ug/m^3 as well as the annual NO_2 NAAQS of 53ppb (100 ug/m^3).

B. Source Emissions

Two basic scenarios are considered for modeling by the AERMOD model. In the first scenario, coal is unloading from trains while barges are loading at the dock in Port of Morrow. The second scenario involves coal loading at Port Westward onto a Panamax while the transloader is testing the emergency generator and a tug boat assisting the barge unloading operation. For both scenarios, AERMOD modeling has been performed for 1-hour and annual NO_2 and SO_2. $PM_{2.5}$ impacts are only modeled for the first scenario.

Pollutant annual emissions for all modeled sources are taken from the Project ER. Table 1 shows total annual emissions for each pollutant (NO_x, SO_2 and $PM_{2.5}$) at Port of Morrow. To convert these annual emissions into hourly emissions required by AERMOD, information about train and tug boat activities documented in the project ER are used. For trains, there will be 607 trains per year and 12 hours for train unloading. For tug boats, there will be 630 trips and 9 hours for barge loading. The storage facility is assumed to be a continuous source (365 days, 24 hours per day).

Table 1 also shows the $PM_{2.5}$ emissions from wind erosion of coal on open barges and open trains (railcars). The project ER states that the four-barge tow is 650 ft long by 84 ft wide, resulting in an exposed surface area of A=1.256 acre. Using the emission factor in Table 11.9-1 of AP-42 for wind erosion from coal piles, wind erosion emissions of open barges can be estimated from:

$$PM_{2.5} \text{ of open barge (lb/hr)} = 0.72*u*A*F = 4.341 \text{ lb/hr}$$

where u is the wind speed (=2*32 where 32 mph is the highest daily wind speed averaged over daytime hours at Hermiston during 2007-2011 and the factor 2 is to account for wind gust),
A is the exposed surface area (=1.256 acre)
F is the fraction of $PM_{2.5}$ (=0.075 from AP-42 Section 13.2.5.3)

The length of a unit train is 5,800 ft (ER p. 2-6) and it has a width of 9.5 ft. Its exposed surface area is calculated to be A = 1.26 acre. Windblown dust emissions from railcars of a unit train are then estimated using the same AP-42 formula above (Phyllis Fox, Train Staging, Oct. 28, 2012):

$$PM_{2.5} \text{ of open train (lb/hr)} = 0.72*64*1.26*0.075 = 4.35 \text{ lb/hr}$$

Table 1
Pollutant Emissions for Modeled Sources at Port of Morrow

Emission Sources	NO_x (tpy)	1-hr NO_x (lb/hr)	SO_2 (tpy)	1-hr SO_2 (lb/hr)	$PM_{2.5}$ (tpy)	24-hr $PM_{2.5}$ (lb/hr)
Train unloading	492	135.09	0.3	0.824	12.8	3.51
Tug boat	39	13.76	0.0088	0.0031	0.92	0.32
Storage facility	--	--	--	--	0.012	0.0027
Open barge	--	--	--	--	--	4.341
Open train	--	--	--	--	--	4.35

Table 2 shows the modeled sources and emissions at Port Westward. Total annual emissions have been taken from the project ER. For converting these annual emissions into hourly emission rates, all modeled sources are assumed to operate continuously (365 days, 24 hours per day) as stated in the project ER.

Table 2
Pollutant Emissions for Modeled Sources at Port Westward

Emission Sources	NO_x (tpy)	1-hr NO_x (lb/hr)	SO_2 (tpy)	1-hr SO_2 (lb/hr)
Panamax	81.5	18.61	14.7	3.36
Transloader (emergency power)	281	64.16	0.048	0.011
Transloader (shore power)	0.33	0.0753	7.9e-5	1.80e-5
Tug boat	32	7.31	0.0042	0.00096

B. Stack Parameters

Project emissions are modeled as point sources. Stack parameters (stack height, diameter, temperature and exit velocity) for the modeled sources are shown in Table 3. They are taken from the modeling studies of port operations conducted by the California Air Resources Board (CARB, 2006) and New Jersey Department of Environmental Protection (NJDEP, 2009). Emissions from tug boats and barges are released from a height of 20 ft. Windblown dust emissions from railcars are modeled as area source with a release height of 16 ft (CARB, 2006).

Table 3. Stack Parameters for Modeled Emission Sources

Source	Height (m)	Diameter (m)	Temperature (K)	Velocity (m/s)
Train engine	4.572	0.61	372.0	3.47
Tug Boat	6.0	0.5	300.0	0.0
Barge	6.0	0.5	300.0	0.0
Open train	5.0	--	--	-
Panamax	43.0	0.50	618.0	16.0
Generator	35.97	0.47	699.82	30.0

Note: Emissions from open trains are modeled as area source

C. Receptors

The AERMOD modeling uses a Cartesian grid of discrete receptors that are located within a radius of 5 km around the ports of Morrow and Westward. The receptor grid has varying resolutions: 50 m within the first 2 km and 100 m between 2 km and 5 km. Receptors located on the leased property at Port of Morrow have been removed from consideration. A total of 16,739 receptors have been used in the AERMOD modeling for Port of Morrow. The modeling at Port Westward has 16,762 receptors. A flagpole height of 1.5 m was also assigned to the modeled receptors. The preprocessor AERMAP has been employed to obtain terrain elevations at these receptors using the National Elevation Data (NED).

D. Meteorological and Ozone Data

For Port of Morrow, the AERMOD modeling uses the 2007-2011 surface meteorological data (including 1-min ASOS wind data to minimize calm hours) from Hermiston and upper-air data from Salem. The dataset has 589 calm hours and 1,662 hours with missing data (3.79% of possible 43,824 hours). The wind rose from Hermiston in Figure 1 shows predominant winds from the southwest.

The modeling for Port Westward uses the 2006-2010 surface data (including 1-min ASOS wind data) from Astoria and upper-air data from Salem. This dataset has 523 calm hours and 1,554 hours with missing data (3.55% of possible 43,824 hours). The wind rose of Astoria surface winds is shown in Figure 2. Wind directions at this station are highly variable, from east to northwest.

For 1-hour NO_2 modeling at Port of Morrow, the AERMOD model uses the Ozone Limiting Method (OLM) and the Plume Volume Molar Ratio Method (PVMRM). Both techniques are considered as Tier 3 by the US EPA and require hourly ozone data as input. Hourly ozone measurements at Hermiston during the same years (2007-2011) as the meteorological data are used as input to the AERMOD model.

E. Background Concentrations

For comparison with the NAAQS, background concentrations at a monitoring station are added to the concentrations predicted by the AERMOD model. Monitoring data during 2007-2008 tabulated in the Oregon DEQ 2011 Air Quality Annual Report (ODEQ, 2012) indicate that a 98th percentile of daily maximum NO_2 of 37 ppb (69.6 ug/m^3) and a 99th percentile of daily maximum SO_2 of 9 ppb (23.5 ug/m^3) were measured at the Hermiston municipal airport. Monitoring data in 2007 at the Hermiston pump station show a 98th percentile of daily maximum $PM_{2.5}$ of 24 ug/m^3. An annual-averaged NO_2 concentration of 8 ppb (15.0 ug/m^3) was also measured at the Hermiston airport. These pollutant

measurements are used as background concentrations for modeling impacts at Port of Morrow.

For modeling at Port Westward, the background concentrations are: 35.3 ppb (66.4 ug/m^3) recorded in Portland as the 2009-2011 average of the 98th percentile of daily maximum 1-hour NO_2 and 8.7 ppb (22.8 ug/m^3) recorded in Portland as the 2009-2011 average of the 99th percentile of daily maximum 1-hour SO_2. For 24-hour $PM_{2.5}$, the 2009-2011 design value of 20 ug/m^3 for the Dalles monitoring station is used as background. Background concentrations used in the modeling are shown Table 4 below.

While we included background concentrations to be consistent with applicable guidance, even if the background concentrations were all assumed to be zero, it would not affect any of the NAAQS violations discussed in this report.

Table 4. Pollutant Background Concentrations (ug/m^3)

Modeled Port	1-hour NO_2	1-hour SO_2	24-hour $PM_{2.5}$	Annual NO_2
Morrow	69.6	23.5	24.0	15.0
Westward	66.4	22.8	20.0	--

Figure 1 – Wind Rose of Hermiston 2007-2011 Surface Winds

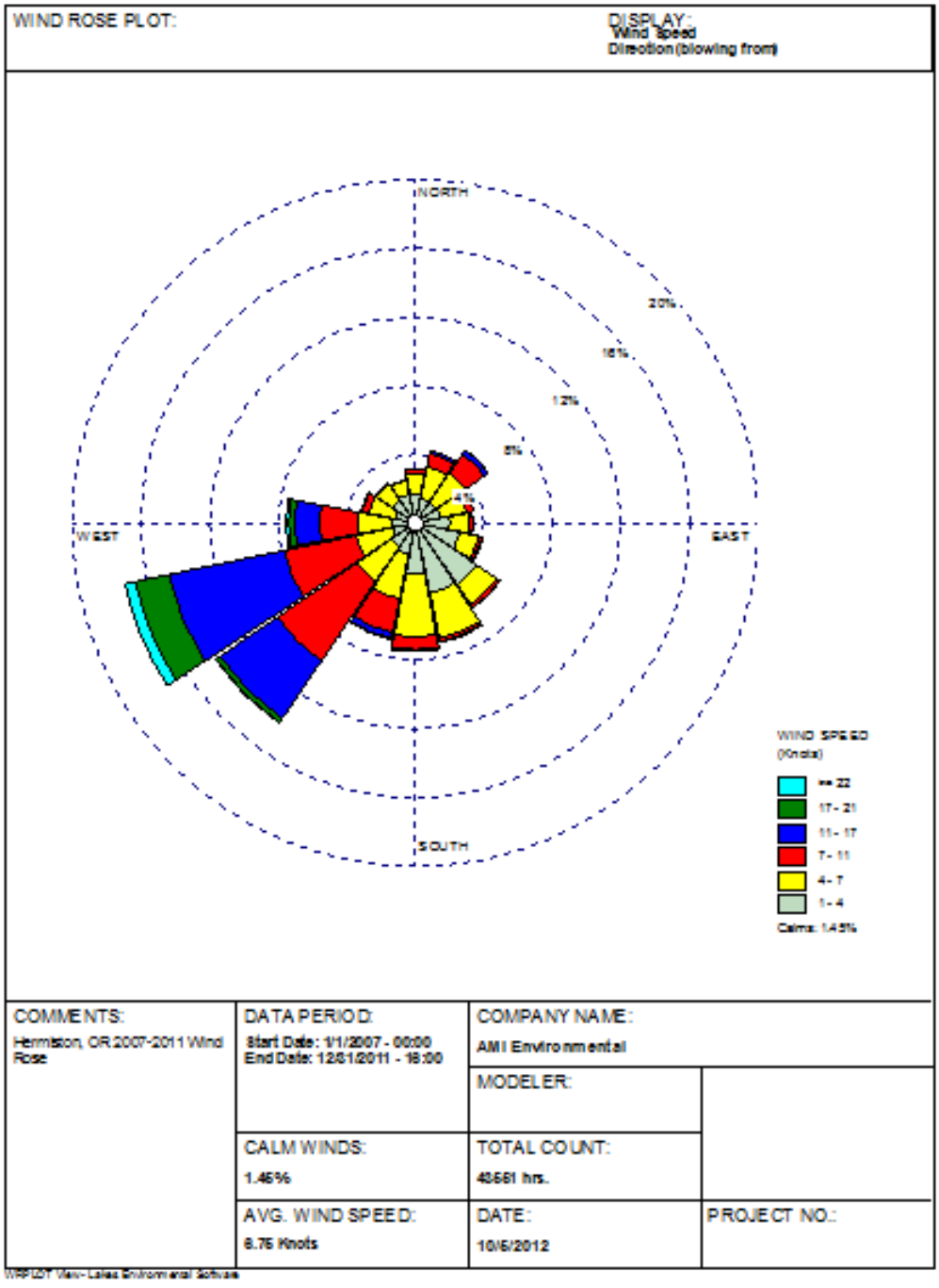
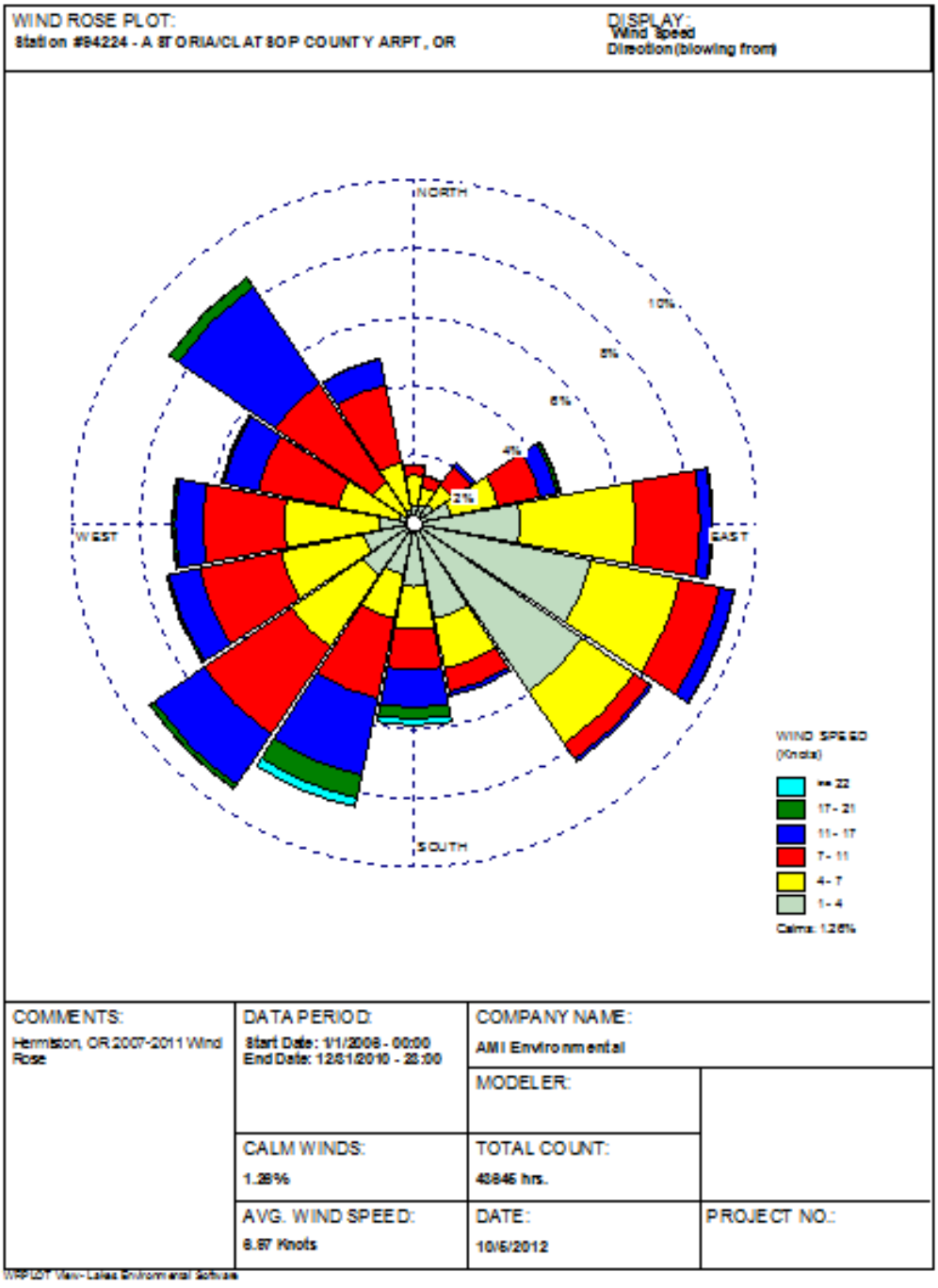


Figure 2 – Wind Rose of Astoria 2006-2010 Surface Winds



III. MODELING RESULTS

A. 1-Hour NO_2 Impacts

In January 2010, US EPA announced a new 1-hour NAAQS which is attained when the 3-year average of the 98th percentile of the daily maximum 1-hour NO_2 concentrations does not exceed 100 ppb (or 188 ug/m^3). Subsequently, US EPA issued in June 2010 a modeling guidance for using the AERMOD model with one year of onsite meteorological data or five years of offsite meteorological data (USEPA, 2010). According to the US EPA, the 8th highest maximum daily 1-hour concentration obtained with one year of onsite data or averaged over five years of offsite data should be used in the NAAQS comparison.

For 1-hour NO_2 modeling, US EPA has recommended several techniques that can be divided into three tiers:

1. Tier 1: Full conversion where the NOx emissions are assumed to be 100% converted into NO_2,

2. Tier 2: The Tier 2 technique is known as the Ambient Ratio Method (ARM). In this technique, a default conversion rate of 0.80 recommended in the US EPA March 2011 guidance is applied to the predicted NO_x concentrations, and

3. Tier 3: Two Tier 3 techniques known as Ozone Limiting Method (OLM) and Plume Volume Molar Ratio Method (PVMRM) are currently available in the AERMOD model.

The Tier 1 and Tier 2 methods are fully approved by the US EPA. The OLM and PVMRM techniques in Tier 3 are considered to be non-regulatory defaults and their use requires the approval of US EPA and state agencies on a case by case basis (US EPA, 2011). AMI Environmental contacted ODEQ regarding the appropriate Tier 3 methodology to use in this setting. ODEQ recommended the use of both techniques (OLM and PVMRM) and, hence, they have been employed in this modeling analysis.

A.1 Impacts of Port of Morrow Operations

1-hour NO_2 impacts from NO_x emissions from train unloading and a tug boat assisting barge loading at Port of Morrow have been modeled by all the above modeling techniques recommended by the US EPA: Tier 1 with full conversion; Tier 2 with 80% conversion; OLM and PVMRM in Tier 3. The Tier 3 techniques use in-stack NO_2/NO_x ratios of 0.15 for locomotive and 0.10 for tug boat. The in-stack ratio for locomotive is obtained from source tests conducted by Southwest Research Institute (Fritz, 2007). The ratio for tug boat is taken from source tests included in the in-stack NO_2/NO_x ratio

database that has recently been setup by the US EPA OAQPS. Hourly ozone measurements at the Hermiston airport from 2007-2011 have also been used as inputs.

Three AERMOD modeling runs (Tier 1, OLM and PVMRM) have been performed with the 2007-2011 meteorological data. Both the train and the tug boat are assumed to operate only during daytime hours (0600-1800). This is a conservative assumption that may understate the impacts since daytime hours typically have stronger wind and more unstable conditions than nighttime hours.

NO_2 modeling results for the 8th highest concentrations are summarized in Appendices A-C and presented in Table 5. As shown in this table, the AERMOD model has predicted, with all modeling techniques, large exceedances of the 1-hour NAAQS of 188 ug/m^3 by project emissions alone. The highest 8th highest concentrations obtained with Tier 1 (12,000.4 ug/m^3) and Tier 2 (9,600.3 ug/m^3) are much higher than those predicted by Tier 3 techniques. The highest concentration predicted by PVMRM (2,064.3 ug/m^3) is slightly higher than that of the OLM technique (1,872.6 ug/m^3).

For Tier 1, a plot of the contour of 188 ug/m^3 is shown in Figure 3. The area with concentrations exceeding 188 ug/m^3, i.e., violating the 1-hr NAAQS due to project emissions alone, has a radius of about 5 km north and west of the project site. These exceedances are also predicted within 3 km east and south of the project. Figure 4 shows that the area of NAAQS exceedances predicted with OLM is much smaller. PVMRM has predicted a much larger area of exceedances than OLM, albeit smaller than that of Tier 1.

Table 5. Predicted 1-Hour NO_2 Impacts of Port of Morrow Operations

Modeling Method	Project Conc. (ug/m^3)	Backgr. Conc. (ug/m^3)	Total Conc. (ug/m^3)	NAAQS (ug/m^3)	Percent Over NAAQS
Tier 1 -100%	12,000.4	69.6	12,070.0	188	**6,320%**
Tier 2 - 80%	9,600.3	69.6	9,669.9	188	**5,044%**
Tier 3-OLM	1,872.6	69.6	1,942.2	188	**933%**
Tier 3-PVMRM	2,064.3	69.6	2,133.9	188	**1,035%**

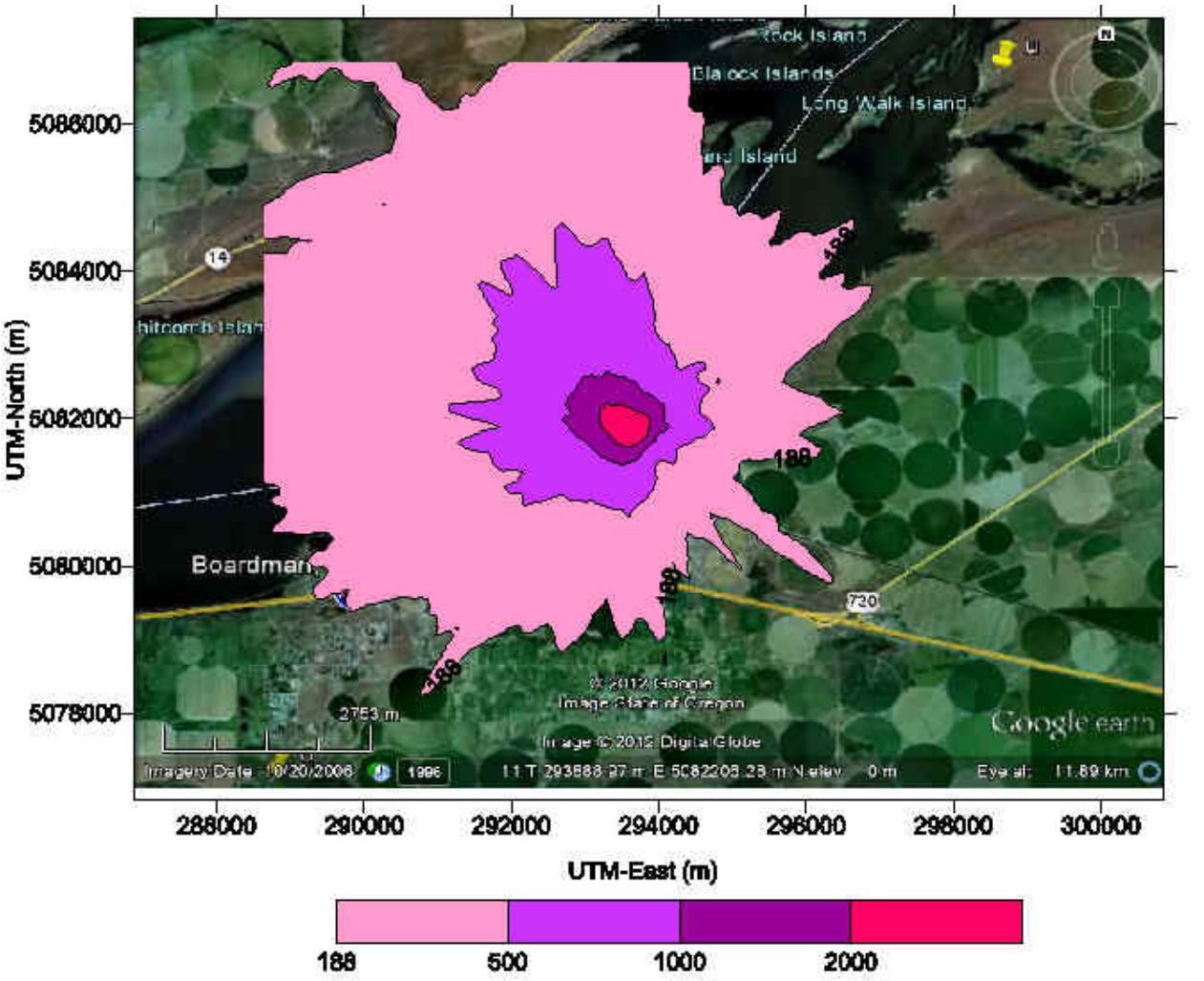


Figure 3. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 1-Full Conversion) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port of Morrow Operations Alone

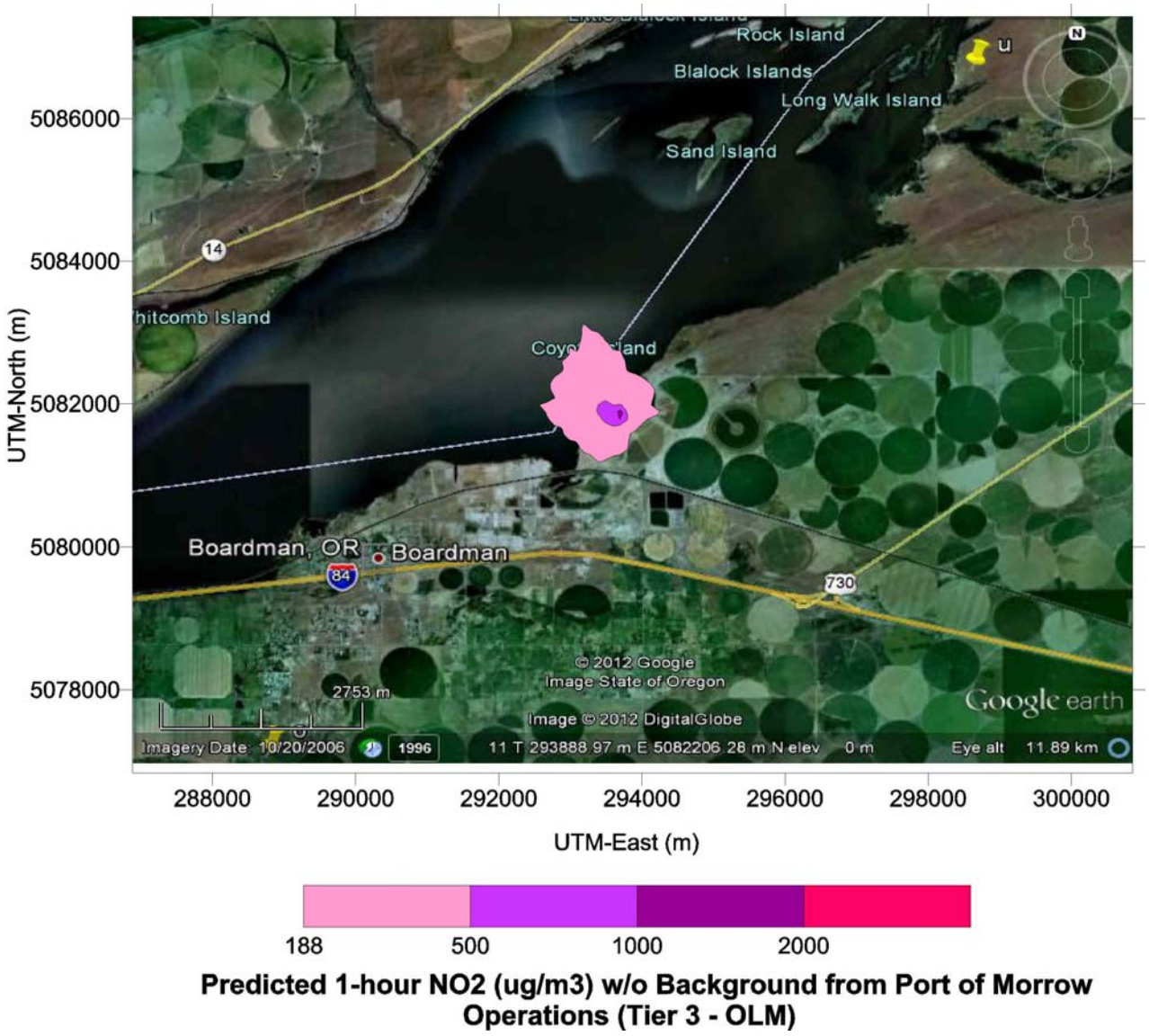


Figure 4. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 3-OLM) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port of Morrow Operations Alone

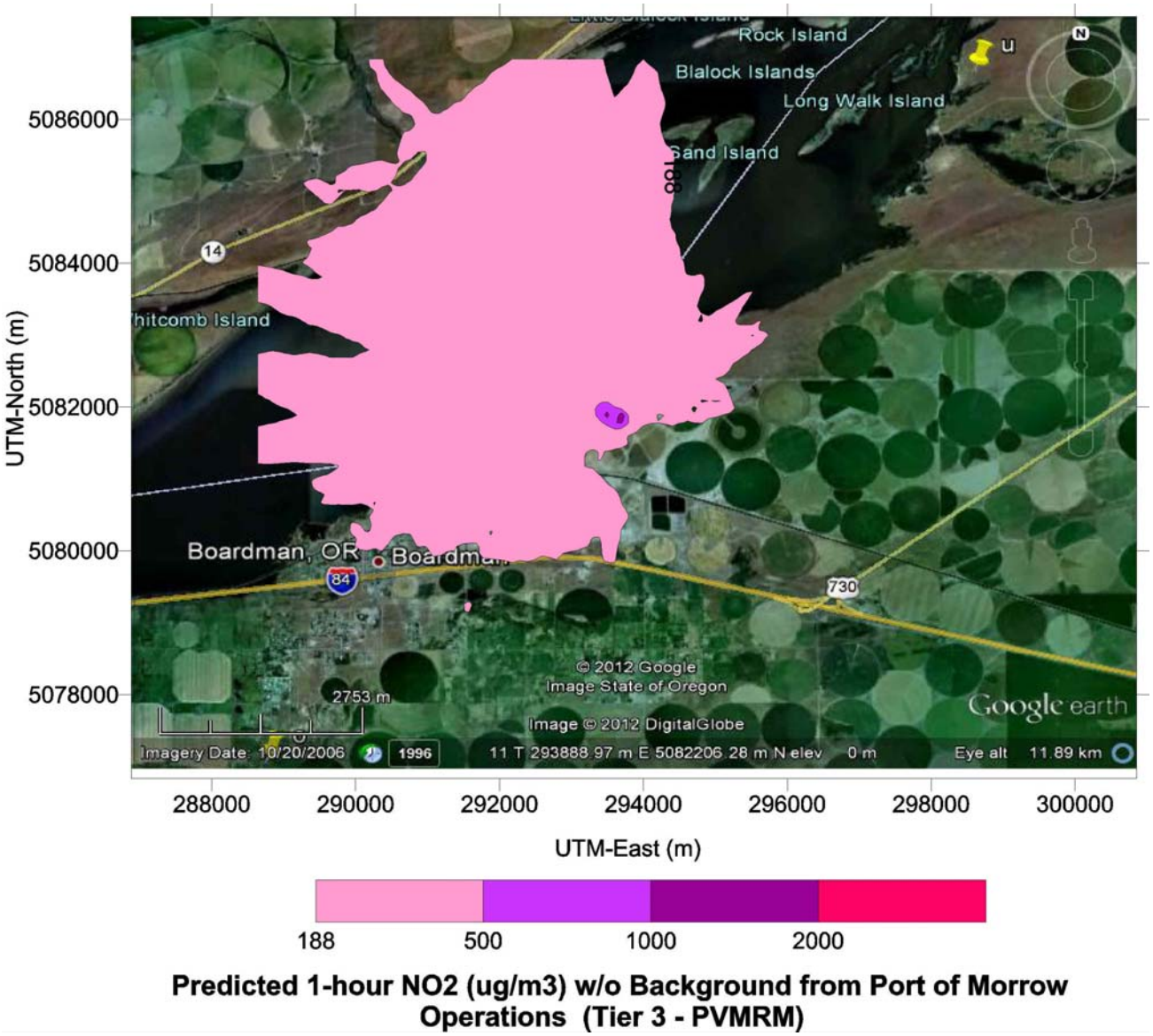


Figure 5. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 3-PVMRM) Exceeding the 1-Hour NAAQS of 188 ug/m_3 by Port of Morrow Operations Alone

A.2 Impacts of Port Westward Operations

1-hour NO_2 impacts from NOx emissions from the OGV Panamax loading, the transloader operating on emergency power and a tug boat assisting the barge unloading at Port Westward have been modeled by Tier 1 with full conversion and Tier 2 with 80% conversion. No Tier 3 technique, OLM or PVMRM, has been performed since Astoria does not have hourly ozone measurements publicly available. Modeling results are summarized in Appendix D. As shown in this Appendix and Table 6, the highest 8th

highest concentrations of from project emissions alone (4,670 ug/m^3 for Tier 1 and 3,736 ug/m^3 for Tier 2) largely exceed the NAAQS of 188 ug/m^3. With the added background of 66.4 ug/m^3, the NAAQS is predicted to be exceeded by 2,419% (Tier 1) and 1,923% (Tier 2).

Another AERMOD run has been performed where the transloader is operating on shore power. As shown in Appendix E and Table 7 below, the highest 8th highest NO_2 of 4,670 ug/m^3 is the same as in the previous modeling scenario with the transloader operating on emergency power. Thus, the NAAQS is predicted to be largely exceeded by 2,419% (Tier 1) and 1,923% (Tier 2) for both modeling scenarios.

The areas of NAAQS exceedances are shown in Figure 6 for the scenario with emergency power and Figure 7 for the scenario with shore power. Comparing these two figures shows that the area of exceedances of the former scenario is larger than that of the latter. Due to the emissions of the emergency generator, the area of exceedances extends about 3 km northwest of the project site.

Table 6. Predicted 1-Hour NO_2 Impacts of Port Westward Operations With Transloader on Emergency Power

Modeling Method	Project Conc. (ug/m^3)	Backgr. Conc. (ug/m^3)	Total Conc. (ug/m^3)	NAAQS (ug/m^3)	Percent Over NAAQS
Tier 1 -100%	4,670.0	66.4	4,736.4	188	**2,419%**
Tier 2 - 80%	3,736.0	66.4	3,802.4	188	**1,923%**

Table 7. Predicted 1-Hour NO_2 Impacts of Port Westward Operations With Transloader on Shore Power

Modeling Method	Project Conc. (ug/m^3)	Backgr. Conc. (ug/m^3)	Total Conc. (ug/m^3)	NAAQS (ug/m^3)	Percent Over NAAQS
Tier 1 -100%	4,670.0	66.4	4,736.4	188	**2,419%**
Tier 2 - 80%	3,736.0	66.4	3,802.4	188	**1,923%**

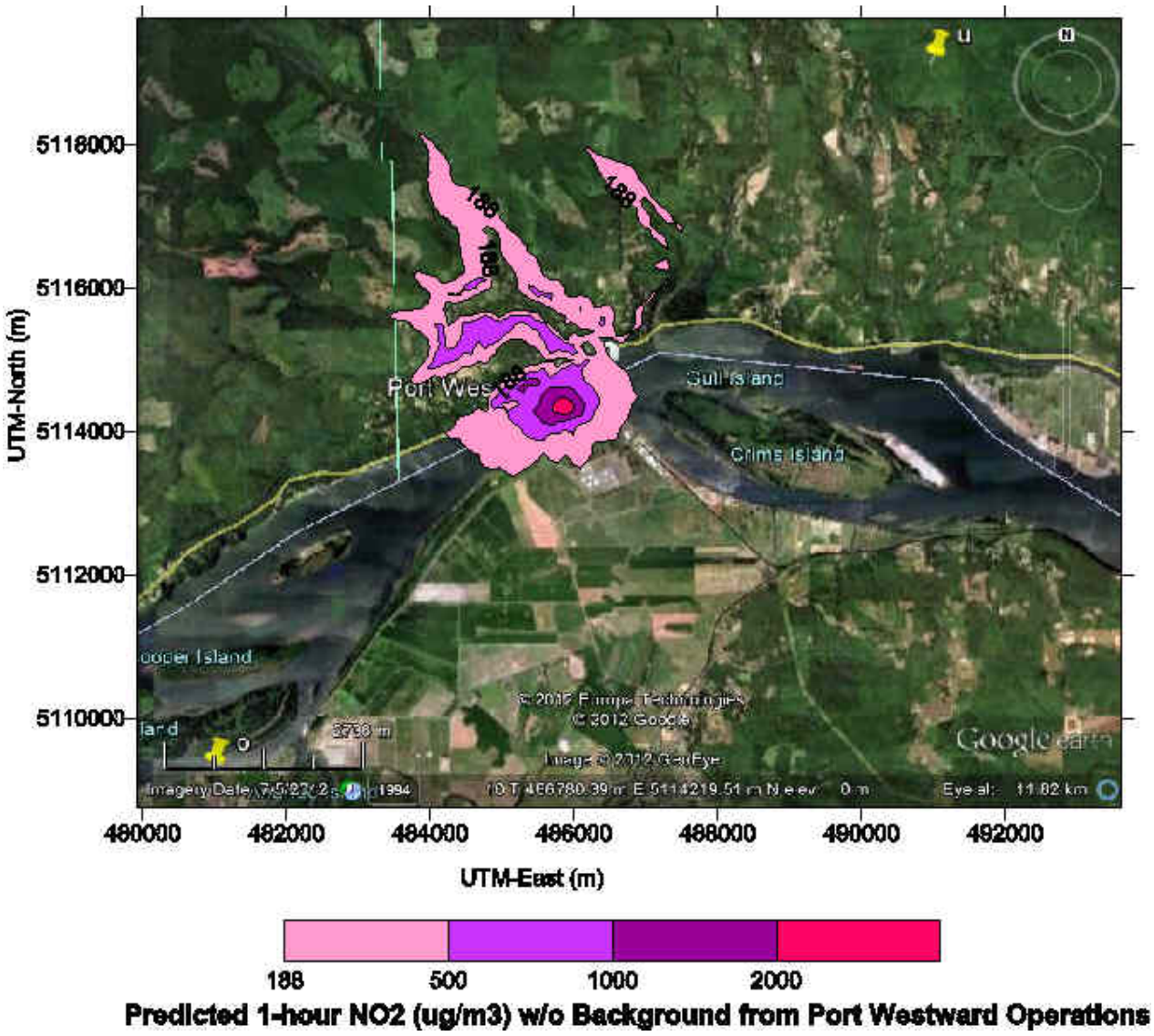


Figure 6. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 1-Full Conversion) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port Westward Operations Alone (with Transloader on Emergency Power)

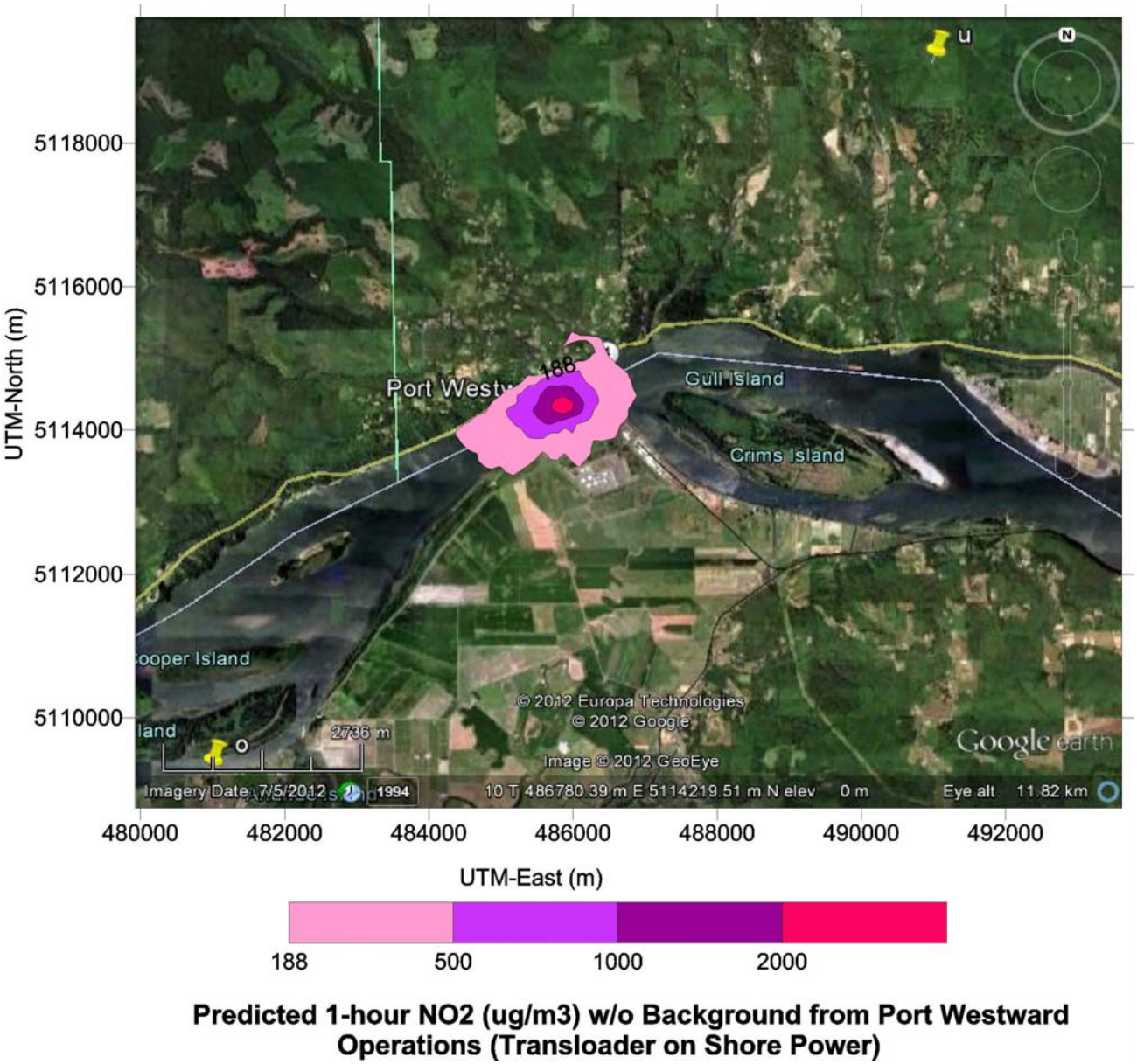


Figure 7. Area with Highest 8th Highest 1-hour NO_2 Concentrations (Tier 1-Full Conversion) Exceeding the 1-Hour NAAQS of 188 ug/m^3 by Port Westward Operations Alone (with Transloader on Shore Power)

B. 1-Hour SO_2 Impacts

In June 2010, US EPA announced a new 1-hour NAAQS which is attained when the 3-year average of the 99th percentile of the daily maximum 1-hour SO_2 concentrations does not exceed 75 ppb (or 196 ug/m^3). Subsequently, US EPA issued in August 2010 a modeling guidance for using the AERMOD model with one year or five years of meteorological data (USEPA, 2010b). According to the US EPA, the 4th highest

maximum daily 1-hour concentrations obtained with one year of onsite data or averaged over the modeled five years of offsite data should be used in the NAAQS comparison.

Impacts from SO_2 emissions from operations from both ports have been modeled. Modeling results are summarized in Appendix F (for Port of Morrow) and Appendix G (for Port Westward). As shown in Table 8 below, the AERMOD model has predicted the highest 4th highest SO_2 concentrations of 7.7 ug/m^3 for the Port of Morrow and 87.1 ug/m^3 for Port Westward. With the added background concentrations, the NAAQS is predicted not to be exceeded at both ports. The low SO_2 concentrations are due to the use of SO_2 emissions that are shown in the project ER. These emissions have been calculated based on the use of ultra low sulfur diesel for both locomotive and boats. We note that the locomotive and boats are currently legally allowed to use much higher sulfur content diesel fuel that what was assumed in the ER. *See* 77 Fed. Reg. 61281 (Oct. 9, 2012).

Table 8. Predicted 1-hour SO_2 (ug/m3) of Port Operations

Modeling Scenario	Project Conc.	Backgr. Conc.	Total Conc.	NAAQS	NAAQS Exceeded?
Port of Morrow	**7.7**	23.5	**31.2**	196.0	**NO**
Port Westward	**87.1**	22.8	**109.9**	196.0	**NO**

C. 24-Hour $PM_{2.5}$ Impacts

In September 2006, US EPA revised the 24-hour $PM_{2.5}$ NAAQS which is attained when the 3-year average of the 98th percentile 24-hour concentrations must not exceed 35 ug/m^3. Subsequently, US EPA issued in August 2010 a modeling guidance for using the AERMOD model with one year of onsite data or five years of offsite meteorological data (USEPA, 2010d). According to the US EPA, the highest 24-hour average concentration obtained with one year of onsite data or the highest average of the maximum 24-hour averages across five years of offsite data should be used in the NAAQS comparison.

Impacts from $PM_{2.5}$ emissions from operations at Port of Morrow with enclosed and open barges and trains have been modeled. Modeling results are summarized in Appendix H (for enclosed barges and trains) and Appendix I (for open barges and closed trains). As shown in Table 9 below, the AERMOD model has predicted exceedances of the 24-hour NAAQS of 35 ug/m^3 by the highest 24-hour $PM_{2.5}$ concentrations of 96.3 ug/m^3 for the enclosed barges and 219.0 ug/m^3 for the open barges. With the added background concentration of 24 ug/m^3, the 24-hour NAAQS is predicted to be exceeded by both types of barges, by 2.4 times with the enclosed barges and by 5.9 times with the open barges.

Due to high emissions from wind erosion, impacts from open barges are much higher than those from enclosed barges. NAAQS exceedances are plotted in Figure 8 for the closed barge/closed train scenario and Figure 9 for the open barge/closed train scenario. In both figures, the NAAQS exceedances are denoted by the contour of 12 ug/m^3 (plus the background of 24 ug/m^3). Figure 8 shows these exceedances for the closed barge/train scenario are predicted to only occur close to the project site in Oregon, i.e. south of the state line on the Columbia River. For the open barge/closed train scenario, they will extend north of the state line, i.e. in Washington.

Another AERMOD modeling run has been performed to assess the impacts of the closed barge/open train scenario. The project ER indicates that up to two unit trains can be present onsite in any given hour (ER, p. 2-6). Their emissions (8.7 lb/hr=2*4.35 lb/hr) are modeled as area source with a length of 1500 ft (the length of rail lines within the MPP property) and a width of 19 ft (9.5 ft x 2). Modeling results are summarized in Appendix J. Table 9 shows that the highest 24-hour $PM_{2.5}$ concentration of 388.6 ug/m^3 is the largest among the modeled scenarios. The 24-hr NAAQS is also predicted to be exceeded by 10.8 times with the open trains. Figure 10 shows that the closed barge/open train scenario has the largest zone of exceedances among the modeled scenarios. The NAAQS exceedances are also predicted to occur in the Washington portion of the Columbia River.

Table 9. Predicted 24-hour $PM_{2.5}$ (ug/m^3) of Port of Morrow Operations

Modeling Scenario	Project Conc.	Backgr. Conc.	Total Conc.	NAAQS	Percent Over NAAQS
Operation with closed barges & closed trains	**96.3**	24.0	**120.3**	35.0	**244%**
Operation with open barges & closed trains	**219.0**	24.0	**243.0**	35.0	**594%**
Operation with closed barges & open trains	**388.6**	24.0	**412.6**	35.0	**1,079%**

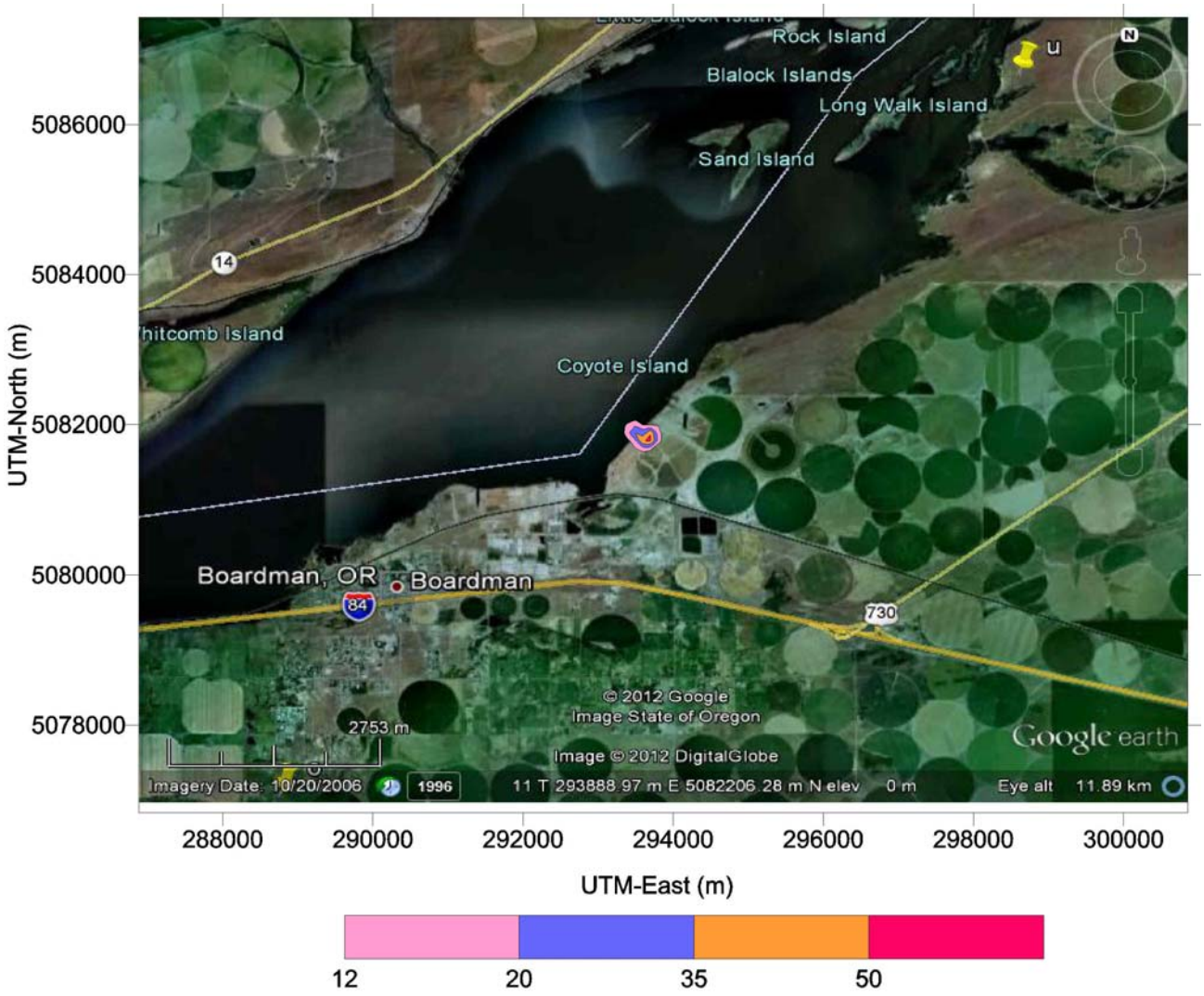


Figure 8. Area with Highest 24-hour $PM_{2.5}$ Concentrations (ug/m^3) Exceeding the 24-Hour NAAQS of 35 ug/m^3 by Port of Morrow Operations with Closed Barges and Trains

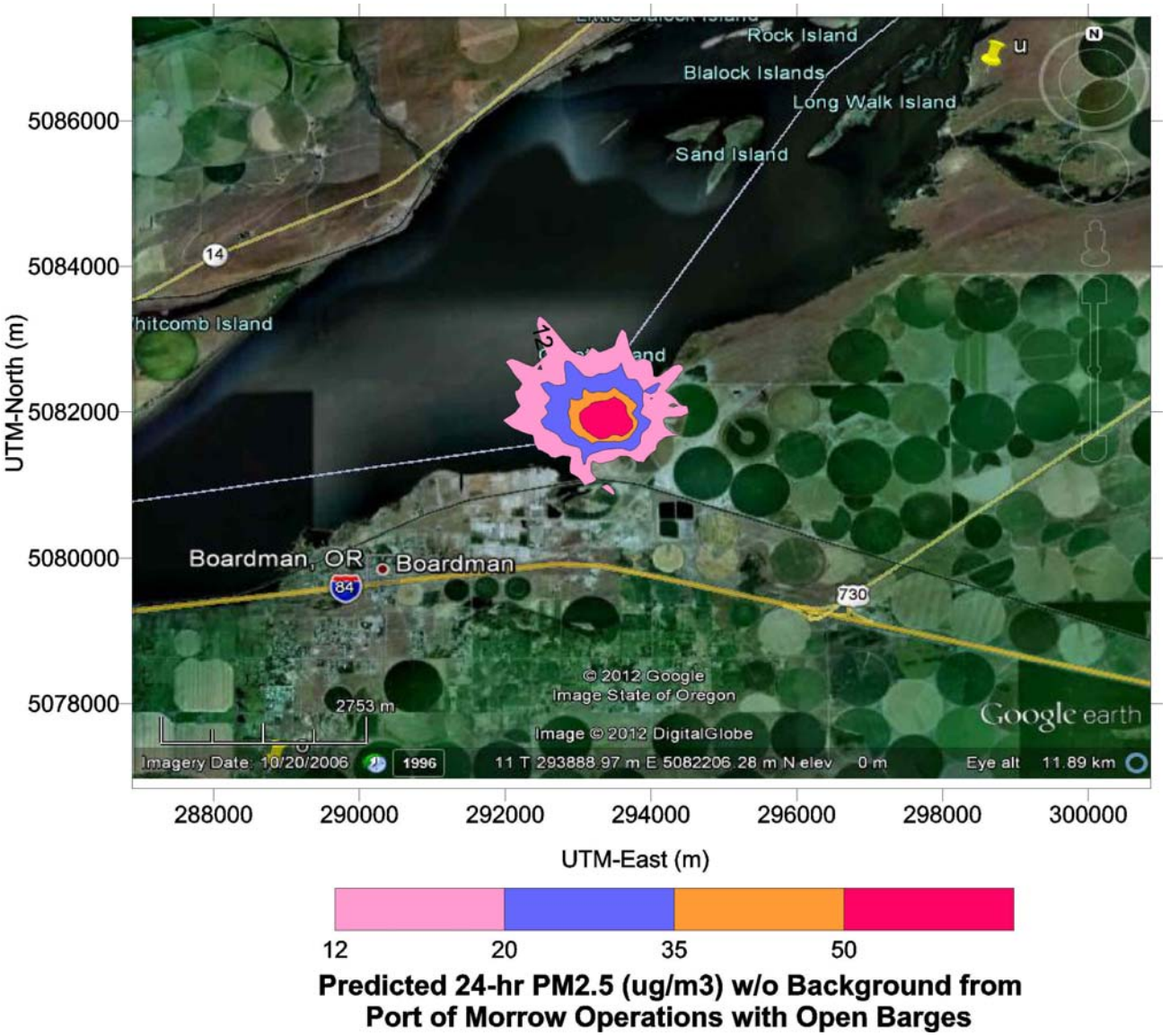


Figure 9. Area with Highest 24-hour $PM_{2.5}$ Concentrations (ug/m^3) Exceeding the 24-Hour NAAQS of 35 ug/m^3 by Port of Morrow Operations with Open Barges and Closed Trains

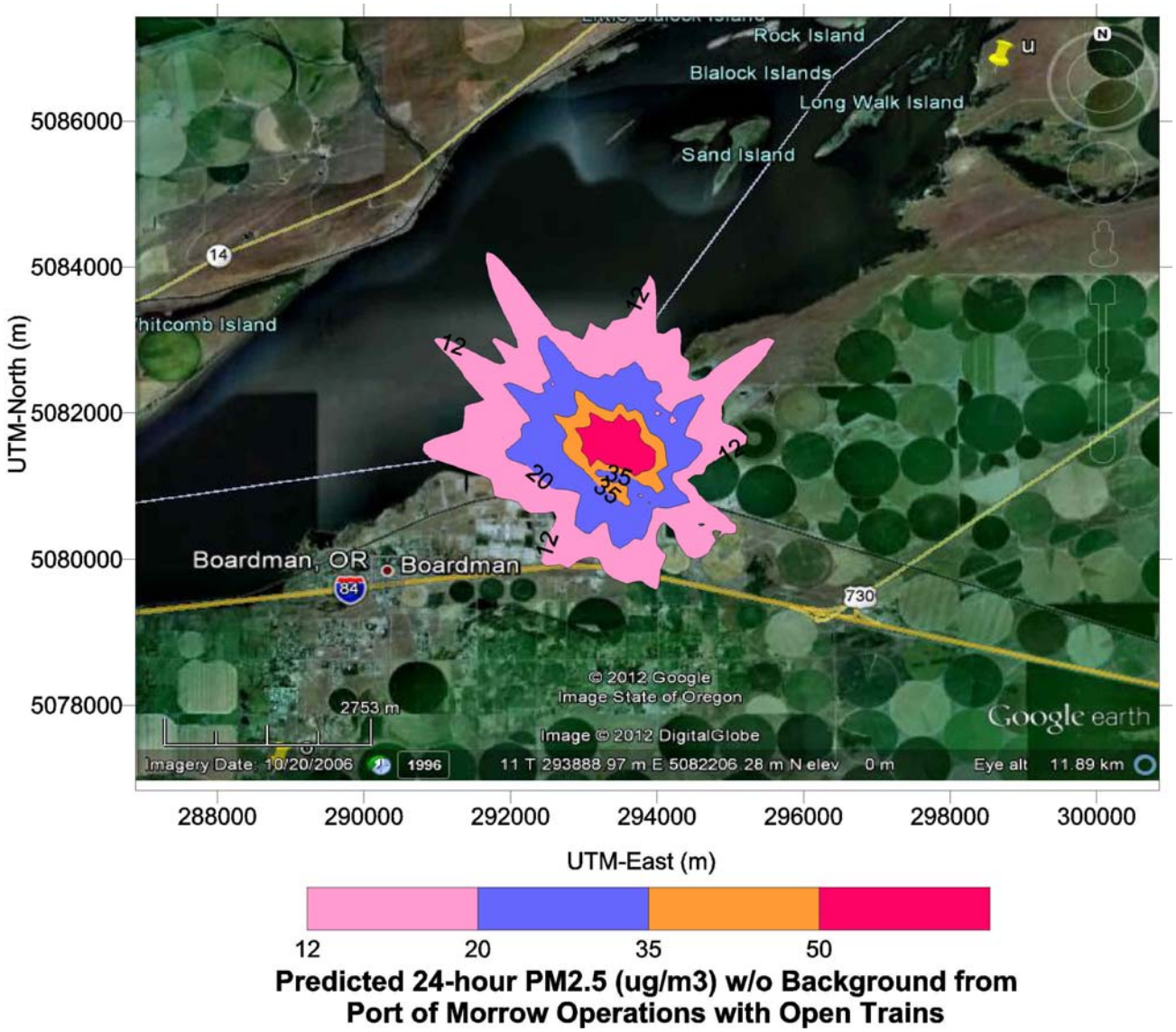


Figure 10. Area with Highest 24-hour $PM_{2.5}$ Concentrations (ug/m^3) Exceeding the 24-Hour NAAQS of 35 ug/m^3 by Port of Morrow Operations with Closed Barges and Open Trains

D. Annual NO_2 Impacts

Annual NO_2 impacts from the operations at Port of Morrow have been analyzed with the AERMOD run. This run uses NOx emissions from train unloading, a tug boat assisting the barge loading and a tug boat travelling on the Columbia River. NO_x emissions of the traveling tug are 3.62 tpy (790/218 where the total emissions are 790 tpy and the distance traveled is 218 miles as shown in the project ER). Table 10 shows that the annual-averaged concentrations predicted for 2007 are the highest among the modeled annual NO_2 concentrations. Modeling results for the year 2007 are summarized in Appendix K.

With the added background of 15 ug/m^3, the annual NAAQS of 100 ug/m^3 is predicted to be largely exceeded, by 16 times with Tier 1 and 12 times with Tier 2 as shown in Table 11. Figure 11 shows these exceedances occurring near the project site. No Tier 3 technique (OLM or PVMRM) has been performed. However, based on the large magnitude of the exceedances predicted by Tier 1 and Tier 2 and the results of applying Tier 3 techniques in 1-hour NO_2 modeling described in Section III. A.1 above, exceedances of the annual NAAQS are also expected with Tier 3 techniques (OLM or PVMRM).

Table 10. Predicted Annual NO_2 (ug/m^3) of Port of Morrow Operations

Modeling Method	2007	2008	2009	2010	2011
Tier 1 -100%	**1,750.9**	1,660.5	1,366.5	1,430.8	1,572.8
Tier 2 - 75%	**1,313.2**	1,245.4	1,024.9	1,073.1	1,179.6

Table 11. Predicted Maximum Annual NO_2 Impacts (ug/m^3) of Port of Morrow Operations

Modeling Method	Project Conc.	Backgr. Conc.	Total Conc.	NAAQS	Percent Over NAAQS
Tier 1 -100%	**1,750.9**	15.0	**1,765.9**	100.0	**1,666%**
Tier 2 - 75%	**1,313.2**	15.0	**1,327.2**	100.0	**1,227%**

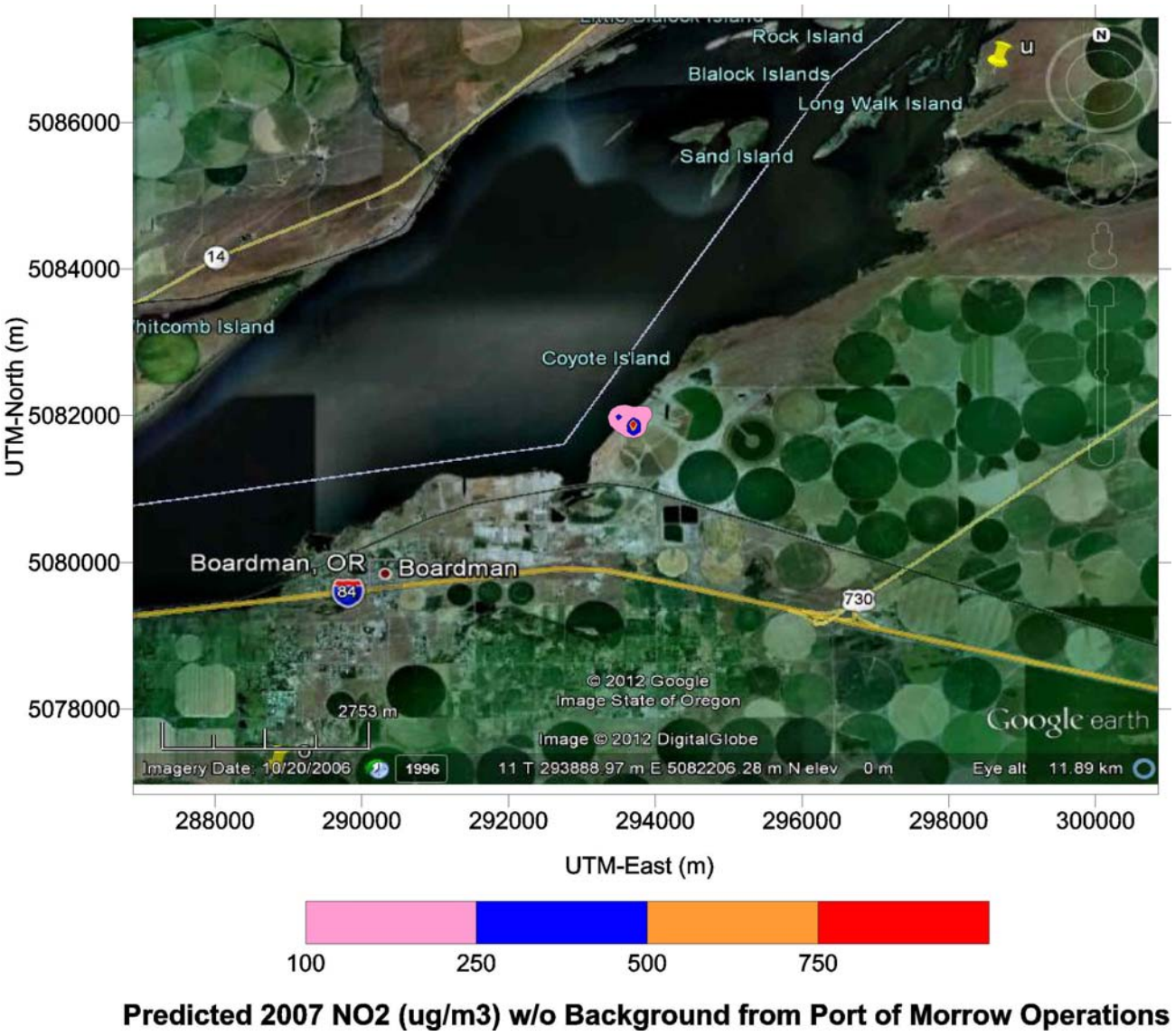


Figure 11. Area with Annual NO_2 (ug/m^3) Exceeding the NAAQS of 100 ug/m^3 by Port of Morrow Operations Alone

E. Nitrogen Deposition Impacts

Nitrogen deposition impacts due to dry and wet deposition from the operations at Port of Morrow have been analyzed with the AERMOD run. This run uses NO_x emissions from trains unloading and tug boats assisting the barge loading. A tug boat travelling on the Columbia River with NO_x emissions of 3.62 tpy is also included. Modeling results for the year 2011 with the highest NO_2 deposition fluxes are summarized in Appendix M. The maximum NO_2 deposition fluxes (in g/m^2/yr) predicted by AERMOD are converted into kg N/ha/yr by multiplying them by 3.043 = 10*(14/46) where 10 is the conversion factor from g/m^2 to kg/ha and (14/46) is the mass ratio of nitrogen (N) over NO_2. The converted maximum impacts are presented in Table 12 and a plot of the predicted deposition in

Figure 12 below. The predicted deposition fluxes largely exceed the ecological screening level (ESL) of 0.5 g/m^2/yr or 5 kg/ha/yr recommended by US EPA (US EPA, 2008).

Table 12. Predicted Nitrogen Deposition (kg N/ha/yr) of Port of Morrow Operations

Modeling Method	2007	2008	2009	2010	2011	ESL
Tier 1 -100%	164.4	155.1	185.7	128.9	**261.2**	**5**
Tier 2 - 75%	123.3	116.3	139.3	96.7	**195.9**	**5**

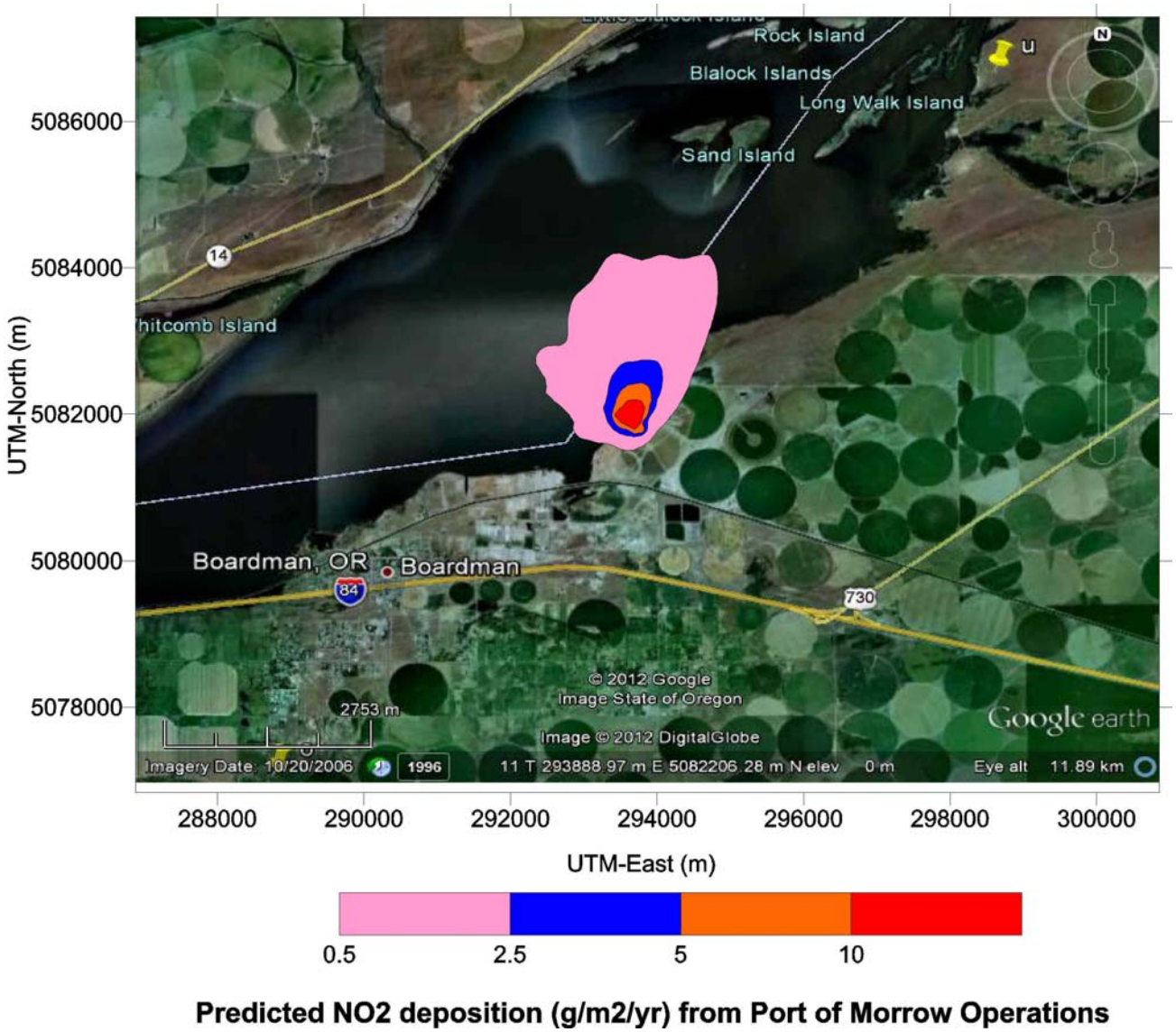


Figure 12. Area with Annual NO_2 Deposition (g/m^2/yr) by Port of Morrow Operations Alone

IV. CONCLUSIONS

Air quality impacts of NO_x, $PM_{2.5}$ and SO_2 emissions from the proposed operations at Port of Morrow and Port Westward of the Morrow Pacific Project have been analyzed with the AERMOD model. For NO_2, modeling techniques known as Tier 1 (full conversion) and Tier 2 recommended by the US EPA have been used for modeling at both ports. Tier 3 techniques (OLM and PVMRM) have also been used for modeling impacts at Port of Morrow. Using primarily project emissions documented in the project ER and the latest US EPA modeling guidance, the AERMOD model has predicted large exceedances of the NO_2 1-hour NAAQS of 196 ug/m^3 (by 9-63 times the NAAQS at Port of Morrow and by 19-24 times the NAAQS at Port Westward), the 24-hour $PM_{2.5}$ at Port of Morrow (by 2.4-10.8 times the NAAQS of 35 ug/m^3) and the annual NO_2 NAAQS at Port of Morrow (by 12-17 times the NAAQS of 100 ug/m^3). These large exceedances have been predicted to occur due to project emissions alone, i.e., without the addition of background concentrations and also in large areas around the project sites. NAAQS exceedances will occur in both Oregon and Washington. SO_2 impacts are insignificant due to low emissions from the use of ultra low sulfur fuel for both locomotive and boat engines. The AERMOD model has also predicted large nitrogen deposition around the Port of Morrow. Thus, the proposed Morrow Pacific Project will cause very adverse air quality impacts in both Oregon and Washington.

The AERMOD modeling files, including input/output files, meteorological data, ozone data and model executable, have been uploaded to box.com and are available from the folder: https://www.box.com/s/tseqhg95g7fe1jdw57lk .

V. REFERENCES

California Air Resources Board, 2006. *Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach*. Available at http://www.arb.ca.gov/ports/marinevess/documents/portstudy0406.pdf

Fritz, S, 2007. US Locomotive After-treatment Retrofit Progress Report: SwRI Test Programs. Southwest Research Institute. Available at http://www.arb.ca.gov/railyard/ryagreement/112807fritz.pdf

New Jersey DEP, 2009. *Estimated Air Quality Impacts on Surrounding Communities of $PM_{2.5}$ and SO_2 Emissions Resulting from Marine Operations at Elizabeth Port Authority Marine Terminal and Port Newark.* Available at http://www.state.nj.us/dep/stopthesoot/Port%20risk%20Summary-final%2010-9-09.pdf

Oregon DEQ, 2012. 2011 Oregon Air Quality Data Summaries. Available at: http://www.deq.state.or.us/aq/forms/2011AirQualityAnnualReport.pdf

U.S. EPA, 2012. Addendum to User's Guide of the AMS/EPA Regulatory Model AERMOD version 12060, February 2012. Available at: http://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip

U.S. EPA, 2011. *Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS*. Memorandum issued on March 1st, 2011 from Tyler Fox, Leader of Air Quality Modeling Group, OAQPS. Available at http://www.epa.gov/region7/air/nsr/nsrmemos/appwNO2_2.pdf

U.S. EPA, 2010a. *Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS*. Memorandum issued on June 28, 2010 from Tyler Fox, Leader of Air Quality Modeling Group, OAQPS. Available at http://www.epa.gov/ttn/scram/guidance/clarification/ClarificationMemo_AppendixW_Hourly-NO2-NAAQS_FINAL_06-28-2010.pdf

U.S. EPA, 2010b. *Guidance Concerning the Implementation of the 1-hour SO_2 NAAQS for the Prevention of Significant Deterioration Program*. Memorandum issued on August 23, 2010 from Stephen D. Page, Director of OAQPS. Available at http://www.epa.gov/region07/air/nsr/nsrmemos/appwso2.pdf

U.S. EPA, 2010c. *Applicability of Appendix W Modeling Guidance for the 1-hour SO_2 NAAQS*. Memorandum issued on August 23, 2010 from Tyler Fox, Leader of Air Quality Modeling Group, OAQPS. Available at http://www.epa.gov/region07/air/nsr/nsrmemos/appwso2.pdf

U.S. EPA, 2010d. *Modeling Procedures for Demonstrating Compliance with $PM_{2.5}$ NAAQS*. Memorandum issued on March 23, 2010 by Stephen D. Page, Director of OAQPS. Available at: http://www.epa.gov/region07/air/nsr/nsrmemos/pm25memo.pdf

U.S. EPA, 2008. *Biological Assessment for Gateway Energy and Coke Company, Granite City, Illinois*. Available at: http://yosemite.epa.gov/r5/r5ard.nsf/c408a2009710018f8625716f004d9038/bab8e1b0ab50bdfc86257412006c2f20/$FILE/GatewayBioAssessment.pdf

Appendix A

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port of Morrow Operations

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	12000.43671 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	2ND HIGHEST VALUE IS	11011.15662 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	3RD HIGHEST VALUE IS	9546.46567 AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	4TH HIGHEST VALUE IS	8619.08562 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	5TH HIGHEST VALUE IS	8446.96889 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	6TH HIGHEST VALUE IS	7982.12692 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	7TH HIGHEST VALUE IS	6129.74109 AT (293495.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	8TH HIGHEST VALUE IS	5478.30847 AT (293645.00, 5081883.00, 88.58, 88.58, 1.50)	DC
	9TH HIGHEST VALUE IS	5425.12949 AT (293436.00, 5081947.00, 81.42, 81.42, 1.50)	DC
	10TH HIGHEST VALUE IS	5407.11800 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC

Appendix B

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-OLM) of Port of Morrow Operations

**MODELOPTs: NonDFAULT CONC ELEV FLGPOL OLM

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	1872.57842 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	2ND HIGHEST VALUE IS	1506.09918 AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	3RD HIGHEST VALUE IS	1269.56877 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	4TH HIGHEST VALUE IS	1157.13116 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	5TH HIGHEST VALUE IS	930.96011 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	6TH HIGHEST VALUE IS	898.70613 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	7TH HIGHEST VALUE IS	888.67937 AT (293645.00, 5081883.00, 88.58, 88.58, 1.50)	DC
	8TH HIGHEST VALUE IS	804.59597 AT (293729.00, 5081905.00, 89.36, 89.36, 1.50)	DC
	9TH HIGHEST VALUE IS	708.92971 AT (293645.00, 5081933.00, 88.68, 88.68, 1.50)	DC
	10TH HIGHEST VALUE IS	708.92971 AT (293645.00, 5081933.00, 88.68, 88.68, 1.50)	DC

Appendix C

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Tier 3-PVMRM) of Port of Morrow Operations

**MODELOPTs: NonDFAULT CONC ELEV FLGPOL PVMRM

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	2064.26610	AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	2ND HIGHEST VALUE IS	1640.03383	AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	3RD HIGHEST VALUE IS	1453.05752	AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	4TH HIGHEST VALUE IS	1349.15566	AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	5TH HIGHEST VALUE IS	1276.62739	AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	6TH HIGHEST VALUE IS	1137.14103	AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	7TH HIGHEST VALUE IS	932.58202	AT (293645.00, 5081883.00, 88.58, 88.58, 1.50)	DC
	8TH HIGHEST VALUE IS	854.25416	AT (293495.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	9TH HIGHEST VALUE IS	826.47500	AT (293436.00, 5081947.00, 81.42, 81.42, 1.50)	DC
	10TH HIGHEST VALUE IS	819.38900	AT (293729.00, 5081905.00, 89.36, 89.36, 1.50)	DC

Appendix D

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port Westward Operations with Transloader using Emergency Power

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	4669.95119	AT (485884.00, 5114327.00, 1.82, 173.28, 1.50)	DC
	2ND HIGHEST VALUE IS	4019.45010	AT (485834.00, 5114327.00, 1.84, 173.28, 1.50)	DC
	3RD HIGHEST VALUE IS	4019.45010	AT (485834.00, 5114327.00, 1.84, 173.28, 1.50)	DC
	4TH HIGHEST VALUE IS	3552.36381	AT (485884.00, 5114377.00, 1.86, 173.28, 1.50)	DC
	5TH HIGHEST VALUE IS	3464.09646	AT (485934.00, 5114327.00, 1.81, 173.28, 1.50)	DC
	6TH HIGHEST VALUE IS	3464.09646	AT (485934.00, 5114327.00, 1.81, 173.28, 1.50)	DC
	7TH HIGHEST VALUE IS	3308.75055	AT (485834.00, 5114377.00, 1.88, 173.28, 1.50)	DC
	8TH HIGHEST VALUE IS	2985.93516	AT (485784.00, 5114327.00, 1.86, 178.84, 1.50)	DC
	9TH HIGHEST VALUE IS	2979.22153	AT (485884.00, 5114277.00, 1.79, 173.28, 1.50)	DC
	10TH HIGHEST VALUE IS	2935.63381	AT (485934.00, 5114377.00, 1.85, 173.28, 1.50)	DC

Appendix E

Summary of AERMOD-Predicted 1-hour NO_2 Impacts (Full Conversion) of Port Westward Operations with Transloader using Shore Power

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	4669.94844	AT (485884.00, 5114327.00, 1.82, 173.28, 1.50)	DC
	2ND HIGHEST VALUE IS	4019.45010	AT (485834.00, 5114327.00, 1.84, 173.28, 1.50)	DC
	3RD HIGHEST VALUE IS	4019.45010	AT (485834.00, 5114327.00, 1.84, 173.28, 1.50)	DC
	4TH HIGHEST VALUE IS	3552.36381	AT (485884.00, 5114377.00, 1.86, 173.28, 1.50)	DC
	5TH HIGHEST VALUE IS	3464.09646	AT (485934.00, 5114327.00, 1.81, 173.28, 1.50)	DC
	6TH HIGHEST VALUE IS	3464.09646	AT (485934.00, 5114327.00, 1.81, 173.28, 1.50)	DC
	7TH HIGHEST VALUE IS	3308.75055	AT (485834.00, 5114377.00, 1.88, 173.28, 1.50)	DC
	8TH HIGHEST VALUE IS	2985.93516	AT (485784.00, 5114327.00, 1.86, 178.84, 1.50)	DC
	9TH HIGHEST VALUE IS	2979.22153	AT (485884.00, 5114277.00, 1.79, 173.28, 1.50)	DC
	10TH HIGHEST VALUE IS	2935.63381	AT (485934.00, 5114377.00, 1.85, 173.28, 1.50)	DC

Appendix F

Summary of AERMOD-Predicted 1-hour SO_2 Impacts of Port of Morrow Operations with Ultra Low Sulfur Fuel

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 4TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF SO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	7.71659 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	2ND HIGHEST VALUE IS	6.87149 AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	3RD HIGHEST VALUE IS	5.11050 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	4TH HIGHEST VALUE IS	4.23968 AT (293645.00, 5081883.00, 88.58, 88.58, 1.50)	DC
	5TH HIGHEST VALUE IS	3.29040 AT (293729.00, 5081905.00, 89.36, 89.36, 1.50)	DC
	6TH HIGHEST VALUE IS	3.11441 AT (293645.00, 5081933.00, 88.68, 88.68, 1.50)	DC
	7TH HIGHEST VALUE IS	3.11441 AT (293645.00, 5081933.00, 88.68, 88.68, 1.50)	DC
	8TH HIGHEST VALUE IS	3.01923 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	9TH HIGHEST VALUE IS	2.90729 AT (293695.00, 5081933.00, 88.78, 88.78, 1.50)	DC
	10TH HIGHEST VALUE IS	2.85823 AT (293591.00, 5081747.00, 87.42, 87.42, 1.50)	DC

Appendix G

Summary of AERMOD-Predicted 1-hour SO_2 Impacts of Port Westward Operations with Ultra Low Sulfur Fuel

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 4TH-HIGHEST MAX DAILY 1-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF SO2 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	87.08375	(485384.00, 5114627.00, 66.26, 173.28, 1.50)	DC
	2ND HIGHEST VALUE IS	80.86337	(485434.00, 5114677.00, 72.72, 173.28, 1.50)	DC
	3RD HIGHEST VALUE IS	71.77678	(485184.00, 5114527.00, 71.23, 173.28, 1.50)	DC
	4TH HIGHEST VALUE IS	71.62989	(485284.00, 5114577.00, 73.47, 173.28, 1.50)	DC
	5TH HIGHEST VALUE IS	68.69739	(485534.00, 5114727.00, 80.33, 173.28, 1.50)	DC
	6TH HIGHEST VALUE IS	68.69739	(485534.00, 5114727.00, 80.33, 173.28, 1.50)	DC
	7TH HIGHEST VALUE IS	66.50215	(485084.00, 5114477.00, 66.86, 178.84, 1.50)	DC
	8TH HIGHEST VALUE IS	65.75496	(485484.00, 5114727.00, 81.25, 173.28, 1.50)	DC
	9TH HIGHEST VALUE IS	65.43326	(485334.00, 5114627.00, 78.25, 173.28, 1.50)	DC
	10TH HIGHEST VALUE IS	65.43326	(485334.00, 5114627.00, 78.25, 173.28, 1.50)	DC

Appendix H

Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Enclosed Barges and Trains

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 1ST-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	96.34646 AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	2ND HIGHEST VALUE IS	92.71799 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	3RD HIGHEST VALUE IS	49.79568 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	4TH HIGHEST VALUE IS	43.46942 AT (293645.00, 5081883.00, 88.58, 88.58, 1.50)	DC
	5TH HIGHEST VALUE IS	39.06540 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	6TH HIGHEST VALUE IS	33.96834 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	7TH HIGHEST VALUE IS	31.94523 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	8TH HIGHEST VALUE IS	30.02961 AT (293729.00, 5081905.00, 89.36, 89.36, 1.50)	DC
	9TH HIGHEST VALUE IS	29.26999 AT (293591.00, 5081747.00, 87.42, 87.42, 1.50)	DC
	10TH HIGHEST VALUE IS	26.18454 AT (293595.00, 5081733.00, 87.43, 87.43, 1.50)	DC

Appendix I

Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Open Barges and Closed Trains

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 1ST-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	96.39479 AT (293634.00, 5081812.00, 88.06, 88.06, 1.50)	DC
	2ND HIGHEST VALUE IS	93.31912 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	3RD HIGHEST VALUE IS	74.26387 AT (293385.00, 5081765.00, 81.44, 89.12, 1.50)	DC
	4TH HIGHEST VALUE IS	58.07956 AT (293486.00, 5081914.00, 81.42, 90.01, 1.50)	DC
	5TH HIGHEST VALUE IS	52.50092 AT (293535.00, 5081880.00, 84.73, 90.01, 1.50)	DC
	6TH HIGHEST VALUE IS	51.74925 AT (293495.00, 5081933.00, 81.42, 81.42, 1.50)	DC
	7TH HIGHEST VALUE IS	50.58559 AT (293436.00, 5081947.00, 81.42, 81.42, 1.50)	DC
	8TH HIGHEST VALUE IS	50.00263 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	9TH HIGHEST VALUE IS	48.44197 AT (293436.00, 5081761.00, 86.93, 86.93, 1.50)	DC
	10TH HIGHEST VALUE IS	47.93824 AT (293303.00, 5081902.00, 81.42, 81.42, 1.50)	DC

Appendix J

Summary of AERMOD-Predicted 24-hour $PM_{2.5}$ Impacts of Port of Morrow Operations with Closed Barges and Open Trains

**MODELOPTs: CONC ELEV FLGPOL

*** THE SUMMARY OF MAXIMUM 1ST-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	388.58720	AT (293395.00, 5081533.00, 92.82, 92.82, 1.50)	DC
	2ND HIGHEST VALUE IS	369.14316	AT (293445.00, 5081483.00, 93.82, 93.82, 1.50)	DC
	3RD HIGHEST VALUE IS	329.09982	AT (293495.00, 5081433.00, 94.48, 94.48, 1.50)	DC
	4TH HIGHEST VALUE IS	321.34654	AT (293545.00, 5081383.00, 94.61, 94.61, 1.50)	DC
	5TH HIGHEST VALUE IS	320.74418	AT (293595.00, 5081333.00, 94.54, 96.30, 1.50)	DC
	6TH HIGHEST VALUE IS	206.12712	AT (293395.00, 5081583.00, 91.05, 91.05, 1.50)	DC
	7TH HIGHEST VALUE IS	203.49253	AT (293645.00, 5081283.00, 96.25, 96.25, 1.50)	DC
	8TH HIGHEST VALUE IS	175.37558	AT (293445.00, 5081533.00, 92.35, 92.35, 1.50)	DC
	9TH HIGHEST VALUE IS	175.37558	AT (293445.00, 5081533.00, 92.35, 92.35, 1.50)	DC
	10TH HIGHEST VALUE IS	174.66553	AT (293345.00, 5081633.00, 91.60, 91.60, 1.50)	DC

Appendix K

Summary of AERMOD-Predicted Annual NO_2 Impacts of Port of Morrow Operations

**MODELOPTs: NonDFAULT CONC DEPOS ELEV FLGPOL
DRYDPLT WETDPLT

*** THE SUMMARY OF MAXIMUM ANNUAL RESULTS AVERAGED OVER 1 YEARS ***

** CONC OF NO2 IN MICROGRAMS/M**3 **

GROUP ID	AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	NETWORK OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	1750.88666 AT (293682.00, 5081859.00, 88.36, 88.36, 1.50)	DC
	2ND HIGHEST VALUE IS	1052.50428 AT (293695.00, 5081883.00, 88.89, 88.89, 1.50)	DC
	3RD HIGHEST VALUE IS	635.06315 AT (293729.00, 5081905.00, 89.36, 89.36, 1.50)	DC
	4TH HIGHEST VALUE IS	435.52880 AT (293745.00, 5081933.00, 89.41, 89.41, 1.50)	DC
	5TH HIGHEST VALUE IS	435.52880 AT (293745.00, 5081933.00, 89.41, 89.41, 1.50)	DC
	6TH HIGHEST VALUE IS	354.24233 AT (293695.00, 5081933.00, 88.78, 88.78, 1.50)	DC
	7TH HIGHEST VALUE IS	330.98272 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	8TH HIGHEST VALUE IS	330.98272 AT (293545.00, 5081933.00, 81.42, 88.09, 1.50)	DC
	9TH HIGHEST VALUE IS	316.01375 AT (293495.00, 5081983.00, 81.42, 81.42, 1.50)	DC
	10TH HIGHEST VALUE IS	305.49073 AT (293795.00, 5081933.00, 89.75, 89.75, 1.50)	DC

Appendix M

Summary of AERMOD-Predicted Nitrogen Deposition Impacts of Port of Morrow Operations

**MODELOPTs: NonDFAULT CONC DEPOS ELEV FLGPOL DRYDPLT WETDPLT

*** THE SUMMARY OF MAXIMUM ANNUAL RESULTS AVERAGED OVER 1 YEARS ***

** DEPO OF NO2 IN GRAMS/M**2/YR **

GROUP ID		TOTAL DEPO	NETWORK RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG) OF TYPE GRID-ID
ALL	1ST HIGHEST VALUE IS	85.83330	AT (293645.00, 5081883.00, 88.58, 88.58, 1.50) DC
	2ND HIGHEST VALUE IS	59.12736	AT (293695.00, 5081933.00, 88.78, 88.78, 1.50) DC
	3RD HIGHEST VALUE IS	56.41767	AT (293695.00, 5081883.00, 88.89, 88.89, 1.50) DC
	4TH HIGHEST VALUE IS	53.31785	AT (293682.00, 5081859.00, 88.36, 88.36, 1.50) DC
	5TH HIGHEST VALUE IS	50.98385	AT (293645.00, 5081933.00, 88.68, 88.68, 1.50) DC
	6TH HIGHEST VALUE IS	50.98385	AT (293645.00, 5081933.00, 88.68, 88.68, 1.50) DC
	7TH HIGHEST VALUE IS	38.15760	AT (293695.00, 5081983.00, 86.48, 89.33, 1.50) DC
	8TH HIGHEST VALUE IS	33.88791	AT (293645.00, 5081983.00, 87.43, 87.43, 1.50) DC
	9TH HIGHEST VALUE IS	26.27295	AT (293495.00, 5081983.00, 81.42, 81.42, 1.50) DC
	10TH HIGHEST VALUE IS	25.56387	AT (293745.00, 5081983.00, 88.92, 88.92, 1.50) DC

Exhibit 4

Fugitive Particulate Matter Emissions from Coal Train Staging at the Proposed Coyote Island Terminal

Oregon Department of Environmental Quality
Standard Air Contaminant Discharge Permit Review Report,
Coyote Island Terminal, LLC,
Permit No.: 25-0015-ST-01

Final Report

July 19, 2013

Prepared for
Sierra Club
San Francisco, CA

Prepared by
Phyllis Fox, Ph.D., PE
Consulting Engineer
Rockledge, Florida

I was asked to review the particulate matter emissions from wind erosion of uncovered railcars while the trains are staged, as estimated by Oregon Department of Environmental Quality ("ODEQ") in its Standard Air Contaminant Discharge Permit Review Report ("Review Report")[1] for the Coyote Island Terminal ("Terminal") and the resulting draft Permit No.: 25-0015-ST-01 ("Permit").[2]

The Coyote Island Terminal will receive 8.8 million tons per year of coal by rail at the Port of Morrow where it will then be loaded for export. Upon arrival, the coal will be uncovered from the point the train enters the Terminal until each car enters the unloading shed where the coal is transferred via rotary dump to a hopper and conveyor. ER,[3] pp. 2-12 to 2-18. Fugitive dust emissions will occur due to wind erosion of the coal in uncovered railcars while the trains are staged, prior to entering the unloading station. The unit trains will be split to avoid blocking Columbia Avenue, which will increase their original processing time of 4.8 hours to a much longer processing time of 12 hours. ER, p. 2-11.

The existing rail network at the Port of Morrow, totaling 18,000 feet, can handle two unit trains at once, each of which is about 5,800 feet long (or over 1 mile). ER, p. 2-6. The type of rail car that would be used is not disclosed, but gondola cars, commonly used for coal, typically have an inside width of about 9.5 feet.[4] Each unit train holds about 14,500 tons of coal, which will be exposed to ambient conditions for up to 12 hours at the terminal, the time required to unload a unit train. ER, p. 2-11. The ER indicates that up to 607 trains per year would import coal to the terminal at up to 12 hours per train to unload. ER, p. 3-139. Thus, coal trains will be present at least 83% of the time.[5]

The site will initially have only a single unloading shed that takes 12 hours to process a single unit train while the rail tracks can accommodate two unit trains simultaneously. ER, pp. 2-6. Thus, trains will be idle on the tracks, with exposed coal that is either dried out upon arrival or can continue to dry out while waiting to be loaded, degrading the coal surface and making it readily erodible by wind.

The draft Permit contains emission factors for PM, PM10, and PM2.5 expressed in pounds of pollutant per ton of coal (lb/ton) that will be used to determine compliance with emission limits in tons per year (ton/yr) in Permit Condition 4.1. Permit, Condition 12.0. These emission factors are underestimated, for the reasons set out below. Further, the draft Permit allows "alternative emission factors provided they are based on actual

---

[1] ODEQ, Standard Air Contaminant Discharge Permit Review Report, Coyote Island Terminal, LLC, Permit No.: 25-0015-ST-01, Application No.: 26945, Draft, May 28, 2013.

[2] ODEQ, Standard Air Contaminant Discharge Permit No.: 25-0015-ST-01, May 28, 2013.

[3] Anderson Perry & Associates, Inc., Environmental Review for the Coyote Island Terminal Dock at the Port of Morrow, Prepared for Coyote Island Terminal, LLC and Ambre Energy North America, June 2012, Updated August 2012.

[4] CSX, Railroad Equipment, Plain Gondola, Available at: http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/

[5] Percent of time trains present: 100(607x12/8760) = 83%.

test data or other documentation..." Permit, Condition 5.6. Any modification to these emission factors should be submitted for public review due to the complex issues involved in their calculation.

Wind blown dust from loaded uncovered railcars, waiting to be unloaded, is a major source of particulate matter emissions. The ODEQ estimated the emissions from and emission factors for loaded uncovered railcars at the site using an equation from AP-42, Section 13.2.5, for wind erosion from flat areas covered with coal dust. Review Report, p. 9. I reviewed the ODEQ's application of this equation and related permit conditions. In my opinion, ODEQ did not use accurate input variables and thus underestimated particulate matter emissions from loaded uncovered railcars. The particulate matter emissions from staging coal cars are much higher than estimated in the Review Report, high enough to classify the terminal as a major source.

I. The ODEQ's Application of the Wind Erosion Equation Underestimates Particulate Matter Emissions From Loaded Uncovered Trains During Staging

The Review Report estimated emissions from wind erosion of staging coal cars using AP-42 Section 13.2.5.3, equations for wind erosion from flat areas covered with coal dust. Review Report, p. 9. The subject equations are:

$$P_i = 58(u^* - u_t^*)^2 + 25(u^* - u_t^*) \qquad (1)$$

where

P_i = the erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances in grams per meter squared (g/m^2)

u^* = friction velocity in m/s (0.599 m/s) = $0.053u^+_{10}$

u_t^* = threshold friction velocity in m/s (0.54 m/s).

The total wind erosion in a year is the sum of the number of disturbances per year or

$$EF = k\sum_{i=1}^{N} P_i \qquad (2)$$

where

k = particle size multiplier

N = number of disturbances per year.

A. Input Assumptions Underestimate Emissions

The ODEQ's use of these equations underestimates particulate matter emissions from the subject rail cars for the reasons set out below.

First, the wind speed in the AP-42 equation (p. 13.2.5-5, Eqn (4)) that ODEQ used to estimate friction velocity (u^*) or $0.053u^+_{10}$, is estimated as 0.053 times the fastest mile of the reference anemometer for the period between disturbances in m/s. ODEQ did not use the fastest mile,[6] but rather the "24-hr highest annual 24-hour average wind speed" (sic). Review Report, p. 9. This underestimates the fastest mile wind speed as it does not include peak wind gusts of short duration (over a few seconds instead of the 24-hour average used by ODEQ). These short gusts are responsible for wind erosion. For the equations that ODEQ used, AP-42 notes that "estimated emissions should be related to the gusts of highest magnitude." AP-42, p. 13.2.5-1. The ODEQ instead used a 24-hr average that does not include peak wind gusts of short duration, thus substantially underestimating wind erosion.

Second, the equation that ODEQ used only applies to flat piles with little penetration into the surface wind layer. Rail cars are not flat piles. The coal surface is located 10 feet or more above ground level, with significant penetration into the surface wind layer. Thus, the friction velocity estimated by this equation is underestimated and with it, wind erosion emissions.

Third, the threshold friction velocity is best estimated from a simple hand sieving test of the material to be disturbed as material characteristics determine erosion potential. AP-42, pp. 13.2.5-3/4. In the absence of test data, AP-42 provides a table of estimates for six materials. AP-42, Table 13.2.5-2. This table was used by ODEQ, who selected the entry called "fine coal dust on concrete pad." Clearly, the surface of a loaded rail car is nothing like fine coal dust on a concrete pad. Footnotes to this table indicate the coal included in this test was at an eastern power plant in 1985 and thus unlikely to be PRB coal. PRB coal is very different from eastern bituminous coals that were likely used in this test. PRB coals are extremely friable and easily degrade into smaller particles, regardless of how they are transported or handled, thus causing fugitive dust emissions.[7] Thus, a much lower threshold friction velocity likely applies.

Fourth, the equations ODEQ used were developed for stationary aggregate storage piles whose surfaces are characterized by finite availability of erodible material (mass/area) referred to as the "erosion potential" or "P". AP-42, p. 13.2.5-1. Erosion is assumed to occur only when there is a disturbance, as when new aggregate is either added to or removed from the old surface. Further, they implicitly assume the exposed material

[6] The fastest-mile wind speed is the wind speed obtained from wind velocity maps prepared by the National Oceanographic and Atmospheric Administration. It is the highest sustained average wind speed based on the time required for a mile-long sample of air to pass a fixed point.

[7] Roderick J. Hossfeld and Rod Hatt, PRB Coal Degradation -- Causes and Cures, PRB Coal Users Group Annual Meeting, April 5-7, 2005. Available at: http://www.prbcoals.com/pdf/paper_archives/56538.pdf

has limited erosion potential. AP-42, p. 13.2.5-3. However, the availability of erodible material for the railcars is unlimited. A total of 607 unit trains will visit the site every year, each staying about 12 hours. The arrival of each train presents fresh erodible material. Further, rail transport of coal continuously jostles the coal en route, exposing new coal for erosion as the trains move along the tracks. Train vibration during transport causes coal particles to break, producing finer material that will be lifted more readily from the coal surface. One study, for example, measured coal losses of 0.2 to 0.4 tons or 400 to 800 pounds per individual rail car during a 500 mile long trip.[8] Others have estimated that 0.5% to 3% of the total coal transported is lost through fugitive dust when no dust control is used.[9] This would amount to 73 to 435 tons for a unit train serving the Terminal, amounting to a substantial amount of "jostling."

Thus, rail cars will arrive with freshly exposed coal, ready to be further eroded at the site. Two unit trains, each about a mile long and 9.5 feet wide, will be present at the site for 12 hours each up to 83% of the time. Thus, about 2.4 acres[10] or about two football fields[11] of fresh exposed coal will be available for wind erosion 83% of the time. The PRB coal that will be imported is known to be highly friable and thus would be expected to have a much greater "erosion potential" than aggregate "with limited erosion potential" as assumed in these equations. Thus, the concept of "erosion potential" as presented in this section of AP-42 underestimates emissions from an unlimited source of erodible material such as PRB coal in newly arrived railcars.

Fifth, the principal equation (AP-42, p. 13.2.5-3, Eqn (3) or Eqn. 1 above) assumes a flat surface. The coal is generally not present as a flat surface in the rail cars, but rather presents as trapezoidal or rounded profiles that extend above the walls of the rail car.[12] This increases the available surface area, increasing emissions.

Finally, ODEQ applied a control efficiency of 85% to the calculated erosion emissions to account for the control of fugitive dust by dust control agents know as "topping agents" in the industry, that are applied at the mine. As discussed below, these topping agents would have worn off by the time the trains reach the Terminal.

As discussed in the next section, when just the correct wind speed and control efficiency are used, the particulate matter emissions from wind erosion of uncovered railcars exceeds the major source threshold of 250 ton/yr.

---

[8] Edward M. Calvin and others, A Rail Emission Study: Fugitive Coal Dust Assessment and Mitigations, Available at: http://www.powerpastcoal.org/wp-content/uploads/2011/08/A-RAIL-EMISSION-STUDY-FUGITIVE-COAL-DUST-ASSESSMENT-AND-MITIGATION.pdf

[9] Robert Kotchenruther, EPA Region 10, Fugitive Dust from Coal Trains: Factors Effecting Emissions & Estimating PM2.5, 2013, Available at: http://lar.wsu.edu/nw-airquest/docs/201306_meeting/20130606_Kotchenruther_coal_trains.pdf

[10] Exposed coal area in rail cars = 2 x 5800 ft x 9 ft x 2.2957E-5 ac/ft^2 = 2.4 acres.

[11] An official NFL football field measures 360 ft long by 160 ft wide. Thus, one football field occupies 360 ft x 160 ft x 2.2957E-5 ac/ft^2 = 1.32 acres.

[12] See, e.g., Calvin et al. and photographs of loaded trains in Kotchenruther 2013.

B. ODEQ Emission Estimates Are Unsupported

The ODEQ used the AP-42 equations, which yield erosion potential in grams per square meter of surface area per event, to estimate PM, PM10, and PM2.5 emissions in pounds per ton of coal as follows (Review Report, p. 17):

- PM: 2.00E-04 lb/ton
- PM10: 1.00E-04 lb/ton
- PM2.5: 1.5E-5 lb/ton

These coal train erosion emission factors are then summed with emission factors for other coal handling operations to yield combined emission factors that are set as permit conditions. Permit, Sec. 12.0. The combined emission factors are proposed to determine compliance. The Permit does not require any demonstration that these assumed emission factors accurately represent actual emissions from the subject railcars. Review Report, pp. 17-18.

The Review Report does not explain how ODEQ converted erosion potential in grams per square meter per event into pounds per ton of coal and then into tons per year. I attempted to reproduce ODEQ's calculations, as set out below. I used the equations and input variables from the Review Report (Review Report, p. 9) and information from the ER to estimate erosion potential. My calculations indicate the uncontrolled erosion potential using ODEQ's input assumptions is 1.68 g/m^2.[13]

It is unclear how ODEQ used this erosion potential to estimate an emission factor in lb/ton and annual particulate matter emissions in ton/yr. The responses to comments should disclose all of the calculations and underlying assumptions to convert erosion potential into pounds of particulate matter per ton of coal as reported in the Review Report at 17 and recirculate the Review Report and draft Permit for public review.

Using the description of the proposed operations, as set out above, the uncontrolled PM emissions from a single erosion event would be 37.9 lbs of particulate matter per event.[14] Assuming the surface of staged unit trains is disturbed only daily and unit trains are present 83% of the time, the annual uncontrolled PM emissions would be 5.7 ton/yr.[15] Assuming 85% control as assumed by ODEQ yields 0.86 ton/yr of PM,

---

[13] Following the procedures in the Review Report, p. 9, the friction velocity u^* is given by $0.053u^+_{10}$ = 0.053 x 25.3 mph x 0.44705 m/s per mph = **0.599 m/s**. The threshold velocity (u_t^*) is taken from AP-42 Table 13.2.5-2 for "fine coal dust on concrete pad" and is **0.54 m/s**. Thus, $P= 58(0.599 - 0.54)^2 + 25(0.599 - 0.54)$ = **1.68 g/m^2.**

[14] PM emissions from one wind erosion event = [(1.68 g/m^2)(0.00220462 lb/g)/10.7639 ft^2/m^2)](2 unit trains x 5800 ft long x 9.5 ft wide) = **37.9 lbs of PM per event**.

[15] Annual PM emissions = (37.9 lb/event)(365 day/yr)(0.83)/2000 lb/ton = **5.7 ton/yr**.

which is very close to the value of 0.88 ton/yr estimated in the Review Report, page 17. However, this underestimates potential emissions as demonstrated below.

C. ODEQ Underestimated Emissions

The PM/PM10/PM2.5 emission factors in lb/ton and total emissions in tons/yr estimated using the above-described procedures are underestimated, assuming ODEQ's undisclosed calculations are similar to mine, as laid out above for three reasons: (1) wrong wind speed (24-hour average instead of fastest mile); (2) low disturbance frequency (one per day instead of multiple); (3) high dust control efficiency (85% instead of 0%). These issues are discussed below.

When the friction velocity is increased to 64 mph and the topping agent control efficiency set to zero, but otherwise using ODEQ's input assumptions (some of which further underestimate PM emissions), PM emissions from uncovered railcars increases from 5.7 ton/yr to at least 270 ton/yr. These revised PM emissions for just train staging exceed the major source threshold for particulate matter of 250 ton/yr. Actual train staging emissions could be even larger under the AP-42 Section 13.2.5 emission model that ODEQ used due to the other errors and omissions in ODEQ's calculations as discussed further below.

1. Fastest Mile

First, the ODEQ calculations are based on a 24-hour average wind speed, rather than the fastest mile, as explicitly required by the AP-42 equation. The fastest mile is no longer reported in the local climatological data, but a good indicator is the maximum 3-second wind. For 2012, the maximum 3-second wind for Astoria was 76 mph and for Portland, it was 48 mph. Historic tabulations yield a range for the fastest mile of 55 mph to 88 mph at Oregon stations with an average of 67 mph for the five available stations.[16] There is no local climatological data for Hermiston. However, in previous work, I used an estimate of 64 mph to account for wind gusts, calculated as two times the highest daily wind speed of 32 mph, averaged over daytime hours at Hermiston during 2007-2011.[17] As this value falls squarely within the range of historic fastest mile wind speeds for Oregon stations, I used it here for the fastest mile to revise ODEQ's train staging particulate matter emission estimates.

2. Disturbance Frequency

Second, the ODEQ calculations appear to assume (based on my reconstruction) one disturbance event per day, where a disturbance event is the arrival of two new unit trains, one every 12 hours. However, it is possible that the staged trains could move

[16] Richard A. Wood (Ed.), Weather of U.S. Cities, Fifth Ed., 1996, pp. 760-783 (Astoria - 55 mph; Medford - 55 mph; Pendelton - 77 mph; Portland - 88 mph; Salem - 58 mph).

[17] Khanh T. Tran, AMI Environmental, AERMOD Modeling of Air Quality Impacts of the Proposed Morrow Pacific Project, Final Report, p. 5, October 2012.

around the site, jostling their contents multiple times, creating additional disturbance events. If each unit train, for example, were disturbed twice per day, once on arrival, and once during transit across the site to the unloading shed, the emissions estimated above would double to 540 ton/yr. Even more disturbances are plausible.

3. Topping Agent Control Efficiency

Third, the calculations in the Review Report assume that the coal arrives treated with a topping agent that controls 85% of the fugitive emissions. Review Report, p. 9. This is the assumed control efficiency at the mine, where topping agent is applied. The control efficiency at the Terminal is likely to be zero due to coal and topper degradation during transit, among other reasons further described below. Additionally, the 85% control assumption for topping agents (or surfactants) even at the mine is questionable and has been criticized as being based on "junk science".[18] There is some evidence that indicates that surfactants/topping agents may even increase coal loss due to "saltation". A declaration by Dr. Mark Viz in a case before the Surface Transportation Board (STB) noted as follows: [19]

[18] Before the Surface Transportation Board, Reasonableness of BNSF Railway Company Coal Dust Mitigation Tariff Provisions, Finance Docket No. 35557, Opening Evidence and Argument of Western Coal Traffic League, American Public Power Association, Edison Electric Institute and National Rural Electric Cooperative Association, October 1, 2012 ("STB Brief"), pdf 18 ("Coal Shippers demonstrated in Dust I that the coal dust mitigation standards in the Original Coal Dust Tariff [the 85% relied on by ODEQ] were predicated on junk science..."). See also Arkansas Electric Cooperative Corporation's Reply Evidence and Argument, pdf 3 ("BNSF created the appearance that toppers are highly effective by simply excluding from testing the real world conditions where they are not effective."), 4 ("BNSF's claim that toppers remain intact until they reach their final destination is refuted by [REDACTED] toppers cannot achieve the promised reductions in fugitive coal deposition between the mine and the power plants."), 9 ("..the profile established at the mine and the coating of the topper on the coal are likely to degrade during the course of the rail journey from the mine. This is particularly true where excessive stresses are placed on the coal load as a result of the railroad's operations (e.g., excessive speed, slack action, etc.,) and/or the state and condition of the track (e.g., modulus changes, worn switches, etc.). Shippers have no control over these factors, which may materially alter the load profile and/or the integrity of the topper that have been applied."), 14 ("The safe harbor toppers put a thin chemical coating over the top of the coal, which is supposed to "keep [] the wind from blowing coal dust out of a coal car or off the top of a coal stockpile."[] that may work well enough on a stationary pile of coal, but coal cars move. Coal leaves a rail car not only because of wind, but also because of vibrations, impacts, and other forces caused by the movement of the train over the track...Moreover, these same forces can cause the thin chemical coating on top of the coal in the car to break apart so that it is no longer effective even to prevent wind-blown coal dust."), 15 ("BNSF's claim that chemical toppers are a silver bullet to prevent deposition of fugitive coal is a fantasy.").

[19] Verified Statement of Mark J. Viz, Ph.D., P.E., on behalf of Western Coal Traffic League, American Public Power Association, Edison Electric Institute and National Rural Electric Cooperative Association, in support of Opening Brief Dust II, Surface Transportation Board, Docket. No. 35557, October 1, 2012, p. 3.

e. I also note at the outset that many if not all of the dust suppressants were designed for use in dust mitigation from static coal stockpiles at coal-burning power plants or similar facilities. In this regard these products are generally recognized to work when applied to a large pile of coal ***that is stationary***, but there are still many aspects of their performance ***in moving railcars*** that have not yet been verified. I have observed from my own field work that crusting agents and other topper sprays essentially break apart when a railcar gets shaken or bumped going over the track. Frequently other events can also occur to either upset the efficacy of the topper agent or in certain cases to make the fugitive loss even worse by a process known as "saltation," i.e., the greater entrainment of particles in a moving air stream as a result of released particles impacting the surface and therefore releasing yet greater amounts of dust. The performance of suppressants during precipitation events and long exposure to wind and solar radiation are also not that well-understood.

Topping agents have a limited useful lifetime as they breakdown by ultraviolet radiation and microbes; abrasion and loss from wind erosion and motion of the train; washout by rain, and degradation of the PRB coal itself.[20] One proposed topping agent, for example, DustBind, is mostly alcohol, which is highly volatile. As noted by Dr. Viz, topping agents have been mainly studied only on stationary coal piles, not on moving trains.[21] Finally, as the topping agent would be applied at the mines, out of sight and control of both the applicant and ODEQ, it is possible that the rail cars would arrive without any topping agent at all, exposing degraded[22] coal that can be eroded by the wind or dislodged during staging. Further, evidence presented in proceedings before the Surface Transportation Board suggests that all or most of the topping agent or surfactant is lost during transit.[23] Thus, any topping agent applied at the mine would not necessarily control wind-blown dust on the trains sitting at the Terminal.

Further, the Review Report and draft Permit do not support 85% dust control. The draft Permit only requires that the "facility must only accept and transfer coal that has had a topping agent applied to all railcars prior to shipping." Permit, Conditions 6.1(d). This is a desirable condition but it is not sufficient to assure that railcar staging

[20] See, e.g., Kotchenruther 2013 ("Effectiveness of controls may wear off throughout journey, leading to more dust later in the journey.").

[21] See Western Coal Transportation League brief, at 19. Viz verified statement at 3. .

[22] See discussion of PRB coal degradation in Hossfeld and Hatt.

[23] Verified statement of Michael Nelson, a coal transportation analyst provided in support of *Arkansas Electric Cooperative Ass'n* reply brief, Dust II proceeding, Surface Transportation Board, Docket. No. FD 35557 , November 15, 2012. "Ultimately, the evidence shows that BNSF's claim that the toppers normally are intact at the destination point is unsupported, incorrect, and entitled to no weight." Further, utilities have noticed that topping agents do not make it through the trip. "Corroboration of the seriousness of enroute topper failure has been provided by coal users who have movements currently receiving treatment with safe harbor toppers. Such users have noticed that the toppers they pay for frequently don't make it all the way to the plant." Nelson, *id.* at 7.

fugitive dust is controlled by 85% at the Terminal. The draft Permit does not explain how this condition will be enforced, i.e., will a traceable loading certificate be required? Will monitoring at the site be conducted and if so, will it be able to ensure that the 85% control is being met continuously? The draft Permit also does not require any specific control efficiency anywhere, including on arrival at the Terminal nor any demonstration of 85% control. How can one judge the control efficiency at the Terminal of an agent applied at the mine? Thus, a specific control efficiency is not enforceable at the Terminal. For purposes of calculating emissions and ambient impacts, a control efficiency of zero should be assumed in calculations, as for example, to determine compliance with Condition 12.0.

The draft Permit implies that ODEQ "may" require addition of topping agent at the Terminal. However this is only optional, subject to determination by undisclosed methods in the future, if at all. Permit, Condition 6.1(h). The draft Permit, for example, requires installation of a system to apply topping agent to railcars as they enter the Terminal or covering each railcar until it enters the Unloading Building if ODEQ determines one is required based on visible emissions monitoring data and information from complaints. Permit, Condition 6.1(h). However, the draft Permit language is not practically enforceable as it leaves undefined the amount and type of visible monitoring and the number and nature of the complaints that will be required to trigger this condition.

HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation,

Plaintiffs,

v.

BNSF RAILWAY COMPANY, a Delaware corporation; CLOUD PEAK ENERGY, Inc., a Delaware corporation; PEABODY ENERGY CORPORATION; a Delaware corporation; GLOBAL MINING HOLDING CO., LLC, a Delaware limited liability company; FIRSTENERGY CORP., an Ohio corporation; AMBRE ENERGY NORTH AMERICA, INC., a Delaware corporation,

Defendants.

CIVIL No. 2:13-cv-00967-JCC

FIRST AMENDED COMPLAINT

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

INTRODUCTION

1. This is a civil suit for declaratory and injunctive relief against Defendant Burlington Northern Santa Fe Railway Company ("BNSF"), for violations of the Federal Water Pollution Control Act (commonly known as the Clean Water Act and hereinafter referred to as the CWA), 33 U.S.C. §§1251 *et seq*.

2. This action is brought pursuant to Section 505 of the CWA (Citizen Suits), 33 U.S.C. §1365.

3. As detailed below, Plaintiffs allege that BNSF has discharged coal, coal chunks, coal dust, metabolites or related byproducts of coal, and other substances or materials added to the coal including, but not limited to, surfactants and suppressants, and petroleum coke ("petcoke") and its byproducts (collectively, hereinafter, "coal pollutants") into waters of the United States, including the Puget Sound and other waterbodies in and around the Seattle area as well as throughout the State of Washington.

4. These discharges have not been permitted under the CWA, so that each discharge violates §301(a) of the CWA, 33 U.S.C. §1311(a).

5. In addition, BNSF is likely to continue to violate the CWA by discharging, from a point source, coal pollutants into the waters of the United States.

6. Plaintiffs seek a declaratory judgment, injunctive relief, remedial relief, the imposition of civil penalties, and the award of costs, including attorney and expert witness fees.

JURISDICTION

7. This Court has subject matter jurisdiction over the claims specified in this Complaint pursuant to 33 U.S.C. §1365(a) and 28 U.S.C. §1331. The relief requested is authorized pursuant to 33 U.S.C. §§1319 and 1365(a), and 28 U.S.C. §§ 2201 and 2202.

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

8. In compliance with 33 U.S.C. §1365(b)(1)(A), on April 2, 2013, Plaintiffs gave notice of the violations specified in this complaint and of their intent to file suit to the Defendant, to the Administrator of the United States Environmental Protection Agency (EPA), to the Regional Administrator of the EPA, and to the State of Washington. On May 9, 2013, Plaintiffs supplemented their Notice of Intent to Sue by adding Spokane Riverkeeper and Natural Resources Defense Council as Notifiers. A copy of the notice letters are attached hereto as Exhibits A & B, respectively, and all details and allegations in the notice letters are incorporated by reference.

9. Sixty days have passed since the notices were served, and the violations complained of in the notice letters are continuing at this time, or are reasonably likely to continue. Defendant remains in violation of the CWA. Neither the EPA nor the Washington Department of Ecology (WADOE) has commenced or is diligently prosecuting a civil or criminal action to redress the violations.

VENUE

10. Venue is appropriate pursuant to Section 505(c)(1) of the CWA, 33 U.S.C. §1365(c)(1), because the sources of the violations complained of have occurred in the District.

PARTIES

Plaintiffs

11. Plaintiffs are seven not-for-profit organizations comprised, in part, of members who live, work, and recreate in the state of Washington. Plaintiffs share similar interests in the protection and preservation of regional water bodies and wild spaces.

Sierra Club

12. Plaintiff Sierra Club is a nonprofit corporation incorporated and headquartered in

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

California, with a regional office located in Seattle and members throughout the State of Washington. Sierra Club is dedicated to exploring, enjoying, and protecting the wild places of the Earth; to practicing and promoting the responsible use of the Earth's resources and ecosystems; to educating and enlisting humanity to protect and restore the quality of the natural and human environment; and to using all lawful means to carry out these objectives. Sierra Club's concerns encompass the protection and restoration of the water quality of the waters of the U.S. within the state of Washington, including the Puget Sound, the Columbia River, and all life connected to these waterbodies, from their headwaters to the Pacific Ocean. Sierra Club has more than 600,000 members nationwide, including over 21,000 in Washington, and brings this action on behalf of itself and its affected members. Sierra Club members reside, work, travel and recreate next to and in the general vicinity of BNSF's railroad tracks in Washington and the waterways into which defendants discharge pollutants. The environmental, health, aesthetic, and recreational interests of Sierra Club members have been, are being, and will be adversely affected by Defendant's illegal coal and petroleum coke pollutant discharges into waters of the United States. Members of Sierra Club use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

13. Sierra Club's members live within the impacted watersheds; recreate by fishing, rafting, hiking, plant gathering, walking, windsurfing, sailing, photographing, and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Puget Soundkeeper

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

14. Puget Soundkeeper 's mission is to protect and preserve the water of Puget Sound by monitoring, cleaning up and preventing pollutants from entering its waters. Puget Soundkeeper is headquartered in Washington with offices in Seattle. Puget Soundkeeper's approximately 1,400 members reside, among other places, throughout the State of Washington, particularly next to and in the general vicinity of BNSF's railroad tracks and the waterways into which defendants discharge pollutants.

15. The environmental, health, aesthetic, and recreational interests of Puget Soundkeeper members have been, are being, and will be adversely affected by Defendant's illegal coal pollutant discharges into waters of the United States. Members of Puget Soundkeeper use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

16. Puget Soundkeeper's members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, sailing, windsurfing, photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

RE Sources for Sustainable Communities

17. RE Sources for Sustainable Communities promotes sustainable communities through recycling, education, advocacy, and conservation of natural resources. RE Sources is based in Washington with offices in Bellingham. RE Sources for Sustainable Communities' approximately 5,200 members reside, among other places, throughout the State of Washington next to and in the general vicinity of BNSF's railroad tracks and the waterways into which

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

defendants discharge pollutants.

18. The environmental, health, aesthetic, and recreational interests of RE Sources for Sustainable Communities members have been, are being, and will be adversely affected by Defendant's illegal coal pollutant discharges into waters of the United States. Members of RE Sources for Sustainable Communities use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

19. RE Sources for Sustainable Communities' members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, windsurfing, sailing, photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Columbia Riverkeeper

20. Columbia Riverkeeper's mission is to restore and protect the water quality of the Columbia River and all life connected to it, from the headwaters to the Pacific Ocean. To achieve these objectives, Riverkeeper operates scientific, educational, and legal programs aimed at protecting water, quality, air quality, and habitat in the Columbia River Basin. Columbia Riverkeeper's over 3000 members reside, among other places, throughout the State of Washington next to and in the general vicinity of BNSF's railroad tracks and the waterways into which defendants discharge pollutants.

21. The environmental, health, aesthetic, and recreational interests of Columbia Riverkeeper's members have been, are being, and will be adversely affected by Defendant's

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

illegal coal pollutant discharges into waters of the United States. Members of Columbia Riverkeeper use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

22. Columbia Riverkeeper's members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, windsurfing, photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Friends of the Columbia Gorge

23. Friends of the Columbia Gorge seeks to vigorously protect the scenic, natural, cultural, and recreational resources of the Columbia River Gorge. Friends of the Columbia Gorge's approximately 5,000 members reside, among other places, throughout the State of Washington next to and in the general vicinity of BNSF's railroad tracks and the waterways into which defendants discharge pollutants.

24. The environmental, health, aesthetic, and recreational interests of Friends of the Columbia Gorge members have been, are being, and will be adversely affected by Defendant's illegal coal pollutant discharges into waters of the United States. Members of Friends of the Columbia Gorge use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

Friends of the Columbia Gorge's members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, windsurfing,

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Spokane Riverkeeper

25. Spokane Riverkeeper is a program of the Center for Justice, which is a Spokane-based, for-impact legal advocacy organization. Spokane Riverkeeper's mission is to protect and restore the health of the Spokane River watershed. Spokane Riverkeeper seeks to accomplish its mission through collaboration, education, and, where necessary, litigation. Spokane Riverkeeper's first priority is to defend the Spokane River, a tributary of the Columbia River, against pollution and polluters.

26. Spokane Riverkeeper's approximately 1200 members reside, among other places, throughout the State of Washington next to and in the general vicinity of BNSF's railroad tracks and the waterways into which defendants discharge pollutants.

27. The environmental, health, aesthetic, and recreational interests of Spokane Riverkeeper members have been, are being, and will be adversely affected by Defendant's illegal coal pollutant discharges into waters of the United States. Members of Spokane Riverkeeper use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

28. Spokane Riverkeeper's members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, windsurfing, photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Natural Resources Defense Council

29. Natural Resources Defense Council (NRDC) is a national, not-for-profit membership corporation that is dedicated to the preservation, protection, and defense of the environment, public health, and natural resources. NRDC has long been active in working to protect water quality and specifically, enforcement of the Clean Water Act.

30. NRDC has more than 363,700 members nationwide, including approximately 14,600 members who reside throughout the State of Washington next to and in the general vicinity of BNSF's railroad tracks and the waterways into which defendants discharge pollutants.

31. The environmental, health, aesthetic, and recreational interests of NRDC members have been, are being, and will be adversely affected by Defendant's illegal coal pollutant discharges into waters of the United States. Members of NRDC use and enjoy the waters and lands into and onto which Defendant's railcars discharge, including waters in the immediate vicinity of, and downstream from, Defendant's discharges into waters of the United States.

32. NRDC 's members live within the impacted watersheds; recreate, or would recreate, by fishing, rafting, hiking, plant gathering, walking, windsurfing, photographing and boating in and around the impacted waters; observe and enjoy wildlife in the watershed around Defendant's discharges; and retain an aesthetic and health interest in the health and restoration of the impacted waters in the vicinity of Defendant's railroad tracks and railcars.

Defendants

Burlington Northern Santa Fe Railway Company ("BNSF")

33. BNSF Railway has a rail network of 32,500 route miles in 28 states and two Canadian provinces. BNSF owns and operates rail lines throughout the state of Washington and along the

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

Columbia River along the Washington/Oregon border. In 2012, BNSF hauled 2.2 million coal shipments. In 2012, BNSF reported that its coal business unit was responsible for nearly one-quarter--$4.8 billion--of the company's $20 billion total freight revenue, and that more than 90% of the coal hauled by BNSF comes from the Powder River Basin.

34. BNSF transports coal from, *inter alia*, the Powder River Basin across waterways via routes in the center and south of Washington to locations throughout Washington and sometimes continuing into Canada. The coal transport trains travel along, among other waterways, the Columbia River and the Puget Sound.

STATUTORY AND REGULATORY FRAMEWORK

35. Under the CWA, the United States has committed itself "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," including establishing a "national goal that the discharge of pollutants into the navigable waters be eliminated." CWA § 101, 33 U.S.C. §1251.

36. Pursuant to the CWA, a discharge of a pollutant means "any addition of any pollutant to navigable waters from any point source," and "any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft." CWA § 502(12), 33 U.S.C. § 1362(12). *See also* CWA § 502(7), 33 U.S.C. § 1362(7) (definition of "navigable waters"); 40 CFR § 122.2 (definition of "waters of the U.S.").

37. The CWA specifies a number of materials and wastes that, if discharged into water, render them pollutants, including, but not limited to, solid waste, chemical wastes, industrial waste, biological materials, sand, and rock. CWA § 502(6), 33 U.S.C. § 1362(6).

38. Under the Clean Water Act, the term "point source" means "any discernible, confined and discrete conveyance, including but not limited to any . . . container [or] rolling stock. . .from

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

which pollutants are or may be discharged." CWA § 502(14), 33 U.S.C. § 1362(14).

49. To advance its goals, Congress established in the CWA that all discharges of pollutants are prohibited "except in compliance" with specified provisions of the CWA including, most importantly, the National Pollutant Discharge Elimination System (NPDES) permitting program. CWA § 301(a), 33 U.S.C. §1311(a); CWA § 402(a), 33 U.S.C. §1342(a); 40 CFR §§122.1 *et seq*.

50. The NPDES program requires a potential discharger to first obtain a NPDES permit that limits the type and quantity of pollutants to be released so as to maintain water quality standards, among other objectives. CWA § 402(a), 33 U.S.C. §1342(a); 40 CFR §122.1. No NPDES permit may be issued where discharges pursuant to it would cause receiving water-bodies to fail to meet water quality standards. *Id*. and 40 CFR §122.4 (prohibitions on permit issuance). Unless done pursuant to a NPDES permit, any coal pollutant discharge from a rail car or train into navigable waters of the U.S. is prohibited under the CWA.

FACTS

Pollutants Being Discharged

51. Defendant, by its ownership, operation, lease of, participation in, contract for, or receipt of material from, trains and rail cars transporting coal, petcoke, and their byproducts (hereinafter, "coal"), has discharged, is discharging, and will continue to discharge coal pollutants to waters of the U.S. within the State of Washington.

52. Such coal pollutants include, but are not limited to, coal, coal chunks, coal dust, coal contaminated water, metabolites or related by-products of coal, surfactants applied to the coal, coal chunks and coal dust, petcoke, petcoke chunks, petcoke dust, petcoke contaminated water, and suppressants.

Discharge Events

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

53. Defendant has discharged, is discharging, and will continue to discharge coal pollutants into waters of the U.S. by each and every one of the Defendant's trains and rail cars that carry coal.

54. Each and every train and each and every rail car discharges coal pollutants to waters of the United States when traveling adjacent to, over, and in proximity to waters of the United States.

55. For example, on Sunday, July 21, 2013, at approximately 8:05 a.m., a west-bound BNSF coal train, while crossing the point of confluence of the White Salmon River and Columbia River approximately one mile west of White Salmon, Washington, discharged a significant quantity of coal particles into the White Salmon and Columbia Rivers.

56. Defendant discharges coal pollutants into waters of the U.S. within the State of Washington through holes in the bottoms and sides of the rail cars and by spillage or ejection from the open tops of the rail cars and trains.

57. Defendant discharges coal pollutants during the transportation of the coal in both normal and abnormal operating conditions, and upon loading and unloading coal.

58. Defendant's discharges of coal pollutants from the container or rolling stock point sources are especially frequent or severe when their coal trains pass over rough rail tracks, track changes, bridges, and switches; during transportation of coal over bumpy terrain, in windy conditions, at high operating speed, during steep descents and ascents and through sag-areas spanning steep ascent and descent reaches of track (or vice versa); during and after precipitation events; at moments of high crosswinds; and during derailments.

59. Defendant's coal pollutant discharges occur despite the use of topping agents, surfactants or suppressants, and these topping agents, surfactants and suppressants themselves are pollutants

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

discharged by Defendant.

60. The specific dates, times, amounts, and exact or approximate locations, along with, for example, the rail conditions, rail car conditions, design and performance of rail cars, weather conditions, passing trains, loading and unloading practices employed, and incline or decline of railways in specific locations of the discharges during each of the years 2008 through the present are, or should be, in the possession of the Defendant.

Waters Affected

61. Waters of the U.S. are located in, in proximity to, or run through the State of Washington and receive Defendant's coal pollutant discharges where defendant BSNF-operated rail lines and rail cars pass by, cross, or are in proximity to such waters.

62. Defendant has discharged, is discharging, and will continue to discharge pollutants from point sources into waters of the United States, including, but not limited to, rivers, streams, lakes, ponds, coulees, estuaries, bays, sounds, canals, shipping canals, fresh water and tidal wetlands, and coastal waters of the Pacific Ocean. These waters derive water from, are tributaries to, forks of, and/or exchange water with many of the waters in the State of Washington, many of which are navigable waters and all of which eventually discharge into the Pacific Ocean.

63. Waters impacted by Defendant's coal pollutant discharges include, but are not limited to, the Puget Sound, Columbia River, Alder Creek, Ashes Lake, Bass Lake, Beckie River, Beckler River, Chamberlain Lake, Chiwawa River, Chuckanut Bay, Coal Creek, Cow Creek, Cowlitz River, Coweeman Confluence, Crab Creek, Crah Creek, Dakota Creek, Dead Canyon, Deschutes River, Drano Lake, East Low Canal, Elliott Bay, Esquatzel Coulee, Franz Lake, Glade Creek, Green River, Grant Lake, Hangman Creek (also known as Latah Creek), Hewett Lake, Horsethief Lake, Howard Hanson Reservoir, Kalama River, Klickitat River, Lake Union, Lewis

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

River, Little White Salmon River, Little Spearfish Lake, Look Lake, Locke Lake, Newaukum River, Nisqually River, Nooksack River, North Fork – Skykomish River, Pilchuk Creek, Pilchuk River, Possession Sound, Quilceda Creek, Rock Cove, Rowland Lake, Salmon Creek, Samish River, Shilshole Bay, Skagit River, Skookumchuck River, Skykomish River, Snake River, Snohomish River, South Fork – Skykomish River, Spokane River, Status Creek, Steamboat Slough, Stillaguamish River, Stuck River, Sultan River, Teanaway River, Toppenish Creek, Toutle River, Union Slough, Wallace River, Washougal River, Wenatchee River, West Canal, White Salmon River, Wind River, Yakima River and their tributaries.[1]

Discharges Unpermitted Under the CWA

64. Defendant has never obtained a NPDES permit allowing its discharges of coal pollutants into State of Washington waterbodies from rail cars and trains. Moreover, the types of discharges that have occurred, are occurring and that are likely to continue to occur are not permitted under federal law.

65. Defendant intends to continue loading and transporting coal and petcoke and related coal pollutants by rail to and through the State of Washington.

ALLEGATIONS

66. Plaintiffs hereby incorporate by reference all preceding paragraphs.

67. Section 301(a) of the CWA, 33 U.S.C. §1311(a), prohibits the discharge of pollutants from a point source into navigable waters of the United States, unless pursuant to the terms of a NPDES permit issued pursuant to Section 402 of the CWA, 33 U.S.C. §1342.

[1] Plaintiffs note that this list is inclusive of some waterways in the Eastern District of Washington, some in the Western District of Washington, and some that flow through both the Western and Eastern Districts of Washington. Plaintiffs have filed a similar action in the Eastern District of Washington and intend to move for consolidation, but, recognizing that some of the waterways overlap Districts, include one list of impacted waterways here for reference.

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

68. Defendant has discharged coal pollutants in contravention of CWA §301, as described herein, during rail transport of coal, since at least April 2008, and such discharges are presently ongoing and likely to continue.

COUNT 1

Discharge of Pollutants Without NPDES Permit into Waters of United States

69. All waterways named herein are waters of the United States protected by the CWA.

70. Defendant did not have and does not retain a NPDES Permit authorizing its discharges of coal pollutants into such waterways.

71. Defendant has discharged coal pollutants from the operation of rail cars and trains into, at least, the listed waterways from April 2008 (and for many years prior to 2008) to present. Such operations and discharges are continuing and are likely to continue into the future.

72. Each such coal discharge from each rail car and train into each separate waterway on each separate day constitutes a separate violation of the CWA.

RELIEF REQUESTED

WHEREFORE, Plaintiffs respectfully request that this Court grant Plaintiffs the following relief:

A. Issue a declaratory judgment that Defendant has violated and continues to violate the CWA;

B. Issue a declaratory judgment that each rail car container constitutes a separate point source;

C. Issue a declaratory judgment that each separate discharge into each waterway constitutes a separate violation;

C. Enjoin Defendant from operating rail cars and trains in such a manner as will result in further violation of the CWA;

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

D. Enjoin Defendant's use of uncovered rail cars for any transport of coal;

E. Enjoin Defendant's use of rail cars that, through design or imperfection – including holes or openings in their sides or bottoms—allow coal pollutants to be discharged into waters of the U.S;

F. Order Defendant to remove coal pollutants that are in-place or otherwise recoverable from receiving water-bodies;

G. Order Defendant to pay civil penalties of up to $37,500 per day for each violation of the CWA, pursuant to Sections 309(d) and 505(a) of the CWA, 33 U.S.C. §§1319(d) and 1365(a), and 40 C.F.R. § 19 *et seq.*, including those identified in Plaintiff's notice letters, violations identified during discovery, and violations committed subsequent to those identified in this Complaint;

H. Order Defendant to monitor and report their coal pollutant discharges to the federal Environmental Protection Agency and the State of Washington Department of Ecology;

I. Order Defendant to provide Plaintiff, for a period beginning on the date of the Court's order and running for five years after defendants achieve compliance with the CWA with a copy of all reports and other documents which defendants submit to EPA, to the Regional Administrator of the EPA, or to the State of Washington regarding Defendant's coal pollutant discharges at the time these documents are submitted to these authorities;

J. Issue a remedial injunction ordering Defendant to pay the cost of any environmental restoration or remediation deemed necessary and proper by the Court to comply with the Clean Water Act and ameliorate the water degradation caused by Defendant's violations;

K. Award Plaintiffs their costs, including reasonable attorney and expert witness fees, as authorized by 33 U.S.C. §1365(d) and 28 U.S.C. §2412(d); and

Andrea K. Rodgers Harris
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: 206-696-2851

Charles M. Tebbutt
Daniel M. Galpern
(*pro hac vice* pending)
Law Offices of Charles M. Tebbutt, PC
941 Lawrence St.
Eugene, OR 97401
Tel: 541-344-3505

Additional Plaintiffs' Counsel on signature page

L. Award such other relief as this Court deems appropriate.

Respectfully submitted this 29th day of July,

/s/ Charles M. Tebbutt
CHARLES M. TEBBUTT (*pro hac vice* forthcoming)
DANIEL M. GALPERN (*pro hac vice* forthcoming)
Law Offices of Charles M. Tebbutt, P.C.
941 Lawrence St.
Eugene, OR 97401
Tel: (541) 344-3505
E-mails: charlie.tebbuttlaw@gmail.com
galpern.tebbuttlaw@gmail.com

Counsel for Plaintiffs except for Natural Resources Defense Council

/s/ Andrea K. Rodgers Harris
ANDREA K. RODGERS HARRIS
WA Bar #38683
Of Counsel
Western Environmental Law Center
2907 S. Adams Street
Seattle, WA 98108
Tel: (206) 696-2851
E-mail: akrodgersharris@yahoo.com

Local Counsel for Plaintiffs

/s/ Jessica Yarnall Loarie
JESSICA YARNALL LOARIE (*pro hac vice* forthcoming)
Sierra Club Environmental Law Program
85 Second St, 2nd Floor
San Francisco, CA 94105
Tel: (415) 977-5636
E-mail: jessica.yarnall@sierraclub.org

Counsel for Plaintiff Sierra Club

/s/ David Pettit
DAVID PETTIT (*pro hac vice* forthcoming)
MORGAN WYENN (*pro hac vice* forthcoming)
Natural Resources Defense Council
1314 Second Street
Santa Monica, CA 90401
Tel: (310) 434-2300
E-mails: dpettit@nrdc.org
mwyenn@nrdc.org

Counsel for Plaintiff Natural Resources Defense Council

CERTIFICATE OF SERVICE

I hereby certify that on JULY 29, 2013, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system, which will automatically send notification of such filing to the following:

Lily N. Chinn
Beveridge & Diamond PC
456 Montgomery St., Ste 1800
San Francisco, CA 94104
Tel: (415) 262-4012
lchinn@bdlaw.com

Denise L. Ashbaugh
Summit Law Group PLLC
315 Fifth Avenue S., Ste. 1000
Seattle, WA 98104
Tel: (206) 676-7000
denisea@summitlaw.com

Timothy M. Sullivan
Beveridge & Diamond PC
201 N. Charles Street, Ste. 2210
Baltimore, MD 21201
Tel: (410) 230-1355
tsullivan@bdlaw.com

Andrew C. Emrich
Holland & Hart LLP
2515 Warren Ave., Ste. 450
P.O. Box 1347
Cheyenne, WY 82001
Tel: (307) 778-4219
acemrich@hollandhart.com

Steven G. Jones
Marten Law Group
1191 Second Ave., Ste. 2200
Seattle, WA 98101
Tel: (206) 292-2629
sjones@martenlaw.com

Svend A. Brandt-Erichsen
Marten Law Group
1191 Second Ave., Ste. 2200
Seattle, WA 98101
Tel: (206) 292-2611
svendbe@martenlaw.com

s/ Daniel M. Galpern
DANIEL M. GALPERN (pro hac vice)
Law Offices of Charles M. Tebbutt, P.C.
941 Lawrence St.
Eugene, OR 97401
Tel: (541) 344-3505
galpern.tebbuttlaw@gmail.com

EXHIBIT A

Law Offices of Charles M. Tebbutt, P.C.
941 Lawrence Street
Eugene, OR 97401
Ph: 541-344-3505 Fax: 541-344-3516

April 2, 2013

CERTIFIED MAIL, RETURN RECEIPT REQUESTED

Matthew K. Rose, Chairman & CEO
BNSF Railway Company, *a division of*
Burlington Northern Santa Fe, LLC
2650 Lou Menk Drive
Fort Worth, TX 76131-2830

Colin Marshall, President & CEO
Cloud Peak Energy
385 Interlocken Crescent, Suite 400
Broomfield, CO 80021

Gregory H. Boyce, Chairman & CEO
Peabody Energy
Peabody Plaza
701 Market St.
St. Louis, MO 63101-1826

Global Mining Holding Co., LLC
Reg. Agent: Corporation Service Company
2711 Centerville Rd, Ste. 400
Wilmington, DE 19808

John W. Eaves, President & CEO
Arch Coal, Inc.
One City Place Drive, Ste. 300
St. Louis, MO 63141

Anthony J. Alexander, President & CEO
FirstEnergy Corp.
76 South Main Street
Akron, OH 44308

Everett King, President & CEO
Ambre Energy North America, Inc.
170 South Main Street, Ste. 700
Salt Lake City, UT 84101

Paul Taylor, President
TransAlta USA Inc.
724 Columbia Street NW, Ste. 320
Olympia, WA 98501

Re: Notice of Intent to Sue under §505 of the Federal Water Pollution Control Act

Dear Sirs and Madams:

This letter is to provide you with notice that the Sierra Club, Inc., Puget Soundkeeper Alliance, Columbia Riverkeeper, Friends of the Columbia Gorge, and RE Sources for Sustainable Communities ("Notifiers") intend to file a citizen lawsuit against Burlington Northern Santa Fe Railroad Company ("BNSF"), and Peabody Energy, Arch Coal, Ambre Energy, Cloud Peak Energy, Transalta and First Energy ("Coal Companies") (BNSF and Coal Companies are hereafter collectively called "Dischargers"), who discharge coal, coal chunks, coal dust, metabolites or related byproducts of coal, and other substances or materials added to the coal including, but not limited to, surfactants and suppressants, and petroleum coke ("petcoke") and its byproducts (collectively hereafter "pollutants") into waters of the United

EXHIBIT A

States throughout the State of Washington. Waters of the U.S. are under or in proximity to the rail lines and rail cars such that pollutants discharge into them from the rail cars. This lawsuit will be brought pursuant to Section 505(a)(1)(A) of the Federal Water Pollution Control Act (commonly known as the "Clean Water Act" (CWA)), 33 U.S.C. §1365(a)(1)(A). Upon the expiration of the sixty (60) day statutory waiting period, Notifiers intend to file a civil action or actions in federal district court.

VIOLATIONS OF FEDERAL LAW

This lawsuit will allege that the Dischargers have violated, are violating, and will continue to violate the Clean Water Act as the discharge of pollutants is unpermitted, and potentially unpermittable, under the Clean Water Act ("CWA"). The discharges also constitute fill material, some of which remains present and visible in areas within the vicinity of the train tracks running on or near wetlands, streams, rivers and other areas subject to CWA jurisdiction. Coal Companies own the coal, and the resultant pollutants, that are transported via rail lines through and within the State of Washington. BNSF operates rail lines in the State of Washington, which rail lines the Coal Companies use for coal transport, and are also used for transporting petroleum coke. Coal Companies, as owners, and BNSF as operator, are persons subject to the requirements of the Clean Water Act. Rail trains and rail cars ("rolling stock") are considered point sources under the Clean Water Act. 33 U.S.C. §1362(14). The point sources include, but are not limited to, each and every train and rail car transporting coal.

The Dischargers have discharged, are discharging, and will continue to discharge pollutants from point sources into waters of the United States, including, but not limited to, rivers, streams, lakes, ponds, coulees, estuaries, bays, sounds, canals, shipping canals, fresh water and tidal wetlands, and coastal waters of the Pacific Ocean. The list of waters of the United States into which the pollutants are discharged is extensive, spanning much of the State of Washington and are named in part below. These waters derive water from, are tributaries to, forks of, and/or exchange water with many of the waters in the State of Washington, many of which are navigable waters and all of which eventually discharge into the Pacific Ocean. The Dischargers have violated, are violating, and will continue to violate the Clean Water Act by illegally discharging pollutants into waters of the United States.

POLLUTANTS BEING DISCHARGED

The pollutants that the Dischargers have discharged, are discharging, and will continue to discharge include, but are not limited to, coal, coal chunks, coal dust, metabolites or related by-products of coal, surfactants applied to the coal, coal chunks and coal dust, petcoke, petcoke chunks, petcoke dust, and suppressants. All pollutants being discharged not set forth specifically in this letter are violations that are or should be known to the Dischargers and may be included in any future legal actions by Notifiers. Such pollutants may only be known to Dischargers and eyewitnesses who are yet to be determined because such discharges have not been reported by Dischargers.

DISCHARGE EVENTS

The Dischargers have discharged, are discharging, and will continue to discharge pollutants to waters of the U.S. by each and every one of the Dischargers' trains, and each and every one of the Dischargers' rail cars. Each and every train and each and every rail car discharges pollutants to waters of the United States when travelling adjacent to, over, and in proximity to waters of the United States. The information concerning the specific dates, amounts, and exact or approximate locations, along with, for example, the rail conditions, rail car conditions, design and performance of rail cars, weather conditions, passing trains, loading practices employed, and incline or decline of railways in specific locations of the discharges during each of the years 2008 through the present are, or should be, in the possession of the Dischargers. Since the Dischargers' entire files are not available to the Notifiers, this information remains exclusively within the control of the Dischargers and, consequently, Notifiers cannot be expected to provide all details of discharge times, locations, or amounts.

By Dischargers' own testimony before the Surface Transportation Board (STB), which testimony is publicly available, each rail car loses between 250 and 700 pounds of coal and coal dust[1] on each trip for an average loss of 500 pounds of coal lost from each car per trip.[2] For trains with 120 cars—the typical length of a coal train—over 30 tons of coal is lost each trip.[3] In other studies, again according to BNSF, as much as three percent of the coal in each car (around 3,600 lbs. per car) can be lost in the form of dust.[4] Furthermore, BNSF's own testimony indicates that in 2008, a limited "cleanup" was attempted near certain streams and waterways, and over 300 rail cars of coal deposits were removed.[5] Evidence indicates that the coal obtained from the Powder River Basin is generally sub-bituminous coal, and can produce a finer dust than other sources of U.S. coal;[6] thus, the behavior of the Powder River Basin coal may exceed the average coal dust loss per transport.

The Notifiers believe in good faith that numerous factors contribute to the discharge of coal, coal chunks, coal dust, metabolites or related byproducts of coal, surfactants, and other substances or materials added to the coal and petcoke into waters of the U.S. First, rail cars used for transporting coal and petcoke are open-top, that is to say that they are not covered or enclosed, but are open to the air. Passing over rough rail tracks, track changes, bridges, and switches causes rail cars to vibrate and chunks of coal, coal dust and petcoke are shaken out of rail cars.[7] Loading coal above the top of a rail car, and transporting coal over windy and bumpy

---

[1] Hearing Transcript and Recording, July 29, 2010, *Arkansas Electric Cooperative Association – Petition for Declaratory Order*, Surface Transportation Board, Docket No. FD 35305, tape 1 at Transcript (Tr.) at 102:9-103:7.
[2] Id. at tape 1 at 37:07, 1h:42; Tr. at 42:5-13, 102:9-103:7 (BNSF Testimony).
[3] Id. An average of 500 lbs./car x 120 cars/train=60,000 lbs. or 30 tons.
[4] Burlington Northern Santa Fe Railway, "Coal Dust FAQ," March 2011. Available at http:// www.coaltrainfacts.org/docs/BNSF-Coal-Dust-FAQs1.pdf.
[5] Id. at Tape 1 at 40:30. Tr. at 45: 13-19 (Testimony of Gregory Fox, Vice President of Transportation for BNSF) "In 2008, BNSF did a very limited clean up of coal dust around waterways and we removed over 300 rail cars of coal dust; 1.58 million tons as shown on the chart would equate to 14,000 rail cars of coal dust that needs to be removed from the joint line, obviously, an extreme condition.". Fox continued: "oftentimes we'll load in rail cars and take it to a disposal site. Other times, frankly, we will put it on to the right of way roads well away from the track structure." Tape 1h:54; Tr. at 114:16-115:8..
[6] Id. at Tape 1 at 10:46, Tr. 17:1-16.
[7] *See, e.g.*, Id. at Tape 2, 4:10; Tr. at 161:13-164: 9.

terrain leads to further coal loss.[8] When combined with high operating speeds, which are known to occur, the chances of coal falling out increases.[9] Second, the discharge of pollutants is pervasive regardless of the terrain, but discharges are even more pronounced on the descending side of an incline. Such descents occur, among other places, in the Cascade Mountains. Coal loss accumulations are higher in pronounced descents and pronounced ascents, and places where a rail line crosses perpendicular to a valley.[10] The same topographic features which cause coal and petcoke to fall out of rail cars also put the rail cars in proximity to waterways when discharges occur.[11] Third, bridges are frequently located at the bottom of "big sags" or pronounced descents, and Dischargers have identified these locations as having high accumulations of coal and petcoke discharges, due in part to the slack action shock waves throughout the train caused by braking on descent and then accelerating to ascend.[12] This shock wave redistributes coal and petcoke in the open-top rail car and causes chunks of coal and petcoke to fall out.[13] Fourth, by design, performance, age, or other factors, rail cars have holes in the sides, bottoms and other places. Rail cars are not watertight, which results in the discharge of pollutants. Discharges from holes in the rail cars are exacerbated in precipitation-related events, which are frequent and regular occurrences for much of the year, particularly west of the Cascade Mountains. Fifth, when there are crosswinds, or winds created from passing trains, more pollutants are discharged. Finally, the use of topping agents such as surfactants is not required. Further, even if topping agents are applied, it is not effective to fully prevent coal and petcoke discharge into waterways.[14] Surfactants themselves are also pollutants and, if applied, would be discharged from the rail cars.

Coal dust has also been shown to be a cause of rail bed instability and derailments, which can pose a significant public safety hazard, as discussed in a recent proceeding before the Surface Transportation Board (STB), which found coal dust to be "a pernicious ballast foulant."[15] "Coal dust, even in small amounts, poses a real threat to the integrity of the ballast section and track stability."[16] Coal train derailments pose a threat to human health and safety and constitute Clean Water Act violations when they spill coal into waterways. Derailments occur on an intermittent, but expected, basis and will likely continue to occur. All discharges resulting from derailments are subject to anticipated action by Notifiers.

---

[8] Id. at Tape 1, 2h:18.; Tr. at 141:4-142:14.
[9] Id. at Tape 2, 9:00; Tr. at 165:10-166:122.
[10] *See, e.g.*, Id. at Tape 2, 4:10; Tr. at 161:13-164:9
[11] Id., Tape 2 at 8:00; 164:22-165:9.
[12] Id., Tape 2 at 9:00.; Tr. at165:10-166: 22.
[13] Id.
[14] While BNSF has a voluntary mandate encouraging the use of surfactants, the Surface Transportation Board (STB) proceedings evaluating that practice are ongoing. In the absence of binding regulation, over 70% of coal shippers are electing not to apply any sort of topping agent or surfactant. *See Some shippers not complying with BNSF coal dust tariff,* Platts Energy Week, November 3, 2011, accessed http://www.wusa9.com/news/local/story.aspx?storyid=173329
[15] *See* Surface Transportation Board Decision, *Re: Ark Arkansas Electric Cooperative Corporation - Petition for Declaratory Order*, Docket No. FD 35305 (Mar. 3, 2011) (available at http://www.stb.dot.gov/decisions/readingroom.nsf/WebDecisionID/40436?OpenDocument).
[16] *See* Testimony of Gregory Fox Vice President of Transportation for BNSF, Surface Transportation Board Hearing Transcript ("STB Hearing Transcript"), *Re: Arkansas Electric Cooperative Corporation – Petition for Declaratory Order*, Docket No. FD 35305 (July 29, 2010), Tape 42:06; Tr. 46:18-20.

WATERS AFFECTED

The waters of the U.S. that are located in, in proximity to, or which run through the State of Washington at issue in this notice and which pollutants reach are numerous. BNSF's northern route for transportation of coal runs from Spokane through Odessa, Ephrata, Wenatchee, to Everett and down to Seattle. BNSF's southern route for transportation of coal runs from Spokane, through Pasco and then west to Vancouver, Washington. BSNF may also transport coal from the Seattle – Everett area north to Vancouver, British Columbia. All throughout the State of Washington, where the rail lines and rail cars pass by, cross, or are in proximity to waters of the United States, pollutants are discharged and remain present in the waters. At a minimum, these waters include, but are in no way limited to, the Columbia River, Puget Sound, Alder Creek, Ashes Lake, Bass Lake, Beckie River, Beckler River, Chamberlain Lake, Chiwawa River, Chuckanut Bay, Coal Creek, Cow Creek, Cowlitz River, Coweeman Confluence, Crab Creek, Crah Creek, Dakota Creek, Dead Canyon, Deschutes River, Drano Lake, East Low Canal, Elliott Bay, Esquatzel Coulee, Franz Lake, Glade Creek, Green River, Grant Lake, Hangman Creek, Hewett Lake, Horsethief Lake, Howard Hanson Reservoir, Kalama River, Klickitat River, Lake Union, Lewis River, Little White Salmon River, Little Spearfish Lake, Look Lake, Locke Lake, Newaukum River, Nisqually River, Nooksack River, North Fork – Skykomish River, Pilchuk Creek, Pilchuk River, Possession Sound, Quilceda Creek, Rock Cove, Rowland Lake, Salmon Creek, Samish River, Shilshole Bay, Skagit River, Skookumchuck River, Skykomish River, Snake River, Snohomish River, South Fork – Skykomish River, Spokane River, Status Creek, Steamboat Slough, Stillaguamish River, Stuck River, Sultan River, Teanaway River, Toppenish Creek, Toutle River, Union Slough, Wallace River, Washougal River, Wenatchee River, West Canal, White Salmon River, Wind River, Yakima River and their tributaries. See Appendix A for dates of examples of violations and photographic representations of violations.

DISCHARGES UNLAWFUL

Section 301 of the Clean Water Act, 33 U.S.C. §1311(a), prohibits the discharge of any pollutant from a point source into waters of the United States unless such discharge is authorized pursuant to a National Pollutant Discharge Elimination System ("NDPES") permit issued pursuant to Section 402 of the Act and/or a dredge and fill permit issued pursuant to Section 404 of the Act. The Dischargers have never obtained a NPDES permit or dredge and fill permit for such discharges. The types of discharges that have occurred, are occurring and that are likely to continue to occur are not permitted under federal law. As Dischargers plan to continue loading and transporting coal and petcoke in the current methods and manners, the Dischargers are continuing, and will continue, to illegally discharge pollutants into waters of the United States without a NPDES permit or a dredge and fill permit.

HISTORY OF VIOLATIONS

Notifiers believe and allege that a history of violations has continued from at least April 2008 (and for many years prior to 2008) and that violations are presently ongoing and continuous. These violations have occurred, are occurring, and will continue to occur on a regular basis (daily, or multiple times per week or per month), during transportation of each coal or petcoke shipment, at virtually all locations where waters of the U.S. are present, along the rail

transportation routes in the State of Washington (as well as other areas along the rail lines). All violations not set forth specifically in this letter, including specific dates and locations of such discharges, are violations that are or should be known to the Dischargers and may be included in any future legal actions by Notifiers. All specific discharges discovered subsequent to the sending of this notice, of similar type and nature, whether occurring prior or subsequent to this notice, shall be included in the action in this case without the need for further notice under 33 U.S.C. §1365(b). Such discharges may only be known to the Dischargers and eyewitnesses who are yet to be determined because such discharges have not been, and are not, reported by Dischargers.

ACTIONS TO BE TAKEN

Absent cessation of the discharges by the Dischargers, Notifiers intend, at the close of the sixty (60) day notice period to file a citizen lawsuit under Section 505 of the Clean Water Act against Dischargers, both individually and collectively, seeking injunctive relief, remedial relief, declaratory relief, and civil penalties for each day of each violation for each U.S. water body over the past five (5) years and sixty (60) days from the date of this notice relating to the illegal discharges through the date of this letter and all violations of Section 301 of the Clean Water Act which occur subsequent to the date of this letter, plus costs, attorney and expert witness fees, and such other relief as may be appropriate. Notifiers will also seek removal of the pollutants from waterways as such discharges constitute illegal fill material in violation of Sections 301 and 404 of the Clean Water Act and the Rivers and Harbors Act of 1899, 33 U.S.C § 403, et seq.

CIVIL PENALTIES

Notifiers intend, at the close of the sixty (60) day notice period, to file a citizen suit under §505 of the Clean Water Act, 33 U.S.C. §1365, against the Dischargers for the applicable statutory maximum for each violation, presently $37,500 per day for each violation. 33 U.S.C. §1319(d) and 40 C.F.R. §19 and §19.4 Table 1 (or as otherwise provided by federal regulations). Civil penalties are mandatory once violations are found. 33 U.S.C. §1319(c); *Leslie Salt Co. v. United States*, 55 F.3d 1388, 1396 (9th Cir. 1995) (civil penalties under Clean Water Act are mandatory, not discretionary). Dischargers are on notice that each day of a discharge into each waterway by each rail car, as well as each train, constitutes a distinct and separate violation subject to civil penalties. Thus, each rail car discharging pollutants into a different waterway constitutes a separate violation. Furthermore, the pollutants that remain in the waterways constitute continuing violations of the Act which are also subject to daily penalties until removed.

The name, address and phone number of the persons giving Notice of Intent to File a Citizen Lawsuit under the Clean Water Act are:

Sierra Club
85 Second Street, 2nd Floor
San Francisco, CA 94105
Tel: (415) 977-5500

Puget Soundkeeper Alliance
5305 Shilshole Avenue NW - #150
Seattle, WA 98115
Tel: (206) 297-7002

Columbia Riverkeeper
111 Third Street
Hood River, OR 97031
Tel: (503) 348-2436

Friends of the Columbia Gorge
522 SW 5th Ave., Ste. 720
Portland, OR 97204
Tel: (503) 241-3762

RE Sources for Sustainable Communities
2309 Meridian Street
Bellingham, WA 98225
Tel: (360) 733-8307

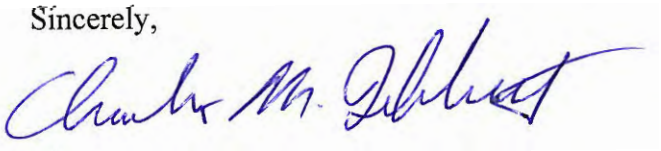
The names, addresses and phone numbers of the counsel for the Notifiers are:

Charles M. Tebbutt, Esq.
Law Offices of Charles M. Tebbutt, P.C.
941 Lawrence St.
Eugene, OR 97401
Tel: (541) 344-3505

Andrea K. Rodgers Harris
Mattson Rodgers, PLLC
2907 S. Adams Street
Seattle, WA 98108
Tel: (206) 696-2851

During the sixty (60) day notice period, we will be available to discuss effective remedies and actions which will assure the Dischargers' future compliance with the Clean Water Act and all applicable state water pollution control laws. In addition, we welcome discussion about whatever facts you believe are relevant which are not itemized in this notice letter. If you wish to avail yourself of this opportunity, please contact the undersigned. The Notifiers request that any person receiving this notice direct all inquiries to the undersigned legal counsel.

Sincerely,



Charles M. Tebbutt
Law Offices of Charles M. Tebbutt, P.C.

cc: Bob Perciasepe, Acting Administrator, U.S. EPA (certified U.S. Mail)
Dennis J. McLerran, Administrator, Region 10, U.S. EPA (via U.S. Mail)
C T Corporation System, Registered Agent for Burlington Northern Sante Fe Railroad and for TransAlta USA Inc. (via U.S. Mail)
Corporation Service Company, Registered Agent for Cloud Peak Energy Logistics, LLC (via U.S. Mail)
Maia Bellon, Director, Washington State Department of Ecology (via U.S. Mail)

APPENDIX A

Locations of Dischargers' violations include, but are not limited to, those listed in the "Waters Affected" section of Notifiers' letter during each and every transport of coal and petcoke. The photographs below, which are also identified by date in the next paragraph, are examples of the types of discharges occurring to some of the affected waters.

Coal was discharged into the water on or before the following dates and locations, including but not limited to: June 28, 2011 (Lake Washington Ship Canal BNSF Rail Bridge, Puget Sound, Shilshole Bay); November 6, 2011 (Colony Creek near the intersection under Chuckanut Drive/SR-11); November 10, 2011 (Skagit River Bridge); November 17, 2011 (Lake Washington Ship Canal BNSF Rail Bridge, Puget Sound, Shilshole Bay); May 16, 2012 (Columbia River at White Salmon River); June 12, 2012; (Snohomish River south of Marysville, WA); July 14, 2012 (Columbia River near Horsethief Lake); November 11, 2012 (Columbia River at White Salmon River); January 9, 2013 (Columbia River near Drano Lake; Columbia River at the mouth of Rock Creek, Stevenson, WA; Columbia River at White Salmon River; Columbia River at Wind River); January 26, 2013 (Columbia River near Horsethief Lake); February 12, 2013 (Cowlitz River; Coweeman River under the railroad bridge just south of the Hwy 432 bridge; Kalama River; Lewis River; Toutle River); February 21, 2013 (Horsethief Lake); February 26, 2013 (Ballard Locks of Puget Sound); February 27, 2013 (Picnic Point Beach, Edmonds, Puget Sound); March 1, 2013 (Marina Beach Park, Edmonds, Puget Sound); March 5, 2013 (Howarth Park, Everett, Puget Sound, Union Slough, Snohomish River); March 8, 2013 (Skagit River Rail Trestle near E Whitmarsh Road and South Burlington Blvd, North of Mt Vernon; Creek flowing into Puget Sound at Golden Gardens Park, Puget Sound); March 18, 2013 (Carkeek Park, Puget Sound; Creek flowing into Puget Sound at Golden Gardens Park, Puget Sound); March 21, 2013 (Creek flowing into Puget Sound at Golden Gardens Park, Puget Sound); March 24, 2013 (Lake Washington Ship Canal BNSF Rail Bridge, Puget Sound, Shilshole Bay); March 26, 2013 (Lake Washington Ship Canal BNSF Rail Bridge, Puget Sound, Shilshole Bay); March 27, 2013 (Columbia River near Horsethief Lake); and March 28, 2013 (Columbia River near Horsethief Lake; Lake Washington Ship Canal BNSF Rail Bridge, Puget Sound, Shilshole Bay).

Coal was observed in the water on these dates. The coal may have been discharged prior to this date.

Location: Columbia River near Horsethief Lake

Date: January 26, 2013

Location: Coweeman River under the railroad bridge just south of the Hwy 432 bridge

Date: February 12, 2013

Location: Columbia River near Horsethief Lake

Date: July 14, 2012

Location: Rock Creek Delta near Stevenson, WA

Date: January 9, 2013

Location: Columbia River near Horsethief Lake

Date: February 20, 2013

Location: Hiram M. Chittenden Locks, Lake Washington Ship Canal at Salmon Bay, Puget Sound ("Ballard Locks")

Date: November 17, 2011

Columbia Riverkeeper
724 Oak Street
Hood River, OR 97031
Phone: (541) 387-3030
www.columbiariverkeeper.org

July 29, 2011

U.S. Army Corps of Engineers
Attn: Danette Guy, Project Manager
P.O. Box 3755
Seattle, WA 98124-3755
Danette.L.Guy@usace.army.mil

Washington Department of Ecology
Attn: SEA Program—Federal Permit Coordinator
P.O. Box 47600
Olympia, WA 98504-7600
ecyrefedpermits@ecy.wa.gov

Via U.S. Email

RE: Public Comment on Longview Fibre Paper and Packaging, Inc.'s Clean Water Act §§ 404 and 401 Permit Application, NWS-2011-00637

To whom it may concern:

Columbia Riverkeeper ("Riverkeeper") submits the following public comments on the Longview Fibre Paper and Packaging, Inc's ("Longview Fibre") Clean Water Act ("CWA") §§ 404 and 401 permit application, NWS-2011-00637. Longview Fibre proposes dredging up to 22,000 cubic yards (cy) of accreted sediment and disposing of the dredged material in the flow land of the Columbia River. The proposed dredging activity will target a depth of -10 feet Columbia River Datum. The purpose of these activities is to "restore adequate navigational depths for shipping vessels using Longview Fibre docking facilities."

Longview Fibre's dredging activities join a long list of recent or proposed dredging and in-water maintenance and deepening projects on the Lower Columbia, including a series of projects within close proximity to Longview Fibre. Based on the large-scale investment in recovering endangered and threatened species in the Lower Columbia River, as well as efforts to improve water quality for various beneficial uses, Riverkeeper urges the U.S. Army Corps of Engineers ("Corps") and Washington Department of Ecology ("Ecology") to carefully consider the direct, indirect, and cumulative impacts of the Port's projects and other actions occurring in close proximity to Longview Fibre's project.

Columbia Riverkeeper is a 501(c)(3) non-profit corporation whose mission is to restore and protect the water quality of the Columbia River and all life connected to it,

from the headwaters to the Pacific Ocean. Riverkeeper's members and volunteers reside, work, and recreate in Oregon and Washington, including near and downstream of Longview Fibre. Many of Riverkeeper's members rely on the Columbia River for their livelihoods and/or enjoy using the Columbia River for recreational and spiritual purposes, including fishing, swimming, and hiking. In addition to working on-the-ground with volunteers to monitor and restore the Columbia, Riverkeeper regularly comments on federal, state, and local permits that impact water quality and habitat. Based on the influx of dredging applications near, upstream, and downstream of Longview Fibre, Riverkeeper requests that the Corps and Ecology carefully assess the cumulative impacts of Longview Fibre's project with other actions in the Lower Columbia River.

I. THE DIRECT, INDIRECT, AND CUMULATIVE IMPACTS OF LONGVIEW FIBRE'S DREDGING PROJECT, IN ADDITION TO PAST, PRESENT, AND REASONABLY FORESEEABLE ACTIONS, IS SIGNIFICANT AND WARRANTS AN EIS.

Longview Fibre's dredging proposal will not occur in a vacuum. The Lower Columbia River is subjected to extensive and ongoing dredging activities. See Ex. A, Columbia River Channel Improvement Project Adaptive Environmental Management Plan. Pursuant to National Environmental Policy Act ("NEPA"), the Corps must evaluate the significance of Longview Fibre's proposal by accounting for the cumulative impacts of past, present, and future dredging activities in the Lower Columbia River.

Longview Fibre's application joins a long list of similar maintenance dredge and deepening projects on the Columbia River. Many of these projects are within close proximity to Longview Fibre. These include, but are not limited to, the following projects:

- Port of Longview Emergency Dredge and Disposal Project
  - RM 47 and 48
  - Proposal: To address channel shoaling, the emergency dredge project will remove 200,000 cy and 300,000 cy in the mainstem Columbia.
  - Permit issued July 2011

- Weyerhaeuser, NWS-2011-00181:
  - RM 63.4-65.8
  - Proposal: The applicant proposes dredging up to 3.1 million cy of sediment over a ten year period, with up to 300,000 cy dredged annually.
  - Public comment period closed July 16, 2011

- Port of Longview, NWP-2000-39:
  - RM 66
  - Proposal: The Port proposes a series of dredging events to maintain existing depths or deepen the Port's currently operational berths.

This includes dredging activities at Berths 1, 2, 4, 5, 6, 7, 8, and 9. The Port also seeks authorization to conduct annual maintenance dredging to address sediment accumulation on an as-needed basis. The Joint Public Notice does not state the amount of sediment that the Port proposes to dredge. As part of this application, the Port also proposes replacing dilapidated, untreated wooden fender piles.
    - Public comment period closed July 19, 2011.

- Millennium Bulk Terminals Longview and Northwest Alloys
    - RM 62.9 – 63.5
    - Proposal: Conduct in- and over-water infrastructure work and maintenance dredging. The project includes: (1) conducting maintenance dredging of approximately 31,300 cy; (2) replacing 12 creosote-treated timber piles with steel pipe; (3) replacing one 18.5-inch octagonal concrete pile with steel pipe; (4) replacing 50 timber cross-braces or bracing members; (5) removing non-functioning derrick loader including 22 14-inch timber piles and 650 sf of over-water decking; and (6) conducting various above-water structural and safety improvements.
    - JARPA submitted June 2011.

In addition, the Port of Kalama (RM 75) and its tenants have recently obtained or submitted applications for dredging projects, such as the Kalama Export dredge project. The Corps and Ecology must evaluate the significance of Longview Fibre's proposed dredging activities in conjunction with cumulative impacts from past, present, and reasonably foreseeable future actions in the Lower Columbia.

In its April 2011 SEPA comments, the Washington Department of Fish and Wildlife ("WDFW") expressed similar concerns about the cumulative impacts of multiple dredging and maintenance projects near the Port of Longview. WDFW's comments are attached as Exhibit F.

Aquatic lands at the Longview Fibre site and adjacent sections of the Columbia River support industrial activities as well as fish runs, including Endangered Species Act ("ESA") listed salmon and smelt. Specifically, Longview Fibre's dredging project will take place near designated critical habitat, or other spawning, rearing and migration habitat, of numerous federally protected species, including multiple runs of salmon and steelhead, green sturgeon, and smelt. See Ex. B, Mary Moser, et al., Do Green Sturgeon in Estuaries Segregate by Distinct Population Segment? (powerpoint) (acoustic studies of federally listed green sturgeon demonstrate species presence near the Port of Longview); Ex. C, Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife 2010 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, (Dec. 7, 2009); Ex. D, Columbia River Channel Project, Final Supplemental Feasibility Report and Environmental Impact Statement, Exhibit K-2, Evaluation Report Smelt (Revised); Ex. E, Factors Contributing to the Decline of Chinook Salmon: An

Addendum to the 1996 West Coast Steelhead Factors for Decline Report, National Marine Fisheries Service, 9 – 10 (June 1998) ("Land and water-use practices, including . . . dredging. . . have, and will continue to substantially altered [sic] watershed functions and features necessary for productive use by anadromous salmonids."). The cumulative impacts of Longview Fibre's proposed dredging, along with past, present, and reasonably foreseeable actions, cross the threshold of significance, requiring preparation of a full EIS.

Last year, the National Marine Fishers Service ("NMFS") listed the Southern Distinct Population Segment of eulachon (*i.e.*, smelt) as threatened under the ESA. 75 Fed. Reg. 13012 (Mar. 18, 2010). Dredging is recognized as a major impact on ESA-listed eulachon (*i.e.*, smelt). See Status Review Update for Eulachon in Washington, Oregon, and California, Prepared by the Eulachon Biological Review Team (Jan. 20, 2010) ("Potential dredging impacts on eulachon consist of direct effects of entrainment of adults and eggs and potential for smother of eggs with sediment . . . Indirect effects may consist of alteration of freshwater spawning habitat and estuarine nursery habitat.") (citations omitted). According to NMFS, "[d]redging during eulachon spawning would be particularly detrimental, as eggs associated with benthic substrates are likely to be destroyed." *Id.* at 13019. The Corps and Ecology must therefore address the direct, indirect, and cumulative impacts of the Longview Fibre's project on eulachon.

In addition to the direct impacts of dredging, the Corps and Ecology must consider the direct, indirect, and cumulative impacts of increased ship traffic that the Port projects will foster. For example, the Corps and Ecology must consider the direct, indirect, and cumulative impacts of invasive species contained in ballast water that would be released in the lower Columbia River as the result of the proposed dredging activities. The Corps and Ecology must also consider the direct, indirect, and cumulative impacts of ballast water uptake and wake stranding on juvenile salmon and steelhead, eulachon and other ESA-listed species.[1] These are potentially significant impacts that should be considered thoroughly in an EIS.

In addition, the timing of Longview Fibre's maintenance dredge project is critical to assess the project's significance and impacts to ESA-listed fish. The Joint Public Notice fails to describe when Longview Fibre intends dredge 22,000 cy of sediment. Without this information, it is entirely unclear how the dredging activities will impact fish and wildlife, including ESA-listed fish.

Dredging in the Columbia River is an action with significant environmental consequences in its own right that should be evaluated in an EIS, along with alternatives. We again ask that the Corps and Ecology conduct a complete environmental review that

1 For example, eulachon larvae are extremely small at 4-8mm in length (about the size of mosquito larvae). They are poor swimmers, simply drifting downstream with the current and out to sea. They would not be able to avoid being drawn into a ship's ballast water.

considers a series of similar actions that impact water quality and habitat at and near Longview Fibre.

II. CONCLUSION.

Riverkeeper urges the Corps and Ecology to assess fully the environmental impact of Longview Fibre's application, including the aggregate impacts of multiple projects which are spatially and temporally similar to the Port's in-water actions. Thank you in advance for considering Riverkeeper's public comments on Longview Fibre's 404 and 401 joint permit application.

Sincerely,

/s/ Lauren Goldberg

Lauren Goldberg
Staff Attorney
Columbia Riverkeeper

cc without encl.:

Steve Gagnon, U.S. Army Corps of Engineers
Mike Wojtowicz, Cowlitz County Building and Planning
Shannon Wills, Assistant Director, Fish Biologist, Cowlitz Tribe
Jeff Fisher, National Marine Fisheries Service
Steven West, Washington Department of Fish and Wildlife
Micah Russell, Columbia River Estuary Study Taskforce

"Committed to the protection and promotion of public health"

Gallatin City-County Health Department

www. gallatin.mt.gov/health

Human Services
215 W. Mendenhall, Rm 117
Bozeman, MT 59715-3478
(406) 582-3100 ● Fax (406) 582-3112

Environmental Health Services
215 W. Mendenhall, Rm 108
Bozeman, MT 59715-3478
406-582-3120 ● Fax: 406-582-3128

August 7, 2012

Brig. Gen. John McMahon, Commander and Division Engineer
U.S. Army Corps of Engineers Northwestern Division
P.O. Box 2870
Portland, OR 97208-2870

Col. John Eisenhauer
Commander, Portland District
U.S. Army Corps of Engineers
P.O. box 2946
Portland, OR 97208-2946

Col. Bruce Estok
Commander, Seattle District
U.S. Army Corps of Engineers
P.O. Box 3755
Seattle, WA 98124-3755

Re: EIS on Coal Export from the West Coast

Gentlemen:

I am writing on behalf of the Board of Health of Gallatin County, Montana. We hereby request that the Army Corps of Engineers (ACE) prepare an area-wide ("programmatic") Environmental Impact Statement concerning coal transport from the Powder River Basin of Wyoming and Montana, through the Northwest to the potential new export facilities on the coast of Washington and Oregon. We understand that ACE already plans to examine the impacts of new ports; our request is to broaden the scope of the process to examine the entire transport corridors from the mines to the ports.

Should the increased coal export come about, the communities of Bozeman, Belgrade and Manhattan in Gallatin County through which trains pass will experience doubled (at least) train traffic. Several potential health and safety impacts to these communities have been brought to our attention. The Board does not have enough information to conclude that these impacts will be negligible, hence our request to examine them. We understand the particular issues to be examined will be identified during the scoping stage of the EIS. The Board's questions can be summarized for scoping as follows:

- How much coal dust is likely to blow off open coal cars in our towns, what are its characteristics and to what extent would it compromise the pulmonary and cardiovascular health of our citizens? Could buildup of coal dust within track ballast increase derailments along the transport corridors? While the loss of coal dust diminishes with distance from the mine mouth, at what point does it cease to be problematic? The potential emission and accumulation of coal dust in our communities raises concern.

- What other proximate air pollutants should be anticipated from, for example, locomotive exhaust emissions and auto traffic idling at blocked crossings? What would their effects be? Belgrade and Bozeman are both very close to becoming non-compliant with existing air quality standards. EPA's recent adoption of a more stringent standard for particulate air pollution pushes us even closer to non-compliance. The proposed increase in coal-train traffic will increase diesel exhaust emissions from moving trains, and auto exhaust emissions from blocked traffic. The Bozeman Rail Yard, where trains are attached to helper engines for their transit over the Bozeman Pass, will experience greatly increased activity. What will be the air-quality impact on the residents adjacent to that facility?

- Residents of Bozeman and Belgrade have expressed concern about a potential doubling (or more) in the number of delays experienced by emergency vehicles. Each unit coal train is between 1.1 and 1.5 miles in length, so these trains simultaneously close all three at-grade crossings in Bozeman, and, in Belgrade, all four at-grade crossings. This effectively blocks access to large parts of the cities and adjoining suburbs. A related issue was recently raised during community health working sessions by residents of Belgrade, who pointed out that their town is effectively "cut in two" by transportation corridors (rail and interstate highway). How would the passage of 3000+ rail cars per day through central Belgrade affect the quality of life there? The Board has no idea how to go about assessing this impact, but it's clearly an important characteristic of the human community.

- A number of residents have expressed concern about noise pollution from trains in Gallatin County at the current level of traffic. The Board understands that frequent loud noise is not just an annoyance, but can be a health hazard. What kinds of health impacts from increased noise should we anticipate from the coal-export project? What can be done to mitigate these impacts?

We understand that preparation of a PEIS usually does not involve the collection of new data, but should there prove to be inadequate information to answer any of these questions, we ask that ACE consider generating new data. The questions for other communities along the coal-transport corridors are likely to be similar to those of Gallatin County. For this reason, we ask for a comprehensive, cumulative and connected analysis.

Please view the Gallatin City-County Board of Health and the Health Department as willing partners in any analysis activities, whether involving new or existing information. Our concern is to understand the magnitude and nature of project impacts, so that our communities can make plans and collaborate with the railroad to implement mitigation measures. Given how little we know now, we consider this the prudent and responsible course for a Board of Health.

You can contact me or Health Officer Matt Kelley at any time regarding our concerns and this letter. Thank you for your consideration.

Sincerely,

Gretchen Rupp, P.E.
Chair, Gallatin City-County Board of Health

Cc: city commissions/councils of Belgrade, Bozeman and Manhattan, Montana
Senator Max Baucus
Senator Jon Tester
Representative Dennis Rehberg

20121107-5048 FERC PDF (Unofficial) 11/7/2012 12:56:16 PM

United States Department of the Interior

NATIONAL PARK SERVICE
Pacific West Region
909 First Avenue, Fifth Floor
Seattle, Washington 98104-1060

IN REPLY REFER TO:

ER12/0684

November 7, 2012

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426.

Subject: Oregon LNG Export Project and Washington Expansion Project, FERC Nos. PF12-18-000, PF12-20-000

Dear Ms. Bose:

The National Park Service (NPS) has reviewed the Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for the proposed Oregon Liquified Natural Gas (LNG) Export Project and Washington Expansion Project (the Project). We offer the following comments for consideration.

The proposed LNG terminal and a portion of the new pipeline segment are located along the Lewis and Clark National Historic Trail (the Trail). Congress established the Trail in an amendment to the National Trails System Act in 1978 [16 U.S.C. § 1244(a)(6)]. The NPS administers the Trail and is charged under this Act with the identification and protection of the historic route, remnants, and artifacts of the Expedition for public use and enjoyment. The NPS also manages the Lewis and Clark National Historical Park. The Lewis and Clark National Historical Park (park) consists of seven sites totaling 3,400 acres in Clatsop County, Oregon and Pacific County, Washington.

The Lewis and Clark National Historic Trail extends from Wood River, Illinois to the mouth of the Columbia River in Oregon, following the outbound and inbound routes of the Lewis and Clark Expedition (the Expedition). In the Project area, the Corps of Discovery explored both the north and south shores of the Columbia River estuary, around Young's Bay, up the present Lewis and Clark River, and along the Pacific Coast. They built a fortification and quarters named Fort Clatsop with the aid of local tribes to spend the winter of 1805-1806. Today, Fort Clatsop Visitor Center, part of the Lewis and Clark National Historical Park, is located approximately three miles from the proposed terminal location. Trail infrastructure in the area is a mix of motor routes, land trails, water trails, waysides, visitor centers, parks, overlooks, etc. This area of the Trail is rich in cultural history, unique and varied natural resources, and outstanding scenery. Preservation of these resources and the public's ability to continue to safely access them for enjoyment is of utmost concern to the NPS.

TAKE PRIDE® IN AMERICA

20121107-5048 FERC PDF (Unofficial) 11/7/2012 12:56:16 PM

We offer the following specific comments:

Safety and Hazards
Constructing and operating an LNG terminal at Warrenton, Oregon introduces substantial new risks to human health and safety in the area. While the NOI identifies "Safety of residents" as an issue to be addressed in the EIS, we request that analysis also consider safety of visitors in the area that are less likely to be familiar with local emergency response plans such as escape routes.

Adding export capabilities to the Oregon LNG facility increases the risks of harming natural resources and the human activities that rely on those resources. The liquification pretreatment process removes sulfur, mercury and other contaminants from the delivered gas. The handling and storage of these materials includes hazards which may affect water and air quality. How these hazards will be addressed should be outlined in the EIS.

Threatened and Endangered Species. Federally listed salmon species rear and forage in the Lewis and Clark River, which is crossed by the proposed pipeline in two locations, as well as in park tributaries. As discussed in the Applicant Prepared Draft Biological Assessment, the Lewis and Clark River is used for rearing and migration of the Lower Columbia River Evolutionary Significant Unit (ESU) of coho (*Oncorhychus kisutch*) and the Lower Columbia River ESU of Chinook (*Oncorhynchus tshawytscha*). In addition, since the South Clatsop Slough Restoration Project in 2007, the park and its partners have sampled at two locations along the Lewis and Clark River – between pipeline milepost 3.1 and pipeline milepost 5.7 – and have documented two additional Federally-listed species: chum (*Oncorhynchus keta*) and coastal cutthroat (*Oncorhynchus clarki*). Genetic testing of juvenile Chinook salmon sampled from the park has indicated that another federally listed ESU of Chinook uses the Lewis and Clark River: Upper Willamette River Chinook. These results were presented at the 2012 Columbia River Estuary Conference and will be published in their proceedings. As a result, the EIS should include impacts to Lower Columbia River coho, Lower Columbia River Chinook, Upper Willamette River Chinook, chum, and coastal cutthroat in the Lewis and Clark River.

Bald Eagles. Though de-listed, bald eagles continue to be protected by the Bald and Golden Eagle Protection Act. A pair of bald eagles uses the park for foraging and maintains an active nest approximately ½ mile from the park. The nest is within 660 feet of the proposed pipeline construction near pipeline milepost 5.

Contiguous Wetlands. At approximately pipeline milepost 5.7, the pipeline comes within 30 feet of the park boundary. At this location, it crosses a delineated wetland, part of which is within the park. Impacts to the portion of the wetland outside of the boundary could cause impacts to the portion of the wetland within the park boundary through its hydrologic and rhizomal connections.

Contaminants from the Astoria Marine Construction Company. The proposed pipeline would cross the Lewis and Clark River at pipeline milepost 3.1 at property associated with the Astoria Marine Construction Company. In March 2011, EPA had proposed the site for inclusion on the Superfund National Priorities List because of the presence of tributyltin and heavy metals from ship refurbishment operations from 1926 to present. In September 2012, EPA deferred the site listing and transferred site

20121107-5048 FERC PDF (Unofficial) 11/7/2012 12:56:16 PM

management to DEQ (Environmental Cleanup Site Information Number (ECSI) 1898). The EIS should address the potential for the construction to re-suspend contaminants into the groundwater and river and identify any necessary monitoring and mitigation. Though the site is ½ mile downstream of the park, the incoming tides reverse the flow of the river and could bring contaminants to the park.

Cultural Landscapes and Viewsheds. Lewis and Clark National Historical Park preserves and restores the cultural landscape that prevailed during the historic period, principally defined as the time of the Lewis and Clark Expedition, in the winter of 1805-06. The look of the landscape is key, and the park's General Management Plan identifies viewsheds from visitor facilities as some of the primary features contributing to the cultural landscape. The EIS should evaluate how the construction of the proposed import terminal site in Warrenton and the pipeline would impact park's cultural landscapes. Project impacts to the viewshed of the Trail should be also analyzed in the EIS. Viewing scenery is an important part of the visitor experience. There are many public viewpoints from which Trail visitors look out across the Columbia River estuary. In addition to the terminal infrastructure, visual impacts from changes in waterway traffic and the introduction of the LNG vessels should be considered.

Historic Sites and Properties. There are a number of significant historic sites associated with the Lewis and Clark story that might be impacted by the proposed Project: Fort Clatsop Visitor Center, Dismal Nitch, Station Camp and Cape Disappointment Historic District. The potential for visual and audible impacts and any potential changes in use or access to these sites should be analyzed in the EIS.

As keeper of the National Register, the National Park Service is charged with preserving historic properties. The EIS should examine the potential for the project to impact historic properties and districts along its route. Through excavation, the project could impact undiscovered eligible sites as well.

Other Recreation Activities and Trails

Various Trail recreational activities in the area could be impacted by the proposed Project. The NPS is particularly concerned about potential impacts to the Lower Columbia River Water Trail. This established 146 mile water trail from the Bonneville Dam to the Pacific Ocean provides sites and facilities for non-motorized boating and a rare opportunity to experience this scenic area of the historic route much as the Expedition did. There are several water trail access sites near the proposed LNG terminal including, but not limited to, the Hammond Launch and the Warrenton Marina. These access points are heavily used for commercial and recreational purposes. Potential impacts from the proposed Project such as limited access or increased hazards to water trail users, and potential ways to minimize or mitigate such impacts, should be examined in the EIS.

There is a great deal of local, regional, and national significance in recognizing and preserving the resources of the Lewis and Clark National Historic Trail and Lewis and Clark National Historical Park. The NPS appreciates the opportunity to comment on the NOI and looks forward to seeing these impact topics addressed in the EIS process. If you have any questions regarding our comments on the Lewis and Clark National Historic Trail, please contact Dan Wiley, Chief of Resources Stewardship, Lewis and Clark National Historic Trail at 402-661-1830 or at Dan_Wiley@nps.gov and for questions regarding our comments pertaining to the Lewis and Clark National Historical Park please contact Chris Clatterbuck,

20121107-5048 FERC PDF (Unofficial) 11/7/2012 12:56:16 PM

Chief of Resources, Lewis and Clark National Historical Park at 503-861-4441 or chris_clatterbuck@nps.gov.

Sincerely,

Chip Jenkins
Deputy Regional Director, Pacific West Region

cc: NPS External Affairs Program, waso_eqd_extrev@nps.gov
Shawn Alam, DOI, shawn_alam@ios.doi.gov
Allison O'Brien, DOI, Allison_O'Brien@ios.doi.gov
Denise Nelson, LECL
Dan Wiley, LECL
Peter Dederich, PWR
Alan Schmierer, PWR
Chris Clatterbuck, LEWI
Stephanie Burkhart, LEWI
Susan Rosebrough, PWR
Chris Hathaway, Lower Columbia River Estuary, CHathaway@lcrep.org

20121107-5048 FERC PDF (Unofficial) 11/7/2012 12:56:16 PM

Document Content(s)

20121106162023820.PDF.....1-4

Scoping Comments of Columbia Riverkeeper, Sierra Club, Greenpeace, Columbia Pacific Commonsense, Landowners and Citizens for a Safe Community, Wahkiakum Friends of the River, Northwest Property Rights Coalition, Friends of Living Oregon Waters (FLOW), Forest Grove Oregon Citizens Against the Pipeline, and Food and Water Watch to the Federal Energy Regulatory Commission on the Proposed Oregon LNG Export Project and Washington Expansion Project,
Docket Nos. PF12-18-000 and PF12-20-000

Submitted December 21, 2012
Via Electronic Filing and U.S. Mail to:

Secretary Kimberly D. Bose
Federal Energy Regulatory Commission
888 First Street NE, Room 1A
Washington, DC 20426

Table of Contents

I. Introduction.....1
II. Summary of the Project……2
III. The National Environmental Policy Act……..3
IV. NEPA Procedural Comments……...5
A. FERC's Disjointed Scoping Process Stymies Public Participation……5
B. FERC May Not Conditionally Approve the LNG Project before Complying with NEPA and other Federal Laws…….....5
C. FERC Failed to Provide Adequate Public Notice……6
V. FERC Should Prepare a Programmatic EIS on LNG Export Proposals……8
VI. The Scope of the EIS…….9
A. Alternatives to LNG……9
B. Purpose and Need……..11
C. Public Safety……..11
D. Water Resources……13
i. Water Quality and Aquatic Resource Impacts……...13
ii. Water Consumption……...16
E. Air Quality and Visual Impacts…….17
F. Impacts to Fish and Wildlife…….19
G. Impacts to State and Private Forestland…….21
H. Noise and Light Pollution……..22
I. Energy Consumption…….23
J. Recreation……..23
K. Cultural Resources and Tribal Consultation……..24
L. Environmental Justice……24
M. Natural Disasters and Geologic Hazards……...25
N. Protection of Flood Control Structures……..27
O. Socioeconomics…….27
P. Increased Natural Gas Production…….28
Q. Climate Change……..29
R. Migratory Birds……..30
S. Marine Resources……...30
VII. Conclusion……...31

I. Introduction.

On behalf of Columbia Riverkeeper, Sierra Club, Greenpeace, Columbia Pacific Commonsense, Landowners and Citizens for a Safe Community, Wahkiakum Friends of the River, Northwest Property Rights Coalition, Friends of Living Oregon Waters (FLOW), Forest Grove Oregon Citizens Against the Pipeline, and Food and Water Watch (hereafter "the Coalition"), we submit these comments on the proposed Oregon LNG Export Project and Washington Expansion Project,[1] Docket Nos. PF12-18-000 and PF12-20-000 (collectively referred to as "Oregon LNG", "the Oregon LNG pipeline", and "the Oregon LNG project"), in response to the Federal Energy Regulatory Commission's (FERC) Notice of Intent to Prepare an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA).[2] FERC's Notice of Intent states that "Oregon LNG plans to amend its pending LNG import terminal proposal and Willamette Valley pipeline route, Dockets Nos. CP9-6-000 and CP09-7-000 (the Oregon LNG Terminal and Pipeline Project) into a bidirectional liquefied natural gas (LNG) terminal and pipeline after completion of FERC's pre-filing review process for the Export Project." The Notice of Intent further states that FERC will analyze the impacts of the Washington Expansion Project natural gas pipeline in in the same EIS as Oregon LNG's proposed pipeline segments and LNG terminal.

Commenters are a diverse coalition of national and local conservation, public health, public safety, and property rights organizations committed to protecting quality of life and natural resources in the Pacific Northwest and beyond. Collectively, our organizations represent thousands of members, many of which are threatened directly by Oregon LNG's terminal, tankers, and the pipeline infrastructure that will feed North American natural gas to the terminal. Many of our members are also threatened by natural gas extraction and associated impacts on domestic gas prices, public health, climate change, and natural resources.

The Coalition urges FERC to prepare an EIS that discloses fully the wide reaching impacts of the Oregon LNG project. Oregon LNG's proposal to build an LNG export terminal, hundreds of miles of pipeline, and export North American natural gas overseas poses grave threats to public safety, the economy, and natural resources in the Pacific Northwest. Along the pipeline route, the LNG export project will impact huge swaths of land and will result in the use

[1] Oregon LNG's new pipeline would traverse Clatsop and Columbia counties in Oregon, travel under the Columbia River to Cowlitz County, Washington, and connect with the interstate gas transmission system of Northwest Pipeline GP (Northwest). FERC determined that Oregon LNG's Export Project and Northwest's Washington Expansion Project would be "connected actions" and, therefore, FERC intends to evaluate both project proposals in the same EIS. FERC Notice of Intent to Prepare and Environmental Impact Statement and Notice of Public Scoping Meetings at 1 (Sept. 24, 2012) (hereafter "Notice of Intent").

[2] 77 Fed. Reg. 59,603 (Sept. 28, 2012).

of eminent domain in both Washington and Oregon to take private land for LNG export. Outside of the Pacific Northwest, the project will also induce additional natural gas production in the United States, primarily involving hydraulic fracturing ("fracking") of unconventional gas sources, causing attendant environmental harm; this inducement will occur notwithstanding Oregon LNG's plan to export gas produced in Canada. The project will also increase domestic gas prices, likely causing an increase in coal fired electricity generation, increasing emissions of greenhouse gas, conventional, and toxic air pollutants. FERC must prepare an EIS that addresses the significant, and in many respects unprecedented, impacts of Oregon LNG's project.

II. Summary of the Proposed Project.

Oregon LNG proposes to export natural gas from a terminal on the banks of the Columbia River in Warrenton, Oregon. Oregon LNG claims that the facility will be "bidirectional," allowing the company to import LNG if market conditions shifted. The project's components, which cross state and national boundaries, are summarized briefly below.

- **Natural Gas Extraction.** According to Oregon LNG's filings, the "vast majority" of the natural gas feedstock for the export terminal would come from resources in Western Canada.[3] Although Oregon LNG states that they expect that market conditions will favor sourcing gas from Canada, the company concedes that the pipeline infrastructure will provide the ability to export gas produced in the U.S., and the Oregon LNG's application to federal regulators offers no legal restriction on Oregon LNG's ability to do so.[4]

- **LNG Terminal.** Oregon LNG's terminal would be located on 96-acres of state-owned land on the Skipanon Peninsula between the Skipanon River and Youngs Bay in Warrenton, Oregon. The terminal would include two, 160,000 cubic meter LNG storage tanks, each 17-stories tall, and facilities that support ship berthing and LNG loading. To export LNG, the company must dredge 1.2 million cubic feet of river bottom material in high-quality salmon habitat.

- **LNG Tankers.** LNG tankers are not your average ship. One LNG tanker alone is bigger than three football fields and towers 20-stories high. According to Oregon LNG's filings, its terminal will require roughly 125 new ships crossing the Columbia River bar (inbound and outbound) every year. Each departing tanker would carry a staggering 8 percent of total U.S. daily gas consumption.

[3] Oregon LNG Prefiling Review Draft Resource Report 1 at 1-4.
[4] Oregon LNG Application for Long-Term Authorization to Export Liquefied Natural Gas to Free Trade Nations, FE Docket No. 12-48-LNG at 2 (May 3, 2012) (hereafter "DOE Application").

- **Oregon LNG's Pipeline in Oregon & Washington.** Oregon LNG proposes ***building 86 miles of high-pressure pipelines*** in Oregon (Clatsop and Columbia counties). The company would drill under the Columbia River and connect to the Williams Pipeline in Woodland, Washington. This route cuts a destructive path through agricultural and forest lands, residential properties, and through rivers and streams.

- **Williams Pipeline in Washington.** The Williams Pipeline Company plans to build ***136 miles of new, high-pressure pipeline*** in ten different segments in or near the existing Northwest Pipeline right-of-way. Segments of the new pipeline would run from Washington's northern border south to Woodland, Washington, threatening hundreds of landowners and communities along the way. Williams will also expand existing compression horsepower at five of Northwest Pipeline's existing compressor stations.

- **Alternate Pipeline Route through the Willamette Valley.** For years, Oregon LNG planned to cross the Willamette Valley to build a pipeline from Warrenton to Molalla. Now, Oregon LNG and FERC have provided conflicting information about whether the Willamette Valley pipeline, originally proposed in 2007, is still being considered. According to Oregon LNG's filings, however, the "Molalla Route Alternative" is still on the table.

III. The National Environmental Policy Act.

The National Environmental Policy Act (NEPA), 42 U.S.C. § 4332 *et seq*., provides the congressionally mandated procedure for assessment of these impacts, and NEPA requires that these procedures be completed "at the earliest possible time," *i.e.*, "*before* decisions are made and *before* actions are taken."[5] Accordingly, FERC cannot proceed with Oregon LNG's request for a conditional license until the NEPA process is completed, including preparation of an EIS.

An EIS must describe:

i. the environmental impact of the proposed action,

ii. any adverse environmental effects which cannot be avoided should the proposal be implemented,

iii. alternatives to the proposed action,

iv. the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

[5] 40 C.F.R. §§ 1501.2, 1500.1(b) (emphases added).

v. any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.[6]

The alternatives analysis "is the heart of the environmental impact statement."[7] Federal agencies must take care not to define the project purpose so narrowly as to prevent the consideration of a reasonable range of alternatives.[8]

An EIS must also describe the direct and indirect effects, and cumulative impacts of, a proposed action.[9] These terms are distinct from one another. Direct effects are "caused by the action and occur at the same time and place."[10] Indirect effects are also "caused by the action" and "are later in time or farther removed in distance, but are still reasonably foreseeable."[11] Indirect effects "may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effect on air and water and other natural systems, including ecosystems.[12]

Cumulative impacts are not causally related to the action. Instead, they are:

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.[13]

The EIS must give each of these categories of effect fair emphasis.

Agencies may also prepare "programmatic" EISs, which address "a group of concerted actions to implement a specific policy or plan; [or] systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive."[14] As we discuss below, such an EIS is appropriate here.

---

[6] 42 U.S.C. § 4332(C).
[7] 40 C.F.R. § 1502.14.
[8] *See, e.g.*, *Simmons v. U.S. Army Corps of Engineers*, 120 F.3d 664, 666 (7th Cir. 1997).
[9] 40 C.F.R §§ 1502.16, 1508.7, 1508.8; *Northern Plains Resource Council v. Surface Transportation Board*, 668 F.3d 1067, 1072-73 (9th Cir. 2011).
[10] 40 C.F.R. § 1508.8(a).
[11] 40 C.F.R. § 1508.8(b).
[12] *Id.*
[13] 40 C.F.R. § 1508.7.
[14] 40 C.F.R. § 1508.17(b)(3).

Finally, while an EIS is being prepared FERC may take no action which would tend to "limit the choice of reasonable alternatives," or "tend[] to determine subsequent development ."[15]

IV. NEPA Procedural Comments.

A. FERC's Disjointed Scoping Process Stymies Public Participation.

Although FERC will prepare a single EIS that covers aspects of Oregon LNG's previous import terminal and the current export project, as well as the connected WEP, FERC's Notice of Intent solicits comments on fractions of the complete project—an export terminal and segments of the pipelines. FERC's decision to notice a mythical project (*i.e.*, an LNG export terminal missing a 41-mile segment of the feeder pipeline and the proposed import infrastructure) undercuts the purpose of NEPA scoping: to identify significant issues to analyze in the EIS, and gaps and in data and information.

Oregon LNG has now produced two entirely separate, lengthy NEPA Prefiling Review Drafts for the import and export components. Neither filing fully evaluates the full impacts of a bidirectional terminal. FERC should require Oregon LNG to submit a new Prefiling Review Draft that covers both projects in a single filing. After FERC has reviewed the Prefiling Review Drafts, FERC should open a new NEPA scoping process, including public hearings, to ensure that federal and state agencies, the Tribes, and the public have the opportunity to provide comments on the actual project that FERC will evaluate in an EIS.

B. FERC May Not Conditionally Approve the LNG Project before Complying with NEPA and other Federal Laws.

Sections 3 and 7 of the Natural Gas Act (NGA), 15 U.S.C. §§717b, 717f, and FERC Certificate Policy Statement, 88 FERC ¶ 61,227 (1999), require FERC to determine whether Oregon LNG's proposed LNG terminal is "in the public interest" and that the proposed pipeline is "required by public necessity" (collectively the "public interest findings"). FERC cannot approve the project under the NGA unless it concludes that the project's benefits outweigh its adverse impacts.

FERC's findings under the NGA require compliance with NEPA and other federal laws, which inform the ultimate public interest findings. FERC must, therefore, abandon its practice of issuing conditional licenses before complying with the Endangered Species Act (ESA) and receiving authorizations delegated to the states under the Clean Water Act (CWA), Coastal Zone Management Act (CZMA), and the Clean Air Act (CAA). In scoping comments on the proposed Jordan Cove LNG terminal and Pacific Connector pipeline, the State of Oregon explained:

[15] 40 C.F.R. § 1506.1.

> [S]uch conditional orders are arbitrary and capricious, because no balancing of the public interest can be made regarding the construction of the proposed LNG export terminal and pipeline project *before* the Commission has quantified and considered the full extent of the benefits and adverse impacts, including the socioeconomic impact on landowners and public safety risks associated with the overall project.[16]

The Coalition concurs with the State of Oregon. FERC must prepare the EIS concurrently with, and integrated with, environmental reviews and studies required under other environmental laws. The State of Oregon scoping comments explain further:

> The State of Oregon's concrete, substantive interest in prescribing mandatory conditions in the Commission's final order authorizing construction of a LNG facility is harmed by the Commission's previous practice of authorizing and issuing a conditional license *before* receiving [the] State's Clean Water Act 401 certification, Coastal Zone Management Act 307 consistency determination, and the Clean Air Act certification as well as before its initiated formal consultation with appropriate federal agencies for the project's effect on protected species under the Endangered Species Act.[17]

Forthcoming authorizations will inform the scope of FERC's EIS. In turn, FERC should refrain from issuing a license until the agency complies with the ESA and Oregon LNG receives authorizations required under the CWA, CAA, and CZMA.

C. FERC Failed to Provide Adequate Public Notice.

FERC should reopen the public comment period based on various flaws in the public notice process, summarized below.

- **FERC's public notice fails to specify if Oregon LNG's proposed 41-mile pipeline through Clatsop County is part of the NEPA scoping comment process.** FERC's Notice of Intent fractures the public comment process by seeking public input on Oregon LNG's export terminal and new pipeline segments. FERC's public notice asks for input on the segments of "newly proposed" pipeline (*i.e.*, Williams Expansion Project (WEP) and Oregon LNG's new pipeline route in Columbia and Cowlitz counties), but ignores the proposed 41-mile long pipeline in Clatsop County.

  > **Question:** Will FERC hold a second NEPA scoping public comment period on the <u>complete</u> pipeline proposal?

- **Lack of public notice to impacted landowners.** Many landowners that are impacted by proposed and alternate routes for the Oregon LNG pipeline have not received FERC's

[16] State of Oregon's Scoping Comments for the Jordan Cove Liquefication (PF12-7-000) and Pacific Connector Pipeline (PF12-17-000) Projects at 2 (Oct. 29, 2012) (emphasis in original).
[17] *Id.* at n. 1 (emphasis in original).

scoping notice. In particular, FERC asked that Oregon LNG clarify its intentions regarding its previous proposed route through Washington, Yamhill, Marion, and Clackamas counties. Currently, many landowners are confused about the status of the project because Oregon LNG submitted maps to FERC showing the route through the Willamette Valley to Molalla as an alternate route. Yet, Oregon LNG also mailed a notice to some landowners on the Willamette Valley route that the pipeline was being re-routed through Columbia County and Cowlitz County.

Question: Is Oregon LNG proposing the Willamette Valley route as an alternate route? If so, FERC must provide accurate information on potential property impacts to facilitate public participation in the scoping process.

Question: Did FERC notify landowners on the proposed pipeline route through Clatsop County of the NEPA scoping comment period and public hearings on the Oregon LNG Export Project and WEP?

Question: Did FERC notify landowners along the Willamette Valley alternate route?

- **Oregon LNG's prefiling resource reports are incomplete and contain contradictory information.** Federal and state agencies, local governments, the Tribes, and the public rely on Oregon LNG's Prefiling Draft Resource Reports to identify significant issues that FERC should analyze in the EIS. Oregon LNG's Prefiling Resource Reports compromise the scoping process because FERC is soliciting input on a project that is not, in fact, the project Oregon LNG intends to build and operate. For example, the Prefiling Resource Reports cross reference extensively Oregon LNG's outdated and incomplete Resource Reports for the proposed LNG import terminal. The Prefiling Resource Reports also contain contradictory information on how the export project will impact aquatic resources via ballast water discharges.[18]

- **FERC is seeking comments prematurely and, in so doing, cutting off meaningful public, state, tribal, and agency engagement.** Oregon LNG is still determining major pipeline route and terminal decisions. For example, FERC recently submitted extensive information requests to both Oregon LNG and Williams. Until the issues raised by FERC are addressed, FERC should maintain an open scoping comment period. It is unreasonable to expect the public—including counties and cities that will be impacted by

[18]For instance, Prefiling Resource Report 3 states that the export terminal "will eliminate the need for ballast water," and later states "the Export terminal will require a total cooling/ballast water intake of 1,610 million gallons per year (MG/Y). Oregon LNG Prefiling Resource Report 3 at 3-49.

the pipelines and the terminal— to comment on the scope of the project when FERC is still collecting key information on the project.

V. FERC Should Prepare a Programmatic EIS on LNG Export Proposals.

Oregon LNG's export proposal is one of many before FERC. Because the effects of these projects are cumulative, and because each approval alters the price and production effects of exports on the economy, FERC must consider these projects' interactions. We note that in the similar proceeding regarding Jordan Cove, LLC's proposal to construct and operate an export terminal in Coos Bay, the State of Oregon and the U.S. Environmental Protection Agency (EPA) requested consideration of this broader context.[19]

FERC can best consider the impacts of *all* gas export proposals at once by preparing a programmatic EIS. NEPA expressly contemplates a programmatic EIS for situations just like this one: where an agency is facing multiple independent permitting decisions that have overlapping, shared, or cumulative impacts.[20] Federal guidance and courts sometimes refer to these reviews as "programmatic," while in other cases they are called "area-wide" or "overview" EISs. The label is not important—it is the content of such an assessment that matters. Council on Environmental Quality (CEQ) guidance (in Q&A format) on this issue states plainly:

> Question: When is an area-wide or overview EIS appropriate?
> Answer: The preparation of an area-wide or overview EIS may be particularly useful when similar actions, viewed with other reasonably foreseeable or proposed agency actions, share common timing or geography. For example, when a variety of energy projects may be located in a single watershed, or when a series of new energy technologies may be developed through federal funding, the overview or area-wide EIS would serve as a valuable and necessary analysis of the affected environment and the potential cumulative impacts of the reasonably foreseeable actions under that program or within that geographical area.[21]

Courts have agreed that a single EIS is required for multiple discreet actions under some circumstances, for example, when the projects have common timing, geography, and/or impacts.

---

[19] EPA, *Scoping Comments – The Jordan Cove Energy Project LP*, FERC Dkt. Nos. PF12-7 and PF12-17, at 3 (Oct. 29, 2012) ("we recommend discussing the proposed project in the context of the larger energy market, including existing export capacity and export capacity under application to the Department of Energy, and clearly describe how the need for the proposed action has been determined.")
[20] *See Native Ecosystems Council v. Dombeck*, 304 F.3d 886 (9th Cir. 2002) (A single NEPA review document is required for distinct projects when the projects are connected, cumulative or similar actions); 40 C.F.R. § 1508.25 (mandating single EIS for separate independent actions under some circumstances); 40 C.F.R. § 1502.4(a), (c) (requiring a single EIS where proposals are related to each other closely).
[21] CEQ Website, http://ceq.hss.doe.gov/nepa/regs/40/20-29.HTM#24.

Such circumstances exist here.[22]

FERC has the discretion to prepare a programmatic EIS, even if it determines that it does not have the duty to do so.[23] Agencies may prepare programmatic EISs, which address "a group of concerted actions to implement a specific policy or plan; [or] systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive."[24] Such a programmatic EIS is appropriate here.

A programmatic EIS would allow FERC, and the public, to understand the impacts of all LNG proposals, their interactions, and their cumulative environmental and economic impacts. That understanding would serve improved decisionmaking, and allow FERC, the public, and industry to identify prudent alternatives to serve the public interest and minimize environmental impacts. FERC must recognize that it is making what is, functionally, a programmatic decision to radically alter the U.S. market and production system by allowing for large-scale LNG export, and conduct an EIS commensurate with the decision it is making, rather than piece-mealing that decision from application to application.

VI. The Scope of the EIS.

The Coalition offers the following, specific comments on the scope of FERC's EIS on Oregon LNG's proposed LNG export terminal and proposed pipeline segments in the State of Oregon (Columbia and Clatsop counties) and pipeline segments in Washington State, which includes the Washington Expansion Project. The Coalition reserves the right to provide additional comments on the proper scope of the EIS as more information becomes available on the proposed pipeline routes, LNG terminal design, source of natural gas, and other factors relevant to the project's impacts.

A. Alternatives to LNG.

The alternatives analysis is "the heart of the environmental impact statement."[25] CEQ's regulations implementing NEPA, 40 C.F.R. § 1502.14, explain that a reasonable range of alternatives should be presented and compared in the EIS to allow for a "clear basis for choice among options by the decision maker and the public." In addition, CEQ's "Forty Most Asked Questions Concerning National Environmental Policy Act Regulations" explain that agencies

[22] *See, e.g., Blue Mountains Biodiversity Project v. Blackwood,* 161 F.3d 1208, 1215 (9th Cir. 1998) (multiple timber sales must be evaluated in a single EIS where the sales were reasonably foreseeable, in a single general area, disclosed at the same time, and developed as part of a comprehensive strategy); *Earth Island Institute v. U.S. Forest Service,* 351 F.3d 1291 (9th Cir. 2003) (confirming that "similar actions"—*i.e.*, actions which have similarities, such as common timing or geography, that warrant comprehensive review—must be considered in a single EIS if it is the "best way" to consider their impacts).
[23] *See* 40 C.F.R. § 1508.17(b)(3).
[24] *Id.*
[25] 40 C.F.R. § 1502.14.

must "[r]igorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated."[26]

Crucially, the alternatives must include "reasonable alternatives not within the jurisdiction of the lead agency," – meaning that FERC must review actions which it cannot directly order – and must include "appropriate mitigation measures not already included in the proposed action or alternatives." *Id.* Because alternatives are central to decisionmaking and mitigation, "the existence of a viable but unexamined alternative renders an environmental impact statement inadequate."[27]

Without limiting this consideration, these alternatives should include, at a minimum, consideration of the following:

(1) Whether to select the "no action" alternative;

(2) Whether conservation, efficiency improvements, and renewable energy can meet part or all of the energy demand Oregon LNG proposes to address;

(3) Whether export from other locations would better serve the public interest by mitigating economic or environmental impacts or by limiting the cumulative impacts of multiple terminals located in one region;

(4) Whether limitations on the sources of exported gas – *e.g.*, limiting export from particular formations or regions – would help to mitigate environmental and economic impacts;

(5) Whether to condition export on the presence of an adequate regulatory framework, including the fulfillment of the recommendations for safe production made by the DOE's Shale Gas Subcommittee, would better serve the public interest by ensuring that the production increases associated with export will not increase poorly-regulated unconventional gas production;

(6) Whether to delay, deny, or condition exports based upon their effect on the U.S. utility market (including changes in air pollution emissions associated with the impacts of increased export demand on fuel choice);

(7) Whether to require exporters to certify that any unconventional gas produced as a result of their proposal (or shipped through their facilities) has been produced in accordance with all relevant environmental laws and according to a set of best production practices;

[26] CEQ, "Forty Most Asked Questions Concerning National Environmental Policy Act Regulations" (http://ceq.hss.doe.gov/nepa/regs/ceq/1502.htm#1502.140).
[27] *Oregon Natural Desert Ass'n*, 625 F.3d at 1122 (internal alterations and citations omitted).

(8) Whether exports, if allowed, should move forward in smaller quantities or a slower time table to mitigate the domestic economic and environmental impacts associated with large export volumes or rapid export schedules;

(9) Whether foreign countries can fuel their economies with non-North American natural gas;

(10) Whether alternative pipeline routes will minimize the potential for geologic hazards, harm to private and public property and safety risks to communities near the pipeline;

(11) Whether to deny export proposals all together as contrary to the public interest.

Other alternatives to LNG are, no doubt, also available, but FERC must at a minimum consider the possibilities listed above, as they are reasonable and bear directly on the public interest findings before it.

B. Purpose and Need.

In satisfying NEPA's EIS requirements, a Federal agency must include the purpose and need for the action.[28] In crafting the purpose and need, FERC should abandon its past practice of identifying an unreasonably narrow purpose and need, and then relying upon the narrow purpose and need to reject reasonable alternatives and the "no action" alternative.

C. Public Safety.

Oregon LNG's proposals raise significant public health and safety issues. The projects would put a significant number of people at risk of catastrophic accidents resulting from an LNG or natural gas accident. The route for LNG tankers and the LNG terminal site itself are extremely close to population centers such as Warrenton and Hammond. The pipelines will cross near residences, through communities, under an interstate highway, and near other areas where accidents or terrorist-induced crimes could leave a devastating toll on human life.

For these reasons, the EIS must fully disclose the consequences of an accidental or terrorist-induced ignition of a vapor cloud from an LNG tank or tanker. Similarly, the planned pipeline has a high-impact blast zone of over 800 feet and would put residents and others along the pipeline route at serious personal risk. The EIS must fully disclose these risks, including risks described below.

- **Terminal safety threats.** The EIS should include an in-depth look at the risks of varying levels of accidents at the terminal, including a catastrophic accident, and a terrorist attack or other crime at Oregon LNG's terminal. This analysis should account for population

[28] 40 C.F.R § 1502.13.

fluctuations during the course of a year. For example, the EIS should evaluate impacts to residents and visitors, including tourists. The Coalition concurs with the National Park Service's comments to FERC: the EIS must analyze safety impacts to visitors of the nearby Lewis and Clark National Historical Park and the Lewis and Clark National Historical Trail.[29]

- **LNG tanker safety threats.** The EIS must include an in-depth look at the risks of a catastrophic accident along the LNG shipping route. The U.S. Coast Guard (Coast Guard) issued a Letter of Recommendation (LOR) regarding waterway suitability for LNG tanker traffic. The Coast Guard's failure to comply with federal law, including NEPA, before issuing the LOR is currently the subject of a federal lawsuit. To date, no agency has disclosed the public safety and environmental risks from LNG tanker traffic, including an LNG tanker accident. FERC has an affirmative duty to disclose the direct, indirect, and cumulative impacts of an LNG tanker accident or terrorist attack, including a spill, release, or explosion. The analysis must address accident scenarios at sea, within U.S. territorial waters, while traveling through the Columbia River Estuary (Estuary), and while docked at the proposed Oregon LNG terminal.

- **Pipeline explosion or release.** As recent natural gas pipeline explosions demonstrate, even with modern safety standards and inspections, deadly pipeline explosions continue to occur. The proposed pipelines will use odor-less gas and have a high-impact blast zone of over 800 feet. The EIS must examine direct, indirect, and cumulative impacts of building and operating the pipelines, including loss of life, property destruction and damage, and wildfires from a pipeline explosion.

- **Maps illustrating threats to loss of human life and property.** The EIS should include clear, visual information that explains the potential risks from accidental or intentional releases in the area around the LNG tanker shipping route, pipelines, and land-based storage that would be affected by a natural gas release, a release and near instantaneous ignition of LNG vapors, or a release that was followed by LNG vapors drifting and subsequent ignition. FERC should also prepare a specific description of the properties and residences that would be adversely affected in the event of a natural gas or LNG release. In addition, FERC should provide maps that show which sensitive community resources, such as schools, senior centers, residences, are encompassed by the various Sandia Labs "Zones of Concern" (zones 1,2 & 3) identified in 2004 and in subsequent Sandia reports.

[29] *See* Letter from the National Park Service to FERC, *Oregon LNG Export Project and Washington Expansion Project, FERC Nos. PF12-18-000, PF12-20-000* (Nov. 7, 2012).

- **Emergency Response Plans.** Oregon LNG has not produced Emergency Response Plans. Additionally, Oregon LNG has not identified resources, including funding, to respond to emergencies. FERC's EIS should encompass emergency response, including funding for emergency response. This analysis should address the spectrum of emergencies that could occur as a result of the project (*i.e.*, equipment failure, earthquake, tsunami, fire, terrorist attack etc.). FERC has a responsibility to use its environmental review to assess the impacts of an LNG spill or pipeline leak, and FERC cannot conduct its review without realistically evaluating the emergency response capabilities in Warrenton and Astoria and communities along the pipeline.

D. Water Resources.

Oregon LNG's project would impact water quality in numerous ways, including stream crossings for the pipeline, water withdrawals during construction, stormwater runoff from terminal facilities, and discharge and suspension or re-suspension of sediment in the Columbia River as a result of dredging and ship transits. FERC's EIS must describe the full range of direct, indirect, and cumulative impacts to water quality.

i. Water Quality and Aquatic Resource Impacts.

LNG tankers, terminals, and pipelines wreak havoc on water quality. Oregon LNG's proposed projects would have serious direct, indirect, and cumulative impacts on water quality and aquatic resources. The scope of FERC's EIS should, at minimum, address the impacts described below.

- **Impacts to water quality during terminal construction.** Oregon LNG proposes building its LNG terminal and industrial dock on undeveloped land, including wetlands, located on the Skipanon Peninsula. The EIS must assess the impacts of polluted stormwater runoff from the terminal construction site. This includes the impacts to water quality from removing riparian habitat and surface runoff to the Columbia and Skipanon rivers.

- **Impacts to water quality and aquatic life from dredging for the LNG dock.** Oregon LNG proposes deepening the Columbia River—removing 1.2. million cubic yards of river bottom—to dock LNG tankers. The company will also dredge 300,000 cubic yards of river bottom every three years to maintain its dock. The EIS must assess the impact of dredging during construction and the impacts of maintenance dredging. Dredge and fill activities associated with construction, for example, would increase turbidity and mobilize toxics in river sediment. In addition to disclosing the direct and indirect impacts of dredging, the EIS must also disclose the cumulative impacts of multiple dredging projects on the Columbia River, including the including

Columbia River Channel Deepening Project and other dredging projects in the Estuary.

- **Impacts to water quality and aquatic habitat from dredge spoil disposal.** The EIS must disclose the direct and indirect impacts of dredge spoil disposal, as well as the cumulative impacts of past, present, and reasonably foreseeable future dredge spoil disposal actions.

- **Impacts to water quality during LNG terminal operations.** Oregon LNG's terminal will increase impervious surfaces, reduce natural infiltration and associated water quality benefits, and increase polluted stormwater runoff to the Skipanon River and Columbia River. During operation, the terminal will discharge polluted process wastewater via the City of Warrenton Publicly Owned Treat Works (POTW). The City of Warrenton POTW has a history of violating National Pollutant Discharge Elimination System (NPDES) permit limits.[30] Oregon LNG's Prefiling Draft Resource Reports grossly underestimate the water quality impacts to the Estuary by concluding, in summary fashion, that the POTW will comply with applicable federal and state standards. The EIS must analyze the direct, indirect, and cumulative impacts of discharging more pollution to the heavily degraded Columbia River, including the City of Warrenton's capacity to treat Oregon LNG's wastewater and the City's ability to comply with new human health criteria for toxics.

- **Invasive species introduced by LNG tankers.** The EIS must examine the impacts of LNG tankers on the introduction of invasive species. This analysis must include the financial and ecological costs of invasive species. FERC must go beyond Oregon LNG's boilerplate 'we will comply with state and federal law' and address the serious economic and ecological threats posed by invasive species. As part of this analysis, FERC must examine the introduction of invasive species from tankers, including but not limited to ballast water discharges.

- **Other water quality impacts from LNG tankers.** The EIS must disclose and analyze the impact of wastewater and stormwater discharged to the Columbia River from LNG tankers, including hot water expelled from tanker engines.

- **Impacts to water quality from pipeline construction.** FERC should analyze the direct and indirect impacts of pipeline construction on water quality. The first – and most dramatic – impact is the potential for a "frac-out." A frac-out occurs when an

[30] Oregon Dept. of Environmental Quality Fact Sheet, City of Warrenton POTW, http://www.deq.state.or.us/wqpr/372_2009120800021CS01.PDF at 2.

HDD fails, fractures a streambed or riverbed, and releases drilling lubricants into the stream. Because the Oregon LNG project and the WEP propose to use HDDs to cross multiple salmon-bearing streams, including the Columbia River itself, FERC must fully assess the potential and impacts of HDD failures. During its import proposal, Oregon LNG repeatedly characterized drilling lubricants (particularly bentonite clay) as "non-toxic." Rather, bentonite clogs fish gills and fish habitat, leading to fish mortality and loss of spawning habitat. At public hearings, both Oregon LNG and WEP characterized HDD as having "no impact" on the environment. The Coalition urges FERC to examine the best available science and reject this characterization. The EIS must disclose the direct, indirect, and cumulative HDD crossings, including the risks for HDD construction impacts and HDD failures.

- **Impacts from pipeline construction to aquatic habitat.** Construction in riparian areas and along steep slopes also increases the risk of erosion and sedimentation in important Columbia River tributaries, some of which are listed as water quality limited (*i.e.,* already in violation of state water quality standards). The EIS must disclose the environmental impacts of pipeline construction at proposed crossings and at alternative crossing locations.

- **Impacts of pipeline construction on ongoing and reasonably foreseeable Estuary restoration work.** Taxpayer dollars have funded extensive restoration work throughout the Estuary. Many restoration projects are currently underway or planned for the near future. For example, the Oregon Department of Fish and Wildlife (ODFW) identified the Lewis & Clark River and its tributaries as being important for Coho salmon, Fall Chinook, and Winters Steelhead. ODFW recommended that the Lewis and Clark River be targeted for easement acquisition to protect functioning riparian areas, as well as restoration of degraded riparian areas, in order to ensure the survival and recovery of these species.[31] The Oregon LNG pipeline directly threatens efforts to stabilize and restore fish and fish habitat. The possibility of HDD frac-out and failure, which Oregon LNG has largely dismissed in its submittals, conflicts with ODFW's identified goal of reducing the sediment load into the Lewis & Clark River and its tributaries. This is one example of why the scope of the EIS must address the potential for Oregon LNG's project to directly or indirectly conflict with completed, ongoing, or reasonably foreseeable future restoration projects in the Estuary, as well along other waterbodies along the proposed pipeline route.

[31] Lower Columbia River Conservation and Recovery Plan For Oregon Populations of Salmon and Steelhead, http://www.dfw.state.or.us/fish/CRP/docs/lower-columbia/OR_LCR_Plan%20-%20Aug_6_2010_Final.pdf .

- **Alternative pipeline locations and impacts to water quality.** The EIS must identify, for each HDD location, alternative crossing locations and methods and, in turn, evaluate the environmental impacts of the alternative locations. If Oregon LNG is forced to relocate its HDD location or use another construction technique, the impact of the pipeline will potentially include surface impacts that have not been evaluated by FERC and other federal agencies. In other pipelines of this size, regulating agencies have required descriptions of potential alternative crossing techniques. Alternate crossing methods would potentially bring pipelines closer to the surface and likely interfere with existing residential, forestry, and agricultural uses, as well as pose an increased safety threat.

ii. Water Consumption.

Oregon LNG's terminal alone will use over four billion gallons of water per year. FERC's EIS must examine the direct, indirect, and cumulative impacts of using precious water resources for LNG. According to Oregon LNG's filings, constructing and testing the pipeline and bidirectional terminal will initially consume 182,900,000 gallons of water.[32] After that, Oregon LNG's proposed bidirectional terminal would consume 4,057,400,000 gallons year-round.[33] Oregon LNG will also use water to hydrostatically test the integrity of the pipeline and parts of the terminal during construction.[34] Oregon LNG intends to purchase the water to hydrostatically test the pipeline from the City of Woodland, Washington.[35] Water to hydrostatically test the infrastructure at the terminal would likely come directly from the Columbia near Warrenton.[36]

Oregon LNG would also use water during the construction of the pipeline for dust control and when conducting horizontal directional drilling under waterways.[37] Oregon LNG's Prefiling Draft Resource Reports state that this water will be withdrawn from the Columbia, the Nehalem, Rock Creek and "various" other sources.[38]

The terminal will need water on a continuous basis for cooling, ballast water, irrigation, fire suppression, and domestic purposes.[39] Oregon LNG is proposing to withdraw water from the Columbia and the Skipanon and/or buy water from the City of Warrenton to meet these water needs.[40] During operation the bidirectional terminal will use over 11 million gallons of water per

[32] Oregon LNG, *Prefiling Review Draft Resource Report 1 — General Project Description*, 1-21, 1-22.
[33] *Id*.
[34] Oregon LNG, *Prefilling Review Draft Resource Report 2 — Water Use and Quality*, 2-15 – 2-18.
[35] *Id*. at 2-15.
[36] *Id*.
[37] Oregon LNG, *Prefiling Review Draft Resource Report 1 — General Project Description*, 1-22.
[38] *Id*.
[39] *Id*. at 1-21.
[40] *Id.*

day.[41] By comparison, water users in the entire city of Astoria use an average of 2.5 million gallons of water per day.[42]

Given the well-documented scarcity of water in the Columbia River Basin, FERC must undertake a robust analysis of the direct, indirect, and cumulative impacts of taking more water out of the Columbia River and its tributaries to support LNG export. This includes evaluating how Oregon LNG's water withdrawals impact water availability, particularly in light on climate change modeling, impacts to Columbia River water quality, impacts to ESA-listed species and other aquatic life and wildlife, and the cumulative impacts of water withdrawals in the Estuary, specifically, and Columbia River Basin, in general.

E. Air Quality and Visual Impacts.

Oregon LNG's terminal would degrade local air quality at the terminal and in the surrounding communities of Warrenton, Hammond, and Astoria. LNG operations emit air pollution from compressors, vaporizers, ships, harbor tugs, support vehicles, gas flares, construction dust, and a myriad of other sources. LNG tankers and the security vessels that accompany them typically run their engines during the entire cargo loading cycle, spewing exhaust and air pollutants that would impact surrounding communities.

FERC must analyze how LNG will degrade clean air and the quality of scenic vistas in the Estuary. As part of this analysis, the EIS must assess the public health impacts of increasing air pollution in the Estuary, along the pipeline route, and in the Pacific Ocean.

- **General impacts to air quality from Oregon LNG's terminal.** Oregon LNG acknowledges the proposed bidirectional terminal is a "major source" and must obtain a preconstruction major source permit (Air Contaminant Discharge Permit) and an operating permit (Title V major source permit). This is a significant change from the LNG import proposal. According to Oregon LNG's FERC filing, the facility exceeds the greenhouse gas PSD threshold. The facility's emissions will also exceed the Significant Emissions Ration (SER) thresholds for NOx, CO, SO2, and PM2.5. The EIS must examine the direct, indirect, and cumulative impacts of Oregon LNG's air pollution emissions.

- **Impacts of fog generation.** FERC noted the potential for the generation of fog during operation of large ambient air vaporizers. FERC must evaluate how the Oregon LNG

[41] Oregon LNG's filings state that it will discharge, at most, 3.5 million gallons of water per day to the City of Warrenton POTW. Oregon LNG Export Project Prefiling Resource Report 1 at 1-25. Consequently, Oregon LNG's consumptive use of water exceeds 7.5 million gallons of water per day.
[42] Daily Astorian, *Where does Astoria's water come from?*, http://www.dailyastorian.com/free/where-does-astoria-s-water-come-from/article_8ccacabe-dfcb-11e0-a440-001cc4c03286.html

project – including both import and export functions – could impact visibility in Warrenton and surrounding communities.

- **Impacts of gas flaring.** The EIS must take hard look at the direct, indirect, and cumulative impacts on air quality from gas flaring at the LNG terminal. FERC should require that Oregon LNG provide a detailed description of how often gas flaring could occur, what gases would be burned, and what the likely emissions would be during maximum flaring operations.

- **Air pollution impacts on public health, including sensitive populations.** Residences, schools, and businesses are located in close proximity to the proposed LNG terminal. FERC must address how overall emissions from the site – including emissions from backup diesel generators, gas flares and docked ships – will impact air quality in nearby areas. For example, many senior citizens live in close proximity to the terminal, including at the Port Warren condominium community on the Skipanon River.

- **Impacts to air quality from LNG tankers and associated vessels.** FERC must evaluate air pollution from LNG tankers and related vessels. LNG tankers and the security vessels that accompany them are required to run their engines during the entire cargo loading cycle, spewing exhaust and air pollutants that would impact surrounding communities.

- **Impacts to air quality from LNG pipelines.** FERC must evaluate how large compressor stations will impact air quality in nearby communities. In particular, FERC must identify the power source and power line route for providing electricity to the large new proposed compressor station in Columbia County. Additionally, FERC must specify whether this station will operate at 48,000 Hp or larger (Oregon LNG's Resource Report 9 suggests 80,000Hp). On the WEP route, Williams has identified multiple compressor stations that could be powered by natural gas, creating significant emissions and impacting air quality for nearby communities. FERC must assess how the emissions from compressors will harm human health near the compressors. Additionally, Williams has requested that plans for its compressor stations be labeled Critical Energy Infrastructure Information (CEII).[43] This designation is inappropriate because it shields basic information from public review, and it frustrates the ability of the public to evaluate the project's impacts. In other pipeline proposals, basic information about compressor stations has not been deemed CEII.

- **Air quality impacts from an LNG import terminal.** Oregon LNG leaves the door open for LNG import and, in turn, FERC must analyze the impacts of LNG import on air

[43] *See* WEP Resource Report 1, Figures 1.1-8 – 1.1-12.

quality. This includes increased combustion of natural gas in the United States and associated impacts on climate change. LNG importation would significantly increase the overall greenhouse gas emissions of natural gas-fired electricity generation in Oregon and the West Coast, due to the added lifecycle emissions of LNG. LNG is up to 30-40 percent more polluting in its greenhouse gas emissions than North American natural gas because of the added emissions that occur in liquefying, shipping, and regasifying LNG.

F. Impacts to Fish and Wildlife.

FERC's EIS must disclose the wide-ranging impacts to endangered and threatened species and other fish and wildlife threatened by LNG. In addition to many of the impacts already identified in Oregon LNG's Prefiling Draft Resource Reports, the EIS must also take a hard look at the direct, indirect, and cumulative impacts of the LNG export terminal, dock, tankers, and pipeline on fish and wildlife, which are described in greater detail below.

- **Impacts to Salmon Recovery.** Oregon and Washington are at the epicenter of salmon recovery. Oregon LNG's project runs directly counter to our region—and the nation's—significant investment in restoring endangered salmon runs. FERC must examine the direct and indirect impacts of LNG and LNG pipelines on ESA-listed salmonids. As part of this analysis, FERC must examine the cumulative effects of other actions and programs of the federal government, and fully disclose the combined impact of ongoing and reasonably foreseeable future actions. This includes the effect of Corps dredging projects, the Bonneville Power Administration's dam operations, water withdrawals authorized by the U.S. Bureau of Reclamation and logging and grazing approved and permitted by the U.S. Forest Service and Bureau of Land Management. FERC must also assess the cumulative impacts of actions authorized and carried out by state, local, and private entities.

- **Impacts to other Threatened and Endangered Species.** Oregon LNG's Prefiling Draft Resource Reports and draft Biological Assessment for the import terminal grossly understate the project's impacts on threatened and endangered species. Yet Oregon LNG relies on these filings for its export terminal, and fails to provide the best available science on how the terminal will impact ESA-listed species. The EIS must go well-beyond the applicant's filings and provide a robust analysis of the project's direct, indirect, and cumulative effects on species such as eulachon and green sturgeon, which were listed after Oregon LNG completed its import terminal resource reports and draft Biological Assessment.

- **Impact from increased ship traffic in the Columbia River Estuary.** The EIS must consider the direct, indirect, and cumulative impacts of increased ship traffic in the Estuary. This includes analyzing increased rates of fish stranding and bank erosion. The

EIS must also assess the increased risk to fish and wildlife from vessel spills and accidents.

- **Cumulative impacts and ESA-listed species.** NEPA requires FERC to analyze the incremental consequences of the Oregon LNG project "when added to other" past, present, and reasonably foreseeable future actions.[44] In turn, FERC must analyze the incremental impact of Oregon LNG project when added to past, present, and reasonably foreseeable future actions on the Columbia River, including dams, logging, industry, cities, and other landscape-level impacts that degrade habitat. For example, coal export speculators are proposing three export terminals on the Columbia: Ambre Energy's 8.8 million ton per year Morrow Pacific Project (Port of Morrow and Port Westward in St. Helens), Kinder Morgan's 30 million ton per year proposal at Port Westward, and Ambre Energy's 44 million tons per year Millennium Bulk Terminals proposal in Longview. Any one of these projects would significantly increase river and marine traffic. Combined, the impacts of coal export and LNG are staggering. FERC must analyze these reasonably foreseeable future energy export projects, as well as other reasonably foreseeable future actions on the Columbia and along the tanker route.

- **Impacts from ballast water and cooling water.** Oregon LNG's resource reports contain inconsistent statements on ballast water and, therefore, the company frustrates the public's ability to comment on the scope of the EIS as it pertains to ballast water impacts.[45] FERC should seek clarification from Oregon LNG and reopen the comment period so that federal and state agencies, the Tribes, and the public can comment on the scope of the EIS as it pertains to ballast water impacts.

- **Impacts from increased ship traffic in the Pacific Ocean.** LNG export directly and indirectly threatens marine life, including ESA-listed species that spend part of their lifecycle in the Pacific Ocean. This issue is addressed in greater detail below.

- **Impacts from pipeline construction and operation on habitat fragmentation.** Habitat fragmentation is one of the most pervasive and difficult to control threats to native ecosystems in the United States. It occurs when land uses break up large contiguous blocks of habitat into smaller patches or when roads, transmission lines, pipelines, or

[44] 40 C.F.R. § 1508.7; *Ctr. for Biological Diversity v. Nat'l Hwy. Traffic Safety Admin.*, 538 F.3d at 1215; *see Or. Natural Resource Council*, 470 F.3d at 822-23 (cumulative impacts analysis inadequate based on failure to consider incremental impacts of timber sales).

[45] *See* Oregon LNG Export Project Prefiling Resource Report 3 at 3-49 ("Export terminal will eliminate the need for ballast water.") *but see* ("The Export terminal will require a cooling/ballast water intake of 1,610 million gallons per year (MG/Y)."). The Resource Report is filed under Oregon LNG's "bidirectional terminal" docket, Docket No. PF12-18-000, yet fails to address ballast water discharges if LNG import occurs.

other corridors penetrate blocks of habitat. FERC's EIS must assess the impacts of habitat fragmentation and the extent to which Oregon LNG's pipeline will compromise the integrity of habitat interior in wetlands, forests, and other ecosystems. For example, habitat fragmentation can have negative effects on wildlife and ecosystems through direct habitat loss or indirectly through changes that occur as a result of the adjacent habitat type and the particular land use associated with it. The EIS must also assess the cumulative impacts of Oregon LNG's proposed pipeline route and existing and reasonably foreseeable future transmission, road, and pipeline right-of-ways that threaten habitat quality and wildlife.

- **Effects of pipeline construction and right-of-ways on habitat disturbance, including increased exotic and invasive species.** The EIS must disclose and evaluate the short-term and long-term impacts of clearing massive right-of-ways to build new pipelines. Impacts include, but are not limited to: providing access for plants and animals that thrive in disturbed environments and the associated detriment to species that require contiguous habitat; opening access to previously remote areas via the new roads and pipelines and the impact of increased human access on fish and wildlife; the spread of invasive plant species; disturbance of sensitive habitats and species of conservation concern, including threatened and endangered species; the increase in car, truck, and heavy machinery traffic; and the impact of pipelines and roads as acting as barriers to movement for many amphibian species and some small mammals.

G. Impacts to State and Private Forestland.

FERC's EIS must disclose the full extent of how Oregon LNG's proposed network of pipelines will impact state and private forestland. The Oregon Department of Forestry (Forestry) submitted extensive comments on December 13, 2012 detailing impacts to state and private forestland, and the Coalition urges FERC to prepare an EIS that addresses the significant concerns raised by Forestry. Although Forestry's comments are specific to the State of Oregon and Oregon law, many of the concerns are equally applicable to Washington State and, therefore, should be addressed for the portions of Oregon LNG's pipeline in Cowlitz County, Washington, and the entire WEP pipeline.

FERC's EIS should address the pipelines' impacts to state and private forestland, including but not limited to:

- consistency with forest management plans
- conflicts with ongoing and future forest operations
- conservation of forest resources
- loss of timber production
- habitat fragmentation

- mass wasting
- stormwater runoff from new forest roads and associated impacts to aquatic resources
- destruction and/or disturbance of riparian habitat
- increased threats of wildfires associated impacts from wildfires
- increased off-road motorized vehicle use in right-of-way corridors and new forest roads
- invasive species
- impacts to hiking trails, camping sites, and water sources for recreationists
- nesting bird sites

The EIS must also analyze the cumulative impacts of Oregon LNG's pipeline and pipeline right-of -ways in addition to existing and reasonably foreseeable future right-of-ways and roads in state and private forestlands.

H. Noise and Light Pollution.

LNG terminals operate around the clock, lighting the night sky as part of their 24-hour surveillance requirements and creating loud noises as they convert natural gas into LNG. According to Oregon LNG's latest filings, the export terminal will require the ability to flare gas —a visual nightmare in the scenic Columbia River Estuary.

The EIS must examine how noise and light pollution will harm the communities in the Estuary, as well as fish and wildlife. The EIS must also disclose the impact of noise and light pollution from pipeline compressor stations. For example, the EIS should disclose the direct and indirect impacts of noise pollution from each compressor station. Specifically, FERC's analysis should evaluate the direct, indirect, and cumulative impacts of noise and light pollution:

- during the LNG terminal construction phase
- in the course of the LNG terminal's operational life
- from LNG tankers
- during pipeline and compressor station construction
- during pipeline maintenance
- from pipeline compressor stations.

The EIS should include a comprehensive discussion of the impacts of noise and light pollution from the Oregon LNG project on public health, including the impacts of light and noise pollution on sleep and attendant health consequence. The EIS should also assess the impact of Oregon LNG's noise and light pollution on aquatic resources and wildlife, including ESA-listed species.

I. Energy Consumption.

The Oregon LNG project will require huge amounts of energy to ship and liquefy natural gas. The source of Oregon LNG's power is unclear, but the company currently plans to purchase power from the grid. Regardless of Oregon LNG's power source, the EIS must address the environmental impacts of generating the power that would fuel the LNG terminal and pipeline compressor stations.

At a minimum, Oregon LNG will likely require 350 MW of energy every day, which is more energy than the average U.S. power plant generates in a day. For example, Jordan Cove LNG plans to build its own gas-fired power plant (the South Dunes Power Project) in order to provide a stable power source for its proposed LNG export terminal in Coos Bay. If Oregon LNG also requires uninterruptible power to operate, FERC must fully evaluate the impact of operating the facility with diesel or future gas-fired generation in the local area. The EIS should also assess the direct, indirect, and cumulative impacts of energy sources that currently generate power for the grid, including hydroelectric and wind power.

J. Recreation.

The EIS must take a hard look at the Oregon LNG's impact on recreation near the LNG terminal, along the LNG tanker route, and along the proposed pipeline route. This includes the project's impact on hiking, biking, kayaking, canoeing, boating, fishing, windsurfing, swimming, camping, and other recreational activities. FERC's analysis should examine the project's impact on lost recreational opportunities, the deterrent effect of LNG on recreation, and LNG's impact on degrading the quality of recreational activities.

On November 7, 2012 the National Park Service (Park Service) submitted detailed comments describing impacts that FERC should evaluate in its EIS. The Park Service manages the Lewis and Clark National Historical Park (Park) and the Lewis and Clark National Historical Trail (Trail). The Coalition agrees with many of the comments raised by the Park Service and recommends that FERC evaluate Oregon LNG's project in light of the Park Service's substantial concerns. These include, but are not limited, the following concerns:

- safety hazards to National Park visitors
- impacts to threatened and endangered species within the Park and along the Trail
- impacts to bald eagles within the Park
- the pipeline's impact to contiguous wetlands located within the Park
- the pipeline's impact on suspending contaminated sediments from the Astoria Marine Construction Company
- impacts to cultural landscapes and viewsheds
- visual and audible impacts to historic sites along the Trail and at the Park
- other recreational impacts, particularly along the Lower Columbia River Water Trail

In addition, the EIS must examine the project's impacts to recreation on private and state-owned lands and local parks.

K. Cultural Resources and Tribal Consultation.

The EIS should evaluate how the construction of the proposed LNG terminal and pipelines will impact cultural resources. This includes impacts to Native American cultural resources, impacts to cultural resources at the Lewis and Clark National Historical Park and along the Lewis and Clark National Historical Trail, and other cultural sites near the terminal, along the LNG tanker route and pipeline route. FERC's EIS will benefit from government-to-government consultation with Columbia River Tribes and other Tribes impacted by the Oregon LNG project.

L. Environmental Justice.

From air pollution to impacts on subsistence fishing, Oregon LNG's project raises significant environmental justice issues. FERC must address these significant impacts in the EIS.

As FERC is aware, on February 11, 1994, President Clinton issued Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." The Executive Order makes it the responsibility of each Federal agency to "make achieving environmental justice part of its mission in identify and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." Accompanying this order was a Presidential Memorandum stating that "each Federal agency shall analyze the environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities, when such analysis is required by the [National Environmental Policy Act]." The CEQ has also issued guidance on incorporating environmental justice considerations in the NEPA process.[46] The guidance states in part:

> Early and meaningful public participation in the federal agency decision making process is a paramount goal of NEPA. CEQ's regulations require agencies to make diligent efforts to involve the public throughout the NEPA process. Participation of low-income populations, minority populations, or tribal populations may require adaptive or innovative approaches to overcome linguistic, institutional, cultural, economic, historical, or other potential barriers to effective participation in the decision-making processes of Federal agencies under customary NEPA procedures.[47]

FERC's actions to date, including inadequate public notice for the Oregon LNG project, described at length above, undercut efforts to inform and engage environmental justice

[46] CEQ, *Environmental Justice: Guidance Under the National Environmental Policy Act*, http://www.epa.gov/environmentaljustice/resources/policy/ej_guidance_nepa_ceq1297.pdf
[47] *Id.* at 13.

communities. The Coalition urges FERC to restart the review process for the newly configured Oregon LNG terminal and pipeline route and engage environmental justice communities in a meaningful way.

M. Natural Disasters and Geologic Hazards.

FERC's EIS must disclose the environmental impacts of Oregon LNG's terminal, tankers, and pipelines in the event of an earthquake, tsunami, and other natural disasters. In addition, the EIS must evaluate proposed pipeline's impacts in light of geologic hazards along the pipeline route. For both the terminal and pipeline, the EIS should address the capacity of first-responders to deal with a catastrophic event caused by an earthquake, tsunami, or other natural disaster. This analysis will assist FERC in reaching a "public interest determination" under the NGA. We offer the following comments for FERC's consideration.

- **Impact of Oregon LNG's terminal in the event of an earthquake or series of earthquakes.** Significant new information about earthquake and tsunami risks has emerged in recent years since Oregon LNG's initial formal application for an import terminal and pipeline in 2008. For example, according to a recently completed study by Oregon State University, geologic data from the past 10,000 years indicates that the Oregon Coast has a significant likelihood of experiencing a subduction zone earthquake in the next 50 years – roughly the lifespan of the Oregon LNG export project.[48] FERC cannot rely on information submitted in previous dockets, CP09-6 & CP09-7, to evaluate earthquake and tsunami hazards in the Cascadia Subduction Zone.

  The EIS must evaluate the direct, indirect, and cumulative impacts of Oregon LNG's terminal in the event of various earthquake scenarios, including the suitability of the Skipanon Peninsula for an LNG terminal. Specifically, Oregon LNG proposes to build its terminal on fill. In Oregon LNG's October 2008 Resource Report 6, the company acknowledged that it had drilled 350 feet deep at the proposed terminal site without reaching bedrock. Oregon LNG proposes "deep soil mixing" to improve the foundation of its project, but this strategy is unproven and may not provide a stable foundation given the very severe geologic risks that could impact the Oregon LNG site.

- **Impacts of Oregon LNG's terminal and pipeline in the event of a tsunami.** A large seismic event in the Pacific Rim has the potential of generating a tsunami on the Oregon Coast. Oregon LNG has failed to identify critical engineering and safety measures that would protect the proposed terminal and pipeline from a large tsunami. The terminal and its marine facilities will have infrastructure located at elevations near sea level, and subject to damage from large waves. FERC must evaluate whether Oregon LNG's proposed system of berms would adequately protect LNG tanks, pipeline infrastructure,

[48] USGS Website, http://pubs.usgs.gov/pp/pp1661f/.

gas flare facilities, and other infrastructure at the LNG terminal. Oregon LNG initially proposed a 10-foot berm for its import terminal. FERC must use the most recent information available in the wake of the Japanese earthquake and tsunami to evaluate the design of the Oregon LNG project.

- **Impact of LNG vessels in the event of a tsunami.** FERC must evaluate the environmental impacts of LNG tanker becoming disabled, damaged, or grounded during a tsunami event.

- **High-water and flooding at the Oregon LNG terminal.** The proposed terminal location is prone to routine weather hazards, including high winds, high waves, and flooding. The EIS must assess the impact of Oregon LNG's terminal on the Columbia River during high-water events.

- **Impact of Oregon LNG's pipeline in the event of an earthquake or series of earthquakes.** The EIS must disclose the direct and indirect impacts of an earthquake, or a series of earthquakes, on pipeline infrastructure. This includes the impacts of pipeline failure, including threats to public safety, wildfires, and impacts to air and water quality.

  Question: How will FERC require Oregon LNG and WEP to plan for simultaneous failures and emergencies at the terminal and on the proposed pipelines?

- **Impact of Oregon LNG's pipeline and landslides.** The EIS should include detailed information about current and historic landslides and how these landslides could impact the integrity of the proposed pipelines. The review should also include risks from operation and construction of the new pipelines to nearby roads, homes, water wells, and other pipelines. For example, the Oregon Department of Transportation and Oregon Department of Forestry expressed concern that pipeline route through the Coast Range poses a long-term threat to slope stability. Along the proposed pipeline route, high winds, heavy rains, and flooding have generated landslides in recent years that have damaged key infrastructure such as roads, pipelines and power lines. Within the past 15 years, land movement has caused multiple pipeline failures in Cowlitz County, and at least one segment of gas pipeline in Cowlitz County near Kelso has been relocated above ground due to an unstable slope.

  Question: Will FERC require an independent, site-specific geologic hazard review for the Oregon LNG pipeline project?

N. Protection of Flood Control Structures.

Oregon LNG's proposed pipelines would intersect dikes and other flood control structures. FERC's EIS must consider the impacts of pipeline construction, operation, and maintenance on these flood control structures and the lives and property they protect. For example, the proposed new pipeline segment beginning in Woodland, Washington, would cross under a dike along the Washington shore of the Columbia River which protects lowland farms around Woodland. On the Oregon side of the Columbia, the new pipeline segment would run for several hundred feet along a dike protecting Deer Island, Oregon. As the proposed pipeline approaches the terminal site, it would intersect various dikes and flood control structures along the lower Lewis and Clark River and around the city of Warrenton, Oregon. The U.S. Army Corps of Engineers (Corps) constructed most or all of these dikes, and maintains on online database and mapping tool describing the exact location of the dikes and flood control structures that lie in the proposed pipeline routes.[49]

Oregon LNG's proposed pipeline construction would require authorization from the Corps. Under the Rivers and Harbors Act, private parties such as Oregon LNG cannot alter federal flood control structures without permission from the Corps. 33 U.S.C. § 408 (hereinafter "Section 408"). Most of the dikes and flood control structures in the path of the pipelines were built, or are owned by, the Corps. Accordingly, Oregon LNG must secure permission under Section 408 from the Corps in order to construct the proposed pipeline segments. Section 408 permits and can require significant data collection and risk analysis by the Corps and the applicant. Riverkeeper encourages FERC to work with the Corps at this early juncture to initiate the Section 408 review process and attendant NEPA analysis.

O. Socioeconomics.

FERC's EIS must address the socioeconomic impacts of authorizing Oregon LNG's project. The Coalition highlights some of the socioeconomic issues FERC should incorporate in the draft EIS.

- **LNG's impact on economic development and property values.** Oregon LNG's terminal will deter economic development, decrease property values, cause the loss of tourism and recreation related jobs, and result in a generally reduced quality of life around the Estuary. The pipelines will degrade property values, including farms and forestlands, by preventing customary uses of land, causing erosion and environmental damage, harming drainage systems, and creating a safety risk. The EIS must account for the direct and indirect impacts of LNG on economic development and decreased property values. This analysis should include an assessment of the attendant impact on state and federal sales and property taxes.

[49] *See* National Levee Database, http://nld.usace.army.mil/egis/f?p=471:1.

- **Impacts to Ratepayers**. LNG export will increase domestic natural gas prices, forcing American ratepayers to outbid high-priced Asian markets. This issue is addressed at length in Sierra Club and Columbia Riverkeeper's comments to the U.S. Department of Energy on Oregon LNG's nFTA application, FE Docket No. 12-77-LNG. The Coalition incorporates those comments by reference and attaches them hereto as Exhibit A. FERC must consider the environmental and social impacts of LNG export on ratepayers.

- **Impacts from Exclusions Zones in the Columbia River.** LNG tankers would require exclusion zones. This will restrict fishing and directly interfere with recreational kayaking and boating. FERC should take a hard look at how LNG tankers and associated marine traffic would change the face of commerce, recreational fishing, and other uses of the Columbia River. For example, many fishing, crabbing, and recreational boats are moored in the Skipanon River. FERC and the USCG must evaluate the potential negative impact of the Oregon LNG project on these local vessels.

P. Increased Natural Gas Production.

FERC must examine significant environmental impacts from increased gas production. The Energy Information Administration (EIA), essentially every other LNG export applicant, and other informed commenters all agree that LNG exports will induce additional production in the U.S. The Oregon LNG proposal is no exception: notwithstanding its stated plan to source gas for export from Canada, Oregon LNG concedes that the proposed project will induce additional production in the U.S.[50]

- **Impact of induced natural gas production in the U.S.** As Oregon LNG explains, if gas produced in Canada is not exported, that gas will enter the U.S. market.[51] This increase of supply in the U.S. market would, in turn, lower gas prices and cause U.S. gas producers to produce less gas than they would otherwise.[52] Conversely, to the extent that Canadian gas is exported, U.S. gas prices will be higher, incentivizing domestic gas producers to increase production.[53] Sierra Club and Columbia Riverkeeper submitted extensive comments on induced natural gas production and Oregon LNG (Exhibit A), which are incorporated by reference. FERC's EIS must examine the direct, indirect, and cumulative impacts of induced gas production

[50] *See* DOE Application at 24 ("the demand induced by . . . exports will spur production" in the U.S.).
[51] *Id.* at 15.
[52] *Id.*
[53] The project may also export gas produced in the U.S., likely produced in the Rocky Mountain states, directly inducing further U.S. production. Although Oregon LNG states that they expect that market conditions will favor sourcing gas from Canada, the application explicitly notes that the pipeline infrastructure will provide the ability to export gas produced in the U.S., and the application offers no legal restriction on Oregon LNG's ability to do so. As the EIA Export Study demonstrates, exports of gas produced in the US will increase US production.

resulting from Oregon LNG project. Even if (contrary to all available evidence and Oregon LNG's own admission) the proposed exports would not induce additional gas production in the U.S., the proposed exports would undoubtedly induce additional production in Canada, and FERC must consider the effect of that induced production on the environment in the U.S.

- **Impact of natural gas production.** Natural gas production—from both conventional and unconventional sources—is a significant air pollution source, can disrupt ecosystems and watersheds, leads to industrialization of entire landscapes, and presents challenging waste disposal issues. Oregon LNG predicts that its gas will primarily come from British Columbia's Horn River Basin, which is mostly shale gas.[54] Shale gas production (as well as coalbed and tight sands production) requires the controversial practice of hydraulic fracturing, or fracking. The EIS must address the impacts of fracking on air pollution, surface and groundwater pollution, habitat destruction, climate change, and other environmental and socioeconomic impacts.

Q. Climate Change.

The EIS must examine the lifecycle greenhouse gas emissions of extracting, exporting, and burning natural gas. This includes the associated impact on climate change. LNG derived from conventional gas wells has a 30% larger carbon footprint than domestic natural gas. On a global scale, LNG will have a greater impact to climate change than current natural gas sources used in the Pacific Northwest.

- **Climate change impacts from powering the LNG terminal.** Oregon LNG project has failed to specify a source of electricity generation for its LNG export terminal. Instead, Oregon LNG claims that it will buy its power from the grid. However, Oregon LNG will be adding to the overall load on the grid, and the source of its electricity must be considered in the overall climate change impact assessment. Indeed, if Oregon LNG is planning to purchase power from Pacific Power, the electricity generated to liquefy LNG may come partially from coal-fired generation, thus increasing the overall carbon footprint of Oregon LNG's proposal.

- **Lifecycle emissions of LNG export.** The EIS must address the overall lifecycle emissions of LNG exports, including but not limited to: fracking of natural gas and the resulting methane leakage in gas fields; fugitive emissions from piping and compressing natural gas; emissions from electricity generation necessary to

[54] DOE Application at 17.

operate the terminal; pollution from shipping gas overseas in tankers powered by bunker fuel; and, emissions from regasifying LNG once it reaches its target market. From cradle to grave, FERC should consider how Oregon LNG will increase global warming pollution.

R. Migratory Birds.

The Center for Biological Diversity (the Center) submitted detailed comments explaining why FERC must evaluate the project's impacts on migratory birds, and the Coalition hereby incorporates those comments by reference. The Center's comments are attached hereto as Exhibit B and incorporated by reference.

FERC must consider the direct impacts of the project, and particularly pipeline construction, on migratory and other birds under NEPA. In addition, FERC must consider the project's transboundary impacts on migratory birds, including impacts where natural gas is extracted. For example, the project may take birds directly through collisions with vehicles, nest disturbances and destruction, and other impacts, and indirectly through increases in predation opportunities and habitat disturbance. Further, FERC must consider the impacts of gas drilling in Canada on birds and other wildlife.

S. Marine Resources.

LNG export poses significant threats to marine life. Oregon LNG's project will increase current ship traffic on the North Pacific Great Circle Route, including passing through sensitive marine life habitat such as feeding and breeding grounds and migratory routes. For example, Oregon LNG's tankers will pass through the Aleutian Islands Alaska Maritime Wildlife Refuge. FERC's EIS must analyze the impacts of additional maritime traffic, including the increased risk of vessel spills, accidents, and harm to sensitive marine life. Oregon LNG's impacts to marine resources are addressed in comments submitted by the Center which, as noted above, the Coalition incorporates by reference.

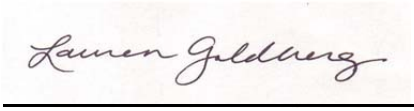
For the reasons explained by the Center, FERC must prepare an EIS that takes a hard look at the direct, indirect, and cumulative impacts of LNG tanker traffic on marine resources. This includes the cumulative impacts of Oregon LNG tanker traffic and past, present, and reasonably foreseeable future ship traffic. For example, FERC must analyze the combined impact of Oregon LNG's tanker traffic and the reasonably foreseeable future impacts of LNG tankers transporting LNG to the proposed Jordan Cove LNG terminal in Coos Bay and Panamax ships exporting coal, which is addressed in greater detail below.

VII. Conclusion.

Oregon LNG's proposal will impose significant environmental and economic harm, which must be disclosed as part of a programmatic EIS on LNG projects, as well as an individual

EIS on the Oregon LNG project. Moving forward, FERC should: (1) prepare a programmatic EIS that examines the serious threats of LNG export nationwide; and (2) reopen the public comment period and request input on the actual project Oregon LNG proposes to build. FERC's disjointed NEPA process stymies effective public input on the project's impacts and, therefore, the agency must rectify this serious problem before proceeding with preparation of an EIS.

Submitted on behalf of Columbia Riverkeeper, Sierra Club, Greenpeace, Landowners and Citizens for a Safe Community, Northwest Property Rights Coalition, Columbia Pacific Commonsense, Friends of Living Oregon Waters, Wahkiakum Friends of the River, Forest Grove Oregon Citizens Against the Pipeline, and Food and Water Watch by:



Lauren Goldberg
Staff Attorney, Columbia Riverkeeper
111 Third Street
Hood River, OR 97031
541-965-0985
lauren@columbiariverkeeper.org

EXHIBIT A

UNITED STATES OF AMERICA
DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY

IN THE MATTER OF	**)**	
	)	**FE DOCKET NO. 12-77-LNG**
LNG Development Company, LLC	**)**	
(d/b/a Oregon LNG)	**)**	
	)	

SIERRA CLUB AND COLUMBIA RIVERKEEPER'S MOTION TO INTERVENE, PROTEST, AND COMMENTS

Nathan Matthews
Associate Attorney
Sierra Club Environmental Law Program
85 2nd St., Second Floor
San Francisco, CA 94105
(415) 977-5695 (tel)
(415) 977-5793 (fax)

Kathleen Krust
Paralegal
Sierra Club Environmental Law Program
85 2nd St., Second Floor
San Francisco, CA 94105
(415) 977-5696 (tel)

Table of Contents

I. Sierra Club and Columbia Riverkeeper Should be Granted Intervention 2
II. Service 4
III. Sierra Club and Riverkeeper Protest this Application Because It Is Not In the Public Interest and Is Not Supported by Adequate Environmental and Economic Analysis 4
A. Legal Standards 5
1. Natural Gas Act 5
2. National Environmental Policy Act 8
3. Endangered Species Act 10
4. National Historic Preservation Act 11
B. All Pending Export Applications, Pipelines, and Studies Must Be Incorporated Into DOE/FE's NEPA, NGA, and Other Analyses 12
1. Williams Pipeline Expansion 12
2. DOE/FE Must Consider the Cumulative Effect of All Pending Export Proposals, and Should Do So Using A Programmatic EIS 13
3. DOE/FE Must Not Act Until Its Pending Study of LNG Exports' Economic Impacts Is Complete 14
4. The Alternatives Analysis Must Consider This Broader Context 14
5. DOE/FE May Not Conditionally Approve Oregon LNG's Proposal Prior to NEPA Review 16
C. Oregon LNG's Proposal Will Have Numerous Harmful Environmental Effects and Is Contrary to The Public Interest 17
1. The Project Will Have Significant Adverse Impacts Not Discussed in Oregon LNG's Application 17
a. Local Environmental Impacts 18
i. Local Air Pollution 18
ii. Terminal and Pipeline Water Quality Impacts 22
iii. Geologic Hazards 23
iv. Wildlife 23
b. Induced Gas Production 23
i. Oregon LNG's Proposal Will Induce Additional U.S. Gas Production 24
ii. Induced Production Must Be Considered in the NEPA and NGA Analyses 26
iii. Environmental Harm Resulting from Induced Production 29
1. Natural Gas Production is a Major Source of Air Pollution 29
2. Gas Production Disrupts Landscapes and Habitats 38
3. Gas Production Poses Risks to Ground and Surface Water 41
c. Other Nationwide and Global Impacts 49
i. Price Increases 49
ii. Changes in Domestic Power Production 53
iii. Effects on Global Greenhouse Gas Emissions 55
2. The Economic Benefits Oregon LNG Predicts are Uncertain and Overstated 59
3. DOE/FE Cannot Rationally Approve Oregon LNG's Export Plan On the Record Before It 61
D. If DOE/FE Does Move Forward, It Must Impose Rigorous Monitoring Conditions 62
IV. Conclusion 63

UNITED STATES OF AMERICA
DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY

IN THE MATTER OF	**)**	
	)	**FE DOCKET NO. 12-77-LNG**
LNG Development Company, LLC	**)**	
(d/b/a Oregon LNG)	**)**	
	)	

SIERRA CLUB AND COLUMBIA RIVERKEEPER'S MOTION TO INTERVENE, PROTEST, AND COMMENTS

LNG Development Company, LLC, d/b/a Oregon LNG ("Oregon LNG"), requests authorization to export up to 1.3 billion cubic feet per day (bcf/d) of natural gas as liquefied natural gas ("LNG") from a proposed LNG export terminal in Warrenton, Clatsop County, Oregon. This proposal cannot move forward without extensive environmental and economic analyses that Oregon LNG has not provided to the Department of Energy Office of Fossil Energy ("DOE/FE"). In any event, the available evidence demonstrates that this proposal is inconsistent with the public interest.

In particular, although Oregon LNG asserts that its facility will primarily export gas produced in Canada, Oregon LNG concedes (as it must) that the proposal would increase natural gas production, especially shale gas production, in the United States. Application at 24. DOE/FE cannot authorize exports without fairly weighing significant environmental and economic impacts of this production. *See, e.g.*, *Udall v. Federal Power Comm'n*, 387 U.S. 428, 450 (1967). Exports will also harm the public interest by increasing domestic gas prices and likely increasing global greenhouse gas emissions. Locally, although Oregon LNG asserts that the project will benefit Clatsop County and Oregon generally, Oregon LNG gives short shrift to the local environmental impacts of the proposal.

Because Sierra Club and Columbia Riverkeeper's many thousands of members have a direct interest in ensuring that domestic natural gas production is conducted safely, and that any exports do not adversely affect domestic consumers, these organizations move to intervene in this proceeding and protest Oregon LNG's application.

I. Sierra Club and Columbia Riverkeeper Should be Granted Intervention

Sierra Club members live and work throughout the area that will be affected by the Oregon LNG export plan, including in the regions adjacent to the proposed facility and in regions near the pipelines necessary to supply the plant. Sierra Club members also live in the domestic gas fields that will likely see increased production as a result of the proposed exports. Sierra Club members everywhere will also be affected by increased gas prices which would be caused by the plan. As of July 2012, Sierra Club had 15,525 members in Oregon and 601,141 members overall. Declaration of Yolanda Andersen at ¶ 7.[1]

Columbia Riverkeeper ("Riverkeeper") is a 501(c)(3) non-profit organization dedicated to restoring and protecting the Columbia River and all life connected to it. Riverkeeper members utilize the land, air, and water throughout the Columbia River estuary and, specifically, the area near and at the Oregon LNG site for economic, recreational, scientific, and aesthetic reasons. Riverkeeper currently has over 3,000 members, including many members who live in Clatsop County. Riverkeeper's members live and/or work near the proposed Oregon LNG site and along the Columbia River and estuary where the proposed tanker routes traverse. Many of Riverkeeper's members live and/or work in communities on the banks of the Columbia River. Some of Riverkeeper's members recreate, on a continuing and ongoing basis, in and along the Columbia River at and/or near the Oregon LNG site. Riverkeeper's members use and enjoy species and habitat of the Columbia River for aesthetic, scientific, education, spiritual and recreational purposes. These uses include, but are not limited to, hiking, swimming, boating, wildlife observation, photography, and general aesthetic enjoyment. Riverkeeper's members intend to continue such uses on an ongoing basis in the future.

To protect their members' interests, Sierra Club and Riverkeeper therefore move to intervene in this proceeding, pursuant to 10 C.F.R. § 590.303(b).Consistent with that rule, Sierra Club and Riverkeeper states that their "asserted rights and interests," in this matter include, but are not limited to, interests in the following:

- The environmental consequences of any gas exports from the Oregon LNG facility, including emissions and other pollution associated with the gasification and liquefaction processes, environmental damage associated with pipeline, facility construction and operation, environmental impacts caused by shipping traffic, and the emissions associated with all phases of the process from production to combustion.
- The environmental and economic consequences of any expansion or change in natural gas production, especially in shale gas plays, as a result of increased gas

[1] Attached as Exhibit 1.

exports. Members living in these regions will be affected by the damage to air, land, and water resources caused by the increasing development of these plays, and the public health risks caused by these harms.

- The economic impacts of any gas exports from the Oregon LNG facility, whether individually or in concert with exports from other such facilities, including the consequences of price changes upon the organizations' members' finances, consumer behavior generally, and industrial and electrical generating facilities whose fuel choices may be affected by price changes. Sierra Club, in particular, works to reduce U.S. and global dependence on fossil fuels, including coal, gas, and oil, and to promote clean energy and efficiency in order to protect public health and the environment. To the extent changes in gas prices increase the use and production of coal and oil, Sierra Club's interests in this proceeding are directly implicated.
- The public disclosure, in National Environmental Protection Act and other documents, of all environmental, cultural, social, and economic consequences of Oregon LNG's proposal, and of all alternatives to that proposal.

In short, Sierra Club and Riverkeeper's members have vital economic, aesthetic, spiritual, personal, and professional interests in the project.

These organizations have demonstrated the vitality of these interests in many ways. Sierra Club runs national advocacy and organizing campaigns dedicated to reducing American dependence on fossil fuels, including natural gas, and to protecting public health. These campaigns, including its Beyond Coal campaign and its Beyond Natural Gas campaign, are dedicated towards promoting a swift transition away from fossil fuels and to reducing the impacts of any remaining natural gas extraction.

Riverkeeper and its members have been and continue to be actively involved in efforts to protect and restore the Columbia River from pollution. These efforts include protecting humans and wildlife from exposure to pollutants. Riverkeeper has pursued numerous avenues to reduce the threats of pollution in the Columbia River and at in the Columbia River Estuary. Riverkeeper and its members have written articles discussing the ecological importance of and threats to the Columbia River and threats posed by LNG terminals and tankers, commented on various federal and state agency actions that affect the Columbia River and Oregon LNG site, and when necessary, pursued litigation.

Thus, although 10 C.F.R. § 590.303 states no particular standard for intervention, Sierra Club and Riverkeeper have interests in this proceeding that would be sufficient to support intervention on any standard. This motion to intervene must be granted.[2]

[2] If any other party opposes this motion, we respectfully requests leave to reply. *Cf.* 10 C.F.R. §§ 590.302, 590.310 (allowing for procedural motions and briefing in these cases).

II. Service

Pursuant to 10 C.F.R. § 590.303(d), Sierra Club and Riverkeeper identify the following persons for service of correspondence and communications regarding this application:

Nathan Matthews
Associate Attorney
Sierra Club Environmental Law Program
85 2nd St., Second Floor
San Francisco, CA 94105
(415) 977-5695 (tel)
(415) 977-5793 (fax)

Kathleen Krust
Paralegal
Sierra Club Environmental Law Program
85 2nd St., Second Floor
San Francisco, CA 94105
(415) 977-5696 (tel)

III. Sierra Club and Riverkeeper Protest this Application Because It Is Not In the Public Interest and Is Not Supported by Adequate Environmental and Economic Analysis

Section 3 of the Natural Gas Act provides that DOE/FE cannot authorize exports unless it finds the exports to be in the public interest. 15 U.C.C. § 717b. Environmental factors must weigh in to this public interest analysis. Accordingly, DOE/FE cannot proceed with Oregon LNG's application without fully evaluating the environmental impacts of Oregon LNG's proposal. The National Environmental Policy Act ("NEPA"), 42 U.S.C. § 4332 *et seq*., provides the congressionally mandated procedure for assessment of these impacts, and NEPA requires that these procedures be completed "at the earliest possible time," *i.e.*, "*before* decisions are made and *before* actions are taken." 40 C.F.R. §§ 1501.2, 1500.1(b) (emphases added). Accordingly, DOE/FE cannot proceed with Oregon LNG's request for conditional export authorization until the NEPA process is completed, including preparation of an Environmental Impact Statement.

Oregon LNG's application is silent as to the environmental impacts of its proposal. For this and other reasons, Oregon LNG utterly fails to demonstrate that its proposal is in the public interest. As we explain below, the proposal will cause three types of significant environmental harm. First, the construction and operation of the terminal, liquefaction facilities, and associated new pipeline will directly impact local water quality, habitats, and air quality. Second, the project will induce additional natural gas production in the United States, primarily involving hydraulic fracturing ("fracking") of unconventional gas sources, causing attendant environmental harm; this inducement will occur notwithstanding Oregon LNG's plan to export gas produced in Canada. Third, the project will increase domestic gas prices, likely causing an increase in coal fired electricity generation, increasing emissions of greenhouse gas, conventional, and toxic air pollutants.

Oregon LNG's economic arguments are unpersuasive. Contrary to Oregon LNG's contentions, LNG export will significantly increase domestic gas prices, harming domestic consumers and, as noted above, increased coal-fired electricity generation. On the other hand, Oregon LNG's predictions of job creation and other economic benefit are overstated. These predictions are derived from flawed IMPLAN input-output models. In particular, these models provide no consideration of counterfactuals, and are therefore unable to identify which of the purportedly "supported" jobs and benefits would have existed anyway.

For these reason and the other reasons set forth below, Sierra Club and Riverkeeper file this protest, pursuant to 10 C.F.R. § 590.304.

A. Legal Standards

DOE/FE has significant substantive and procedural obligations to fulfill before it can authorize Oregon LNG's export proposal. We discuss some of those obligations created by the Natural Gas Act, the National Environmental Policy Act, the Endangered Species Act, and the National Historic Preservation Act, here, before explaining why these obligations preclude Oregon LNG's request for conditional authorization.

1. Natural Gas Act

Pursuant to the Natural Gas Act and subsequent delegation orders, DOE/FE must determine whether Oregon LNG's proposal to export LNG to nations which have not signed a free trade agreement ("FTA") with the United States is in the public interest.[3] Courts, the Federal Energy Regulatory Commission ("FERC"), and DOE/FE, and Oregon LNG all agree that the "public interest" at issue in this provision includes environmental impacts.

Section 3 of the Act provides:

> [N]o person shall export any natural gas from the United States to a foreign country or import any natural gas from a foreign country without first having secured an order of [DOE/FE] authorizing it do so. [DOE/FE] shall issue such order upon application unless, after opportunity for

[3] The Natural Gas Act separately provides that DOE/FE must approve exports to nations that have signed a free trade agreement requiring national treatment for trade in natural gas "without modification or delay." 15 U.S.C. § 717b(c). DOE/FE has previously authorized Oregon LNG to export 1.25 bcf/d LNG to such nations. DOE/FE Order No. 3100 (May 31, 2012).

> hearing, it finds that the proposed exportation or importation will not be consistent with the public interest.

15 U.S.C. § 717b(a).[4]

Courts have interpreted this provision to include environmental effects. While the public interest inquiry is rooted in the Natural Gas Act's "fundamental purpose [of] assur[ing] the public a reliable supply of gas at reasonable prices," *United Gas Pipe Line Co v. McCombs*, 442 U.S. 529 (1979), the Natural Gas Act also grants DOE/FE "authority to consider conservation, environmental, and antitrust questions." *Nat'l Ass'n for the Advancement of Colored People v. Federal Power Commission*, 425 U.S. 662, 670 n.4 (citing 15 U.S.C. § 717b as an example of a public interest provision); n.6 (explaining that the public interest includes environmental considerations) (1976). In interpreting an analogous public interest provision applicable to hydroelectric power and dams, the Court has explained that the public interest determination "can be made only after an exploration of all issues relevant to the 'public interest,' including future power demand and supply, alternate sources of power, the public interest in preserving reaches of wild rivers and wilderness areas, the preservation of anadromous fish for commercial and recreational purposes, and the protection of wildlife." *Udall v. Fed. Power Comm'n*, 387 U.S. 428, 450 (1967) (interpreting § 7(b) of the Federal Water Power Act of 1920, as amended by the Federal Power Act, 49 Stat. 842, 16 U.S.C. § 800(b)). Other courts have applied this *Udall* holding to the Natural Gas Act. *See, e.g.*, *N. Natural Gas Co. v. Fed. Power Comm'n*, 399 F.2d 953, 973 (D.C. Cir. 1968) (interpreting section 7 of the Natural Gas Act).[5]

DOE has similarly acknowledged the breadth of the public interest inquiry, including environmental concerns. Deputy Assistant Secretary Smith recently testified that "[a] wide range of criteria are considered as part of DOE's public interest review process, including . . . U.S. energy security . . . [i]mpact on the U.S. economy . . . [e]nvironmental considerations . . . [and] [o]ther issues raised by commenters and/or interveners

[4] The statute vests authority in the "Federal Power Commission," which has been dissolved. DOE/FE has been delegated the former Federal Power Commission's authority to authorize natural gas exports. Department of Energy Redelegation Order No. 00-002.04E (Apr. 29, 2011). The Federal Energy Regulatory Commission has separately been delegated authority regarding the permitting, siting, construction and operation of export facilities. Department of Energy Delegation Order No. 00-004.00A. *See also* Executive Orders 12038 & 10485 (vesting any executive authority to allow construction of export facility in the Federal Power Commission and its successors).

[5] Further support for the inclusion of environmental factors in the public interest analysis is provided by NEPA, which declares that all federal agencies must seek to protect the environment and avoid "undesirable and unintended consequences." 42 U.S.C. 4331(b)(3).

deemed relevant to the proceeding." Testimony of Christopher Smith, Deputy Assistant Secretary of Oil and Gas Before the Senate Committee on Energy and Natural Resources (Nov. 8, 2011).[6] DOE rules require export applicants to provide information documenting "[t]he potential environmental impact of the project." 10 C.F.R. § 590.202(b)(7). In a previous LNG export proceeding, DOE determined that the public interest inquiry looks to "domestic need" as well as "other considerations" that included the environment. *Phillips Alaska Natural Gas Corporation and Marathon Oil Company*, 2 FE ¶ 70,317, DOE FE Order No. 1473, *22 (April 2, 1999); *accord* Opinion and Order Conditionally Granting Long-Term Authorization to Export [LNG] from Sabine Pass LNG Terminal to Non-Free Trade Agreement Nations ("Sabine Pass"), DOE/FE Order 2961 at 29 (May 20, 2011) (acknowledging that the public interest inquiry extends beyond effects on domestic natural gas supplies). Finally, DOE has applied its "policy guidelines" regarding the public interest to focus review "on the domestic need for the natural gas proposed to be exports; whether the proposed exports pose a threat to the security of natural gas supplies, *and any other issue determined to be appropriate*." Sabine Pass at 29 (citing 49 Fed. Reg. 6,684 (Feb. 22, 1984)) (emphasis added).[7]

FERC has agreed that environmental issues weigh on the public interest calculus. In FERC's recent order approving siting, construction, and operation of LNG export facilities in Sabine Pass, Louisiana, FERC considered potential environmental impacts of the terminal as part of its public interest assessment. 139 FERC ¶ 61,039, PP 29-30 (Apr. 14, 2012).[8]

Similarly, Oregon LNG acknowledges that the public interest inquiry has consistently been interpreted to include impacts on the environment. Application at 13.

Although DOE/FE has adopted a presumption that LNG export applications are consistent with the public interest, this presumption is rebuttable and not determinative. The DC Circuit Court has explained to DOE/FE this presumption is "highly flexible, creating *only* rebuttable presumptions and leaving parties free to assert other factors." *Panhandle Producers and Royalty Owners Ass'n v. Economic Regulatory Administration*, 822 F.2d 1105, 1110-1111, 1113 (D.C. Cir. 1987) (emphasis added, internal quotation marks omitted). Put differently, although DOE/FE may "presume" that an application should be granted, this presumption is not determinative, and DOE/FE retains an independent duty to determine whether an application is, in fact, in

[6] Attached as Exhibit 2.

[7] Although germane here, these Policy Guidelines are merely guidelines: they "cannot create a norm binding the promulgating agency." *Panhandle Producers and Royalty Owners Ass'n v. Economic Regulatory Administration*, 822 F.2d 1105, 1110-1111 (D.C. Cir. 1987).

[8] Sierra Club contends that other aspects of this order were wrongly decided, as was FERC's subsequent denial of Sierra Club's petition for rehearing, as we explain below.

the public interest. *See* 10 C.F.R. § 590.404.

2. **National Environmental Policy Act**

NEPA requires federal agencies to consider and disclose the "environmental impacts" of proposed agency actions. 42 U.S.C. § 4332(C)(i). This requirement is implemented via a set of procedures that "insure [sic] that environmental information is available to public officials and citizens *before* decisions are made and *before* actions are taken." 40 C.F.R. § 1500.1(b) (emphases added). Agencies must "carefully consider [ ] detailed information concerning significant environmental impacts" and NEPA "guarantees that the relevant information will be made available" to the public. *Dep't of Transp. v. Public Citizen*, 541 U.S. 752, 768 (2004) (quoting *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989)). The Council on Environmental Quality ("CEQ") directs agencies to "integrate the NEPA process with other planning at the earliest possible time to insure that planning and decisions reflect environmental values." 40 C.F.R. § 1501.2. "It is DOE's policy to follow the letter and spirit of NEPA; comply fully with the [CEQ] Regulations and apply the NEPA review process early in the planning stages for DOE proposals." 10 C.F.R. § 1021.100. DOE has adopted CEQ's NEPA regulations in full. *Id.* § 1021.103. The NEPA rules apply to "any DOE action affecting the quality of the environment of the United States, its territories or possessions." *Id.* § 1021.102.

For purposes of the intersection of NEPA and the NGA, the NGA designated the former Federal Power Commission as the "lead agency" for NEPA purposes. 15 U.S.C. § 717n. The lead agency prepares NEPA documents for an action that falls within the jurisdiction of multiple federal agencies. FERC has since generally filled that role, preparing the NEPA documents for LNG export and import decisions, as it did in *Sabine Pass*. *See* 10 C.F.R. § 1021.342 (providing for interagency cooperation). Whether or not FERC takes a lead role, however, DOE's ultimate NEPA obligations are the same: It may not move forward until the full scope of the action *it* is considering – here the approval of LNG export – has been properly considered. Thus, if FERC prepares an deficient NEPA analysis, this will not meet DOE/FE's NEPA obligations, and DOE/FE will be unable to rely thereon.

The NEPA process is embodied in preparation of an "environmental impact statement" ("EIS") where, as here, the proposed major federal action would "significantly affect[] the quality of the human environment." 42 U.S.C. § 4332(C). With regard to this proposed project, FERC has already committed to completion of an EIS, 77 Fed. Reg. 59,603 (Sept. 28, 2012), including future circulation of a draft EIS and public comment thereon, *id.* at 59,605. DOE/FE regulations similarly provide that "[a]pprovals or disapprovals of authorizations to import or export natural gas… involving major operational changes (such as a major increase in the quantity of liquefied natural gas imported or exported" will "normally require [an] EIS." 10 C.F.R. Part 1021, Appendix D, D9. We agree that a full EIS is appropriate and required here. Furthermore, if the EIS

FERC prepares is inadequate to inform DOE/FE's decision or discharge DOE/FE's NEPA obligations, DOE/FE must prepare a separate EIS.

An EIS must describe:

> i. the environmental impact of the proposed action,
>
> ii. any adverse environmental effects which cannot be avoided should the proposal be implemented,
>
> iii. alternatives to the proposed action,
>
> iv. the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and
>
> v. any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

42 U.S.C. § 4332(C). The alternatives analysis "is the heart of the environmental impact statement." 40 C.F.R. § 1502.14. Here, the proposed action is to export LNG from the proposed facility; DOE/FE must consider alternatives to this action. DOE/FE must take care not to define the project purpose so narrowly as to prevent the consideration of a reasonable range of alternatives. *See, e.g.*, *Simmons v. U.S. Army Corps of Engineers*, 120 F.3d 664, 666 (7th Cir. 1997). If it did otherwise, it would lack "a clear basis for choice among options by the decisionmaker and the public." *See* 40 C.F.R. § 1502.14.

An EIS must also describe the direct and indirect effects, and cumulative impacts of, a proposed action. 40 C.F.R §§ 1502.16, 1508.7, 1508.8; *Northern Plains Resource Council v. Surface Transportation Board*, 668 F.3d 1067, 1072-73 (9th Cir. 2011). These terms are distinct from one another: Direct effects are "caused by the action and occur at the same time and place." 40 C.F.R. § 1508.8(a). Indirect effects are also "caused by the action" but:

> are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effect on air and water and other natural systems, including ecosystems.

40 C.F.R. § 1508.8(b). Cumulative impacts, finally, are not causally related to the action. Instead, they are:

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

40 C.F.R. § 1508.7. The EIS must give each of these categories of effect fair emphasis.

Agencies may also prepare "programmatic" EISs, which address "a group of concerted actions to implement a specific policy or plan; [or] systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive." 40 C.F.R. § 1508.17(b)(3); *see also* 10 C.F.R. § 1021.330 (DOE regulations discussing programmatic EISs). As we discuss below, such an EIS is appropriate here.

Finally, while an EIS is being prepared "DOE shall take no action concerning the proposal that is the subject of the EIS" until the EIS is complete and a formal Record of Decision has been issued. 10 C.F.R. § 1021.211. During this time, DOE may take no action which would tend to "limit the choice of reasonable alternatives," or "tend[] to determine subsequent development ." 40 C.F.R. § 1506.1.

3. **Endangered Species Act**

Pursuant to the Endangered Species Act's (ESA) directive that all agencies "shall seek to conserve endangered species," 16 U.S.C. § 1531(c)(1), DOE/FE must ensure that its approval of the Oregon LNG project "is not likely to jeopardize the continued existence of any endangered species . . . or result in the destruction or adverse modification of [critical] habitat of such species." 16 U.S.C. § 1536(a)(2). "Each Federal agency shall review its actions at the earliest possible time to determine whether any action may affect listed species or critical habitat." 50 C.F.R. § 402.14(a); *see also* 16 U.S.C. § 1536(a)(2).

This determination must be wide-ranging, because Oregon LNG's export proposal will increase gas production activities nationwide. Thus, DOE/FE must consider not just the effects of the project at the proposed site (although it must at least do that)[9], but the effects of increased gas production across the full region the plant affects.

[9] In a biological assessment prepared in connection with Oregon LNG's prior import proposal, FERC identified 42 listed or candidate species as potentially occurring in the

To make this determination, DOE/FE should, first, conduct a biological assessment, including the "results of an on-site inspection of the area affected," "[t]he views of recognized experts on the species at issue," a review of relevant literature, "[a]n analysis of the effects of the action on the species and habitat, including consideration of cumulative effects, and the results of any related studies," and "[a]n analysis of alternate actions considered by the Federal agency for the proposed action." *See* 50 C.F.R. § 402.12(f). If that assessment determines that impacts are possible (as is likely here), DOE/FE must enter into formal consultation with the Fish and Wildlife Service and the National Marine and Fisheries Service, as appropriate, to avoid jeopardizing any endangered species or adversely modifying its habitat as a consequences of its approval of Oregon LNG's proposal. 16 U.S.C. § 1536(a), (b).

4. **National Historic Preservation Act**

DOE/FE must also fulfill its obligations under the National Historic Preservation Act (NHPA) to "take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register." 16 U.S.C. § 470f; *see also Pit River Tribe v. U.S. Forest Serv.*, 469 F.3d 768, 787 (9th Cir. 2006) (discussing the requirements of the NHPA). Because "the preservation of this irreplaceable heritage is in the public interest," 16 U.S.C. § 470(b)(4), it behooves DOE/FE to proceed with caution.

DOE/FE must, therefore, initiate the NHPA section 106 consultation and analysis process in order to "identify historic properties potentially affected by the undertaking, assess its effects and seek ways to avoid, minimize or mitigate any adverse effects on historic properties." 36 C.F.R. § 800.1(a). NHPA regulations make clear that the scope of a proper analysis is defined by the project's area of potential effects, *see* 36 C.F.R. § 800.4, which in turn is defined as "the geographic area . . . within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties," 36 C.F.R. § 800.16(d). This area is "influenced by the scale and nature of an undertaking," *Id.* The area of potential effects should sweep quite broadly here because, as in the ESA and NEPA contexts, the reach of Oregon LNG's proposal extends to the entire area in which it will increase gas production. Thus, to approve Oregon LNG's proposal, DOE/FE must first understand and mitigate its impacts on any historic properties which it may affect. *See also* DOE Policy P.141.1 (May 2001) (providing that DOE will fully comply with the NHPA and many other cultural resources preservation statutes).

The regulations governing this process provide that "[c]ertain individuals and organizations with a demonstrated interest in the undertaking may participate as

---

project area. FERC Dkt. CP09-6, Biological Assessment at 1-8 (Nov. 3, 2010), attached as Exhibit 3.

consulting parties" either "due to the nature of their legal or economic relation to the undertaking or affected properties, or their concern with the undertaking's effects on historic properties." 36 C.F.R. § 800.2(c)(5). Sierra Club and Riverkeeper meet that test, because the organizations and their members are interested in preserving intact historic landscapes, for their ecological and social value, and reside through the regions affected by the Oregon LNG's proposal. Our members have worked for years to protect and preserve the rich human and natural fabric of these regions, and would be harmed by any damage to those resources. Sierra Club and Riverkeeper must therefore be given consulting party status under the NHPA for this application.

B. All Pending Export Applications, Pipelines, and Studies Must Be Incorporated Into DOE/FE's NEPA, NGA, and Other Analyses

As explained above, the NGA, NEPA, ESA and NHPA all require DOE/FE's determination to be informed by the context in which the proposed project would occur. Similarly, DOE/FE's analysis must not be confined to local, direct effects of the particular application; DOE/FE must consider the broader constellation of indirect and cumulative effects. Accordingly, NEPA review of this application must also encompass the associated pipeline proposals pending before FERC (without which this project cannot proceed) and the other LNG export proposals pending before DOE/FE and FERC. To ensure adequate consideration of this context, DOE/FE must not act on the pending application until DOE/FE's pending study of the economic impacts of LNG exports. The broader backdrop of related and similar projects, in turn, must inform the NEPA alternatives analysis. Finally, NEPA bars DOE/FE from granting conditional authorization prior to completion of the NEPA process, including the above analyses.[10]

1. Williams Pipeline Expansion

In its application to DOE/FE, Oregon LNG describes the construction of the terminal and liquefaction facilities in Warrenton, Oregon, and the "Oregon Pipeline," an 86 mile pipeline necessary to connect with the Williams pipeline system. Application at 10. The Oregon Pipeline expansion is itself insufficient, however, to enable operation of the proposed LNG terminal. An additional 136 miles of 36 inch pipe must be added to the Williams system before the requisite volumes of gas can be delivered to the Oregon LNG terminal, as part of the "Washington Expansion Project." *Id.* at 10 n.24. FERC has already concluded that the Washington Expansion Project and Oregon LNG's proposal are "connected actions," such that both will be considered in a single EIS. 77 Fed. Reg. 59604. DOE/FE must similarly ensure that it considers both in its public interest determination.

[10] Similarly, Sierra Club protests any request for final, rather than conditional, authorization prior to completion of NEPA review.

NEPA regulations clearly state that "[p]roposals or parts of proposals which are related to each other closely enough to be, in effect, a single course of action shall be evaluated in a single impact statement." 40 C.F.R. § 1502.4(a). Similarly, actions that are "independent parts of a larger action and depend on the larger action for their justification" are "connected actions" that "should be discussed in the same impact statement." *Id.* § 1508.25(a)(1). Separately, if DOE/FE accepts Oregon LNG's invitation to count purported economic benefit from the Washington Expansion Project as a justification for the Oregon LNG's proposal, DOE/FE must also consider the environmental impacts of the Washington Expansion Project.[11] Application at 6.

2. **DOE/FE Must Consider the Cumulative Effect of All Pending Export Proposals, and Should Do So Using A Programmatic EIS**

Oregon LNG's export proposal is only one of many before DOE/FE. Because the effects of these projects are cumulative, and because each approval alters the price and production effects of exports on the economy, DOE/FE must consider these projects' interactions. We note that in the similar proceeding regarding Jordan Cove, LLC's proposal to construct and operate an export terminal in Coos Bay, Oregon, EPA requested consideration of this broader context. EPA, *Scoping Comments – The Jordan Cove Energy Project LP*, FERC Dkt. Nos. PF12-7 and PF12-17, at 3 (Oct. 29, 2012) ("we recommend discussing the proposed project in the context of the larger energy market, including existing export capacity and export capacity under application to the Department of Energy, and clearly describe how the need for the proposed action has been determined.").[12]

DOE/FE can best do so by conducting a programmatic EIS considering the impacts of *all* gas export proposals at once. DOE/FE has the discretion to do so, even if it determines that it does not have the duty to do so. *See* 40 C.F.R. § 1508.17(b)(3); *see also* 10 C.F.R. § 1021.330. Such a programmatic EIS would allow DOE/FE, and the public, to understand the impacts of all of these proposals, their interactions, and their cumulative environmental and economic impacts. That understanding would serve improved decisionmaking, and allow DOE/FE, the public, and industry to identify prudent alternatives to serve the public interest and minimize environmental impacts. DOE/FE must recognize that it is making what is, functionally, a programmatic decision to radically alter the U.S. market and production system by allowing for large-scale LNG export, and conduct an EIS commensurate with the decision it is making, rather than piece-mealing that decision from application to application.

[11] As we explain in part III.C.2 below, Oregon LNG's predictions of economic benefits are overstated.

[12] Attached as Exhibit 4.

3. **DOE/FE Must Not Act Until Its Pending Study of LNG Exports' Economic Impacts Is Complete**

DOE/FE has commissioned two broad studies of exports' impacts. In the first, requested that the Energy Information Administration ("EIA") analyze "the impacts of increased domestic natural gas demand, as exports." EIA, *Effect of Increased Natural Gas Exports on Domestic Energy Markets* ("*EIA Export Study*"), p.1 (Jan. 19, 2012).[13] We discuss this study in detail in part III.C.1.b below. The EIA Export Study predicts price increases from all gas export scenarios, economic impacts to residential and industrial users and environmental harm as gas fired electricity generation to switch to coal power. *Id.* at 6. The study did not, however, consider the macroeconomic impacts of these effects. *Id.* at 3.

DOE has also commissioned a second study that will consider macroeconomic impacts. *See* Christopher Smith, DOE Deputy Assistant Secretary for Oil and Natural Gas, *letter to Representative Edward J. Markey* (February 24, 2012).[14] DOE has committed to withholding final authorization of any pending export application until review of these studies was complete. *Id.* DOE/FE must honor this commitment with respect to Oregon LNG's application. Moreover, because the forthcoming study will inform DOE/FE's decision, DOE/FE should not take action on the application (including granting a conditional authorization) until the public has had an opportunity to comment on this fundamental and underlying study. Because the forthcoming study should address fundamental issues underlying the public interest analysis, any public interest analysis made pursuant to a conditional authorization would need to be wholly revisited once the study is released.

4. **The Alternatives Analysis Must Consider This Broader Context**

Both NEPA and the NGA require DOE/FE fully to consider alternatives to Oregon LNG's proposal. Specifically, the NGA public interest analysis requires an "exploration of all issues relevant to the 'public interest'," an inquiry which the Supreme Court held in *Udall* must be wide-ranging. In that case, which concerned hydropower, the regulatory agency was required to consider, for instance, "alternate sources of power," the state of the power market generally, and options to mitigate impacts on wildlife. 387 U.S. at 450. dHere, likewise, DOE/FE must consider alternatives to the export proposal which would better serve the public interest, broadly analyzing other approaches to structuring LNG exports and gas use generally, given exports' sweeping effects on the economy.

[13] Attached as Exhibit 5.
[14] *Drill Here, Sell There, Pay More* (Appendix 1 at 3).

NEPA is designed to support this sort of broad consideration. The alternatives analysis is "the heart of the environmental impact statement," presenting sharply defined issues which offer "clear basis for choice among options by the decisionmaker and the public." 40 C.F.R. § 1502.14. Crucially, the alternatives must include "reasonable alternatives not within the jurisdiction of the lead agency," – meaning that DOE/FE must review actions which it cannot directly order – and must include "appropriate mitigation measures not already included in the proposed action or alternatives." *Id.* Because alternatives are so central to decisionmaking and mitigation, "the existence of a viable but unexamined alternative renders an environmental impact statement inadequate." *Oregon Natural Desert Ass'n*, 625 F.3d at 1122 (internal alterations and citations omitted).

Without limiting this consideration, these alternatives should include, at a minimum, consideration of the following:

(1) Whether, consistent with the *EIA Export Study*, exports, if allowed, should move forward in smaller quantities or a slower time table to mitigate the domestic economic and environmental impacts associated with large export volumes or rapid export schedules;

(2) Whether export from other locations would better serve the public interest by mitigating economic or environmental impacts or by limiting the cumulative impacts of multiple terminals located in one region (*i.e.*, the Gulf Coast);

(3) Whether limitations on the sources of exported gas – e.g., limiting export from particular plays, formations, or regions – would help to mitigate environmental and economic impacts;

(4) Whether to condition export on the presence of an adequate regulatory framework, including the fulfillment of the recommendations for safe production made by the DOE's Shale Gas Subcommittee, would better serve the public interest by ensuring that the production increases associated with export will not increase poorly-regulated unconventional gas production;

(5) Whether to delay, deny, or condition exports based upon their effect on the U.S. utility market (including changes in air pollution emissions associated with the impacts of increased export demand on fuel choice);

(6) Whether to require exporters to certify that any unconventional gas produced as a result of their proposal (or shipped through their facilities) has been produced in accordance with all relevant environmental laws and according to a set of best production practices (such as that discussed by the DOE's Shale Gas Subcommittee);

(7) Whether to deny export proposals all together as contrary to the public interest.

Other alternatives are, no doubt, also available, but DOE/FE must at a minimum consider the possibilities listed above, as they are reasonable and bear directly on the public interest determination before it.

5. DOE/FE May Not Conditionally Approve Oregon LNG's Proposal Prior to NEPA Review

Although as a general matter DOE/FE may issue "conditional" orders, *see* 10 C.F.R. § 590.402, this general authority cannot trump DOE's specific rules barring the agency from taking any "action concerning [a] proposal" that is the subject of an EIS, 10 C.F.R. § 1021.211, if that action tends to "limit the choice of reasonable alternatives," or "tend[] to determine subsequent development." 40 C.F.R. § 1506.1. Because FERC, the lead agency for purposes of NEPA review, has already determined that an EIS is needed here, DOE/FE's regulations prohibit DOE/FE from issuing a conditional authorization now.

Specifically, a conditional approval would limit alternatives, and determine subsequent choices, in precisely this forbidden way. The Sabine Pass EA and DOE/FE conditional approval in that case provide a good example of this problem. In *Sabine Pass*, DOE/FE expressed its "conditional" view that the project was in the public interest, conditioned on "the satisfactory completion of the environmental review process [by FERC] and on issuance by DOE/FE of a finding of no significant impact or a record of decision pursuant to NEPA." *Sabine Pass* at 41.

This decision was, first, irrational: As we have discussed at length above, DOE/FE cannot complete a public interest determination without weighing environmental factors. Because these factors are integral to DOE/FE's decision, and NEPA is purely procedural statute, DOE/FE must weigh environmental interests at the same time that weighs all other interests. It may not parcel them into a separate process without irrationally ignoring required statutory factors and important aspects of the problem before it on the record.

Second, DOE/FE's approval, even if nominally "conditional," plainly influenced the NEPA process. In the Sabine Pass EA, although FERC acknowledged that DOE/FE was making a broad public interest determination, FERC functionally treated DOE/FE's decision as already made. As such, in its alternatives analysis, FERC summarily rejected the "no-action" alternative because "the no-action alternative could not meet the purpose and need for the Project." Sabine Pass EA at 3-1. This statement is incoherent, if FERC truly understood DOE/FE not to have made a decision. DOE/FE is, after all, considering *whether* to allow gas exports. Because that decision has *not* been made, it is wholly appropriate to select a "no-action" alternative (including, for FERC, a decision not site a

facility whose exports have not been permitted). The fact that FERC felt that it was not free to do so indicates that conditional approvals in fact tend to limit alternatives and steer the development decisionmaking process.

To avoid this illegal effect, DOE/FE therefore may not approve the Oregon LNG export proposal, conditionally or not, until it has considered all alternatives to doing so through the NEPA and NGA processes.

C. Oregon LNG's Proposal Will Have Numerous Harmful Environmental Effects and Is Contrary to The Public Interest

Oregon LNG's proposal will harm the local environment surrounding the proposed terminal and pipeline expansion, it will induce environmentally harmful gas production, it will increase prices domestic consumers and industry pay for natural gas, and it will increase domestic coal consumption causing attendant harm to public health and the environment. Oregon LNG's application does not address any of these economic and environmental costs. These environmental harms translate into economic damage. If pollution sickens people, or restricts their travel, economic productivity will suffer – as it will, more directly, if clean air and water and adequate waste disposal capacity are not available. Similarly, as landscapes are industrialized, tourism, agricultural, forestry, hunting and angling, and other place-dependent industries will suffer. Thus, DOE/FE must both consider these environmental impacts in and of themselves and monetize them to weigh them against other economic harms in the public interest analysis.

On the other hand, Oregon LNG's application overstates the economic benefit of its proposal by relying on a faulty economic model that has been extensively criticized by economists.

We explain these deficiencies in the application below. In light of these costs and reduced benefits, if DOE/FE were to make a decision on the available record (rather than engaging in further study of these issues), DOE/FE would have to conclude that these impacts outweigh any possible benefit of the project.

1. The Project Will Have Significant Adverse Impacts Not Discussed in Oregon LNG's Application

Oregon LNG's proposal will impose significant environmental costs. The environmental costs fall into three categories: direct effects of the terminal and associated pipeline construction, indirect effects of the additional gas production the project will induce, and non-localized effects resulting from increased domestic gas prices and resultant increases in coal consumption. As we explain below, each of these categories of effects must be considered in DOE/FE's NEPA and NGA analyses, and each weighs against finding that the proposed project is consistent with the public interest.

a. Local Environmental Impacts

The proposed project involves major infrastructure construction, including a new slip, liquefaction facilities, LNG storage tanks, associated terminal industrial equipment, 222 miles of pipeline (86 miles in the Oregon Pipeline project and 136 miles in the Washington Expansion Project), and many new pipeline compressors. Construction and operation of these facilities will have significant impacts on air, water, landscapes, and wildlife. These impacts must be considered in both the NEPA analysis and in DOE/FE's public interest determination. We offer preliminary comments on these impacts now, although these impacts cannot be fully identified until additional information is presented in the NEPA process (particularly for the Washington Expansion Project, which has only begun submitting draft resource reports to FERC).[15]

i. Local Air Pollution

Operation of the proposed terminal, pipeline, and other facilities will emit harmful carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic chemicals (VOC), greenhouse gases (GHGs), sulfur dioxides (SO_x), particulate matter (PM_{10} and $PM_{2.5}$), and hydrogen sulfide (H_2S) pollution. At this stage, we discuss solely the emissions associated with operation of the project, but as Oregon LNG application acknowledges, construction of the project will result in significant emissions in addition to the quantities discussed below.[16]

VOC and NO_x

The proposed Oregon LNG project will cause significant emissions of volatile organic chemicals ("VOCs") and NO_x, emitted directly from project facilities and indirectly from tanker and other ship traffic and operations. In total, Oregon LNG estimates emissions of 736.1 tons per year ("tpy") of NO_x emissions and 60.47 tpy of VOC.[17]

These figures are an incomplete picture, because they do not include emissions from the Washington Expansion Project. The Washington Expansion Project includes

[15] In particular, we note that at this stage, we use Oregon LNG's own estimates on several issues, such as the volume of air pollutants emitted. Sierra Club and Riverkeeper reserve the right to challenge these estimates once additional information is available.

[16] Sierra Club and Riverkeeper expect to provide further comment on these emissions during the NEPA public comment period.

[17] The 736.1 tpy of NO_x includes 76.1 tpy from terminal operations, 53.9 tpy from ship and dredging activity near the terminal site, 304 tpy from induced tanker transits Oregon exclusive economic zone ("EEZ"), and 306.1 tpy in the Alaska EEZ. *See* FERC Dkt. PF12-18, Resource Report ("RR") 9-16 to 9-19. For VOC, 35.8 tpy are emitted from terminal facilities,

installation of an additional 90,000 horsepower of compression.[18] The documents submitted in connection with that project so far do not specify whether these compressors will be powered by electricity from the grid, natural gas, or some other power source. Because natural gas fired compressors have significant NOx and VOC emissions, total emissions resulting from the project could much higher than the above.[19] Where electrical compressors are used, the EIS must consider the power source and power line route that will service the compressors.

These emissions will harm the environment by increasing the formation of ground level ozone. VOCs and NO_x contribute to the formation of ground-level ozone (also referred to as smog). Smog pollution harms the respiratory system and has been linked to premature death, heart failure, chronic respiratory damage, and premature aging of the lungs.[20] Smog may also exacerbate existing respiratory illnesses, such as asthma and emphysema, or cause chest pain, coughing, throat irritation and congestion. Children, the elderly, and people with existing respiratory conditions are the most at risk from ozone pollution.[21]

Significant ozone pollution also damages plants and ecosystems.[22] Ozone also contributes substantially to global climate change over the short term. According to a recent study by the United Nations Environment Program (UNEP), behind carbon dioxide and methane, ozone is now the third most significant contributor to human-caused climate change.[23]

---

[18] FERC Dkt. PF12-20 RR 1-1, 1-42 (Aug. 16, 2012).

[19] The proposal for the Oregon Pipeline proposes electrically driven compression, the environmentally preferable option with few direct NOx or VOC emissions. RR 1-18, 9-13.

[20] EPA, *Proposed New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry: Regulatory Impact Analysis*, 4-25 (July 2011), *available at* http://www.epa.gov/ttnecas1/regdata/RIAs/oilnaturalgasfinalria.pdf and attached as Exhibit 6. (hereinafter O&G NSPS RIA) Jerrett *et al.*, *Long-Term Ozone Exposure and Mortality*, New England Journal of Medicine (Mar. 12, 2009), *available at* http://www.nejm.org/doi/full/10.1056/NEJMoa0803894#t=articleTop, attached as Exhibit 7.

[21] *See* EPA, *Ground-Level Ozone, Health Effects*, *available at* http://www.epa.gov/glo/health.html attached as Exhibit 8. EPA, Nitrogen Dioxide, Health, available at http://www.epa.gov/air/nitrogenoxides/health.html, attached as Exhibit 9.

[22] O&G NSPS RIA at 4-26.

[23] *Id. See also* United Nations Environment Programme and World Meteorological Organization, (2011): *Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers* (hereinafter "UNEP Report," available at http:// www.unep.org/dewa/Portals/67/pdf/Black_Carbon.pdf), at 7, attached as Exhibit 10.

CO

Operation of the proposed terminal will directly emit 150.5 tpy of CO, with an additional 197.18 tpy of marine vessel emissions.[24] As with NOx and VOC, additional compressors installed as part of the Washington Expansion Project may raise this total. CO can cause harmful health effects by reducing oxygen delivery to the body's organs and tissues.[25] CO can be particularly harmful to persons with various types of heart disease, who already have a reduced capacity for pumping oxygenated blood to the heart. "For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion."[26]

GHGs

Oregon LNG estimates that the terminal, pipeline, and associated facilities will directly emit over 2.6 million tpy of carbon dioxide equivalent in greenhouse gases ("CO2e"), with an additional 118,544.6 tpy emitted by marine vessel traffic.[27] Cheniere estimates that the proposed terminal and associated compressor stations will directly emit nearly 3.5 million tpy of carbon dioxide equivalent (CO_2e) in greenhouse gases. RR 9-20, 9-23. These greenhouse gas emissions will increase global warming, harming both the local and global environments.

The impacts of climate change caused by greenhouse gases include "increased air and ocean temperatures, changes in precipitation patterns, melting and thawing of global glaciers and ice, increasingly severe weather events, such as hurricanes of greater intensity and sea level rise."[28] A warming climate will also lead to loss of coastal land in densely populated areas, shrinking snowpack in Western states, increased wildfires, and reduced crop yields.[29] More frequent heat waves as a result of global warming have already affected public health, leading to premature deaths. And threats to public health are only expected to increase as global warming intensifies. For example, a warming climate will lead to increased incidence of respiratory and infectious disease, greater air and water pollution, increased malnutrition, and greater casualties from fire, storms, and floods.[30] Vulnerable populations—such as children, the elderly, and those with existing health problems—are the most at risk from these threats.

---

[24] RR 9-16 to 9-18.

[25] http://www.epa.gov/air/carbonmonoxide/health.html, attached as Exhibit 11.

[26] *Id.*

[27] RR 9-16 to 9-19.

[28] 76 Fed. Reg. at 52,791-22 (citing U.S. EPA, 2011 U.S. GREENHOUSE GAS INVENTORY REPORT EXECUTIVE SUMMARY (2011), attached as Exhibit 12.

[29] *Id.* at 66,532–33.

[30] EPA, *Climate Change, Health and Environmental Effects*, *available at* http://epa.gov/climatechange/effects/health.html, attached as Exhibit 13.

Sulfur Dioxide

The proposed terminal and compressor stations will directly emit an estimated 72 tpy of SO_2, with an additional 80.88 tpy emitted by marine vessel traffic.[31] Sulfur dioxide causes respiratory problems, including increased asthma symptoms. Short-term exposure to sulfur dioxide has been linked to increased emergency room visits and hospital admissions. Sulfur dioxide reacts in the atmosphere to form particulate matter (PM), an air pollutant which causes a great deal of harm to human health.[32] PM is discussed separately below.

Particulate Matter

The proposed terminal and compressor stations will directly emit an estimated 14.9 tpy of particulate matter, with an additional 51.2 tpy emitted by marine vessel traffic.[33] PM consists of tiny particles of a range of sizes suspended in air. Small particles pose the greatest health risk. These small particles include "inhalable coarse particles," which are smaller than 10 micrometers in diameter (PM_{10}), and "fine particles" which are less than 2.5 micrometers in diameter ($PM_{2.5}$). PM_{10} is primarily formed from crushing, grinding or abrasion of surfaces. $PM_{2.5}$ is primarily formed by incomplete combustion of fuels or through secondary formation in the atmosphere.[34]

PM causes a wide variety of health and environmental impacts. PM has been linked to respiratory and cardiovascular problems, including coughing, painful breathing, aggravated asthma attacks, chronic bronchitis, decreased lung function, heart attacks, and premature death. Sensitive populations, include the elderly, children, and people with existing heart or lung problems, are most at risk from PM pollution.[35] PM also reduces visibility,[36] and may damage important cultural resources.[37] Black carbon, a component of PM emitted by combustion sources such as flares and older diesel engines, also warms the climate and thus contributes to climate change.[38]

---

[31] RR 9-16 to 9-19.

[32] EPA, Sulfur Dioxide, Health, *available at* http://www.epa.gov/air/sulfurdioxide/health.html, attached as Exhibit 14.

[33] RR 9-16 to 9-19.

[34] *See* EPA, Particulate Matter, Health, *available at* http://www.epa.gov/pm/health.html, attached as Exhibit 15; BLM, *West Tavaputs Plateau Natural Gas Full Field Development Plan Final Environmental Impact Statement* ("West Tavaputs FEIS"), at 3-19 (July 2010), *available at* http://www.blm.gov/ut/st/en/fo/price/energy/Oil_Gas/wtp_final_eis.html.

[35] O&G NSPS RIA at 4-19; EPA, Particulate Matter, Health

[36] EPA "Visibility – Basic Information" http://www.epa.gov/visibility/what.html, attached as Exhibit 16.

[37] *See* EPA, Particulate Matter, Health West Tavaputs EIS, at 3-19; O&G NSPS RIA at 4-24.

[38] UNEP Report at 6; IPCC (2007) at Section 2.4.4.3.

ii. Terminal and Pipeline Water Quality Impacts

The proposed project will impact water quality in numerous ways, including stream crossings for the pipeline, water withdrawals during construction, stormwater runoff from terminal facilities, and discharge and suspension or re-suspension of sediment in the Columbia River as a result of dredging and ship transits.

Construction of the pipeline will require numerous stream crossings. Oregon LNG states that many of these crossings will be done with horizontal directional drilling. When successful, horizontal directional drilling has lower environmental impacts than other forms of stream crossing. Nonetheless, even where horizontal directional drilling succeeds without a "frack out" failure, and even where work in streams is conducted during periods of low seasonal flow, Oregon's past experiences with construction in streams demonstrates work can lead to large unanticipated sediment discharge. Moreover, there is a substantial risk that horizontal directional drilling will fail at some crossings, with adverse environmental consequences. For example, as the National Marine Fisheries Service cautioned in a comment on the prior import proposal, "a frac-out from horizontal directional drilling will cause bentonite, a very fine clay, to be released into the water column that has the potential, if fish are present, to clog their gills, causing them to suffocate. Whether it is a toxic compound or not, the particle size of the clay is of concern for fish."[39]

Another vector for impacts to water quality is the proposal for hydrostatic testing of the pipeline. Construction of the terminal and Oregon Pipeline, including hydrostatic testing of the pipeline, will require 19.7 million gallons of water.[40] For the Washington Extension Project, hydrostatic testing alone will require 40.9 million gallons of water.[41] We discuss the general problems of water withdrawals in part III.C.1.b.iii.3 below. In the context of hydrostatic testing, an additional issue is disposal of water after the testing has occurred. Because water is moved along the length of the pipeline in the course of this testing, the process has the potential cause inter-basin transfer of non-native species, and can spread pathogens such as P. lateralis, which causes disease in Port-Orford cedars. Discharge of the used water can also spread chemicals found inside the pipeline.

Stormwater runoff from the terminal site will also adversely affect the water quality. Stormwater from the terminal site is likely to contain heavy metals, petroleum products and brake chemicals and compounds that are deleterious to fish and fish habitat.

---

[39] FERC Dkt. PF07-10, NMFS Comment at 11 (July 18, 2008), attached as Exhibit 17.
[40] RR 1-22.
[41] WEP RR 1-24 to 1-25.

Finally, dredging, construction of in-water facilities, and ship transits all have the potential to suspend or re-suspend sediment in the Columbia River, adversely affecting water quality.

iii. Geologic Hazards

The proposed project faces numerous geologic hazards. For example, routing the Oregon pipeline through the Range poses a long-term threat to slope stability. FERC's standard erosion control methods do not specify additional methods that may be needed based on local conditions and variations, particularly in the Coast Range where steep and potentially unstable slopes prevail and high, prolonged rainfall is inherent. For example, sidecast, tailings, or spoils on steep slopes will require additional special erosion control methods.

iv. Wildlife

Finally, the project will impact wildlife and species habitat in numerous ways. Clearing of timber along the pipeline right-of-way directly removes habitat, provides a conduit for the spread of wildfires, and provides a tempting route for off-highway vehicle users, despite efforts to introduce barriers to such uses, and these vehicles have the potential to spread noxious weeds, insects, or diseases. Water intake, whether for ship operations, hydrostatic testing, or other uses, risks fish entrainment. Other impacts to water quality can degrade the value of this habitat. Noise from construction and compressor operations may harass and displace species. The project will impact wildlife and habitat in these and numerous other ways. As noted above, FERC has identified 42 listed or candidate species as potentially occurring in the project area.[42]

b. Induced Gas Production

Further, and perhaps greater, environmental impacts will result from increased gas production. The EIA, essentially every other LNG export applicant, and other informed commenters all agree that LNG exports will induce additional production in the U.S. The Oregon LNG proposal is no exception: notwithstanding its stated plan to source gas for export from Canada, Oregon LNG concedes that the proposed project will induce additional production in the U.S. *See* Application at 3, 24. Moreover, available tools allow DOE to predict where this increased production will occur, although such localized predictions are not necessary for meaningful analysis of environmental impacts. NEPA and the NGA therefore require DOE/FE to consider the effects of this additional production. Although DOE/FE recently refused to consider induced production in the *Sabine Pass* proceeding, that order is not final, applies the wrong legal standard of foreseeability, and understates DOE's own ability to predict induced drilling.

[42] FERC Dkt. CP09-6, Biological Assessment at 1-8 (Nov. 3, 2010).

i. Oregon LNG's Proposal Will Induce Additional U.S. Gas Production

As Oregon LNG itself concedes, its export proposal will increase U.S. gas production, notwithstanding Oregon LNG's stated plan to source gas for export from Canada. Application at 24 ("the demand induced by . . . exports will spur production" in the U.S.). Exports' inducement of production is obvious in light of the interconnected nature of the North American gas market. As Oregon LNG explains, if gas produced in Canada is not exported, that gas will enter the U.S. market. *Id.* at 15. This increase of supply in the U.S. market would, in turn, lower gas prices and cause U.S. gas producers to produce less gas than they would otherwise. *Id.* Conversely, to the extent that Canadian gas is exported, U.S. gas prices will be higher, incentivizing domestic gas producers to increase production.[43]

Although Oregon LNG does not estimate the amount by which its proposal would increase U.S. production, other studies suggest that production increases closely correspond with the volume of exported gas. For example, the Energy Information Administration, in a study of effects of U.S. exports commissioned by DOE/FE, estimated that the majority of exported gas would come from increased production, primarily from shale gas. *EIA Export Study*, 6, 11. Specifically, EIA predicts that "about 60 to 70 percent" of the volume of LNG exported would be supplied by increases in domestic production, with the remainder supplied reductions in domestic consumption of current production, and that "about three quarters of this increased production is from shale sources." *Id.* at 6. Simple application of these predictions to Oregon LNG's request to export 1.3 bcf/d indicates that the proposal would result in at least application estimates that the application would result in at least 0.78 bcf/day of increased production in North America, including 0.59 of shale gas production.

Furthermore, EIA and DOE have more precise tools to estimate how U.S. production will change in response to Oregon LNG's proposed exports, including the ability to predict how and when production will increase in individual gas plays. EIA's core analysis tool is the National Energy Modeling System ("NEMS"). NEMS was used to produce the EIA exports study. NEMS models the economy's energy use through a series of interlocking

[43] The project may also export gas produced in the U.S., likely produced in the Rocky Mountain states, directly inducing further U.S. production. Although Oregon LNG states that they expect that market conditions will favor sourcing gas from Canada, the application explicitly notes that the pipeline infrastructure will provide the ability to export gas produced in the U.S., and the application offers no legal restriction on Oregon LNG's ability to do so. As the EIA Export Study demonstrates, exports of gas produced in the US will increase US production.

modules that represent different energy sectors on geographic levels.[44] Notably, the "Natural Gas Transmission and Distribution" module already models the relationship between U.S. and Canadian gas production, consumption, and trade, specifically projecting U.S. production, Canadian production, imports from Canada, etc. *Id.* at 59. For each region, the module links supply and demand annually, taking transmission costs into account, in order to project how demand will be met by the transmission system.[45] Importantly, the Transmission Module is *already* designed to model LNG imports and exports, and contains an extensive modeling apparatus to do so on the basis of production in the U.S., Canada, and Mexico. *See id.* at 22-32. Right now, the Module focuses largely on LNG imports, which have been the status quo up to this point, but it also already links the Supply Module to the existing Alaskan *export* terminal to project exports from that site and their impacts on production. *See id.* at 30-31. Thus, there is no technical barrier to such modeling going forward.. Indeed, EIA used this model for its export study, which forecast production and price impacts.

Similarly, the "Oil and Gas Supply" module models individual regions and describes how production responds to demand across the country. Specifically, the Supply Module is built on detailed state-by-state reports of gas production curves across the country.[46] As EIA explains, "production type curves have been used to estimate the technical production from known fields" as the basis for a sophisticated "play-level model that projects the crude oil and natural gas supply from the lower 48." *Id.* at 2-3. The module distinguishes coalbed methane, shale gas, and tight gas from other resources, allowing for specific predictions distinguishing unconventional gas supplies from conventional supplies. *Id.* at 2-7. The module further projects the number of wells drilled each year, and their likely production – which are important figures for estimating environmental impacts. *See id.* at 2-25 -2-26. In short, the supply module "includes a comprehensive assessment method for determining the relative economics of various prospects based on future financial considerations, the nature of the undiscovered and discovered resources, prevailing risk factors, and the available technologies. The model evaluates the economics of future exploration and development from the perspective of an operator making an investment decision." *Id.* Thus, for each play in the lower 48 states, the EIA is able to predict future production based on existing data. Importantly, the EIA makes clear that "the model design provides the flexibility to evaluate alternative or

[44] Energy Information Administration ("EIA"), *The National Energy Modeling System: An Overview*, 1-2 (2009), attached as Exhibit 18, available at http://www.eia.gov/oiaf/aeo/overview/pdf/0581(2009).pdf

[45] EIA, *Model Documentation: Natural Gas Transmission and Distribution Module of the National Energy Modeling System*, 15-16 (2012), attached as Exhibit 19, available at http://www.eia.gov/FTPROOT/modeldoc/m062(2011).pdf

[46] EIA, *Documentation of the Oil and Gas Supply Module*, 2-2(2011), attached as Exhibit 20, available at http://www.eia.gov/FTPROOT/modeldoc/m063(2011).pdf

new taxes, environmental, or other policy changes in a consistent and comprehensive manner." *Id.*

EIA is not alone in its ability to predict localized effects of LNG exports. A study and model developed by Deloitte Marketpoint claims the ability to make the sort of localized predictions that FERC claims are necessary to assessment of environmental impacts, and numerous other LNG export terminal proponents have relied on this study in applications to FERC and DOE.[47] According to Deloitte, its "North American Gas Model" and "World Gas Model" allow it to predict how gas production, infrastructure construction, and storage will respond to changing demand conditions, including those resulting from LNG export: "The end result is that valuing storage investments, identifying maximally effectual storage field operation, positioning, optimizing cycle times, demand following modeling, pipeline sizing and location, and analyzing the impacts of LNG has become easier and generally more accurate."[48]

Finally, even if (contrary to all available evidence and Oregon LNG's own admission) the proposed exports would not induce additional gas production in the U.S., the proposed exports would undoubtedly induce additional production in Canada, and DOE/FE would be required to consider the effect, if any, of that induced production on the environment in the U.S. *See Border Power Plant Working Group v. Department of Energy*, 260 F.Supp.2d 997 (S.D.Cal. 2003).

ii. Induced Production Must Be Considered in the NEPA and NGA Analyses

DOE/FE must consider the environmental effects of this induced production (both U.S. production and Canadian production potentially impacting the U.S.). As noted above, NEPA requires consideration of "indirect effects" of the proposed action, which include "growth inducing effects" and "reasonably foreseeable" effects "removed in distance" from the site of the proposed action. 40 C.F.R. § 1508.8(b). For example, the Ninth Circuit recently held that, where the Surface Transportation Board was considering a proposal to expand a railway line which would enable increased coal production at

---

[47] Deloitte Marketpoint, *Made in America: The Economic Impact of LNG Exports from the United States* (2011) (hereinafter "*Deloitte Report*"), available at http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Energy_us_er/us_er_MadeinAmerica_LNGPaper_122011.pdf and attached as Exhibit 21.

[48] Deloitte, *Natural Gas Models*, available at: http://www.deloitte.com/view/en_US/us/Industries/power-utilities/deloitte-center-for-energy-solutions-power-utilities/marketpoint-home/marketpoint-data-models/b2964d1814549210VgnVCM200000bb42f00aRCRD.htm and attached as Exhibit 22.

several mines, NEPA required the Board to consider the impacts of increased mining. *Northern Plains Resource Council v. Surface Transportation Board*, 668 F.3d 1067, 1081-82 (9th Cir. 2011). Similarly, in a prior DOE proceeding regarding an electricity transmission line, DOE was required to consider the effect this line would have on inducing upstream electricity generation, including the environmental effects thereof. *Border Power Plant Working Group*, 260 F.Supp.2d 997 (rejecting DOE's decision to exclude these upstream impacts from analysis).[49] Consideration of induced impacts was required even though the upstream electricity generation would occur in Mexico, outside the jurisdiction of DOE or any other U.S. agency. Thus, it is clear that induced production is the type of "growth inducing," "induced changes in the pattern of land use," or other indirect effect contemplated by 40 C.F.R. § 1508.8(b). EPA, in scoping comments it submitted regarding another LNG export proposal, has opined that in light of the regulatory definition indirect effects and the EIA Export Study's prediction of induced production, "it is appropriate to consider available information about the extent to which drilling activity might be stimulated by the construction of an LNG export facility on the west coast, and any potential environmental effects associated with that drilling expansion."[50]

Induced drilling is also "reasonably foreseeable" so as to be amenable to NEPA analysis. Although DOE/FE recently "accept[ed] and adopt[ed] [FERC's] determination that induced shale gas production is not a reasonably foreseeable effect [of LNG exports] for purposes of NEPA analysis" in another proceeding, that decision rests on factual and legal errors, and is currently being reviewed by DOE. *Sabine Pass* DOE/FE Order 2961-A at 28, *see also* Order Granting Rehearing for Further Consideration, FE Docket 10-111-LNG (Oct. 5, 2012).[51]

The first flaw in DOE/FE's *Sabine Pass* decision is that DOE/FE demanded an unlawfully high level of certain in predictions of future effects. DOE/FE stated that it is "unknown" if "any" new production will result from the proposed exports. Although this cannot be known with absolute certainty, certainty is not required. "An impact is 'reasonably foreseeable' if it is sufficiently likely to occur that a person of ordinary prudence would

---

[49] Notably, *Border Power Plant Working Group* also involved a determination as to whether the project was in the public interest. The final EIS for the project (produced after remand from the court) is available at: http://energy.gov/nepa/downloads/eis-0365-final-environmental-impact-statement. Upstream air quality impacts are considered in pages 4-43 to 4-65 of this final EIS.

[50] EPA, Scoping Comments – The Jordan Cove Energy Project LP, FERC Dkt. Nos. PF12-7 and PF12-17, at 14 (Oct. 29, 2012), attached as Exhibit 23.

[51] DOE is not bound by its prior decisions: it may reverse its position "with or without a change in circumstances" so long as it provides "a reasoned analysis" for the change. *Louisiana Pub. Serv. Comm'n v. FERC*, 184 F.3d 892, 897 (D.C. Cir. 1999) (quoting *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 57 (1983)).

take it into account in reaching a decision." *City of Shoreacres v. Waterworth*, 420 F.3d 440, 453 (5th Cir. 2005).[52] NEPA requires "[r]easonable forecasting and speculation," and courts "must reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as 'crystal ball inquiry.'" *Scientists' Inst. for Pub. Info., Inc. v. Atomic Energy Comm'n*, 481 F.2d 1079, 1092 (D.C. Cir. 1973). As explained above, every available source concludes that it is *likely* that the majority of exported gas will come from induced additional production. Thus, an aggregate production increase is unarguably "reasonably foreseeable."

DOE/FE's second error in its final authorization in *Sabine Pass* was to adopt FERC's conclusion that induced production was outside the scope of NEPA analysis because "while it may be the case that additional shale gas development will result from the Liquefaction Project, the amount, timing and location of such development activity is simply unknowable at this time." 140 FERC ¶ 61,076, P9 (July 26, 2012). Such specific, localized predictions are not required for meaningful environmental analysis, but even if they were, DOE/FE has the resources to provide them. On the first point, analysis of the environmental impacts of induced gas production does not require knowledge of the precise sites where additional production will occur. Environmental costs (and the economic costs which accompany them) can be determined in aggregate. The net increases in, for instance, air pollution associated with the number of wells that will be induced can be quantified based on EPA's emissions inventories, for instance. The net volumes of waste similarly can be derived from industry reports and state discharge figures. And these impacts can be localized, at a minimum, by region. Indeed, for many of the environmental impacts, such as emissions of many air pollutants and water consumption, the impacts are likely to be experienced at the regional level, so there would be little value in localizing them further. Even for those impacts that are more closely tied to a specific location, such as habitat fragmentation, DOE/FE can and must acknowledge that the impact will occur, including an estimate of the severity of the impact averaged across potential locations. *See Scientists' Inst. for Pub. Info.*, 481 F.2d 1096-97 (where there are reasonable estimates of the deployment of nuclear power plants, the amount of waste produced, and the land needed to store waste, NEPA required analysis of the impacts of such storage even though the agency could not predict *where* such storage would occur).

Even if DOE/FE were to wrongfully conclude that NEPA would only require analysis of the impacts of induced drilling if it was possible to predict where that drilling would occur, DOE/FE has the tools to make precisely that prediction, as we explain in the previous section. To the extent that these predictions of local impact are not yet in the

[52] In this proceeding, FERC endorses this formulation of "reasonable foreseeability." FERC "Order Granting Section 3 Authorization" 139 FERC ¶ 61,039, FERC Docket CP11-72-001 ¶ 95(April 16, 2012) (hereinafter "FERC April Order").

record, NEPA regulations provide that DOE/FE "shall" obtain this information unless DOE/FE demonstrates that the costs of obtaining it are "exorbitant." 40 C.F.R. §1502.22.

Finally, insofar as Oregon LNG argues that the economic benefits to the Canadian economy of induced production in Canada should be considered, Application at 34, DOE/FE must also consider the environmental effects of such production: the scope of the environmental inquiry cannot be narrower than the scope of the economic inquiry. *Northern Plains Resource Council*, 668 F.3d 1067, *Scientists' Inst. for Pub. Info.*, 481 F.2d at 1092.

In summary, all the available evidence indicates that Oregon LNG's proposed exports will induce additional gas production in the U.S., and this increase can be reasonably foreseen so as to support informed NEPA analysis. NEPA therefore requires consideration of the environmental impacts of induced production.

iii. Environmental Harm Resulting from Induced Production

Natural gas production—from both conventional and unconventional sources—is a significant air pollution source, can disrupt ecosystems and watersheds, leads to industrialization of entire landscapes, and presents challenging waste disposal issues. EIA concluded that "On average, across all cases and export scenarios, the shares of the increase in total domestic production coming from shale gas, tight gas, [and] coalbed sources are 72 percent, 13 percent, [and] 8 percent," respectively. *EIA Export Study* at 11. Oregon LNG predicts that its gas will primarily come from British Columbia's Horn River Basin, which is primarily shale gas. Application at 17. A Subcommittee of the DOE's Secretary of Energy's Advisory Board, recently highlighted "a real risk of serious environmental consequences" resulting from continued expansion of shale gas production. DOE, Secretary of Energy's Advisory Board, *Shale Gas Production Subcommittee Second 90-Day Report* (Nov. 18, 2011) at 10.[53] Shale gas production (as well as coalbed and tight sands production) requires the controversial practice of hydraulic fracturing, or fracking. As we explain below, natural gas production in general, and fracking in particular, imposes a raft of environmental problems. Although some states and federal agencies are taking steps to limit these harms, these efforts are uncertain and, even if fully implemented, will not eliminate the environmental harms.

1. Natural Gas Production is a Major Source of Air Pollution

Below, we briefly describe some of the primary air pollution problems caused by the industry. These issues include direct emissions from production equipment and indirect emissions, caused by natural gas replacing cleaner energy sources. EPA has moved to correct some of these problems with new air regulations finalized this year, but as we

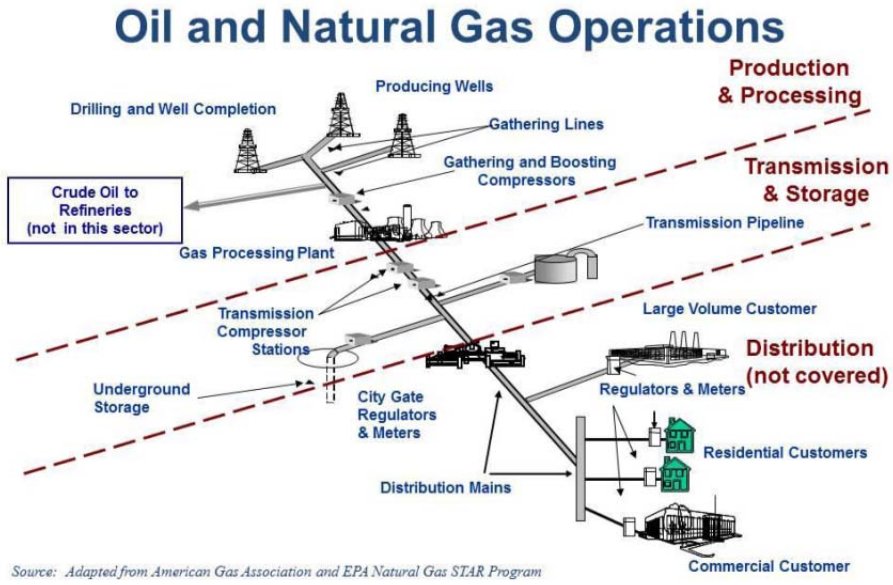
[53] Attached as Exhibit 24. The Board's First 90-Day Report is attached as Exhibit 25.

later discuss, these standards do not fully address the problem. FERC must therefore consider the air pollution impacts of increased natural gas production even if EPA's rules are finalized.

Air Pollution Problems from Natural Gas

Oil and gas operations emit methane (CH_4), volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), and particulate matter (PM_{10} and $PM_{2.5}$). Oil and natural gas operations also emit listed hazardous air pollutants (HAPs) in significant quantities, and so contribute to cancer risks and other acute public health problems. Pollutants are emitted during all stages of natural gas development, including (1) oil and natural gas production, (2) natural gas processing, (3) natural gas transmission, and (4) natural gas distribution.[54] Within these development stages, the major sources of air pollution include wells, compressors, pipelines, pneumatic devices, dehydrators, storage tanks, pits and ponds, natural gas processing plants, and trucks and construction equipment.

Figure 1: The Oil and Natural Gas Sector



There is strong evidence that emissions from natural gas production are higher than have been commonly understood. In particular, a recent study by a consortium of researchers led by the National Ocean and Atmospheric Administration (NOAA) Earth System Research Laboratory recorded pollution concentrations near gas fields substantially greater than EPA estimates would have predicted. That research

[54] EPA, Oil and Natural Gas Sector: Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution, Background Technical Support Document for the Proposed Rules ("TSD") at 2-4 (July 2011), attached as Exhibit 26.

monitored air quality around oil and gas fields.[55] It observed high levels of methane, propane, benzene, and other volatile organic compounds, in the air around the fields. The researchers write that their "analysis suggests that the emissions of the species we measured" – that is the cancer-causing, smog-forming, and climate-disrupting pollutants released from these operations – "are most likely underestimated in current inventories," perhaps by as much as a factor of two.[56]

These emissions have dire practical consequences. A second research team, led by the Colorado School of Public Health, measured benzene and other pollutants released from unconventional well completions.[57] Elevated levels of these pollutants correspond to increased cancer risks for people living within half of a mile from a well[58] – a very large population which will increase as drilling expands.

We discuss the harmful effects of many of these pollutants in part III.C.1.a, above. Below, we detail the sources of emissions within the gas production industry and provide further information regarding the serious global, regional, and local impacts these exploration and production emissions entail:

Methane: Methane is the dominant pollutant from the oil and gas sector. Emissions occur as result of intentional venting or unintentional leaks during drilling, production, processing, transmission and storage, and distribution. For example, methane is emitted when wells are completed and vented, as part of operation of pneumatic devices and compressors, and as a result of leaks (fugitive emissions) in pipelines, valves, and other equipment. EPA has identified natural gas systems as the "single largest contributor to United States anthropogenic methane emissions."[59] The industry is responsible for over 40% of total U.S. methane emissions.[60] Methane causes harm both because of its contributions to climate change and as an ozone precursor.

Beginning with climate change, methane is a potent greenhouse gas that contributes substantially to global climate change. Methane has at least 25 times the global warming potential of carbon dioxide over a 100 year time frame and at least 72 times

---

[55] G. Petron *et al.*, *Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study*, 117 J. of Geophysical Research 4304, DOI 10.1029/2011JD016360 (2012), attached as Exhibit 27.
[56] *Id.* at 4304.
[57] L. McKenzie *et al.*, *Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources*, Science of the Total Environment (In Press, Mar. 22, 2012), attached as Exhibit 14.
[58] *Id.* at 2.
[59] 76 Fed. Reg. 52,738, 52,792 (Aug. 23, 2011) (EPA proposed air rules for oil and gas production sector), attached as Exhibit 28.
[60] *Id.* at 52,791–92.

the global warming potential of carbon dioxide over a 20-year time frame.[61] The oil and gas production industry's methane emissions amount to 5% of all carbon dioxide equivalent (CO_2e) emissions in the country.[62]

Because of methane's effects on climate, EPA has found that methane, along with five other well-mixed greenhouse gases, endangers public health and welfare within the meaning of the Clean Air Act.[63]

Methane also reacts in the atmosphere to form ozone.[64] As we discuss elsewhere, ozone is a major public health threat, linked to a wide range of maladies. Ozone can also damage vegetation, agricultural productivity, and cultural resources. Ozone is also a significant greenhouse gas in its own right, meaning that methane is doubly damaging to climate – first in its own right, and then as an ozone precursor.

***Volatile Organic Compounds (VOCs) and NO_x*:** The gas industry is a major source of the ozone precursors VOCs and NO_x.[65] VOCs are emitted from well drilling and completions, compressors, pneumatic devices, storage tanks, processing plants, and fugitives from production and transmission.[66] The primary sources of NO_x are compressor engines, turbines, and other engines used in drilling and hydraulic fracturing.[67] NO_x is also produced when gas is flared or used for heating.[68]

---

[61] *IPCC 2007—The Physical Science Basi*s, Section 2.10.2, and *IPCC 2007- Summary for Policymakers*, attached as Exhibit 29. We note that these global warming potential figures may be revised upward in the next IPCC report. A more recent study by Shindell *et al.* estimates methane's 100-year GWP at 33; this same source estimates methane's 20-year GWP at 105.

[62] 76 Fed. Reg. 52,738 at 52,791–92.

[63] EPA, Endangerment and Cause or Contribute Findings for Greenhouse Gases, 74 Fed. Reg. 66,496, 66,516 (Dec. 15, 2009) ("Endangerment Finding"), attached as Exhibit 30.

[64] 76 Fed. Reg. at 52,791.

[65] *See, e.g.*, EPA Fact Sheet at 3; Al Armendariz, Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements (Jan. 26, 2009), available at http://www.edf.org/documents/9235_Barnett_Shale_Report.pdf (hereinafter "Barnett Shale Report") at 24, attached as Exhibit 31.

[66] *See, e.g.,* TSD at 4-7, 5-6, 6-5, 7-9, 8-1; *see also* Barnett Shale Report at 24.

[67] *See, e.g.*, TSD at 3-6; See also Barnett Shale Report at 24. Air Quality Impact Analysis Technical Support Document for the Revised Draft Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project at 11 (Table 2.1).

[68] TSD at 3-6; Colorado Department of Public Health and Environment, *Colorado Visibility and Regional Haze State Implementation Plan for the Twelve Mandatory Class I Federal Areas in Colorado*, Appendix D at 1 (2011), available at

As a result of significant VOC and NO_x emissions associated with oil and gas development, numerous areas of the country with heavy concentrations of drilling are now suffering from serious ozone problems. For example, the Dallas Fort Worth area in Texas is home to substantial oil and gas development. Within the Barnett shale region, as of September 2011, there were more than 15,306 gas wells and another 3,212 wells permitted.[69] Of the nine counties surrounding the Dallas Fort Worth area that EPA has designated as "nonattainment" for ozone, five contain significant oil and gas development.[70] A 2009 study found that summertime emissions of smog-forming pollutants from these counties were roughly comparable to emissions from motor vehicles in those areas.[71]

Oil and gas development has also brought serious ozone pollution problems to rural areas, such as western Wyoming.[72] On March 12, 2009, the governor of Wyoming recommended that the state designate Wyoming's Upper Green River Basin as an ozone nonattainment area.[73] The Wyoming Department of Environmental Quality conducted an extended assessment of the ozone pollution problem and found that it was "primarily due to local emissions from oil and gas . . . development activities: drilling, production, storage, transport, and treating."[74] Last winter alone, the residents of Sublette County suffered thirteen days with ozone concentrations considered "unhealthy" under EPA's current air-quality index, including days when the ozone pollution levels exceeded the worst days of smog pollution in Los Angeles.[75] Residents

---

http://www.cdphe.state.co.us/ap/RegionalHaze/AppendixD/4-FactorHeaterTreaters07JAN2011FINAL.pdf, attached as Exhibit 32.

[69] Texas Railroad Commission history of Barnett Shale, attached as Exhibit 33.

[70] Barnett Shale Report at 1, 3.

[71] *Id.* at 1, 25-26.

[72] Schnell, R.C, *et al*. (2009), "Rapid photochemical production of ozone at high concentrations in a rural site during winter," *Nature Geosci.* 2 (120 – 122). DOI: 10.1038/NGEO415, attached as Exhibit 34.

[73] *See* Letter from Wyoming Governor Dave Freudenthal to Carol Rushin, Acting Regional Administrator, USEPA Region 8, (Mar. 12, 2009) ("Wyoming 8-Hour Ozone Designation Recommendations"), *available at* http://deq.state.wy.us/out/downloads/Rushin%20Ozone.pdf, attached as Exhibit 35; Wyoming Department of Environmental Quality, *Technical Support Document I for Recommended 8-hour Ozone Designation of the Upper Green River Basin* (March 26, 2009) ("Wyoming Nonattainment Analysis"), at vi-viii, 23-26, 94-05, *available at* http://deq.state.wy.us/out/downloads/Ozone%20TSD_final_rev%203-30-09_jl.pdf, attached as Exhibit 36.

[74] Wyoming Nonattainment Analysis at viii.

[75] EPA, *Daily Ozone AQI Levels in 2011 for Sublette County, Wyoming*, *available at* http://www.epa.gov/cgi-bin/broker?msaorcountyName=countycode

have faced repeated warnings regarding elevated ozone levels and the resulting risks of going outside.[76]

Ozone problems are mounting in other Rocky Mountain states as well. Northeastern Utah recorded unprecedented ozone levels in the Uintah Basin in 2010 and 2011. In the first three months of 2010—which was the first time that winter ozone was monitored in the region—air quality monitors measured more than 68 exceedances of the federal health standard. On three of these days, the levels were almost twice the federal standard.[77] Between January and March 2011, there were 24 days where the National Ambient Air Quality Standard (NAAQS) for ozone were exceeded in the area. Again, ozone pollution levels climbed to nearly twice the federal standard.[78] The Bureau of Land Management (BLM) has identified the multitude of oil and gas wells in the region as the primary cause of the ozone pollution.[79]

&msaorcountyValue=56035&poll=44201&county=56035&msa=-1&sy=2011&flag=Y&_debug=2&_service=data&_program=dataprog.trend_tile_dm.sas, attached as Exhibit 37; *see also* Wendy Koch, *Wyoming's Smog Exceeds Los Angeles' Due to Gas Drilling*, USA Today, *available at* http://content.usatoday.com/communities/greenhouse/post/2011/03/wyomings-smog-exceeds-los-angeles-due-to-gas-drilling/1, attached as Exhibit 38.

[76] *See, e.g., 2011 DEQ Ozone Advisories*, Pinedale Online! (Mar. 17, 2011) (documenting ten ozone advisories in February and March 2011), *available at* http://www.pinedaleonline.com/news/2011/03/OzoneCalendar.htm, attached as Exhibit 39; Wyoming Department of Environmental Quality, Ozone Advisory for Monday, Feb. 28, Pinedale Online! (Feb. 27, 2011), *available at* http://www.pinedaleonline.com/news/2011/02/OzoneAdvisoryforMond.htm, attached as Exhibit 40.

[77] Scott Streater, *Air Quality Concerns May Dictate Uintah Basin's Natural Gas Drilling Future*, N.Y. TIMES, Oct. 1, 2010, *available at* http://www.nytimes.com/gwire/2010/10/01/01greenwire-air-quality-concerns-may-dictate-uintah-basins-30342.html, attached as Exhibit 41.

[78] *See* EPA, AirExplorer, Query Concentrations (Ozone, Uintah County, 2011), available at http://www.epa.gov/cgi-bin/htmSQL/mxplorer/query_daily.hsql?msaorcountyName=countycode&msaorcountyValue=49047&poll=44201&county=49047&site=-1&msa=-1&state=-1&sy=2011&flag=Y&query=download&_debug=2&_service=data&_program=dataprog.query_daily3P_dm.sas, attached as Exhibit 42.

[79] BLM, *GASCO Energy Inc. Uinta Basin Natural Gas Development Draft Environmental Impact State*ment ("GASCO DEIS"), at 3-13, *available at* http://www.blm.gov/ut/st/en/fo/vernal/planning/nepa_/gasco_energy_eis.html, attached as Exhibit 43.

Rampant oil and gas development in Colorado and New Mexico is also leading to high levels of VOCs and NO_x. In 2008, the Colorado Department of Public Health and Environment concluded that the smog-forming emissions from oil and gas operations exceed vehicle emissions for the entire state.[80] Moreover, significant additional drilling has occurred since 2008. Colorado is now home to more than 46,000 wells.[81] There is also significant development in the San Juan Basin in southeastern Colorado and northwestern New Mexico, with approximately 35,000 wells in the Basin. As a result of this development and several coal-fired power plants in the vicinity, the Basin suffers from serious ozone pollution.[82] This pollution is taking a toll on residents of San Juan County. The New Mexico Department of Public Health has documented increased emergency room visits associated with high ozone levels in the County.[83]

VOC and NO_x emissions from oil and gas development are also harming air quality in national parks and wilderness areas. Researchers have determined that numerous "Class I areas" – a designation reserved for national parks, wilderness areas, and other such lands[84] – are likely to be impacted by increased ozone pollution as a result of oil and gas development in the Rocky Mountain region, including Mesa Verde National Park and Weminuche Wilderness Area in Colorado and San Pedro Parks Wilderness Area, Bandelier Wilderness Area, Pecos Wilderness Area, and Wheeler Peak Wilderness Area in New Mexico.[85] These areas are all near concentrated oil and gas development in the San Juan Basin.[86]

---

[80] Colo. Dept. of Public Health & Env't, Air Pollution Control Division, Oil and Gas Emission Sources, *Presentation for the Air Quality Control Commission Retreat*, at 3-4 (May 15, 2008), attached as Exhibit 44.

[81] Colorado Oil & Gas Conservation Commission, *Colorado Weekly & Monthly Oil and Gas Statistics*, at 12 (Nov. 7, 2011), available at http://cogcc.state.co.us/ (library—statistics—weekly/monthly well activity), attached as Exhibit 45.

[82] *See Four Corners Air Quality Task Force Report of Mitigation Options*, at vii (Nov. 1, 2007), *available at* http://www.nmenv.state.nm.us/aqb/4C/TaskForceReport.html, attached as Exhibit 46.

[83] Myers *et al.*, *The Association Between Ambient Air Quality Ozone Levels and Medical Visits for Asthma in San Juan County* (Aug. 2007), *available at* http://www.nmenv.state.nm.us/aqb/4c/Documents/SanJuanAsthmaDocBW.pdf, attached as Exhibit 47.

[84] *See* 42 U.S.C. § 7472(a).

[85] Rodriguez et al., *Regional Impacts of Oil and Gas Development on Ozone Formation in the Western United States*, 59 Journal of the Air and Waste Management Association 111 (Sept. 2009), available at http://www.wrapair.org/forums/amc/meetings/091111_Nox/Rodriguez_et_al_OandG_Impacts_JAWMA9_09.pdf, attached as Exhibit 48.

[86] *Id.* at 1112.

As oil and gas development moves into new areas, particularly as a result of the boom in development of shale resources, ozone problems are likely to follow. For example, regional air quality models predict that gas development in the Haynesville shale will increase ozone pollution in northeast Texas and northwest Louisiana and may lead to violations of ozone NAAQS.[87]

Sulfur dioxide: Oil and gas production emits sulfur dioxide, primarily from natural gas processing plants.[88] Sulfur dioxide is released as part of the sweetening process, which removes hydrogen sulfide from the gas.[89] Sulfur dioxide is also created when gas containing hydrogen sulfide (discussed below) is combusted in boilers or heaters.[90]

Hydrogen sulfide: Some natural gas contains hydrogen sulfide. When hydrogen sulfide levels are above a specific threshold, gas is classified as "sour gas."[91] According to EPA, there are 14 major areas in the U.S., found in 20 different states, where natural gas tends to be sour.[92] All told, between 15 and 20% of the natural gas in the U.S. may contain hydrogen sulfide.[93]

Given the large amount of drilling in areas with sour gas, EPA has concluded that the potential for hydrogen sulfide emissions from the oil and gas industry is "significant."[94] Hydrogen sulfide may be emitted during all stages of development, including exploration, extraction, treatment and storage, transportation, and refining.[95] For example, hydrogen sulfide is emitted as a result of leaks from processing systems and from wellheads in sour gas fields.[96]

---

[87] *See* Kemball-Cook et al., *Ozone Impacts of Natural Gas development in the Haynesville Shale* 44 Environ. Sci. Technol. 9357, 9362 (Nov. 18, 2010), attached as Exhibit 49.
[88] 76 Fed. Reg. at 52,756.
[89] TSD 3-3 to 3-5.
[90] 76 Fed. Reg. at 52,756.
[91] 76 Fed. Reg. at 52,756. Gas is considered "sour" if hydrogen sulfide concentration is greater than 0.25 grain per 100 standard cubic feet, along with the presence of carbon dioxide. *Id.*
[92] EPA, Office of Air Quality Planning and Standards, *Report to Congress on Hydrogen Sulfide Air Emissions Associated with the Extraction of Oil and Natural Gas* (EPA-453/R-93-045), at ii (Oct. 1993) (hereinafter "EPA Hydrogen Sulfide Report"), attached as Exhibit 50.
[93] Lana Skrtic, *Hydrogen Sulfide, Oil and Gas, and People's Health* ("Skrtic Report"), at 6 (May 2006), *available at* http://www.earthworksaction.org/pubs/hydrogensulfide_oilgas_health.pdf, attached as Exhibit 51.
[94] EPA Hydrogen Sulfide Report at III-35.
[95] *Id.* at ii.
[96] TSD at 2-3.

Hydrogen sulfide emissions from the oil and gas industry are concerning because this pollutant may be harmful even at low concentrations.[97] Hydrogen sulfide is an air pollutant with toxic properties that smells like rotten eggs and can lead to neurological impairment or death. Long-term exposure to hydrogen sulfide is linked to respiratory infections, eye, nose, and throat irritation, breathlessness, nausea, dizziness, confusion, and headaches.[98] Although hydrogen sulfide was originally included in the Clean Air Act's list of hazardous air pollutants, it was removed with industry support.[99]

Although direct monitoring of hydrogen sulfide around oil and gas sources is limited, there is evidence that these emissions may be substantial, and have a serious impact on people's health. For example, North Dakota reported 3,300 violations of an odor-based hydrogen sulfide standard around drilling wells.[100] People in northwest New Mexico and western Colorado living near gas wells have long complained of strong odors, including but not limited to hydrogen sulfide's distinctive rotten egg smell. Residents have also experienced nose, throat and eye irritation, headaches, nose bleeds, and dizziness.[101] An air sample taken by a community monitor at one family's home in western Colorado in January 2011 contained levels of hydrogen sulfide concentrations 185 times higher than safe levels.[102]

Particulate Matter (PM): The oil and gas industry is a major source of PM pollution. This pollution is generated by heavy equipment used to move and level earth during well pad and road construction. Vehicles also generate fugitive dust by traveling on access roads during drilling, completion, and production activities.[103] Diesel engines used in drilling

---

[97] *See* James Collins & David Lewis, Report to CARB, Hydrogen Sulfide: Evaluation of Current California Air Quality Standards with Respect to Protections of Children (Sept. 1, 2000), *available at* http://oehha.ca.gov/air/pdf/oehhah2s.pdf, attached as Exhibit 52.

[98] EPA, Office of Air Quality Planning and Standards, *Report to Congress on Hydrogen Sulfide Air Emissions Associated with the Extraction of Oil and Natural Gas* (EPA-453/R-93-045), at ii (Oct. 1993) (hereinafter "EPA Hydrogen Sulfide Report"), attached as Exhibit 50.

[99] *See* Pub. L. 102-187 (Dec. 4, 1991). We do not concede that this removal was appropriate. Hydrogen sulfide meets section 112 of the Clean Air Act's standards for listing as a hazardous air pollutant, and should be so regulated.

[100] EPA Hydrogen Sulfide Report at III-35.

[101] See Global Community Monitor, *Gassed! Citizen Investigation of Toxic Air Pollution from Natural Gas Development*, at 11-14 (July 2011), attached as Exhibit 53.

[102] *Id.* at 21.

[103] *See* BLM, GASCO Energy Inc. Uinta Basin Natural Gas Development Project Draft Environmental Impact Statement, at App. J at 2 (Oct. 2010) ("GASCO DEIS")

rigs and at compressor stations are also large sources of fine PM/diesel soot emissions. VOCs are also a precursor to formation of $PM_{2.5}$.[104]

PM emissions from the oil and gas industry are leading to significant pollution problems. For example, monitors in Uintah County and Duchesne County, Utah have repeatedly measured wintertime $PM_{2.5}$ concentrations above federal standards.[105] These elevated levels of $PM_{2.5}$ have been linked to oil and gas activities in the Uinta Basin.[106] West Tavaputs FEIS at 3-20. Modeling also shows that road traffic associated with energy development is pushing PM_{10} levels very close to violating NAAQS standards.[107]

EPA's Air Rules Will Not Fully Address These Air Pollution Problems

Although EPA's recently finalized new source performance standards and standards for hazardous air pollutants[108] do reduce some of these pollution problems, they will not solve them. The rules, first, do not even address some pollutants, including NO_x, methane, and hydrogen sulfide, so any reductions of these pollutants occur only as co-benefits of the VOC reductions that the rules require.[109] Second, the rules do not control emissions from most transmission infrastructure.[110] Third, existing sources of air pollution are not controlled for any pollutant, meaning that increased use of existing infrastructure will produce emissions uncontrolled by the rules. Fourth, without full enforcement, the rules will not reduce emissions completely. Fifth, the rules will not address important emissions effects of LNG in particular, including LNG exports' tendency to increase the use of coal power. Thus, though DOE/FE might work with EPA to fully understand the emissions levels likely after the rules are fully implemented, it may not rely upon the EPA rules to avoid weighing and disclosing these impacts.

2. Gas Production Disrupts Landscapes and Habitats

Increased oil and gas production will transform the landscape of regions overlying shale gas plays, bringing industrialization to previously rural landscapes and significantly

---

[104] O&G NSPS RIA at 4-18.
[105] GASCO DEIS at 3-12.
[106] West Tavaputs FEIS, at 3-20 (July 2010).
[107] *See* GASCO DEIS at 4-27.
[108] *See* EPA, Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants, Final Rule (Apr. 17, 2012), not yet published in the Federal Register, but available at http://www.epa.gov/airquality/oilandgas/actions.html.
[109] *See id.*128-31.
[110] *See, e.g.*, *id.* at 173, 177

affecting ecosystems, plants, and animals. These impacts are large and difficult to manage.

Land use disturbance associated with gas development impacts plants and animals through direct habitat loss, where land is cleared for gas uses, and indirect habitat loss, where land adjacent to direct losses loses some of its important characteristics.

Regarding direct losses, land is lost through development of well pads, roads, pipeline corridors, corridors for seismic testing, and other infrastructure. The Nature Conservancy ("TNC") estimated that in Pennsylvania, "Well pads occupy 3.1 acres on average while the associated infrastructure (roads, water impoundments, pipelines) takes up an additional 5.7 acres, or a total of nearly 9 acres per well pad." TNC, Pennsylvania Energy Impacts Assessment, Report 1: Marcellus Shale Natural Gas and Wind (2010) at 10, [111] *see also id.* at 18. New York's Department of Environmental Conservation reached similar estimates. New York Department of Environmental Conservation's Revised Draft Supplemental General Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program, 5-5 (Sept. 2011) (hereinafter "NY RDSGEIS").[112] After initial drilling is completed the well pad is partially restored, but 1 to 3 acres of the well pad will remain disturbed through the life of the wells, estimated to be 20 to 40 years. *Id.* at 6-13. Associated infrastructure such as roads and corridors will likewise remain disturbed. Because these disturbances involve clearing and grading of the land, directly disturbed land is no longer suitable as habitat. *Id.* at 6-68.

Indirect losses occur on land that is not directly disturbed, but where habitat characteristics are affected by direct disturbances. "Adjacent lands can also be impacted, even if they are not directly cleared. This is most notable in forest settings where clearings fragment contiguous forest patches, create new edges, and change habitat conditions for sensitive wildlife and plant species that depend on "interior" forest conditions." TNC, *Pennsylvania Energy Impacts Assessment, Report 1: Marcellus Shale Natural Gas and Wind* at 10. "Research has shown measureable impacts often extend at least 330 feet (100 meters) into forest adjacent to an edge." NY RDSGEIS 6-75.

TNC's study of the impacts of gas extraction in Pennsylvania is particularly telling. TNC mapped projected wells across the state, considering how the wells and their associated infrastructure, including roads and pipelines, interacted with the landscape. TNC's conclusions make for grim reading. It concluded:

- About 60,000 new Marcellus wells are projected by 2030 in Pennsylvania with a range of 6,000 to 15,000 well pads, depending on the number of wells per pad;

[111] Attached as Exhibit 54.
[112] Available at http://www.dec.ny.gov/energy/75370.html

- Wells are likely to be developed in at least 30 counties, with the greatest number concentrated in 15 southwestern, north central, and northeastern counties;

- Nearly two thirds of well pads are projected to be in forest areas, with forest clearing projected to range between 34,000 and 83,000 acres depending on the number of number of well pads that are developed. An additional range of 80,000 to 200,000 acres of forest interior habitat impacts are projected due to new forest edges created by well pads and associated infrastructure (roads, water impoundments);

- On a statewide basis, the projected forest clearing from well pad development would affect less than one percent of the state's forests, but forest clearing and fragmentation could be much more pronounced in areas with intensive Marcellus development;

- Approximately one third of Pennsylvania's largest forest patches (>5,000 acres) are projected to have a range of between 1 and 17 well pads in the medium scenario;

- Impacts on forest interior breeding bird habitats vary with the range and population densities of the species. The widely-distributed scarlet tanager would see relatively modest impacts to its statewide population while black-throated blue warblers, with a Pennsylvania range that largely overlaps with Marcellus development area, could see more significant population impacts;

- Watersheds with healthy eastern brook trout populations substantially overlap with projected Marcellus development sites. The state's watersheds ranked as "intact" by the Eastern Brook Trout Joint Venture are concentrated in north central Pennsylvania, where most of these small watersheds are projected to have between two and three dozen well pads;

- Nearly a third of the species tracked by the Pennsylvania Natural Heritage Program are found in areas projected to have a high probability of Marcellus well development, with 132 considered to be globally rare or critically endangered or imperiled in Pennsylvania. Several of these species have all or most of their known populations in Pennsylvania in high probability Marcellus gas development areas.

- Marcellus gas development is projected to be extensive across Pennsylvania's 4.5 million acres of public lands, including State Parks, State Forests, and State Game Lands. Just over 10 percent of these lands are legally protected from surface development.

TNC, *Pennsylvania Energy Impacts Assessment, Report 1: Marcellus Shale Natural Gas and Wind* (2010) at 29.[113] Increased gas production will exacerbate these problems, which is bad news for the state's lands and wildlife, and the hunting, angling, tourism, and forestry industries which depend upon them. Although TNC adds that impacts could be reduced with proper planning, *id.*, more development makes mitigation more difficult. Indeed, the Pennsylvania Department of Conservation and Natural Resources recently concluded that "zero" remaining acres of the state forests are suitable for leasing with surface disturbing activities, or the forests will be significantly degraded. Penn. Dep't of Conservation and Natural Resources, *Impacts of Leasing Additional State Forest for Natural Gas Development* (2011).[114] These costs are not in the public interest.

Presumably, the additional production Oregon LNG's proposal will induce will occur primarily in the Rockies, rather than the Marcellus Shale. The TNC report nonetheless highlights the extreme changes the gas boom is bringing to affected landscapes, and it is likely that similar effects are being felt elsewhere. Oregon LNG's proposal would add fuel to this fire.

These effects will harm rural economies and decrease property values, as major gas infrastructure transforms and distorts the existing landscape. They will also harm endangered species in regions where production would increase in response to Cheniere's exports. Harm to these species and their habitat is, too, against the profound public interest in species conservation, as expressed in the Endangered Species Act and similar statutes.

3. Gas Production Poses Risks to Ground and Surface Water

As noted above, most of the increased production that would result from Cheniere's proposal will be from shale and other unconventional gas sources, and producing gas from these sources requires hydraulic fracturing, or fracking. *See* DOE, *Shale Gas Production Subcommittee First 90-Day Report* at 8.[115]. Hydraulic fracturing involves injecting a base fluid (typically water),[116] sand or other proppant, and various fracturing chemicals into the gas-bearing formation at high pressures to fracture the rock and release additional gas. Each step of this process presents a risk to water resources. Withdrawal of the water may overtax the water source. Fracking itself may contaminate groundwater with either chemicals added to the fracturing fluid or with naturally occurring chemicals mobilized by fracking. After the well is fracked, some water will

[113] *See* Exhibit 54.
[114] Attached as Exhibit 55.
[115] Attached as Exhibit 56.
[116] The majority of hydraulic fracturing operations are conducted with a water based fracturing fluid. Fracking may also be conducted with oil or synthetic-oil based fluid, with foam, or with gas.

return to the surface, composed of both fracturing fluid and naturally occurring "formation" water. This water, together with drilling muds and drill cuttings, must be disposed of without further endangering water resources.

Water Withdrawals

The first step is the procurement of water. The precise amount of water varies by the shale formation being fracked. To use one example formation, fracking a Marcellus Shale well requires between 4 and 5 million gallons of water. TNC, *Pennsylvania Energy Impacts Assessment, Report 1: Marcellus Shale Natural Gas and Wind*, 5.[117] Fresh water constitutes 80% to 90% of the total water used a well even where operators recycle "flowback" water from the fracking of previous well for use in fracking the current one. New York Department of Environmental Conservation's *Revised Draft Supplemental General Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program*, 6-13 (Sept. 2011) (hereinafter "NY RDSGEIS").[118]

Water withdrawals can drastically impact aquatic ecosystems and human communities. Reductions in instream flow negatively affect aquatic species by changing flow depth and velocity, raising water temperature, changing oxygen content, and altering streambed morphology. *Id.* 6-3 to 6-4. Even when flow reductions are not themselves problematic, the intake structures can harm aquatic organisms. *Id.* at 6-4. Where water is withdrawn from aquifers, rather than surface sources, withdrawal risks permanent depletion. This risk is even more prevalent with withdrawals for fracking than it is for other withdrawal, because fracking is a consumptive use. Fluid injected during the fracking process is (barring accident) deposited below freshwater aquifers and into sealed formations. *Id.* 6-5; DOE Subcommittee First 90 day report at 19 ("in some regions and localities there are significant concerns about consumptive water use for

---

[117] *Accord* New York Department of Environmental Conservation's *Revised Draft Supplemental General Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program*, (September 2011) ("Between July 2008 and February 2011, average water usage for high-volume hydraulic fracturing within the Susquehanna River Basin in Pennsylvania was 4.2 million gallons per well, based on data for 553 wells."), *available at* http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf. Other estimates are that as much as 7.2 million gallons of frack fluid may be used in a 4000 foot well bore. NRDC, *et al.*, *Comment on NY RDSGEIS on the Oil, Gas and Solution Mining Regulatory Program* (Jan. 11, 2012) (Attachment 2, Report of Tom Myers, at 10), attached as Exhibit 57 (hereafter *Comment on NY RDSGEIS*).

Water needs in other geological formations vary. See Exhibit 25 at 19 (estimating that nationwide, fracking an individual well requires between 1 and 5 million gallons of water).

[118] Available at http://www.dec.ny.gov/energy/75370.html

shale gas development."). Thus, the water withdrawn from the aquifer will be used in a way that provides no opportunity to percolate back down to the aquifer and recharge it.

Fracturing

Fracturing poses a serious risk of groundwater contamination. Contaminants include chemicals added to the fracturing fluid and naturally occurring chemicals that are mobilized from deeper formations to groundwater by the fracking process. Contamination may occur through several methods, including where the well casing fails or where the created fractures intersect an existing a poorly sealed well. Although information on groundwater contamination is incomplete, the available research indicates that contamination has already occurred on multiple occasions.

One category of potential contaminants includes chemicals added to the drilling mud and fracturing fluid. The fluid used for slickwater fracturing is typically comprised of more than 98% fresh water and sand, with chemical additives comprising 2% or less of the fluid. NY RDSGEIS 5-40. Chemicals are added as solvents, surfactants, friction reducers, gelling agents, bactericides, and for other purposes. *Id.* 5-49. New York recently identified 322 unique ingredients used in fluid additives, recognizing that this constituted a partial list. *Id.* 5-41. These chemicals include petroleum distillates; aromatic hydrocarbons; glycols; glycol ethers; alcohols and aldehydes; amides; amines; organic acids, salts, esters and related chemicals; microbicides; and others. *Id.* 5-75 to 5-78. Many of these chemicals present health risks. *Id.* Of particular note is the use of diesel, which the DOE Subcommittee has singled out for its harmful effects and recommended be banned from use as a fracturing fluid additive. DOE Subcommittee First 90-Day Report, 25. The minority staff of the House Committee on Energy and Commerce determined that despite diesel's risks, between 2005 and 2009 "oil and gas service companies injected 32.2 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 19 states." Natural Resources Defense Council, Earthjustice, and Sierra Club, *Comments [to EPA] on Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels* (June 29, 2011) at 3 (quoting Letter from Reps. Waxman, Markey, and DeGette to EPA Administrator Lisa Jackson (Jan. 31, 2001) at 1) (hereafter Comment on Diesel Guidance).[119]

Contamination may also result from chemicals naturally occurring in the formation. Flowback and produced water "may include brine, gases (e.g. methane, ethane), trace metals, naturally occurring radioactive elements (e.g. radium, uranium) and organic compounds." DOE Subcommittee first 90 day report at 21; *see also* Comment on NY RDSGEIS (attachment 3, Report of Glen Miller, at 2). For example, mercury naturally occurring in the formation becomes mixed in with water-based drilling muds, resulting

[119] Attached as Exhibit 58.

in up to 5 pounds of mercury in the mud per well drilled in the Marcellus region. Comment on NY RDSGEIS (attachment 1, Report of Susan Harvey, at 92).

There are several vectors by which these chemicals can reach groundwater supplies. Perhaps the most common or significant are inadequacies in the casing of the vertical well bore. DOE Subcommittee First 90 Day Report, 20. The well bore inevitably passes through geological strata containing groundwater, and therefore provides a conduit by which chemicals injected into the well or traveling from the target formation to the surface may reach groundwater. The well casing isolates the groundwater from intermediate strata and the target formation. This casing must be strong enough to withstand the pressures of the fracturing process--the very purpose of which is to shatter rock. Multiple layers of steel casing must be used, each pressure tested before use, then centered within the well bore. Each layer of casing must be cemented, with careful testing to ensure the integrity of the cementing. Comment on Diesel Guidance, 5-9.

Separate from casing failure, contamination may occur when the zone of fractured rock intersects an abandoned and poorly-sealed well or natural conduit in the rock. Comment on NY RDSGEIS (Attachment 3, Report of Tom Myers, 12 - 15). One recent study concluded, on the basis of geologic modeling, that frack fluid may migrate from the hydraulic fracture zone to freshwater aquifers in less than ten years.[120]

Available empirical data indicates that fracking has resulting in groundwater contamination in at least five documented instances. One study "documented the higher concentration of methane originating in shale gas deposits . . . into wells surrounding a producing shale production site in northern Pennsylvania." DOE Subcommittee first 90 day report at 20 (citing Stephen G. Osborn, Avner Vengosh, Nathaniel R. Warner, and Robert B. Jackson, *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing*, Proceedings of the National Academy of Science, 108, 8172-8176, (2011)). By looking at particular isotopes of methane, this study was able to determine that the methane originated in the shale deposit, rather than from a shallower source. *Id.* The DOE Subcommittee referred to this as "a recent, credible, peer-reviewed study." *Id.* Two other reports "have documented or suggested the movement of fracking fluid from the target formation to water wells linked to fracking in wells." Comment on NY RDSGEIS (Attachment 2, Report of Tom Meyers, 13). "Thyne (2008)[[121]] had found bromide in wells 100s of feet above the

[120] Tom Myers, *Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers*, Ground Water (Apr. 17, 2012), attaches as Exhibit 59.
[121] Dr. Meyers relied on Thyne, G. 2008. *Review of Phase II Hydrogeologic Study.* Prepared for Garfield County, Colorado.

fracked zone." *Id.* "The EPA (1987)[122] documented fracking fluid moving into a 416-foot deep water well in West Virginia; the gas well was less than 1000 feet horizontally from the water well, but the report does not indicate the gas-bearing formation." *Id.*

More recently, EPA has investigated groundwater contamination in Pavillion, Wyoming and Dimock, Pennsylvania. In Pavillion, EPA's draft report concludes that "when considered together with other lines of evidence, the data indicates likely impact to ground water that can be explained by hydraulic fracturing." EPA, Draft Investigation of Ground Water Contamination near Pavillion, Wyoming (Dec. 2011), at xiii.[123] EPA tested water from wells extending to various depths within the range of local groundwater. At the deeper tested wells, EPA discovered inorganics (potassium, chloride), synthetic organic (isopropanol, glycols, and tert-butyl alcohol), and organics (BTEX, gasoline and diesel range organics) at levels higher than expected. *Id.* at xii. At shallower levels, EPA detected "high concentrations of benzene, xylenes, gasoline range organics, diesel range organics, and total purgeable hydrocarbons." *Id.* at xi. EPA determined that surface pits previously used for storage of drilling wastes and produced/flowback waters were a likely source of contamination for the shallower waters, and that fracturing likely explained the deeper contamination. *Id.* at xi, xiii. Although this is a draft report in an ongoing investigation, an independent expert who reviewed the EPA Pavillon study at the request of Sierra Club and other environmental groups has supported EPA's findings.[124] it demonstrates a possibility of contamination that DOE must consider in its public interest evaluation.

EPA is also investigating groundwater contamination in Dimock, Pennsylvania. EPA Region III, *Action Memorandum - Request for Funding for a Removal Action at the Dimock Residential Groundwater Site* (Jan. 19, 2012).[125] In Dimock, EPA has determined that "a number of home wells in the Dimock area contain hazardous substances, some of which are not naturally found in the environment." *Id.* at 1. Specifically, wells are contaminated with arsenic, barium, bis(2(ethylhexyl)phthalate, glycol compounds, manganese, phenol, and sodium. *Id.* at 3-4. Many of these chemicals are hazardous

---

[122] Environmental Protection Agency. 1987. Report to Congress, Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy, Volume 1 of 3, Oil and Gas. Washington, D.C., available at nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20012D4P.txt, attached as Exhibit 60.

[123] Attached as Exhibit 61, available at http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf

[124] Tom Myers, *Review of DRAFT: Investigation of Ground Water Contamination near Pavillion Wyoming* (April 30, 2012), attached as Exhibit 62 and available at http://docs.nrdc.org/energy/files/ene_12050101a.pdf.

[125] Attached as Exhibit 63, available at http://www.epaosc.org/sites/7555/files/Dimock%20Action%20Memo%2001-19-12.PDF

substances as defined under CERCLA section 101(14); *see also* 40 C.F.R. § 302.4. EPA's determination is based on "Pennsylvania Department of Environmental Protection (PADEP) and Cabot Oil and Gas Corporation (Cabot) sampling information, consultation with an EPA toxicologist, the Agency for Toxic Substances and Disease Registry (ATSDR) Record of Activity (AROA), issued, 12/28/11, and [a] recent EPA well survey effort." *Id.* The PADEP information provided reason to believe that drilling activities in the area led to contamination of these water supplies. Drilling in the area began in 2008, and was conducted using the hazardous substances that have since been discovered in well water. *Id.* at 1, 2. Shortly thereafter methane contamination was detected in private well water. *Id.* at 2. In addition, there were several surface spills in connection with the drilling operation. *Id.* at 1. After the contamination was detected, PADEP entered a consent decree with Cabot which required permanent restoration or replacement of the water supply. *Id.* at 2. Cabot has installed or is installing a "gas mitigation" system for the affected wells. *Id., see also* Agency for Toxic Substances and Disease Registry, *Record of Activity/Technical Assist* (Dec. 28, 2011) at 2 (hereafter ATSDR).[126]

Pursuant to the consent decree, Cabot was providing replacement water to all 18 homes until November 30, 2011, at which point Cabot halted deliver with PADEP's consent. ATSDR at 2. EPA has intervened because "EPA does not know what, if any, hazardous substances these 'gas mitigation' systems, originally designed to address methane, are removing." EPA Action Memorandum at 2. EPA sampled water from 64 home wells.[127], "EPA found hazardous substances, specifically arsenic, barium or manganese, all of which are also naturally occurring substances, in well water at five homes at levels that could present a health concern. In all cases the residents have now or will have their own treatment systems that can reduce concentrations of those hazardous substances to acceptable levels at the tap."[128]

Waste Management

Fracturing produces a variety of liquid and solid wastes that must be managed and disposed of. These include the drilling mud used to lubricate the drilling process, the drill cuttings removed from the well bore, the "flowback" of fracturing fluid that returns to the surface in the days after fracking, and produced water that is produced over the life of the well (a mixture of water naturally occurring in the shale formation and lingering fracturing fluid). These wastes contain the same contaminants described in the

[126] Attached as Exhibit 64, available at http://www.epa.gov/aboutepa/states/dimock.pdf.
[127] EPA, *EPA Completes Drinking Water Sampling in Dimock, Pa* (July 25, 2012), attached as Exhibit 65, and available at http://yosemite.epa.gov/opa/admpress.nsf/0/1A6E49D193E1007585257A46005B61AD
[128] *Id.*

preceding section. They present environmental hazards with regard to their onsite management and with their eventual disposal.

On site, drilling mud, drill cuttings, flowback and produced water are often stored in pits. Such open pits can have harmful air emissions, can leach into shallow groundwater water, and can fail and result in surface discharges. Many of these harms can be minimized by the use of seal tanks in a "closed loop" system. *See, e.g.*, NY RDSGEIS at 1-12. Presently, only New Mexico mandates the use of closed loop waste management systems, and pits remain in use elsewhere.

Flowback and produced water must ultimately be disposed of offsite. Some of these fluids may be recycled and used in further fracturing operations, but even where a fluid recycling program is used, recycling leaves concentrated contaminants that must be disposed of. The most common methods of disposal are disposal in underground injection wells or through water treatment facilities leading to eventual surface discharge.

Underground injection wells present risks of groundwater contamination similar to those identified above for fracking itself. Gas production wastes are not categorized as hazardous under the Safe Drinking Water Act, 42 U.S.C. § 300f *et seq.*, and may be disposed of in Class II injection wells. Class II wells are brine wells, and the standards and safeguards in place for these wells were not designed with the contaminants found in fracking wastes in mind. *See also* NRDC *et al.*, Petition for Rulemaking Pursuant to Section 6974(a) of the Resource Conservation and Recovery Act Concerning the Regulation of Wastes Associated with the Exploration, Development, or Production of Crude Oil or Natural Gas or Geothermal Energy (Sept. 8, 2010).[129]

Additionally, underground injection of fracking wastes appears to have induced earthquakes in several regions. Underground injection of fracking waste in Ohio has been correlated with earthquakes as high as 4.0 on the Richter scale. Columbia University, Lamont-Doherty Earth Observatory, *Ohio Quakes Probably Triggered by Waste Disposal Well, Say Seismologists* (Jan. 6, 2012).[130] Underground injection may cause earthquakes by causing movement on existing fault lines: "Once fluid enters a preexisting fault, it can pressurize the rocks enough to move; the more stress placed on the rock formation, the more powerful the earthquake." *Id.* Underground injection is more likely than fracking to trigger large earthquakes via this mechanism, "because more fluid is usually being pumped underground at a site for longer periods." *Id.* In light of the apparent induced seismicity, Ohio has put a moratorium on injection in the affected region. *Id.* Similar associations between earthquakes and injection have

[129] Attached as Exhibit 66.

[130] Attached as Exhibit 67, available at http://www.ldeo.columbia.edu/news-events/seismologists-link-ohio-earthquakes-waste-disposal-wells

occurred in Arkansas, Texas, Oklahoma and the United Kingdom. *Id*., Alexis Flynn, *Study Ties Fracking to Quakes in England*, Wall Street Journal (Nov. 3, 2011).[131] In light of these effects, Ohio and Arkansas have placed moratoriums on injection in the affected areas. Lamont-Doherty Earth Observatory; Arkansas Oil and Gas Commission, *Class II Commercial Disposal Well or Class II Disposal Well Moratorium* (Aug. 2, 2011).[132] The recently released abstract of a forthcoming United States Geological Survey study affirms the connection between disposal wells and earthquakes. Ellsworth, W. L., *et al*., *Are Seismicity Rate Changes in the Midcontinent Natural or Manmade?*, Seismological Society of America, (April 2012).[133]

As an alternative to underground injection, flowback and produced water is also sent to water treatment facilities, leading to eventual surface discharge. This presents a separate set of environmental hazards, because these facilities (particularly publicly owned treatment works) are not designed to handle the nontraditional pollutants found in fracking wastes. For example:

> One serious problem with the proposed discharge (dilution) of fracture treatment wastewater via a municipal or privately owned treatment plant is the observed increases in trihalomethane (THM) concentrations in drinking water reported in the public media (Frazier and Murray, 2011), due to the presence of increased bromide concentrations. Bromide is more reactive than chloride in formation of trihalomethanes, and even though bromide concentrations are generally lower than chloride concentrations, the increased reactivity of bromide generates increased amounts of bromodichloromethane and dibromochloromethane (Chowdhury, et al., 2010). Continued violations of an 80microgram/L THM standard may ultimately require a drinking water treatment plant to convert from a standard and cost effective chlorination disinfection treatment to a more expensive chloramines process for water treatment. Although there are many factors affecting THM production in a specific water,

---

[131] Attached as Exhibit 68, available at http://online.wsj.com/article/SB10001424052970203804204577013771109580352.html

[132] Attached as Exhibit 69, available at http://www.aogc.state.ar.us/Hearing%20Orders/2011/July/180A-2-2011-07.pdf

[133] This abstract is attached as Exhibit 70, and is available at http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-recid=224&-format=%2Fmeetings%2F2012%2Fabstracts%2Fsessionabstractdetail.html&-lay=MtgList&-find

> simple (and cheap) dilution of fracture treatment water in a stream can result in a more expensive treatment for disinfection of drinking water. This transfer of costs to the public should not be permitted.

Comment on NY RDSGEIS (attachment 3, Report of Glen Miller, at 13). Similarly, municipal treatment works typically to not treat for radioactivity, whereas produced water can have high levels of naturally occurring radioactive materials. In one examination of three samples of produced water, radioactivity (measured as gross alpha radiation) were found ranging from 18,000 pCi / L to 123,000 pCi/L, whereas the safe drinking water standard is 15 pCi/L. *Id.* (Miller Report at 4).

c. Other Nationwide and Global Impacts

i. Price Increases

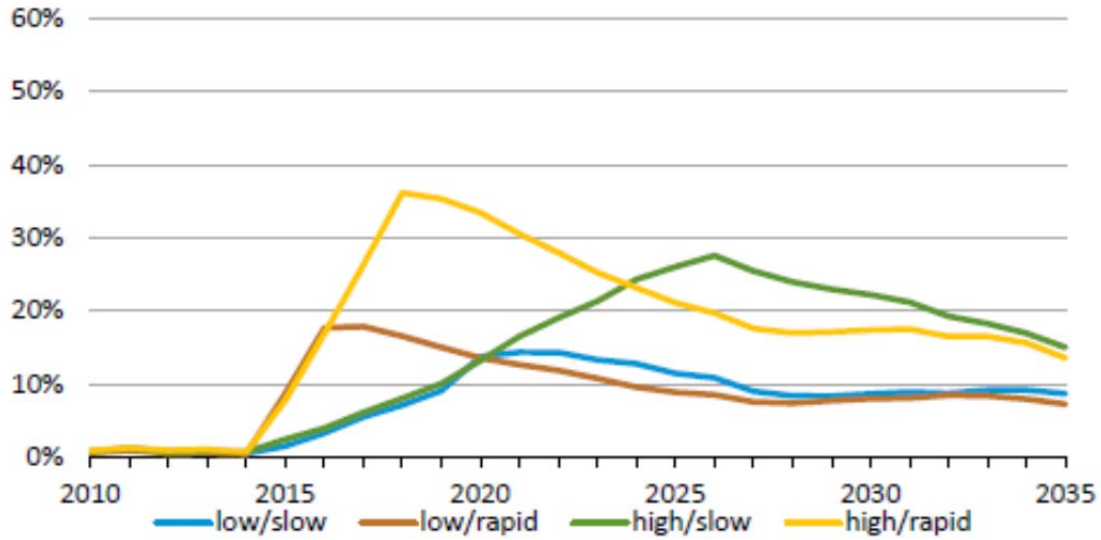
The *EIA Export Study* predicts that LNG exports will significantly increase demand for natural gas and thereby raise domestic gas prices. *EIA Export Study* at 6. Higher gas prices will in turn hurt American consumers and limit or eliminate manufacturing and farming jobs, in addition to inflicting the environmental effects described above. *Id*.[134] Although Oregon LNG offers its own differing predictions, DOE/FE should adopt the estimates of its own sub-agency. Even if DOE/FE were to accept Oregon LNG's own, lower predictions of price impacts, however, DOE/FE would have to conclude that these impacts constituted a significant harm to the public interest.

The *EIA Export Study* predicts striking price increases from a range of export scenarios. EIA considered several combinations of conditions of shale gas export rates and economic circumstances. It considered a "low" export case of 6 bcf/d, phased in either quickly or slowly starting in 2015, and a "high" case of 12 bcf/d, again phased in quickly or slowly. *EIA Export Study* at 1. These four export volumes and timelines were then evaluated in the contexts of four background scenarios: the EIA's Annual Energy Outlook ("AEO") 2011 reference case, cases where shale recoveries were 50% higher or lower than in the reference case, and a high economic growth reference case. *Id.* Models were run from 2015 (the year in which the first exports were presumed to begin) through 2035. *EIA Export Study* 1. EIA forecast effects of export on wellhead gas prices, on various gas consumers, and on residential electricity bills. *EIA Export Study* 6-16. The

[134] *See also* Democratic Staff, House Natural Resources Comm., *Drill Here, Sell There, Pay More: The Painful Price of Exporting Natural Gas* (2012) ("*Drill Here, Sell There, Pay More*"), attached as Exhibit 71; Industrial Energy Consumers of America, *Response to Hamilton Project: "A Strategy for U.S. Natural Gas Exports" by Michael Levi* (July 16, 2012), *available at* http://www.ieca-us.com/wp-content/uploads/07.16.12_IECA-Response-to-Brookings.pdf and attached as Exhibit 72.

study summarizes its results for its four export scenarios on the reference economic case as follows:

Figure 1:[135] Natural Gas Wellhead Price Percentage Increases from the AEO 2011 Baseline under Four Export Scenarios



These figures likely understate the impact of aggregate exports, because the volume of proposed exports greatly exceeds EIA's "high" export scenario, and because current estimates of total reserves are much lower than those used in the EIA Export Study. Beginning with export volumes, EIA's "high" export cases of 12 bcf/d fall far short of the 27.58 bcf/d of exports for which applications are presently pending before DOE/FE.[136] For perspective, note that 27.58 bcf/d is over 36% of current domestic gas production. EIA, Monthly Natural Gas Gross Production Report (November 2, 2012). [137] On the other end, EIA has drastically reduced its estimates of total gas supplies. The EIA production cases were derived from EIA's 2011 Annual Energy Outlook, which assumed total

[135] From the EIA Export Study, at 8.

[136] *Applications Received by DOE/FE to Export Domestically Produced LNG from the Lower-48 States (as of October 16, 2012)*, available at http://fossil.energy.gov/programs/gasregulation/reports/Long_Term_LNG_Export_10-16-12.pdf and attached as Exhibit 73.

[137] Available at http://www.eia.gov/oil_gas/natural_gas/data_publications/eia914/eia914.html and attached as Exhibit 74. This report states that, for the month of August 2012, gross U.S. withdrawals (not limited to the lower 48) were 76.60 bcf/d. The highest monthly production in the past 12 months was 83.06 bcf/d in January 2012: the proposed exports amount to over 33% of this total.

domestic reserves of 827 tcf of natural gas. The more recent 2012 Annual Energy Outlook cuts the estimates of reserves by over 40%, to 482 tcf.[138]

Oregon LNG offers separate (and lower) predictions of price impacts. Absent a strong showing that the EIA estimates are inferior to those prepared by Oregon LNG, it would be arbitrary and capricious for DOE/FE to use industry estimates instead of the estimates produced by the impartial federal agency DOE/FE specifically tasked with examining this particular issue. 5 U.S.C. § 706, *Motor Vehicle Mfrs. Ass'n of the United States v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983). Oregon LNG has failed to make such a showing here.

Oregon LNG's estimates must also be excluded because they fail to account for the cumulative impacts of pending export proposal. The Navigant study Oregon LNG commissioned used three cases: the status quo, approval of Oregon LNG's proposal but no other pending export proposals, and an "aggregate" LNG export scenario under which 6.8 bcf/d of LNG is exported. Application at 23. In light of the 27.58 bcf/d of proposed exports, DOE/FE cannot rest on these low export scenarios. Although Oregon LNG may contend that it is unlikely that all, or even many, of the proposed export projects will come to fruition or operate at full capacity, the possibility of that volume of exports is hardly so "remote and speculative" that it can be discounted. *See New York v. NRC*, 681 F.3d 471, 482 (D.C. Cir. 2012) (under NEPA, agency may only exclude analysis of an event and its consequences when the event "is so 'remote and speculative' as to reduce the effective probability of its occurrence to zero."), *San Luis Obispo Mothers for Peace v. Nuclear Regulatory Comm'n*, 449 F.3d 1016, 1031 (9th Cir. 2006) (same). Therefore, DOE/FE must consider the cumulative impacts of all pending export proposals, and thus consider Oregon LNG's application in light of other pending proposals. Consideration of the cumulative effects of the pending proposals is necessary because the public, after all, will not experience each proposed terminal as an individual project: It will experience them cumulatively, through the gas and electricity prices that they will raise and the environmental damage that they will cause. To determine whether any one export proposal is consistent with the public interest, DOE/FE must consider whether a given proposal will harm the public in concert with (a) all proposals which have already been approved and (b) whether it will cause harm if all reasonably foreseeable proposals were approved. If the answer to this second question is yes, DOE/FE must be able to justify why it is still in the public interest to approve the project before it.[139]

---

[138] EIA 2012 Annual Energy Outlook at 9, 13, *see also* Exhibit 5.

[139] Although it would be unlawful to consider the price impacts of Jordan Cove's proposed exports in isolation, such consideration would nonetheless reveal a significant impact. Jordan Cove itself predicts that the effects of its exports, if considered in isolation, would increase gas prices in the Pacific Northwest by 3.9% to 7.2%. Application at 15. As the EIA explains, this level of increase is detrimental to consumers,

All of EIA's scenarios predict greater price increases than Oregon LNG does. The high export/low recovery scenarios predict that in the years leading up to 2020, wellhead prices will increase over 50%.[140] Similarly, over the longer term, EIA's low-recovery high-export scenarios predict Henry Hub price increases of $1.46 (20%) to $2.33 (32%) by 2025 and $0.94 (10%) to $1.59 (18%) by 2035.[141] EIA predicts similar increases in wellhead prices for these periods.[142] Even the low/slow exports reference case predicts predicts Henry Hub prices to increase by $0.60 per MMBtu, or over 9%, by 2035.[143] These predictions are all significantly higher than Oregon LNG's predictions of 5.43% to 4.96% increases in Henry Hub prices as a result of aggregate exports between 2017 and 2045. Application at 23.

Even if DOE/FE were to accept Oregon LNG's projections, DOE/FE would have to conclude that these projections were significant and contrary to the public interest. Oregon LNG's aggregate scenario predicts price increases of 5.71% to 8.49% at the nearby Sumas hub in 2017 and 2045, respectively, and 5.43% (2017) to 4.96% (2045) at the more distant Henry Hub. Application 25-26. Although these price predictions are significantly lower than the *EIA Export Study*'s projections of hub price increases, Oregon LNG's predictions are still significant enough to risk the economic impacts outlined in the EIA Export Study.

EIA predicts that in light of these price increases, all consumers of natural gas—residential, commercial, industrial, and electricity generating users—will decrease consumption. EIA Export Study at 11, 15. Despite decreased consumption, each consumer type would pay a higher total gas bill. As EIA explains:

> On average, from 2015 to 2035, natural gas bills paid by end-use consumers in the residential, commercial, and industrial sectors combined increase 3 to 9 percent over a comparable baseline case with no exports, depending on the export scenario and case, while increases in electricity bulls paid by end-use customers range from 1 to 3 percent. In the rapid growth cases, the increase is notably greater in the early years relative to the later years. The slower

---

industry, and electricity generators. EIA Export Study at 6, 11, 15. Jordan Cove offers no argument as to why these increases are not contrary to the public interest.

[140] EIA Export Study Figure 4.

[141] EIA Export Study tables B3 and B4.

[142] *Id.*

[143] EIA Export Study at Table B4. For other export scenarios and reference cases, EIA's estimates range from $0.40 to $1.59. *Id.*

> export growth cases tend to show natural gas bills increasing more towards the end of the projection period.

EIA Export Study at 6. Industrial consumers would pay 6.4% to 14.6% more annually. *Id.* at 15.

These percentage increases are very large in absolute terms. In the low/slow scenario, gas and electricity bills increase by $9 billion *per year*, and this increase grows to $20 billion per year in other scenarios. *EIA Export Study* at 14. Industries particularly dependent on natural gas—such as farming, steel production, fertilizer manufacturing, and chemical manufacturing—will all be particularly impacted by these increases.[144] Increased costs to these industries will likely result job losses, or at least stymied job growth, offsetting job growth exports would create in the natural gas production industry. *Id.*

ii. Changes in Domestic Power Production

Oregon LNG's export proposal will further increase air pollution by increasing the amount of coal used for domestic electricity production. The EIA Export Study predicts that exports, by causing natural gas prices to rise, will drive more electricity generation t coal than to renewable energy. EIA Export Study at 6 (The power sector will "primarily" respond by shifting to coal-fired generation, and only secondarily to renewable sources), *see also id.* at 17 ("higher natural gas prices lead electric generators to burn more coal and less natural gas."). Specifically, EIA predicts that 72 percent of the decrease in gas-fired electricity production will be replaced by coal-fired production, with increased liquid fuel consumption, increased renewable generation, and decreases in total consumption making up the remainder (8, 9, and 11 percent, respectively). *Id.* at 18.

The shift from gas- to coal-fired electricity generation will increase emissions of both traditional air pollutants and greenhouse gases. Gas-fired power plants generate less than a third of the nitrogen oxides and one percent of the sulfur oxides that coal-fired plants generate.[145] Thus, the EIA Export Study demonstrates that exports will harm the local environment by causing the opposite shift here.

Coal-fired plants also release roughly twice the carbon dioxide combustion emissions as gas-fired plants, *id.*, although as discussed in the following section, some of this combustion advantage is offset by the greenhouse gas emissions resulting from gas

---

[144] Drill Here, Sell There, Pay More at 9-13; Industrial Energy Consumers of America, *Response to Hamilton Project: "A Strategy for U.S. Natural Gas Exports" by Michael Levi* (July 16, 2012).

[145] EPA, Air Emissions, attached as Exhibit 75, available at http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

production. Accordingly, the price increase and corresponding shift to coal-fired power generation risks increasing greenhouse gas pollution. The *EIA Export Study* examined the effects of 6 or 12 bcf/d of exports, phased in slowly or quickly, together with various estimates for the extent of shale gas reserves and the pace of US economic development. EIA concluded that under every scenario exports would produce a significant increase in domestic greenhouse gas emissions, as illustrated by the table below.

Table 1: Cumulative CO_2 Emissions from 2015 to 2035 With Various Export Scenarios[146]

Case	no added exports	low/slow	low/rapid	high/slow	high/rapid
Reference					
Cumulative carbon dioxide emissions	125,056	125,699	125,707	126,038	126,283
Change from baseline		643	651	982	1,227
Percentage change from baseline		0.5%	0.5%	0.8%	1.0%
High Shale EUR					
Cumulative carbon dioxide emissions	124,230	124,888	124,883	125,531	125,817
Change from baseline		658	653	1,301	1,587
Percentage change from baseline		0.5%	0.5%	1.0%	1.3%
Low Shale EUR					
Cumulative carbon dioxide emissions	125,162	125,606	125,556	125,497	125,670
Change from baseline		444	394	335	508
Percentage change from baseline		0.4%	0.3%	0.3%	0.4%
High Economic Growth					
Cumulative carbon dioxide emissions	131,675	131,862	132,016	131,957	132,095
Change from baseline		187	341	282	420
Percentage change from baseline		0.1%	0.3%	0.2%	0.3%

Source: U.S. Energy Information Administration, National Energy Modeling System, with emissions related to natural gas assumed to be consumed in the liquefaction process included.

The fact that gas exports will tend to favor coal as a fuel for domestic electrical generation has particularly important implications for national emissions control efforts. EPA has just released proposed carbon pollution standards for electricity generating units which set emissions levels based upon the performance of natural gas combined-cycle plants. *See*77 Fed. Reg. 22,392 (Apr. 13, 2012). EPA anticipates no notable compliance costs for the rule because it expects utilities to react to low gas prices, among other factors, by avoiding constructing expensive coal-fired plants. *See id.* at 22,430. If LNG exports move forward, however, gas prices will increase, making it more difficult and expensive to capture combustion-side carbon pollution reductions from fossil-fuel fired power plants. This interference with national efforts to control global warming, which endangers public health and welfare, *see* 74 Fed. Reg. 66,496 (Dec. 15, 2009), is not in the public interest.

[146] From the *EIA Export Study* at 19.

iii. Effects on Global Greenhouse Gas Emissions

Several other export applicants have argued that LNG exports will benefit the environment by allowing importing countries to burn natural gas in place of coal, fuel oil, or other fuels with higher carbon intensities, and that LNG exports will thereby reduce global greenhouse gas emissions. This argument is wrong for two reasons.

First, looking at importing countries' response to exports, a recent study by the International Energy Agency predicts that international trade in LNG and other measures to increase global availability of natural gas will lead many countries to use natural gas in place of wind, solar, or other renewables, displacing these more environmentally beneficial energy sources instead of displacing other fossil fuels, and that these countries may also increases their overall energy consumption beyond the level that would occur with exports.[147] In the United States alone, the IEA expects the gas boom to result in a 10% reduction in renewables relative to a baseline world without increased gas use and trade.[148] The IEA goes on to conclude that high levels of gas production and trade will produce "only a small net shift" in global greenhouse gas emissions, with atmospheric CO2 levels stabilizing at over 650 ppm and global warming in excess of 3.5 degrees Celsius, "well above the widely accepted 2°C target." *Id.*

Second, even where importing countries do substitute gas for coal or fuel oil, the available evidence indicates that this substitution is likely to cause little, if any, reduction in global greenhouse gas emissions. On this issue, it is important to highlight the energy and environmental costs LNG incurs in beyond those incurred by domestic gas use. Liquefying natural gas is an energy intensive process. Additional energy is then consumed in the transportation of the gas, with attendant greenhouse gas emissions. Finally, the LNG must be regasified at the import terminal, often by being heated with the combustion of other gas. These operations drastically increase the lifecycle greenhouse gas emissions of LNG, adding between 24.7 and 27.5 tons of CO_2e per MMBtu.[149]

---

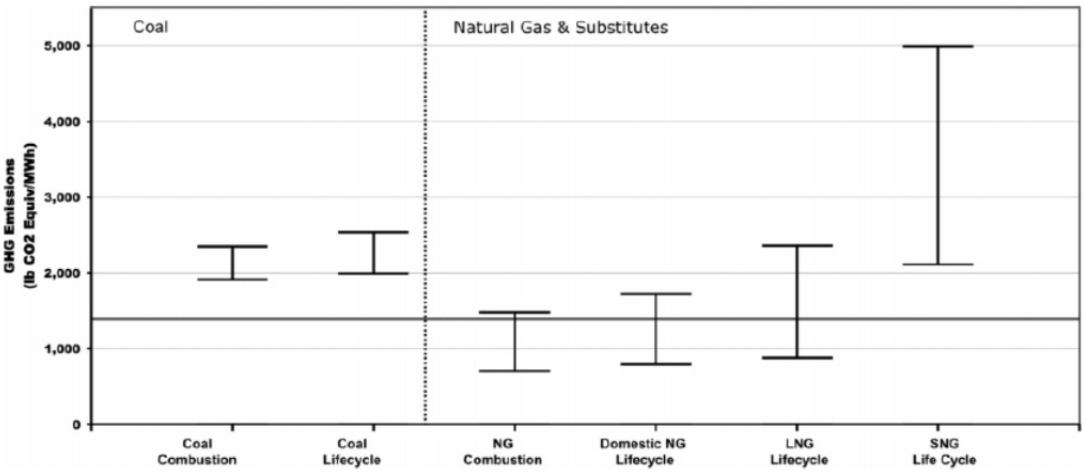
[147] International Energy Agency, *Golden Rules for a Golden Age of Gas*, Ch. 2 p. 91 (2012), attached as Exhibit 76 and available at http://www.iea.org/publications/freepublications/publication/WEO2012_GoldenRulesReport.pdf

[148] *Id.* at 80.

[149] Paulina Jaramillo, W. Michael Griffin, H. Scott Matthews, Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation, 41 Environ. Sci. Technol. 6,290 (2007) (Jaramillo 2007). Available at http://www.ce.cmu.edu/~gdrg/readings/2007/09/13/Jaramillo_ComparativeLCACoalNG.pdf, and attached as
Exhibit 77. The supporting information for this article is available at http://pubs.acs.org/doi/suppl/10.1021/es063031o/suppl_file/

Emissions from liquefaction, transportation and gasification mean that LNG is significantly worse than domestic natural gas in terms of greenhouse gas emissions. For perspective, natural gas *combustion* emits roughly 120 pounds of CO_2e per MMBtu. *See, e.g.*, Jaramillo Supporting Info at 9. Using the above conservative figures, the process of liquefying, transporting, and regasifying LNG accordingly emits 19% to 23% of the CO_2e emitted by natural gas combustion itself—a substantial increase. Jaramillo 2007 concluded that this increase could bring LNG's lifecycle greenhouse gas emissions into parity with coal:

Figure 2: Life-Cycle Emissions of LNG, Natural Gas, and Coal in Electricity Generation[150]



Moreover, Jaramillo's analysis understates LNG's lifecycle greenhouse gas emissions, because this analysis does not reflect recent studies that have raised estimates for emissions associated with natural gas production. The Jaramillo studies were conducted prior to shale gas boom. As noted in part III.C.1.b.iii.1 above, shale gas production's methane emissions are drastically higher than those of conventional gas production. Moreover, in April 2011 (well after the Jaramillo studies were published), EPA released improved methodologies for estimating fugitive methane emissions from all natural gas systems (unconventional and otherwise), which lead to higher estimates. EPA, *Inventory*

---

es063031osi20070516_042542.pdf, and attached as Exhibit 78 ("Jaramillo Supporting Information"). An earlier, related report with some additional information is Paulina Jaramillo, W. Michael Griffin, H. Scott Matthews, *Comparative Life Cycle Carbon Emissions of LNG Versus Coal and Gas for Electricity Generation* (2005), available at http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo_LifeCycleCarbonEmissionsFromLNG.pdf, and attached as Exhibit 79.

[150] From Jaramillo 2007 at 6,295. "SNG," in the figure, refers to synthetic natural gas made from coal.

of U.S. Greenhouse Gas Emissions And Sinks: 1990 – 2009, U.S. EPA, EPA 430-R-11-005.[151]

These recent studies estimate that aggregate domestic natural gas production releases at least 44 pounds of CO_2e per MMBtu. A report from the Worldwatch Institute and Deutsche Bank summarizes much of the recent work.[152] Specifically, the Worldwatch Report synthesizes three other reports that used "bottom-up" methodologies to estimate natural gas production emissions, prepared by Dr. Robert Howarth et al., of Cornell,[153] Mohan Jiang et al. of Carnegie-Mellon,[154] and Timothy Skone of NETL.[155] The Worldwatch Report separately derived a "top-down" estimate, which produced a result similar to the NETL estimate. Worldwatch Report at 9. These various assessments are summarized in the following chart.

/ / /

/ / /

/ / /

/ / /

/ / /

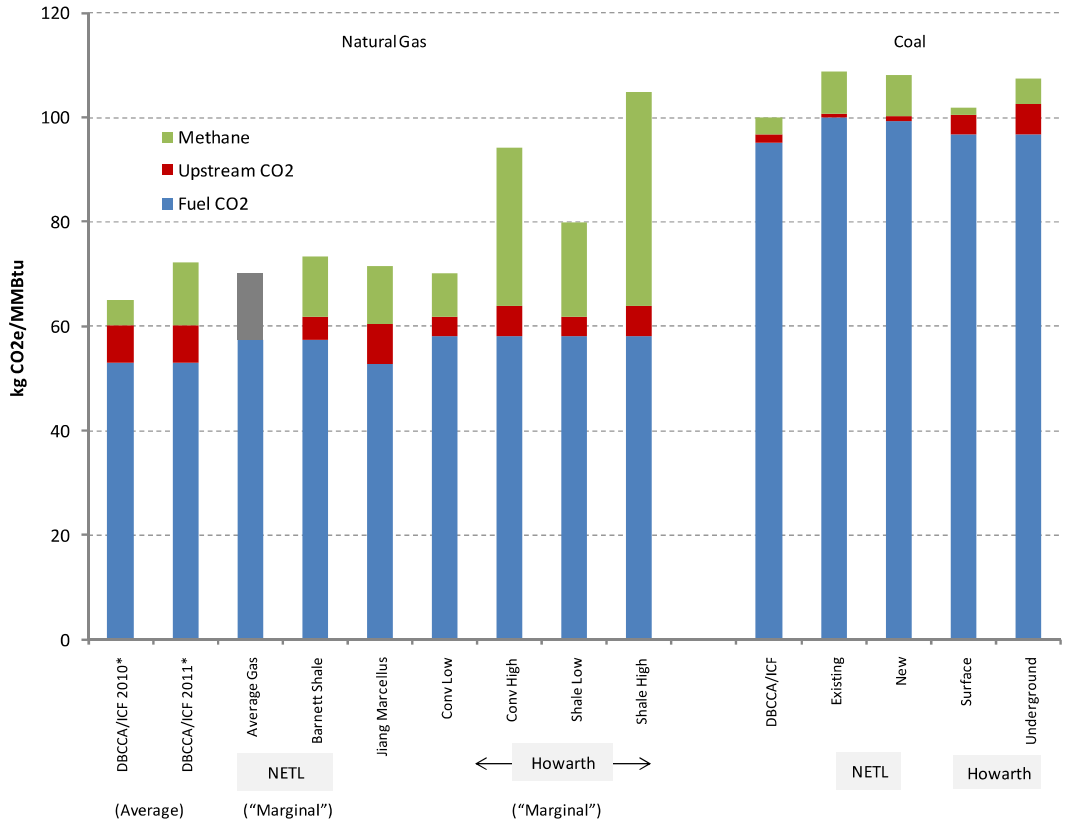
/ / /

/ / /

/ / /

[151] Attached as Exhibit 80. The executive summary to this document is Exhibit 81.
[152] Mark Fulton *et al.*, *Comparing Life-Cycle Greenhouse Gas Emissions from Natural Gas and Coal* (Aug. 25, 2011) ("Worldwatch Report"), attached as Exhibit 82.
[153] Robert W. Howarth *et al*., *Methane and the greenhouse-gas footprint of natural gas from shale formations*, Climactic Change (Mar. 2011), attached as Exhibit 83.
[154] Mohan Jiang *et al.*, *Life cycle greenhouse gas emissions of Marcellus shale gas*, Environ. Res. Letters 6 (Aug. 2011), attached as Exhibit 84.
[155] Timothy J. Skone, *Life Cycle Greenhouse Gas Analysis of Natural Gas Extraction and Delivery in the United States*, Presentation to Cornell (May 12, 2011), attached as Exhibit 85. NETL has also put out a fuller version of this analysis. *See also* Timothy J. Skone, *Life Cycle Greenhouse Gas Inventory of Natural Gas Extraction, Delivery and Electricity Production* (Oct. 24, 2011), attached as Exhibit 86.

Figure 3: Comparison of Recent Life-Cycle Assessments[156]



Source: DBCCA Analysis 2011; NETL 2011; Jiang 2011; Howarth 2011. Note: NETL Average Gas study includes bar shaded grey due to inability to segregate upstream CO2 and methane values, which were both accounted for in the study. See page 10 for more information. *2011 EPA methodology compared to 2010.

As this figure demonstrates, although the 2011 studies differ, they all estimate production greenhouse gas emissions (combined methane and "upstream CO_2") in a similar range. Synthesizing these studies, the Worldwatch Report estimated normalized life-cycle GHG emissions from domestic natural gas production (i.e., excluding liquefaction, transport, and gasification of LNG) at approximately 20.1 kilograms, or over 44 pounds, of CO_2e/MMBtu. Worldwatch Report at 15 Ex. 8. Some studies estimate that production emissions are significantly higher.

Jaramillo used production emission estimates that are much lower than those produced by the more recent studies, and using the recent and higher figures appears to erode what little climate advantage Jaramillo found LNG to have over coal. Jaramillo used estimates of 15.3 to 20.1 pounds CO_2e/ MMBtu, *i.e.*, estimates that were *at least* 24 pounds lower than the 2011 studies'. Jaramillo Supporting Information at 8. Jamarillo estimated total life-cycle emissions for LNG at 149.6 to 192.3 lbs CO_2e/MMBtu. *Id.* Simply increasing these life-cycle estimates by 24 lbs CO_2e represents a 12% to 16%

[156] Worldwatch Report at 3.

increase in total emissions. This increase substantially erodes any climate advantage LNG-fired electricity generation may have over coal-fired generation.

Finally, any LNG exported from Oregon LNG will likely have life cycle emissions that are even higher than the above estimates. The above studies generally estimate gas production emissions in aggregate, mixing conventional gas extraction with unconventional sources such as shale gas. As noted above, the EIA Export Study predicts that extraction induced by exports will overwhelmingly be from shale gas sources, EIA Export Study at 11, and shale gas has higher production emissions than conventional sources.[157] This fact highlights the need for a thorough study regarding the indirect and cumulative impacts of export prior to any DOE/FE authorization. Further study is similarly needed to combine the analysis of export on fuel switching domestically with life-cycle emissions of LNG exports. Nonetheless, using even the more conservative estimates in the existing record, it is unlikely LNG export will reduce global greenhouse gas emissions.

2. **The Economic Benefits Oregon LNG Predicts are Uncertain and Overstated**

Oregon LNG claims that construction of the terminal and associated pipeline will deliver over $800 million in annual economic benefit during the construction period, followed by $100 million in annual benefit during operation of the project. Application at 5.

These predictions, however, rest on a flawed analysis that overstates the number and quality of jobs created. Oregon LNG's arguments relating to job creation and economic benefit all rest on predictions made using IMPLAN modeling software. *See, e.g.*, Application at Appendix C page 11. To use IMPLAN or any other input-output model, the user inputs a description of economic activity in a given set of economic sectors, and the model responds by tracing this spending through the economy. Specifically, the model uses accounting tables to track how the initial expenditure will flow through various industrial sectors and then uses local multipliers to estimate how this allocation will alter employment decisions.

IMPLAN, like input-output models generally, suffers from numerous significant limitations that lead it to drastically overestimates economic benefits. A recent study by Amanda Weinstein and Dr. Mark Partridge, of Ohio State University, explains why many of these limitations matter. *See* Amanda Weinstein and Mark D. Partridge, *The Economic Value of Shale Natural Gas in Ohio*, OHIO STATE UNIVERSITY, Swank Program in Rural-Urban Policy Summary and Report (December 2010) ("*Ohio Study*").[158] Further

[157] EPA recently estimated methane emissions from a conventional well completion at only 0.80 tons, while completion of a hydraulically fractured well yielded 158.55 tons of methane. *See* O&G NSPS TSD at 4-7 (Table 4-2).
[158] Attached as Exhibit 87.

limitations are discussed by David Kay, *The Economic Impacts of Marcellus Shale Gas Drilling: What Have We Learned? What are the Limitations?* (Apr. 2011).[159]

First, input-output models do not consider counterfactuals and foregone opportunities. They map the consequences of a particular expenditure, rather than asking how the economy might have grown had investors and regulators made different choices. Nor do they consider how the particular choice at issue might displace other economic activity. The absence of a counter-factual is at the core of the Ohio Study's critique. *Id.* at 11. Specifically, input-output models "do not include various displacement effects and do not reflect the true counterfactual of comparing what would have happened *without*" the activity in question. *Id.* (emphasis in original). Looking at the particular case of input-output models of oil and natural gas drilling, the Ohio Study explains that these omitted factors include "higher local wages and land costs, *which reduce employment that would have occurred elsewhere in the economy*. Likewise, the environmental effects may reduce activity in the tourism sector and other residents may not want to live near such degrading activity." *Id.* (emphasis added).

Second, input-output studies may not reflect actual spending patterns, as the Ohio Study explains. *Id.* at 14-15. For example, construction employees may choose to save their money (which may be prudent in light of the temporary nature of facility construction work) rather than to spend it. *Id.*

Third, input-output models are static, providing a series of one-year snapshots. Thus, input-output models measure "job-years" but not jobs held year to year. As the Ohio Study explains, "impact studies do not produce continuous employment numbers. If an impact study says there are 200,000 jobs, this does not mean 200,000 workers are continuously employed on a permanent basis. . . . [W]hile the public is likely more interested in continuous ongoing employment effects, impact studies are producing total numbers of supported jobs that occur in a more piecemeal fashion." Ohio Study at 11.

Fourth, input-output models cannot determine how many jobs are *created*. The model identifies the number of jobs *supported* by the predicted spending. *Id.* Job support cannot be treated as job creation without consideration of a counterfactual, however, because absent a counterfactual, it is impossible to determine whether the job would have existed without the project under consideration. *Id.*

Fifth, as a result of the above limitations, input models are not readily able to "evaluate economic circumstances in which the change in the economy has been or will be rapid and large," or to deal with the complicated series of individual choices and community disruptions (including the displacement of existing economic activity) occasioned by the

[159] Attached as Exhibit 88.

boom. David Kay, *The Economic Impacts of Marcellus Shale Gas Drilling: What Have We Learned? What are the Limitations?*, 5-6, 22-30 (Apr. 2011).[160] Input output models struggle, particularly, to map these distributional effects, where some prosper while others suffer, and, more generally, is not designed to chart the long-term effects of such major dislocations. *See id.* at 22-30.

In summary, input-output model result should be seen as estimates of solely the effects of increased expenditures on a particular project (here, gas exports and production), and limited and overly-optimistic ones at that, rather than as a reliable comparison of how the economy would fare with and without gas exports. The NGA's "public interest" test requires DOE/FE to determine whether the country would be better off with Oregon LNG's proposal than without it. Input-output -based analyses cannot answer this question, but these are the only analyses Oregon LNG offers.

3. **DOE/FE Cannot Rationally Approve Oregon LNG's Export Plan On the Record Before It**

The NGA, and subsequent DOE delegation orders and regulations, charge DOE/FE with determining whether or not a gas export application is in the public interest. *See, e.g.* 15 U.S.C. § 717b(a). DOE/FE must make this decision on the record before it. This means that, regardless of DOE/FE's decision to presume, initially, that an application should be granted, this presumption does not, and cannot, absolve DOE/FE of its duty to make its *own* determination. *Panhandle Producers and Royalty Owners Ass'n*, 822 F.2d at 1110-1111. Simply put, "the *agency* must examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made." *Motor Vehicle Mfrs. Ass'n of the United States v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983) (emphasis supplied). DOE/FE cannot rationally find for Oregon LNG on the record in this case.

As we have demonstrated, record support for Oregon LNG's claimed benefits is extraordinarily thin. Oregon LNG has submitted input-output model derived argument of economic benefit, but the underlying model does not show whether the economy would improve *more* without Oregon LNG proposal than it would without it. Oregon LNG further argues that export will not cause significant gas price increases, but this argument is contradicted by the *EIA Export Study* that DOE/FE itself commissioned.

Sierra Club and Riverkeeper, on the other hand, have shown that the gas and electricity price increases associated with exports will add billions of dollars in costs to the consumers. These costs will propagate through the economy, retarding growth. We have also shown that the economic benefits, if any, associated with gas production increases may actually do long-term damage to the U.S. economy by plunging large

[160] *See* Exhibit 88.

regions of the country into a boom-and-bust extractive cycle. Further, we have shown that gas extraction and export have major environmental (and, hence, additional economic) costs, which Oregon LNG has failed to even acknowledge.

On this record, DOE/FE cannot approve export. Were it do so, it would be violating basic norms of agency record rulemaking, as well as its own rules. *See, e.g.*, 5 U.S.C. § 706; 10 C.F.R. § 590.404 (requiring DOE/FE to base its final opinion "solely on the official record of the proceeding" and to impose terms "as may be required by the public interest" after record review).

D. If DOE/FE Does Move Forward, It Must Impose Rigorous Monitoring Conditions

If DOE/FE nonetheless approves Oregon LNG's application, it must recognize its continuing duty to protect the public interest, as it explained in its *Sabine Pass* decision. This duty is of crucial importance in the context of LNG export, where circumstances are rapidly changing. DOE/FE therefore announced its intention to monitor environmental, economic, and other relevant considerations. *Sabine Pass* at 31-33. Such a monitoring provision must be imposed here, as well, but must be significantly expanded.

Specifically, although *Sabine Pass* announces an intention to monitor many different considerations, it most clearly states that the agency will act if there is a "reduction in the supply of natural gas needed to meet essential domestic needs." *Id.* at 32. This consideration is undoubtedly of great importance, but it is not the only way in which changing circumstances could imperil the public interest.

On the contrary, as we have demonstrated at length in these comments, there is strong evidence that the public interest will be impaired by gas exports. These impairments include (1) regional and national economic dislocations and disruptions caused by natural gas extraction, including by the industry's boom-and-bust cycle, (2) national increases in gas and electricity prices and resulting shifts to more polluting fuels, (3) and environmental impacts of many sorts. Any one of these categories of interests could be impaired by gas export. DOE/FE must therefore state that it will monitor each of these areas, providing specific monitoring terms and thresholds which will trigger agency actions of various types, ranging from further study through reductions in export volume or changes in timing to a revocation of DOE/FE's approval.[161]

If DOE/FE fails to include such provisions in any final approval, it will fail to fulfill its "continuing duty to protect the public interest," *id.* at 31, and so violate the Natural Gas Act. Because neither Oregon LNG nor DOE/FE have described or proposed such terms,

[161] Providing a clear monitoring plan of this sort will also benefit Jordan Cove, which will be better able to determine when and how DOE/FE may act, improving the company's ability to plan its actions and investments.

Sierra Club and Riverkeeper also protest this application to the extent that DOE/FE fails to develop adequate monitoring terms of the sort we have described.

IV. Conclusion

Sierra Club and Riverkeeper therefore move to intervene, offer the above comments, and protest Oregon LNG's export proposal for the reasons described above. Oregon LNG's application is not consistent with the public interest and must be denied.

Respectfully submitted,

Nathan Matthews
Sierra Club Environmental Law Program
85 2nd St., Second Floor
San Francisco, CA 94105

EXHIBIT B

CENTER for BIOLOGICAL DIVERSITY Because life is good.

Via eFiling

December 21, 2012

Secretary Kimberly D. Bose
Federal Energy Regulatory Commission
888 First Street NE, Room 1A
Washington, DC 20426

Re: Scoping Comments on the Oregon LNG Export Project and Northwest's Washington Expansion Project, Docket No. PF12–18–000 and PF12–20–000

Dear Secretary Bose,

The Center for Biological Diversity ("the Center") thanks you for this opportunity to submit scoping comments on the upcoming Federal Energy Regulatory Commission ("FERC") Environmental Impact Statement ("EIS") for two proposed projects: the Oregon Liquefied Natural Gas Export ("LNG") Project and Northwest's Washington Expansion Project (Docket No. PF12–18–000 and PF12–20–000). 77 Fed. Reg. 59,603 (Sept. 28, 2012). We strongly oppose these projects due to their significant environmental impacts, although we agree with the agency's decision to issue an EIS to evaluate these impacts.

We hereby incorporate by reference the comments submitted by Columbia Riverkeeper on these projects, dated December 21, 2012. As described in those comments, construction and operation of these projects will cause serious, irreparable harm to the environment, including increased air pollution including the substantial emission of greenhouse gases, water pollution and dredging impacts, and the alteration of terrestrial habitat. We would like to highlight two additional issues that we feel merit particular attention in the agency's EIS – impacts to marine resources and impacts to migratory and other birds.

The Oregon LNG Export Project

As the agency is aware, the Oregon LNG project was originally proposed in 2008 as an import receiving terminal, which will include the construction of a marine terminal with an LNG carrier berth and turning basin, various storage facilities, and a pipeline. The company is now proposing to add an export component to the same project, so the project can be operated bidirectionally. The new export component will include the construction of two liquefaction trains and more production and storage facilities at the same location in Warrenton, Oregon and a new 39-mile pipeline segment between Woodland, Washington and Warrenton. The projects' new and primary purpose is to reexport Canadian natural gas to foreign markets and to distribute Canadian gas to Pacific Northwest markets. *2012 Oregon LNG Export Project Prefiling Review Draft Resource Report 1*, at 1-3 (2012) ("*2012 Oregon LNG Terminal Draft Report*"). In the same EIS, FERC will also be considering the Washington Expansion Project ("WEP"), proposed

by Northwest, to expand the capacity of Northwest's pipeline between Sumas and Woodland to provide natural gas to the proposed Oregon LNG facility.

Although the agency's EIS will ultimately cover both aspects of the project (the previous import component and the current export component), as well as the connected WEP, in a single EIS, FERC has issued scoping notices on the two components separately. We note that it is difficult to provide comments on the export component alone, as the import and export components involve the very same LNG facility, and thus obviously overlap. We therefore address both the export and import components in these comments. Similarly, Oregon LNG has now produced two entirely separate, lengthy NEPA Prefiling Review Drafts for the import and export components. Neither document fully evaluates the projects' impacts, and the production of two separate documents obscures the cumulative impacts. FERC should require the company to submit a new Prefiling Review Draft that covers both projects in a single document.

Marine Impacts of the Oregon LNG Project

The Center expresses substantial concern over the Oregon LNG project's marine impacts, as this project will cause a substantial increase in shipping, which will increase the risk that marine mammals will be struck by ships, add to already significant underwater noise, increase air pollution, and create a new risk of LNG spill. The 2012 Export Terminal documents predict a substantial increase in shipping facilitated by the Terminal's construction. The documents estimate that 125 vessels will arrive annually at the Export Terminal and will travel primarily to and from Asia along the North Pacific Great Circle Route, past the Aleutian Islands. *2012 Oregon LNG Terminal Draft Report*, at 1-12. These additional 250 trips will increase travel along this route by around 6 percent. *Id.* Further, the proponent's 2008 Import Terminal documents estimated that the additional trips, calculated even before the project included an export component, could increase traffic along coastal California, Oregon, and Washington by over 4 percent. *2008 Oregon LNG Terminal and Oregon Pipeline Project Draft Resource Report 1*, at 1-26 (2008) ("*2008 Oregon LNG Terminal Draft Report*").

1. Ship Strikes

Ship strikes are a major cause of death for numerous marine species, including Endangered Species Act-listed whales and turtles. A 2003 report identified 292 confirmed or possible ship strikes between 1975 and 2002, finding fin and humpback whales are the species most commonly found struck.[1] Sea turtles are also struck by ships. Most ship strikes to large whales result in death.[2] In its most recent Stock Assessment Report, NMFS has also documented numerous vessel-related mortalities and serious injuries for humpback whales, fin whales, killer whales, and other species on the West Coast, including some off of Oregon and Washington.[3] However, the number of documented ship strikes grossly underestimates actual incident and

[1] Jensen, A.S. and G.K. Silber. 2003. Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR-25, 37 pp. Available at: www.nmfs.noaa.gov/pr/pdfs/shipstrike/lwssdata.pdf.

[2] *Id.*

[3] Caretta, J.V. et al. 2001. U.S. Pacific Marine Mammal Stock Assessments: 2011. NOAA-TM-NMFS-SWFSC-488. Available at: http://www.nmfs.noaa.gov/pr/pdfs/sars/po2011.pdf.

mortality numbers, as many of animals sink, are scavenged, or are otherwise never seen. *Id.* Recent studies have estimated that only 2 percent of cetaceans killed are ever recovered, and thus mortality estimates based on stranded animals may vastly underestimate actual mortality.[4] Based on annual census records of Southern Resident killer whales, carcasses from confirmed deaths of known individuals are recovered only 6% of the time.[5]

In a Technical Memo, revised in June 2012, the Oregon LNG proponents attempt to estimate the likelihood of ship strike from the project, and conclude, based on the number of documented ship strikes in the area, that the likelihood is relatively low, around 0.05 per year per species. *See Oregon LNG: Estimate of Potential Whale Strikes*, at 3 (June 2012). Because the number of documented ship strikes does not reflect the actual number of ship strikes, this estimate is unrealistically low and ultimately unhelpful. We encourage FERC to fully and adequately consider the increased risk of vessel strikes as a result of shipping associated with this project. We also encourage the agency to consider this project's shipping impacts cumulatively with other upcoming shipping-related projects, including the Jordan Cove LNG export facility and coal exporting facilities along the coast. Further, shipping through the Aleutian Islands is expected to increase as the Arctic sea ice recedes from global warming. This adds to the risk of ship strikes, underwater noise, and greenhouse gas and other emissions from the ships. We encourage the agency to consider both the proposed impacts of this project in addition to the anticipated impacts of increased shipping through the North Pacific Great Circle Route.

Further, the proponents note that LNG carriers typically travel at almost 20 knots at ocean speeds, and 10 to 12 knots once in the Columbia River. *Id.* Research has shown a direct correlation between vessel speed and ship strikes resulting in whale mortality, including "clear evidence of a sharp rise in mortality and serious injury rate with increasing vessel speed."[6] For example, studies have found that the vast majority of lethal and serious whale ship strikes involved vessels exceeding 14 knots, and no lethal or serious injuries occurred at speeds below 10 knots. We encourage the agency to consider an alternative that requires ship speed limits on approach to the facility or other mitigation measures.

---

[4] Williams, R. et al. 2011. Underestimating the damage: interpreting cetacean carcass recoveries in the context of the *Deepwater Horizon*/BP incident, Conservation Letters, Vol. 4, Issue 3, pp. 288-233 (June/July 2011) DOI: 10.1111/j.1755-263X.2011.00168.x.

[5] Fisheries and Oceans Canada. 2008. Recovery strategy for the northern and southern resident killer whales (Orcinus orca) in Canada. Fisheries and Oceans Canada, Ottawa, Canada. Available at: www.cbc.ca/bc/news/bc-081009-killer-whale-recovery-strategy.pdf; *see also* Kraus, S.D. et al. 2005. North Atlantic right whales in crisis. *Science* 309:561-562. Available at: http://www.sciencemag.org/content/309/5734/561 (estimating that only approximately 17 percent of ship struck North Atlantic right whale are actually detected).

[6] Pace, R.M. and Silber, G.K. 2005. Abstract: Simple Analyses of ship and large whale collisions: Does speed kill? Sixteenth Biennial Conference on the Biology of Marine Mammals. San Diego, December 2005; Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. 2001. Collisions between ships and whales. Marine Mammal Science 17(1): 35-75; Vanderlaan, A.S.M. and Taggart, C.T. 2007. Vessel Collisions with Whales: The probability of lethal injury based on vessel speed. Marine Mammal Science 23(1): 144-156.

2. Underwater Noise

Over the past 50 years, there has been a dramatic increase in ocean noise pollution from human sources including navy active sonar, seismic surveys used for research and oil and gas exploration, and commercial shipping. Vessel traffic is the largest source of noise pollution in the marine environment, and the intense, low frequency noise pollution generated by ships can travel great distances through the water.[7] This low frequency propeller noise is also in the same lower-frequency range used for communication by whales, dolphins, and other marine animals.[8]

Numerous studies have documented the potential impacts of increasing ocean noise, which can mask communication and impede reproduction, feeding, navigation, and ultimately survival of marine animals.[9] Further, a recent study documented that chronic stress in North Atlantic right whales is associated with exposure to low frequency noise from ship traffic, which can cause long-term reductions in fertility and decreased reproductive behavior, increased vulnerability to diseases, and permanent cognitive impairment.[10] Reducing ship speed can reduce noise levels,[11] and again, the agency should consider requiring some mitigation for these effects.

3. Air Pollution

Ocean-going ships emit substantial amounts of air pollutants, including sulphur dioxide (SOx), nitrogen dioxide (NOx), and particulate matter that can cause serious human health impacts like respiratory inflammation, worsening of existing respiratory diseases, and even premature death.[12] Environmental impacts of these pollutants are also serious and include nitrogen nutrient loading, acidification, smog caused by NOx and other precursor gases, and changes in visibility.[13]

---

[7] Hildebrand, J. 2005. Impacts of anthropogenic sound *In*: *Marine Mammal Research Conservation Beyond Crisis.* Edited by*:* J.E. Reynolds III, W.F. Perrin, R.R. Reeves, S. Montgomery and T.J. Ragen. Johns Hopkins University Press, Baltimore, Maryland, pp. 101-124.

[8] *Id.*

[9] *See* Final Report of the NOAA International Symposium: Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology. Arlington, VA. May 2004 (summarizing studies). Available at: www.nmfs.noaa.gov/pr/pdfs/acoustics/shipping_noise.pdf; Wright, A.J. 2008. International Workshop on Shipping Noise and Marine Mammals, Hamburg, Germany, 21st-24th April 2008. Okeanos - Foundation for the Sea, Auf der Marienhohe 15, D-64297 Darmstadt. 33+v p.

[10] Rolland, R.M. et al. 2012. Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B. Feb. 8, 2012; Rolland, R.M. et al. 2007. The inner whale: hormones, biotoxins and parasites. In: Kraus S.D. and R.M. Rolland, (eds.). The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press, Cambridge, MA.

[11] Wright 2008; *see also* Southall, B. L. and A. Scholik-Schlomer. 2008. Final report of the NOAA International Conference: "Potential Application of Vessel-Quieting Technology on Large Commercial Vessels," 1-2 May, 2007, Silver Spring, MD, U.S.A. (noting the correlation between vessel speed and noise).

[12] *See* Proposal to Designate an Emission Control Area of Nitrogen Oxides, Sulphur Oxides and Particulate Matter, International Maritime Organization, Marine Environment Protection Committee, Submitted by the United States and Canada (Apr. 2009).

[13] *Id.*

Further, ships also emit substantial amounts of greenhouse gases. For example, in 2007 alone, shipping resulted in carbon dioxide emissions of 1046 million metric tons per year in 2007, almost three percent of global greenhouse gas emissions.[14] A single container ship can emit more pollution than 2,000 diesel trucks. Ships also contribute as much as 30 percent of the world's nitrogen oxide emissions, an estimated 27.8 million tons per year.[15] Ships also emit black carbon, or soot, as they burn fossil fuels. Marine shipping was responsible for 3.6 percent of the United States' black carbon emissions in 2002,[16] and shipping is responsible for all black carbon released over the oceans.[17] All of these pollutants contribute to the ongoing and increasing impacts of global climate change. Further, the absorption of carbon dioxide into the ocean causes ocean acidification, altering seawater chemistry and impacting species.

FERC must calculate and consider all air emissions of the shipping associated with this project and evaluate the impacts this air pollution will have on human health and the environment, in addition to all other direct and indirect air emissions associated with this project.

4. Spills

Finally, FERC must fully evaluate the potential for and full effects of both minor and major spills from an LNG carrier or the facility itself. Commonly, LNG carriers can transport 125,000 m^3 to 145,000 m^3 of LNG, and newly designed carriers may carry up to 265,000 m^3 of LNG.[18] If spilled, the LNG may volatilize and transport as a vapor cloud or spread as a liquid on the water's surface.[19] Further, the LNG may ignite, causing an additional safety concern. While a major spill may be unlikely, the impacts of such a spill could be substantial. FERC must fully evaluate the consequences of an LNG carrier spill over water, including impacts to marine mammals and shorebirds.

Migratory Birds, including Impacts from Drilling in Canada

FERC must fully consider the direct impacts of the project, and particularly the pipeline construction, on migratory and other birds under NEPA. 40 C.F.R. § 1508.8. The project may

[14] Marine Environment Protection Committee, International Maritime Organization (IMO), Prevention of Air Pollution from Ships: Second IMO GHG Study 2009 (Apr. 9, 2009). Prepared by Øyvind Buhaug et al.
[15] Friends of the Earth International (FOEI). 2007a. Prevention of Air Pollution from Ships: Recent Findings on Global Warming Justifying the Need for Speedy Reductions of Greenhouse Gas Emissions from Shipping. Submitted to the Marine Environment Protection Committee, IMO (May 4, 2007).
[16] Battye, W. and K. Boyer. 2002. Methods for Improving Global Inventories of Black Carbon and Organic Carbon Particulates, Report No. 68-D-98-046. Prepared for U.S. EPA by EC/R Inc. Available at http://www.epa.gov/ttn/chief/conference/ei11/ghg/battye.pdf.
[17] Reddy, M. Shekar and O. Boucher. 2006. Climate impact of black carbon emitted from energy consumption in the world's regions. *Geophysical Research Letters* 34: L11802.
[18] Luketa, A., et al. 2008. Breach and Safety Analysis of Spills Over Water from Large Liquefied Natural Gas Carriers. Sandia National Laboratories. Available at: http://www.energy.ca.gov/lng/documents/2008-09-11_SANDIA_2008_Report.PDF.
[19] Hightower, M. et al. 2004. Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water. Sandia National Laboratories. Available at: http://www.energy.ca.gov/lng/documents/2004-12_SANDIA-DOE_RISK_ANALYSIS.PDF.

take birds directly through collisions with vehicles, nest disturbances and habitat destruction, and other impacts, and indirectly through increases in predation opportunities and habitat disturbance. FERC must consider the impacts on migratory birds and other birds within the project area under NEPA.

Further, FERC must consider the impacts of gas drilling in Canada on birds and other wildlife. NEPA requires FERC to consider all direct, indirect, and cumulative impacts of its decision on this project. 40 C.F.R. § 1508.8. Indirect impacts include all effects that "are caused by the action and are . . . farther removed in distance, but are still reasonably foreseeable." *Id.* The purpose of this project is to distribute Canadian natural gas, thus construction and operation of this facility will facilitate ongoing and additional natural gas production in Canada. *2012 Oregon LNG Terminal Draft Report*, at 1-3; *see, e.g.*, *Mid-States Coalition for Prog. v. Surface Transp. Bd.*, 345 F.3d 520 (8th Cir. 2003) (invalidating EIS evaluating rail line transporting coal because agency failed to consider the indirect effects of the project on the market for alternative sources of energy that had lesser air quality impacts). These indirect impacts must be fully evaluated in the agency's EIS.

Natural gas production can have substantial impacts on migratory birds. For example, FWS has documented that oil and gas waste pits present significant risks to wildlife. Pits can "entrap and kill migratory birds and other wildlife" as birds mistake waste pits for bodies of water and become covered with substances that may cause exposure and exhaustion.[20] In addition, the New Mexico Department of Game and Fish has expressed concern about the hazards of hydrocarbon toxicity to wildlife including "acute and chronic ingestion or absorption toxicity, loss of thermal stability from oiling of fur or feathers, and reproductive failure due to absorption of chemicals from the maternal bird body through the shell of eggs."[21]

Further, migratory birds are fully protected under the Migratory Bird Protection Act ("MBTA"), which prohibits the "take" of migratory birds and their nests or eggs, except as permitted by regulation. 16 U.S.C. § 703(a). "Take" is defined by the MBTA as "pursue, hunt, shoot, capture, collect, [or] kill." *Id.* § 715(n). The prohibition applies broadly to all taking done "at any time, by any means or in any manner." *Id.* § 703(a). FERC must ensure that the projects' construction, eventual operation, and the Canadian drilling that may be facilitated by the projects does not cause the unlawful take of migratory birds and must seek an appropriate MBTA permit if necessary.

Conclusion

The Center opposes the Oregon LNG Project and Northwest's Washington Expansion Project (Docket No. PF12–18–000 and PF12–20–000). We encourage the agency to fully comply with NEPA in issuing its EIS and consider all of the very serious direct, indirect, and cumulative impacts of these projects on the environment.

[20] U.S. Fish & Wildlife Service, Region 6 Envtl. Contaminants Program, Reserve Pit Mgmt.: Risks to Migratory Birds (2009).

[21] Kirkpatrick, Lisa, Letter from Lisa Kirkpatrick, Conservation Services Division Dept of Fish and Game, to New Mexico Oil and Conservation Division, Environmental Bureau re OCD Rule "Pits and Below-Grade Tanks" NMAC 19.15.2.40; NMGF Project No. 11251 (Feb 2, 2007).

Sincerely,

Sarah Uhlemann
Senior Attorney
Center for Biological Diversity
2400 NW 80th Street
Seattle, WA 98117
Tel: (206) 327-2344
Email: suhlemann@biologicaldiversity.org

RON WYDEN, Oregon, *Chairman*
TIM JOHNSON, South Dakota
MARY L. LANDRIEU, Louisiana
MARIA CANTWELL, Washington
BERNARD SANDERS, Vermont
DEBBIE STABENOW, Michigan
MARK UDALL, Colorado
AL FRANKEN, Minnesota
JOE MANCHIN, III, West Virginia
CHRISTOPHER A. COONS, Delaware
BRIAN SCHATZ, Hawaii
MARTIN HEINRICH, New Mexico
LISA MURKOWSKI, Alaska
JOHN BARRASSO, Wyoming
JAMES E. RISCH, Idaho
MIKE LEE, Utah
DEAN HELLER, Nevada
JEFF FLAKE, Arizona
TIM SCOTT, South Carolina
LAMAR ALEXANDER, Tennessee
ROB PORTMAN, Ohio
JOHN HOEVEN, North Dakota

JOSHUA SHEINKMAN, STAFF DIRECTOR
SAM E. FOWLER, CHIEF COUNSEL
KAREN K. BILLUPS, REPUBLICAN STAFF DIRECTOR
PATRICK J. McCORMICK III, REPUBLICAN CHIEF COUNSEL

United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, DC 20510–6150
WWW.ENERGY.SENATE.GOV

March 13, 2013

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, DC 20310-0108

Dear Assistant Secretary Darcy:

I am concerned about the potential for coal export terminal development along the Columbia River. I strongly encourage the U.S. Army Corps of Engineers (USACE) to conduct a full environmental impact statement (EIS) for any existing and future coal export project, along the environmentally and culturally sensitive Columbia River corridor.

Multiple studies and months of media reports have raised concerns of increased coal dust and noise as a result of coal export activity. Additionally, there is a potential for air and water quality degradation in local communities and the sensitive landscapes in close proximity to the Columbia River. The resulting increased rail and barge traffic could pose a threat to endangered species; disrupt life in small towns bisected by railroad tracks; impact the local tourist economy; and put the United States at risk of breaching various treaties with federally recognized Indian tribes in the region.

If approved, millions of tons of coal would be shipped annually by railroads and barges through communities and environmentally sensitive areas in Oregon. The increased rail and barge traffic would occur in the Columbia River Gorge National Scenic Area, which is adjacent to the Mark O. Hatfield Wilderness, both of which are protected by federal law. Furthermore, the river is home to multiple endangered species, and is an important fishing ground for Columbia River Treaty Tribes.

Given these concerns, the USACE should conduct an EIS for any existing and future coal export project along the Columbia River. In conducting its evaluation of such projects, I ask that the USACE consult with the appropriate federal, state and local agencies, as well as affected Indian tribes.

Thank you for your attention to this very important matter.

Sincerely,

Ron Wyden

Ron Wyden
Chairman

JON TESTER
MONTANA

COMMITTEES:
APPROPRIATIONS
BANKING
INDIAN AFFAIRS
VETERANS' AFFAIRS
HOMELAND SECURITY AND
GOVERNMENTAL AFFAIRS

United States Senate

SENATE HART BUILDING
SUITE 706
WASHINGTON, DC 20510
202-224-2644

MONTANA TOLL FREE NUMBER
1-866-554-4403

INTERNET:
http://tester.senate.gov/contact

March 14, 2013

The Honorable Daniel R. Elliott III, Chairman
Surface Transportation Board
395 E Street, S.W.
Washington, DC 20423-0001

The Honorable Ann D. Begeman, Vice Chairman
Surface Transportation Board
395 E Street, S.W.
Washington, DC 20423-0001

The Honorable Francis P. Mulvey, Commissioner
Surface Transportation Board
395 E Street, S.W.
Washington, DC 20423-0001

Dear Chairman Elliott, Vice Chairman Begeman, Commissioner Mulvey:

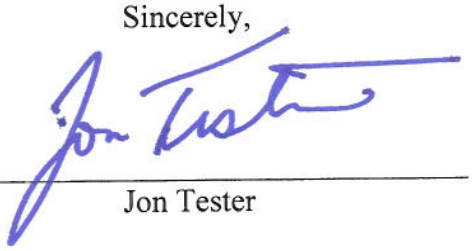
I write regarding the Surface Transportation Board's (the Board) pending permit application for construction of the re-proposed Tongue River Railroad and the Tongue River Railroad Company's (TRRC) preferred alternative, the Colstrip Alignment. I urge the Board to take the time to conduct an analysis on both the transportation merits and the cumulative environmental impacts of the railroad. I believe that this process must consider these impacts in Montana and throughout the affected region.

I ask that the Board review the impacts a new railroad would have on existing regional rail networks and current shippers. For instance, shippers of agricultural products face some of the highest tollage in the country. It is vital to the regional economy that existing shippers are able to continue to financially compete with other shippers and that there is sufficient rail capacity to handle the additional traffic. A full and thorough analysis will also allow communities, decision-makers, and public officials to weigh the true costs and benefits of such a project.

I also encourage the Board to expand the scope of the Environmental Impact Statement (EIS) to include communities along the shipping routes between the mine mouth and the delivery point for the product.

I urge the Board to expand its scope of study in the Tongue River Railroad EIS and in the transportation merits analysis to include the total cumulative impacts. Thank you for considering my request and I look forward to receiving your response.

Sincerely,



Jon Tester

STATE OF OREGON

STATE OF WASHINGTON

March 25, 2013

The Honorable Nancy Sutley, Chair
Council on Environmental Quality
Executive Office of the President
722 Jackson Place NW
Washington, DC 20503

Dear Chairwoman Sutley:

The U.S. Army Corps of Engineers is reviewing several permit applications for coal export shipping terminals in Oregon and Washington under Section 404 of the federal Clean Water Act, and Section 10 of the federal Rivers and Harbors Act. The permit applications include the Gateway Pacific terminal north of Bellingham, Washington (Peabody Energy - up to 48 million tons per year); the Millennium Bulk Terminals proposal in Longview, Washington (Ambre Energy - up to 44 million tons per year); and the Morrow Pacific Terminal at the Port of Morrow in Boardman, Oregon with a downstream barging component to Port Westward, also in Oregon (Ambre Energy - up to 8 million tons per year). Collectively, these proposals could result in the export of up to 100 million tons of coal per year. The expected end use of this coal is for energy production in Asia. No final decisions have been made on the related applications for state permits for these facilities. Our agencies are committed to a rigorous, fair and objective process to review these applications, within the scope of our respective authorities.

As you know, while coal consumption is declining in the United States, consumption in Asia is driving a substantial increase in global coal use. Although China and India are working to increase their use of other fuels and renewables, coal consumption in Asia has more than doubled in the last ten years. According to the International Energy Agency (IEA), global coal demand will grow by 16.9 percent over the next five years, or 2.6 percent per year. To date, coal exports from the United States have not been a major source of supply for foreign markets, but that is beginning to change. U.S. coal exports already have grown from 50 million tons in 2006 to just under 100 million tons in 2012 according to the U.S. Energy Information Agency (EIA). The U.S. holds the world's largest recoverable coal reserves, according to the EIA, much of which are found on federal lands in the western U.S. The recent interest in coal export shipping terminals along the west coast, along with decreasing domestic demand, is a clear indication that the U.S. could become a significant supplier of coal to Asia.

Coal will inevitably play an important part in the global energy supply in the short term. However, before the United States and our trading partners make substantial new investments in coal generation and the infrastructure to transport coal, extending the world's reliance on this fuel for decades, we need a full public airing of the consequences of such a path. Coal is the major source of global greenhouse gas emissions, and its share is increasing rapidly. Increasing levels of greenhouse gases and other pollutants resulting from the burning of coal, including pollutants other than CO_2, are imposing direct costs on people, businesses and communities in the U.S. and around the world. These costs include the public health costs of increased atmospheric deposition of mercury in drinking water sources, as well as costs resulting from ocean acidification, rising sea levels, wildfires, and shrinking snow packs that are key sources of water for the western U.S.

As the major owner of coal reserves in the western U.S., the federal government must consider whether it has appropriately priced the coal leases that it continues to grant, including the practice of granting non-competitive leases. Senators Ron Wyden and Lisa Murkowski recently asked the U.S. Department of the Interior for information concerning alleged industry practices using in-house trading affiliates to avoid paying royalties that reflect actual export sales. These issues raise significant concerns that we are subsidizing the export of coal at the same time we are winding down domestic consumption due to serious environmental and health concerns.

We believe the federal government must examine the true costs of long-term commitments to supply coal from federal lands for energy production, whether that production occurs domestically or in Asia. We cannot seriously take the position in international and national policymaking that we are a leader in controlling greenhouse gas emissions without also examining how we will use and price the world's largest proven coal reserves.

The Council on Environmental Quality (CEQ) has issued draft guidance for agencies concerning when and how they need to consider the climate change effects of their actions. Given that the cumulative total of coal exports from Oregon and Washington could result in CO_2 emissions on the order of 240 *million* tons per year, well above the significance level described in the draft guidance – it is hard to conceive that the federal government would ignore the inevitable consequences of coal leasing and coal export. We believe the decisions to continue and expand coal leasing from federal lands and authorize the export of that coal are likely to lead to long-term investments in coal generation in Asia, with air quality and climate impacts in the United States that dwarf those of almost any other action the federal government could take in the foreseeable future.

For these reasons, we urge the CEQ in the strongest possible terms to undertake and complete a thorough examination of the greenhouse gas and other air quality effects of continued coal leasing and export *before* the U.S. and its partners make irretrievable long-term investments in expanding this trade. We understand that the draft CEQ guidance under the National Environmental Policy Act (NEPA) that is referenced above is likely to be finalized in the near future, and applaud that step and urge that the new policy be applied to coal export terminal proposals now pending as well as to all future decisions concerning coal leases. We also ask that you evaluate and determine the proper policies for pricing coal leases from federal lands, both as

a matter of securing a fair return for this resource, and to account for the direct costs of the resulting emissions to U.S. businesses and communities. These steps are needed for the U.S. to make sound decisions as the international demand for the coal resources in the U.S. continues to grow, and to ensure that we do not simply pass these tough issues on to future generations.

Thank you in advance for your careful consideration of this matter. We would welcome the opportunity to discuss these concerns in more detail.

Sincerely,

John A. Kitzhaber, M.D.
Governor of Oregon

Jay Inslee
Governor of Washington

cc: The Honorable Ken Salazar, Secretary of the Interior
The Honorable Bob Perciasepe, Acting Administrator, Environmental Protection Agency
The Honorable John McHugh, Secretary of the Army
The Honorable Jo-Ellen Darcy, Assistant Secretary of the Army for Civil Works
The Honorable Lisa Murkowski, United States Senate
Oregon State Congressional Delegation
Washington State Congressional Delegation

JAY INSLEE
Governor

STATE OF WASHINGTON
OFFICE OF THE GOVERNOR
P.O. Box 40002 • Olympia, Washington 98504-0002 • (360) 902-4111 • www.governor.wa.gov

March 25, 2013

Maia Bellon, Director
Washington Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

Dear Ms. Bellon:

Oregon Governor John Kitzhaber and I today jointly sent the enclosed letter to the President's Council on Environmental Quality, calling on the federal government to evaluate the effects of the leasing and export of the nation's coal reserves.

I believe it is necessary and appropriate for the federal government to complete an examination of the effects of continued coal leasing and export before making long-term investments in expanding this trade. I also believe they should determine the proper policies for pricing coal leases from federal lands, both as a matter of securing a fair return for this resource, and to account for the costs of resulting emissions to our businesses and communities. These steps are needed for the nation to make sound decisions as the international demand for coal resources continues to grow, and to meet our obligation to future generations.

For these reasons, I joined Governor Kitzhaber in asking the federal government to step up and undertake this comprehensive review.

I emphasize in the letter that no final decisions have been made on the applications for state permits for the proposed coal export facilities that would be located in our state. Washington State must remain committed to a rigorous, fair and objective process to review these applications, within the scope of our laws. I know you share this commitment and will execute your regulatory role accordingly.

Very truly yours,

Jay Inslee
Governor

Enclosure

cc: The Honorable Peter Goldmark, Commissioner of Public Lands
Phil Anderson, Director, Department of Fish and Wildlife
Lynn Peterson, Secretary, Department of Transportation
Dave Danner, Chair, Utilities and Transportation Commission

Congress of the United States
Washington, DC 20515

April 22, 2013

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, D.C. 20310-0108

Dear Assistant Secretary Darcy:

As Members of the U.S. House of Representatives who serve the citizens of Oregon we are writing to strongly urge the U.S. Army Corps of Engineers (USACE) to conduct a full environmental impact statement (EIS) for the proposed coal export facility at the Port of Morrow in Boardman.

During the past months we have heard from a great number of our constituents who have raised serious and legitimate concerns about potential health, environmental, safety, and economic impacts of exporting coal through the Pacific Northwest.

Despite these concerns, the proposed facility at the Port of Morrow is the only coal export proposal in the Pacific Northwest where the USACE has not already made an initial determination to conduct an EIS.

Given the agency's determination to forgo an environmental assessment in favor of an EIS for the Gateway Pacific Terminal project at Cherry Point across the Columbia River in Washington State, it is unclear to us why the same determination was not made for the Port of Morrow project. We believe Oregonians deserve the same robust analysis and information as Washingtonians.

An EIS would address critical issues important to Oregonians and decision- makers alike, including: health and air quality impacts resulting from coal dust, potential pollution of the Columbia River and local waterways, forced delays in emergency response times of area responders, barge and/or rail congestion – just to name a few.

Moreover, it strikes us that an EIS at the Port of Morrow is very likely required under the National Environmental Policy Act and that failure to conduct an EIS can be reasonably expected to result in substantial delays, costly litigation against the Agency, and in the end you will likely be forced to do an EIS.

Accordingly, we urge the USACE in the strongest possible terms to avoid unnecessary regulatory delay, save taxpayers money, and provide the same detailed analysis and information to Oregonians as you will to Washingtonians by making an immediate decision to conduct an EIS for the Port of Morrow project.

Thank you for your consideration in this matter.

Sincerely,

Peter DeFazio
Member of Congress

Earl Blumenauer
Member of Congress

PRINTED ON RECYCLED PAPER

August 13, 2013

U.S. Army Corps of Engineers
Attn: Steve Gagnon
P.O. Box 2946
Portland, OR 97208-2946
nwp-2007-998@usace.army.mil

Submitted via U.S. mail and email.

RE: Comments on Cascade Kelly Holdings LLC's Rivers and Harbors Act Section 10 Permit Application (NWP-2007-998).

Dear Mr. Gagnon,

Columbia Riverkeeper (Riverkeeper), the Northwest Environmental Defense Center (NEDC), and the Sierra Club request that the U.S. Army Corps of Engineers (Corps) deny Cascade Kelly Holdings LLC's (Cascade Kelly)[1] application for a § 10 Rivers and Harbors Act permit to facilitate crude oil shipments at Port Westward (NWP-2007-998). The commenters are all non-profit organizations, representing tens of thousands of members, dedicated to protecting public health, the environment, and natural resources. We appreciate the opportunity to provide comments on Cascade Kelly's proposal to significantly increase crude oil handling along and over the Columbia River.

The Corps has the responsibility and authority to protect the Columbia River Estuary. The Lower Columbia River is a federally-designated Estuary of National Significance under the Clean Water Act's National Estuary Program, and the Columbia River was designated in 2006 as one of the U.S. Environmental Protection Agency's (EPA) seven Priority Large Aquatic Ecosystems. The Columbia is a local treasure, and a national priority for watershed health. The Columbia River Estuary faces numerous threats, but none with the potential to quickly and comprehensively devastate this ecosystem like a crude oil or vessel fuel spill.

[1] Cascade Kelly Holdings LLC is wholly owned by Global Partners LP, a company specializing in transporting crude oil and other petroleum products. Global Partners LP Website, http://www.globalp.com/news/article.cfm?articleID=278 (last accessed 7/11/2013).

The fundamental question before the Corps is whether the Columbia River and surrounding communities should become a conduit for millions of gallons of crude oil and millions of tons of coal. The Corps may not issue Cascade Kelly a permit to expand the dock if the resulting uses of the dock—such as shipping crude oil and coal—would be "contrary to the public interest." 30 C.F.R. § 320.4(a)(1). Riverkeeper, NEDC, and the Sierra Club request that the Corps seriously consider whether shipping crude oil and coal through the Columbia River Estuary is in the public interest, and explain your answer to the public, before making a decision on this application.

I. Crude Oil and the Port Westward Dock

Cascade Kelly's proposal calls for overhauling the existing Port Westward dock to facilitate Cascade Kelly's crude oil export operations and lays the groundwork for major expansions in oil shipments. Cascade Kelly began shipping crude oil at the Port Westward ethanol facility in November of 2012. These over-water operations have never been reviewed by the Corps, the National Marine Fisheries Service, or the U.S. Fish and Wildlife Service. For the reasons explained below, Cascade Kelly's proposed dock expansion and its intended use—massive shipments of crude oil—threaten the public's use of the Columbia River and endangered salmon and other species. We therefore urge the Corps to reject the inevitable impacts and severe risks associated with this project.

Cascade Kelly's Port Westward loading facility is the first large-scale crude oil terminal to operate in Oregon or Washington in decades.[2, 3] Cascade Kelly acquired the existing Port Westward ethanol refinery, which includes a bulk liquid trans-loading facility capable of handling crude oil, thereby largely circumventing the government oversight and public involvement process that would normally accompany the construction of a crude oil terminal. Presently, Cascade Kelly's terminal can handle 28,600 barrels of oil per day.[4] A major failing of Cascade Kelly's application is that it does not include any information about the quantity of crude oil Cascade Kelly intends to transport in the future. This makes it very difficult for the public or the Corps to understand the intensity of environmental and social impacts that could result from this project. A representative of Cascade Kelly asserted that the facility is "limited in its total capacity by EPA and others," but—for some reason—Cascade Kelly's application did not include these 'limits' or where they derive from.

The Corps' review of Cascade Kelly's application will set the tone for the agency's reviews of future proposals that would enable more crude oil shipping in the lower Columbia—and such proposals are coming.[5] In the late 2000s, advances in technology led to an oil rush in the Bakken shale formation in the North Dakota/Montana/Saskatchewan/Manitoba region. The rapid growth in crude oil production put pressure on pipeline capacity and pushed oil companies

[2] Global Partners LP Website, http://www.globalp.com/terminals/terminal.cfm?terminalID=4000 (last accessed 7/11/2013) (describing the Port Westward dock as a "crude oil" terminal).
[3] http://www.oregonlive.com/environment/index.ssf/2013/05/former_ethanol_plant_in_clatsk.html
[4] Exhibit 1. Sightline Institute, *The Northwest's Pipeline on Rails* at 4 (Aug. 2013).
[5] *Id.*

to start using rail to move crude to market. In turn, Cascade Kelly's application is likely the first of many that will threaten Oregon and Washington's waterways with crude oil.[6]

While Cascade Kelly appears focused on shipping Bakken crude oil at present, the Corps should critically investigate whether this project could: (1) transport Canadian Tar Sands crude oil for international export, or (2) facilitate and/support coal handling activities proposed by Pacific Transloading LLC, d/b/a Ambre Energy, at the Port Westward dock. There is no apparent reason why the facility could not accommodate Tar Sands heavy crude in the future. Wider use of Tar Sands oil is currently impeded by transport bottlenecks, including staunch opposition to pipeline construction in U.S. and Canada.[7] Some observers have concluded that "build-out of oil-by-rail projects in the Northwest could, in effect, serve as a pipeline on wheels for Canadian tar sands."[8] Canadian Tar Sands oil poses even more severe environmental and global warming risks than conventional crude,[9] and exporting tar sands crude is contrary to the public interest within the meaning of 30 C.F.R. § 320.4(a)(1).

II. Coal and the Port Westward Dock

Despite Cascade Kelly's protestations, the objective evidence clearly shows that this project is related to or benefits Ambre Energy's proposed coal export terminal. As the Corps knows, Ambre Energy's "Morrow Pacific Project" contemplates using the Port Westward dock to transfer coal from river barges to Panamax vessels for overseas export.[10] Ambre Energy's Environmental Review Document stated that its coal barges would utilize the "existing dock at Port Westward."[11]

Last week, Ambre Energy sent a letter to the Oregon Department of State Lands reiterating that coal trans-loading would utilize the Port Westward dock.[12] In fact, Ambre Energy's web page has a graphic of a Panamax ship moored at the Port Westward dock, being loaded with coal.[13] Further, the Port of St. Helens, which owns the Port Westward dock, has contracted with Ambre Energy to find space at Port Westward for the Morrow Pacific coal trans-loading project,[14] giving the Port of St. Helens the incentive—and possibly the obligation—to allow Ambre Energy to load coal onto Panamax ships at the Port Westward dock. There is no apparent practical reason, based on the very limited information in Cascade Kelly's application, why the expanded dock could not alternately accommodate Panamax vessels loading coal and crude oil. Additionally, the objective evidence shows that Ambre Energy intends to use the

---

[6] Oil from Cascade Kelly's operations is currently bound for U.S. oil refineries. The future of the U.S. ban on overseas export of U.S. derived oil is uncertain. Footnote 5, *supra*. Additionally, it is not clear that all Bakken crude reaching the terminal is subject to that ban because some of it may originate in Canada.
[7] Exhibit 1 at 3, 4.
[8] *Id.*
[9] Exhibit 2. U.S. Environmental Protection Agency, *Comments on the Draft Supplemental Environmental Impact Statement for the Keystone XL Pipeline*, 2, 3 (April 2013).
[10] Ambre Energy's website for the Morrow Pacific Project, (http://www.morrowpacific.com/the-project) (last viewed 7/16/2013).
[11] Exhibit 3, Ambre Energy's Environmental Review Document for the Morrow Pacific Project at 3.
[12] Exhibit 4, Ambre Energy letter to Oregon Department of State Lands at 3.
[13] Exhibit 5. *See* http://morrowpacific.com/wp-content/uploads/2012/08/MorrowPacificMap-large.jpg.
[14] Exhibit 6. Pacific Transloading LLC / Port of St. Helens - Option and Terminal Services Agreement (Jan. 2012).

expanded dock to facilitate its coal export trans-loading scheme. Because the Corps has the duty to assess whether "the proposed activity *and its intended use*" are contrary to the public interest, the Corps must also consider trans-loading coal onto Panamax vessels when deciding whether the intended uses of the expanded dock are in the public interest. 30 C.F.R. § 320.4(a)(1) (emphasis added). Similarly, the Corps must analyze and describe the environmental effects of coal trans-loading in the EIS for the dock expansion. *See* 40 C.F.R. § 1508.25(c)(1), (2).

III. Request for Public Hearing.

Riverkeeper, NEDC, and the Sierra Club request that the Corps hold a public hearing on the proposed § 10 permit. Based on the applicant's failure to fully disclose the nature and scope of its operation, many members of the public are not aware of the significant ramifications of expanding the capacity of the Port Westward dock. For example, a public hearing would facilitate full disclosure of how this project would impact:

- public safety
- endangered and threatened species
- recreational activities on the Columbia River, including recreational fishing and boating
- commercial and subsistence fishing
- commerce on the Columbia River

A hearing would also facilitate public understanding of, and facilitate public input on, how Cascade Kelly's proposal would enable coal export.

The Northwest is at the center of an unprecedented movement to export crude oil. The public's interest and engagement in the Port of Vancouver's recent decision to lease property to Tesoro Savage for a crude oil terminal underscores the importance of holding a public hearing on Cascade Kelly's proposal.[15] Tesoro Savage proposes shipping more crude oil per day than the TransMountain pipeline—one of the largest oil pipelines on the West Coast, and roughly half the amount of oil proposed for transport in the controversial Keystone XL pipeline. This amounts to eight mile-and-half long trains per day—four full, four empty. Based on Cascade Kelly's application, it is unclear how much oil Cascade Kelly plans to handle. Nonetheless, the strong public reaction evoked by the Port of Vancouver crude-by-rail proposal highlights the importance of public hearings. A public hearing would support and facilitate a public dialogue on Cascade Kelly's proposed dock work and crude oil operations that the Northwest is sorely lacking.

IV. The Corps should deny Cascade Kelly's application because crude oil shipment in the Columbia River Estuary is contrary to the public interest.

[15] http://www.columbian.com/news/2013/jul/22/port-of-vancouver-foes-fill-meeting-on-oil-plan/; http://www.columbian.com/news/2013/jul/30/vancouver-port-meetings-law-oil-terminal-tesoro/.

The Corps may not issue Cascade Kelly a permit to expand the dock if doing so would be "contrary to the public interest." 30 C.F.R. § 320.4(a)(1). To determine whether a project is contrary to the public interest, the Corps balances the "benefits which reasonably may be expected to accrue from the proposal" against the "reasonably foreseeable detriments" "of the proposed activity *and its intended use* . . . ." *Id.* (emphasis added). When assessing whether the impacts of this "proposed activity" (dock expansion), and its "intended use" (crude oil and coal shipping and loading), are contrary to the public interest, the Corps must consider "[a]ll factors which may be relevant . . . ." *Id.*[16] The public interest review is intended to be broad, capturing all issues that could impact the environment, human health, and natural resources.

Cascade Kelly's proposal to overhaul the Port Westward dock to facilitate crude oil and coal loading and shipping is contrary to the public interest because the foreseeable detriments to the public far outweigh any potential benefits. The severe impacts of Cascade Kelly's project, such as potential crude oil leaks and spills into the Columbia, toxic air pollution from diesel train and ship engines, toxic air pollution associated with vented emissions off of the crude oil itself, and the risk of catastrophes like the recent explosion and fire in Quebec,[17] are all contrary to the "welfare of the people." 30 C.F.R. § 320.4(a)(1). Accordingly, the Corps should deny the permit.

Before making its public interest determination, the Corps should fill in the informational gaps in Cascade Kelly's application. The application lacks basic information about the project's size, design, and scope. The application fails to disclose the quantity of 'bulk liquid commodity' Cascade Kelly intends to handle, the number or frequency of Panamax ships using the dock, how 'bulk commodity loading' would proceed at the dock, or the number or frequency of unit trains hauling 'bulk liquid commodity' to the dock. Without such fundamental information, the Corps cannot make an informed decision about how the project will impact the public, and whether the project is contrary to the public interest.

a. The project is contrary to the public interest because it increases the risk of crude oil spills in the Columbia River Estuary, which would devastate this fragile environment and the numerous public benefits it provides.

Expanding crude oil loading and shipment on the Columbia River is contrary to the public interest because such activities pose the unacceptable risk of a devastating oil spill in this unique and fragile environment. It stands to reason that docking larger vessels would allow and lead Cascade Kelly to ship more crude oil, thus increasing the probability of an accident and/or the magnitude of a resulting spill. To truly appreciate the 'foreseeable detriments' to the public, the Corps needs to analyze and discuss the probability of spills, and discuss the environmental

[16] For the purposes of the public interest test, factors which may be relevant include, but are not limited to: "conservation, economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife values, flood hazards, floodplain values, land use, navigation, shore erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, considerations of property ownership and, in general, the needs and welfare of the people." 30 C.F.R. § 320.4(a)(1).
[17] Washington Post, *40 still missing in deadly Canada oil train derailment; police say higher death toll certain* (July 8, 2013) (http://www.washingtonpost.com/world/the_americas/40-still-missing-in-deadly-canada-train-derailment-police-say-higher-death-toll-inevitable/2013/07/07/56961b80-e76a-11e2-818e-aa29e855f3ab_story.html).

and socio-economic impacts from a large crude oil spill in the Columbia River Estuary. Additionally, the Corps should consider the known navigational dangers that could lead to spills, like crossing the perilous Columbia River Bar. Without investigating and discussing the potential for oil spills resulting from this project, the Corps cannot possibly determine that such a potentially destructive project is consistent with the "public interest" in a clean and healthy the Columbia River. 30 C.F.R. § 320.4(a)(1).

b. The project is contrary to the public interest because it threatens public health and safety.

A recent train derailment and explosion in Lac-Mégantic, Quebec, demonstrated that Bakken crude oil can burn and explode, and can be extremely dangerous to anyone nearby.[18, 19] First-hand accounts of the Lac-Mégantic tragedy are chilling. Anne-Julie Hallee, a Lac-Mégantic resident, explained her experience: "There was a cloud of flames, rolling and rolling. It was really scary . . . ."[20] "[I]t was like hell."[21] Another resident added: "I saw a mushroom cloud, like an atomic bomb, explode in the air."[22] These horrific events demonstrated that the possibility of an accident involving Bakken crude is real, and that a crude oil fire or explosion at a train car, an over-water pipeline, or a Panamax vessel poses a credible threat to public health and safety. Subjecting workers and local residents to these dangers is contrary to the public interest.

In addition to the threat of fires and explosions, crude oil shipment could also subject workers and local residents to toxic air emissions. Bakken crude oil, the type of crude Cascade Kelly ships, often contains high levels of hydrogen sulfide gas, a colorless, flammable, and toxic gas. Chronic exposure to sulfide gas can cause lung, liver and kidney damage, infertility, immune system suppression, disruption of hormone levels, blood disorders, gene mutations, birth defects, and cancer.[23] According to the Occupational Safety and Health Administration, hydrogen sulfide is immediately dangerous to life and health at concentrations above 100 parts per million (ppm). When the concentration rises over 100 ppm, hydrogen sulfide is odorless because it paralyzes the olfactory nerves. At concentrations as low as 50-200 ppm, hydrogen sulfide can cause shock, convulsions, and coma. Cascade Kelly's application does not mention how emissions of sulfide gas and other potential toxic air pollutants from rail cars, the trans-loading pipeline, or receiving ships will be monitored and regulated to ensure human health and

[18] Exhibit 7. Pictures from aftermath of an oil-train explosion in Lac-Megantic, Quebec.
[19] Exhibit 8. National Geographic. *Oil Train Tragedy in Canada Spotlights Rising Crude Transport by Rail* (July 28, 2013); *see also* The Daily Beast, Inside the Brutal Clean-up Efforts in Lac-Megantic (July 16, 2013) (http://www.thedailybeast.com/articles/2013/07/16/inside-the-brutal-clean-up-efforts-in-lac-megantic.html); *see also* Washington Post, *40 still missing in deadly Canada oil train derailment; police say higher death toll certain* (July 8, 2013) (http://www.washingtonpost.com/world/the_americas/40-still-missing-in-deadly-canada-train-derailment-police-say-higher-death-toll-inevitable/2013/07/07/56961b80-e76a-11e2-818e-aa29e855f3ab_story.html).
[20] Exhibit 9. *See* http://www.ctvnews.ca/canada/residents-recall-terrifying-moments-in-lac-megantic-train-disaster-1.1357750#ixzz2YW82LsBj.
[21] *Id*.
[22] Exhibit 9. *See* http://www.rcinet.ca/en/2013/07/08/quebec-town-a-war-zone-after-derailed-train-explosions/.
[23] Utah Department of Environmental Quality, *Adverse Health Effects from Exposure to Crude Oil Mixtures* (June 2010).

safety. Nevertheless, such serious impacts almost certainly exist, and are contrary to the public interest.

Expanding crude oil and coal loading and shipment on the Columbia River is also contrary to the public interest because the Panamax vessels, support vessels, and trains that would be involved would all emit substantial amounts of toxic diesel pollution. The fine particulates associated with diesel emissions "can cause lung damage, aggravate respiratory disease such as asthma, and are thought to be a human carcinogen. Diesel emissions have a high potential to impact people who are sensitive to the health effects of fine particles (e.g. children, elderly, and those with existing heart or lung disease, asthma or other respiratory problems)."[24] The increased diesel exhaust emissions associated with Cascade Kelly's proposal, and the cumulative diesel emissions resulting from similar fossil fuels export proposals, are not in the public interest.

c. The project is contrary to the public interest because increased Panamax vessel traffic could degrade the estuary and public uses of the river.

Fishermen, commercial shippers, and recreational boaters, use the Columbia River Estuary and the shipping channel in the lower Columbia River extensively, and Panamax-class oil tankers transiting the ship channel would disrupt those uses. Cascade Kelly's application claims that the project will decrease shipping traffic from the Port Westward dock by 30 to 50 percent; but this figure masks the fact that smaller oil barges would be replaced by very large Panamax vessels, and ignores the additional Panamax vessel traffic associated with coal shipping and loading. When assessing the project's foreseeable detriments to the public, the Corps must consider how Panamax vessel traffic would impact existing recreation and commercial activity on the river. The Corps must consider not only the impacts of Panamax vessels serving Cascade Kelly's project, but the foreseeable cumulative impacts of all Panamax vessel traffic from the various fossil fuel export projects currently proposed in the lower Columbia.[25] 30 C.F.R. § 320.4(a)(1) ("The decision whether to issue a permit will be based on an evaluation of the probable impacts, *including cumulative impacts*, of the proposed activity and its intended use on the public interest.") (emphasis added). The shipping channel in the estuary and near the river mouth is a popular location for salmon and sturgeon fishing, and an important commercial transit corridor. The individual and cumulative impacts of Panamax vessel traffic would disrupt existing uses of the river and are contrary to the public interest.

In addition to disrupting exiting uses of the river, increased Panamax vessel traffic could harm the river and estuary ecosystem in various ways. For instance, increased Panamax vessel traffic could increase wake stranding and mortality of endangered juvenile salmon and

[24] Letter from Kate Kelly, Director, Office of Ecosystems, Tribal and Public Affairs, U.S. Environmental Protection Agency, to Mr. Steve Gagnon, U.S. Army Corps of Engineers, *Re: Comments on Public Notice for Permit Application under Section 10 of the Rivers and Harbors Act for a Coal Transloading Facility, Port of Morrow, Oregon* (Apr. 5, 2012).

[25] *See* Section V.a., *infra*, describing other planned fossil fuel export projects in the Columbia River Estuary.

steelhead[26] that use the estuary for migration and rearing habitat.[27] Similarly, increased frequency and intensity of wakes from large Panamax ships could result in shoreline erosion, potentially damaging man-made structures as well as wetlands and riparian habitat throughout the estuary. Additionally, increased vessel visits threaten to introduce aquatic invasive species through ballast-water transfers or ship fouling. The Corps must consider these consequences of increased Panamax vessel traffic from the expanded dock and from the cumulative impacts of all proposed fossil fuels shipping activities in the Columbia. These impacts to the Columbia River's ecosystem are not in the public interest.

d. The project is contrary to the public interest because crude oil shipment exacerbates global warming.

The impacts of Cascade Kelly's project are contrary to the public interest because extracting and bringing crude oil to market exacerbates global warming. Unfortunately, Cascade Kelly provides no figures on the amount of crude oil or other carbon-based fuel it plans to ship, so calculating the project's true contribution global warming is nearly impossible. However, the Corps has a duty to examine the project's cumulative impacts, which, when added to the global warming impacts of all other proposed fossil fuels shipping proposals along the Columbia,[28] are significant by any measure.

Global warming is one of the greatest ecological and humanitarian threats of the modern era. In 2007, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released its frequently cited report reflecting the new scientific consensus that unrestrained greenhouse gas (GHG) emissions are causing global warming. As summarized by a United Nations press release:

> The IPCC, which brings together the world's leading climate scientists and experts, concluded that major advances in climate modeling and the collection and analysis of data now give scientists "very high confidence"—at least a nine out of ten chance of being correct—in their understanding of how human activities are causing the world to warm. This level of confidence is much greater than the IPCC indicated in their last report in 2001. The report confirmed that it is "very likely" that greenhouse gas emissions have caused most of the global temperature rise observed since the mid-twentieth century. Ice cores, going back 10,000 years, show a dramatic rise in greenhouse gases from the onset of the industrial age. The co-chair of the IPCC working group stated, "There can be no question that the increase in these greenhouse gases are dominated by human activity.

[26] Exhibit 10, Pearson *et al., A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results* (2006).
[27] Exhibit 11, NMFS, *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (2011); Exhibit 12, Fresh *et al*., *NOAA Technical Memorandum NMFS-NWFSC-69: Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (2005); 78 Fed. Reg. 2,726 (January 14, 2013) (*Proposed Critical Habitat Designation for Lower Columbia Coho Salmon*).
[28] *See* Section V.a., *infra*, describing other planned fossil fuel export projects in the Columbia River Estuary.

The United Nations went on to summarize the key findings of the report:

> The report describes an accelerating transition to a warmer world—an increase of three degrees Celsius is expected this century—marked by more extreme temperatures including heat waves, new wind patterns, worsening drought in some regions, heavier precipitation in others, melting glaciers and arctic ice, and rising global average sea levels.

More recent scientific analysis has demonstrated that the urgency to act on climate impacts is even greater than it was in 2007. The recent Copenhagen Climate Science Congress, attended by 2,000 scientists, concluded with this "Key Message 1:"

> Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realized. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperatures, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.[29]

Numerous studies predict severe impact from climate change in Oregon, including dramatic reductions in snowpack, declining river flows, increased deaths from temperatures and air pollution, increased risk of wildfires, loss of salmon and shellfish habitat, lost hydropower generation, and flooding. The Oregon Department of Energy summarized these impacts:

> **Rain and Snow Patterns**
> Rainstorms and snowstorms could increase in severity, but less snow would build up in the mountains. Snowpacks might melt faster, increasing flooding. Less water would be available for recreation, irrigation, drinking and fish habitat. The concentration of pollutants in the water could increase during summer and fall.
>
> **Sea Level Rise**
> A rise in sea level could threaten beaches, sandy bluffs and coastal wetlands. Coast towns could experience more flooding, causing increased damage to roads, buildings, bridges and water and sewer systems.
>
> **Diminished Water Supplies and Crop Productivity**
> Oregon's crops and livestock could be affected by warmer temperatures, less water availability and drier soils. Some crops, such as wheat, might thrive in warmer temperatures, while others, such as potatoes, could be harmed. Less water available for irrigation would harm agriculture.

[29] International Scientific Congress, *Climate Change: Global Risks, Challenges, and Decisions* (Mar. 12, 2009).

Ecosystems
Native species adapted to Oregon's climate could suffer if temperatures rise. Warmer streams and rivers would harm salmon and other native species and non-native species could replace them. The cultural practices of Oregon's tribes could be affected, as could the businesses and recreation practices of those who rely on the state´s native species.

Based on the substantial contribution of GHG emissions associated with Cascade Kelly's crude oil in conjunction with the cumulative global warming impacts of all fossil fuels shipping proposals in the Columbia, the project and its intended use are contrary to the public interest. 30 C.F.R. § 320.4(a)(1).

V. The Corps must use the NEPA process to evaluate the environmental risks and impacts of crude oil and coal shipment at Port Westward.

The Corps decision about whether to approve Cascade Kelly's application triggers NEPA's review and disclosure requirements. NEPA is America's basic "charter for protection of the environment." 40 C.F.R. § 1500.1(a). NEPA serves two purposes: it (1) ensures that the agency will carefully consider detailed information concerning significant environmental impacts of the proposed project, and (2) "guarantees that the relevant information will be made available" so that the public may play a role in the decision-making process. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989). By focusing the agency attention on the environmental consequences of proposed actions, NEPA "ensures that important effects will not be overlooked or underestimated only to be discovered after resources have been committed or the die otherwise cast." *Id*.

a. Scope of NEPA analysis

The Corps' NEPA analysis must look beyond the installation of dolphins at the Port Westward dock. The Council on Environmental Quality's (CEQ) regulations governing the scope of NEPA analyses require agencies like the Corps to analyze the direct, indirect, and cumulative impacts of each proposed action. 40 C.F.R. § 1508.25(c). Accordingly, the Corps' review must address the environmental impacts of the crude oil and coal shipping that the dock alterations would facilitate, and the cumulative impact of this project in conjunction with other similar crude oil and fossil fuel shipping proposals.

The Corps' NEPA review must address the environmental impacts of transporting crude oil and coal to the dock, loading crude oil and coal at the dock, and shipping crude oil and coal in Panamax vessels from the dock and through the Columbia River Estuary. The CEQ's regulations require the Corps to analyze the direct and indirect[30] impacts and effects of the proposed dock alterations. 40 C.F.R. § 1508.25(c)(1) & (2). The effects of altered or increased crude oil and coal shipping on Panamax vessels are effects of the proposed dock alterations

[30] Indirect effects, for NEPA purposes, are those effects "which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect effects include the ways that human use of an area changes as a result of the proposed action, and the consequential effects of those changed uses on air, water, and ecosystems. *Id*.

because the dock alterations are specifically designed to facilitate this crude oil shipping, and the activity is a "reasonably foreseeable" result. *Id.* Accordingly, the Corps' NEPA analysis must address the impacts of crude oil and coal shipping on the Columbia River's water and ecosystems.

Additionally, the Corps must explain the overall environmental impact of this project *and* the numerous other crude oil and fossil fuel shipping projects proposed in the Columbia River Estuary. The CEQ's regulations require the Corps to analyze the cumulative environmental impact of each proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. 40 C.F.R. §§ 1508.7, 1508.25(c)(3). In recent years, various companies have proposed, or even begun, shipping fossil fuels—including crude oil, coal, and liquefied natural gas (LNG)—through the Columbia River Estuary. These projects include, but are not limited to:

- Cascade Kelly's current shipments of Bakken crude oil from the Port Westward dock.
- Ambre Energy's proposed Morrow Pacific Project to export coal, also using the Port Westward dock.[31]
- The Port of Vancouver's recently approved a lease with Tesoro-Savage to construct and operate a very large crude oil terminal.[32]
- Millennium Bulk Terminal's proposed coal export terminal at Longview, Washington.[33]
- Oregon LNG's proposed LNG export terminal at Warrenton, Oregon.[34]

All of these projects are either presently occurring or reasonably foreseeable, and all have the potential to impact the Columbia River in similar ways. Accordingly, NEPA compels the Corps to assess and describe the cumulative impact that all of these fossil fuel shipping activities would have on the Columbia River.

b. The Corps should prepare an Environmental Impact Statement to evaluate the environmental risks and impacts of crude oil shipment from the Port Westward dock.

An Environmental Impact Statement (EIS) is the appropriate NEPA document to assess the environmental consequences and risks of crude oil transport in the Columbia River Estuary because there are substantial questions about whether the project may significantly impact the Columbia River. An agency must prepare an EIS when substantial questions exist about whether the proposed project "*may*" significantly degrade the environment. *Native Ecosystems Council v. U.S. Forest Service*, 428 F.3d 1233, 1239 (9th Cir. 2005) (emphasis in original); *see also* 42 U.S.C. § 4332(2)(C). "This is a low standard." *Klamath Siskiyou Wildlands Ctr. v. Boody*, 468

[31] See Section II, *supra*.
[32] The Columbian, *Port of Vancouver runs afoul of meetings law* (July 30, 2013) (http://www.columbian.com/news/2013/jul/30/vancouver-port-meetings-law-oil-terminal-tesoro/).
[33] Letter from Millennium Bulk Terminals LLC to the Corps (Feb. 13, 2012) (http://millenniumbulk.com/wp-content/uploads/2012/05/February-13-2012-Letter-to-Michelle-Walker.pdf).
[34] 77 Fed. Reg. 59,603 (September 28, 2012) (FERC notice of intent to prepare an EIS for Oregon LNG's proposed LNG export project.).

F.3d 549, 562 (9th Cir. 2006); *California Wilderness Coalition v. U.S.*, 631 F.3d 1072, 1097 (9th Cir. 2011).

The Council on Environmental Quality's (CEQ) NEPA regulations contain ten 'intensity' factors that agencies like the Corps must consider when evaluating whether a project's impacts may be significant, requiring an EIS. 40 C.F.R. § 1508.27(b); *Ocean Advocates v. U.S. Army Corps of Eng'rs*, 361 F.3d 1108, 1124 (9th Cir. 2004). These factors include:

> (1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.
>
> (2) The degree to which the proposed action affects public health or safety.
>
> (3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
>
> (4) The degree to which the effects on the quality of the human environment are likely to be highly controversial.
>
> (5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
>
> (6) The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
>
> (7) Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
>
> (8) The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.
>
> (9) The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
>
> (10) Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

40 C.F.R. § 1508.27(b). Most of these factors apply to crude oil and coal shipment in the Columbia River Estuary, and the presence of just one of these factors may compel the

preparation of an EIS. *Ocean Advocates v. U.S. Army Corps of Engineers*, 402 F.3d 846, 865 (9th Cir. 2005).

i. Impacts are 'significant' because the proposed action affects public health and safety to a high degree.

The Corps should prepare an EIS because shipping crude oil—especially potentially-explosive Bakken crude—could seriously affect public health and safety. CEQ's second 'intensity' factors is "[t]he degree to which the proposed action affects public health or safety." 40 C.F.R. § 1508.27(b)(2). Tragically, a recent train derailment and explosion in Lac-Mégantic, Quebec, demonstrated that crude oil shipping can have disastrous consequences for public health and safety. [35] Accordingly, the Corps should analyze these impacts in an EIS.

As the recent tragedy in Quebec illustrated, Bakken crude burns and explodes, and is extremely dangerous to workers and residents in the vicinity.[36] First-hand accounts of the Lac-Mégantic tragedy are chilling. Anne-Julie Hallee, a Lac-Mégantic resident, explained her experience: "There was a cloud of flames, rolling and rolling. It was really scary . . . ." [37] "[I]t was like hell."[38] Another resident added: "I saw a mushroom cloud, like an atomic bomb, explode in the air."[39] These are the kinds of significant human health and safety impacts that the Corps should evaluate in an EIS.

The proposed dock improvements will facilitate more oil shipment, and therefore increase the probability of a significant spill or other accident. A crude oil spill, fire, or explosion at a ruptured over-water pipeline or at the point of loading onto a vessel poses a very real threat to public health and safety. The proposed dock improvements would also allow, for the first time, immense Panamax tankers to carry crude through the estuary, in close proximity to towns, homes, and commercial and recreational river users. A fire or explosion resulting from a crude oil spill or other accident on board a Panamax tanker could have catastrophic consequences for people nearby. Finally, Cascade Kelly's proposed project would add an undisclosed number of crude oil tanker-trains to Oregon's rail system. These trains have the potential to strike vehicles and pedestrians, close intersections delaying emergency response times in small communities, and have catastrophic accidents like the one in Lac-Mégantic. These health and safety risks are extremely significant, and deserve a thorough discussion in an EIS.

---

[35] Exhibit 8. National Geographic. *Oil Train Tragedy in Canada Spotlights Rising Crude Transport by Rail* (July 28, 2013); *see also* The Daily Beast, Inside the Brutal Clean-up Efforts in Lac-Megantic (July 16, 2013) (http://www.thedailybeast.com/articles/2013/07/16/inside-the-brutal-clean-up-efforts-in-lac-megantic.html); *see also* Washington Post, *40 still missing in deadly Canada oil train derailment; police say higher death toll certain* (July 8, 2013) (http://www.washingtonpost.com/world/the_americas/40-still-missing-in-deadly-canada-train-derailment-police-say-higher-death-toll-inevitable/2013/07/07/56961b80-e76a-11e2-818e-aa29e855f3ab_story.html).

[36] Exhibit 7. Pictures from aftermath of an oil-train explosion in Lac-Megantic, Quebec.

[37] Exhibit 9. *See* http://www.ctvnews.ca/canada/residents-recall-terrifying-moments-in-lac-megantic-train-disaster-1.1357750#ixzz2YW82LsBj.

[38] *Id.*

[39] Exhibit 9. *See* http://www.rcinet.ca/en/2013/07/08/quebec-town-a-war-zone-after-derailed-train-explosions/.

In addition to the threat of fires and explosions, crude oil shipment could also subject workers and local residents to diesel exhaust from frequent trains and immense Panamax vessels, and toxic air emissions from the crude oil itself. Cascade Kelly handles Bakken crude oil at Port Westward. Bakken crude often contains high levels of hydrogen sulfide gas, a colorless, flammable, and toxic gas. Chronic exposure to sulfide gas can cause lung, liver and kidney damage, infertility, immune system suppression, disruption of hormone levels, blood disorders, gene mutations, birth defects, and cancer.[40] According to the Occupational Safety and Health Administration, hydrogen sulfide is immediately dangerous to life and health at concentrations above 100 parts per million (ppm). When mixed with air, hydrogen sulfide is explosive. When the concentration rises over 100 ppm, hydrogen sulfide is odorless because it paralyzes the olfactory nerves. At concentrations as low as 50–200 ppm, hydrogen sulfide can cause shock, convulsions, and coma. Cascade Kelly's application does not mention how emissions of sulfide gas and other potential toxic air pollutants from rail cars, the trans-loading pipeline, or receiving ships will be monitored and regulated to ensure human health and safety. Nevertheless, such serious impacts almost certainly exist, and the Corps should discuss these impacts in an EIS.

ii. Impacts are 'significant' because the project may adversely affect the Columbia River Estuary's unique ecological, cultural, and historic resources.

The Corps should prepare an EIS because the project could devastate the Columbia River Estuary and its unique ecological and cultural resources. CEQ's third and eighth 'intensity' factors counsel in favor of preparing an EIS when the proposed project would negatively impact unique ecological, cultural, or historic resources. 40 C.F.R. § 1508.27(b)(3), (8). Specifically, intensity factor three contemplates an EIS when a project is proposed in an area close "to historic or cultural resources, park lands, prime farmlands, wetlands, . . . or ecologically critical areas." 40 C.F.R. § 1508.27(b)(3). Similarly, intensity factor eight considers the degree to which the proposed project "may cause loss or destruction of significant scientific, cultural, or historical resources." 40 C.F.R. § 1508.27(b)(8). Shipping and loading crude oil in the midst of the Columbia River Estuary's unique ecological, social, and cultural resources deserves analysis in an EIS.

The Columbia River supports a vibrant tradition of subsistence, commercial, and sport salmon fishing. Salmon fishing in the estuary and lower Columbia River is a cultural and economic practice with a rich history reaching back many generations. Cascade Kelly proposes to ship crude oil through the middle of the lower Columbia River salmon fisheries, potentially causing the loss, destruction, or disruption of these significant cultural and historical resources. The Corps should therefore use an EIS to analyze the impacts of Panamax ship traffic and potential crude oil spills on salmon fishing in the lower Columbia. 40 C.F.R. §§ 1508.27(b)(3) & (8).

The lower Columbia River and estuary is an "ecologically critical area," 40 C.F.R. § 1508.27(b)(3), that is essential to the survival juvenile salmon and steelhead, waterfowl, and

[40] Utah Department of Environmental Quality, *Adverse Health Effects from Exposure to Crude Oil Mixtures* (June 2010).

many other species.[41] The lower river is lined with wetlands, riparian areas, and park lands[42] which could all be impacted by increased vessel traffic or invasive species brought in by oil tankers. Further, a crude oil spill at the dock, or from a Panamax vessel in the river, could devastate the ecologically critical areas downstream and upstream from the Port Westward loading dock. Before subjecting the unique and irreplaceable Columbia River Estuary to these extreme threats, the Corps should analyze the potential impacts in an EIS. 40 C.F.R. §§ 1508.27(b)(3) & (8).

iii. Impacts are 'significant' because the project entails highly uncertain and controversial risks.

Cascade Kelly's proposal would likely result in the shipment of Bakken crude oil, a substance that may be chemically different from other crude oils, and may have a propensity to explode or catch fire. CEQ's fourth and fifth 'intensity' factors counsel in favor of preparing an EIS when the impacts of the proposed project are highly controversial or uncertain, or the project involves unique risks. 40 C.F.R. § 1508.27(b)(4), (5). The recent crude oil train disaster in Lac-Mégantic, Quebec demonstrated that transporting Bakken crude oil is risky, and that those risks are unique and poorly-understood.

Bakken crude often contains high levels of hydrogen sulfide gas, a colorless, flammable, toxic gas. Chronic exposure to sulfide gas can cause lung, liver and kidney damage, infertility, immune system suppression, disruption of hormone levels, blood disorders, gene mutations, birth defects, and cancer.[43] When mixed with air, hydrogen sulfide is explosive. Highlighting these concerns with Bakken crude, an oil shipping company recently asked the Federal Energy Regulatory Commission to regulate the amount of hydrogen sulfide gas that could be contained in crude oil for rail transport.[44] Additionally, the Canadian Transportation Safety Board is still investigating the cause of the Lac-Mégantic disaster, in part to determine if unsafe levels of hydrogen sulfide gas or other substances in the Bakken crude contributed to the explosion and fires seen there.[45] Clearly, the problems and risks associated with transporting Bakken crude are not sufficiently understood to allow anything less than the thorough review provided by the EIS process. 40 C.F.R. § 1508.27(b)(4), (5).

---

[41] Exhibit 11, NMFS, *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (2011); Exhibit 12, Fresh *et al*., *NOAA Technical Memorandum NMFS-NWFSC-69: Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (2005); 78 Fed. Reg. 2,726 (January 14, 2013) (*Proposed Critical Habitat Designation for Lower Columbia Coho Salmon*).

[42] *E.g.* Julia Butler Hansen Refuge for the Columbian White-Tailed Deer, Lewis and Clark National Wildlife Refuge.

[43] Utah Department of Environmental Quality, *Adverse Health Effects from Exposure to Crude Oil Mixtures* (June 2010).

[44] Reuters, *U.S. energy regulator approves sulfide gas limit in Bakken crude* (June 7, 2013) (http://www.reuters.com/article/2013/06/07/enbridge-bakken-sulfide-idUSL1N0EJ0SS20130607).

[45] The Globe and Mail, *Probe of Lac-Mégantic train disaster turns to composition of oil* (July 19, 2013) (http://www.theglobeandmail.com/news/national/probe-of-lac-megantic-train-disaster-turns-to-composition-of-oil/article13315064/).

If, as discussed above, the project could result in the shipment of Tar Sands crude oil or coal, the Corps should prepare an EIS because transporting those substances also poses unique, controversial, and poorly-understood risks. *Id.*

iv. The cumulative impact of this project and other, similar projects is 'significant.'

Cascade Kelly's proposed project is just one of many proposed and existing fossil fuels shipping projects in the Columbia River, and the cumulative impact of all these projects is undoubtedly significant. CEQ's seventh 'intensity' factor directs agencies to prepare an EIS when the cumulative impacts of a proposed project would be significant. 40 C.F.R. § 1508.27(b)(7). As explained in Section II.a. above, there are numerous proposals for crude oil, coal, and LNG shipping in the lower Columbia. Cumulatively, these projects would drastically increase the shipping traffic on the Columbia River, rail traffic in local communities, domestic and foreign greenhouse gas emissions, and the probability of an accident or oil spill in the Columbia River. Taken together, the impact of all those projects in addition to Cascade Kelly's proposal will result in a cumulatively significant impact on the human environment in the lower Columbia.

The EIS cannot ignore the cumulative contribution of this project, and others like it, to climate change. NEPA requires a quantification of the "incremental impact[s] that [the proposed project's] emissions will have on climate change … in light of other past, present, and reasonably foreseeable actions." *Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1216 (9th Cir. 2008); *see also Center for Biological Diversity v. National Highway Traffic Safety Administration*, 508 F.3d 508, 550 (9th Cir. 2007) ("The impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct."). Even if this proposed crude oil and coal shipping project had an "individually minor" effect on the environment—which it probably does not—it and other similar projects are "collectively significant actions taking place over a period of time" that contribute significantly to climate change. 40 C.F.R. § 1508.7. NEPA requires analysis of the "actual environmental effects" resulting from those cumulative emissions. *Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1216 (9th Cir. 2008). Accordingly, the Corps must quantify and evaluate, in an EIS, the cumulative and incremental effects of climate change resulting from this crude oil and coal shipping proposal in conjunction with the effects of the other fossil fuels shipping projects currently proposed along the Columbia.

iv. Impacts are 'significant' because the project is likely to adversely affect threatened and endangered species.

The Corps should prepare an EIS because the project may seriously impact threatened or endangered species. CEQ's ninth 'intensity' factor favors the preparation of an EIS when a proposed project would substantially adversely affect an endangered or threatened species or its designated critical habitat. 40 C.F.R. § 1508.27(b)(9). The project has the potential to drastically harm listed species of salmon and steelhead that rely on a healthy estuary environment for rearing and migration.

Multiple studies and publications have identified shallow-water and off-channel habitats in the Lower Columbia River and Estuary as vitally important for salmonid rearing and species recovery.[46] Development or destruction of riparian wetlands and shallow-water habitats, and the construction of over-water structures like piers and docks, has significantly degraded the lower Columbia River's ability to support juvenile salmonids.[47]

Increased Panamax vessel traffic could lead to the wake-stranding, and death, of endangered juvenile salmonids, which frequent shallow, near-shore habitats in the estuary. Additionally, an oil spill or explosion at the loading dock or elsewhere would devastate the estuary's salmon habitat for years or decades. Along with ESA consultation, discussed more fully in Section IV below, an EIS is the proper analytical tool to discuss the risks to threatened salmon and steelhead posed by oil shipping in the estuary.

VI. The Biological Assessment is inadequate and jeopardizes the sufficiency of the ESA §7 consultation.

The Biological Assessment[48] prepared for the Corps takes an illegally narrow view of the action and therefore does not address key threats to listed species. In ESA § 7 consultation, the Corps and the expert scientific agencies (the National Marine Fisheries Service and/or the U.S. Fish and Wildlife Service) must consider the direct and indirect impacts of the proposed action on listed species. 50 C.F.R. § 402.02. The Biological Assessment focuses almost exclusively on the in-water construction and ignores the direct and indirect effects of crude oil and coal shipping. Specifically, the Biological Assessment fails to discuss how a crude oil, coal, or fuel spill could impact listed species. Additionally, the Biological Assessment fails to discuss the potential for increased or altered shipping to incidentally transport invasive species into the Columbia River Estuary and the consequent effects on listed species.

The Biological Assessment also takes an illegally narrow view of the 'action area.' The "action area" that is the focus of the ESA § 7 consultation includes "all areas to be affected directly or indirectly by the Federal action *and not merely the immediate area involved in the action*."[49] 50 C.F.R. § 402.02 (emphasis added). The Biological Assessment for the dock ignores this requirement, and only addresses the area imediately adjacent to the dock. The ESA §7 consult must address the impacts to listed species *at least* throughout the Columbia River estuary, where coal and crude oil shipping traffic would occur.

---

[46] Exhibit 11, NMFS, *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (2011); Exhibit 12, Fresh *et al*., *NOAA Technical Memorandum NMFS-NWFSC-69: Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (2005); 78 Fed. Reg. 2,726 (January 14, 2013) (*Proposed Critical Habitat Designation for Lower Columbia Coho Salmon*).

[47] *Id.*

[48] Exhibit 13. Biological Assessment for the Columbia Pacific Bio-Refinery Dock Modernization Project (June 6, 2013).

[49] *See also Final ESA Section 7 Consultation Handbook* at 4-18 (1998) ("The action area should be determined based on consideration of all direct and indirect effects of the proposed agency action.").

Additionally, the § 7 consult should be expanded to address impacts to Bull Trout. Page three (3) of the Biological Assessment states that, because Bull Trout are not found in the project area, they will not be considered in the § 7 consultation. However, the project area appears to be designated critical habitat for bull trout. 78 Fed. Reg. 63,898, 63,998 (Oct. 18, 2010). Part of the purpose of a § 7 consultation is to ensure against destruction or adverse modification of designated critical habitat, regardless of whether an applicant believes such critical habitat is currently occupied.

The § 7 consult should also consider how enlarging and operating a crude oil and coal trans-loading and shipping facility would impact endangered Columbia White-tailed Deer. According to page ten (10) of Cascade Kelly's application, "White Tailed Deer . . . thrive at this location." Even if the dock construction would not physically occupy Columbia White-Tailed Deer habitat, the noise, disruption, and human traffic associated with construction, enlargement, and operation of a coal and crude oil shipping facility could negatively impact these endangered animals, which "thrive" in the project area.

The Corps—and the Services—should take this opportunity to re-define the scope of the ESA § 7 consultation for the Port Westward dock expansion.

VII. The Corps should not allow Cascade Kelly to do in-water work when endangered salmon and steelhead are rearing or migrating near the dock.

If the Corps issues the permit, Cascade Kelly should not be allowed to perform any construction work on the dock outside of the in-water work period or 'fish window.' The Columbia River near the dock is rearing or migration habitat for 13 threatened or endangered species of salmon and steelhead. *Biological Assessment* at 4. In-water construction, such as the proposed vibratory- and impact-hammering to drive new dock pilings, could harm juvenile salmon and steelhead migrating or rearing near the dock. *Biological Assessment* at 16. The Oregon Department of Fish and Wildlife (ODFW) has made recommendations for time periods to avoid in-water construction in order to protect threatened and endangered anadromous fish, and other species.[50] In reference to this project, the ODFW specifically commented to DSL that all "in-water work should occur within the ODFW preferred in-water work window . . . ." Because in-water construction could harm or kill threatened and endangered salmon and steelhead, and because protecting fish is ODFW's area of expertise, the Corps should rely on ODFW's advice and limit Cascade Kelly's operations to Oregon's in-water work window.

VIII. The Corps must request and obtain a Clean Water Act § 401 Certification from the Oregon Department of Environmental Quality.

The Corps may not issue the § 10 Rivers and Harbors Act permit until the State of Oregon certifies, pursuant to Clean Water Act §401, that the activities facilitated by the Corps' permit comply with Oregon's water quality standards. Clean Water Act § 401 requires state approval any time a federally-licensed activity may result in a discharge to navigable waters. 33

[50] ODFW, *Oregon Guidelines for Timing of In-water Work to Protect Fish and Wildlife Resources*, 1 (June, 2008) (http://www.dfw.state.or.us/lands/inwater/Oregon_Guidelines_for_Timing_of_%20InWater_work2008.pdf).

U.S.C. § 1341(a)(1); *S.D. Warren Co. v. Maine Board of Envtl. Protection et al.*, 547 U.S. 370, 380 (2006). Both the Supreme Court[51] and the U.S. Environmental Protection Agency (EPA)[52] have noted that § 10 Rivers and Harbors Act permits can trigger state § 401 certification requirements. Further, Cascade Kelly concedes that a § 401 certification is necessary, because Cascade Kelly's application states: "All conditions of DEQ's 401 Water Quality Certification will be followed."[53] As EPA's guidance explains, § 401's certification requirement is triggered by the mere *possibility* that the federally-permitted *activity* will cause a discharge.[54] Here, the federally-permitted activities—crude oil and coal shipping—may result in discharges because of the possibility for crude oil and coal spills from ships and loading equipment. The re-suspension of sediment that will almost certainly occur during the installation and removal of pilings also constitutes a discharge triggering § 401. Therefore, Cascade Kelly's § 10 permit, and the activities it authorizes, satisfy the jurisdictional test triggering § 401 certification.

The Corps, therefore, must obtain § 401 certification from the State of Oregon before issuing Cascade Kelly's permit. While the ultimate onus to apply for § 401 certification falls on Cascade Kelly, the Corps should notify the Oregon Department of Environmental Quality (DEQ) that this Rivers and Harbors Act § 10 Permit requires § 401 certification. Notifying DEQ seems to be the Corps' standard operating procedure, in Oregon, when permitting a project that the Corps believes requires § 401 certification. The Corps should actively solicit DEQ's certification because, regardless of where the ultimate responsibility for initiating the § 401 certification process lies, the Corps cannot issue the § 10 Rivers and Harbors permit without the § 401 certification.[55]

Conclusion

For the Columbia River and its iconic salmon and steelhead runs, Cascade Kelly's project means a significant increase in Panamax vessel traffic, toxic air emissions, and the risk of catastrophic crude oil spills. For the people living along the river, crude oil and coal shipment are new and potential very dangerous neighbors. This project may be in Cascade Kelly's interest, but it is not in the public interest, and the Corps should therefore deny the permit application. 30 C.F.R. § 320.4(a)(1).

---

[51] *See PUD No. 1 of Jefferson Cty. v.Washington Dep't of Ecology*, 511 U.S. 700, 722–23 (1993).

[52] EPA, *Clean Water Act Section 401 Water Quality Certification: A Water Quality Protection Tool For States and Tribes* at 1–2 (2010); Officials at EPA Headquarters confirmed EPA's position: Section 401certification applies to RHA Section 10 permits, even in the absence of a CWA Section 404 permit, and states have the authority to determine if a Section 401 certification is required. *Pers. Comm.* Brian Topping, Office of Wetlands, Oceans, and Watersheds, EPA Headquarters (Dec. 10, 2012).

[53] Cascade Kelly's Application at 8 (http://docs.dsl.state.or.us/PublicReview/docview.aspx?id=1652650&&dbid=0).

[54] EPA, *Clean Water Act Section 401 Water Quality Certification: A Water Quality Protection Tool for States and Tribes* at 4 (2010).

[55] *See City of Fredericksburg v. FERC*, 876 F.2d 1109, 113 (4th Cir. 1989) (invalidating a FERC license issued without the required § 401 certification from as state).

Sincerely,

_____

Miles Johnson
Clean Water Attorney
Columbia Riverkeeper
(541) 272 – 0027
miles@columbiariverkeeper.org

_____

Marla Nelson
Legal Fellow
Northwest Environmental Defense Center
(503) 768 – 6726
msnelson@nedc.org

_____

Devorah Ancel
Attorney
Sierra Club Beyond Oil Campaign

Enclosures:

- Exhibit 1: Sightline Institute, *The Northwest's Pipeline on Rails*.
- Exhibit 2: EPA, *Comments on the Draft Supplemental Environmental Impact Statement for the Keystone XL Pipeline.*
- Exhibit 3: Ambre Energy's Environmental Review Document for the Morrow Pacific Project.
- Exhibit 4: Ambre Energy's letter to Oregon Department of State Lands.
- Exhibit 5: Graphic from Ambre Energy depicting Panamax vessel at Port Westward dock being loaded with coal.
- Exhibit 6: Pacific Transloading LLC / Port of St. Helens - Option and Terminal Services Agreement.
- Exhibit 7: Pictures of oil-train explosion in Lac-Megantic, Quebec.
- Exhibit 8: National Geographic. *Oil Train Tragedy in Canada Spotlights Rising Crude Transport by Rail* (July 28, 2013).
- Exhibit 9: Collected quotes from residents of Lac-Megantic, Quebec.
- Exhibit 10, Pearson *et al.*, *A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results* (2006).
- Exhibit 11: NMFS, *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (2011).
- Exhibit 12: Fresh *et al*., *NOAA Technical Memorandum NMFS-NWFSC-69: Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (2005).
- Exhibit 13: Biological Assessment for the Columbia Pacific Bio-Refinery Dock Modernization Project (June 6, 2013).

cc via email:

Richard Whitman, Natural Resource Policy Director, Office of the Governor
Nina DeConcini, Northwest Region Administrator, Oregon DEQ
Ben Meyer, Habitat Conservation Division, National Marine Fisheries Service
Doug Young, U.S. Fish and Wildlife Service
Paul Lumley, Executive Director, Columbia River Inter-Tribal Fish Commission
Carl Merkle, Confederated Tribes of the Umatilla Indian Reservation
Audi Huber, Confederated Tribes of the Umatilla Indian Reservation
Kristina Proszek, Confederated Tribes and Bands of the Yakama Nation